MINISTRY OF TRANSPORT, VIETNAM

SPECIAL ASSISTANCE FOR PROJECT IMPLEMENTATION (SAPI) FOR ITS INTEGRATION PROJECT ON NEW NATIONAL HIGHWAY NO.3 & NORTHERN AREA OF VIETNAM

APPENDIX 7

SUMMARY OF ITS MASTER PLAN (REVISED VERSION)
DRAFT ITS DESIGN STANDARDS (REVISED VERSION)
DRAFT ITS MESSAGE/DATA STANDARDS (REVISED VERSION)
DRAFT ITS COMMUNICATION SYSTEM PLAN (REVISED VERSION)

AUGUST 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS CO., LTD.
NEXCO EAST ENGINEERING CO., LTD.
NIPPON KOEI CO., LTD
TRANSPORTATION RESEARCH INSTITUTE CO., LTD
LANDTEC JAPAN INC.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
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FOR ITS INTEGRATION PROJECT ON
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SUMMARY OF ITS MASTER PLAN (REVISED VERSION)

FINAL REPORT IN AUGUST 2012

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1. Introduction

1.1 Background of Developing the Master Plan

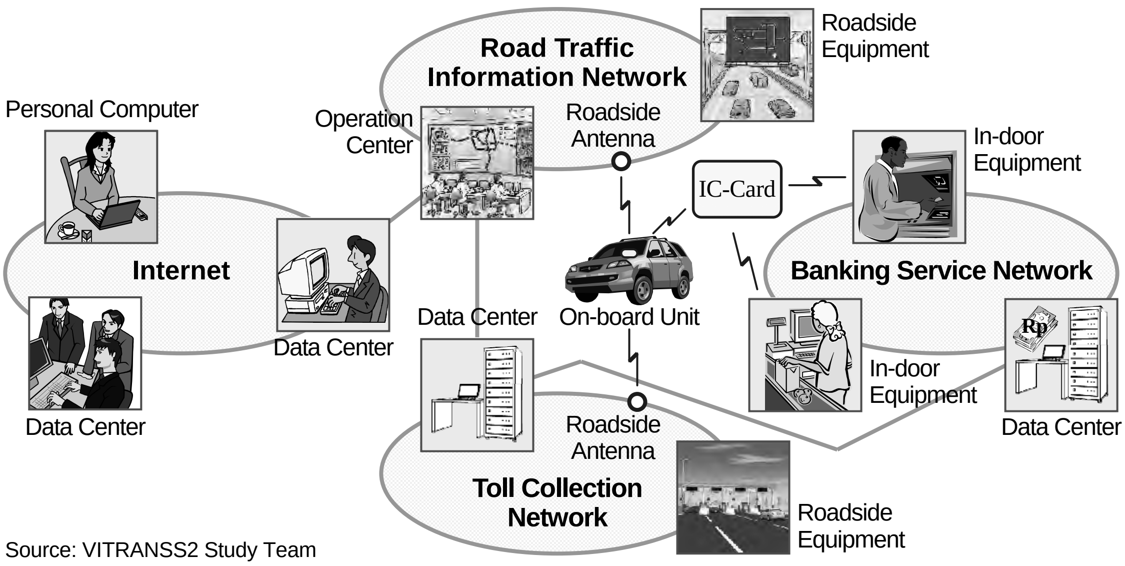
In Vietnam, expressway construction has begun to increase rapidly. Furthermore, the burden of the construction is shared by various organizations funded by the Official Development Assistance (ODA) of many different countries, the Asian Development Bank (ADB), the World Bank (WB), and the domestic banks and the private companies as the investors of the Build Operate Transfer (BOT). Consequently, it is conceivable that the constructed expressway network will be operated by many different organizations.

On the other hand, the communication network has been achieving a remarkable breakthrough in the world. As symbolized by the Internet, information/communication services are provided through a nationwide or worldwide network that includes a number of networks operated by different organizations. ITS (Intelligent Transport systems) also actualized by data exchange among various devices and centers on the communication network in many countries. Most of the devices are standardized and provided by many different suppliers. The standardization aims at cost reduction through market competition.

Figure 1.1 Expressway Network Plan in Vietnam

Source: VITRANSS2 Study Team

Figure 1.2 Conceptual Illustration of ITS

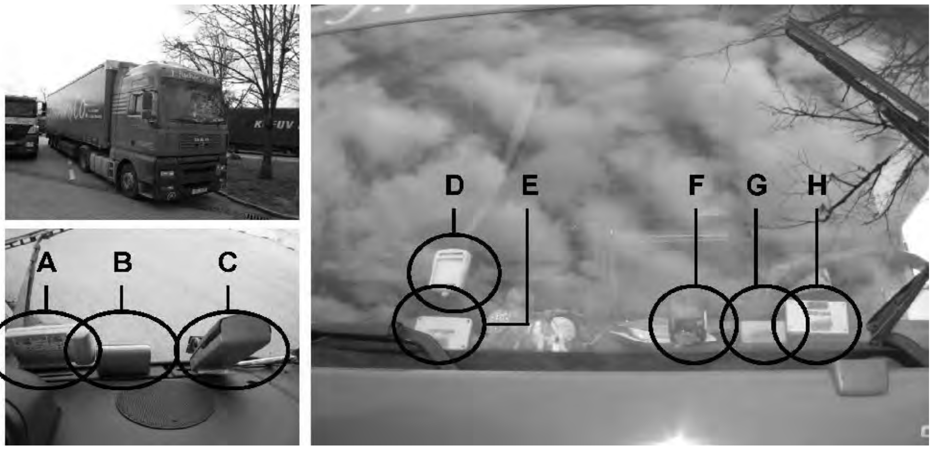


Source: VITRANSS2 Study Team

However, the unified policy for ITS is not yet established in Vietnam, which may include toll collection, traffic information/control and communication network operation/management. If the expressway construction continues to go this way, unconformity and lack of coordination among different road sections will become apparent, and a waste of the system implementation/operation cost and inconvenience in the expressway usage will come true.

For example, it is conceivable that incomplete standardization of the road-to-vehicle communication of ETC will bring an unhappy situation as shown in the pictures below. The drivers are required to prepare many OBUs (on-board units) for passing continuously through the different road sections.

Figure 1.3 Unhappy Situation by Incomplete Standardization

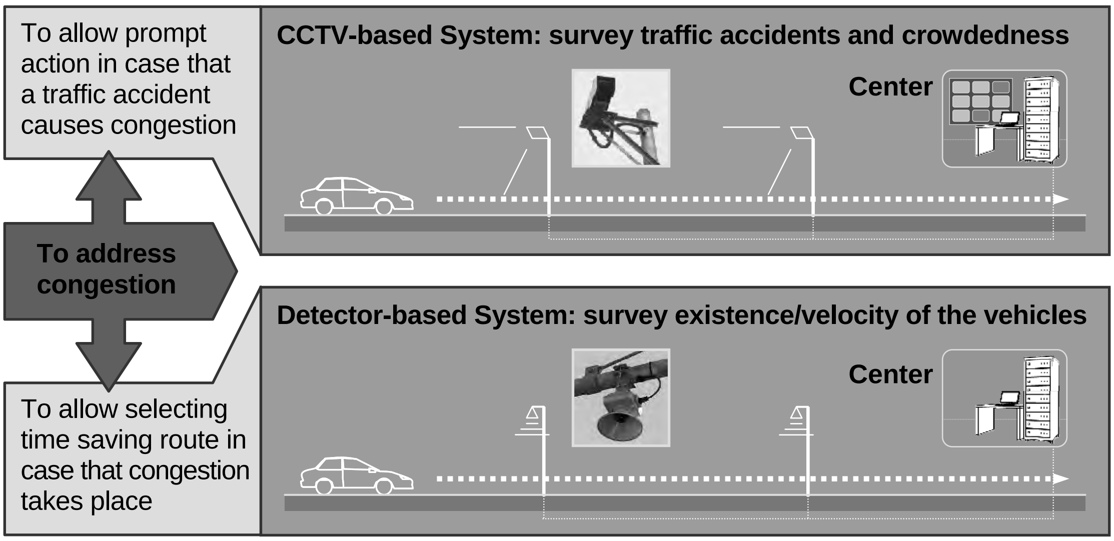


Note, A–H: Many OBUs in a vehicle

Source: Offered by Mr. Noguchi

The first step of standardization is to clarify the policy and requirements of ITS in Vietnam. Indistinct requirement often causes useless system installation and profitless costs. Even to address congestion, different systems can be developed as below.

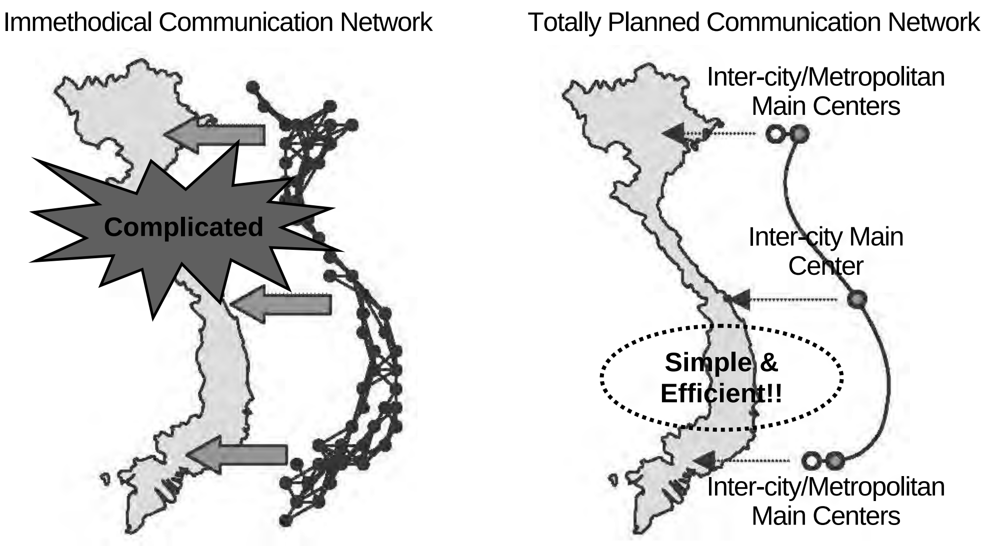
Figure 1.4 Necessity to Clarify the Policy and Requirements



Source: VITRANSS2 Study Team

A totally planned communication network is necessary to provide ITS services all over the country; otherwise, a number of small-scale centers are likely to be built depending on the section-by-section road construction. Such an immethodical communication network and small centers will bring complicated data exchange and profitless costs.

Figure 1.5 Necessity of Total Plan of Communication Network



Source: VITRANSS2 Study Team

For the reasons mentioned above, this Master Plan is needed as the preliminary stage of standardization of ITS for the inter-city road network.

1.2 Goals of ITS for Inter-city Road Network

Preparatory to the discussion in the Master Plan, seven goals below are proposed for ITS implementation of the inter-city road network in Vietnam.

- Increase operational efficiency of transportation system
- Provide smooth and punctual transport
- Improve safety and security of transport
- Enhance convenience and comfort of transport
- Decrease energy consumption and environmental costs
- Activate industries by developing advanced technologies
- Secure smooth access to urban arteries.

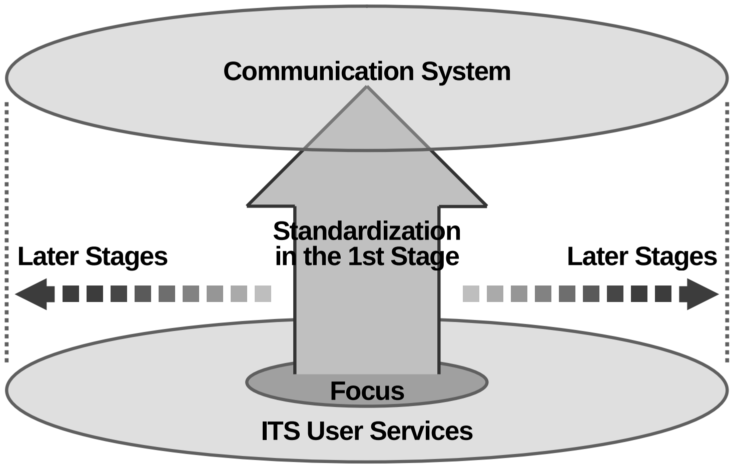
ITS serves the road users through required system operation. That is quite different from the road structures that serve road users only by construction.

Appropriateness of the goals is verified later referring to the background issues in Chapter 2.

1.3 Scope of the Master Plan

In the Master Plan, the scope of discussion shall focus to the priority ITS user services that provide clear assistance to the road operation. A required communication system for ITS can be reasoned out from the priority ITS services. The scope of discussion can be extended to further services in the later stages.

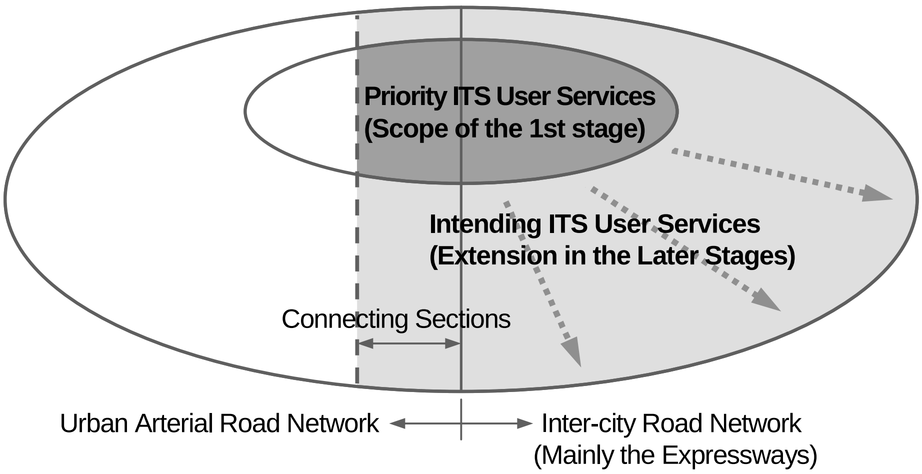
Figure 1.6 Focusing in the 1st Stage and Extension in Later Stages



Source: VITRANSS2 Study Team

The Scope of the Master Plan is the inter-city road network, mainly the expressways, and connecting sections of the urban arterial road network. ITS services shall be provided continuously to road users en route; accordingly, it is not appropriate to limit the scope of the services to only within the inter-city road network. The Scope defines the location of roadside equipment; however, the location of the centers, in-door equipment and communication network are not to be limited in the scope.

Figure 1.7 Scope of the Master Plan



Source: VITRANSS2 Study Team

1.4 Approach of the Master Plan

ITS will provide the road users with advanced services using the communication network. It will be achieved by various subsystems and by many operating bodies. Issues on ITS are to be discussed from the following three aspects in the Master Plan.

- **Aspect of Traffic Service:** ***"What services shall be provided?"***

Various scenes of the usage of ITS are imaginable; however, ITS user services shall be prepared appropriately for the specific road network conditions and traffic characteristics in Vietnam. In the event of congestion, for example, it depends on the existing conditions of road network and traffic whether the most important thing is to remove the cause of congestion or to support appropriate route selection. ITS user services and their effects shall be discussed appropriately to the proposed goals.

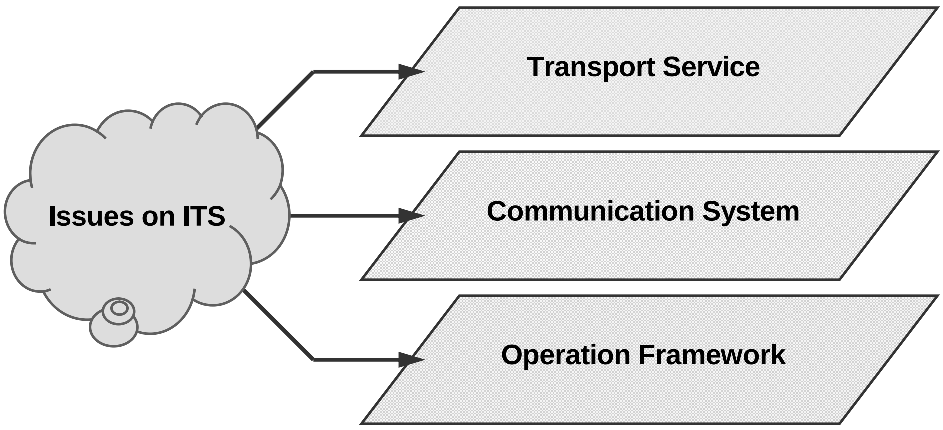
- **Aspect of Communication System:** ***"What methods shall be adopted for each service?"***

Many different system architectures can be selected for realizing an ITS service, and the implementation cost depends on the system architecture. Hence, alternatives of system architecture shall be listed and appropriate one shall be selected for service requirements and budgetary constraints. Furthermore, it shall be considered that standardization of the system has particular importance for reducing its implementation cost.

- **Aspect of Operation Framework:** ***"What organizations shall be set for operation?"***

For successful development of ITS, the system shall be managed by appropriate operating bodies. Accordingly, requirements for the operating bodies shall be brought into discussion. Setting up of the operating bodies appropriate for the requirements and cooperation among them shall be promoted.

Figure 1.8 Three Aspects of Discussion in the Master Plan

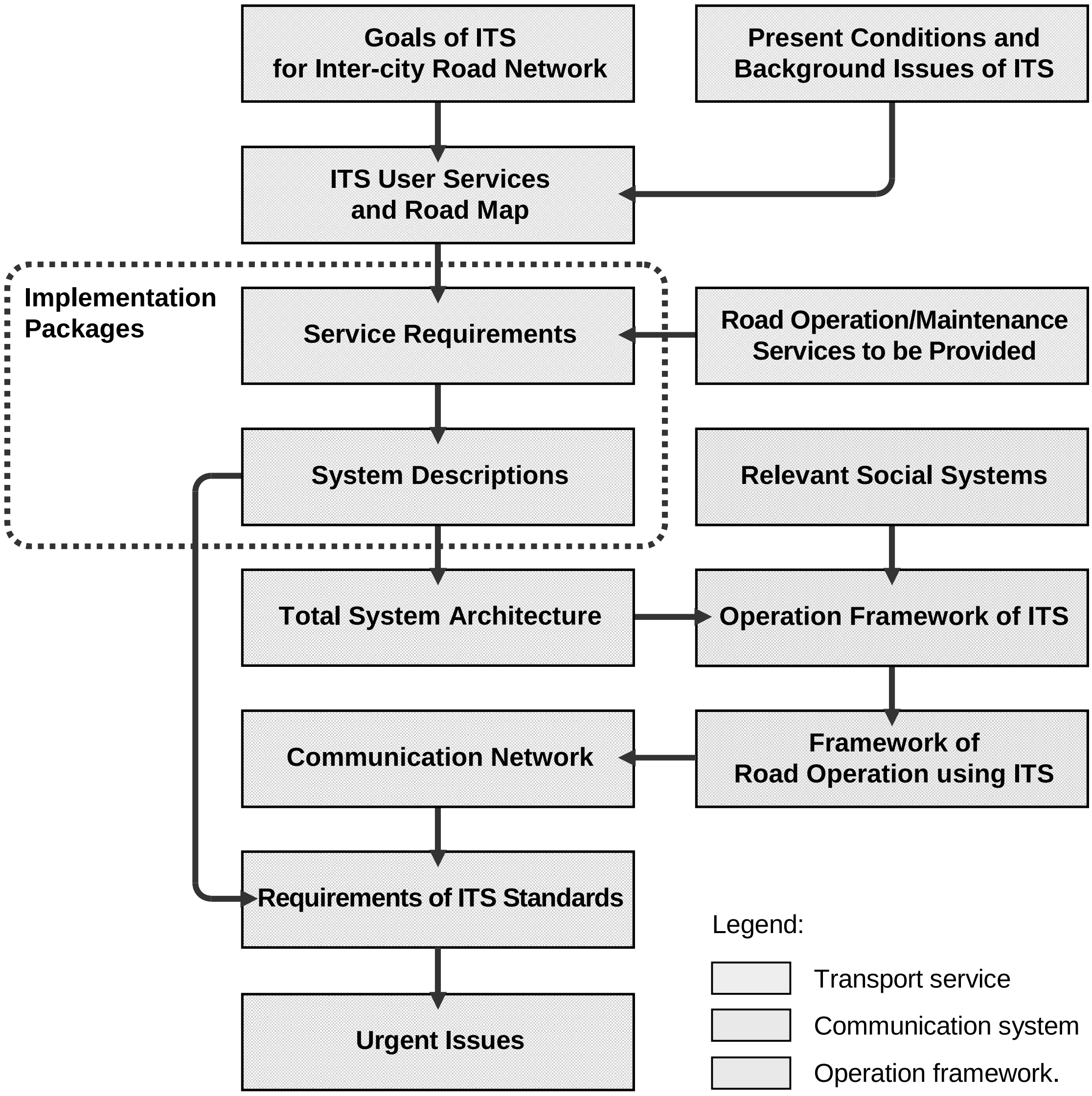


Source: VITRANSS2 Study Team

1.5 Structure of the Master Plan

In the master plan, the form of ITS to be introduced to the inter-city road network in Vietnam is discussed from the three aspects aforementioned. The structure and procedure of the master plan is shown in the figure below.

Figure 1.9 Structure of the Master Plan



Source: VITRANSS2 Study Team

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2. ITS User Services and Road Map

2.1 General

Priority/intending ITS user services are proposed in this chapter.

- Traffic information/control
- Non-stop toll collection
- Heavy truck control

} Priority ITS User Services

- Inter-city bus assistance
- Convenient parking assistance.

} ITS User Services to be Introduced in the Future

The ITS user services to be cooperated in urban areas are subsequently proposed, such as road pricing. The effects provided by the services are assembled in a table related to the goals of ITS. The proposed services are finally organized in the road map of ITS with three stages of implementation and the main objectives of each stage are clarified.

2.2 Priority ITS User Service -1: Traffic Information/Control

Service Descriptions: This service provides accurate surveillance of traffic conditions on expressway and adjacent arterial roads. This service assists prompt action of the road operator and the emergency vehicles by notifying occurrence of traffic accidents, broken-down vehicles and other obstacles. This service allows drivers en route and in advance to avoid the influence of the incidents by providing accurately updated information. This service also allows appropriate interchange/route selection by providing drivers en route with information; such as crowdedness and travel-time. This service makes it possible to measure actual traffic volume continuously for developing rational road construction/improvement plan.

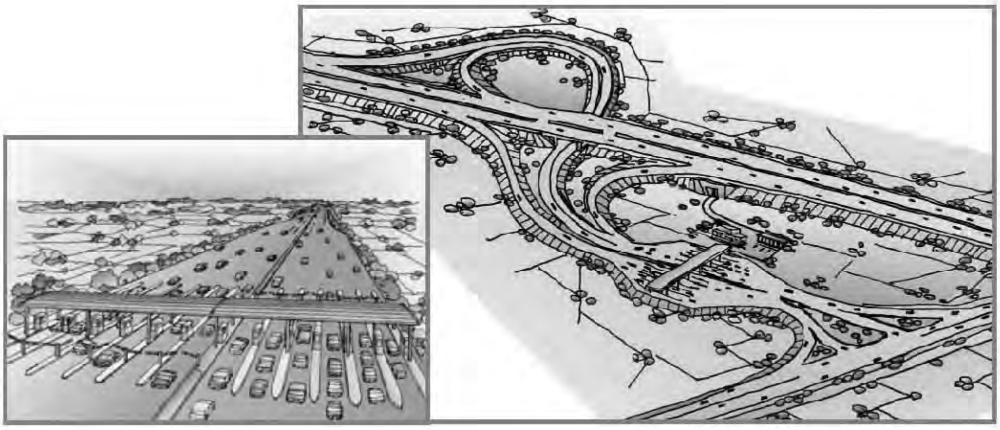
Figure 2.1 Traffic Information/Control

Source: Southern Vietnam Expressway FS by JETRO

2.3 Priority ITS User Service -2: Non-stop Toll Collection

Service Descriptions: This service enables toll collection without stopping vehicles: ETC (Electronic Toll Collection). This service relieves bottlenecks at the tollgates and allows smooth incoming and outgoing at the interchanges. This service reduces the number of tollbooths and solves the problem of land acquisition for the tollgates in suburban areas where traffic congestion will become an issue in near future. This service realizes simple vehicle inspection at the border crossings, and provides road or vehicle operators with the time of vehicle passage at the tollgates. Computerized toll management can vastly reduce uncollected toll revenue due to the failure in counting/classifying vehicles and can realize appropriate sharing of the toll revenue among different road operators.

Figure 2.2 Non-stop Toll Collection

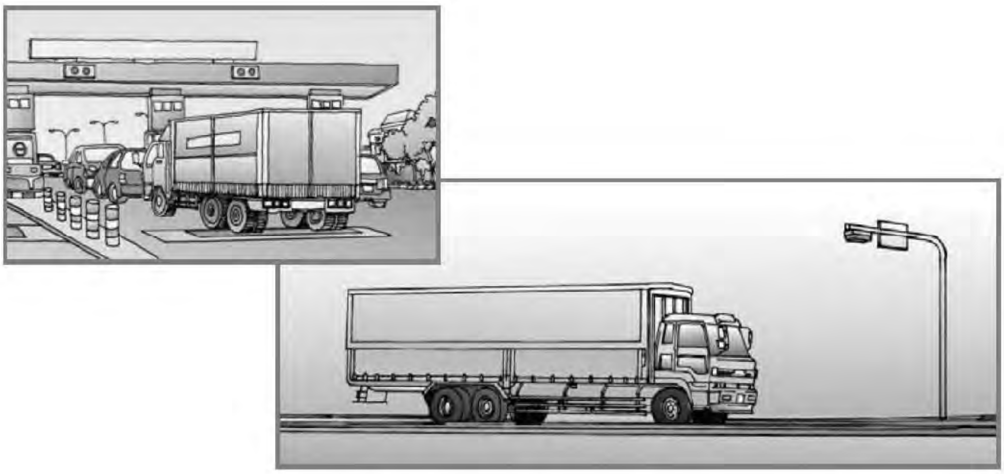


Source: Southern Vietnam Expressway FS by JETRO

2.4 Priority ITS User Service -3: Heavy Truck Control

Service Descriptions: This service eliminates overloading of heavy trucks by automatic execution of vehicle weighing at interchanges. It restrains damage to the road structure and extends its durable lifetime. This service restrains congestion caused by heavy trucks and allows freight trans-port to improve safety by eliminating overloading. This service allows prompt action of the road operator at the occurrence of serious accidents caused by heavy trucks and hazardous-material trucks and appropriate vehicle operation by keeping track of the trucks on the expressway network.

Figure 2.3 Heavy Truck Control

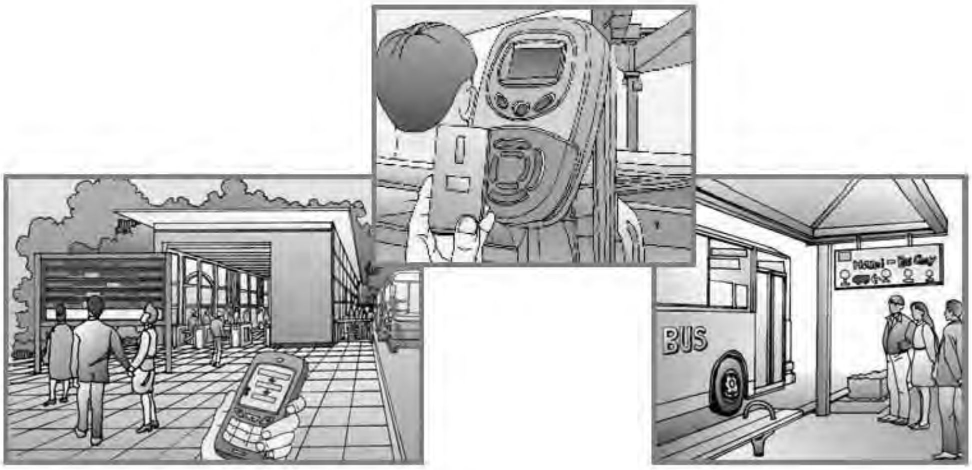


Source: Southern Vietnam Expressway FS by JETRO

2.5 Intending ITS User Service -1: Inter-city Bus Assistance

Service Descriptions: This service keeps track of the bus on the inter-city road network and reduces the time waiting for buses at home, in the hotels or at the bus-stops by providing bus operation information. This service facilitates automatic bus fare collection by touch-and-go. This service enhances convenience in use of the inter-city buses. This service can promote the use of inter-city buses for the motorbike riders and can reduce the number of traffic accidents caused by unreasonably long drive of motor-bike.

Figure 2.4 Inter-city Bus Assistance

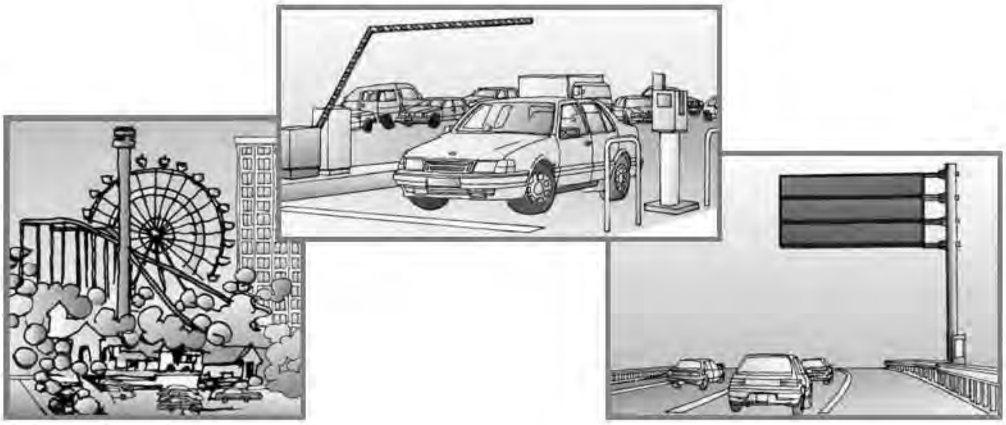


Source: Southern Vietnam Expressway FS by JETRO

2.6 Intending ITS User Service -2: Convenient Parking Assistance

Service Descriptions: This service allows drivers to conveniently park at rest areas on the inter-city road network by providing information of parking availability for the drivers en route and automatic parking fee collection. This service facilitates automatic fare collection also for the payment of commercial/amusement establishments by a single IC-card. That enhances the amenity of the rest area and the roadside facilities, and can promote the drivers to enjoy long-distance drives using the inter-city road network.

Figure 2.5 Convenient Parking Assistance



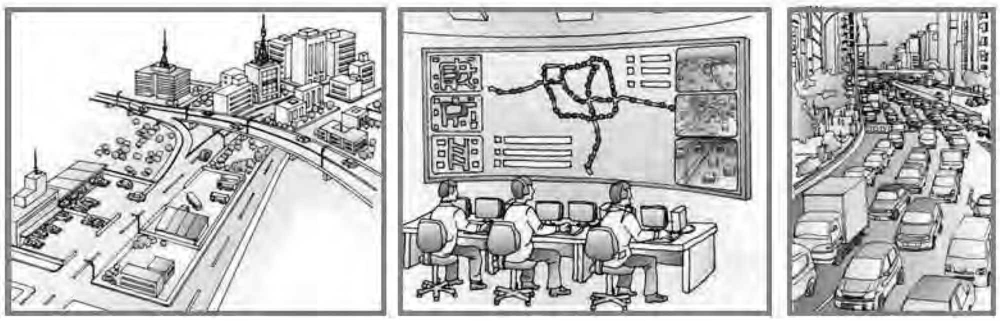
Source: Southern Vietnam Expressway FS by JETRO

2.7 ITS User Services to be Integrated in Urban Areas

Traffic Information/Control

Service Descriptions: This service, aforementioned as that on the inter-city road network, is to be provided also on the arterial road networks in urban areas. Traffic information shall be exchanged between the centers of the inter-city road network and of arteries in urban areas.

Figure 2.6 Traffic Information/Control

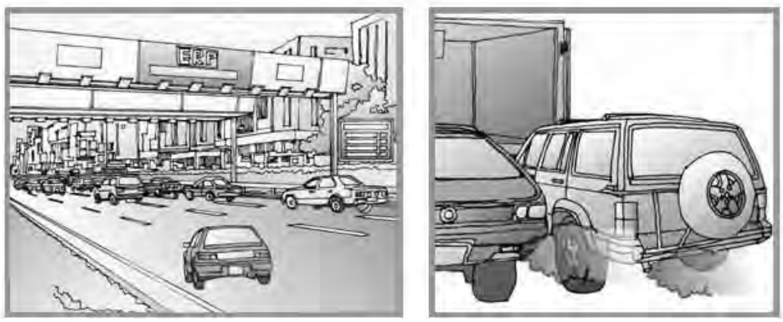


Source: Southern Vietnam Expressway FS by JETRO

Road Pricing

Service Descriptions: This service charges the vehicles for entering certain zones with air pollution or certain streets with heavy congestion in urban areas, in order to manage the traffic demand and promote selecting and using the appropriate means of transport. The charge is conducted using the method integrated with ETC on the inter-city road network: ERP (Electronic Road Pricing). This service disseminates serious worsening of the roadside environmental conditions to the drivers even from a long distance to urban areas.

Figure 2.7 Road Pricing



Source: Southern Vietnam Expressway FS by JETRO

Inter-city Bus Assistance

Service Descriptions: This service, aforementioned as that on the inter-city road network, is to be provided also on the arterial road networks in urban areas. This service allows an integrated fare collection and discounts for pooled amount of the parking fee and the public transports, and can promote park-and-ride in urban areas.

Figure 2.8 Inter-city Bus Assistance

Source: Southern Vietnam Expressway FS by JETRO

<u>Convenient Parking Assistance</u>

Service Descriptions: This service, aforementioned as that on the inter-city road network, is to be provided also on the arterial road networks in urban areas. This service allows drivers to convenient park in urban areas by providing information of parking availability for the drivers en route and automatic parking fee collection.

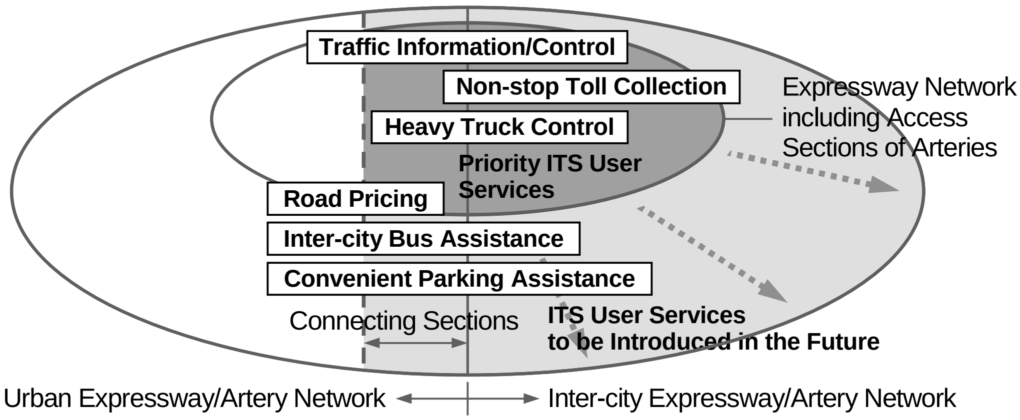
Figure 2.9 Convenient Parking Assistance

Source: Southern Vietnam Expressway FS by JETRO

2.8 Distribution of ITS User Services

Distribution of the ITS user services is shown below. In the first stage, ITS implementation shall focus on the priority user services, and that are to be extended in the later stages.

Figure 2.10 Distribution of ITS User Services



Source: VITRANSS2 Study Team

2.9 Effects of ITS User Services

Introduction of the ITS user services brings the effects and aids in the goals of ITS as below. (→ See APPENDIX-3 and APPENDIX-4.)

Table 2.1 Effects of ITS User Services

ITS User Services / **Goals of ITS** and Effects	Traffic Information/Control	Non-stop Toll Collection	Heavy Truck Control	Inter-city Bus Assistance	Convenient Parking Assistance	Road Pricing
Increase operational efficiency of transportation system	**X**	**X**	**X**	**X**	**X**	**X**
• Increase number of passengers of a vehicle				X		X
• Reduce administration and regulatory cost		X	X		X	
• Reduce infrastructure operating cost			X			
• Reduce vehicle operating cost	X		X	X		
• Increase man-power savings		X	X	X	X	
Provide smooth and punctual transport	**X**	**X**	**X**		**X**	**X**
• Increase lane carrying capacity	X					
• Increase lane carrying capacity at tollgates		X				
• Reduce incident related capacity restrictions	X					
• Reduce exposure to accidents and incidents	X					
• Reduce number of stops		X				
• Reduce queue length	X					
• Reduce queue length at tollgates		X				
• Reduce queue length at parking gates					X	
• Increase travel time savings			X			
• Reduce traffic volume						X
• Reduce vehicle hours of delay by insufficient acceleration			X			
• Remove unnecessary vehicle kilometers by bewildered vehicles					X	
Improve safety and security of transport	**X**		**X**			
• Reduce incident severity preventing secondary accidents	X					
• Reduce number of security incidents on freight transport			X			
• Reduce time between incident and response	X		X			
Enhance convenience and comfort of transport	**X**			**X**	**X**	**X**
• Reduce congestion and incident-related delay	X					
• Reduce inter-modal transfer time				X		
• Reduce individual travel time	X			X	X	
• Reduce individual travel time variability	X			X	X	
• Increase time for leisure and business				X		
• Promotes use of public transport				X		X
Decrease energy consumption and environmental costs		**X**			**X**	**X**
• Reduce emissions including carbon-dioxide		X			X	X
Activate industries by developing advanced technologies	**X**	**X**	**X**	**X**	**X**	**X**
Secure smooth access to urban arteries	**X**			**X**	**X**	**X**

Source: VITRANSS2 Study Team

2.10 Road Map of ITS for Inter-city Road Network

Time period for ITS implementation on the inter-city road network in Vietnam is to be divided into the following three stages:

- 1st Stage: up to 2015
- 2nd Stage: from 2015 to 2020
- 3rd Stage: from 2020 to 2030.

The implementation of the three priority ITS user services shall be started in the 1st stage:

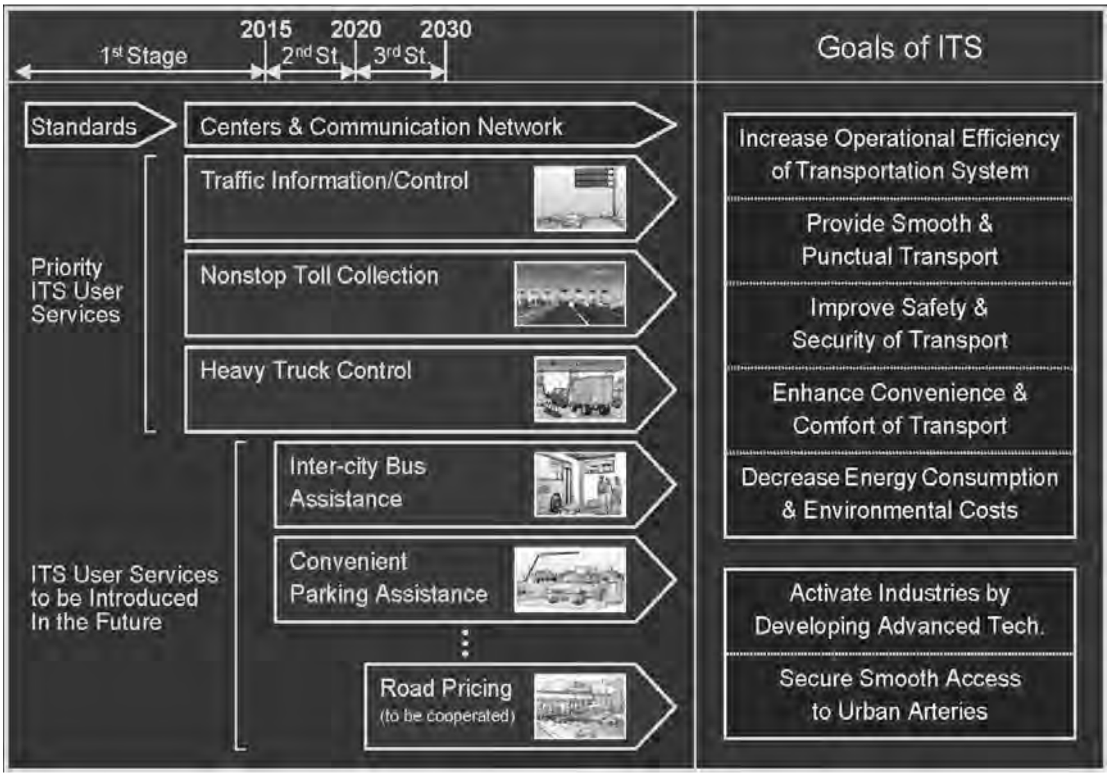
- Traffic information/control
- Non-stop toll collection
- Heavy truck control.

The implementation of the following two intending ITS user services are to be started in the 2nd stage:

- Inter-city bus assistance
- Convenient parking assistance.

Aiming at the goals aforementioned in Chapter 1, the road map of ITS for the inter-city road network is summarized as below.

Figure 2.11 Road Map of ITS for Inter-city Road Network



Source: VITRANSS2 Study Team

Main objectives of each stage are clarified as shown in the following three tables. The itemization in the tables are responding to the priority and intending ITS user services. Discussion in and after Chapter 4 is focused on the priority ITS user services whose implementation is to begin in the 1st stage as shown below.

Table 2.2 Main Objectives of ITS in the 1st Stage

Main Objectives of ITS (by 2015)			
Increase Operational Efficiency of Transportation System	Attainment of traffic information/control based on incident/congestion/ weather-condition monitoring at specific spots, non-stop toll collection at tollgates and over-loading regulation. 1. Incident notification assistance and information 2. Traffic congestion information related to incidents 3. Weather information 4. Traffic control assistance responding to occurrences of incidents 5. Center-to-center data exchange for traffic information and control 6. Non-stop toll collection at toll island 7. Center-to-center data exchange for non-stop toll collection 8. Overloading regulation by automatic vehicle weighing 9. Center-to-center data exchange for overloading regulation.		
Provide Smooth & Punctual Transport	1, 2, 3, 4, 6, 8.	Lower Energy Consumption & Environmental Costs	2, 4, 6, 8.
Improve Safety & Security of Transport	1, 3, 4, 8.	Activate Industries by Developing Advanced Tech.	1, 2, 3, 4, 5, 6, 7, 8, 9.
Enhance Convenience & Comfort of Transport	1, 2, 3, 4, 6.	Secure Smooth Access to Urban Area	--

Source: ITS Integration Project (SAPI) Study Team

Table 2.3 Main Objectives of ITS in the 2nd Stage

Main Objectives of ITS (by 2020)			
Increase Operational Efficiency of Transportation System	Attainment of traffic information/control based on day-to-day-congestion /travel-time monitoring, specific long-haul truck/bus tracking and crowdedness information for parking at rest areas. 1. Traffic congestion information 2. Travel-time information 3. Traffic control assistance 4. Heavy/hazardous-material truck tracking 5. Center-to-center data exchange for truck tracking 6. Bus tracking information provision 7. Center-to-center data exchange for bus tracking 8. Parking information provision 9. Center-to-center data exchange for convenient parking assistance.		
Provide Smooth & Punctual Transport	1, 2, 3, 4, 6, 8.	Lower Energy Consumption & Environmental Costs	1, 3, 8.
Improve Safety & Security of Transport	3, 4.	Activate Industries by Developing Advanced Tech.	1, 2, 3, 4, 5, 6, 7, 8, 9.
Enhance Convenience & Comfort of Transport	1, 2, 3, 6, 8.	Secure Smooth Access to Urban Area	6.

Source: ITS Integration Project (SAPI) Study Team

Table 2.4 Main Objectives of ITS in the 3rd Stage

Main Objectives of ITS (by 2030)			
Increase Operational Efficiency of Transportation System	Attainment of traffic information/control based on incident monitoring on continuous road section, ETC exclusive interchanges, parking fee collection at the rest area with amusement establishments, park&bus-ride and coordination with ERP in urban areas. 1. Incident information by monitoring continuously along the roads 2. Non-stop toll collection on free-flow at ETC exclusive interchange 3. Automated border crossing 4. Parking fee collection for the highway-oasis 5. Integrated fee collection for park&bus-ride 6. Center-to-center data exchange for park&bus-ride fee collection 7. Cooperation with road pricing in urban areas.		
Provide Smooth & Punctual Transport	1, 2, 3, 4, 5, 7.	Lower Energy Consumption & Environmental Costs	2, 4, 5, 7.
Improve Safety & Security of Transport	1.	Activate Industries by Developing Advanced Tech.	1, 2, 3, 4, 5, 6, 7.
Enhance Convenience & Comfort of Transport	1, 2, 3, 4, 5, 6.	Secure Smooth Access to Urban Area	5, 7.

Source: ITS Integration Project (SAPI) Study Team

Figure 2.12 ITS User Service Implementation Schedule

	1st Stage (to 2015)	2nd Stage (2015–2020)	3rd Stage (2020–2030)
Traffic Control/ Information	• Incident notification assistance and information • Traffic congestion information related to incidents • Weather information • Traffic control assistance responding to occurrences of incidents • Center-to-center data exchange for traffic information and control	• Traffic congestion information • Travel-time information • Traffic control assistance	• Incident information by monitoring continuously along the roads
Non-stop Toll Collection	• Non-stop toll collection at toll island • Center-to-center data exchange for non-stop toll collection		• Non-stop toll collection on free-flow at ETC exclusive interchange
Heavy Truck Control	• Overloading regulation by automatic vehicle weighing • Center-to-center data exchange for overloading regulation	• Heavy/hazardous-material truck tracking • Center-to-center data exchange for truck tracking	
Inter-city Bus Assistance		• Bus tracking information provision • Center-to-center data exchange for bus tracking	
Convenient Parking Assistance		• Parking information provision • Center-to-center data exchange for convenient parking assistance	• Parking fee collection at highway-oasis • Integrated fee collection for park&bus-ride • Center-to-center data exchange for park& bus-ride fee collection
Road Pricing			• Cooperation with road pricing in urban areas

Source: ITS Integration Project (SAPI) Study Team

3. Minimal Service Levels of Expressway Operation

3.1 General

Outlines of the road operation/maintenance are mentioned in this chapter. The policy of a combined toll rate system is proposed for the road network in the metropolitan area. The policies of toll revenue are mentioned and the policy of vehicle classification is assumed for the discussion in the following chapters.

Finally, the minimal service requirements for expressways are proposed for discussing the required service level of ITS quantitatively in the Master Plan.

3.2 Road Operation/Maintenance

1) Outlines of Road Operation/Maintenance

The operator needs to provide road operation/maintenance services for the road use as shown in the table below. The road operation, which includes road/facility management, toll collection, traffic information/control and communication system management, is to be supported by ITS.

Based on the minimal service requirements, the operator is to provide the services shown in the table below. It is to be defined as a premise for discussion in the Study that ITS is to be applied to a part of the road operation, which includes road structure/facility management, toll collection/management, traffic information/control and communication system management.

Table 3.1 Services of Road Operation/Maintenance

Operation	Maintenance
(a) Road Structure/Facility Management Cleaning-up, green space management, disaster recovery, energy and water supply and checkups of structure and facility in order to secure safety and comfort in road use.	Maintenance for restoring structure and facility to their original state of function and performance. - Pavement - Bridge - Tunnel - Semi-underground structure - Architectural structure - Mechanical equipment - Electrical equipment.
(b) Toll Collection/Management Toll collection from the road users and its management.	
(c) Traffic Information/Control (d) Heavy Truck Control Routine patrol, regulation against illegal vehicles and traffic control for safe/comfortable drive and smooth traffic flow.	
(e) Communication System Management Fiber optic cable network system operation and management.	**Applicable Scope of ITS**

Source: ITS Integration Project (SAPI) Study Team

A single organization can be in charge both of construction and operation/maintenance of the road section; however, some parts of the work can be transferred to the other organization under contract.

There can be the case where a single organization is in charge both of construction and operation/maintenance of the road section; however, some parts of them can be transferred to the other organization under contract.

(1) Road/Facility Management

Road/facility management includes the service items below and the scope and purpose of each are to be standardized.

- Energy and water supply
- Cleaning-up (for safety)
- Green space management (for environment conservation)
- Checkups of structure and facility
- Disaster recovery.

These service items are to be carried out by the road operator itself or by other organization under contract. Some items need to be carried out at any cost referring to the relevant decrees/laws; however, some items can be decreased in frequency for labor saving. The frequency shall be defined for each service item and is to be readjusted considering the number of claims from road users and the number of incidents occurred.

Performance of the service item shall be evaluated using the outcome index as below:

- Rate of accident
- Hours of traffic regulation
- Rate of road structure conservation.

(2) Toll Collection

Toll collection includes the service items below and the scope and purpose of each are to be standardized.

- Toll collection process at the roadside
- Toll management/clearance
- IC-card/OBU operation
- Toll enforcement.

These service items need to be carried out by the road operator itself or by other organization under contract according to the regulated toll rate system and the relevant decrees/laws.

Performance of the service item shall be evaluated using the outcome index as below:

- Average vehicle processing time
- Rate of ETC vehicles
- Rate of enforced illegal passage.

(3) Traffic Information/Control

Traffic information/management includes the service items below and the scope and purpose of each are to be standardized.

- Routine patrol
- Regulation against illegal vehicles
- Traffic surveillance/information-provision
- Traffic regulation/control.

These service items are to be carried out by the road operator itself or by other organization under contract. Some items need to be carried out at any cost referring to the relevant decrees/laws; however, some items can be decreased in frequency for labor saving. The frequency shall be defined for each service item and is to be readjusted considering the number of claims from road users and the number of incidents occurred.

The regulation criteria shall be defined on weight limits, speed limits and lane controls. The speed limits shall respond to the weather conditions and the existence of incident/obstruction.

Performance of the service item shall be evaluated using the outcome index as below:

- Rate of accident
- Number of fatalities/injuries
- Hours of delay by traffic congestion.

(4) Communication System Management

Communication system management includes the service items below and the scope and purpose of each are to be standardized.

- System management
- Data communication service
- Network lease service.

These service items need to be carried out by the road operator itself or by other organization under contract according to the regulated toll rate system and the relevant decrees/laws.

Performance of the service item shall be evaluated using the outcome index as below:

- Actual data traffic
- Hours of system-down.

(5) Maintenance

Subjects of maintenance are as shown below and the scope and purpose of maintenance of each are to be standardized.

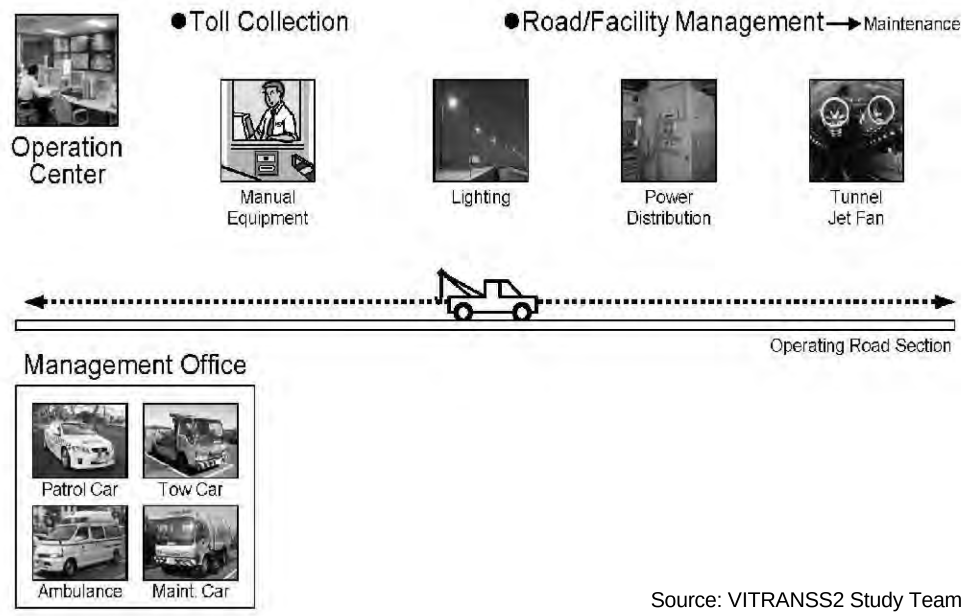
- Pavement
- Bridge
- Tunnel
- Semi-underground structure
- Architectural structure
- Mechanical equipment
- Electrical equipment.

The evaluation criteria and frequency for maintenance shall be defined for each subject, and the frequency shall be readjusted considering the number of claims from road users and the number of incidents occurred.

2) Road Operation Using ITS

Traditional road operation is based on the standalone systems. That needs to be largely supported by manpower and is likely to waste time.

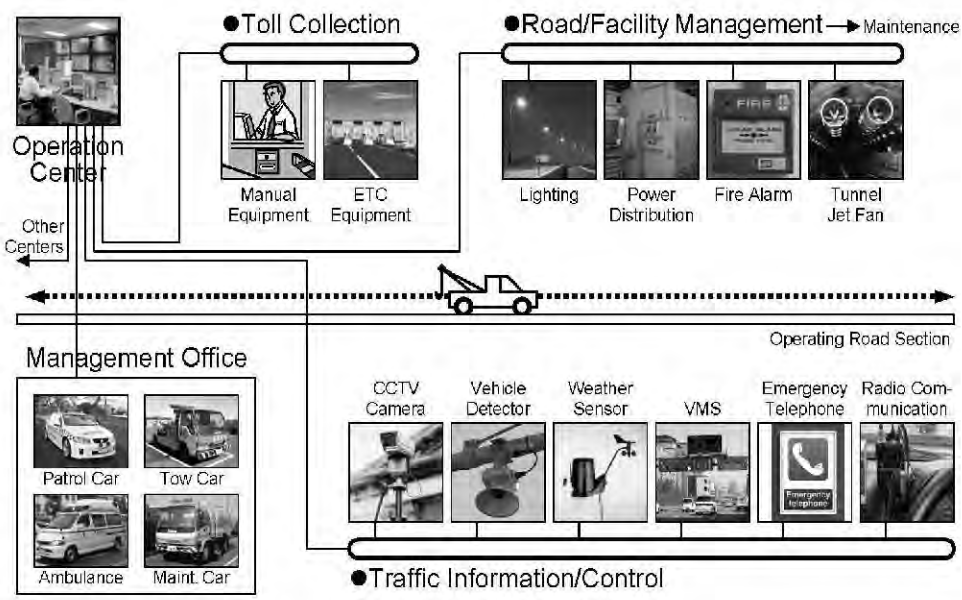
Figure 3.1 Traditional Road Operation based on Standalone Systems



Source: VITRANSS2 Study Team

Advanced way of the road operation is based on ITS and is supported by data change on the communication network. That allows proper judgment and prompt action for the road operator.

Figure 3.2 Advanced Road Operation using ITS



Source: VITRANSS2 Study Team

3.3 Operation/Maintenance Service to be Provided on Expressway

1) Role Sharing on Road Operation/Maintenance

The ownership of the road facility is in public organization; however the role sharing between the public and private organizations shown in the table below needs to be considered in the discussion on the road operation/maintenance.

Table 3.2 Role Sharing between Public and Private Organization

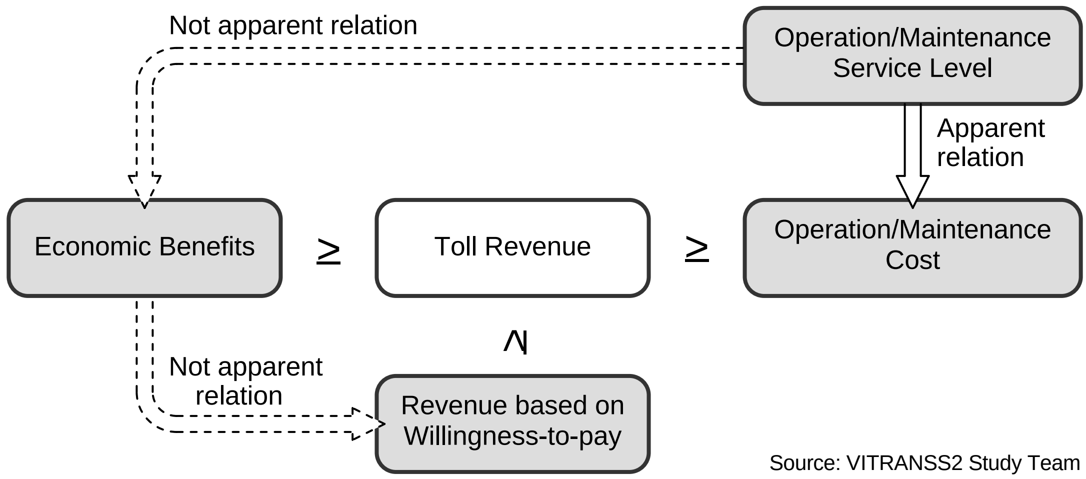
	Service Contract	Management Contract	Lease Contract	O/M Concession
Roles of Public Org.	- Ownership of the road facility. - Responsible for O/M service, funding capital investments and tariff setting.	- Ownership of the road facility. - Ultimately responsible for O/M service, and responsible for funding capital investments and tariff setting.	- Ownership of the road facility. - Responsible for new and replacement investments, establishing performance standard and monitoring.	- Ownership of the road facility. - Responsible for establishing performance standard and monitoring.
Roles of Private Org.	- Transferred O/M services only in working level by fee payment from public org.	- Transferred O/M services including daily management level by fee payment from public org. - Responsible for preparation of working capital.	- Responsible for service provision including O/M, collecting toll and making a specified lease payment to public org. - Responsible for working capital and rehabilitation cost.	- Responsible service provision including O/M and collecting toll based on the concession contract. - Responsible for all capital investment as well as for working capital.
Revenue Risk	Public	Public	Private	Private

Source: VITRANSS2 Study Team

2) Necessity of Minimal Service Requirements

Improvement in the road operation/maintenance causes apparently a cost rise and a decrease in profits for the road operator. However, it is not easy to raise the toll amount, because the increase in benefit and willingness-to-pay of the road users is not apparent. On that account, the operator tends to be effortless in improvement of the road operation/maintenance.

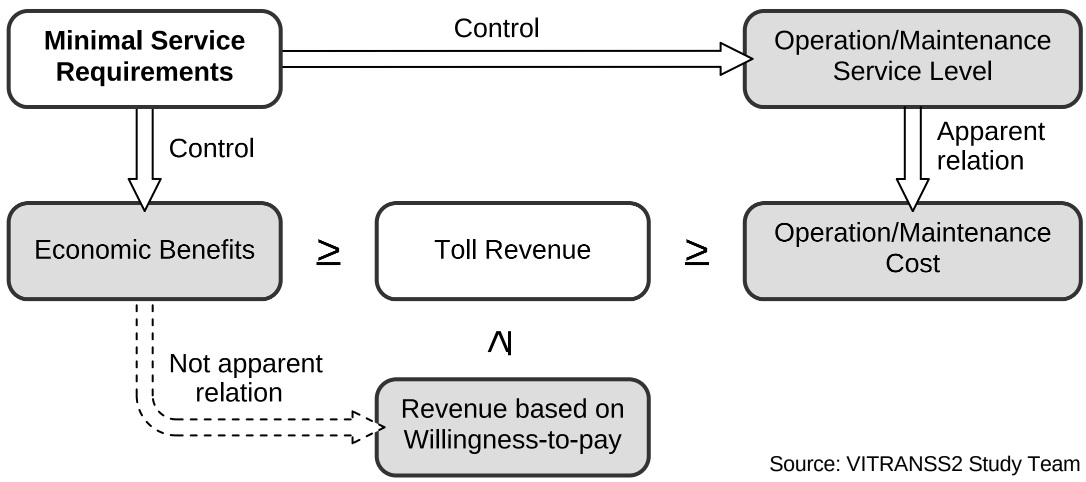
Figure 3.3 Relation between O/M Service Level and Toll Revenue



Source: VITRANSS2 Study Team

Consequently, minimal service level of the road operation/maintenance shall be defined as the requirements. The minimal service standard allows to control the operation/maintenance service level of the road operators as shown in the figure below. In addition, a rise in the specific toll amount is to be accepted responding to the degree of achievement of the minimal service level by the road operator.

Figure 3.4 Minimal Service Requirements for Controlling O/M Service Level



Source: VITRANSS2 Study Team

3) Minimal Service Requirements for the Expressways

The service substances below are to be described in the minimal service requirements.

The following benefits to be provided through expressway operation shall be specified in the Minimal Service Requirements:

- Accessibility
- Mobility
- Safety & response to incident
- Environmental protection.

In the table, correspondences of the Minimal Service Requirements to the services of road operation/maintenance and to the priority ITS user services (→See Section 2.2) are indicated by the following symbols:

(a) : Road structure/facility management
(b) : Toll collection/management →Non-stop toll collection (as a priority ITS user service)
(c) : Traffic information/control →Traffic information/control (as a priority ITS user service)
(d) : Heavy truck control →Heavy truck control (as a priority ITS user service)
(e) : Communication system management.

Table 3.3 Minimal Service Requirements for Expressway Operation

Accessibility	• Establishment of appropriate access control system to expressway network: - Rejection of vehicles above the dimensional limits to reduce damage to road structure →(a) - Rejection of impermissible type of vehicles including motor bikes →(b) - Rejection of overloading heavy trucks to reduce damage to road structure →(d) - Rejection of vehicles without payment adequate for regulated toll rate →(b) • Establishment of fair and reliable toll collection system based on the latest toll rate regulation for expressway network: - Availability for any drivers who intend to use expressway network rightfully →(b) - Reliability of automated toll collection: Error ratio by frequency less than 0.0001% on checking sufficiency of prepaid balance with reference to the vehicle class defined by the regulation →(b) • Provision of sufficient vehicle processing capacity at the tollgate by non-stop and one-stop toll collection responding to traffic volume: - Non-stop toll collection at average service-time less than 4.5 sec/vehicle →(b) - One-stop toll collection at average service-time less than 9.0 sec/vehicle →(b). • Connectability of communication network in conformity with the Standards. →(e) • Inter-operability of information/data in conformity with the Standards. →(e)
Mobility	• Establishment of road management offices equipped with adequate system for monitoring traffic, patrol crews for restoring road functions and enforcing/releasing traffic restrictions and vehicles for road operation including tow car, police car and ambulance →(a), (c), (e) • Provision of smooth traffic flow by dispatching routine patrol using operation vehicles: more than 4 times a day →(a), (c) • Provision of smooth traffic flow through traffic information/control: responding to locations of the vehicle on the road network and traffic volume →(c) • Maximum speed: 120 km/hr →(c) • Lowest speed to be secured: 50 km/hr (to be not less than maximum speed –70 km/hr, otherwise coming-in traffic shall be restricted) →(c) • Average travel speed: more than 60 km/hr →(c) • Traffic surveillance and information dissemination with update intervals: 5 minutes →(c).
Safety & Response to Incident	• Establishment of adequate organization to keep road structure/facility well-maintained to secure safety for road traffic →(a), (c) • Establishment of appropriate framework to address incidents including traffic accidents notified by emergency calls (including 113 and 115) →(c), (e) • Securing of means for emergency call with a delay time less than 10 minutes from the incident occurrence even in mountainous areas →(c) • Provision of traffic safety by dispatching road operation vehicles to an incident site with a delayed time less than 1 hour from the reception of emergency call →(c) • Enforcement of adequate traffic restrictions responding to the incident occurrences and the traffic conditions →(c) • Information dissemination of incident with a delay time less than 1 hour →(c), (e).
Environmental Protection	• Promotion of installation and dissemination of non-stop toll collection →(b) • Keeping smooth traffic flow by enhancing traffic information/control →(c).

Note: (a), (b), (c), (d), (e) are to be referred to Table 3.1.
Source: ITS Integration Project (SAPI) Study Team

4. Implementation Package

4.1 General

The concept of implementation packages is clarified first in this chapter. Subsequently, the specific implementation packages and their alternatives are defined responding to the priority ITS user services by using the following descriptions:

- Service requirements
- Breakdown of implementation packages
- System descriptions
- Supplementary explanation.

As the result of discussion on the implementation packages, the total system architecture is illustrated for ITS implementation on the inter-city road network. The details necessary for specifying the requirements of ITS standards are shown in APPENDIX-1. Finally, the recommendations on the alternatives of the following technologies are mentioned:

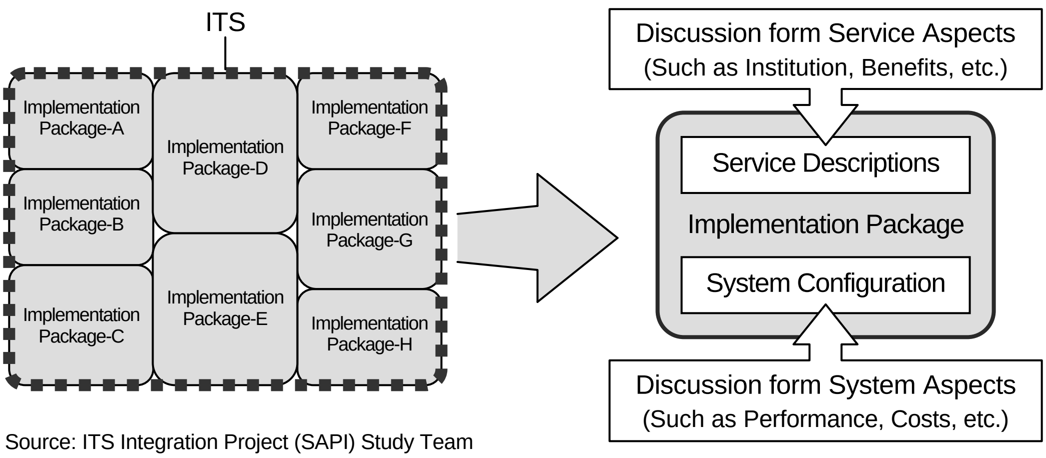
- CCTV camera
- Vehicle detection
- VMS (Variable Message Sign)
- Road-to-vehicle communication for ETC
- Contact-less IC-card.

(Relevant international standards are shown in APPENDIX-2.)

4.2 Concept of Implementation Package

The ITS user services aforementioned are to be implemented stepwise based on the selection suited to regional properties and are to be divided into smaller packages accordingly. For this purpose, implementation packages are prepared in the Master Plan. The concept of implementation packages provides a common ground for the discussion of two aspects as shown below and allows sharing of specific recognition of ITS among the persons in charge.

Figure 4.1 Concept of Implementation Package



Source: ITS Integration Project (SAPI) Study Team

Implementation packages for the priority ITS user services are specified in the following.

4.3 Implementation Packages for Traffic Information/Control

1) Service Requirements

Traffic information/control is the priority ITS user service whose implementation is to be started in the 1st stage (by 2015) as shown in Chapter 3. That can be detailed and defined by the following service requirements. Reference numbers attached to the subtitles indicate the corresponding implementation packages and the alternatives to be hereinafter described.

➢ **Incident Information → 1-(a), (b)**

< from the 1st Stage >

- Receiving information of incident occurrence/place/situation, including left obstruction and natural disaster on the road, from the person concerned or the witness by 10 minutes at the latest,
- Round-the-clock surveillance at the incident-prone spots,
- Notification to the road operation vehicles immediately after receiving the information of incident,
- Arrival of the road operation vehicles at the site by 1 hour at the latest from the incident occurrence,
- Decision/implementation of traffic restriction immediately after arrival of the road operation vehicles,
- Incident/restriction information dissemination to the drivers en-route on adjacent section immediately after the decision of restriction, and prevention of the secondary incidents,
- Information update every 15 minutes for dissemination,
- Prompt incident/restriction information dissemination to the drivers en-route for reducing vehicles to the concerned section,
- Prompt incident/restriction information dissemination to the drivers in advance.

< from the 3rd Stage >

- Round-the-clock surveillance on the selected continuous road sections,
- Compiling/storing/providing data for incident information.

Figure 4.2 Incident Information

Source: Southern Vietnam Expressway FS by JETRO

➢ **Weather Information → 4**

< from the 1st Stage >

- Round-the-clock monitoring of rainfall, wind direction/velocity and temperature at every interchange on the expressway network,
- Weather information dissemination, as needed, to the drivers en-route/in-advance,

- Information update every 15 minutes for dissemination,
- Compiling/storing/providing data for weather information.

➢ **Center-to-center Data Exchange for Incident Notification → 9-1**

< from the 1st Stage >

- Round-the-clock information reception of incident occurrence/situation/place at the traffic information/control center from the traffic police operation center,
- Round-the-clock prompt information provision of incident occurrence/situation/place from the traffic information/control center to the traffic police operation center and the emergency vehicle operation center.

< from the 2nd Stage >

- Provision of weather information from the traffic information/ control center to the traffic police operation center and the emergency vehicle operation center.

➢ **Traffic Congestion Information → 2-(a), (b), (c), (d), (e)**

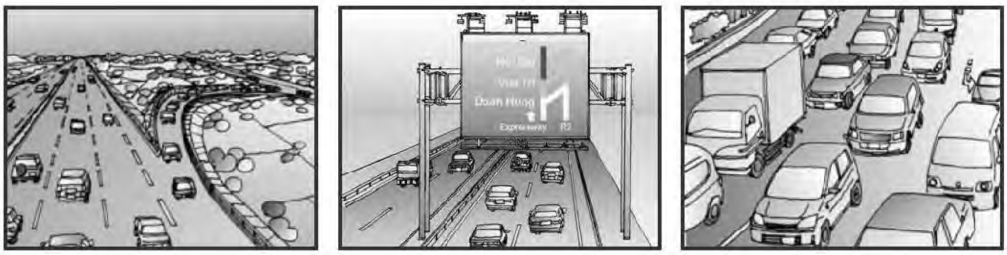
< from the 1st Stage >

- Receiving information of congestion caused by an incident from the road operation vehicle,
- Round-the-clock surveillance at the congestion-prone section,
- Detecting the congestion with length of 1 km or further,
- Analyzing property of existing traffic excluding disturbing factors,
- Decision/implementation of the restriction of incoming traffic as needed at the interchange,
- Traffic congestion information dissemination to the drivers en-route on adjacent section immediately after grasping the congestion for prevention of the collision from behind, and to the drivers en-route/in-advance as needed,
- Prompt restriction information dissemination to the drivers en-route/in-advance.
- Information update every 15 minutes for dissemination.

< from the 3rd Stage >

- Round-the-clock surveillance on the selected continuous road sections,
- Analyzing property of traffic, and forecasting the congestions,
- Congestion forecast information dissemination to the drivers en-route/in-advance.
- Compiling/storing/providing data for traffic congestion information.

Figure 4.3 Traffic Congestion Information



Source: Southern Vietnam Expressway FS by JETRO

- **Center-to-center Data Exchange for DSRC Probe → 9-2**

< from the 2nd Stage >
- Generating DSRC probe data at the DSRC probe data center using data from the toll management center and the road pricing operation center and excluding disturbing factors caused by the measurement,
- Provision of the generated data to the traffic information center, the cargo-truck operation center and the inter-city bus operation center,
- Data update every 15 minutes for provision.

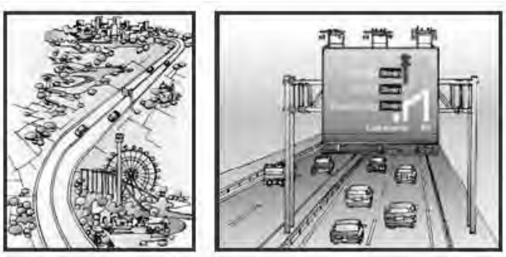
- **Center-to-center Data Exchange for GPS/WL Probe → 9-3**

< from the 2nd Stage >
- Generating GPS/WL probe data at the GPS/WL probe data center using data from the cargo-truck operation center and the inter-city bus operation center and excluding disturbing factors caused by the measurement,
- Provision of the generated data to the traffic information center, the cargo-truck operation center and the inter-city bus operation center,
- Data update every 15 minutes for provision.

- **Travel-time Information → 3-(a), (b), (c), (d)**

< from the 2nd Stage >
- Analyzing/estimating travel-time between the interchanges and the junctions on the whole expressway network excluding disturbing factors,
- Travel-time information dissemination to the drivers en-route/in-advance as needed,
- Information update every 15 minutes for dissemination,
- Compiling/storing/providing data for travel-time information.

Figure 4.4 Travel-time Information



Source: Southern Vietnam Expressway FS by JETRO

- **Center-to-center Data Exchange for Travel Information → 9-4**

< from the 1st Stage >
- Provision of traffic information (including incident, congestion and restriction) from the traffic information/control center to the traffic police operation center, the information provider center and the TV/Radio broadcasting center.

< from the 3rd Stage >
- Provision of congestion forecast information from the traffic information/control center to the traffic police operation center, the information provider center and the TV/Radio broadcasting center.

➢ **Traffic Control Assistance → 5-(a), (b), (c), (d), (e)**

< from the 1st Stage >
- Notification to the road operation vehicles immediately after receiving the information of incident,
- Arrival of the road operation vehicles at the site by 1 hour at the latest from the incident occurrence,
- Decision/implementation of traffic restriction immediately after arrival of the road operation vehicles,
- Incident/restriction information dissemination to the drivers en-route on adjacent section immediately after the decision of restriction, and prevention of the secondary incidents,
- Prompt incident/restriction information dissemination to the drivers en-route for reducing vehicles to the concerned section,
- Traffic congestion information dissemination to the drivers en-route on adjacent section immediately after grasping the congestion for prevention of the collision from behind,
- Decision/implementation of the restriction of incoming traffic at the interchange as needed,
- Prompt restriction information dissemination to the drivers en-route,
- Information update every 15 minutes for dissemination.

< from the 2nd Stage >
- Travel-time/weather information dissemination to the drivers en-route.

< from the 3rd Stage >
- Congestion forecast information dissemination to the drivers en-route.

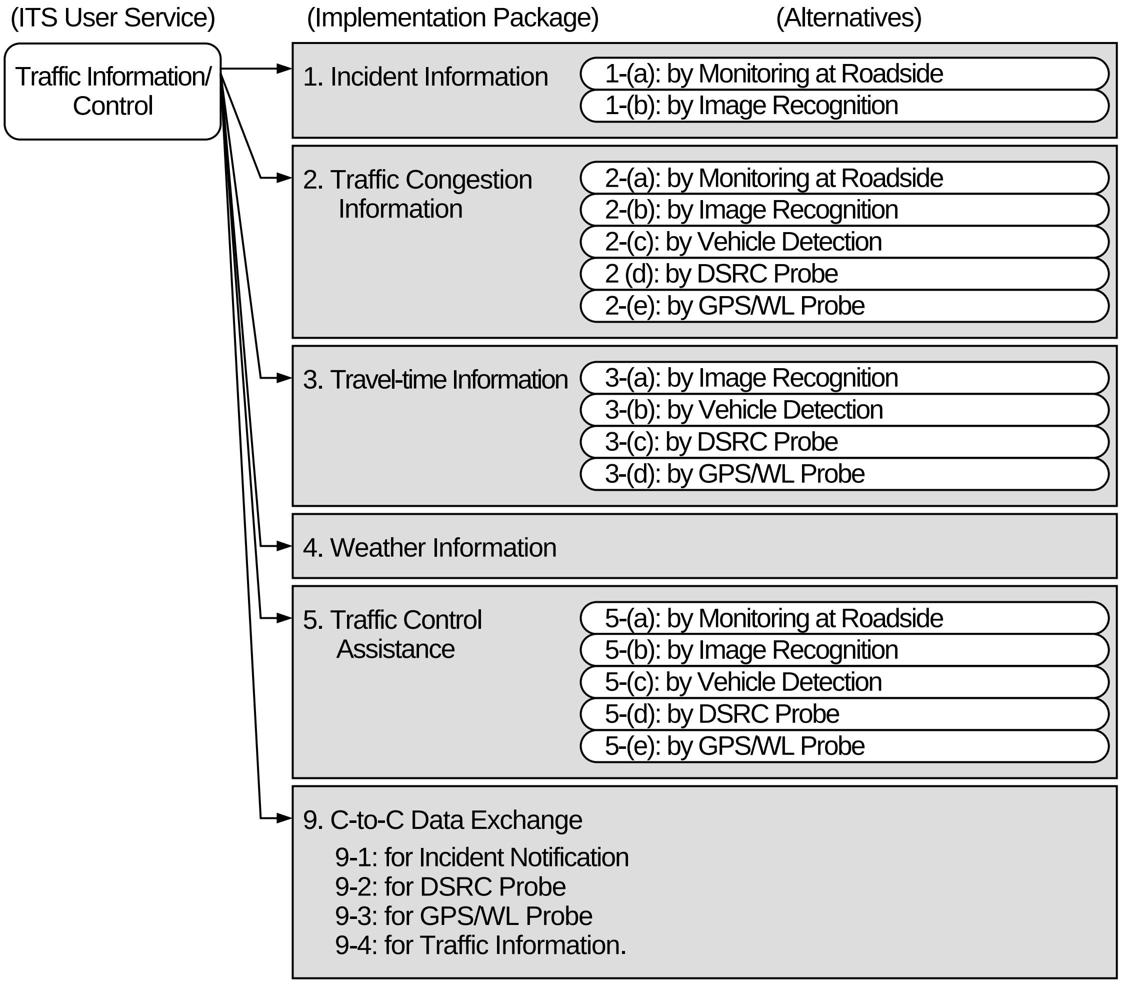
Figure 4.5 Traffic Control Assistance

Source: Southern Vietnam Expressway FS by JETRO

2) Breakdown of Implementation Packages

Traffic information/control can be broken down into six implementation packages as shown below. Each package has one or more alternatives, and four use cases are assumed for the package of center-to-center data exchange.

Figure 4.6 Implementation Packages and Alternatives of Traffic Information/Control



Source: VITRANSS2 Study Team / Oriental Consultants Co., Ltd.

System outlines for the traffic information/control are shown in the following pages corresponding to the implementation packages and the alternatives above.

4) Detailed Discussion on Traffic Information/Control

(1) Key-device of Alternative

Figure 4.7 Key-device of Alternative

	by Monitoring at Roadside	by Image Recognition	by Vehicle Detection	by DSRC Probe	by GPS/WL Probe
Key-device of Alternative					

Source: VITRANSS2 Study Team / Southern Vietnam Expressway FS by JETRO

(2) Recommendations on Alternatives

The foregoing recommendations on the alternatives for traffic information/control (discussed in the ITS Working Group shown in APPENDIX-5) are summarized in the table below.

Table 4.1 Recommendations on Alternatives for Traffic Information/Control

	Incident Information	Traffic Congestion Information	Travel-time Information	Weather Information	Traffic Control Assistance
by Monitoring at Roadside	Useful as a Complement 1-(a)	Useful as a Complement 2-(a)	--	--	Useful as a Complement 5-(a)
by Image Recognition	Recommended 1-(a)	Useful as a Complement 2-(b)	Not Suitable 3-(a)	--	Necessary 5-(b)
by Vehicle Detection	--	Recommended 2-(c)	Not Suitable 3-(b)	--	Necessary 5-(c)
by DSRC Probe	--	Not Suitable 1-(d)	Recommended 3-(c)	--	Necessary 5-(d)
by GPS/WL Probe	--	Not Suitable 1-(e)	Useful as a Complement 3-(db)	--	Useful as a Complement 5-(e)
by Weather Sensor	--	--	--	Necessary 4	--

Source: VITRANSS2 Study Team

4.4 Implementation Packages for Non-stop Toll Collection

1) Service Requirements

Non-stop toll collection is the priority ITS user service whose implementation is to be started in the 1st stage (by 2015) as shown in Chapter 3. That can be detailed and defined by the following service requirements. Reference numbers attached to the subtitles indicate the corresponding implementation packages and the alternatives to be hereinafter described.

- **Toll Collection → 6**

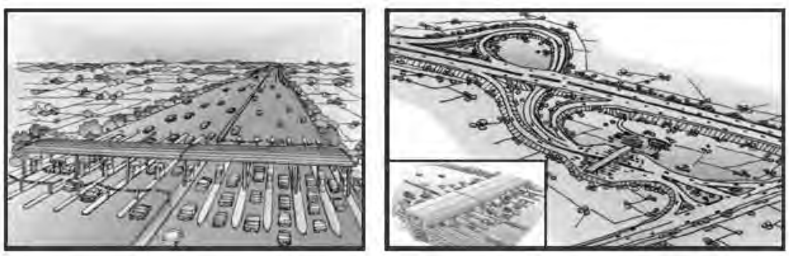
< from the 1st Stage >

- Non-stop toll collection responding to the distance-proportional/sectional/flat tariff system,
- Capability of combined use of non-stop toll collection and one-stop toll collection for efficient implementation of roadside equipment: in-coming by non-stop and out-going by one-stop, and in-coming by one-stop and out-going by non-stop as well,
- Average service-time less than 4.5sec/vehicle by non-stop toll collection such as ETC,
- Average service-time less than 6.0sec/vehicle by one-stop toll collection such as Touch&Go,
- Toll payment by prepayment,
- Capability of checking sufficiency/shortage of prepaid balance by the driver in advance or en-route using OBU and contact-less IC-card: balance-in-card,
- Shared use of OBU among different road sections under the different road operators for convenience of the user,
- Achieving a low error ratio (less than 0.01%) of treating the short prepaid balance as sufficient, and the sufficient prepaid balance as short,
- Achieving a low error ratio (less than 0.01%) of falling into inoperable situation by system errors, and easy procedure to recover the system errors,
- Conformance to the vehicle classification defined by the Vietnamese Government,
- Identifying vehicle class without costly detectors, and easy system modification for revision of the vehicle classification,
- Capability of sure prevention of unlawful passage including violation,
- Simple roadside equipment component for non-stop/one-stop toll collection to be connected to existing system for manual toll collection by the stepwise implementation.

< from the 3rd Stage >

- Shared use of OBU and contact-less IC-card with ERP (Electronic Road Pricing) in the urban area.

Figure 4.8 Toll Collection



Source: Southern Vietnam Expressway FS by JETRO

- **Center-to-center Data Exchange for Toll Settlement → 9-5**

< from the 1st Stage >

- Toll clearance to be prepared for many different road operators over the whole expressways and other toll roads
- Toll clearance by using contact-less IC-card for prepayment,
- Issue/recharge of contact-less IC-card to be utilized conveniently in the city as well as the roadside,
- Adequate data exchange for toll clearance between the toll management center of the road operator and the prepayment service center such as the center of the bank,
- Appropriate and reliable apportionment of the toll revenue among the road operators preventing unfair billings to the prepayment service center for establishing the sustainable toll clearance system,
- Stepwise establishment of the toll clearance system for enhancing convenience for the users.

- **Center-to-center Data Exchange for IC-card Operation → 9-6**

< from the 1st Stage >

- Storage of the IC-card issue/recharge data in the prepayment service center for prevention of illegal recharge,
- Reception of the notification of lost IC-card from the user to the prepayment service center,
- Transmission of the lost IC-card list from the prepayment service center to the toll management centers of the road operators (through the clearing center) for invalidating the lost IC-card over the whole expressways and other toll roads.

- **Center-to-center Data Exchange for OBU Management → 9-7**

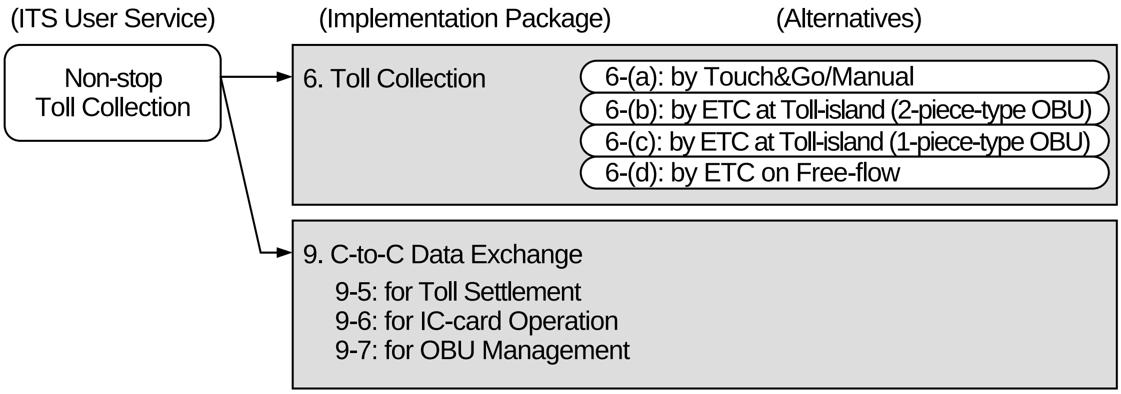
< from the 1st Stage >

- Storage of the OBU registration data in the center, which is transferred from the OBU shop where OBU is issued to the user and installed in the vehicle,
- Reception of the notification of lost OBU from the user to the OBU registration center,
- Transmission of the lost OBU list from the OBU registration center to the toll management centers of the road operators for invalidating the lost OBU over the whole expressways and other toll roads.

2) Breakdown of Implementation Packages

Non-stop toll collection can be broken down into the two implementation packages as shown below. Each package has one or more alternatives, and four use cases are assumed for the package of center-to-center data exchange.

Figure 4.9 Implementation Packages and Alternatives of Non-stop Toll Collection



Source: VITRANSS2 Study Team / Southern Vietnam Expressway FS by JETRO

System outlines for the non-stop toll collection are shown in the following pages corresponding to the implementation packages and the alternatives above.

4) Detailed Discussion on Non-stop Toll Collection

(1) Key-device of Alternative

Figure 4.10 Key-device of Alternative

	by Touch& Go/Manual	by ETC at Toll-island (2-p)	by ETC at Toll-island (1-p)	by ETC on Free-flow
Key-device of Alternative				

Source: VITRANSS2 Study Team / Southern Vietnam Expressway FS by JETRO

(3) Recommendations on Alternatives

The foregoing recommendations on the alternatives for non-stop toll collection (discussed in the ITS Working Group shown in APPENDIX-5) are summarized in the table below.

Table 4.2 Recommendations on Alternatives for Non-stop Toll Collection

	Non-stop Toll Collection	Pre-payment	Balance-in-card	Processing Error Rate /Recovery	Violation Preven tion	Combined Use with Touch&Go	Cost of OBU	Grading
by Touch& Go/Manual 6-(a)	Not Capable	Capable	Capable	Low /Easy	Easy	--	--	Useful as a Complement
by ETC at Toll-island (2-piece) 6-(b)	Capable	Capable	Capable	Low /Easy	Average	Capable	Average	Recommended
by ETC at Toll-island (1-piece) 6-(c)	Capable	Difficult	Not Capable	Low /Difficult	Average	Incapable	Low	Not Suitable
by ETC on Free-flow 6-(d)	Capable	Capable	Capable	Low /Ignore	Difficult	Capable	Average	Too Early

Source: VITRANSS2 Study Team

Comparison factors shown in the first line of the table above are discussed in detail in the following pages.

4.5 Implementation Packages for Heavy Truck Control

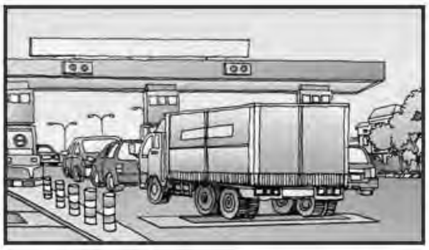
1) Service Requirements

Heavy truck control is the priority ITS user service whose implementation is to be started in the 1st stage (by 2015) as shown in Chapter 3. That can be detailed and defined by the following service requirements. Reference numbers attached to the subtitles indicate the corresponding implementation packages and the alternatives to be hereinafter described.

- **Overloading regulation → 7-(a), (b)**

< from the 1st Stage >
- Weighing heavy trucks with/without stopping them,
- Identification of illegally loading (including/excluding the vehicle weight according to the standardization),
- Assist the regulation of illegally loading (according to the standardized procedure of the standalone method to weigh/reject the overloaded trucks at roadside, or of the online method to store overloading records in the negative database for the penalty later on).

Figure 4.11 Overloading regulation

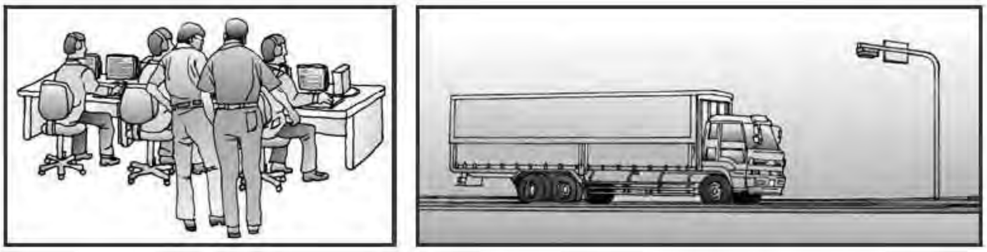


Source: Southern Vietnam Expressway FS by JETRO

- **Heavy/Hazardous-material Truck tracking → 8-(a), (b)**

< from the 2nd Stage >
- Notification to the road operator at the coming of the heavy/hazardous-material truck into the expressway network,
- Tracking the actual driving route of the heavy/hazardous-material truck and the section where the truck exists,
- Identification of the management office in charge of response/clearance of the incident caused by the heavy/hazardous-material truck,

Figure 4.12 Heavy/Hazardous-material Truck tracking



Source: Southern Vietnam Expressway FS by JETRO

- Information of the heavy/hazardous-material truck to the management office in case of incident,
- Information of actual position of the truck to the cargo-truck operators,
- Provision of heavy/hazardous-material truck data to the road operator at the occurrence of the accident.

➢ **Center-to-center Data Exchange for Heavy Truck Control → 9-8**

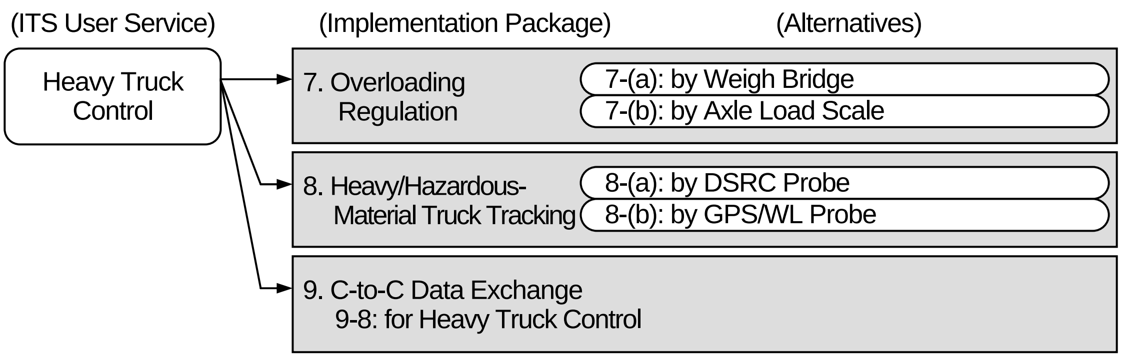
< from the 2nd Stage >

- Actual positioning data of the heavy/hazardous-material trucks generated in the centers of DSRC probe and GPS/WL probe,
- Provision of the positioning data to the centers of heavy truck control and cargo-truck operation.

2) Breakdown of Implementation Packages

Heavy truck control can be broken down into three implementation packages as below. Each package has one or more alternatives, and a use cases is assumed for the package of center-to-center data exchange.

Figure 4.13 Implementation Packages and Alternatives of Heavy Truck Control



Source: VITRANSS2 Study Team / Oriental Consultants Co., Ltd.

System outlines for the heavy truck control are shown in the following pages corresponding to the implementation packages and the alternatives above.

4) Detailed Discussion on Heavy Truck Control

(1) Key-device of Alternative

Figure 4.14 Key-device of Alternative

Key-device of Alternative	by Weighing at Parking Space	by Weighing in Motion	by DSRC Probe	by GPS/WL Probe
				

Source: VITRANSS2 Study Team / Oriental Consultants Co., Ltd.

(3) Recommendations on Alternatives

The foregoing recommendations on the alternatives for heavy truck control (discussed in the ITS Working Group shown in APPENDIX-5) are summarized in the table below.

Table 4.3 Recommendations on Alternatives for Heavy Truck Control

Overloading Regulation	by Weighing at Parking Space 7-(a)	by Weighing in Motion 7-(b)
Measuring Value	Vehicle Weight	Axle Load
Accuracy of Measurement	High	Lowering by Condition
Lead-in/Parking Space	Necessary	Not Necessary
Manpower Distribution on Site	Necessary	Not Necessary
Prevention of Unfairness/Avoidance	Difficult	Can be Controlled
Prevention of Damage Dispersion	Difficult	Can be Controlled
Grading	Not Suitable	Recommended
Heavy/Hazardous-material Truck Tracking	**by DSRC Probe 8-(a)**	**by GPS/WL Probe 8-(b)**
Tracking Area	Limited	Not Limited
Time Intervals of Tracking	Long	Short
Roadside Equipment	Concurrent Use with ETC	Not Necessary
In-vehicle Equipment	Concurrent Use with ETC	Concurrent Use with Driving Rec.
Grading	Recommended	Useful as a Complement

Source: VITRANSS2 Study Team

Comparison factors shown in the left side row of the table above are to be discussed and detailed in the following.

5. Requirements of ITS Standards

5.1 General

The concept of the key-stones of standardization is shown in this chapter. The requirements of ITS standards are listed up for the priority ITS user services: traffic information/control, non-stop toll collection and heavy truck control. The items to be described as the requirements of ITS message/data are shown subsequently referring to ISO11179 and ISO/ DIS14817. Finally, necessity and urgency of the requirements are shown in comparison with the implementation status of ITS in ongoing expressway projects.

5.2 Key-stones of Standardization

Key-stones below are necessary for standardization of ITS to prevent the possible problems aforementioned in Chapter 1.

- Service requirements
- System architecture
- Performance and installation of equipment
- Compatibility of equipment components
- Connectability of interfaces
- Inter-operability of data
- Communication network system.

(1) Service Requirements

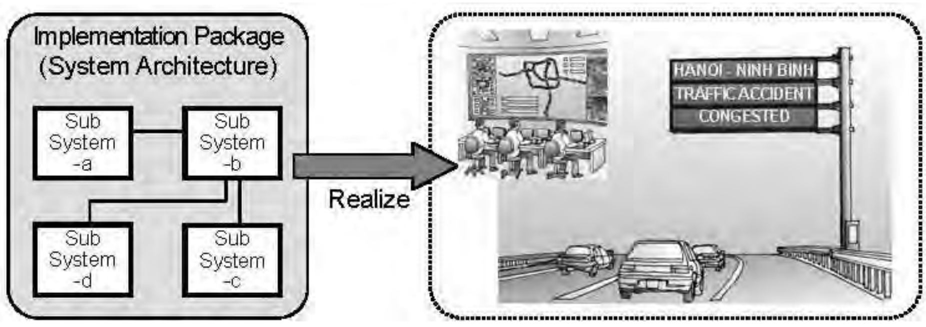
An implementation package realizes a part of the ITS. Distinct service requirements are to be defined for each implementation package in order to preclude unsuitable system installation and to eliminate profitless costs.

Service requirements of the specific implementation packages are already shown in Chapter 4.

(2) System Architecture

The implementation package aforementioned is realized by a set of subsystems that are segmented responding to the difference on the function and the location as shown below.

Figure 5.1 System Architecture of Implementation Package



Source: Southern Vietnam Expressway FS by JETRO

However, even for a set of service requirements, many different configurations of subsystems can be adopted. Unified system architecture needs to be defined for securing connectability of the interfaces, compatibility of the equipment and inter-operability of the data and for realizing efficient implementation. And taking a view of the total system architecture of ITS, appropriate organization is to be allocated to each subsystem for realizing efficient operation.

The total system architecture are shown in Chapter 6 and is to be detailed as the ITS System Architecture for implementation packages in Chapter 7.

(3) Performance and Installation of Equipment

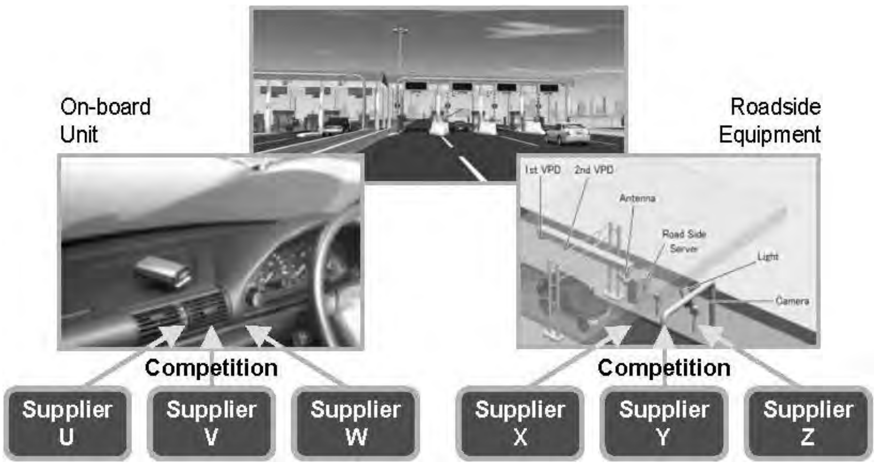
The service requirements are realized by integrating the performance of equipment. The equipment is to be segmented into a set of subsystems that provide the function of sensing, processing and indication, and each subsystem needs to have adequate HMI (Human Machine Interface) and to be installed in the appropriate location on the road network or in the center responding to its function.

Accordingly, fulfillment of the service requirements depends on the performance and installation of equipment, and that is the major part of the ITS standards.

(4) Compatibility of Equipment Components

ITS comprises enormous pieces of equipment, and compatibility among them is indispensable requisite for the efficiency of system implementation. Standardization needs to be pursued in order to secure the compatibility among them. That allows many suppliers to enter the market of equipment and will provide the cost reduction through competition. That will expand business opportunities for Vietnamese companies as well.

Figure 5.2 Competition in Equipment Component Market

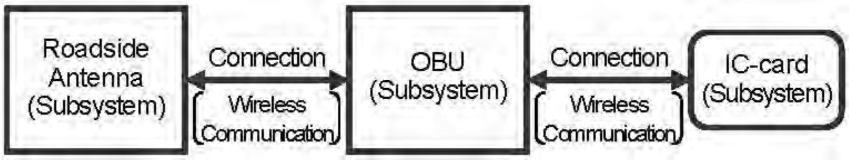


Source: Southern Vietnam Expressway FS by JETRO

(5) Connectability of Interfaces

The system architecture is actualized by the connection of subsystems for data exchange. For example, the roadside antenna, OBU and IC-card are to be connected by wireless communication to exchange the data for toll collection.

Figure 5.3 Connectability of Interfaces

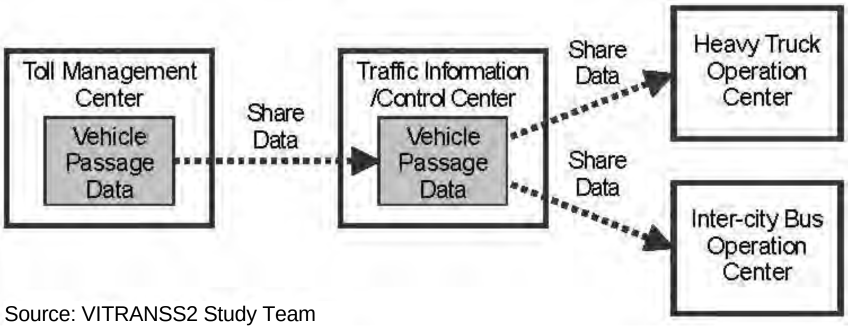


Source: VITRANSS2 Study Team

(6) Inter-operability of Data

Shared use of the data among different subsystems is necessary for efficient operation of ITS and can be achieved by the standardization of data. For example, inter-operability of the vehicle passage data among different centers is necessary for ITS as shown below.

Figure 5.4 Inter-operability of Vehicle Passage Data



Source: VITRANSS2 Study Team

(7) Structure of Communication Network System

ITS will be actualized on the communication network. A unified communication network system with the rational hierarchical structure and center location is to be defined with consideration given to the following issues:

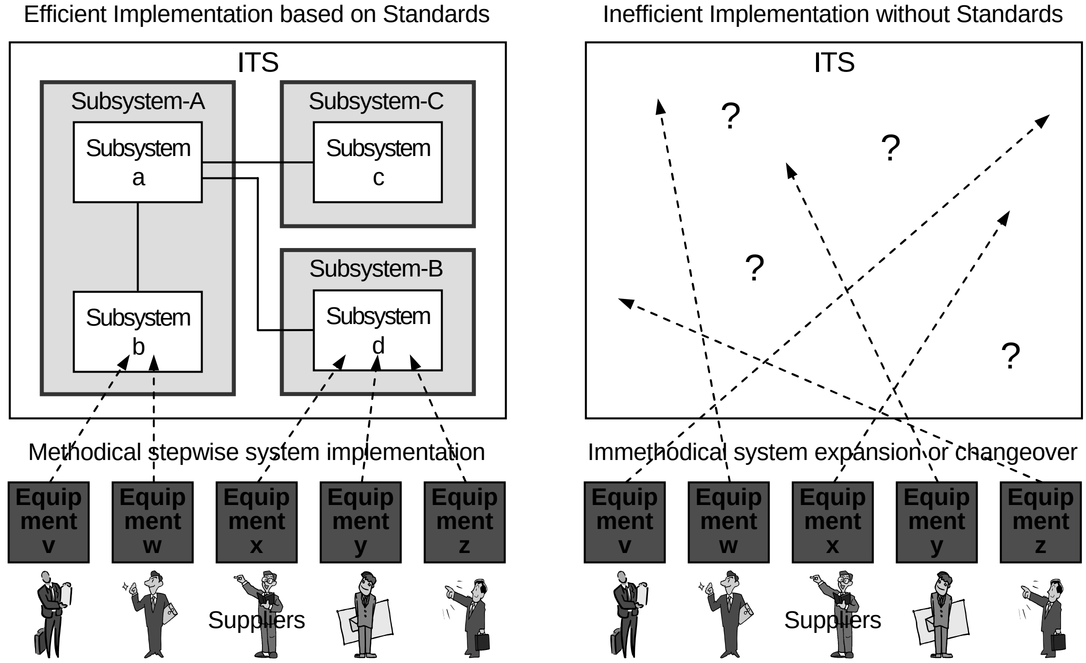
- Required capacity and security of data communication
- Existence of different operating organizations
- Implementation and operation cost.

6. System Architecture

6.1 General

ITS is to be illustrated using the system architecture consists of simple graphical symbols and texts in order to share understanding of system configuration of ITS among all persons in charge. Thereby, when equipment components are substituted by suppliers for subsystems in the system architecture through actual implementation, appropriateness of the substitution can be verified easily and clearly in reference to the system architecture.

Figure 6.1 Efficient ITS Implementation by Sharing Understanding

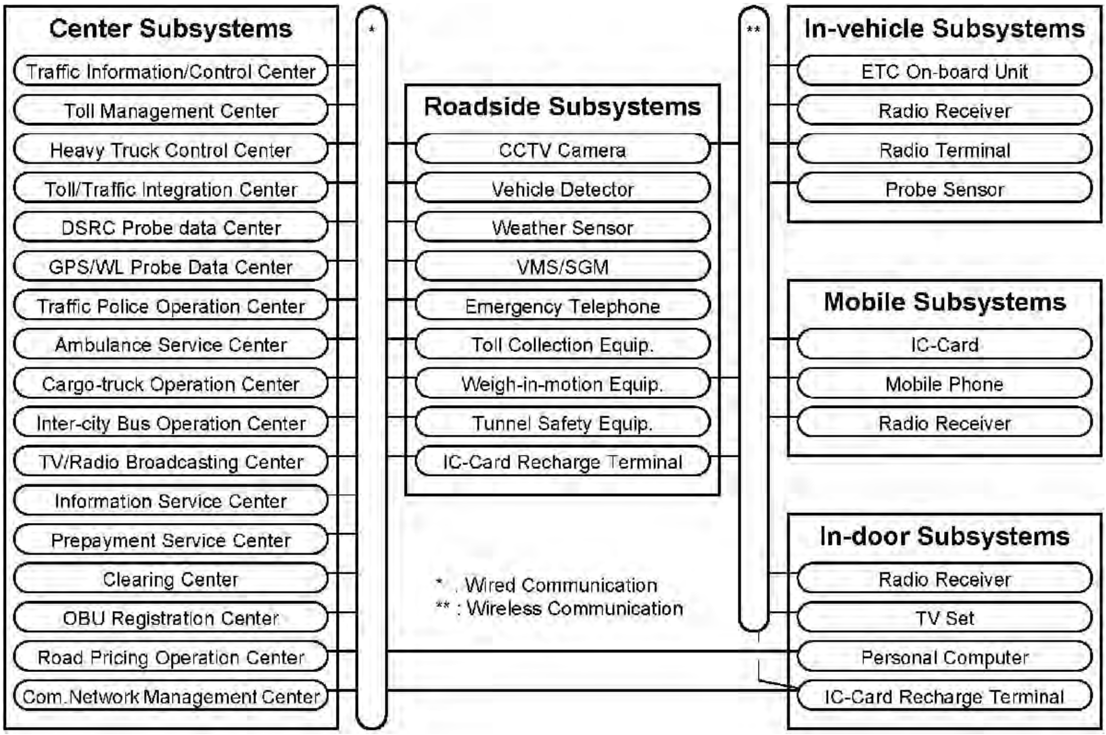


Many diagrams will be shown in the following sections of ITS Master Plan for the system architecture. Notation of these diagrams is to conform to UML (Unified Modelling Language), which is adopted for the reference model architecture for the ITS sector shown in ISO/CD 14813.

6.2 Outlines of System Architecture

As the result of discussion on the implementation packages in the foregoing sections, the total system architecture of ITS to be implemented in the inter-city road network in Vietnam is illustrated below. The whole discussion in the Master Plan is premised on the system architecture, which is to be referred to and upgraded by the persons responsible for ITS standardization in the next stage of the Master Plan.

Figure 6.2 Total System Architecture of ITS



Source: VITRANSS2 Study Team

The total system architecture is illustrated using only the top-level subsystems indicated by ( ), which is called as the "Sausage Diagram". The top-level subsystems are categorized into five groups: centre, roadside, in-vehicle, mobile and in-door, and that are connected through the wired communication and the wireless communication.

The diagrams of detailed system architecture provides a common ground for the discussion on standardization and allows to share the specific recognition of ITS among the persons in charge. The system architecture includes the following diagrams.

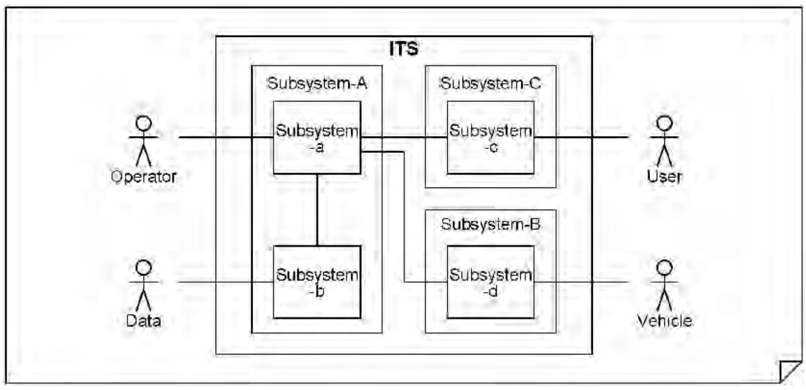
Use Case Diagram

This diagram indicates the cases to use the system including the actors who use/operate it.

Collaboration Diagram

This diagram indicates a system by the combination of subsystems and interfaces for sharing basic understanding of the system.

Figure 6.3 Collaboration Diagram

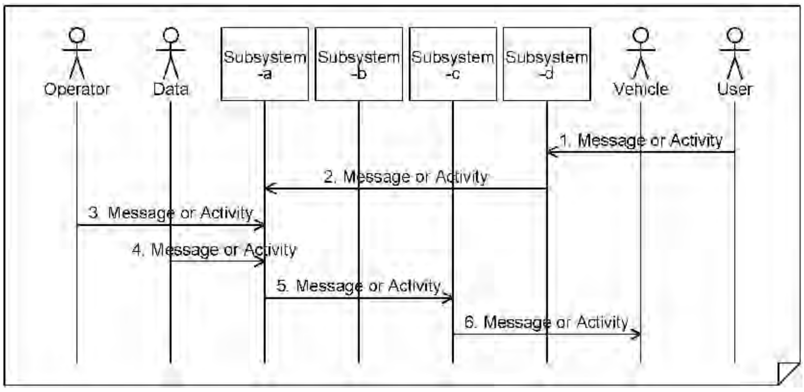


Source: VITRANSS2 Study Team

Message Sequence Diagram

This diagram indicates a sequence of exchanging messages and their data elements for making discussions on interoperability of the data.

Figure 6.4 Message Sequence Diagram



Source: VITRANSS2 Study Team

The system architecture is to be divided into many subsystems, which can be classified as following figure.

Figure 6.5 Classification of Subsystem

Subsystem	Elements of a system defined by considering differences in function, location and envisioned operating body, which can be broken down to the lower-levels; the high-end subsystem is to respond to the total framework for ITS operation.
Functional Package	In-between Subsystem; a group of equipment components that collaborate for realizing a function of a system; unit for the ITS standards and system introduction
Equipment Component	Low-end subsystem; minimum units considered for describing the system architecture of ITS.

Note: an equipment component that does not include any hardware is to be called software component as distinguished from others.

Source: ITS Integration Project (SAPI) Study Team

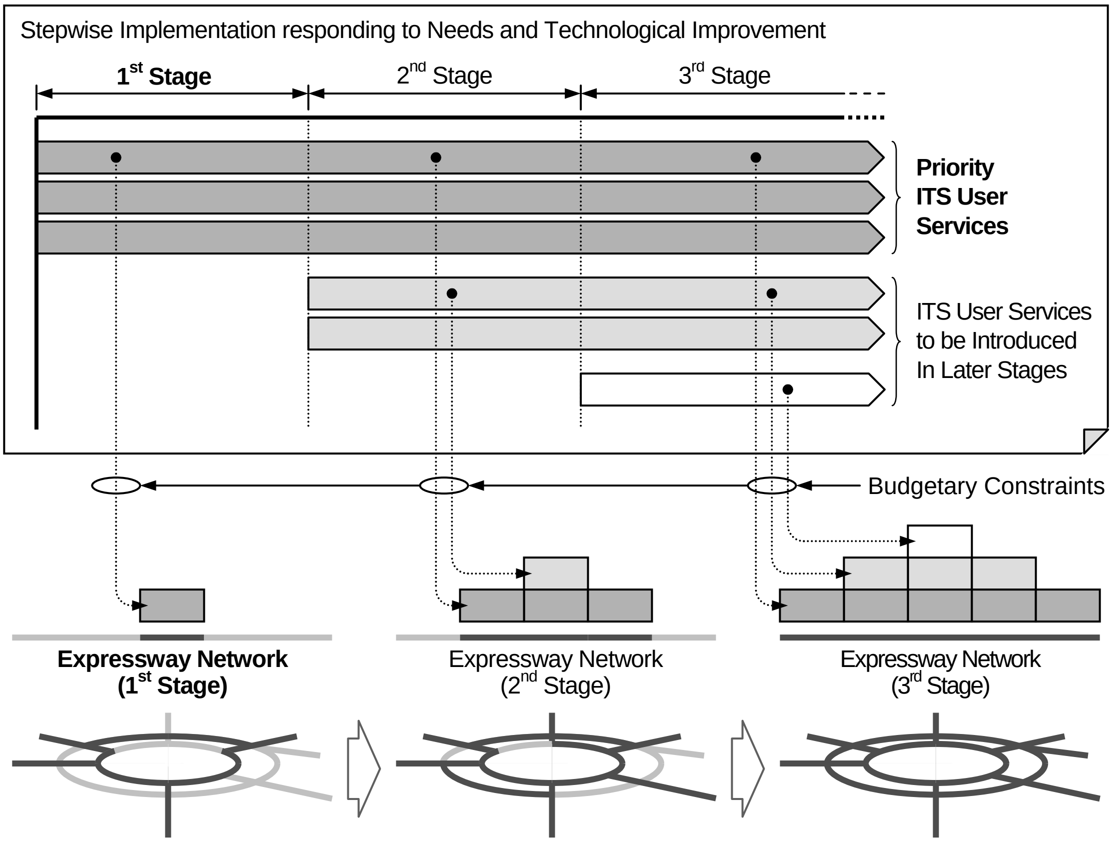
6.3 Policy of Stepwise ITS Implementation by Package

ITS user services are to be introduced stepwise divided into three stages shown in the road map keeping pace with progress of road network construction and changes in volume/quality of road traffic and in user needs. However, for responding to smaller scale of progress and changes, ITS is to be implemented stepwise.

For launching of stepwise implementation of ITS through the Project, issues are discussed in the Study on the premise of stepwise implementation for the following reasons:

- To meet changes in needs responding to economics or traffic
- To harmonize with progress of the expressway network construction
- To meet budgetary constraints
- To respond to technological improvement

Figure 6.6 Stepwise Implementation of ITS

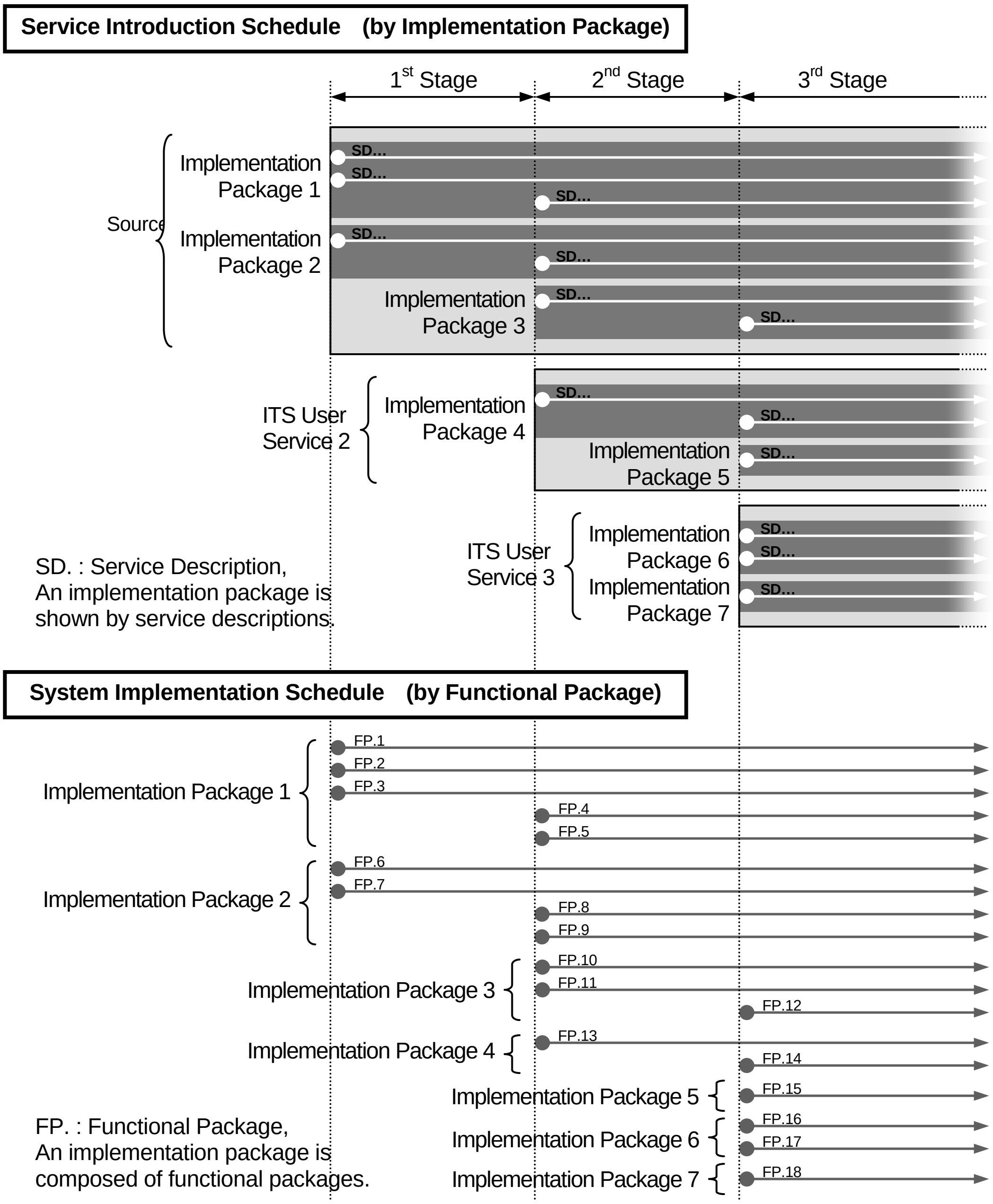


Source: ITS Integration Project (SAPI) Study

It is to be proposed in the Plan to implement ITS by package for responding to the smaller scale of progress road network construction and changes in user needs. That means the services are to be introduced by implementation package, and for composing and realizing each implementation package, the system is to be implemented by functional package as shown in the following figure. A part of ITS user service can be realized by an implementation package and the implementation package is to be composed a set of functional packages.

Consequently, the ITS user service implementation schedule aforementioned can be actualized through the stepwise implementation by functional package.

Figure 6.7 Conceptual Illustration of Stepwise ITS Implementation by Package



Source: ITS Integration Project (SAPI) Study Team

7. System Architectures for Implementation Packages

The descriptions/diagrams for each implementation package and alternative are shown in the pages in the table below.

Table 7.1 Page Table of Descriptions/Diagrams

Implementation Package	Alternatives	Service Requirements	Service Requirements, Use Case (UC)	Collaboration Diagram (CD), Equipment & Installation	Message Sequence Diagram (MSD)
1. Incident Information	1-(a): by Monitoring at Roadside	4.3	7.1-UC	7.1-(a).CD	7.1-(a).MSD
	1-(b): by Image Recognition			7.1-(b).CD	7.1-(b).MSD
2. Traffic Congestion Information	2-(a): by Monitoring at Roadside		7.2-UC	7.2-(a).CD	7.2-(a).MSD
	2-(b): by Image Recognition			7.2-(b).CD	7.2-(b).MSD
	2-(c): by Vehicle Detection			7.2-(c).CD	7.2-(c).MSD
	2-(d): by DSRC Probe			7.2-(d).CD	7.2-(d).MSD
	2-(e): by GPS/WL Probe			7.2-(e).CD	7.2-(e).MSD
3. Travel-time Information	3-(a): by Image Recognition		7.3-UC	7.3-(a).CD	7.3-(a).MSD
	3-(b): by Vehicle Detection			7.3-(b).CD	7.3-(b).MSD
	3-(c): by DSRC Probe			7.3-(c).CD	7.3-(c).MSD
	3-(d): by GPS/WL Probe			7.3-(d).CD	7.3-(d).MSD
4. Weather Information	4-(a): by Weather Sensors		7.4-UC	7.4-(a).CD	7.4-(a).MSD
5. Traffic Control Assistance	5-(a): by Traffic Event Data		7.5-UC	7.5-(a).CD	7.5-(a).MSD
6. Toll Collection	6-(a): by T&G/Manual	4.4	7.6-UC	7.6-(a).CD	7.6-(a).MSD
	6-(b): by ETC at Toll Island (2p-OBU)			7.6-(b).CD	7.6-(b).MSD
	6-(c): by ETC at Toll Island (1p-OBU)			7.6-(c).CD	7.6-(c).MSD
	6-(d): by ETC on Free-flow			7.6-(d).CD	7.6-(d).MSD
7. Overloading Regulation	7-(a): by Weigh Bridge	4.5	7.7-UC	7.7-(a).CD	7.7-(a).MSD
	7-(b): by Axle Load Scale			7.7-(b).CD	7.7-(b).MSD
8. Heavy/HazMat Truck Tracking	8-(a): by DSRC Probe		7.8-UC	7.8-(a).CD	7.8-(a).MSD
	8-(b): by GPS/WL Probe			7.8-(b).CD	7.8-(b).MSD
9. C-to-C Data Exchange	9-1: for Incident Notification	4.3	7.9-UC	7.9-(a).CD	7.9-(a).MSD
	9-2: for DSRC Probe			7.9-(b).CD	7.9-(b).MSD
	9-3: for GPS/WL Probe			7.9-(c).CD	7.9-(c).MSD
	9-4: for Traffic Information			7.9-(d).CD	7.9-(d).MSD
	9-5: for Toll Settlement	4.4		7.2-(e).CD	7.2-(e).MSD
	9-6: for IC-card Operation			7.2-(f).CD	7.2-(f).MSD
	9-7: for OBU Management			7.2-(g).CD	7.2-(g).MSD
	9-8: for Heavy Truck Control	4.5		7.2-(h).CD	7.2-(h).MSD

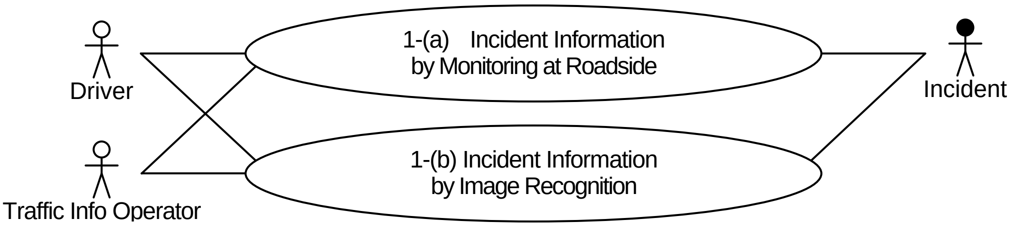
Source: ITS Integration Project (SAPI) Study Team

1) Incident Information

(1) Use Cases Diagram

The following two alternative use cases (UC) are to be discussed for incident information.

Figure 7.1-UC Incident Information



Source: VITRANSS2 Study Team

(2) Collaboration Diagram

The following collaboration diagrams (CD) are reasoned out from the service descriptions aforementioned.

Figure 7.1-(a).CD Incident Information by Monitoring at Roadside
(Graded as "Useful as a Complement")

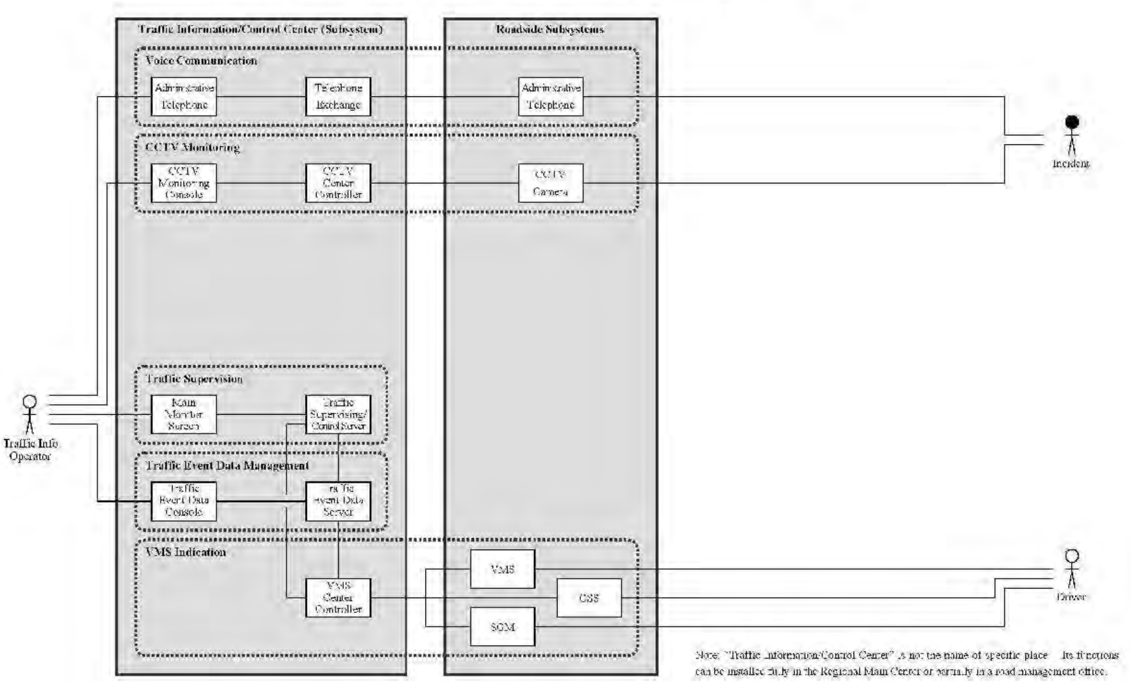
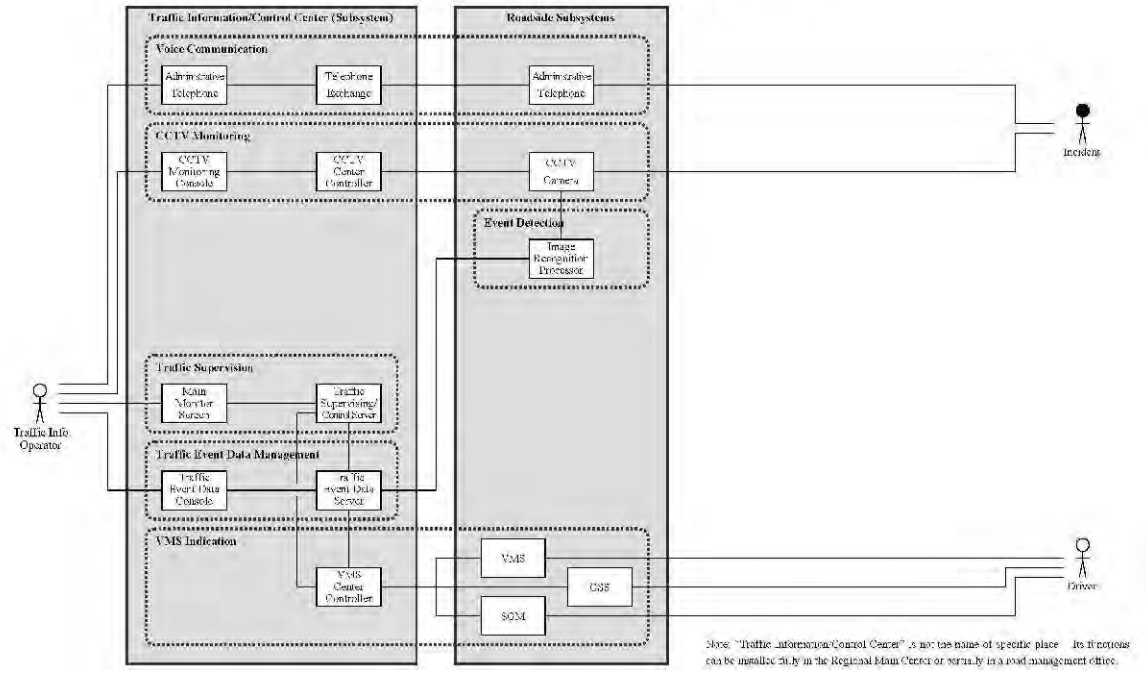


Figure 7.1-(b).CD Incident Information by Image Recognition
(Graded as "Recommended")



(3) Message Sequence Diagram

The following message sequence diagrams (MSD) are derived from the service descriptions aforementioned.

Figure 7.1-(a).MSD Incident Information by Monitoring at Roadside

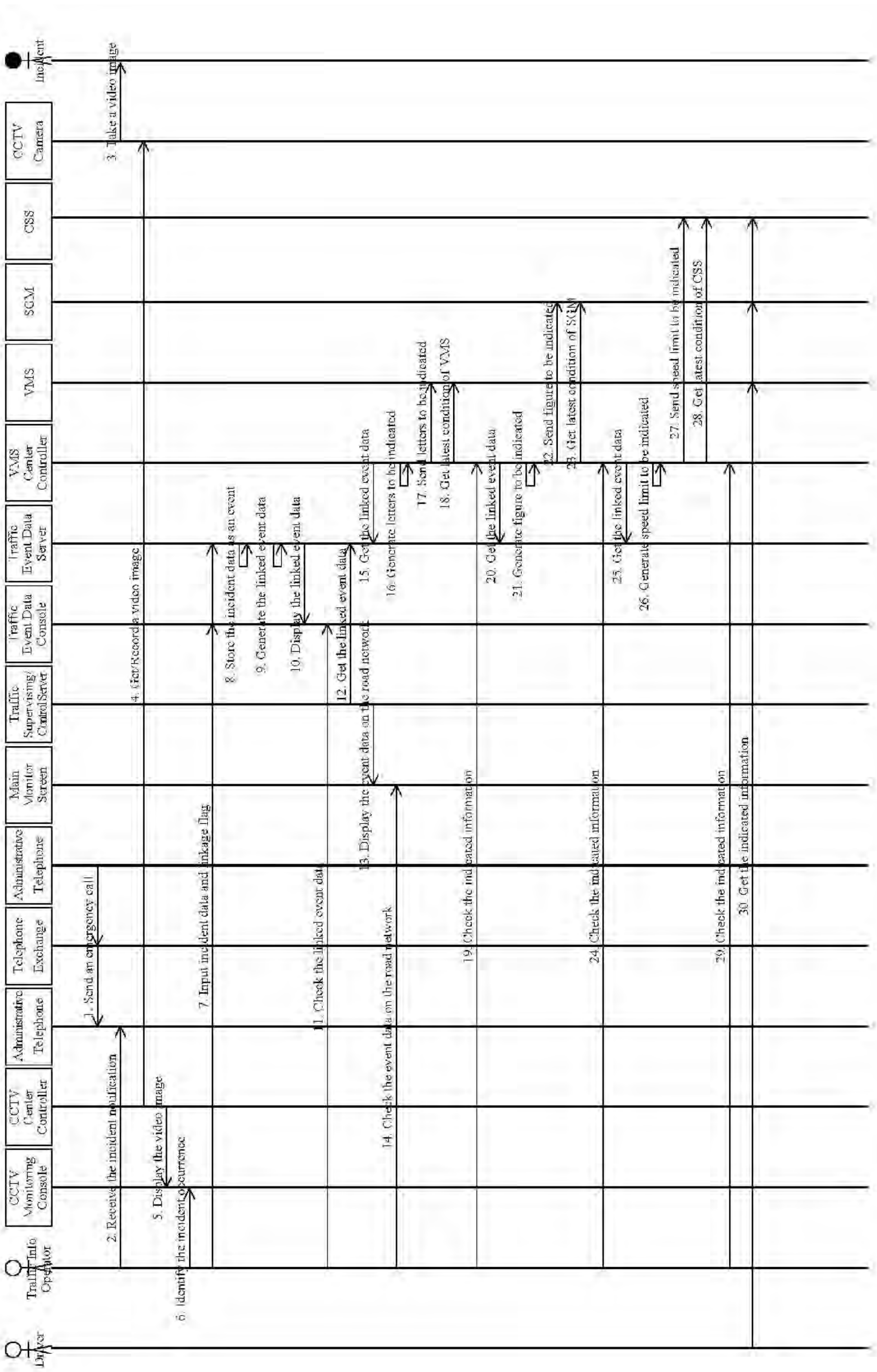
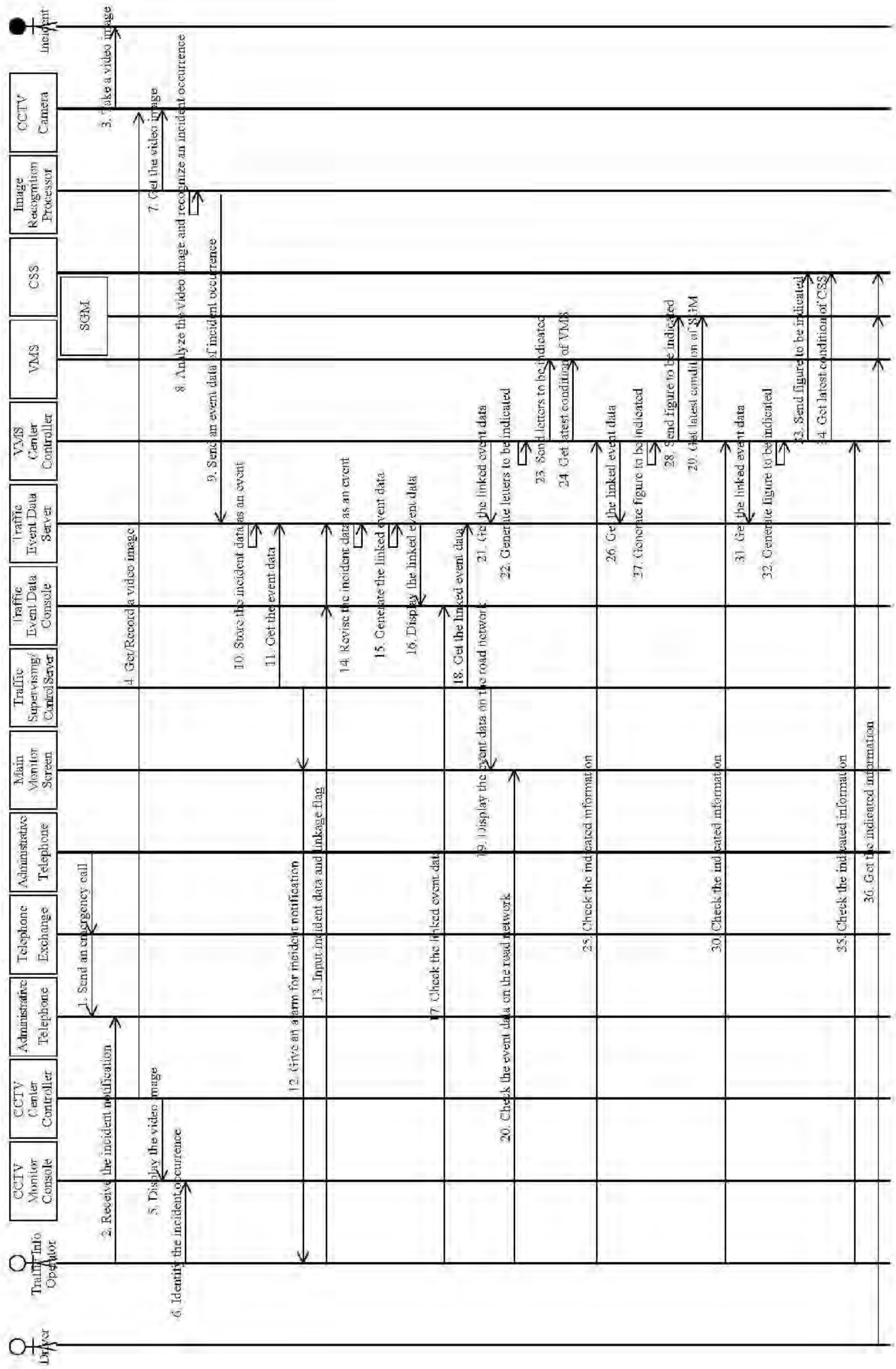


Figure 7.1-(b).MSD Incident Information by Image Recognition

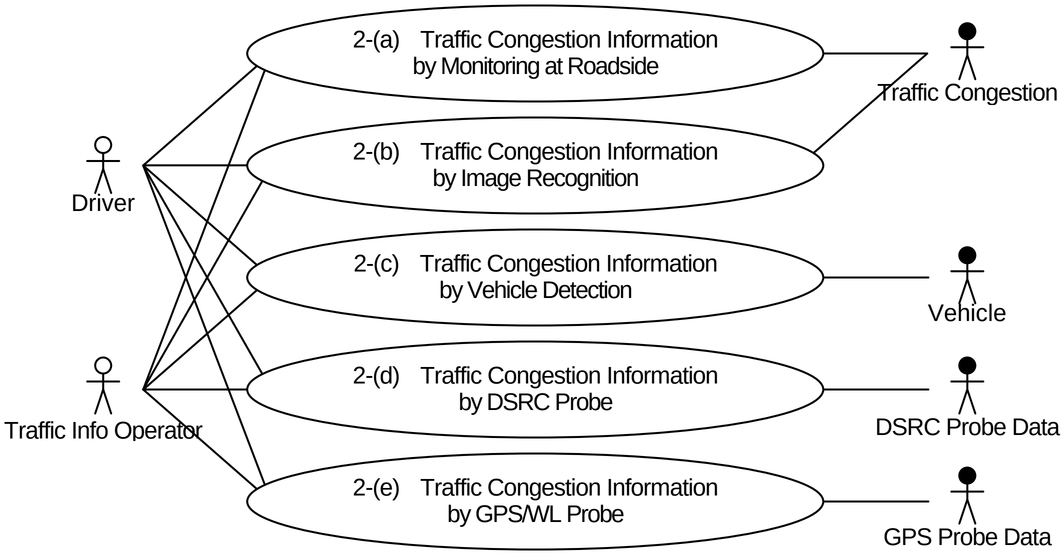


2) Traffic Congestion Information

(1) Use Cases Diagram

The following five alternative use cases (UC) are to be discussed for traffic congestion information.

Figure 7.2-UC Traffic Congestion Information



Source: VITRANSS2 Study Team

(2) Collaboration Diagram

The following collaboration diagrams (CD) are reasoned out from the service descriptions aforementioned.

Figure 7.2-(a).CD Traffic Congestion Information by Monitoring at Roadside
(Graded as "Useful as a Complement")

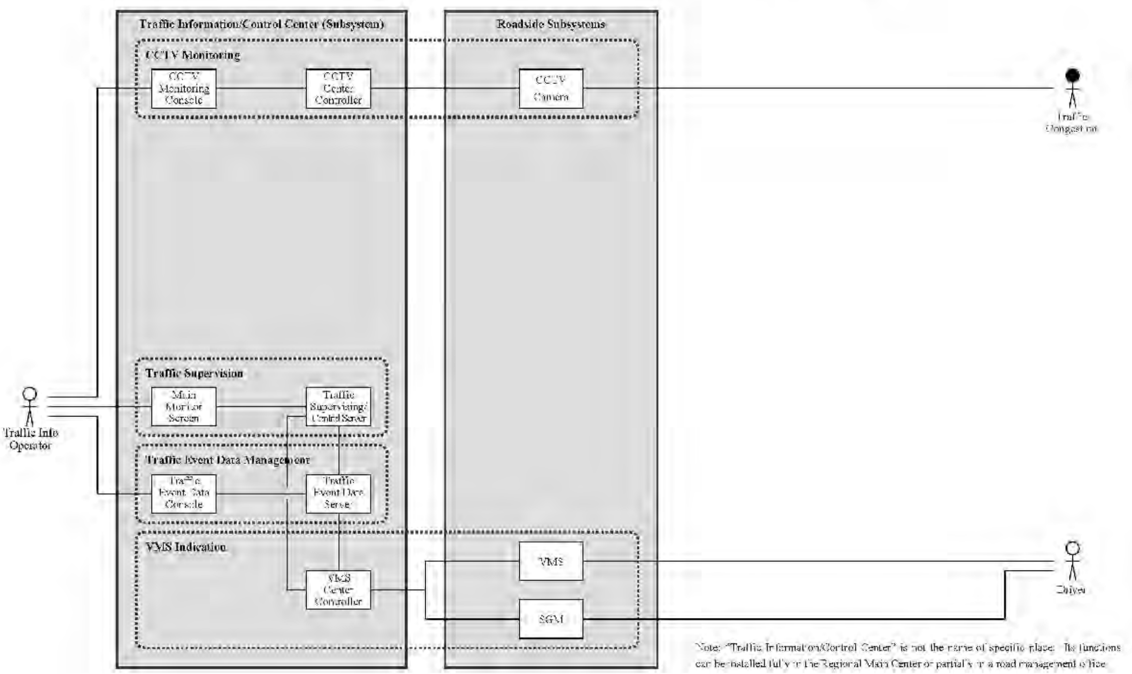


Figure 7.2-(b).CD Traffic Congestion Information by Image Recognition (Graded as "Useful as a Complement")

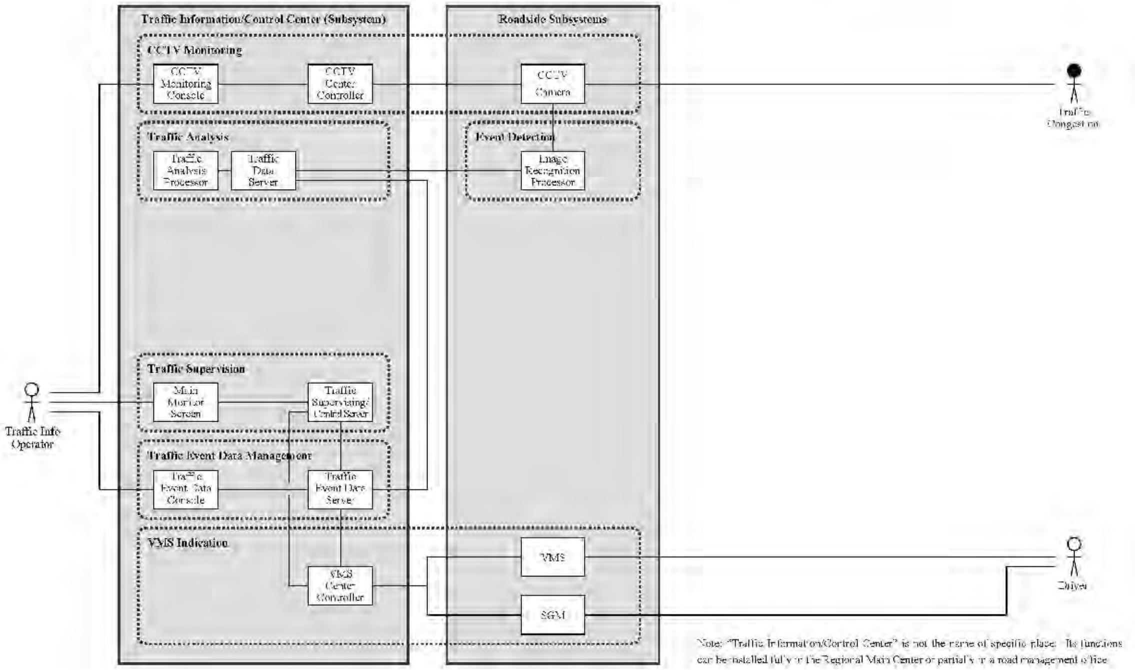


Figure 7.2-(c).CD Traffic Congestion Information by Vehicle Detection (Graded as "Recommended")

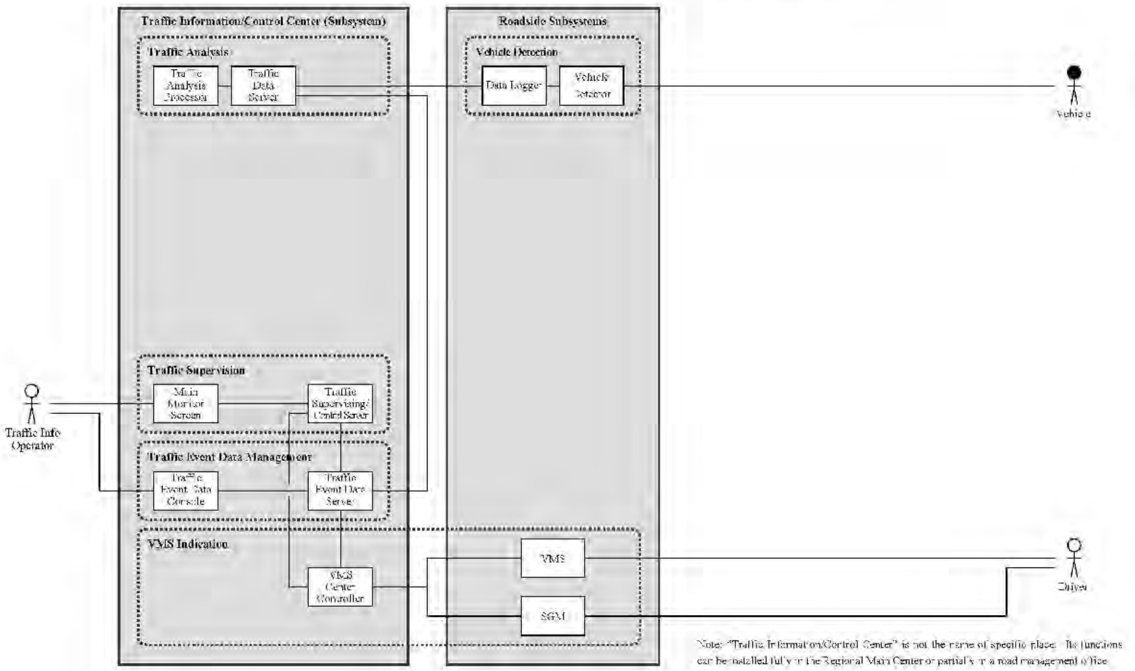


Figure 7.2-(d).CD Traffic Congestion Information by DSRC Probe
(Graded as "Not Suitable")

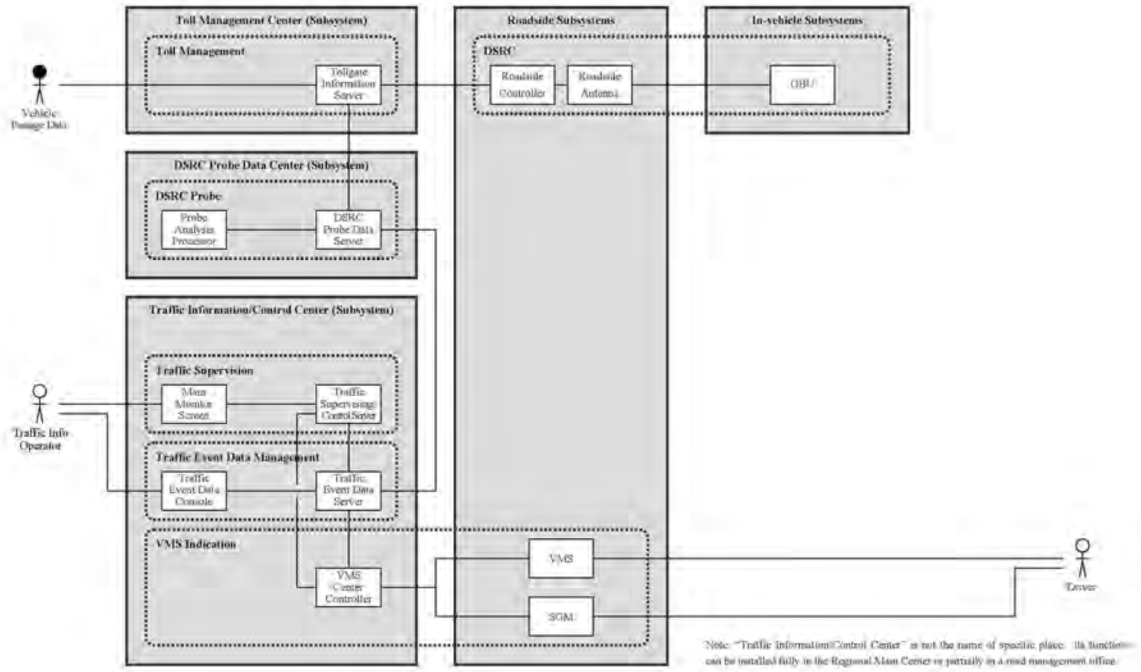
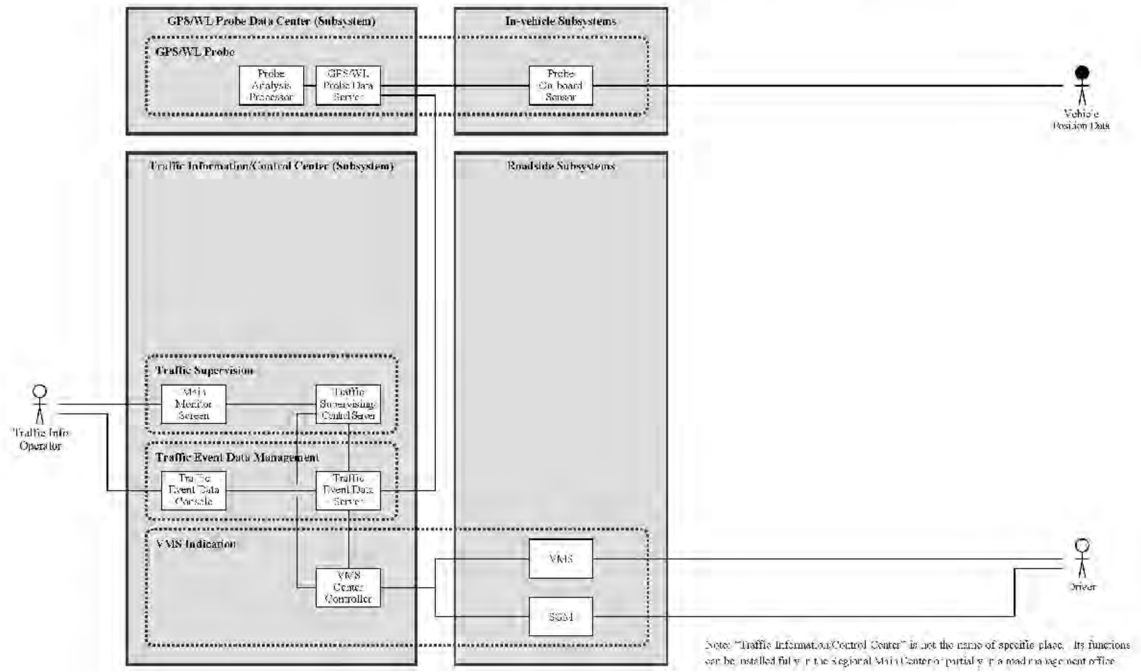


Figure 7.2-(e).CD Traffic Congestion Information by GPS/WL Probe
(Graded as "Not Suitable")



(3) Message Sequence Diagram

The following message sequence diagrams (MSD) are derived from the service descriptions aforementioned.

Figure 7.2-(a).MSD Traffic Congestion Information by Monitoring at Roadside

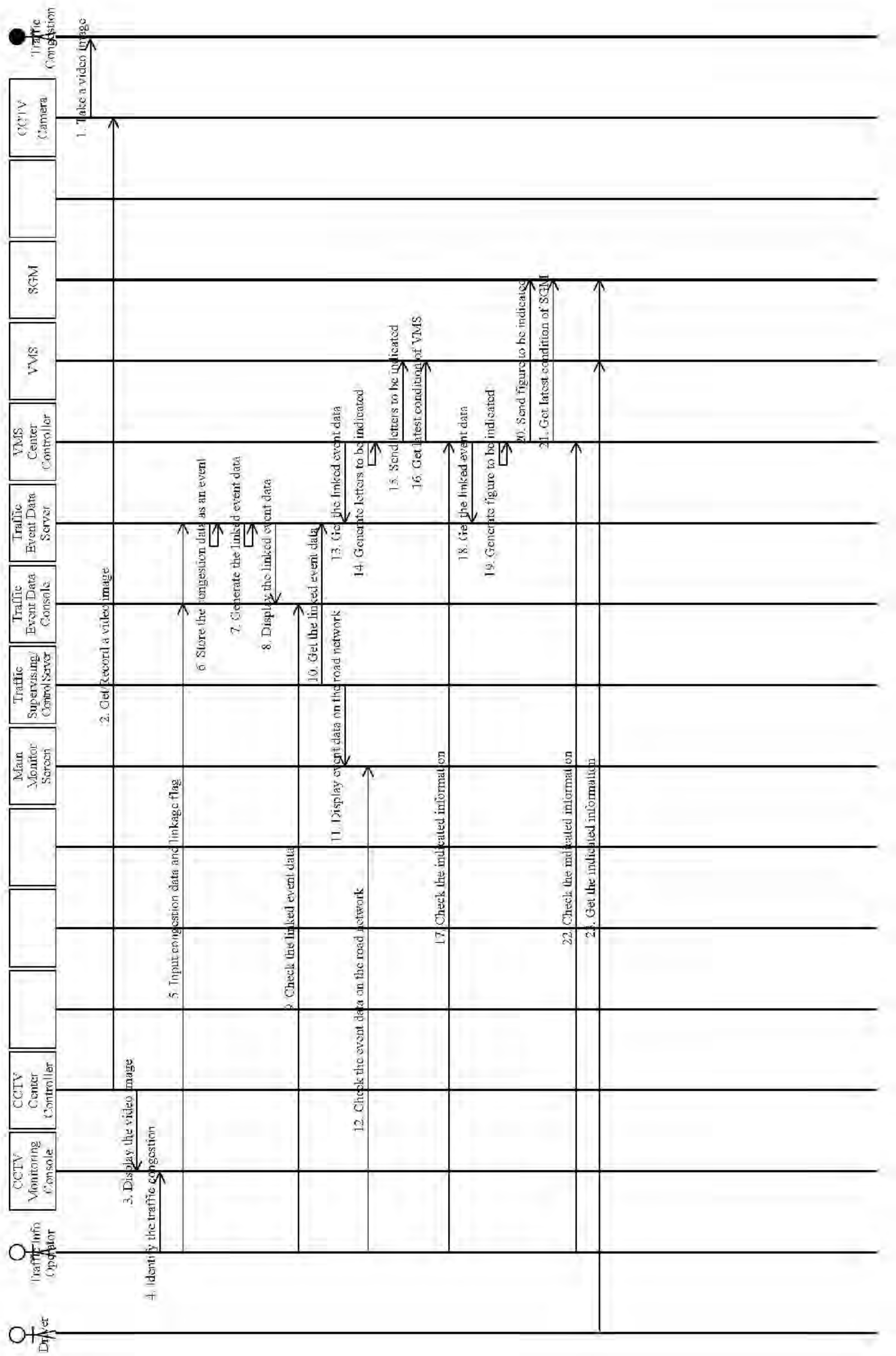


Figure 7.2-(b).MSD Traffic Congestion Information by Image Recognition

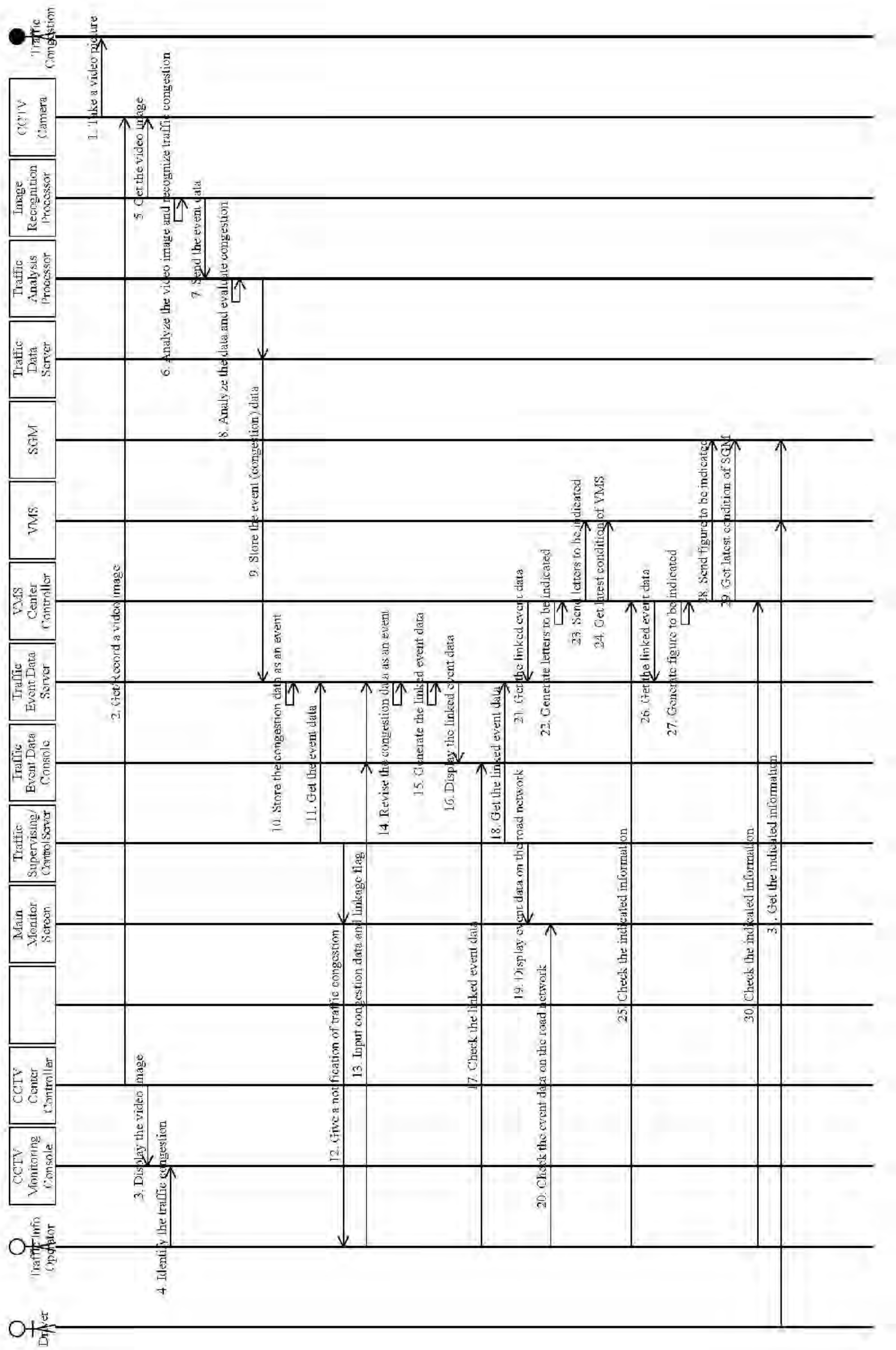


Figure 7.2-(c).MSD Traffic Congestion Information by Vehicle Detection

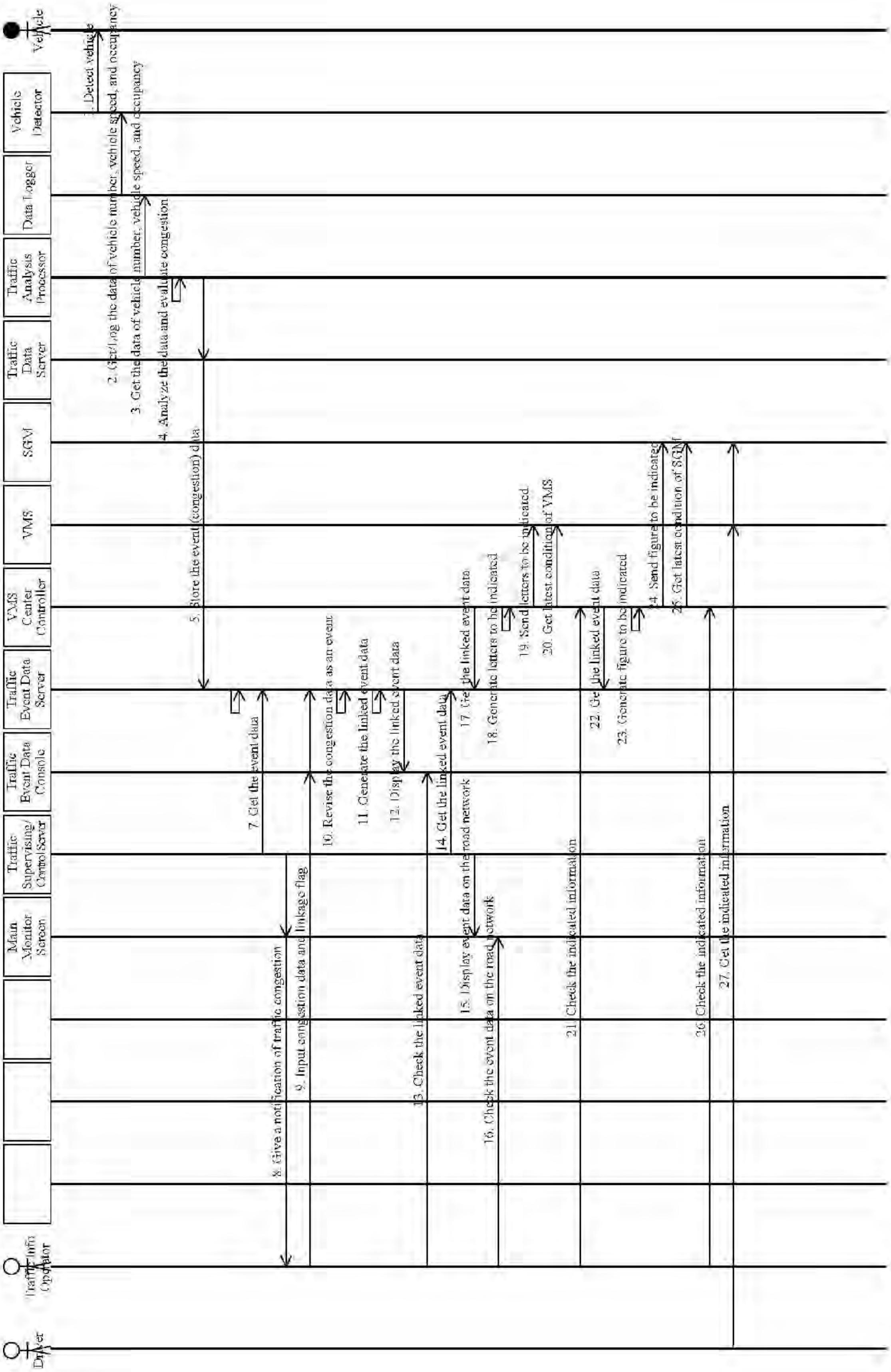


Figure 7.2-(d).MSD Traffic Congestion Information by DSRC Probe

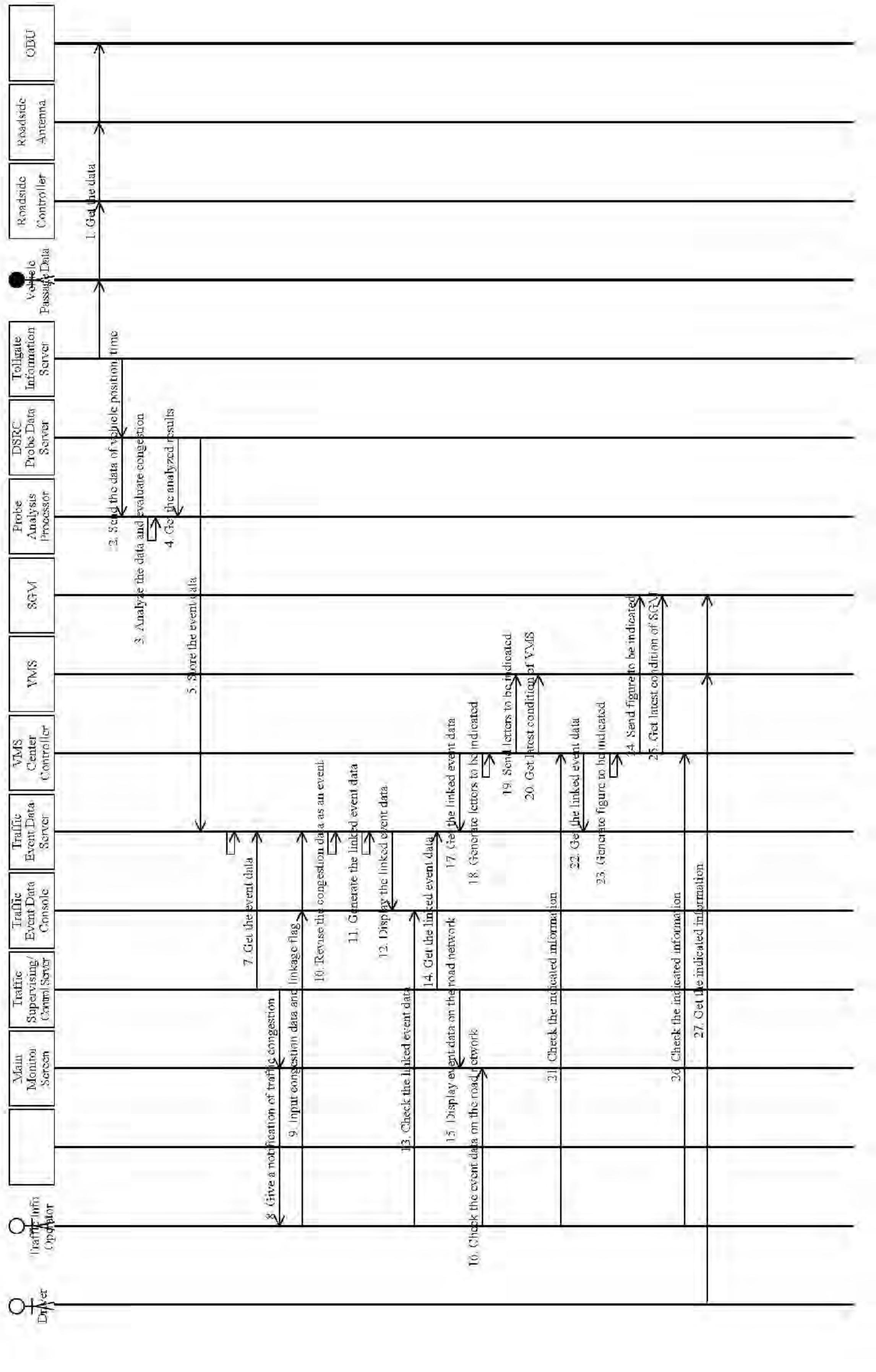
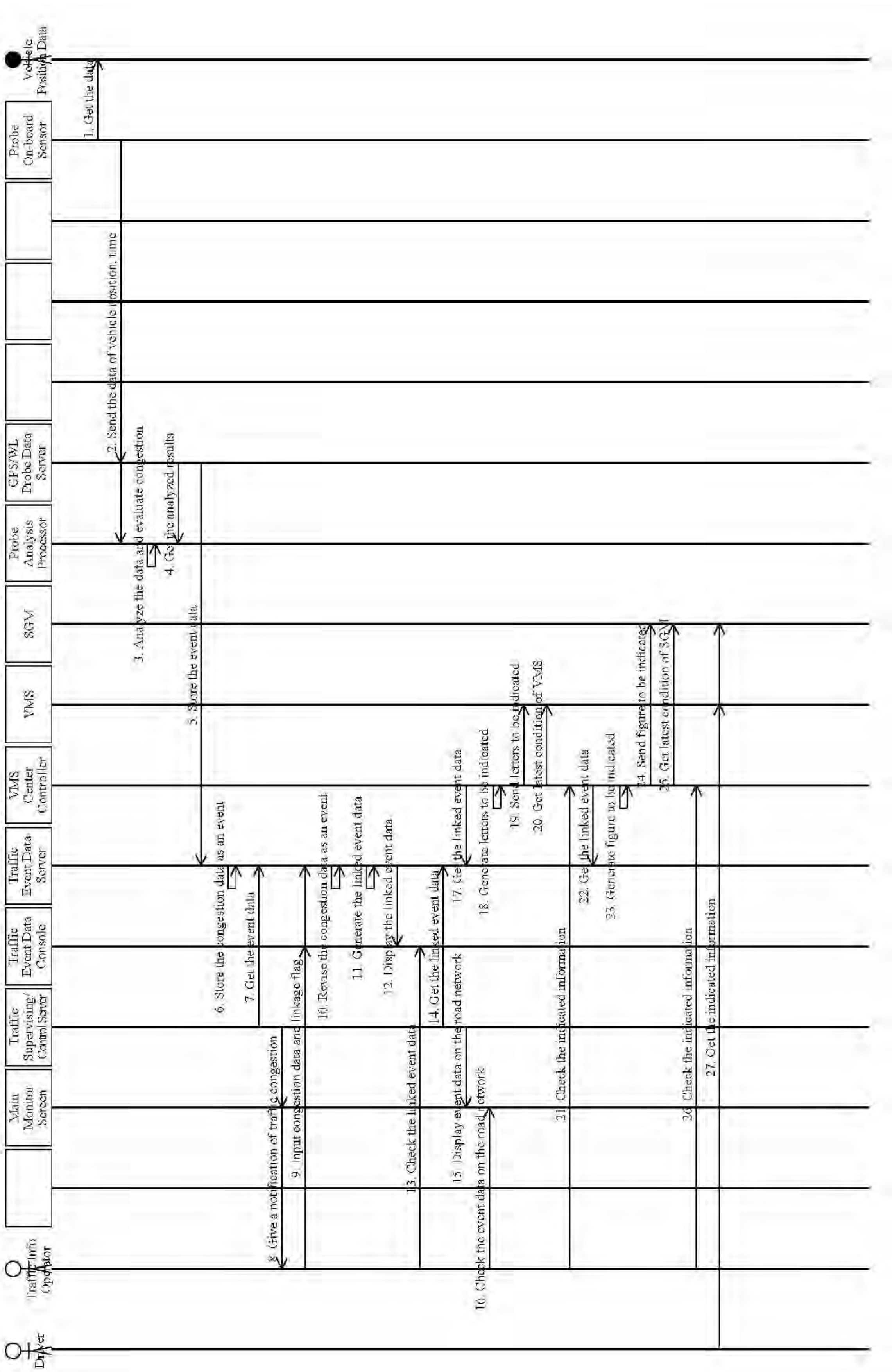


Figure 7.2-(e).MSD Traffic Congestion Information by GPS/WL Probe

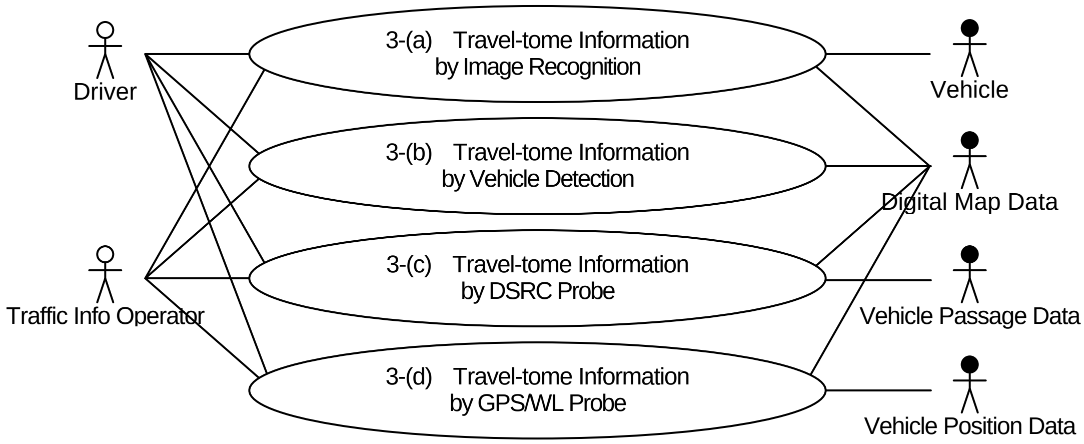


3) Travel-time Information

(1) Use Cases Diagram

The following four alternative use cases (UC) are to be discussed for travel-time information.

Figure 7.3-UC Travel-time Information



Source: VITRANSS2 Study Team

(2) Collaboration Diagram

The following collaboration diagrams (CD) are reasoned out from the service descriptions aforementioned.

Figure 7.3-(a).CD Travel-time Information by Image Recognition
(Graded as "Not Suitable")

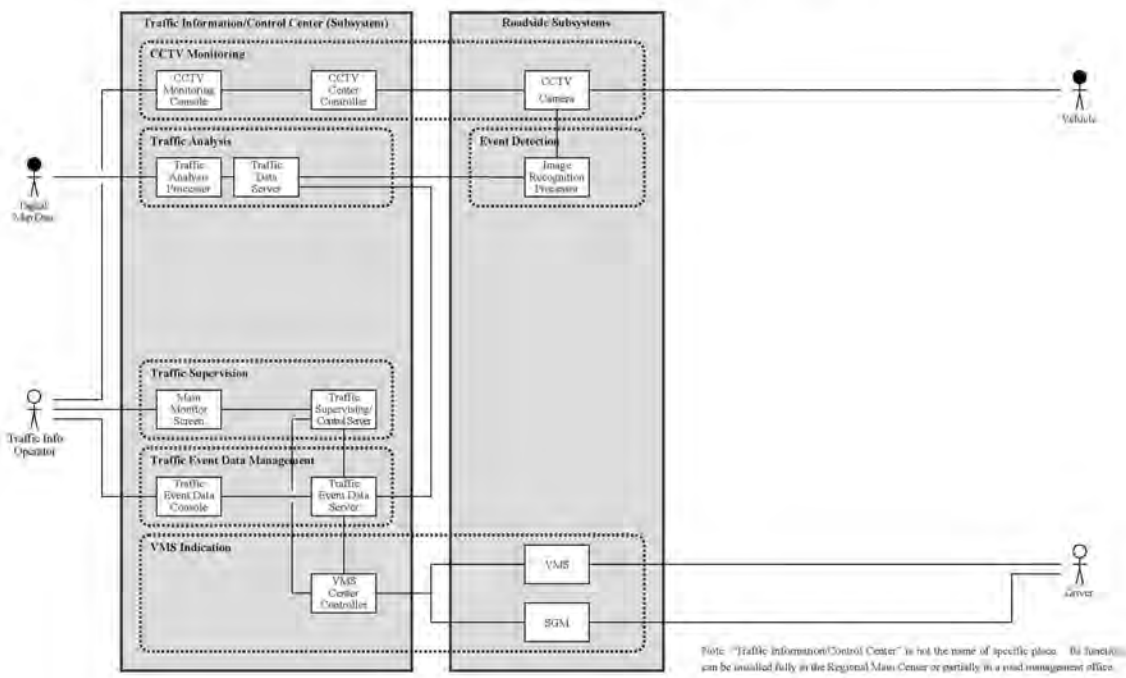


Figure 7.3-(b).CD Travel-time Information by Vehicle Detection
(Graded as "Not Suitable")

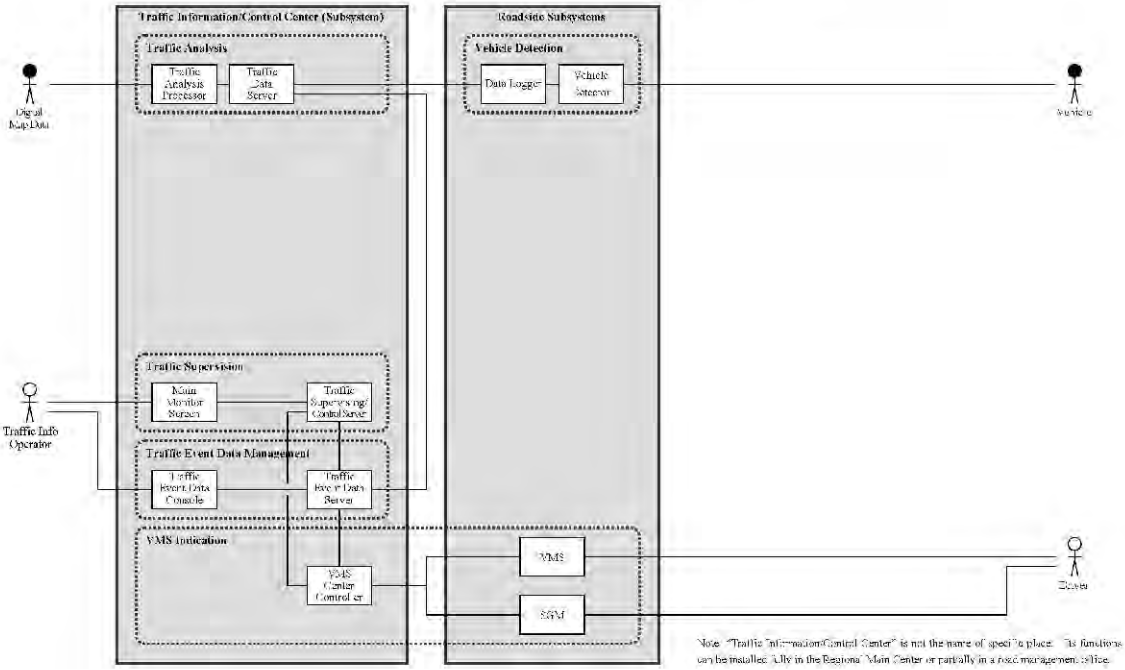


Figure 7.3-(c).CD Travel-time Information by DSRC Probe
(Graded as "Recommended")

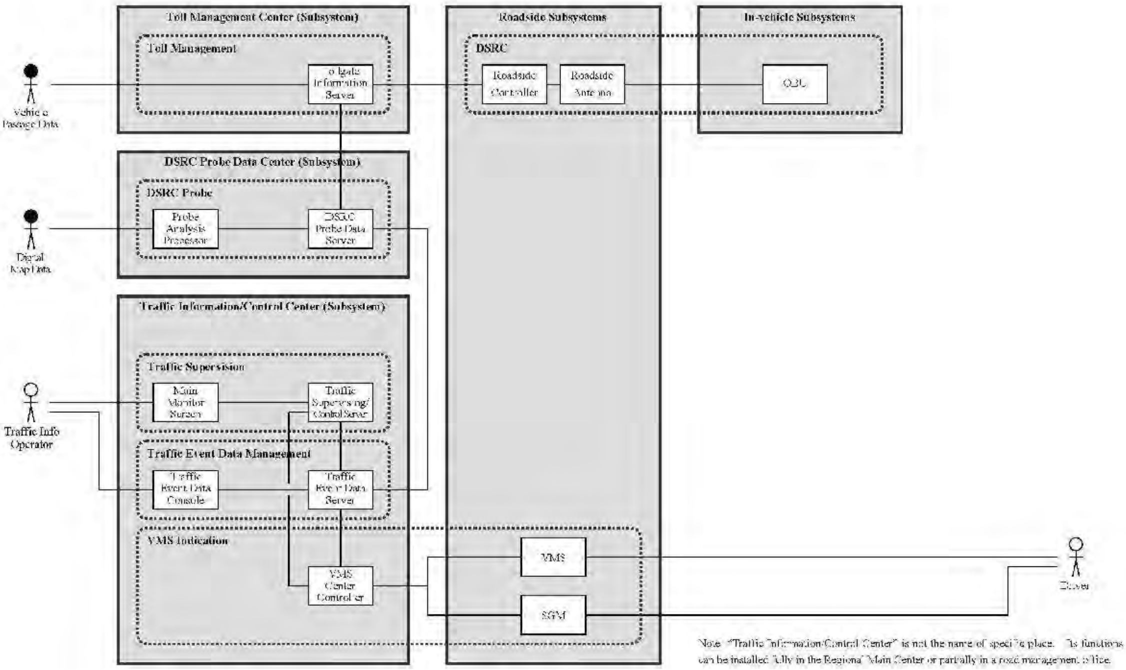
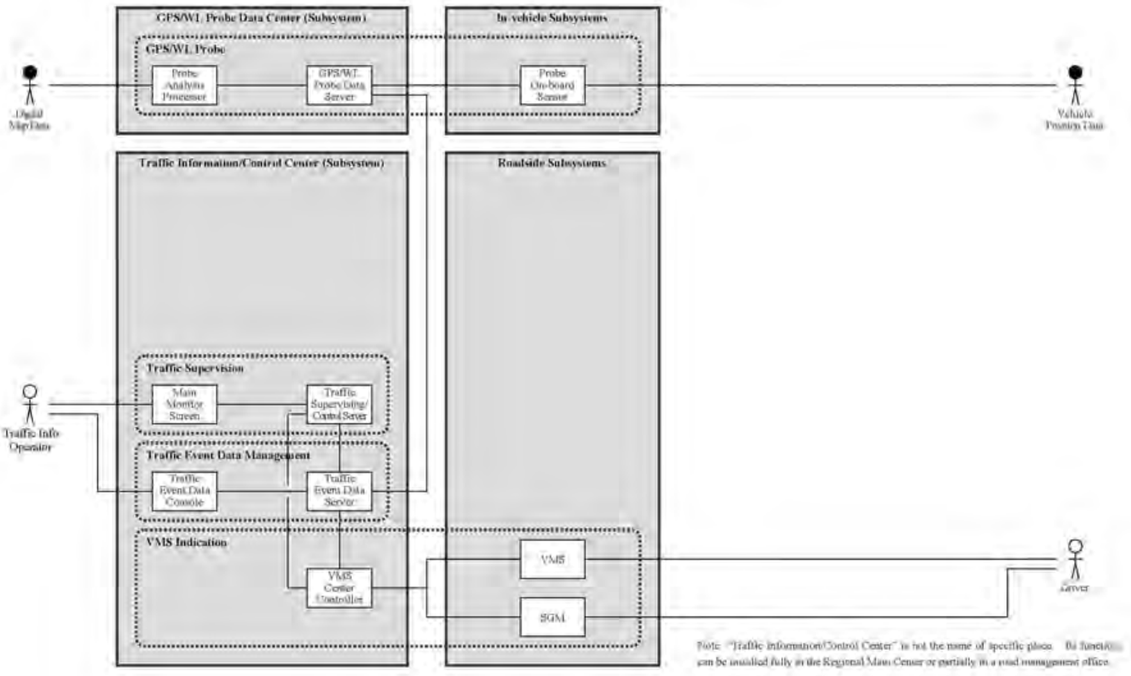


Figure 7.3-(d).CD Travel-time Information by GPS/WL Probe
(Graded as "Useful as a Complement")



(3) Message Sequence Diagram

The following message sequence diagrams (MSD) are derived from the service descriptions aforementioned.

Figure 7.3-(a).MSD Travel-time Information by Image Recognition

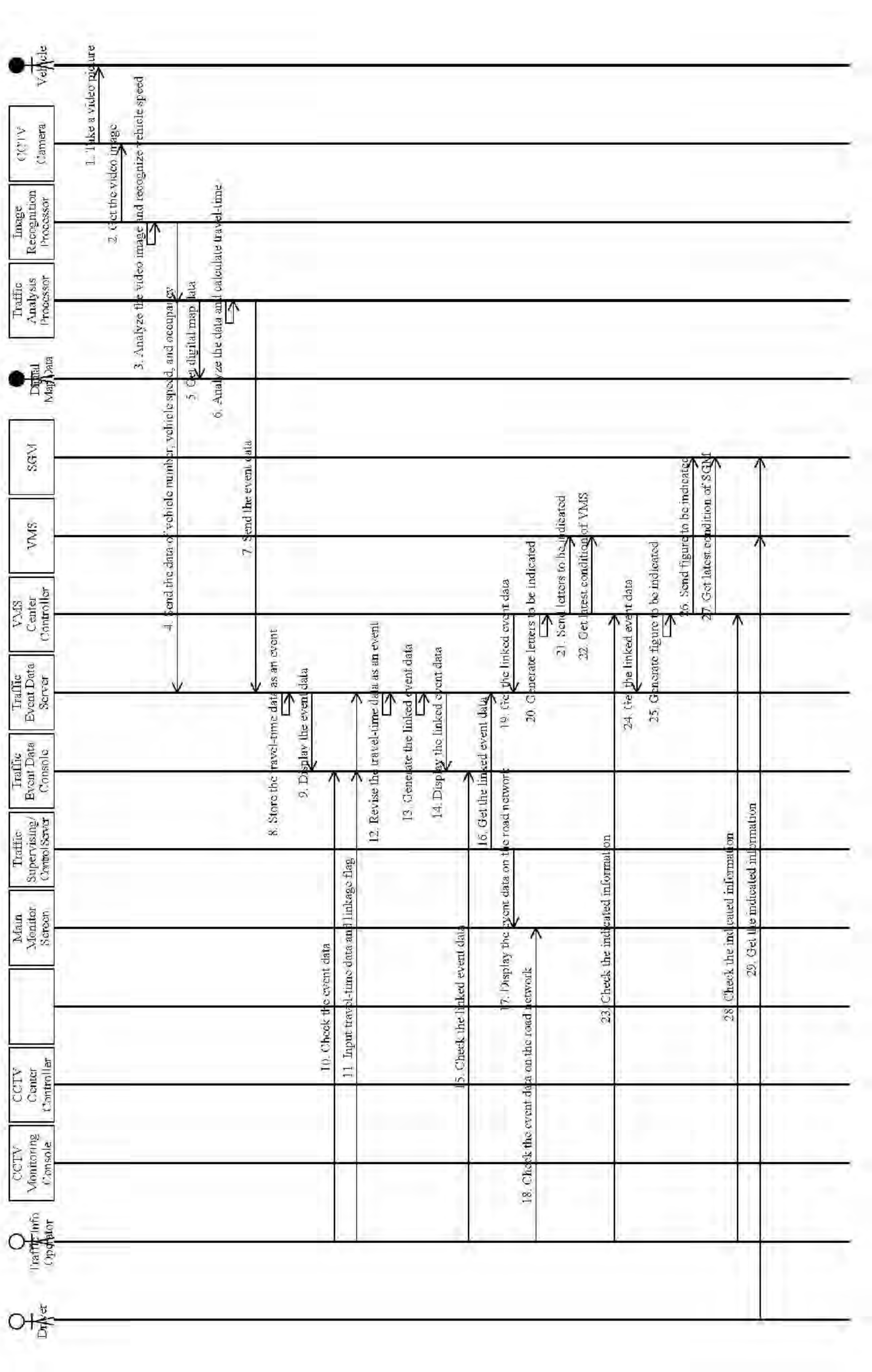


Figure 7.3-(b).MSD Travel-time Information by Vehicle Detection

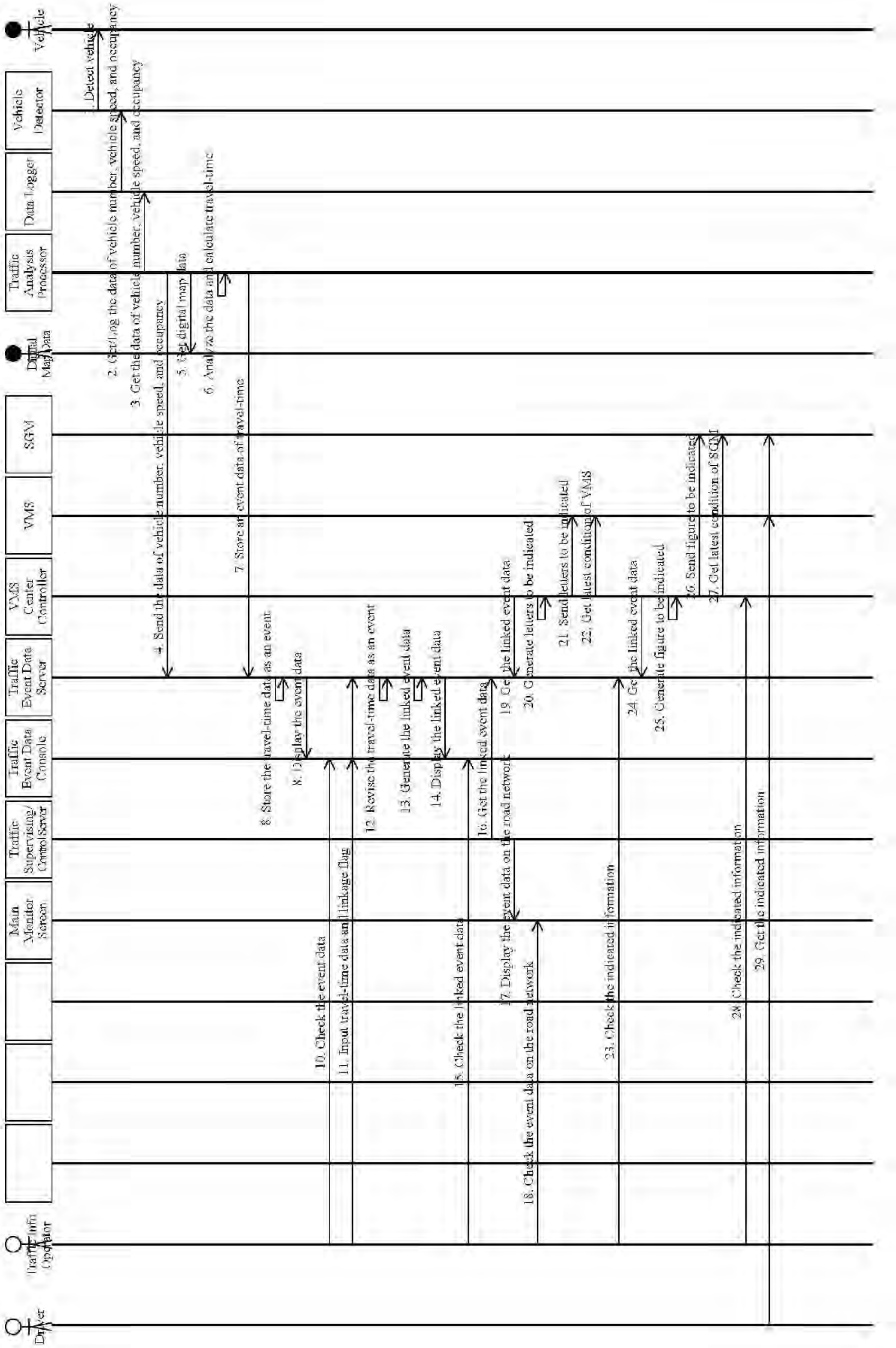


Figure 7.3-(c).MSD Travel-time Information by DSRC Probe

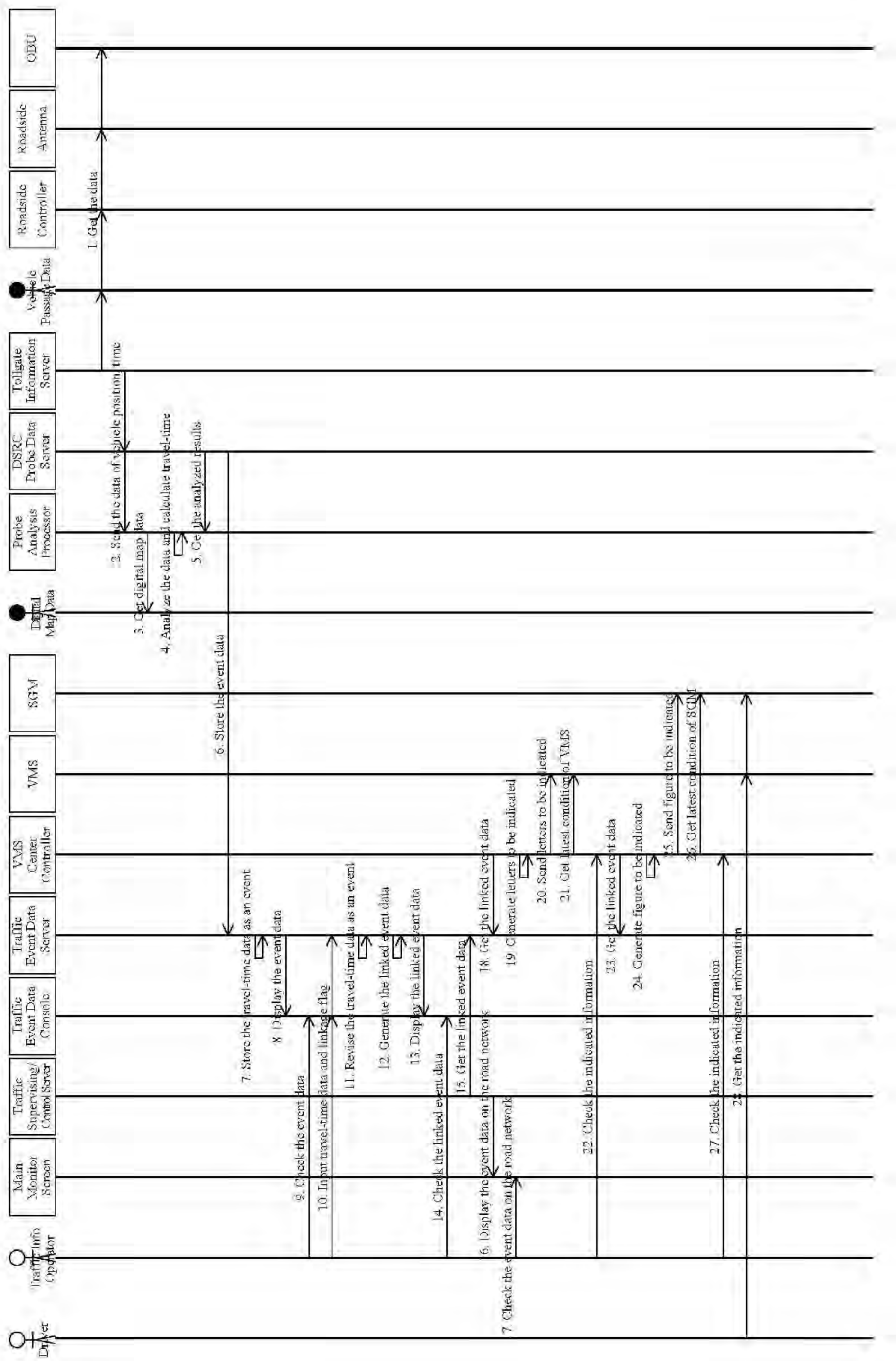
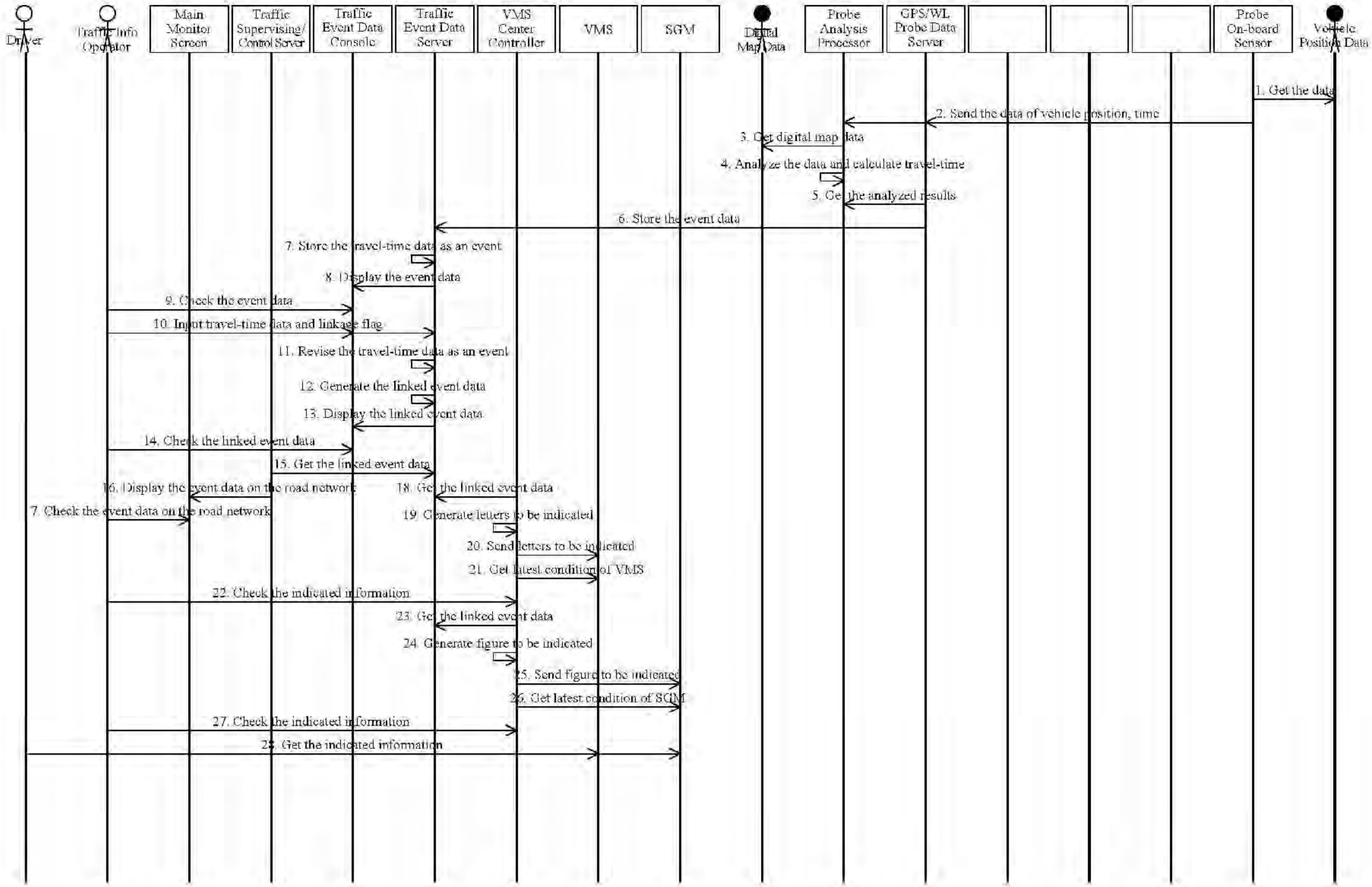


Figure 7.3-(d).MSD Travel-time Information by GPS/WL Probe

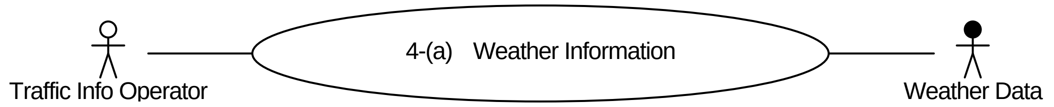


4) Weather Information

(1) Use Cases Diagram

The following mandatory use case (UC) is to be discussed for weather information.

Figure 7.4-UC Weather Information

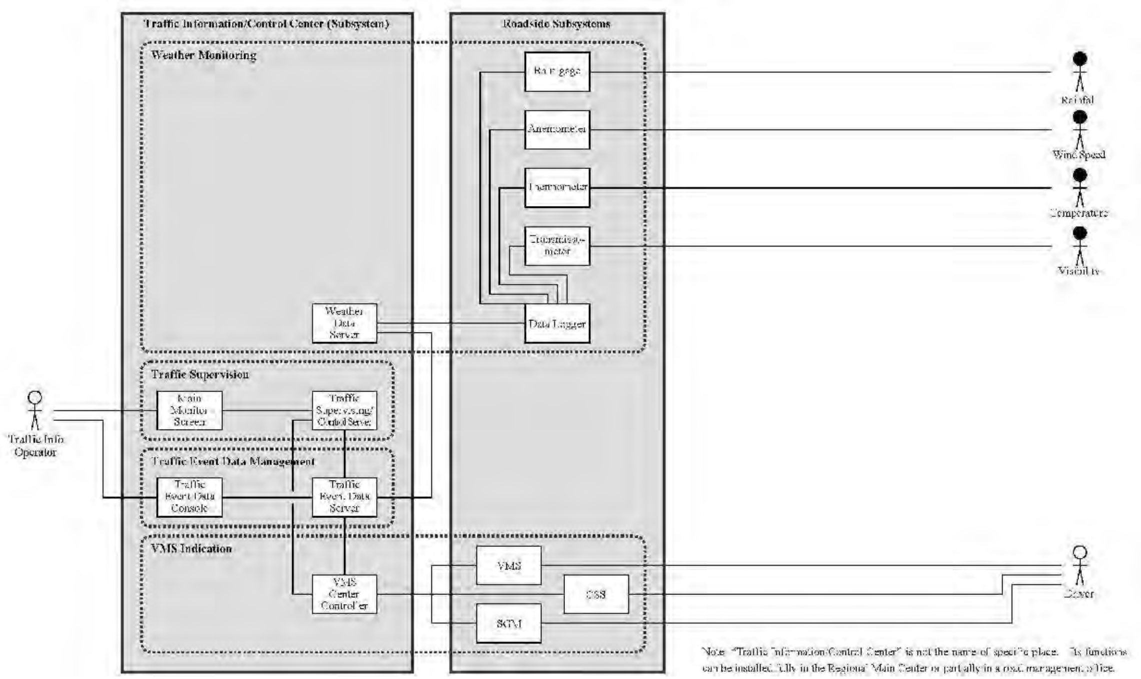


Source: VITRANSS2 Study Team

(2) Collaboration Diagram

The following collaboration diagram (CD) is reasoned out from the service descriptions aforementioned.

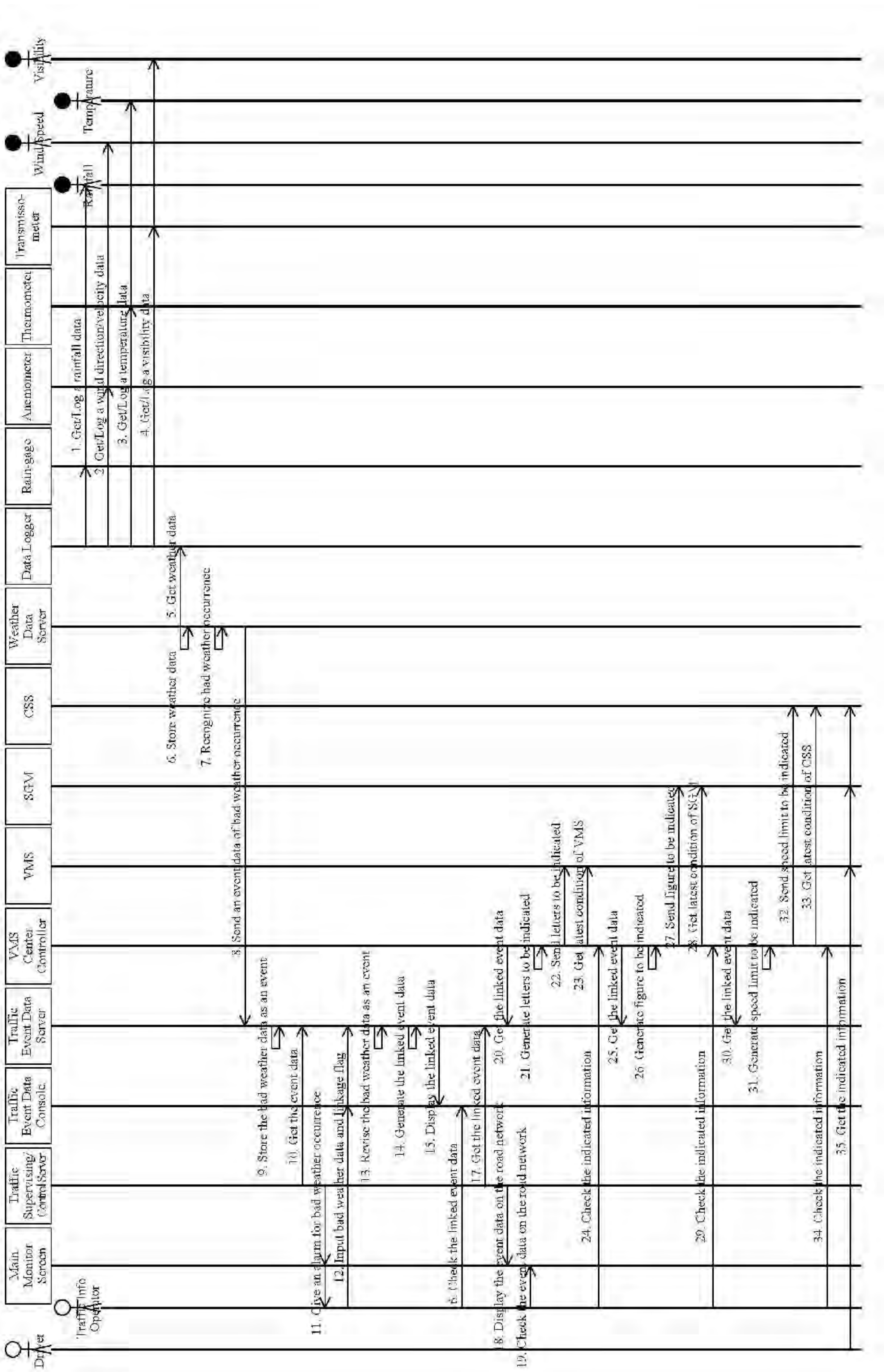
Figure 7.4-(a).CD Weather Information
(Graded as “Necessary”)



(3) Message Sequence Diagram

The following message sequence diagram (MSD) is derived from the service descriptions aforementioned.

Figure 7.4-(a).MSD Weather Information

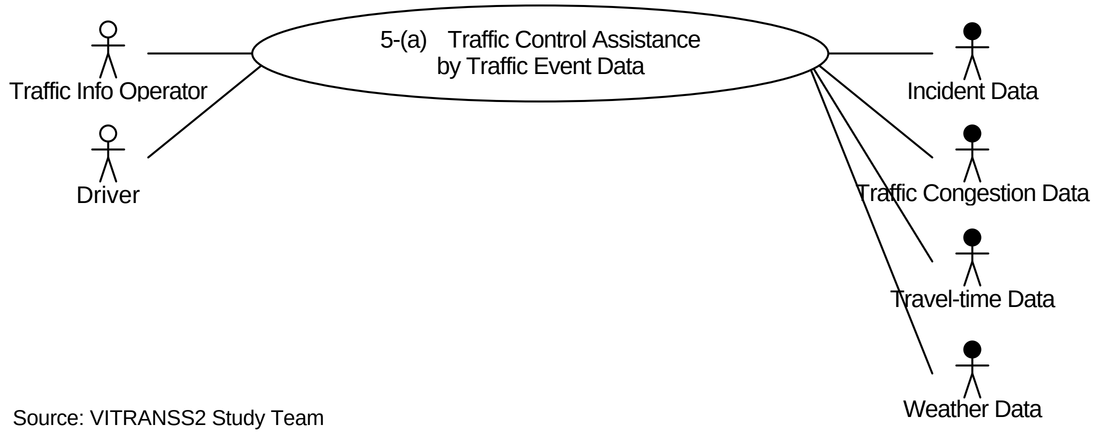


5) Traffic Control Assistance

(1) Use Cases Diagram

The following mandatory use case (UC) is to be discussed for traffic control assistance.

Figure 7.5-UC　Traffic Control Assistance

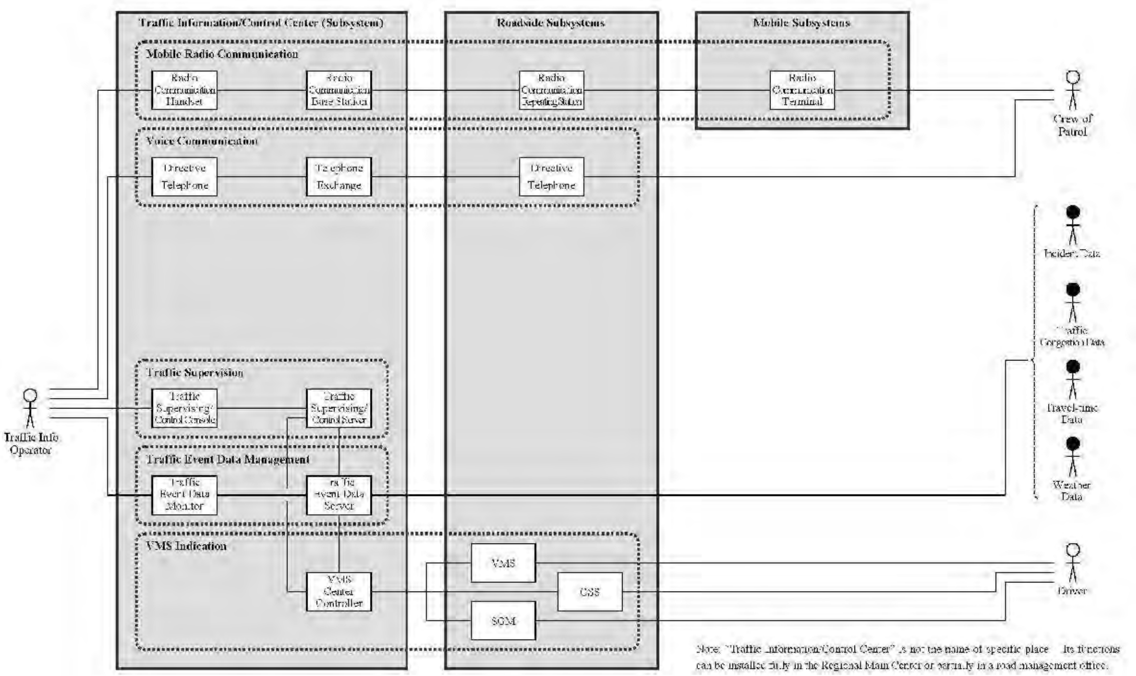


Source: VITRANSS2 Study Team

(2) Collaboration Diagram

The following collaboration diagram (CD) is reasoned out from the service descriptions aforementioned.

Figure 7.5-(a).CD　Traffic Control Assistance by Traffic Event Data
(Graded as "Useful as a Complement")



(3) Message Sequence Diagram

The following message sequence diagram (MSD) is derived from the service descriptions aforementioned.

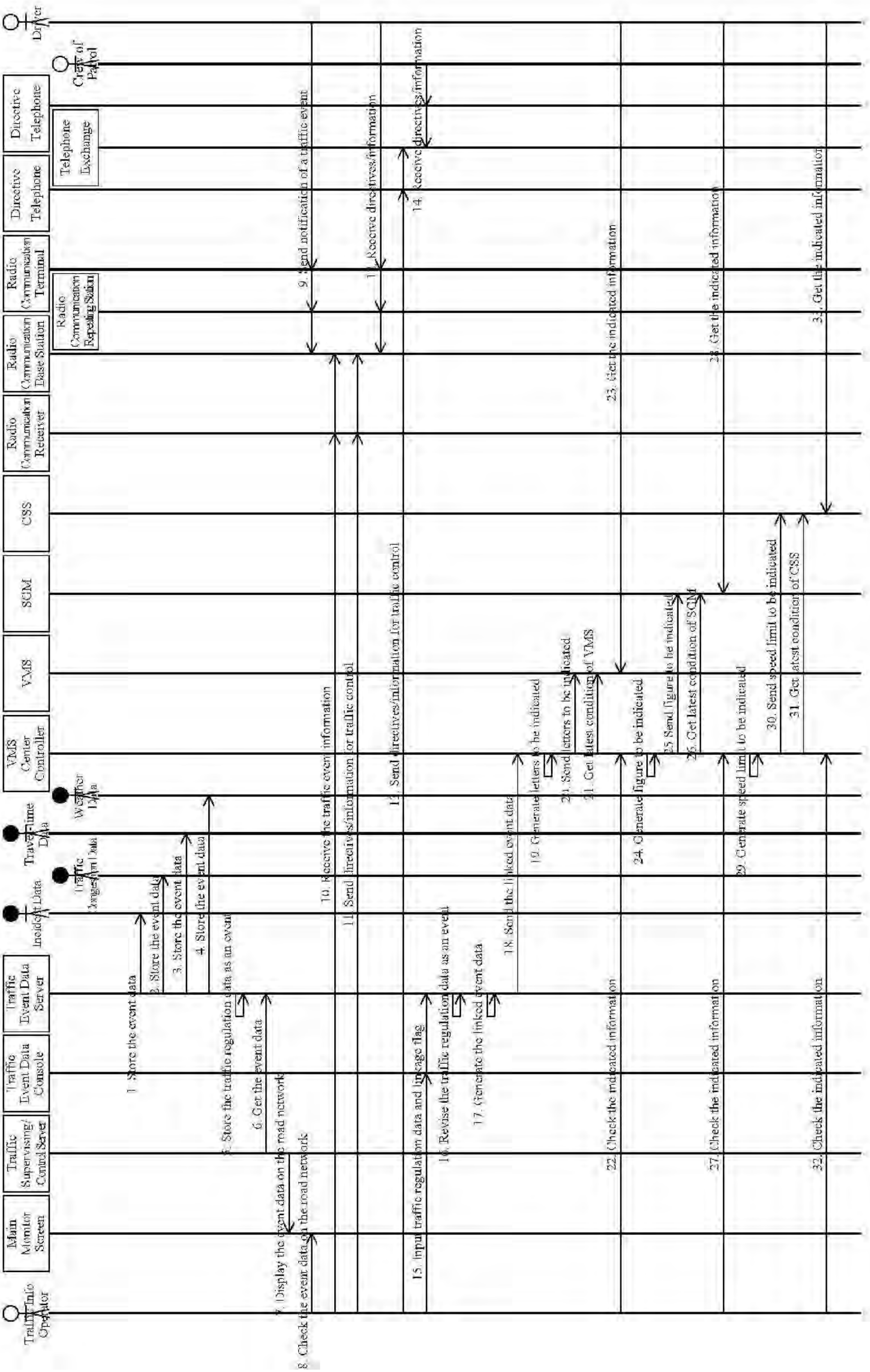


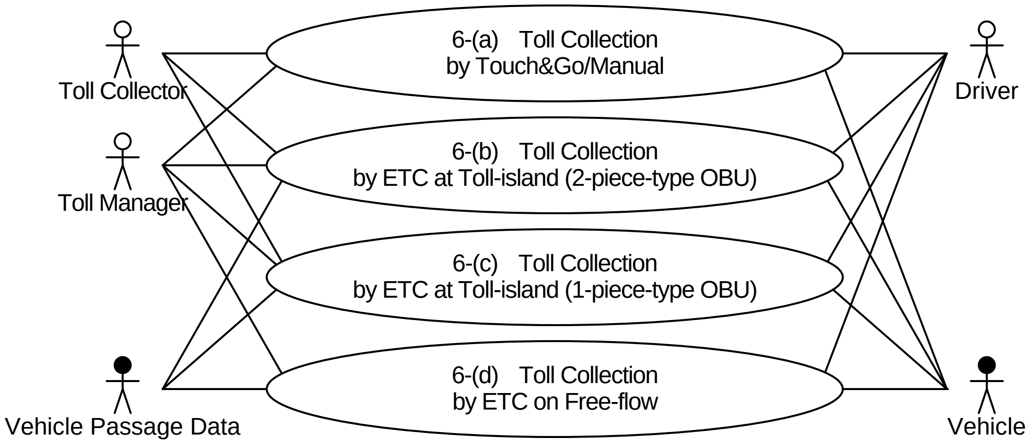
Figure 7.5-(a).MSD Traffic Control Assistance by Traffic Event Data

6) Toll Collection

(1) Use Cases Diagram

The following four alternative use cases (UC) are to be discussed for toll collection.

Figure 7.6-UC Toll Collection



Source: VITRANSS2 Study Team

(2) Collaboration Diagram

The following collaboration diagrams (CD) are reasoned out from the service descriptions aforementioned.

Figure 7.6-(a).CD Toll Collection by Touch&Go/Manual
(Graded as "Useful as a Complement")

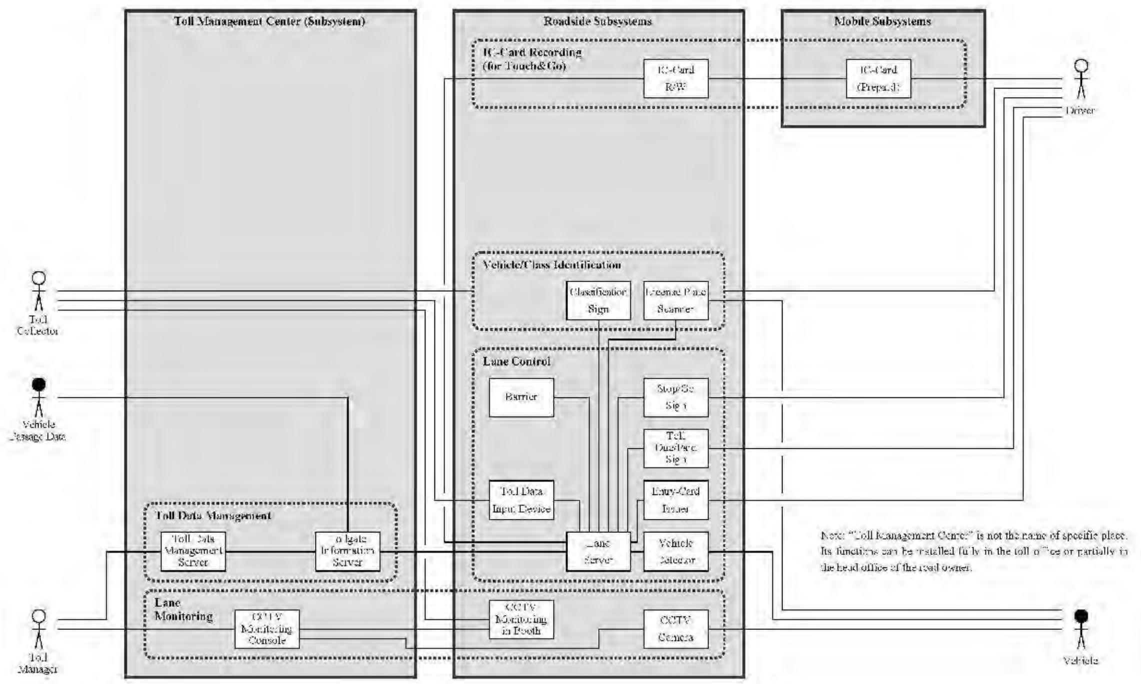


Figure 7.6-(b).CD Toll Collection by ETC at Toll Island (2-piece type OBU)
(Graded as "Recommended")

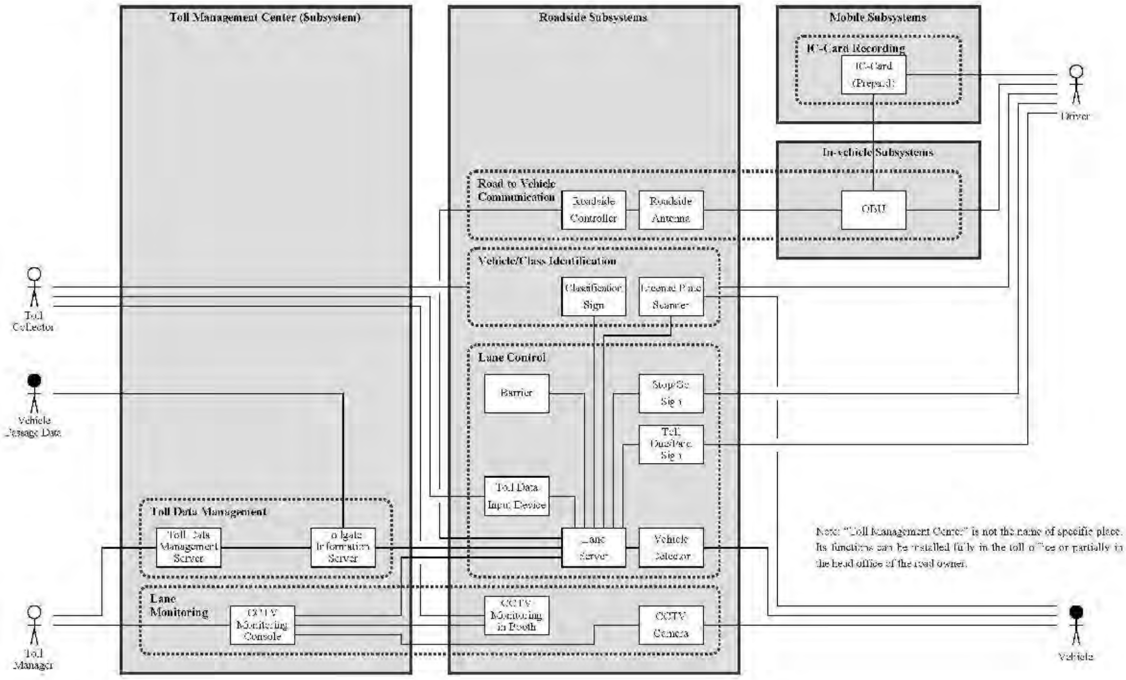


Figure 7.6-(c).CD Toll Collection by ETC at Toll Island (1-piece type OBU)
(Graded as "Not Suitable")

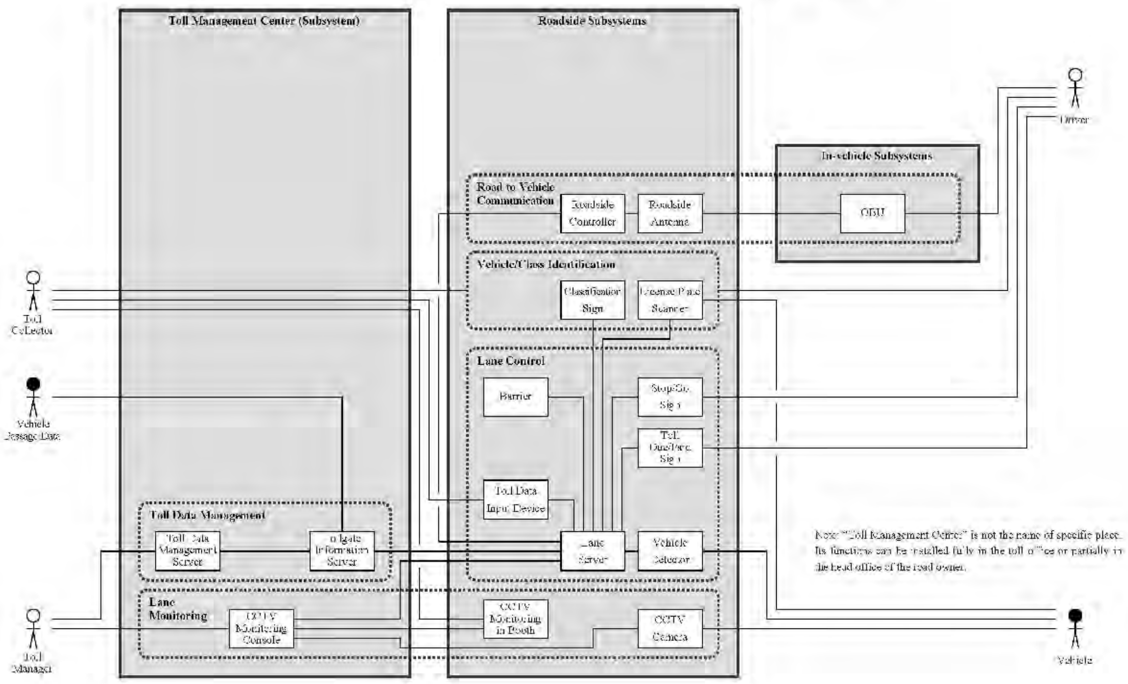
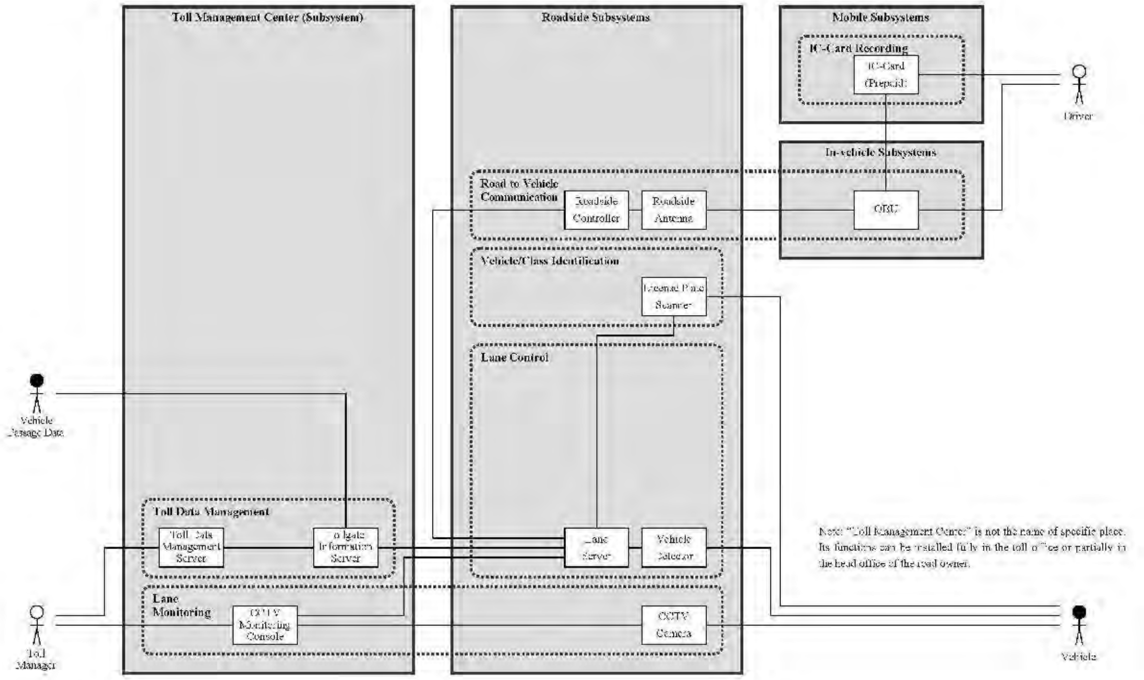


Figure 7.6-(d).CD Toll Collection by ETC on Free-flow
(Graded as “Too Early”)



(3) Message Sequence Diagram

The following message sequence diagrams (MSD) are derived from the service descriptions aforementioned.

Figure 7.6-(a).MSD Toll Collection by Touch&Go/Manual (1)

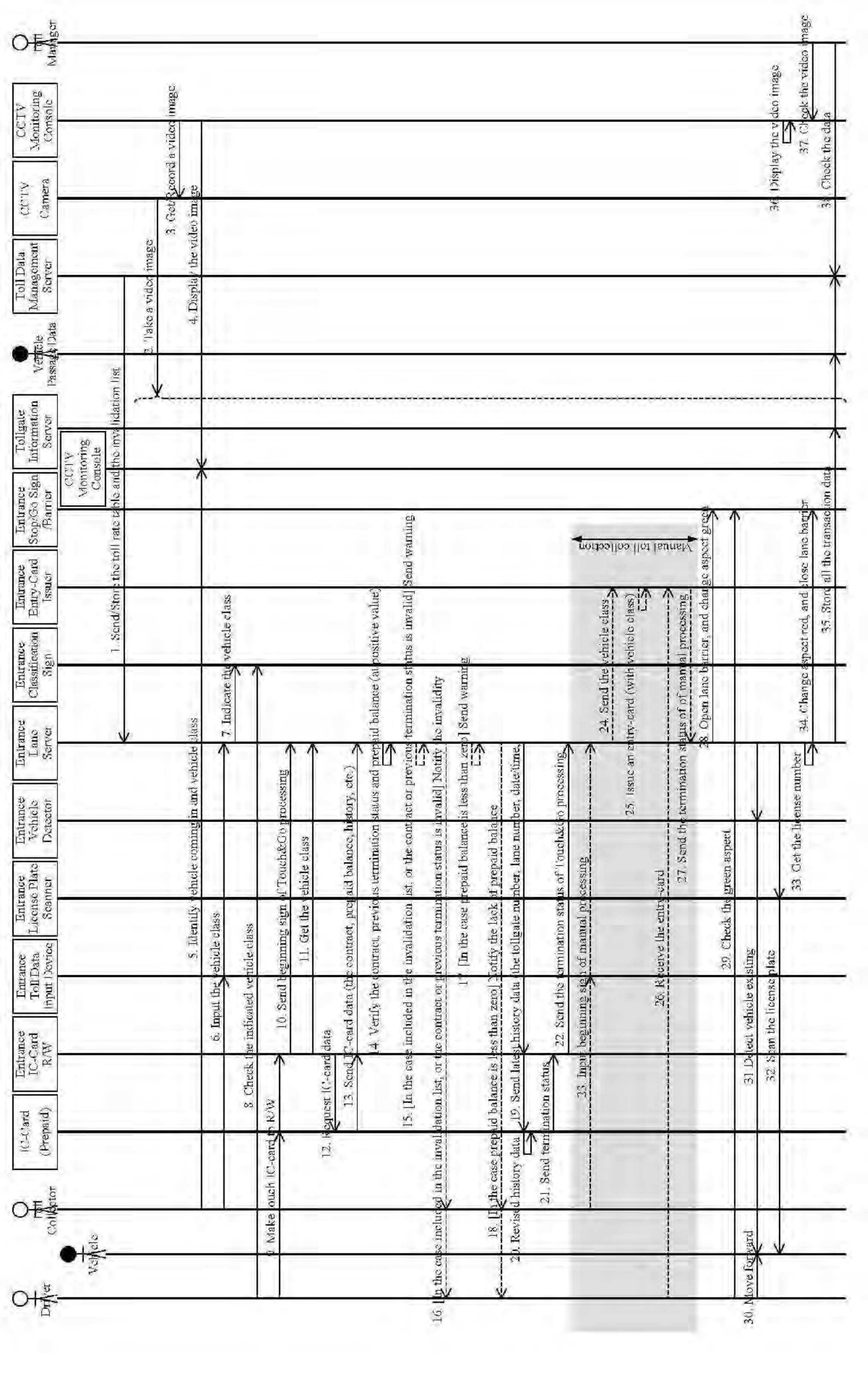


Figure 7.6-(a).MSD Toll Collection by Touch&Go/Manual (2)

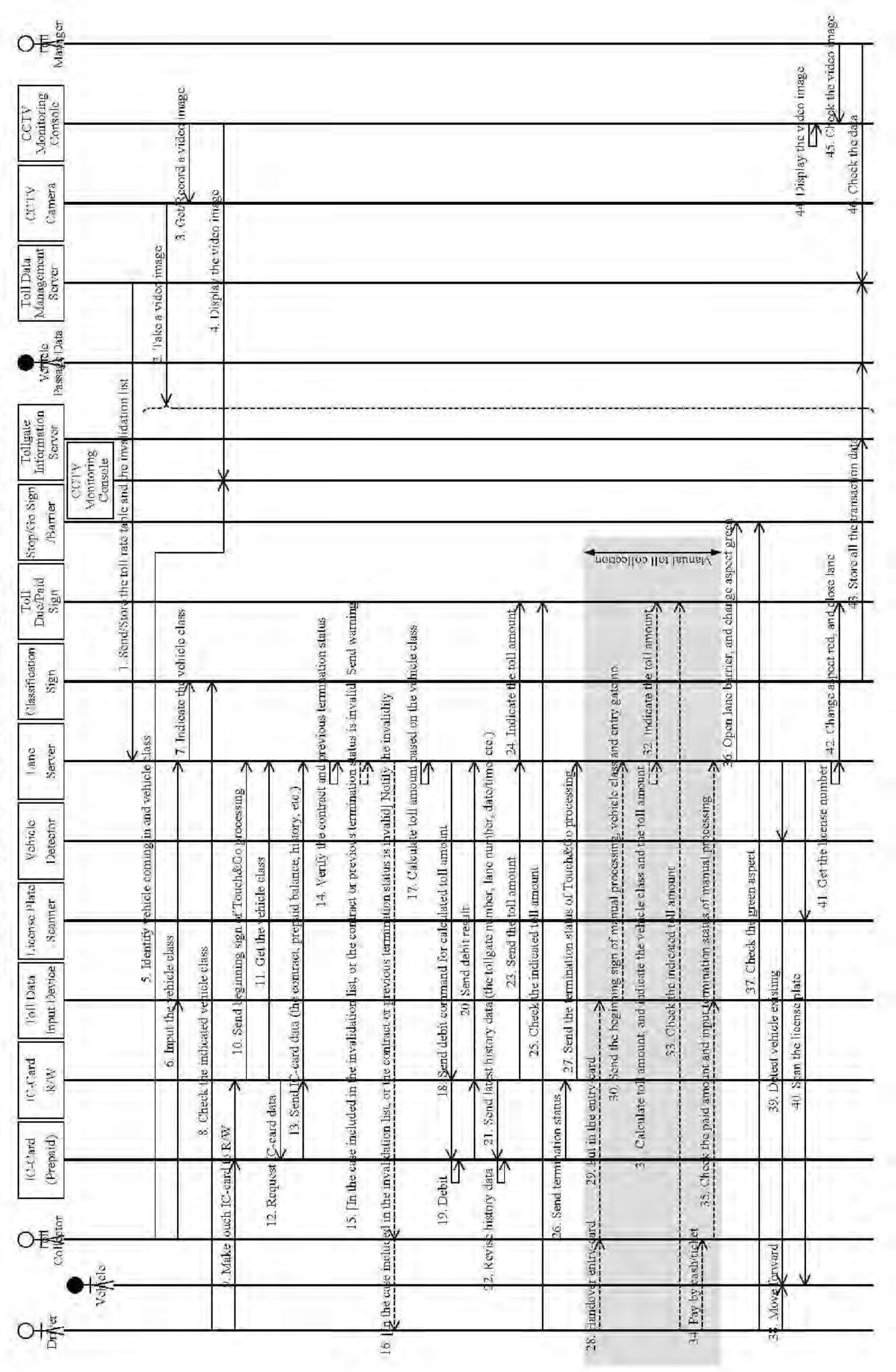


Figure 7.6-(b).MSD Toll Collection by ETC at Toll-island (2p-OBU) (1)

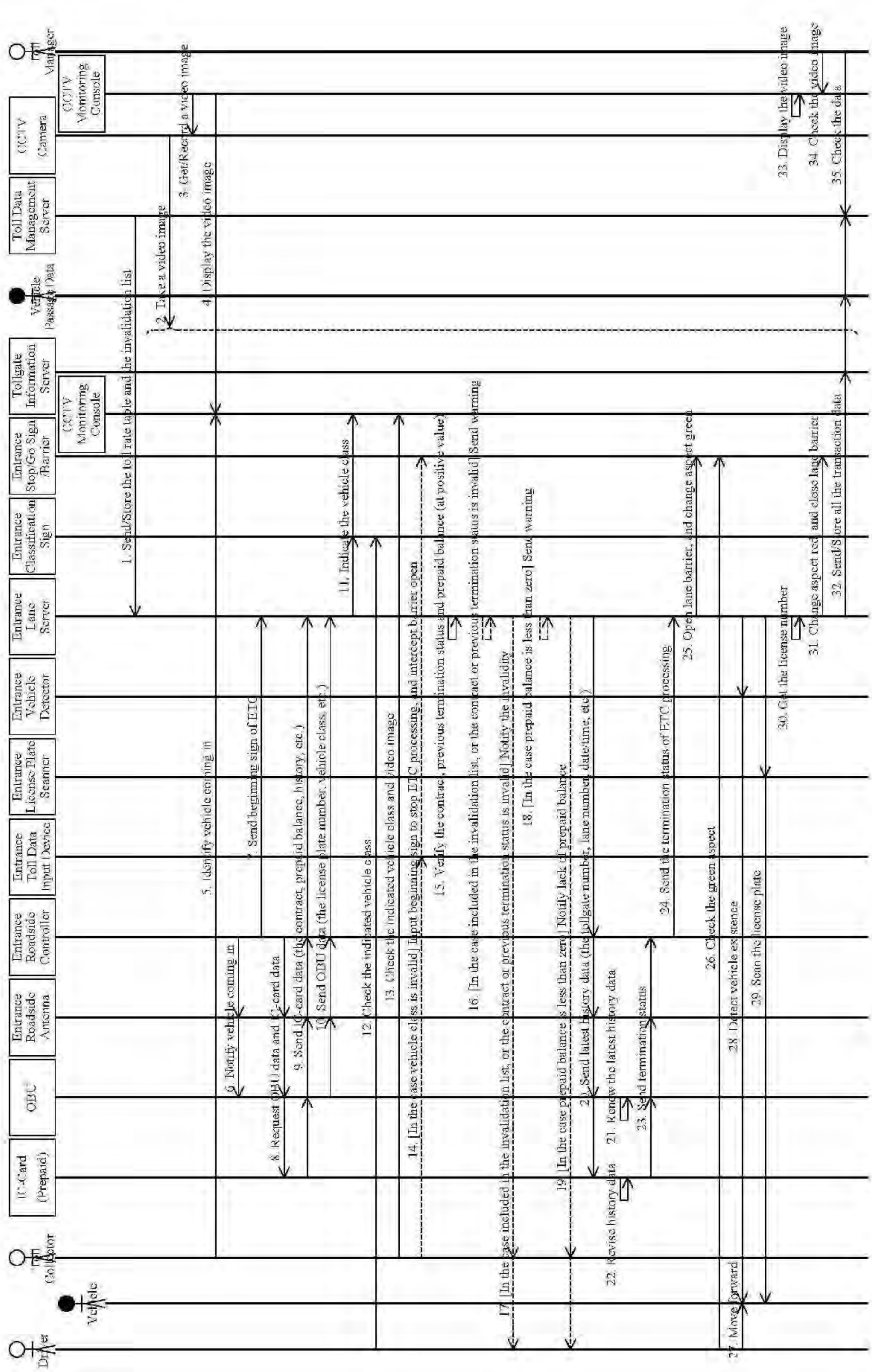


Figure 7.6-(b).MSD Toll Collection by ETC at Toll-island (2p-OBU) (2)

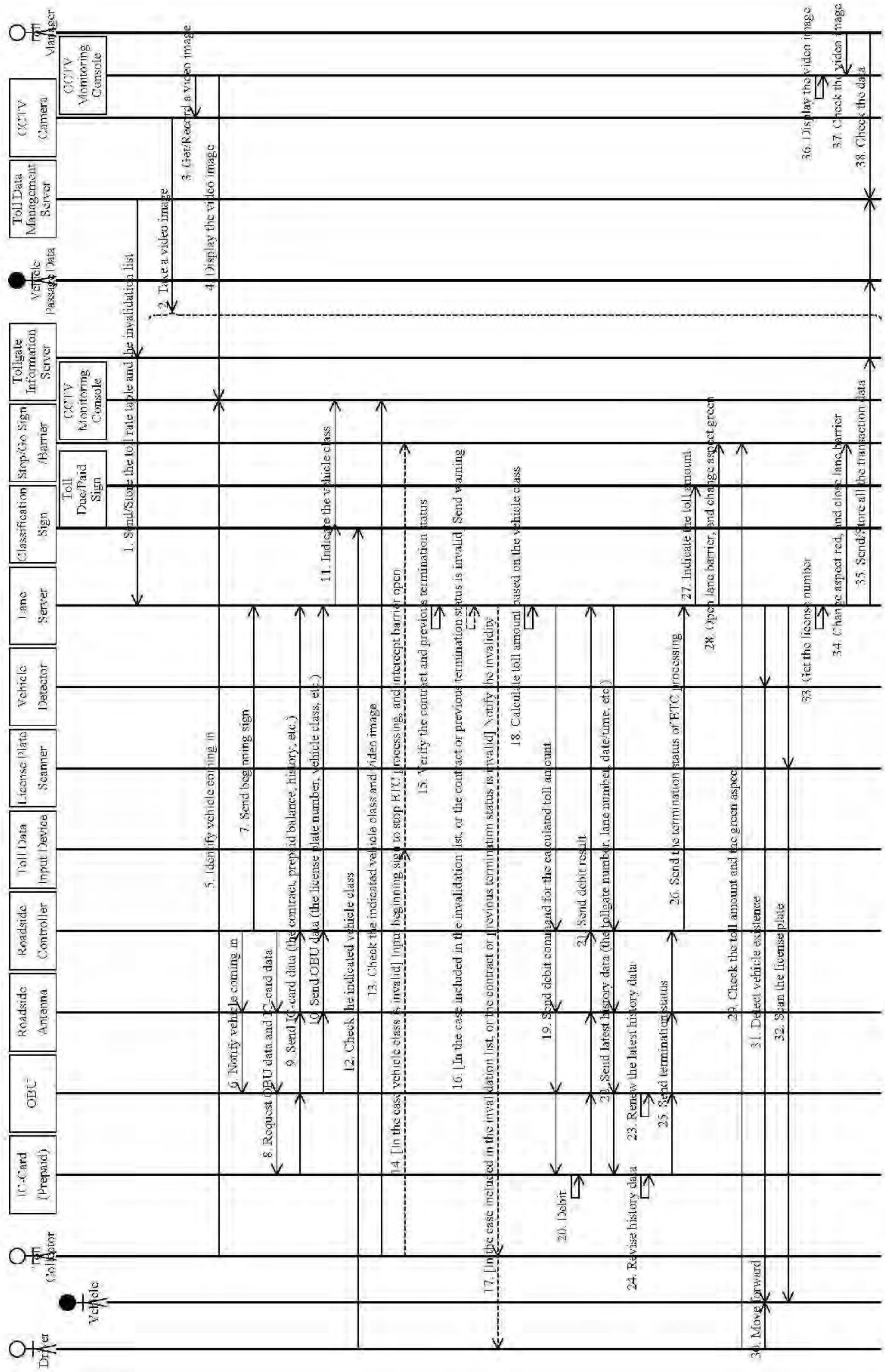


Figure 7.6-(c).MSD Toll Collection by ETC at Toll-island (1p-OBU) (1)

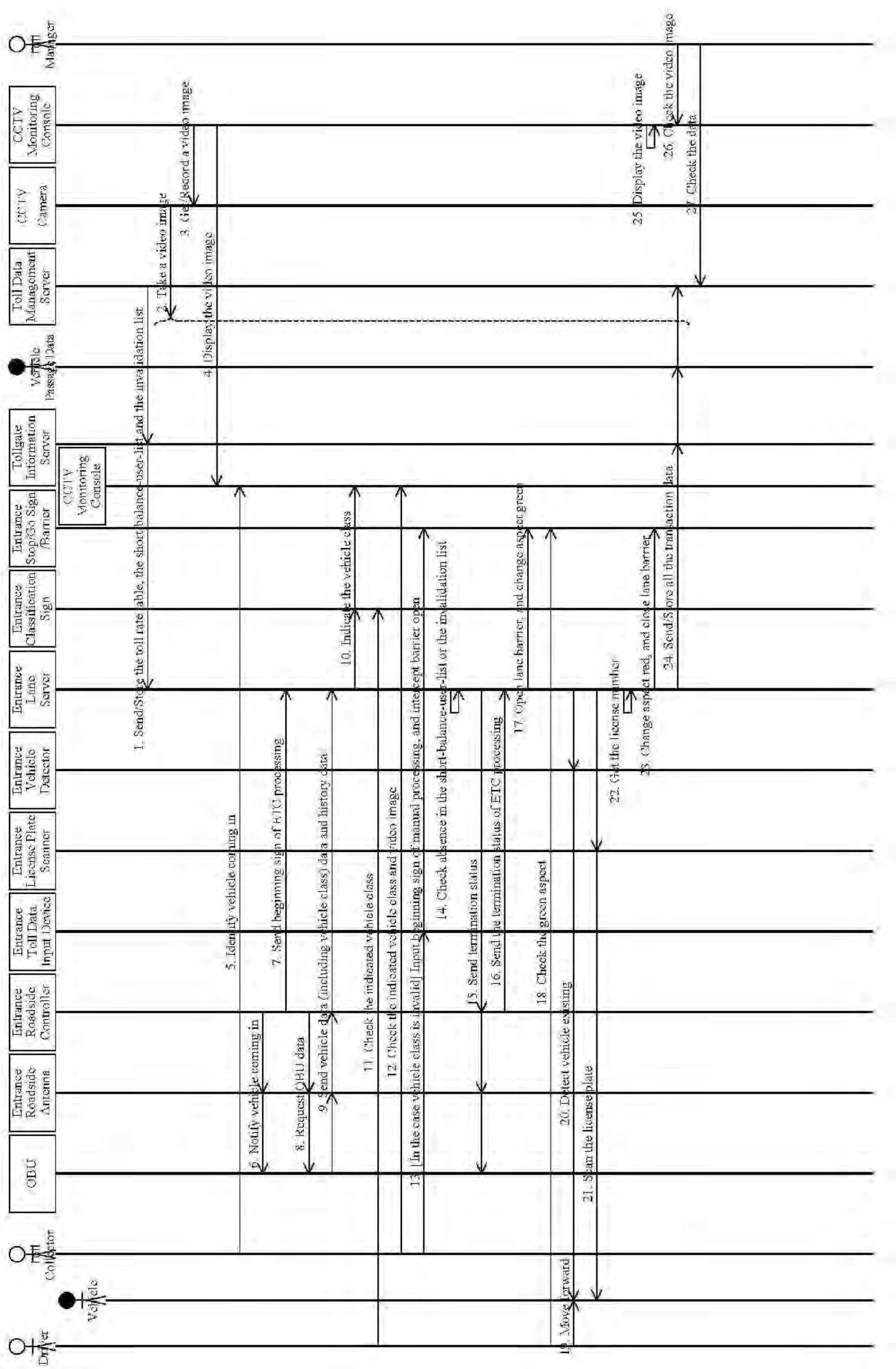


Figure 7.6-(c).MSD Toll Collection by ETC at Toll-island (1p-OBU) (2)

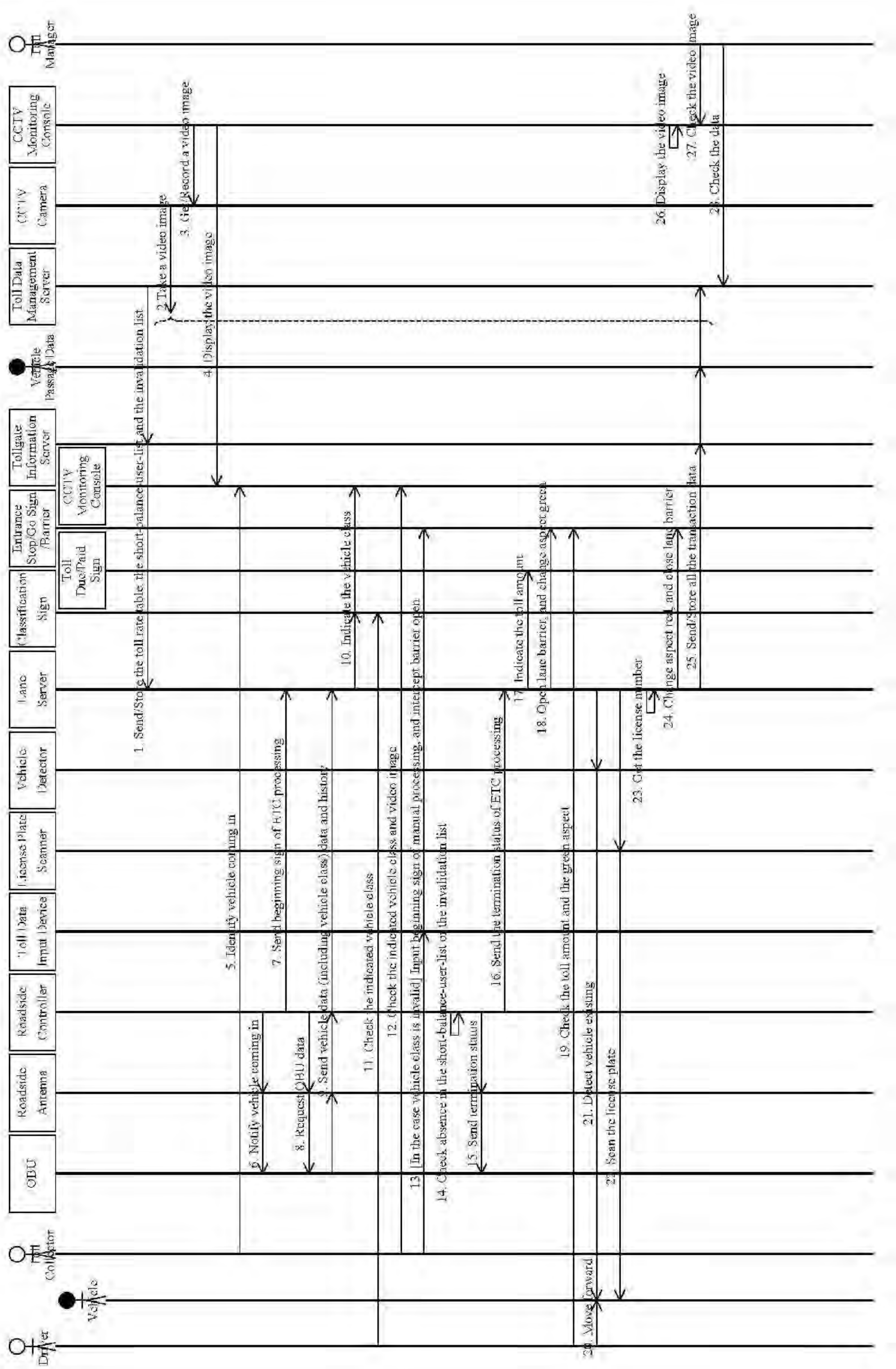
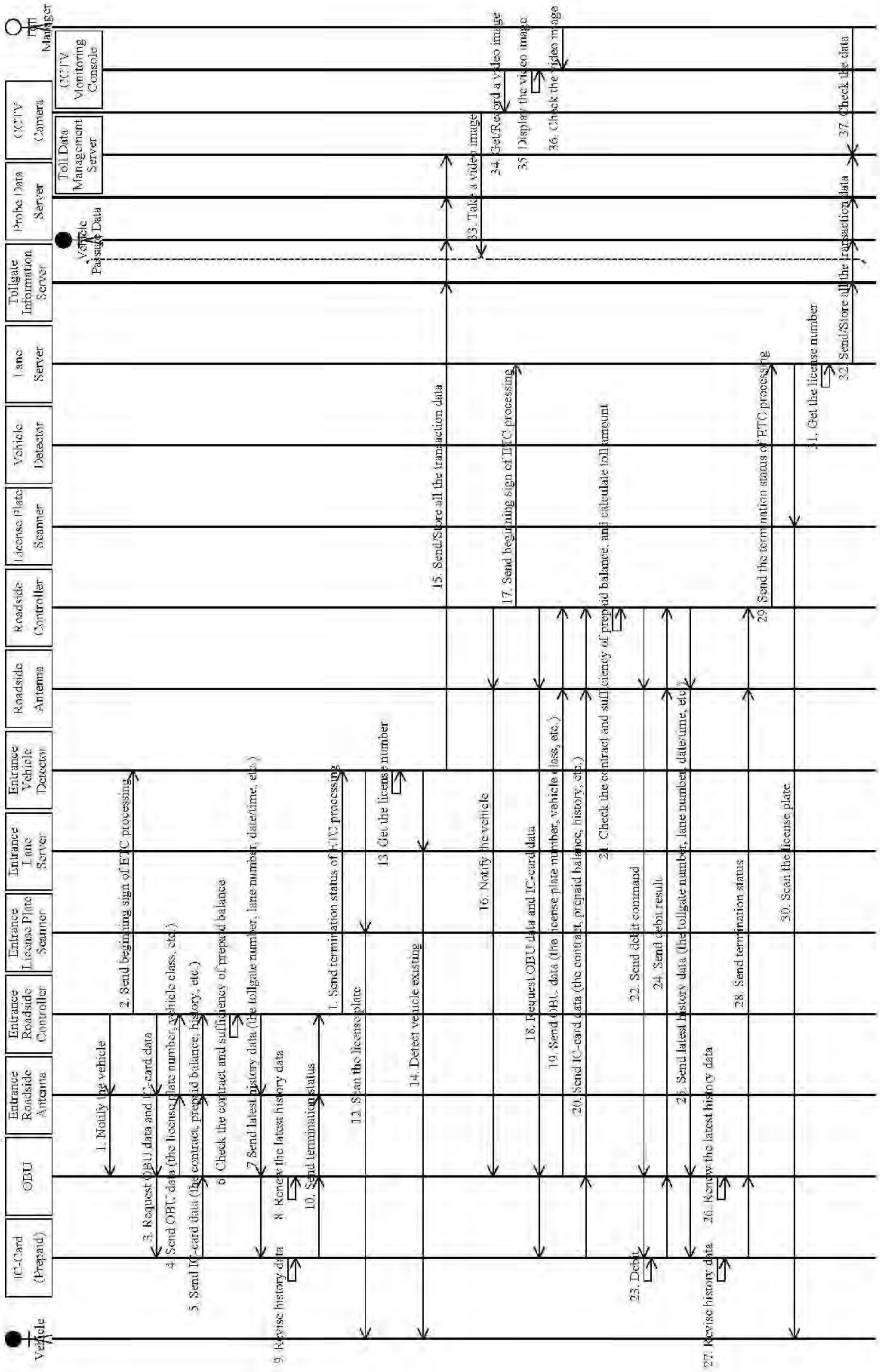


Figure 7.6-(d).MSD Toll Collection by ETC on Free-flow

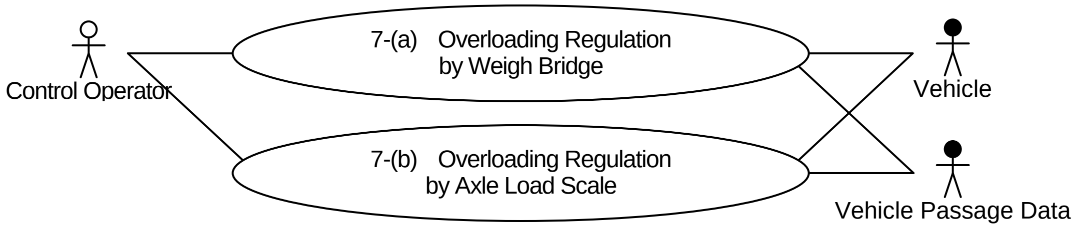


7) Overloading Regulation

(1) Use Cases Diagram

The following two alternative use cases (UC) are to be discussed for overloading regulation.

Figure 7.7-UC Overloading Regulation

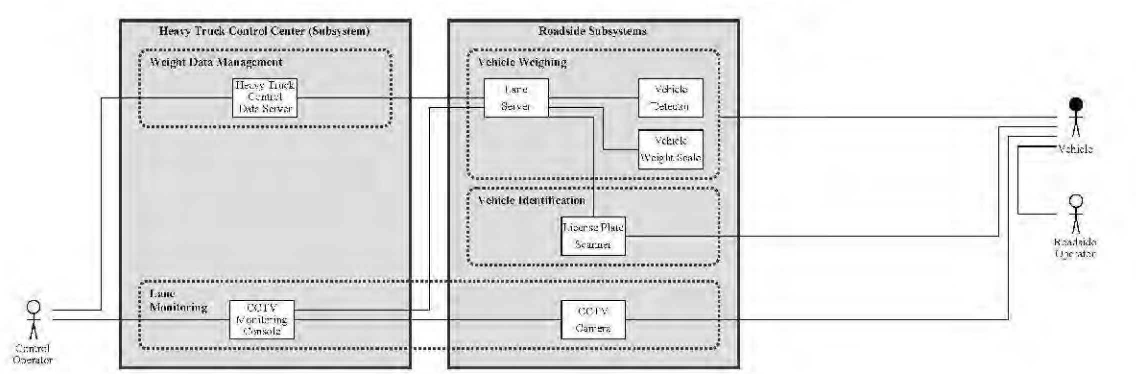


Source: VITRANSS2 Study Team

(2) Collaboration Diagram

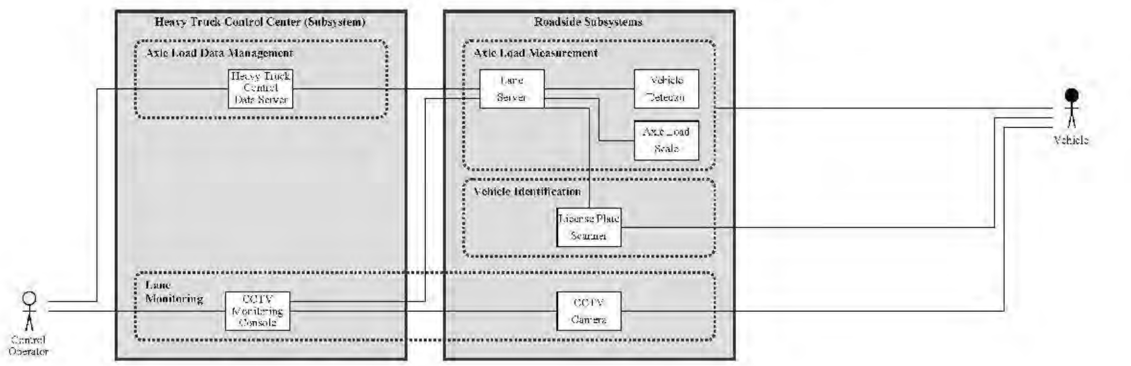
The following collaboration diagrams (CD) are reasoned out from the service descriptions aforementioned.

Figure 7.7-(a).CD Overloading Regulation by Weigh Bridge
(Graded as "Not Suitable")



Note: "Heavy Truck Control Center" is not the name of specific place. Its functions can be installed firmly in a toll office or a road management office.

Figure 7.7-(b).CD Overloading Regulation by Axle Load Scale
(Graded as "Recommended")



Note: "Heavy Truck Control Center" is not the name of specific place. Its functions can be installed firmly in a toll office or a road management office.

(3) Message Sequence Diagram

The following message sequence diagrams (MSD) are derived from the service descriptions aforementioned.

Figure 7.7-(a).MSD Overloading Regulation by Weigh Bridge

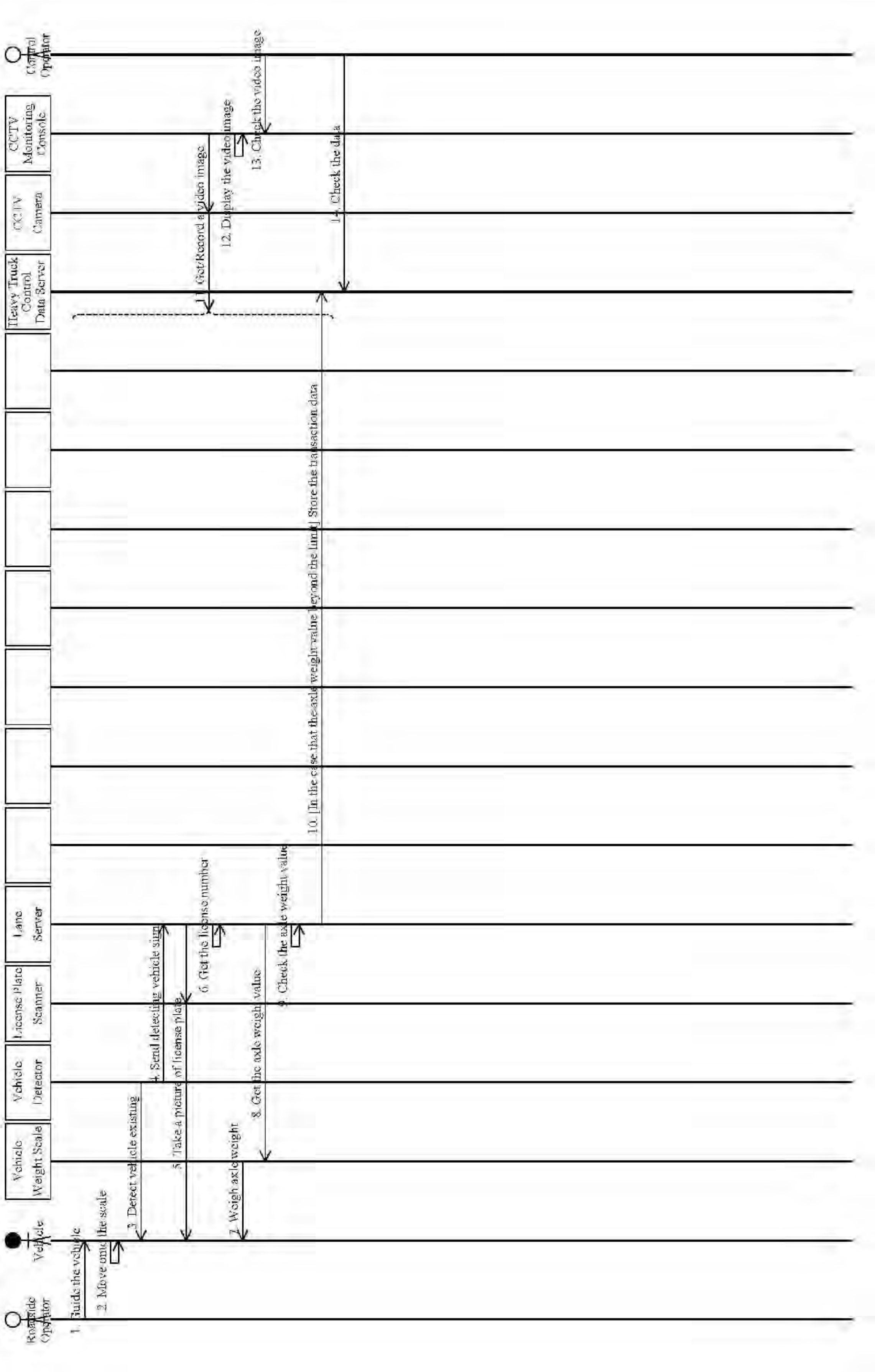
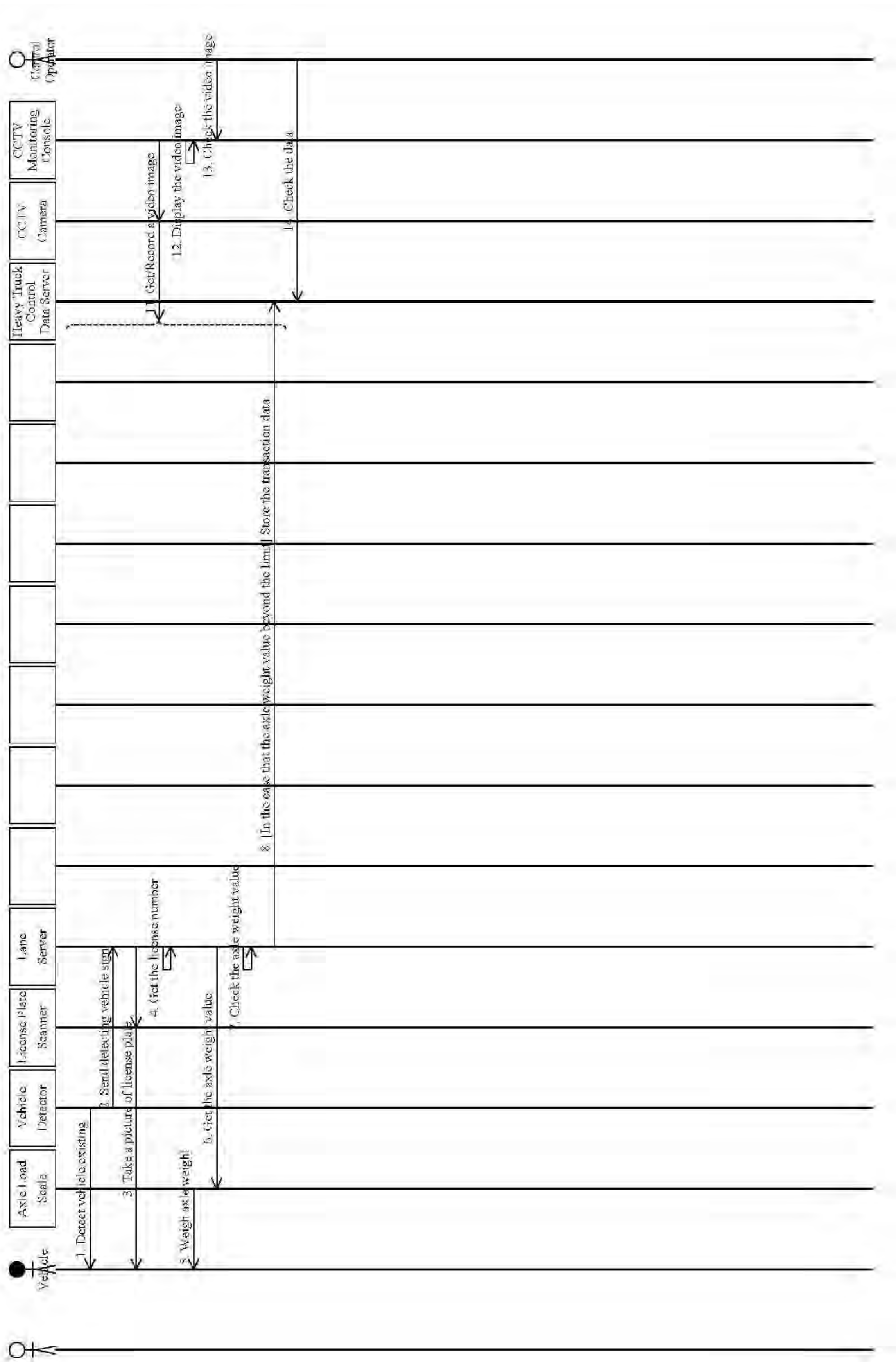


Figure 7.7-(b).MSD Overloading Regulation by Axle Load Scale

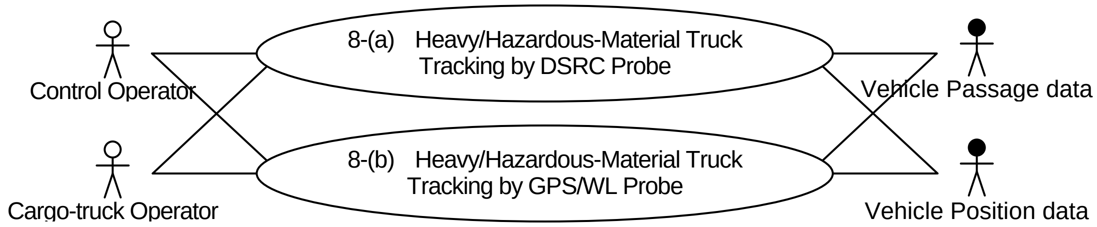


8) Heavy/Hazardous-material Truck Tracking

(1) Use Cases Diagram

The following four alternative use cases (UC) are to be discussed for heavy/hazardous-material truck tracking.

Figure 7.8-UC Heavy/Hazardous-material Truck Tracking



Source: VITRANSS2 Study Team

(2) Collaboration Diagram

The following collaboration diagrams (CD) are reasoned out from the service descriptions aforementioned.

Figure 7.8-(a).CD Heavy/Hazardous-material Truck Tracking by DSRC Probe (Graded as "Recommended")

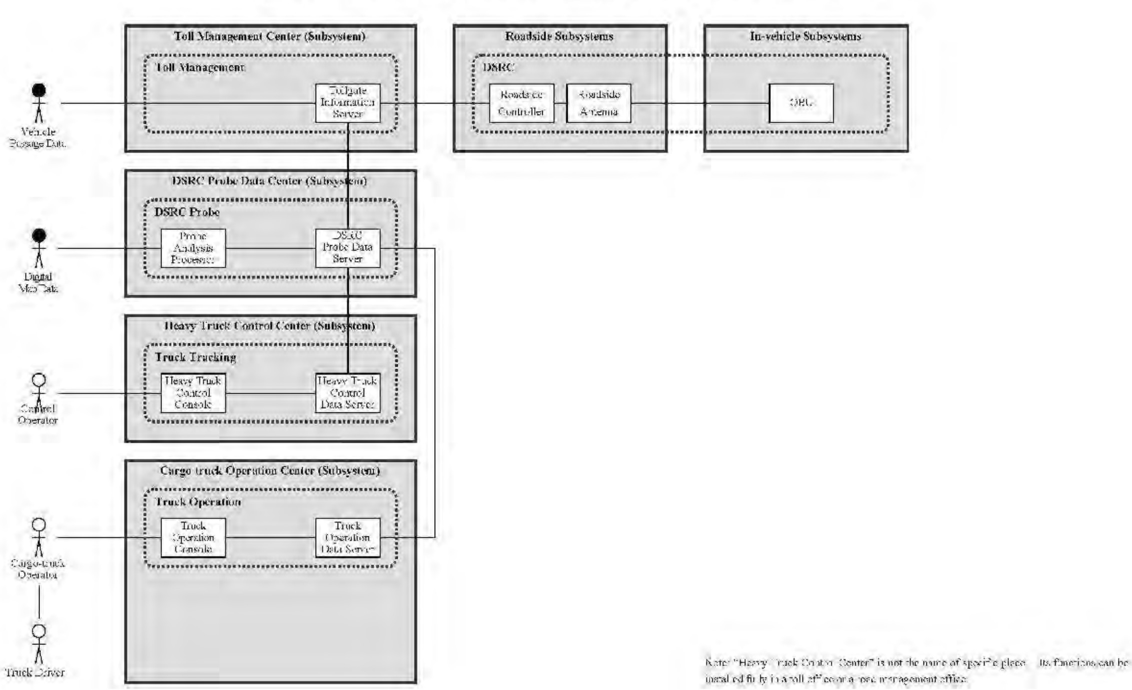
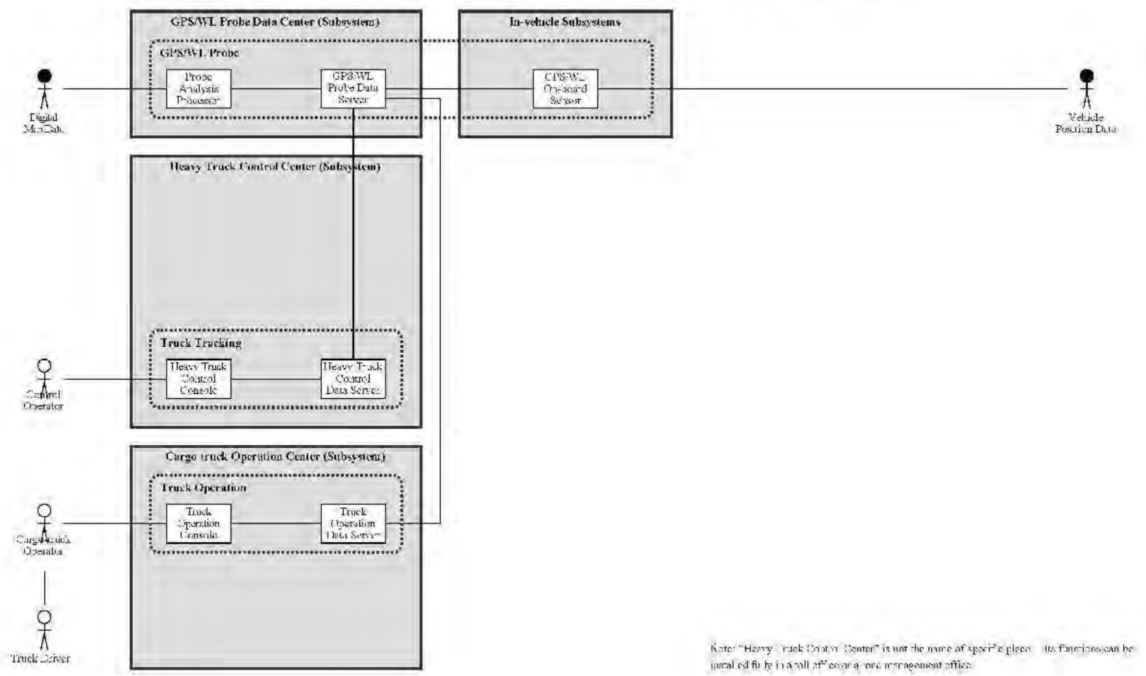


Figure 7.8-(b).CD Heavy/Hazardous-material Truck Tracking GPS/WL Probe
(Graded as “Useful as a Complement”)



(3) Message Sequence Diagram

The following message sequence diagrams (MSD) are derived from the service descriptions aforementioned.

Figure 7.8-(a).MSD Heavy/Hazardous-Material Truck Tracking by DSRC Probe

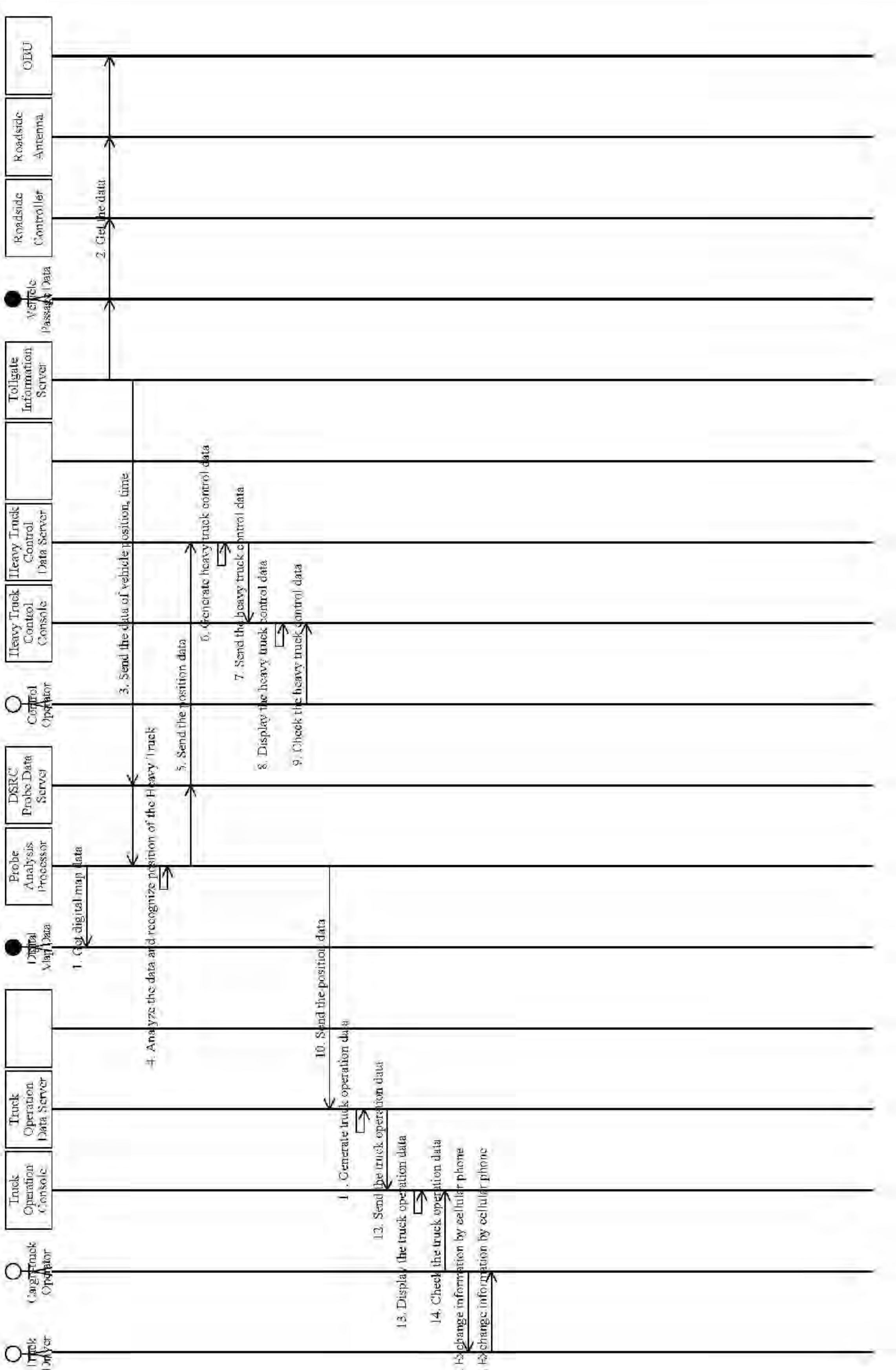
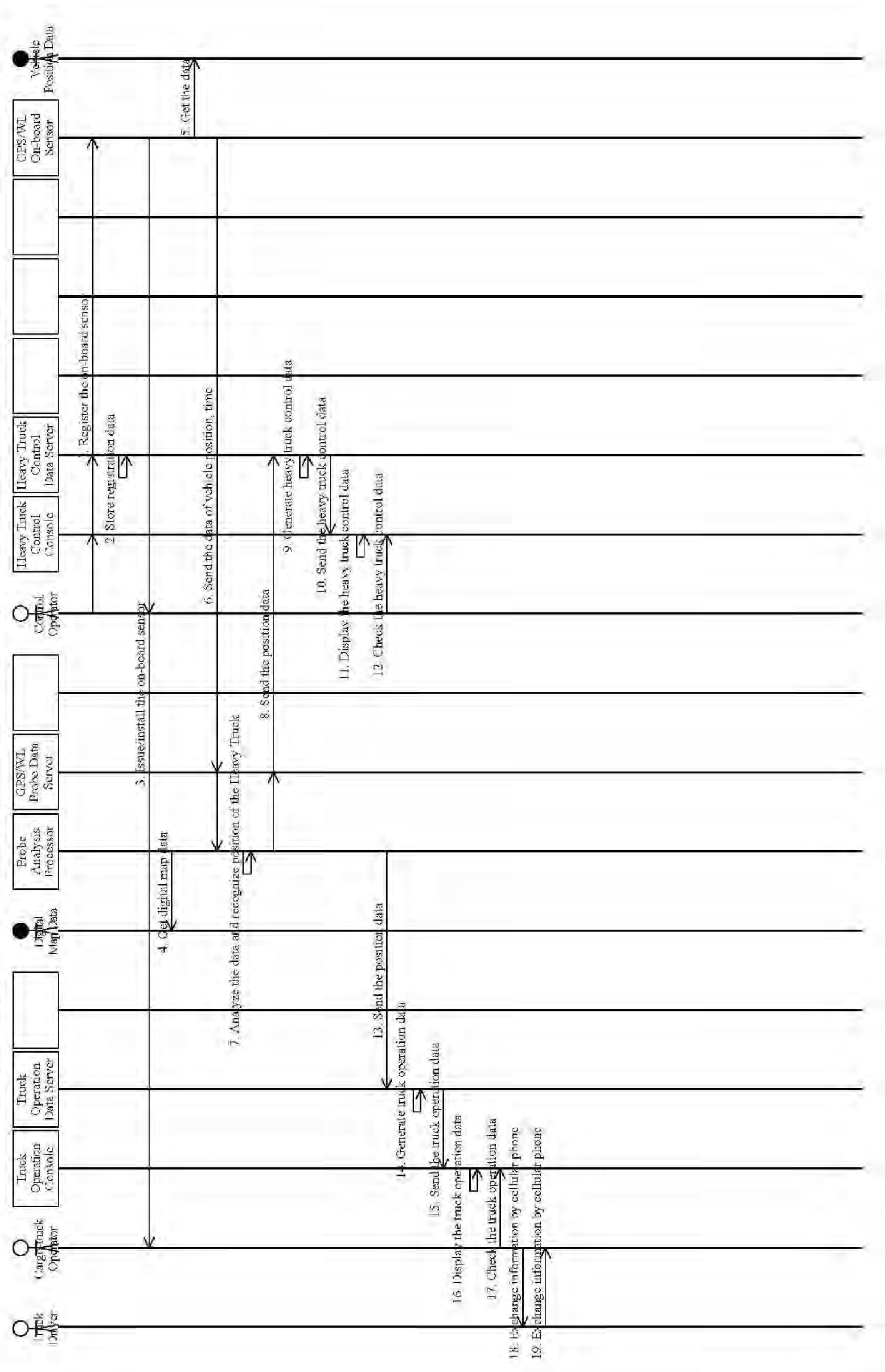


Figure 7.8-(b).MSD Heavy/Hazardous-Material Truck Tracking by GPS/WLC Probe

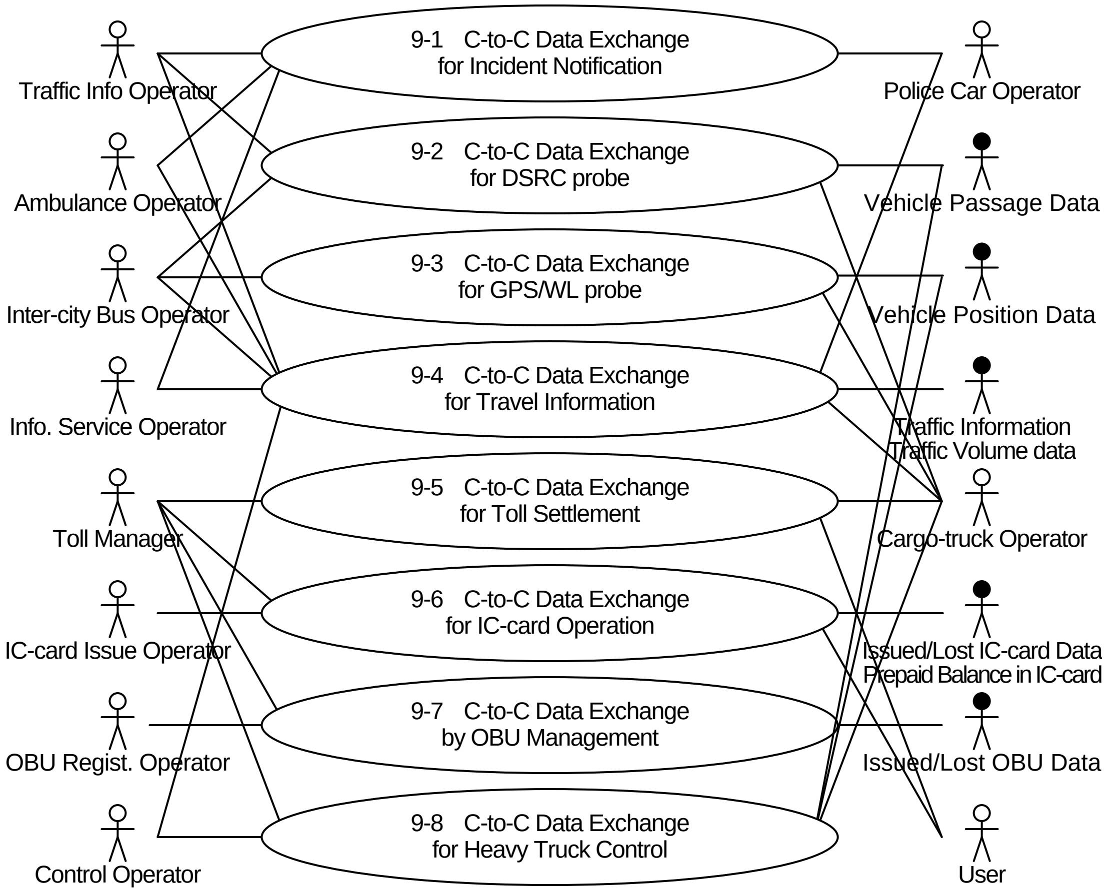


9) Center-to-center Data Exchange

(1) Use Cases Diagram

The following nine mandatory use cases (UC) are to be discussed for center-to-center data exchange.

Figure 7.9-UC Heavy/Hazardous-material Truck Tracking

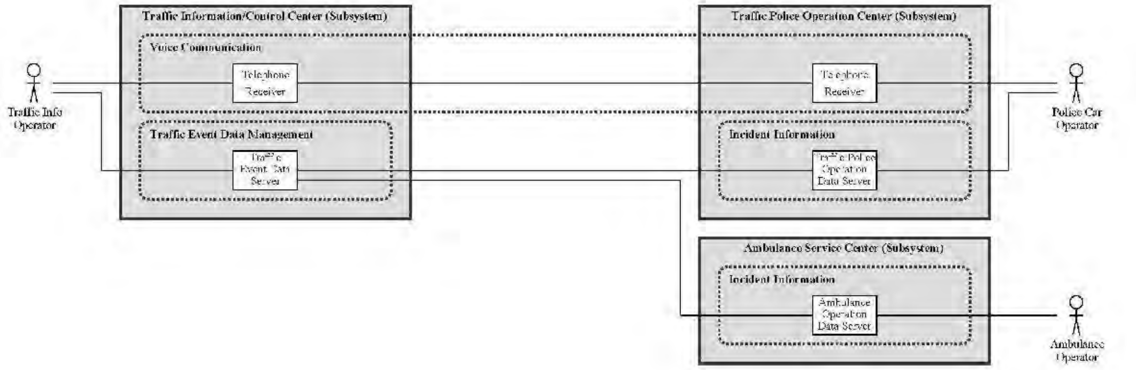


Source: VITRANSS2 Study Team

(2) Collaboration Diagram

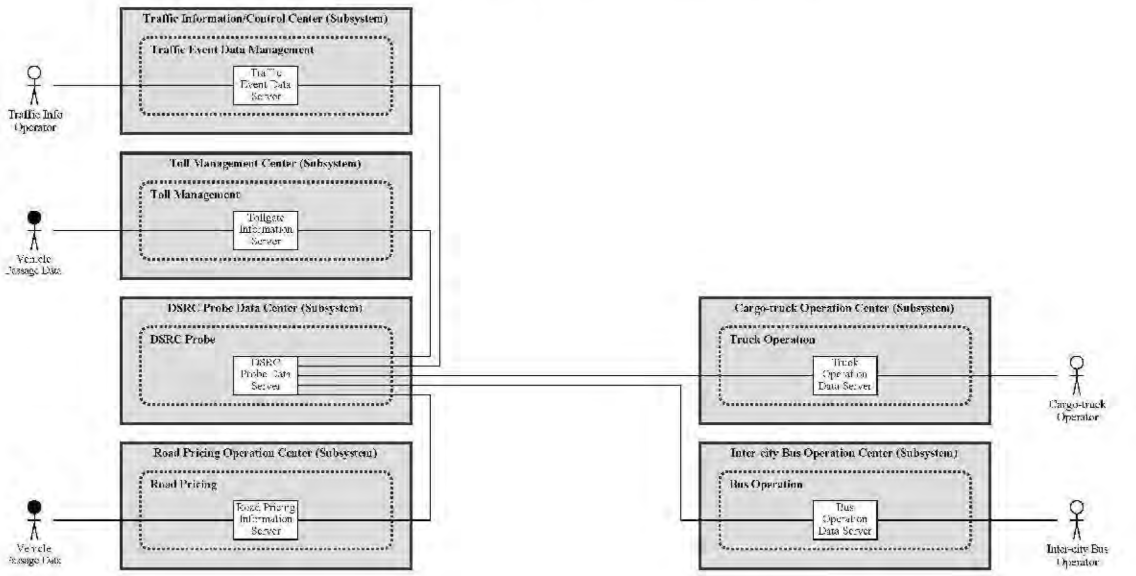
The following collaboration diagrams (CD) are reasoned out from the service descriptions aforementioned.

Figure 7.9-1.CD Center-to-center Data Exchange for Incident Notification (Graded as "Necessary")



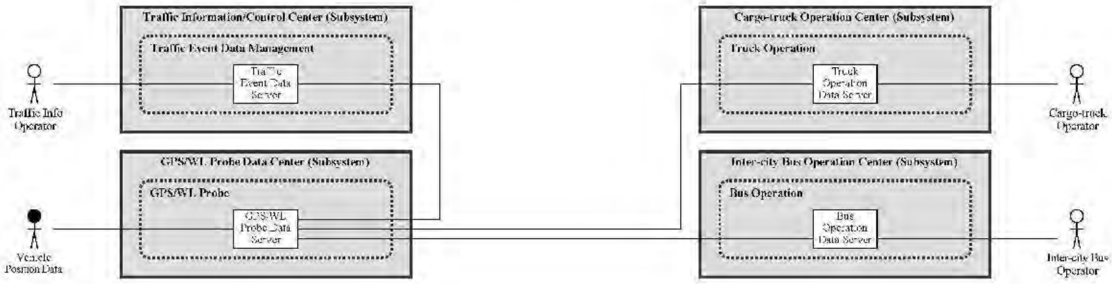
Note: "Traffic Information/Control Center" is not the name of specific place. Its functions can be installed in the Regional Main Center or a road management office.

Figure 7.9-2.CD Center-to-center Data Exchange for DSRC probe (Graded as "Necessary")



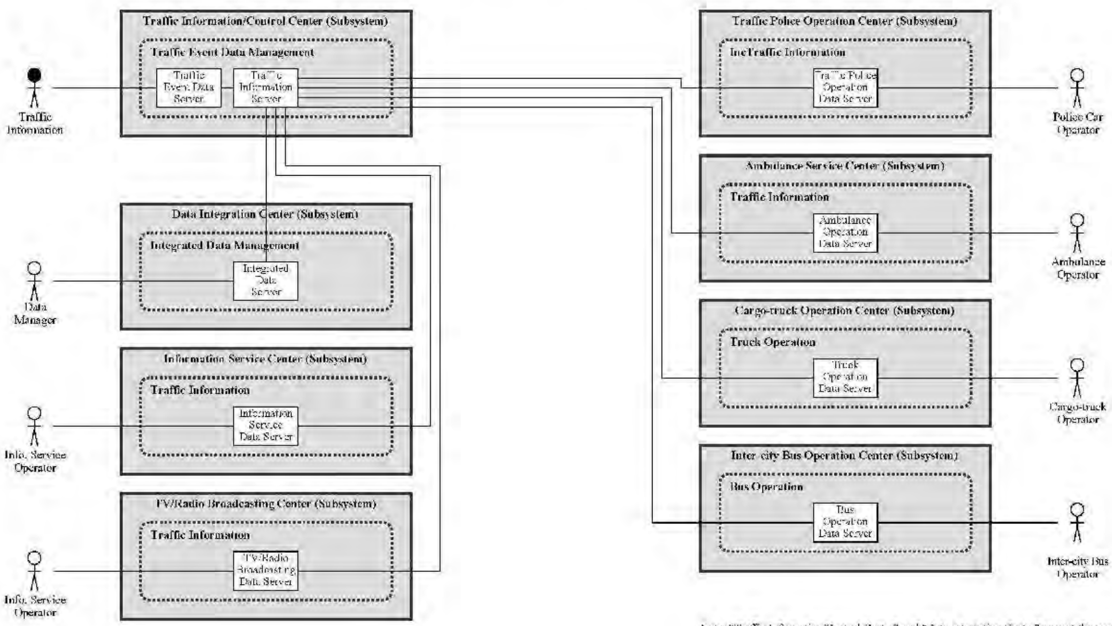
Note: "Traffic Information/Control Center" is not the name of specific place. Its functions can be installed in the Regional Main Center or a road management office.

Figure 7.9-3.CD Center-to-center Data Exchange for GPS/WL probe
(Graded as "Necessary")



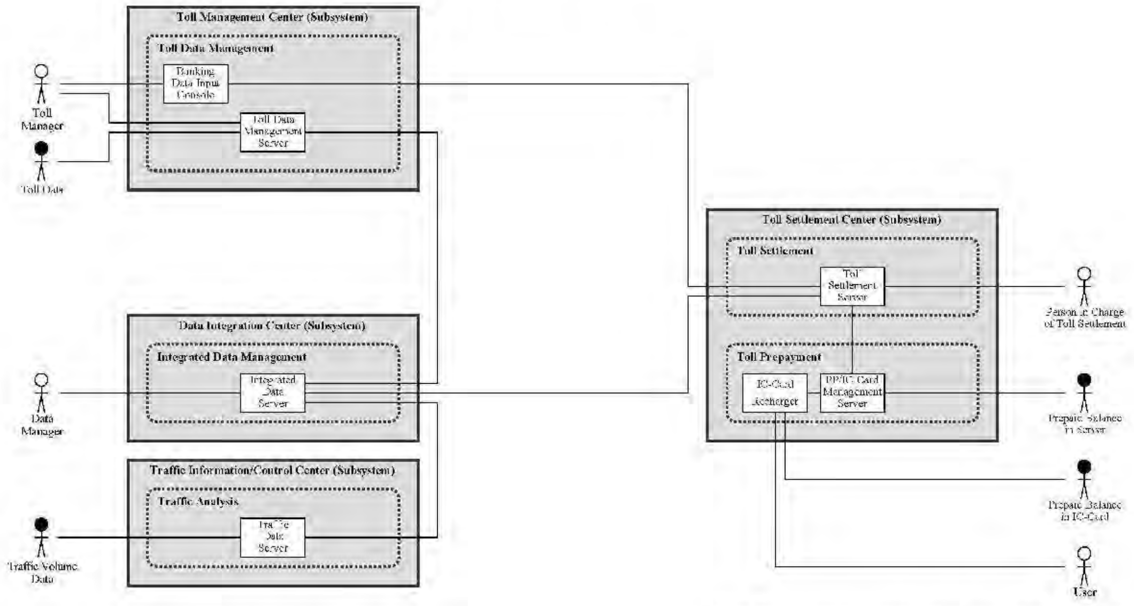
Note: "Traffic Information/Control Center" is not the name of specific place. Its functions can be installed in the Regional Main Center or a road management office.

Figure 7.9-4.CD Center-to-center Data Exchange for Traffic Information
(Graded as "Necessary")



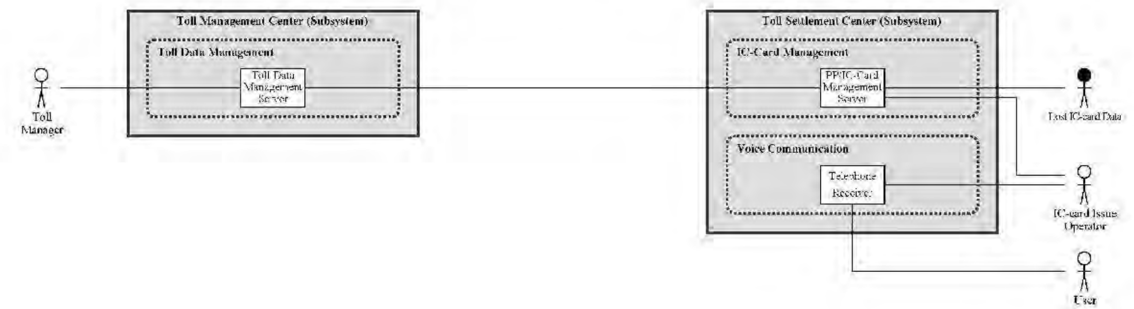
Note: "Traffic Information/Control Center" and "Data Integration Center" are not the names of specific places. Their functions can be installed in the Regional Main Center.

Figure 7.9-5.CD Center-to-center Data Exchange for Toll Settlement
(Graded as "Necessary")



Note: "Traffic Information/Control Center" and "Data Integration Center" are not the names of specific places. Their functions can be installed in the Regional Main Center.

Figure 7.9-6.CD Center-to-center Data Exchange for IC-card Operation
(Graded as "Necessary")



Note: "Toll Management Center" is not the name of specific place. Its functions can be installed fully in the toll office or partially in the head office of the road owner.

Figure 7.9-7.CD Center-to-center Data Exchange for OBU Management
(Graded as "Necessary")

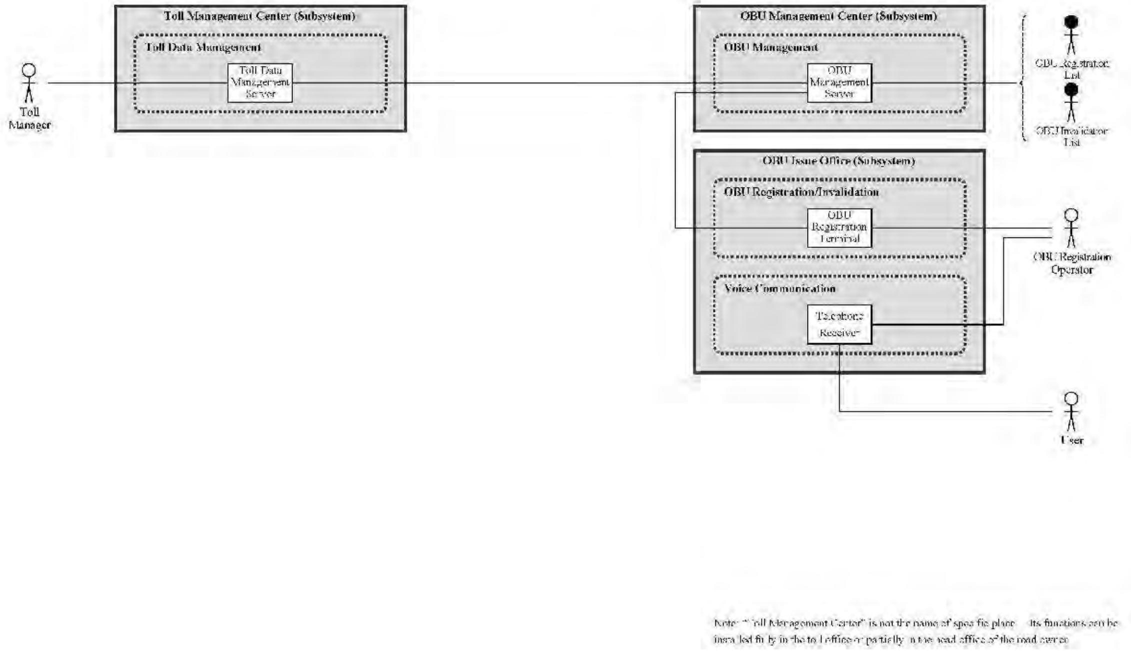
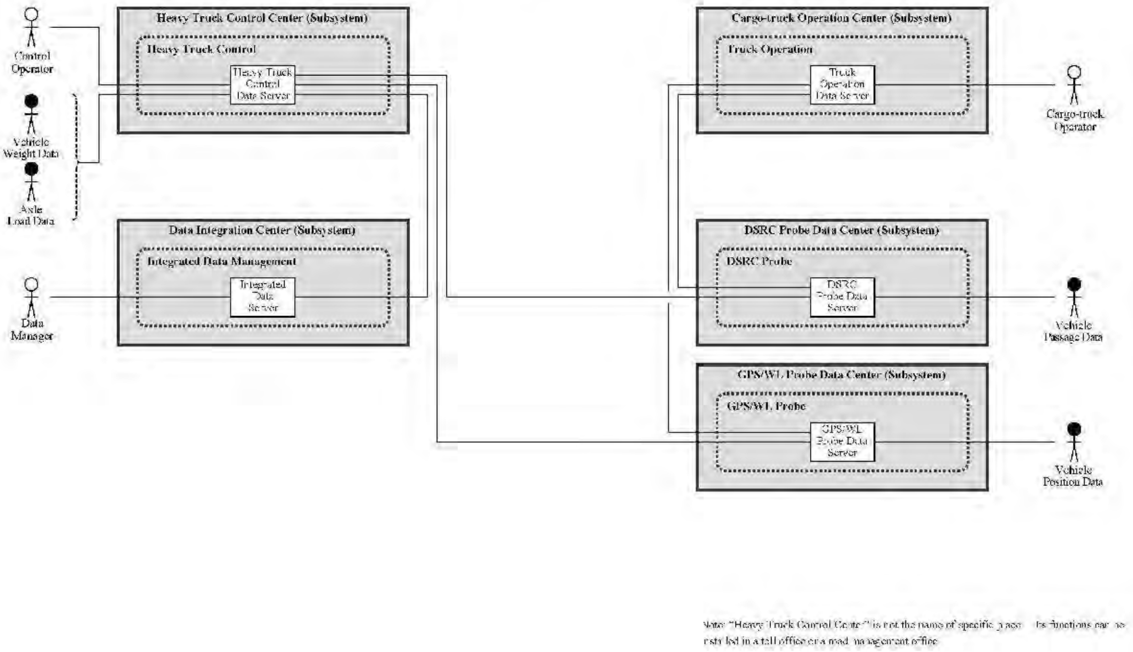


Figure 7.9-8.CD Center-to-center Data Exchange for Heavy Truck Control
(Graded as "Necessary")



(3) Message Sequence Diagram

The following message sequence diagrams (MSD) are derived from the service descriptions aforementioned.

Figure 7.9-1.MSD C-to-C Data Exchange for Incident Notification

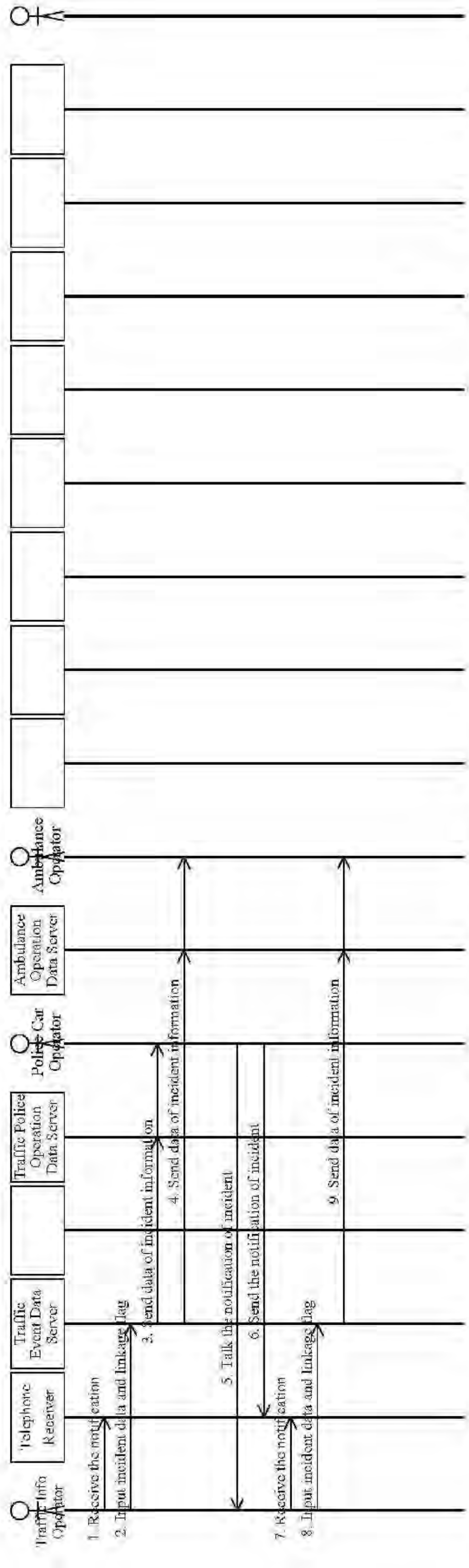


Figure 7.9-2.MSD C-to-C Data Exchange for DSRC Probe

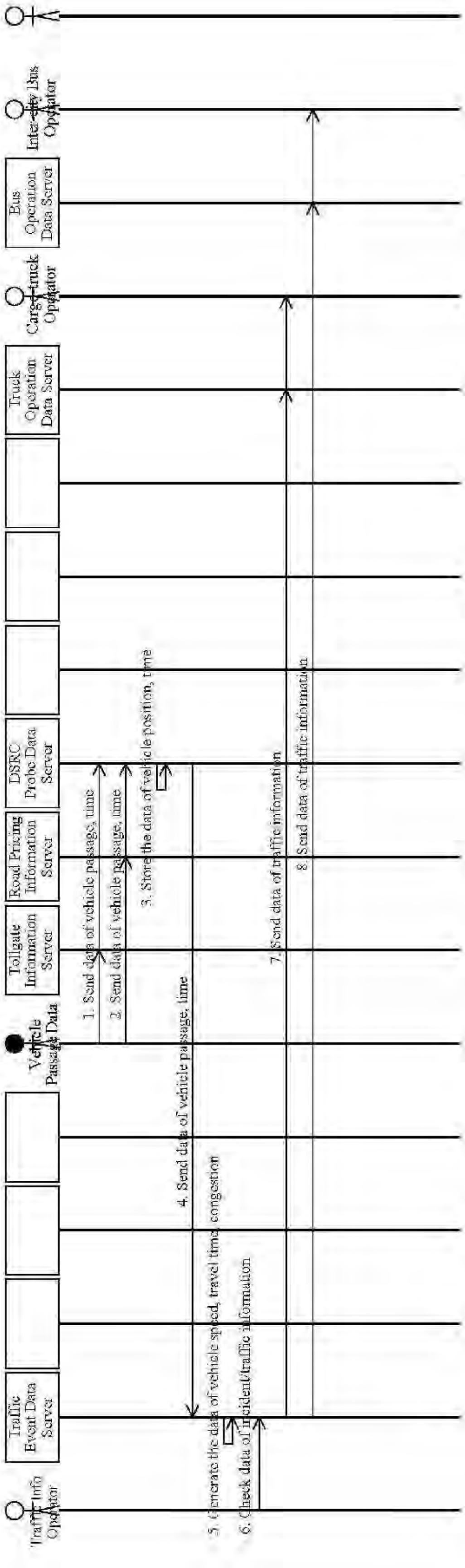


Figure 7.9-3.MSD C-to-C Data Exchange for GPS/WL Probe

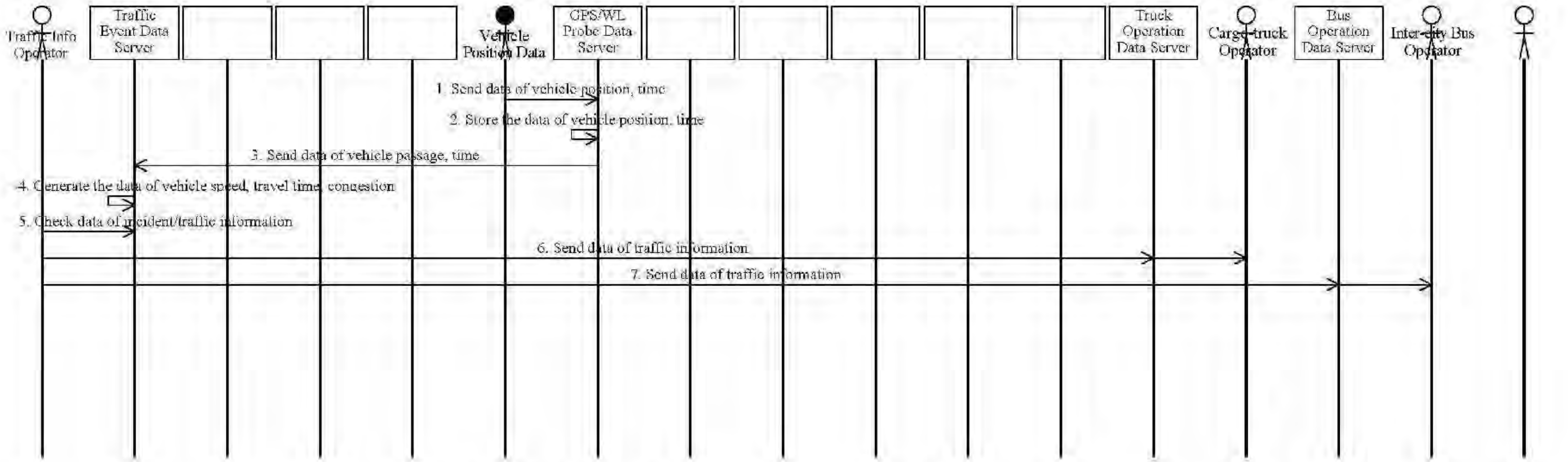


Figure 7.9-4.MSD C-to-C Data Exchange for Traffic Information

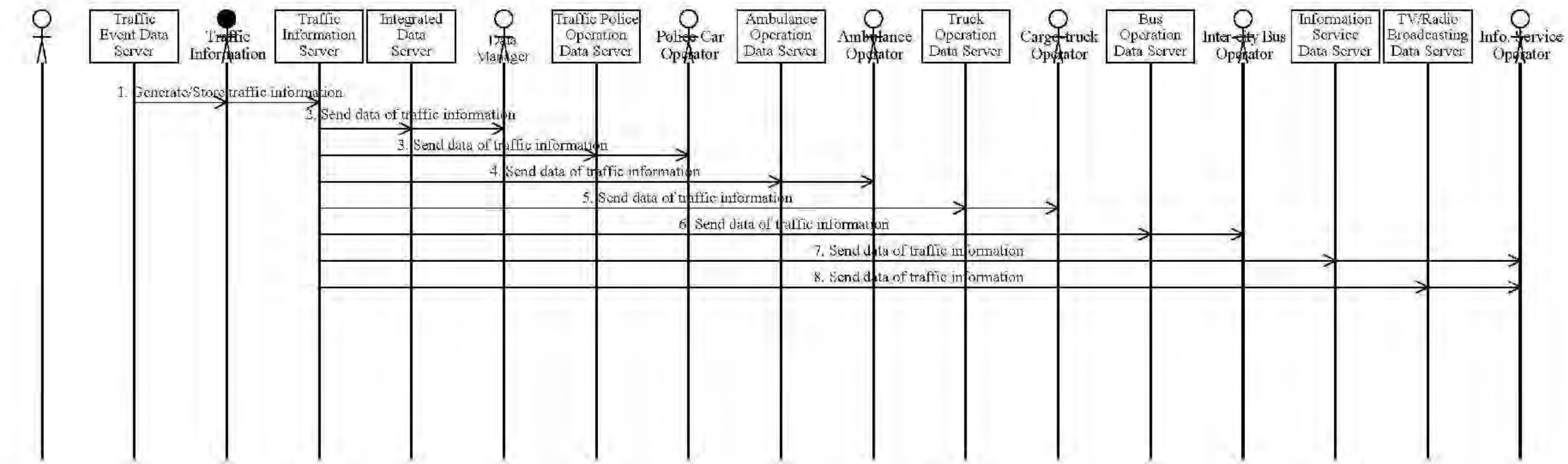


Figure 7.9-5.MSD C-to-C Data Exchange for Toll Settlement

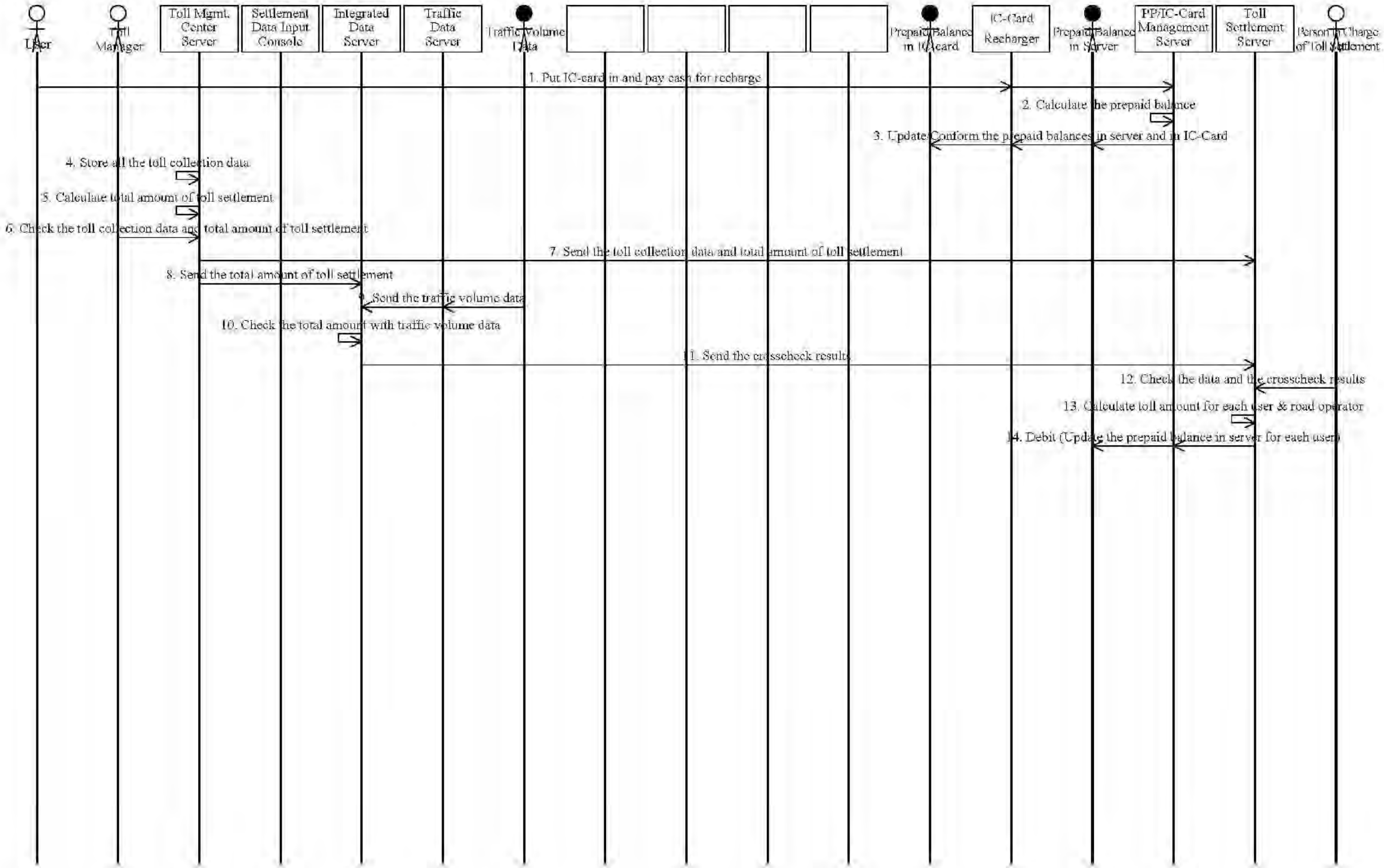


Figure 7.9-6.MSD C-to-C Data Exchange for IC-card Operation

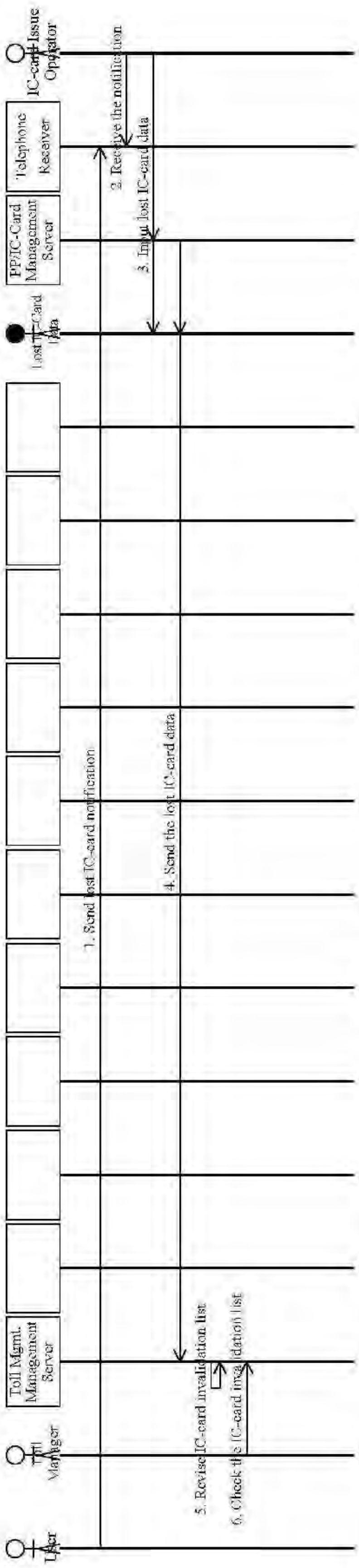


Figure 7.9-7.MSD C-to-C Data Exchange for OBU Management

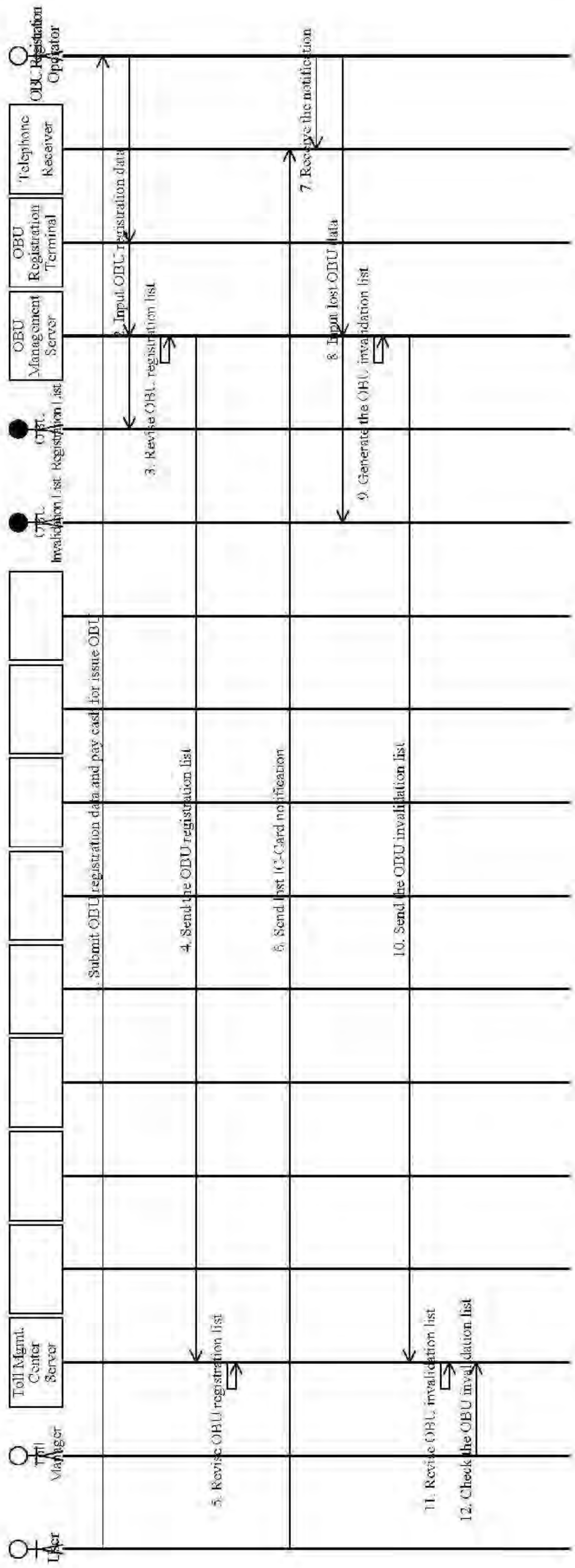
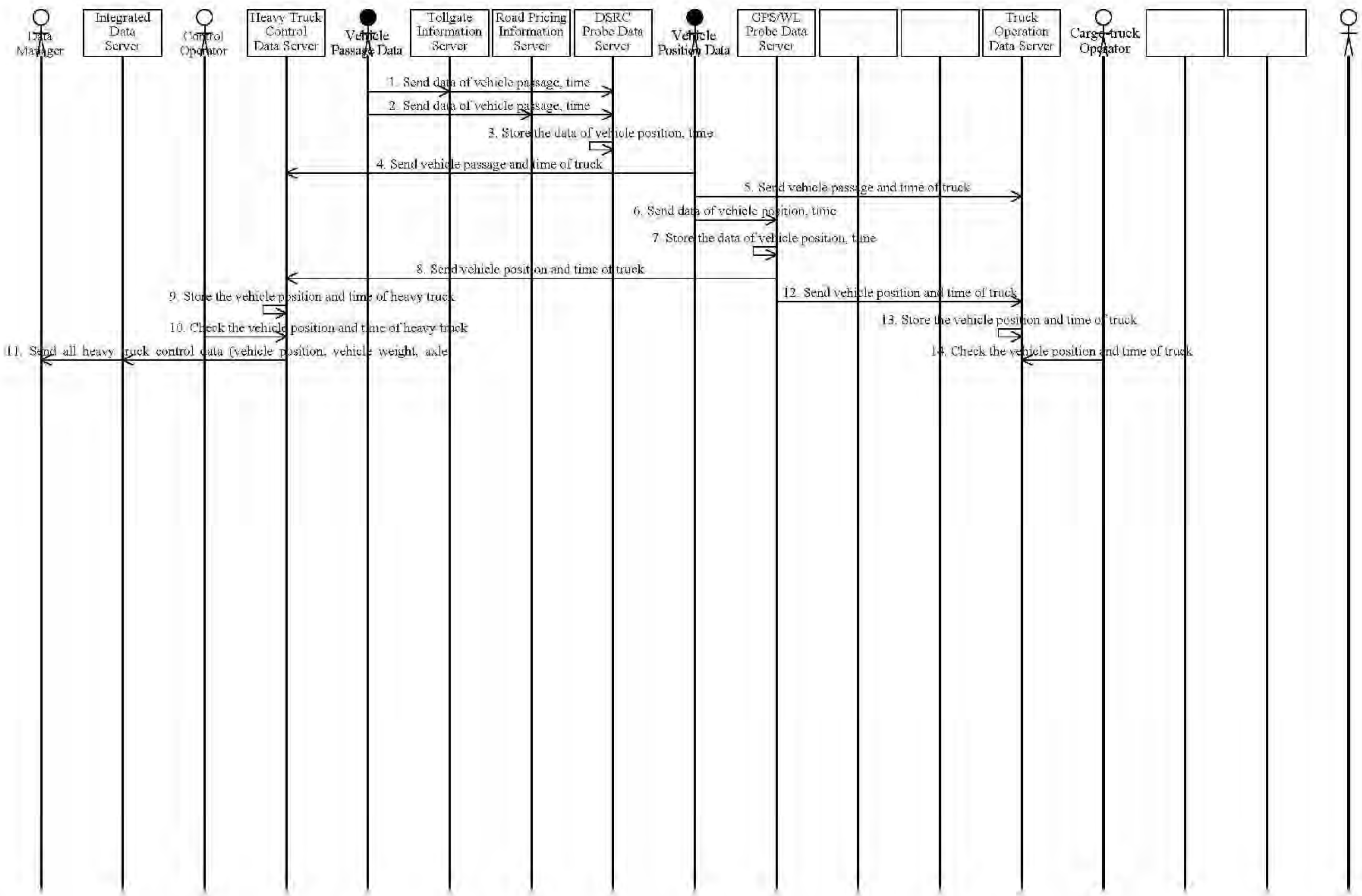


Figure 7.9-8.MSD C-to-C Data Exchange for Heavy Truck Control



JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF TRANSPORT, VIETNAM

SPECIAL ASSISTANCE FOR PROJECT IMPLEMENTATION (SAPI)
FOR ITS INTEGRATION PROJECT ON
NEW NATIONAL HIGHWAY NO.3 & NORTHERN AREA OF VIETNAM

DRAFT ITS DESIGN STANDARDS (REVISED VERSION)

FINAL REPORT IN AUGUST 2012

ORIENTAL CONSULTANTS CO., LTD
NEXCO EAST ENGINEERING CO., LTD
NIPPON KOEI CO., LTD
TRANSPORTATION RESEARCH INSTITUTE CO., LTD
LANDTEC JAPAN INC.

Introduction

The revised version of Draft Design Standards are organized in 3 volumes corresponding to the priority ITS user services as follows:

(1) Traffic Information/Control System
(2) Automated Toll Collection/Management System
(3) Vehicle Weighing System

1) Traffic Information/Control System

This volume of the Draft Design Standards defines basic concepts, general architecture and actualization methods as a unified form for designing the system of traffic information/control. The outline of the service to be provided by traffic information/control is described below.

This service provides accurate surveillance of traffic conditions on expressways and adjacent arterial roads. This service assists prompt action of the road operator and emergency vehicles by notifying occurrences of traffic accidents, broken-down vehicles and left obstacles. This service allows drivers en route and in advance to avoid the influence of the incidents by providing accurately updated information. This service also allows appropriate interchange/ route selection by providing drivers en route with information on crowdedness and estimated travel-time. This service makes it possible to measure actual traffic volume continuously for developing road improvement plans.

This volume of the Draft Design Standards includes the following functional packages:

(1) Voice Communication
(2) CCTV Monitoring
(3) Event Detection (by Image)
(4) Vehicle Detection
(5) Traffic Analysis
(6) Weather Monitoring
(7) Traffic Event Data Management
(8) Traffic Supervision
(9) VMS Indication
(10) Mobile Radio Communication
(11) Traffic Information.
(12) Integrated Data Management.

2) Automated Toll Collection/Management System

This volume of the Draft Design Standards defines basic concepts, general architecture and actualization methods as a unified form for designing the system of toll collection/management. The outline of the service to be provided by non-stop toll collection is described below.

This service enables toll collection without stopping vehicles: ETC (Electronic Toll Collection). This service relieves bottlenecks at the tollgates and allows smooth incoming and outgoing of vehicles at interchanges. This service reduces the number of tollbooths and solves the problem of land acquisition, especially for tollgates in suburban areas where traffic congestion will become an issue in the near future. This service allows simple vehicle inspection at border crossings, and provides the road/vehicle operators with the time of vehicle passage at tollgates. Computerized toll management can vastly reduce uncollected toll revenue due to the failure in counting/classifying vehicles, and can realize appropriate sharing of the toll revenue among the different road operators.

This volume of the Draft Design Standards includes the following functional packages:

(1) Tollgate Lane Monitoring
(2) Vehicle Identification
(3) Lane Control
(4) Road-to-Vehicle Communication
(5) IC-card Recording
(6) Toll Management
(7) OBU Management.

3) Vehicle Weighing System

This volume of the Draft Design Standards defines basic concepts, general architecture and actualization methods as a unified form for designing the system of vehicle weighing. The outline of the service to be provided by heavy truck control is described below.

This service eliminates overloading of heavy trucks by automatic execution of vehicle weighing at interchanges. It reduces damage to the road structure and extends its durable lifetime. This service reduces congestion caused by heavy trucks and allows freight transport to improve safety by eliminating overloading. This service allows prompt action of the road operator at the occurrence of serious accidents caused by heavy trucks and hazardous material trucks, and taking appropriate vehicle operation by keeping track of trucks on the expressway network.

This volume of the Draft Design Standards includes the following functional packages:

(1) Axle Load Measurement
(2) Measurement Lane Monitoring.

TRAFFIC INFORMATION/CONTROL SYSTEM

TABLE OF CONTENTS

1. Introduction

Service descriptions:

This service provides accurate surveillance of traffic conditions on expressway and adjacent arterial roads. This service assists prompt action of the road operator and the emergency vehicles by notifying occurrence of traffic accidents, broken-down vehicles and other obstacles. This service allows drivers en route and in advance to avoid the influence of the incidents by providing accurately updated information. This service also allows appropriate interchange/route selection by providing drivers en route with information; such as crowdedness and travel-time. This service makes it possible to measure actual traffic volume continuously for developing rational road construction/improvement plan.

Functional packages to be included in the system:

(1) Voice communication
(2) CCTV monitoring
(3) Event detection (by image)
(4) Vehicle detection
(5) Traffic analysis
(6) Weather monitoring
(7) Traffic event data management
(8) Traffic supervision
(9) VMS indication
(10) Mobile radio communication
(11) Traffic information
(12) Integrated data management.

2. Use Case and General System Architecture

Use cases and general system architecture are illustrated for the following implementation packages of traffic information/control:

(1) Incident Information
(2) Traffic Congestion Information
(3) Weather Information
(4) Traffic Control Assistance
(5) Center-to-Center Data Exchange.

Relationships between the system and users/operators/other-systems are illustrated by the following use case diagrams in the design drawings:

Road traffic supervision

- Incident reporting by mobile phone
- Incident identification
- Bad weather identification
- Traffic restriction
- Routine patrol
- Traffic event management at regional main center
- Traffic event management at road management office
- Traffic event management by patrol crew
- Traffic information by VMS
- Traffic information for internet
- Traffic information cancellation

- Integrated data management
- Routine monitoring in regional main center.

The general system architecture is sown using collaboration diagrams and message sequence diagrams titled as below in the design drawings:

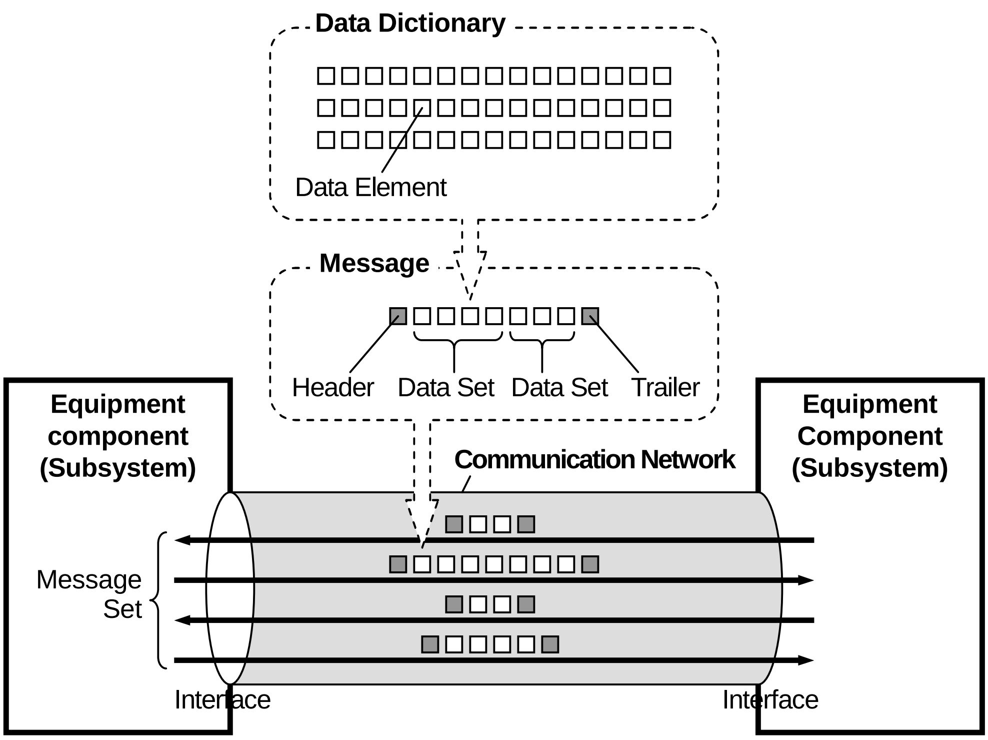
(1) Incident Information by monitoring at roadside
(2) Incident Information by image recognition
(3) Traffic congestion information by monitoring at roadside
(4) Traffic congestion information by image recognition
(5) Traffic congestion information by vehicle detection
(6) Weather information by weather sensors
(7) Traffic control assistance by traffic event data
(8) Center-to-center data exchange for incident notification
(9) Center-to-center data exchange for traffic information.

3. Message/Data Design

3.1 General

ITS consists of many pieces of equipment, which are illustrated as the equipment components in the diagrams of system architecture. The equipment components need to be connected with each other by communication network in order to exchange messages and data between them, to actualise the system and to provide intended services.

Figure 3.1 Conceptual Illustration of Message/Data Exchange



Source: ITS Integration Project (SAPI) Study Team

3.2 Major Message List

The major message list for traffic information/control system is shown in the following table.

Table 3.1 Message List of Traffic Information/Control System

Name of Message	A Pair of Equipment Components on Both Side of Interface through Which Message is Exchanged		Name of Include Data Sets
Event Input Message	Data Input Device	Traffic Event Data Server	Traffic Event Data Set Image Recognition Result Data Set
	Traffic Event Data Server	Traffic Information Server	Traffic Event Data Set Image Recognition Data Set
Vehicle Detection Message	Vehicle Detector	Traffic Analysis Processor	Vehicle Detection Data Set
	Traffic Analysis Processor	Traffic Event Data Server	Vehicle Detection Data Set
Traffic Congestion Message	Traffic Analysis Processor	Traffic Event Data Server	Traffic Congestion Data Set
Traffic Congestion Input Message	Data Input Device	Traffic Event Data Server	Traffic Congestion Data Set
Image Data Message	CCTV Center Control Server	Traffic Supervising/Control Server	Event Image Data Set
Weather Observation Message	Weather Sensor	Weather Monitor Server	Weather Monitoring Dataset
Bad Weather Input Message	Data Input Device	Traffic Event Data Server	Bad Weather Data Set
	Traffic Event Data Server	Traffic Information Server	Bad Weather Data Set
	Weather Monitor Server	Traffic Event Data Server	Bad Weather Data Set
Weather Observation Message	Weather Monitor Server	Traffic Event Data Server	Weather Monitoring Dataset
Construction Work Input Message	Data Input Device	Traffic Event Data Server	Construction Work Data Set
	Traffic Event Data Server	Traffic Information Server	Construction Work Data Set
Traffic Restriction Input Message	Data Input Device	Traffic Event Data Server	Traffic Restriction Data Set
	Traffic Event Data Server	Traffic Information Server	Traffic Restriction Data Set
Traffic Event Message	Traffic Supervising/Control Server	Traffic Event Data Server	Traffic Event Data Set
VMS Indication Message	Traffic Event Data Server	VMS Center Controller	VMS Indication Data Set
	Traffic Event Data Server	Traffic Information Server	VMS Indication Data Set
VMS Control Input Message	Data Input Device	VMS Center Controller	VMS Control Input Data Set
VMS Control Message	VMS Center Controller	VMS	VMS Control Data Set
CSS Control Input message	Data Input Device	VMS Center Controller	CSS Control Input Data Set
CSS Control message	VMS Center Controller	CSS	CSS Control Data Set

Source: ITS Integration Project (SAPI) Study Team

3.3 Primary Data Dictionary

Primary data dictionary for traffic information/control system is shown in the table below.

Figure 3.2 Primary Data Dictionary for Traffic Information/Control System

	Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin	Definition
1	Incident Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where an incident occurred (Jurisdiction of a Road Management Office)
		Lane ID	INT*	2	1			An unique identifier of the lane where an incident occurred (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where an incident occurred (For information dissemination)
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where an incident occurred
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where an incident occurred
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Incident Status	INT*	2	1			Class of incident input referring to the video image: - 1: Traffic Accident - 2: Incident in Tunnel - 3: Reverse Driving - 4: Broken-down Vehicle - 5: Left Obstacle - 6: Natural Disaster - 7: Vandalism
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
2	Image Recognition Result Data Set <G - Image Processor >	Road Management Office ID	INT*	4	1	When an event occurs	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Image Recognition Result Status	INT*	2	1			Status analyzed by image recognition processor (Values are to be proposed by contractor including traffic accidents, breakdown vehicles, left obstacles, reverse driving, vandalism and natural disaster)
		Video Image Address	TXT	60	1			The network address of where the video image file is stored
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
3	Vehicle Detection Data Set <G - Vehicle Detector>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Cumulative Number of Vehicles	INT*	4	1			Cumulative number of vehicles detected by vehicle detector
		Vehicle Speed	FLOAT	5	N			Vehicle speed detected by vehicle detector (unit: km/h)
		Vehicle Length	FLOAT	4				Vehicle length detected by vehicle detector (unit: m)
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
4	Traffic Volume Data Set <G - Traffic Analysis Processor >	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Total Traffic Volume per Day	INT	5	1			Total traffic volume per day
		Large Vehicle Ratio	FLOAT	5	1			Percentage of large vehicles to the total number of vehicles
		Traffic Volume per Day of vehicle class 1	INT	5	1			Traffic volume per day vehicle class 1: Ordinary vehicle
		Traffic Volume per Day of vehicle class 2	INT	5	1			Traffic volume per day vehicle class 2: Large vehicle
		Traffic Volume per Day of vehicle class 3	INT	5	1			Traffic volume per day vehicle class 3: Trailer vehicle
		Traffic Volume per Day of vehicle class 4	INT	5	1			Traffic volume per day vehicle class 4: Reserved
		Traffic Volume per Day of vehicle class 5	INT	5	1			Traffic volume per day vehicle class 5: Reserved
		Total Traffic Volume per Hour	INT*	4	1			Total traffic volume in the latest one hour
		Large Vehicle Ratio	FLOAT	5	1			Percentage of large vehicles to the total number of vehicles
		Traffic Volume per Hour of vehicle class 1	INT*	4	1			Traffic volume in the latest one hour of vehicle class 1: Ordinary vehicle
		Traffic Volume per Hour of vehicle class 2	INT*	4	1			Traffic volume in the latest one hour of vehicle class 2: Large vehicle
		Traffic Volume per Hour of vehicle class 3	INT*	4	1			Traffic volume in the latest one hour of vehicle class 3: Trailer vehicle
		Traffic Volume per Hour of vehicle class 4	INT*	4	1			Traffic volume in the latest one hour of vehicle class 4: Reserved
		Traffic Volume per Hour of vehicle class 5	INT*	4	1			Traffic volume in the latest one hour of vehicle class 5: Reserved
		Total Traffic Volume per 15 minutes	INT*	3	1			Total traffic volume in the latest 3 sets of 5 minutes
		Traffic Volume per 15 minutes of vehicle class 1	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 1: Ordinary vehicle
		Traffic Volume per 15 minutes of vehicle class 2	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 2: Large vehicle
		Traffic Volume per 15 minutes of vehicle class 3	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 3: Trailer vehicle
		Traffic Volume per 15 minutes of vehicle class 4	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 4: Reserved
		Traffic Volume per 15 minutes of vehicle class 5	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 5: Reserved
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
5	Traffic Congestion Data Set <G -	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Cumulative Number of Vehicles	INT*	4	1			Cumulative number of vehicles detected by vehicle detector in the latest 3 sets of 5 minutes

	Traffic Analysis Processor >	Average Vehicle Speed	INT*	4	1			Average value of detected vehicle speed in the latest 3 sets of 5 minutes
		Traffic Congestion Status	INT*	2	1			Class of traffic congestion generated referring to the results - 1: Congestion on Trough Lanes 1 - 2: Congestion on Trough Lanes 2 - 3: Congestion on Trough Lanes 3 - 4: Crowdedness on Trough Lanes - 5: Congestion at Exit 1 - 6: Congestion at Exit 2 - 7: Congestion at Exit 3
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of vehicle queuing
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of vehicle queuing
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
6	Weather Monitoring Data Set <G - Weather Sensor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a weather monitoring device
		Precipitation	FLOAT	2	1			Accumulated precipitation during specific 5 minutes (unit: mm)
		Wind Speed	FLOAT	2	1			Average, minimum, and maximum observed wind speed during specific 5 minutes (unit: m/s)
		Visibility	FLOAT	2	1			Average, minimum, and maximum observed visibility during specific 5 minutes (unit: m)
		Temperature	FLOAT	2	1			Average, minimum, and maximum observed temperature during specific 5 minutes (unit: Celsius degree)
		Alarm Status of Precipitation	INT*	2	1			Alarm to be issued when specific level of precipitation aforementioned is detected
		Alarm Status of Wind Speed	INT*	2	1			Alarm to be issued when specific level of wind speed aforementioned is detected
		Alarm Status of Visibility	INT*	2	1			Alarm to be issued when specific level of visibility aforementioned is detected
		Alarm Status of Temperature	INT*	2	1			Alarm to be issued when specific level of temperature aforementioned is detected
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
7	Bad Weather Data Set <G - Weather Server>	Road Management Office ID	INT*	4	1	When a bad weather occurs	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a weather monitoring device
		Precipitation	FLOAT	2	1			Precipitation (converted from 10 min. data) measured by rain gauge. (unit: mm/h)
		Wind Speed	FLOAT	2	1			Wind speed (10 min. average) measured by wind sensor (unit: m/s)
		Visibility	FLOAT	2	1			Visibility (10 min. average) measured by visibility sensor (unit: m)
		Temperature	FLOAT	2	1			Temperature (10 min. average) measured by thermometer (unit: Celsius degree)
		Heavy Rain Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of heavy rain in traffic event class: - 1: Heavy Rain 1 - 2: Heavy Rain 2 - 3: Heavy Rain 3
		High Wind Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of high wind in traffic event class: - 1: High Wind 1 - 2: High Wind 2 - 3: High Wind 3
		Low Visibility Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of lowering of visibility in traffic event class: - 1: Dense Fog 1 - 2: Dense Fog 2 - 3: Dense Fog 3
		High Temperature Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of high temperature in traffic event class: - 1: High Temperature
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
8	Construction Work Data Set <I - Server>	Road Management Office ID	INT*	4	1	When a construction work is scheduled	1 month after end of construction	An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where a construction work applied (Jurisdiction of a Road Management Office)
		Lane ID	INT*	2	1			An unique identifier of the lane where a construction work applied (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where a construction work applied (For information dissemination)
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where a construction work applied
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where a construction work applied
		Construction Work Status	INT*	2	1			Status of construction work: - 1: Scheduled - 2: Under construction - 3: Finished
		Number of document	TXT	20	1			Official number of permission document
		Permission Date	TXT	8	1			The date (Day/month/year) of permission of construction work
		Date/Time Begin	TXT	≥14	1			The begin time (Day/month/year/hour/minutes/second) of construction work
		Date/Time End	TXT	≥14	1			The end time (Day/month/year/hour/minutes/second) of construction work
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
9	Traffic Restriction Data Set <I -	Road Management Office ID	INT*	4	1	When an event occurs	1 month after end of restrictio	An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where a construction work applied (Jurisdiction of a Road Management Office)

	Server>	Lane ID	INT*	2	1		n	An unique identifier of the lane where a construction work applied (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where a construction work applied (For information dissemination)
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where a traffic restriction applied
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where a traffic restriction applied
		Construction Work Status	INT*	2	1			Status of construction work: - 1: Scheduled - 2: Under construction - 3: Finished
		Permission Date	TXT	8	1			The date (Day/month/year) of permission of traffic restriction
		Date/Time Begin	TXT	≥14	1			The begin time (Day/month/year/hour/minutes/second) of traffic restriction
		Date/Time End	TXT	≥14	1			The end time (Day/month/year/hour/minutes/second) of traffic restriction
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
10	Traffic Event Data Set <G/C - Server>	Traffic Event Data ID	INT	8	1	When an event occurs	1 year	An unique identifier of the traffic event data
		Road Management Office ID	INT*	4	1			An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where a traffic event occurred (Jurisdiction of a Road Management Office)
		Road Link ID	INT*	4	1			An unique identifier of a segmentation of road network divided by diverging/ merging points at interchanges/ junctions or barrier tollgates
		Lane ID	INT*	2	1			An unique identifier of the lane where a traffic event occurred (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where a traffic event occurred (For information dissemination)
		Traffic Event Category ID	INT*	4	1			An unique identifier of traffic event data category: - 1: Special Event - 2: Incident - 3: Construction Work - 4: Bad Weather - 5: Traffic Congestion - 6: Traffic - 7: Restriction
		Traffic Event Class ID	INT*	4	1			An unique identifier of traffic event data class 01: Special Event 19: High Temperature 02: Traffic Accident 20: Congestion on Trough Lanes 1 03: Incident in Tunnel 21: Congestion on Trough Lanes 2 04: Reverse Driving 22: Congestion on Trough Lanes 3 05: Broken-down Vehicle 23: Crowdedness on Trough Lanes 06: Left Obstacle 24: Congestion at Exit 1 07: Natural Disaster 25: Congestion at Exit 2 08: Vandalism 26: Congestion at Exit 3 09: Construction Work 27: Entry Closure 10: Heavy Rain 1 28: Closure 11: Heavy Rain 2 29: Exit Closure 12: Heavy Rain 3 30: Lane Closure 13: High Wind 1 31: Speed Limitation 1 14: High Wind 2 32: Speed Limitation 2 15: High Wind 3 16: Dense Fog 1 17: Dense Fog 2 18: Dense Fog 3
		Causal Traffic Event Data ID	INT	8	1			An unique identifier of the causal traffic event data
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where a traffic event occurred
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where a traffic event occurred
		Input Person	TXT	32	1			Name of the person who input traffic event data set
		Event Status	TXT	4	1			Status of traffic event
		Video Image address	TXT	60	1			The network address of where the Video image file is stored
		Main Center Check Status	INT*	4	1			Approval status by the main center: - 0: Not yet approved - 1: Approved
		Road Management Office Check Status	INT*	4	1			Approval status by the road management office: - 0: Not yet approved - 1: Approved
		Status of Traffic Event	INT*	2	1			Status of traffic event: - 1: Occurred and existing - 2: Removed
		Date/Time End	TXT	≥14	1			Day/month/year/hour/minutes/second of the traffic event input by operator
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
11	Event Image Data Set <G - Server>	Road Management Office ID	INT*	4	1	When an event is checked	1 year	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Place ID	INT*	4	1			An unique identifier of the place where the traffic event occurred (For information dissemination)
		Video Image ID	INT	8	1			An unique identifier of the video image
		Event Video Image	IMG	var	1			Video image data during time interval from 5 min before incident to 10 min after incident
		Traffic Event Data ID	INT	8	1			An unique identifier of the traffic event data
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
12	Integrated Data Sed <G - Server>	Date/Time	TXT	≥14	1	Every 1 hour	1 year	Date and time for the reference of a data set
		Road Section ID	INT*	4	1			An unique identifier for the reference of a data set (Jurisdiction of a Road Management Office)
		Kilometer Post	TXT	6	1			Kilometer post for the reference of a data set
		Lane ID	INT*	2	1			An unique identifier of the lane for the reference of a data set (Numbered from the median)

		Data Set ID	INT*	2	1			An unique identifier of the kind for the reference of a data set - 1: Incident Data Set - 2: Traffic Volume Data Set - 3: Traffic Congestion Data Set - 4: Bad Weather Data Set - 5: Construction Work Data Set - 6: Traffic Restriction Data Set - 7: Traffic Event Data Set - 8: Hourly Toll Collection Data Set - 9: Axle Load Management Data Set
		<u>Data Set</u>	Set	var	1			A data set corresponding to Date/time, Road Section ID, Kilometer Post, Lane ID and Data Set ID
13	VMS Check /Indication Data Set <G/C - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a VMS
		Traffic Event Class ID	INT*	4	1			An unique identifier of the traffic event class
		Place ID	INT*	4	1			An unique identifier of the place where a traffic event occurred (For information dissemination)
		Place Name	TXT	28	1			Name of the place where a traffic event occurred
		Traffic Event ID	INT	8	1			An unique identifier of the traffic event (including indication of "Under Repair")
		Traffic Event Name	TXT	20	1			Name of the traffic event occurred
		Causal Place ID	INT*	4	1			An unique identifier of the place where the causal traffic event occurred (For information dissemination)
		Causal Place Name	TXT	28	1			Name of the place where the causal traffic event occurred
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
14	VMS Input/Indication Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a VMS
		Traffic Event Class ID	INT*	4	1			An unique identifier of the traffic event class
		Place ID	INT*	4	1			An unique identifier of the place where a traffic event occurred (For information dissemination)
		Place Name	TXT	28	1			Name of the place where a traffic event occurred
		Traffic Event ID	INT	8	1			An unique identifier of the traffic event (including indication of "Under Repair")
		Traffic Event Name	TXT	20	1			Name of the traffic event occurred
		Causal Place ID	INT*	4	1			An unique identifier of the place where the causal traffic event occurred (For information dissemination)
		Causal Place Name	TXT	28	1			Name of the place where the causal traffic event occurred
		Free Text	TXT	var	1			The characters input using data input device
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
15	CSS Indication Data Set <G/C - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CSS
		Speed Limit	INT*	3	1			The limit speed input using data input device
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

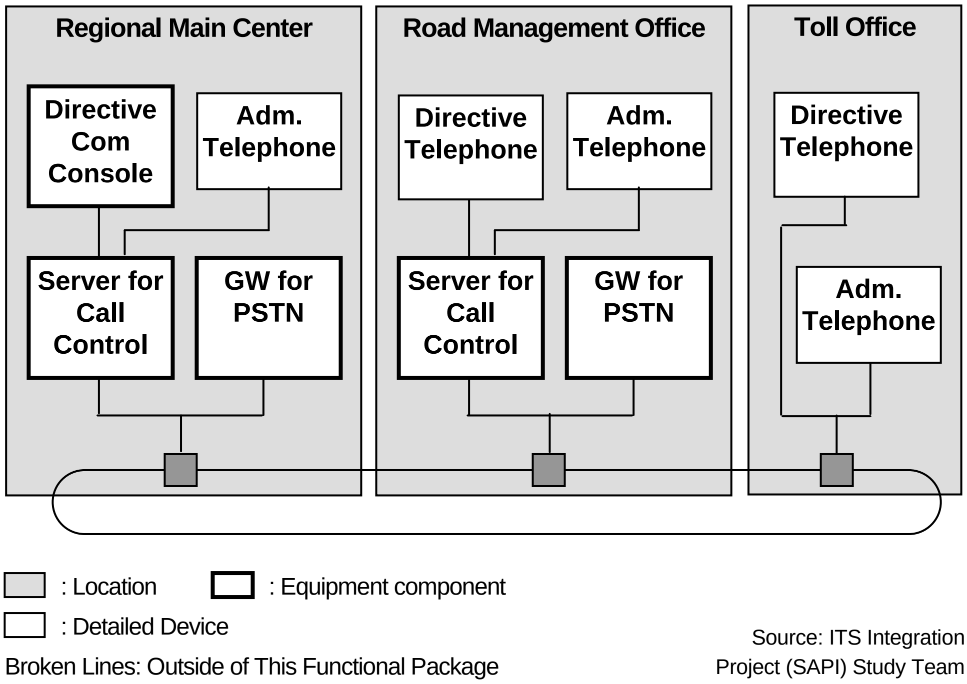
Source: ITS Integration Project (SAPI) Study Team

4. Voice Communication

4.1 Outline and System Architecture

This functional package allows connecting interactive voice communication among Regional Main Center, Road Management Offices, and Toll Offices, and allows sending directives to the units concerned simultaneously for clearing incidents and enforcing traffic restrictions. In addition, this functional package allows connecting PSTN.

Figure 4.1 System Architecture for Voice Communication



Source: ITS Integration Project (SAPI) Study Team

4.2 Required Function of Voice Communication

The communication network of ITS will be developed on the basis of Internet Protocol, therefore interactive voice communication will be realized with Voice over IP with in the ITS network.

In the planned voice communication, two types are recommended to introduce. The one is directive and the other is administrative telephone.

The directive is used for the communication under event occurrence and so on. The directive is made from Regional Main Center to all Road Management Offices and Toll Offices simultaneously or used from Regional Main Center to concerned Road Management Offices and Toll Offices simultaneously. The directive communication should be connected 100% whenever required without calling loss.

In Regional Main Center, the Directive Communication Console is required to install, and directive telephone set is required to install for all Road Management Offices and Toll Offices. The detailed number of telephone set is to be mention later.

As for the administrative telephone, it is used for normal expressway operation and maintenance business activities, and it is realized to connect among Regional Main Center, Road Management Offices, Toll Offices, and Public Switched Telephone Network (PSTN). For the administrative telephone, the calling loss is allowed. The detailed number of administrative telephone is also to be shown later.

The call control is made with Server for Call Control and connection with PSTN is realized with Gateway for PSTN.

The Server for Call Control should equip the function of registrar, proxy server and redirect server. The Server is also required to control Gateway for PSTN.

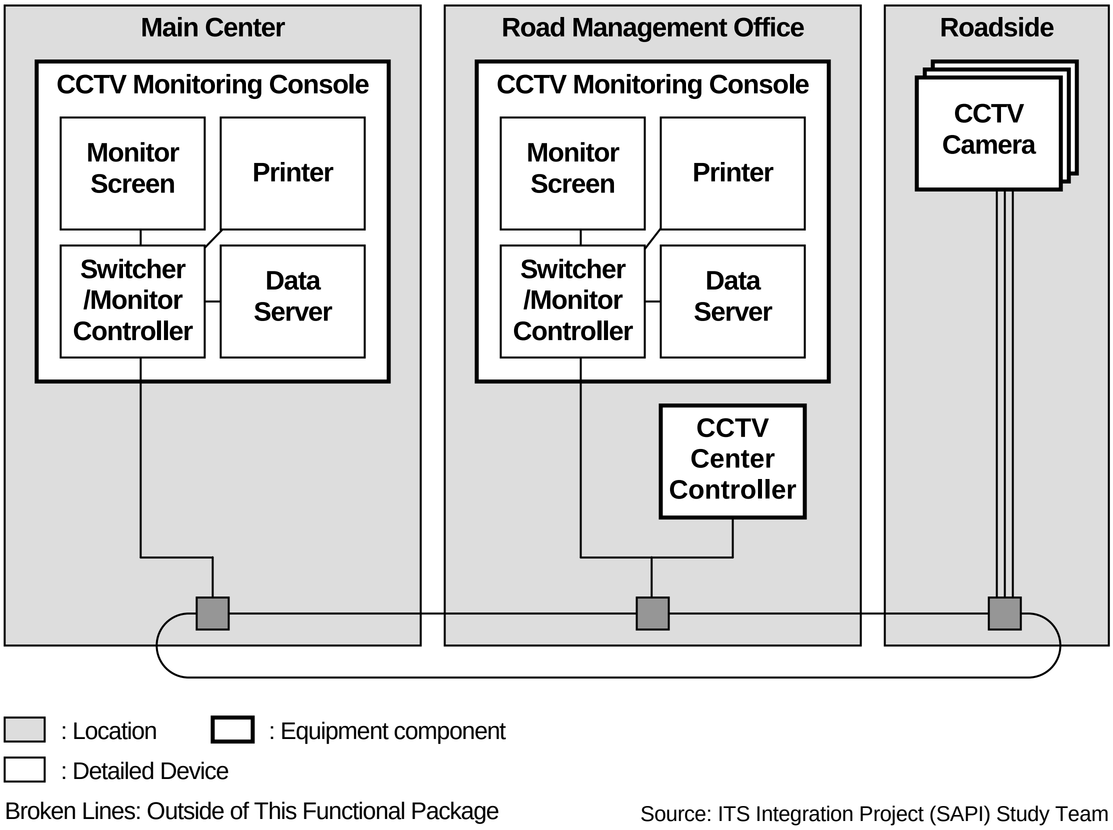
The Gateway for PSTN is required to convert voice packet which can be transmit in IP network, into voice traffic in PSTN which is encoded into digital signal, and vice versa. In addition, it is also required to convert call control signal in PSTN into call control signal in IP network, and vice versa, and it is required to interconnecting between administrative telephone in ITS network and telephone set in PSTN.

5. CCTV Monitoring

5.1 Outline and System Architecture

This functional package allows the road operators to capture current situation of traffic accidents, broken-down vehicles, left obstacles, driving in the reverse direction, vandalism, natural disaster and traffic conditions on the expressways and to monitor the captured video image at the Main Centers and road management offices by using cameras installed at road sections where traffic can be stuck easily after incidents and at long tunnel sections.

Figure 5.1 System Architecture for CCTV Monitoring



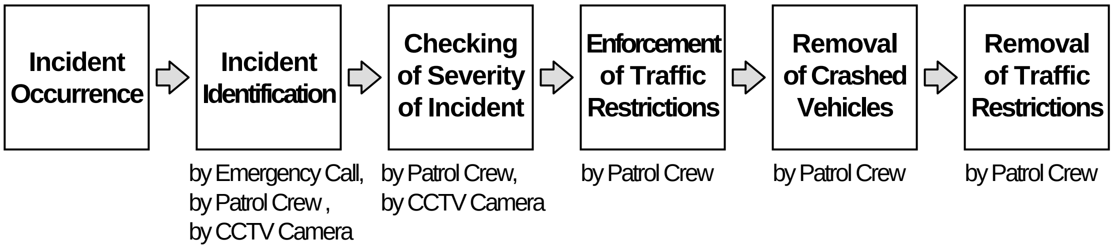
Source: ITS Integration Project (SAPI) Study Team

5.2 Traffic Event to be Monitored

CCTV camera can be used for various different purposes on the expressway; however, installed location and condition corresponding to the intended purpose. In this study, discussion on the usage of CCTV cameras focuses on incident identification.

Incidents are addressed generally by the procedure shown in the figure below.

Figure 5.2 Procedure of Addressing Incidents



by Emergency Call	X				
by Patrol Crew	X	X	X	X	X
by CCTV Camera	X	X			

Source: ITS Integration Project (SAPI) Study Team

As shown in the figure, CCTV cameras can be effective only for identifying incidents and checking severity of incidents. Enforcement/removal of traffic restrictions and removal of crashed vehicles must be done by patrol crews. Hence, even when CCTV cameras are installed on the expressway, sufficient number of crews and vehicles are necessary to address incidents.

5.3 Required Function/Performance of CCTV Camera

(1) Types of Camera

There are two types of CCTV camera: PTZ Type and Fixed Type. PTZ Type has the functions Panning, Tilting and Zooming. Fixed Camera does not have these functions.

In addition, sometime Fixed Type has zooming function but they do not have the capability of Tilting and Panning. Therefore, a focal point is one point only, which is not good for surveillance.

The following table shows an example of the Specification for Fixed Camera and PTZ Type.

Figure 5.3 Type of CCTV camera

Fixed camera   PTZ camera

Source: ITS Integration Project (SAPI) Study Team

PTZ Camera: The camera shall have mechanical capability of panning, tilting and zooming for focusing the objective of interest for traffic surveillance.

Fixed camera: The camera does "Not" have mechanical capability of panning and tilting for focusing the objective of interest for traffic surveillance.

(2) Mechanical Functions

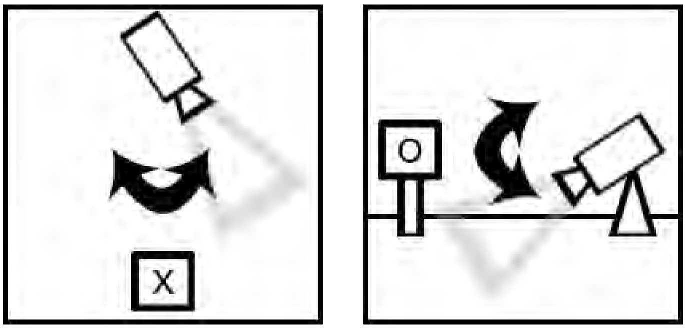
Panning:

Panning refers to the rotation in a horizontal plane of a video camera. Panning a camera results in a motion similar to that of someone shaking their head "no".

Tilting:

Tilting refers to the stationary and rotation in a vertical plane (or tilting plane). A rotation in a horizontal plane is known as panning. Tilting the camera results in a motion similar to someone nodding their head "yes".

Figure 5.4 Panning and Tilting



Panning function | Tilting function

Source: ITS Integration Project (SAPI) Study Team

Zooming:

Zoom adjusts the Angle of View. It is a magnification of image as a result. The function of zooming, there are two type of zoom such as Digital Zoom and Optical Zoom. For our purpose, digital zoom is not really zoom, in the strictest definition of the term. What digital zoom does is enlarge a portion of the image, thus 'simulating' optical zoom. In other words, the camera crops a portion of the image and then enlarges it back to size.

Against that, optical zoom is really zoom, It is capable a magnification of image by extend the focal length of between lens and image sensor. Optical zoom doesn't make a deterioration of images compare with Digital zoom.

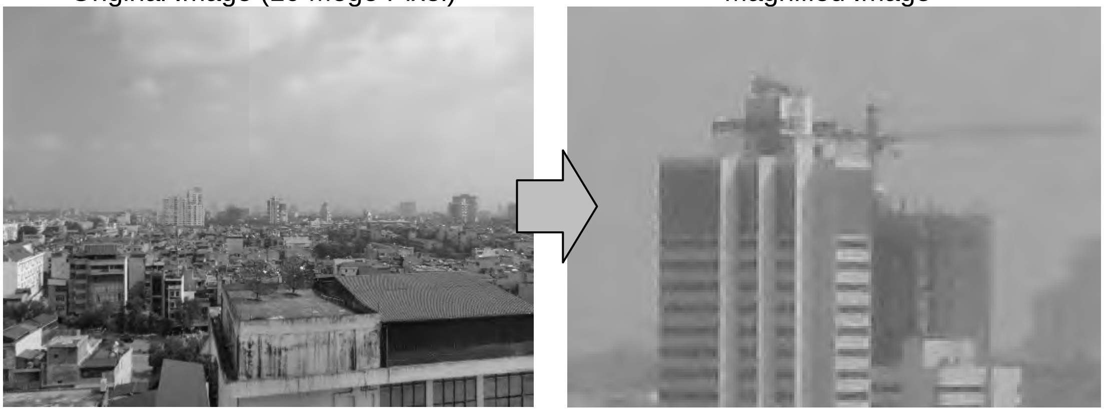
For example, see Figure 4.6. Upper stand, show the magnification of image (10 mega pixel) by using digital zoom function. Lower stand, show the magnification of image (1 mega pixel) by using optical zoom function.

Resolution of the original image is 10 mega pixels on Digital zoom whereas, resolution of the original image is 1 mega pixel on Optical zoom. Optical zoom image is 1/10 times the resolution however, the quality of the image after the magnification is more clear than Digital zoom.

Figure 5.5 Comparison of Digital Zoom and Optical Zoom

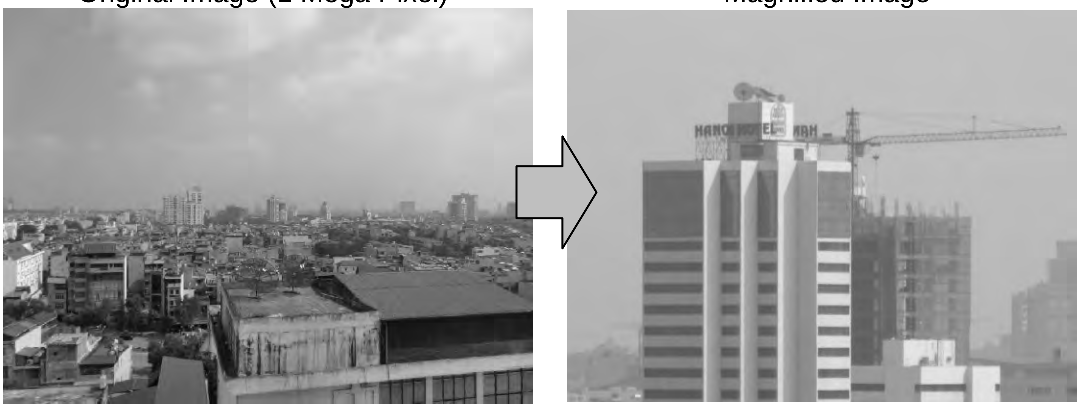
Digital zoom

Original Image (10 Mege Pixel) Magnified Image



Optical zoom

Original Image (1 Mega Pixel) Magnified Image



Source: ITS Integration Project (SAPI) Study Team

(3) Optical Functions/Performance

Width of image sensor :

There are two type of image sensor, such as CCD image sensor and CMOS sensor. Both types of sensor accomplish the same task of capturing light and converting it into electrical signals. In previous time, CCD image sensor was better than CMOS sensor. However, CMOS sensor is advance by means of technological innovation in today. CMOS sensor can potentially be implemented with use less power, faster reboot and cheaper than CCD. Therefore, most of CCTV camera are using CMOS sensor.

The meaning of the image Sensor are large, the camera has a larger area per 1pixel in case of the number of pixel is the same. Then, a larger amount of light to be received on 1pixel, collect the light efficiency is increased. Then, there are a lot of light coming into the image sensor, can be stayed on top of the subsequent of image processing, there will be less noise as a result. In other words, it is possible to record images of a more natural state.

Focal length of lens:

It is effect to surveillance range. The focal length of a lens determines the magnification at which it images distant objects. It is equal to the distance between the image plane and a pinhole that images distant objects the same size as the lens in question.

Resolution:

Resolution is the term used to describe the number of pixels, used to display an image. Higher resolutions mean that more pixels are used to create the image, resulting in a crisper, cleaner image. The number of pixel is to provide a more accurate figure for the resolution of the CCTV camera. Recently, the resolution is more than 1 mega pixel in general.

Minimum Illumination:

Minimum illumination is a way to measure the sensitivity of a camera. In another word It is mean, how dark the camera can still see usable image. There is the Day/Night function that colour video image at daytime, switch to black and white video image at night, to provide the best image automatically by determine the brightness of the day or night.

(4) Data and Interface

Encoding:

Encoding is a compression method of video images by using codec. There are several type of codec such as MPEG-2, MPEG-4, H.264 and so on. The quality the codec can achieve is heavily based on the compression format the codec uses. A codec is not a format, and there can be multiple codec that implement the same compression specification. For example, MPEG-1 codec typically do not achieve quality/size ratio comparable to codec that implement the more modern H.264 specification. But quality/size ratio of output produced by different implementations of the same specification can vary.

Frame rate:

Frame rate is the frequency at which an imaging device produces unique consecutive images called frames. Frame rate is most often expressed in frames per second (fps). In case of there are many more frames per second image becomes video image smoothly, as the data size of the video image becomes larger.

Ingress Protection:

The ingress protection or IP Code consists of the letters IP followed by two digits or one digit and one letter and an optional letter. As defined in international standard IEC 60529, IP Code classifies and rates the degrees of protection provided against the intrusion of solid objects, dust, accidental contact, and water in mechanical casings and with electrical enclosures.

CCTV camera shall be protected against dust and water ingress, where it will be installed outdoors in typical road section in accordance with IP66 of the international standards IEC 60529 or equivalent.

First Digit:

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.

Table 5.1 Meaning of First Digit in IPXX

Level	Object size protected against	Effective against
0	-	No protection against contact and ingress of objects
1	>50 mm	Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part
2	>12.5 mm	Fingers or similar objects
3	>2.5 mm	Tools, thick wires, etc.
4	>1 mm	Most wires, screws, etc.
5	Dust protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact
6	Dust tight	No ingress of dust; complete protection against contact

Source: ITS Integration Project (SAPI) Study Team

Second Digit:

Protection of the equipment inside the enclosure against harmful ingress of water.

Table 5.2 Meaning of Second Digit in IPXX

Level	Protected against	Details
0	Not protected	-
1	Dripping water	Test duration: 10 minutes Water equivalent to 1mm rainfall per minute
2	Dripping water when tilted up to 15°	Test duration: 10 minutes Water equivalent to 3mm rainfall per minute
3	Spraying water	Test duration: 5 minutes / Water volume: 0.7 litres per minute Pressure: 80–100 kN/m²
4	Splashing water	Test duration: 5 minutes / Water volume: 10 litres per minute Pressure: 80–100 kN/m²
5	Water jets	Test duration: at least 3 minutes Water volume: 12.5 litres per minute Pressure: 30 kN/m² at distance of 3m
6	Powerful water jets	Test duration: at least 3 minutes Water volume: 100 litres per minute Pressure: 100 kN/m² at distance of 3m
7	Immersion up to 1 m	Test duration: 30 minutes / Immersion at depth of 1m
8	Immersion beyond 1 m	Test duration: continuous immersion in water Depth specified by manufacturer

Source: ITS Integration Project (SAPI) Study Team

Interface:

Each device is assumed to be connected to Ethernet. The device is required to equip Ethernet interface. In addition, in order to streamline the piping and wiring of communication cable and power cable therefore, in order, the device is equipped the PoE (Power over Ethernet) what is power supply through the Ethernet cable. However, in case of the PTZ camera should be equipped a High PoE. It is capable supply a large amount of Power.

(5) Ambient Conditions and Others

Operating temperature / humidity range:

An operating temperature / humidity is the temperature / humidity at which an electrical or mechanical device operates. The device will operate effectively within a specified temperature / humidity range which varies based on the device function and application context, and ranges from the minimum to the maximum operating temperature / humidity.

Consumed power:

That is the amount of power consumed when the device is operating. Keeping the guideline value of the power consumption of the device on the specification, consideration to be required and ensured that electrical equipment does not exceed the electric capacity provided from the road side.

5.4 Range of Surveillance

(1) Basic Parameters/Values

Scope of View of CCTV cameras will be estimated based on the location and height of camera and objective of the monitoring. In the design, the monitoring range and the viewpoint will be calculated based on the case of monitoring through lane and diverging or merging point in ramp of interchanges.

In the case of installation at through lane, the installation interval is dependent on the specification of equipment and other conditions as follows;

Equipment Specifications:

- Size of the screen
- Width and height of image sensor of CCTV Camera
- Focal length of lens

Other conditions :

- Distance from the operator to the screen
- Eyesight of Operator
- Required monitor size of vehicle on the screen
- Height of camera installation, etc

Under ideal circumstances, the calculation results of Maximum Range of surveillance of each display size is shown in Table 4.3. The size of the display to show scenes all the time for each camera is about 20 inches (at least). When a more detailed check on the status is required, switch to a larger display of about 60 inches or more.

Table 5.3 Sample CCTV PTZ / Fixed Cameras specifications

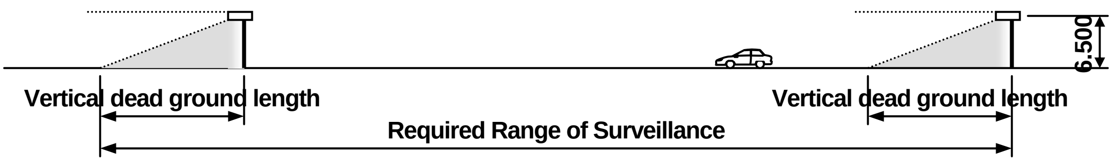
		PTZ Camera	Fixed Camera
Width of image sensor		4.8 mm (1/3" sensor)	4.8 mm (1/3" sensor)
Focal length of lens		4.7 – 84.6 mm	5.0 mm (3.1 – 10 mm (Manually adjustable))
Resolution		1.3 Mega Pixel	1.3 Mega Pixel
		1280 x 720 (16:9)	1280 x 720 (16:9)
Minimum Illumination		0.5 lx (Day mode, colour) 0.06 lx (Night mode, B/W)	0.3 lx (Day mode, colour) 0.05 lx (Night mode, B/W)
Panning		350 degrees	-
Tilting		120 degrees	-
Zooming		x10 optical	-
Maximum range of surveillance	without Zooming	192.52 m	204.81 m
	with Zooming	1,925.24 m *	-

The calculation is done on the following conditions :The aspect ratio of the screen is 0.5625 = 16:9 ; The width of CCD sensor is 4.8 mm (in case 1/3" CCD sensor) ; Display size is 60 inch, Distance from the operator to the screen is 5.0 m, Eyesight of Operator is 1.0 ; Required monitor size of vehicle on the screen is 10.7 mm
Note, * : it is in case of ideal condition, Not guaranteed.

Table 5.4 Calculation Results of Maximum Range of Surveillance

Size of Monitoring Screen	Required Horizontal Resolution	Focal Length of Lens (mm)	Maximum Range of Surveillance (m)
20 inches	166 lines	4.7	64.2
		5.0	68.3
		47.0 **	641.7 ****
		84.6 ***	1155.1 ****
30 inches	249 lines	4.7	96.3
		5.0	102.4
		47.0 **	962.6 ****
		84.6 ***	1732.7 ****
60 inches	498 lines	4.7	192.5
		5.0	204.8
		47.0 **	1925.2 ****
		84.6 ***	3465.4 ****
100 inches	830 lines	4.7	320.9
		5.0	341.4
		47.0 **	3208.7 ****
		84.6 ***	5775.7 ****

The calculation is done on the following conditions ;
The aspect ratio of the screen is 0.5625 = 16:9 ; The width of CCD sensor is 4.8 mm (in case 1/3" CCD sensor) ; Distance from the operator to the screen is 5.0 m ; Eyesight of Operator is 1.0 ; Required monitor size of vehicle on the screen is 10.7 mm
Note, ** : Focal length under 10 times zooming of 4.7 mm,
*** : Focal length under 18 times zooming of 4.7 mm.
**** : it is in case of ideal condition, Not guaranteed.



(2) Maximum Surveillance Range on Through Lanes

PTZ Camera

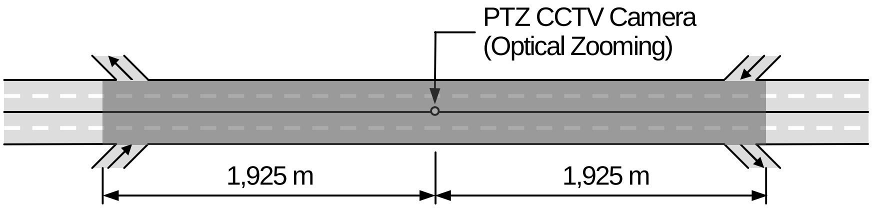
The CCTV camera shall provide image fineness by using a wide-angle lens to secure a sufficient depth of the field. For meeting this requirement, a maximum range of monitoring is calculated at 1,925 m by the following formula:

L=f x (V/V') x (B/0.9b)

Where b: the width of image sensor is 4.8(1/3-inch image sensor)
0.9: over-scanning ratio
V: the width of an actual vehicle is 1,500 mm
V': the width of the displayed vehicle is 10.6 mm, and
f: the focal length of lens of the CCTV camera is 47.0 mm

Installation of CCTV PTZ camera: The camera shall be installed attached on the median around the diverging point aimed at the travelling direction of the vehicles. The maximum of surveillance of the CCTV camera is calculated at 1,925 m.

Figure 5.6 Maximum surveillance range of PTZ Camera (Hypothetical Monitoring range)



Source: ITS Integration Project (SAPI) Study Team

Fixed Camera

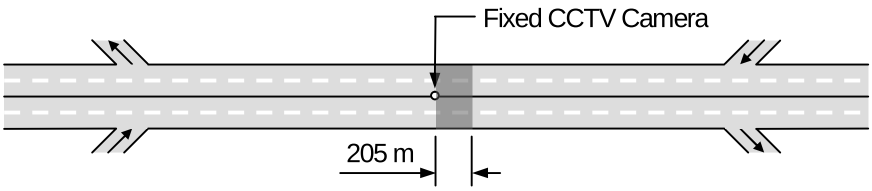
The CCTV camera shall provide image fineness by using a wide-angle lens to secure a sufficient depth of the field. For meeting this requirement, a maximum range of monitoring is calculated at 205 m by the following formula:

L=f x (V/V') x (B/0.9b)

Where b: the width of image sensor is 4.8(1/3-inch image sensor)
0.9: over-scanning ratio
V: the width of an actual vehicle is 1,500 mm
V': the width of the displayed vehicle is 10.6 mm, and
f: the focal length of lens of the CCTV camera is 5.0 mm

Installation of CCTV Fixed camera: The camera shall be installed attached on the median around the diverging point aimed at the travelling direction of the vehicles. The maximum of surveillance of the CCTV camera is calculated at 205 m.

Figure 5.7 Maximum surveillance range of Fixed Camera (Hypothetical Monitoring range)



Source: ITS Integration Project (SAPI) Study Team

(3) Maximum Surveillance Range on Ramp

Fixed Camera

The CCTV camera shall provide image fineness by using a wide-angle lens to secure a sufficient depth of the field. For meeting this requirement, a maximum range of monitoring is calculated at 205 m by the following formula:

L=f x (V/V') x (B/0.9b)

Where b: the width of image sensor is 4.8(1/3-inch image sensor)

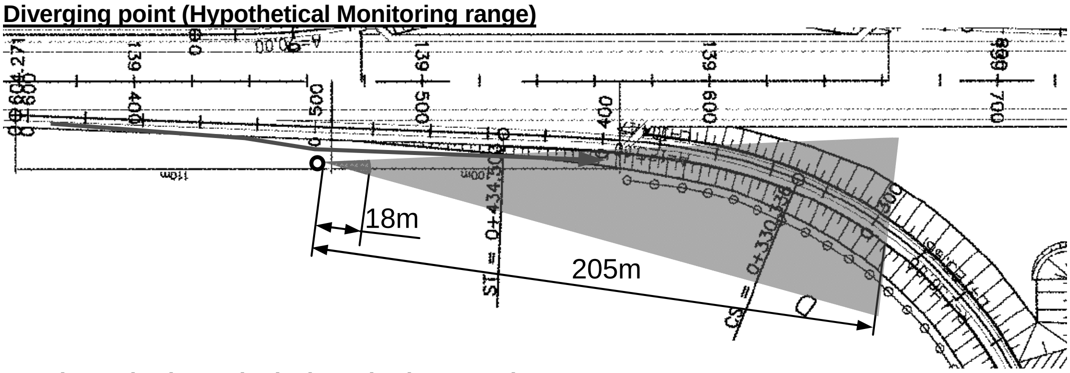
- 0.9: over-scanning ratio
- V: the width of an actual vehicle is 1,500 mm
- V': the width of the displayed vehicle is 10.6 mm, and
- f: the focal length of lens of the CCTV camera is 5.0 mm

Installation of CCTV Fixed camera: The camera shall be installed attached on the median around the diverging point aimed at the travelling direction of the vehicles. The maximum of surveillance of the CCTV camera is calculated at 205 m.

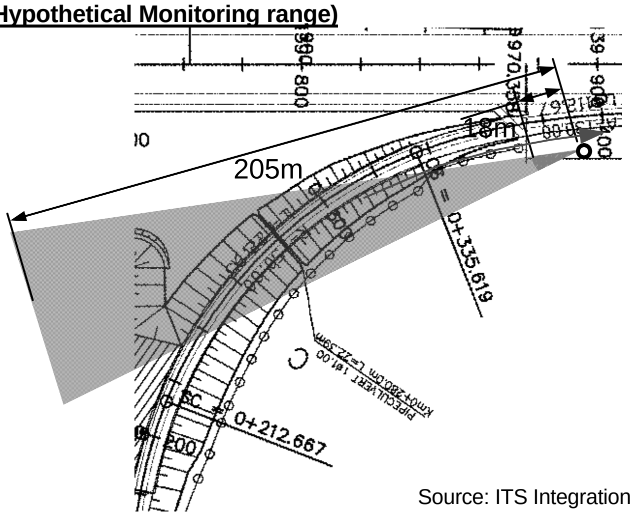
In the design, the monitoring range is assumed as shown in Figure 4.5. CCTV camera will be installed on the roadside for monitoring the ramp of interchanges.

Figure 5.8 Maximum surveillance range of Fixed Camera in an ideal condition

Diverging point (Hypothetical Monitoring range)



Merging point (Hypothetical Monitoring range)

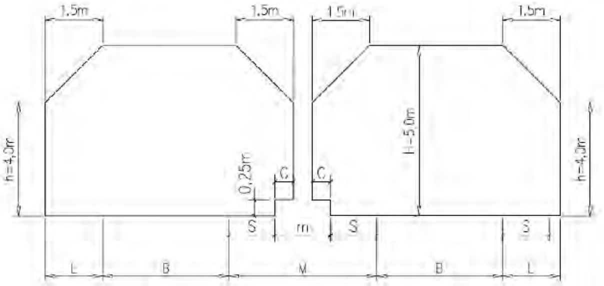


Source: ITS Integration Project (SAPI) Study Team

5.5 Installation Height/Angle of CCTV Camera

The height of CCTV camera, PTZ camera should be installed 6-7m above ground level. It is consider about the vertical clearance limit of road (H=5.0m), and make a margin 1.0m from the clearance. Fixed camera should be installed 7-8m above ground level. It is consider that sometimes Fixed camera and PTZ camera are attached the same pole therefore, ,make a margin 1.0m from the height of PTZ camera installation.

Figure 5.9 Clearance limit of Expressway



Source: TCVN5729 Expressway Standard Design

Figure 5.10 Height of CCTV camera

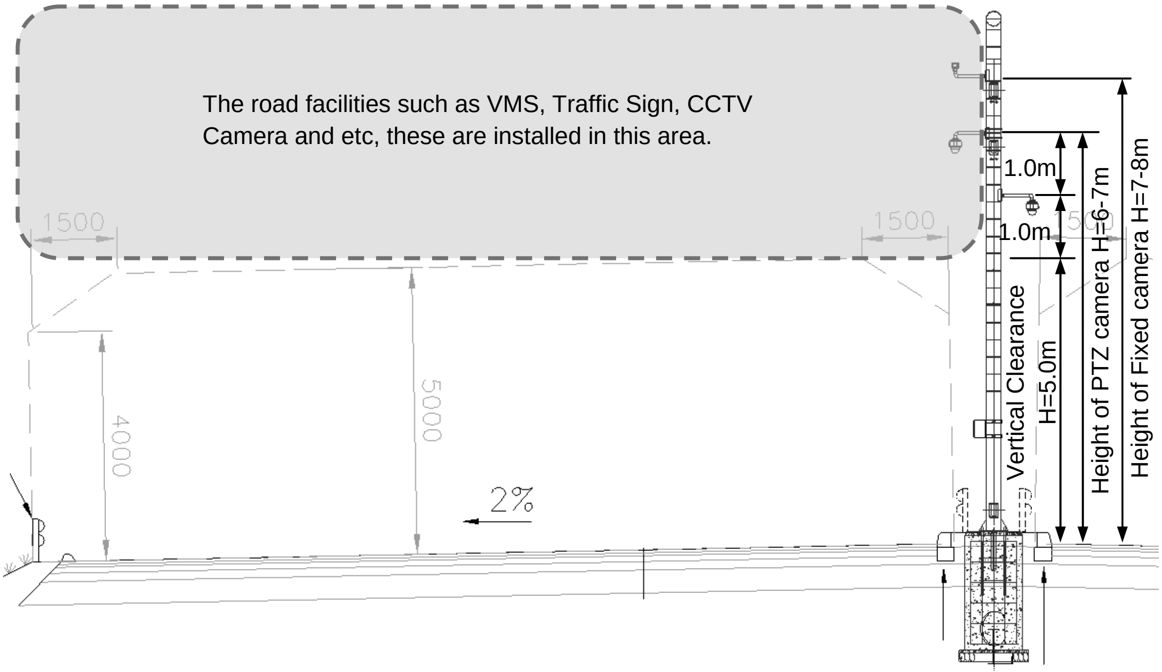


Table 5.5 Height of CCTV Camra

Type of Camera	Height
PTZ Camera	6-7m above Ground level
Fixed Camera	7-8m above Ground level

Source: ITS Integration Project (SAPI) Study Team

Field of view of PTZ camera is interrupted by mounting pole as shown Figure 5.11. For example, PTZ camera is located at median, the interrupted width of view is 5,229mm in case of width of one side road is 11,500mm. Also, the interrupted width of view is 8,014mm in case of width of road is 18,000mm. Additionally, Light pole are located continuously, the poles are become the interruption to field of view as shown Figure 5.12.

Therefore, PTZ camera shall be located two cameras for both sides at the location as shown Figure 5.13.

Figure 5.11 Disrupting by Mounting Pole

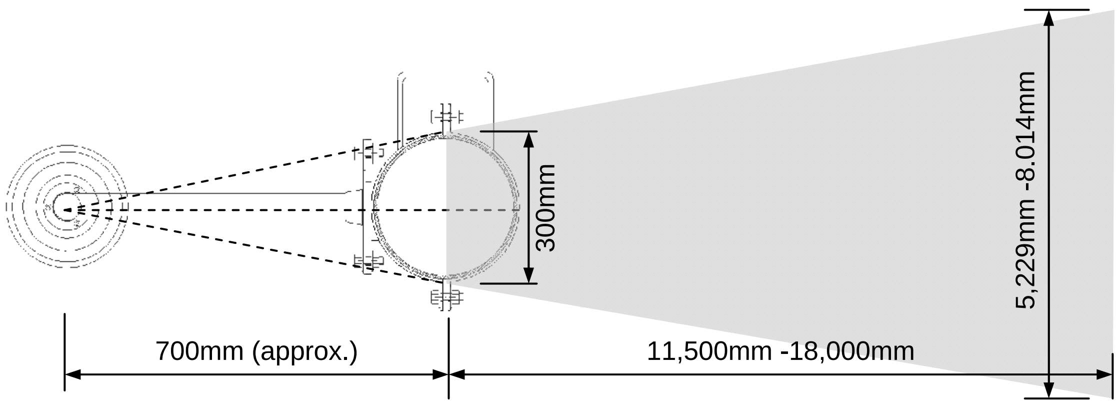


Figure 5.12 Disrupting by Lighting pole

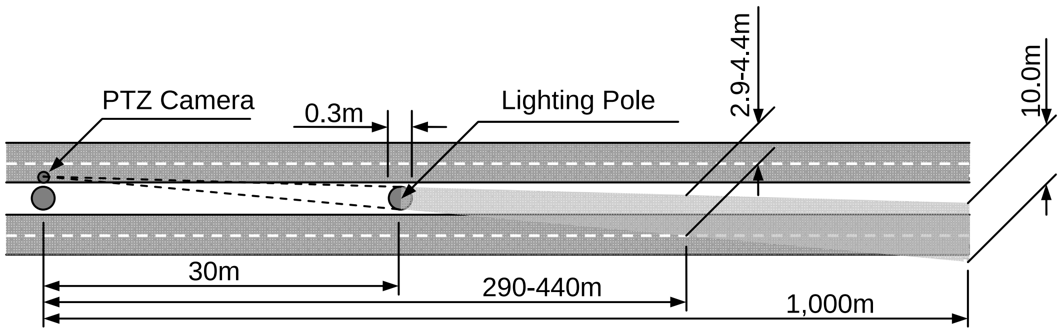
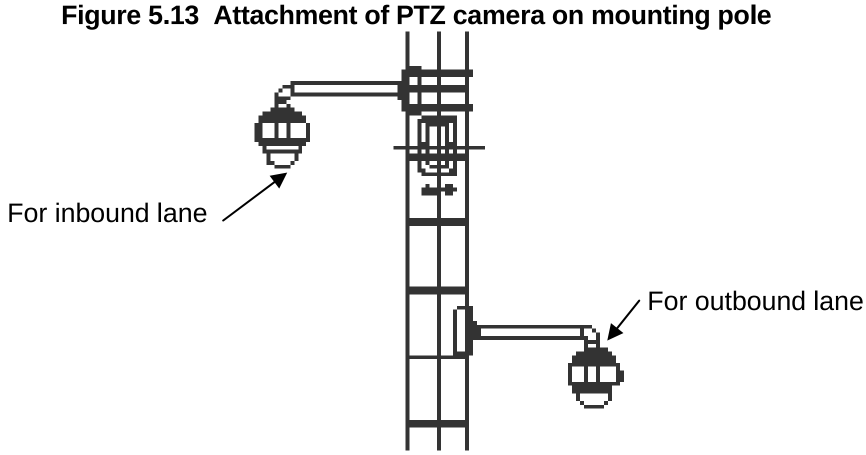


Figure 5.13 Attachment of PTZ camera on mounting pole



Source: ITS Integration Project (SAPI) Study Team

5.6 Location of CCTV Camera

(1) Basic Policy

Perform study of operation / monitoring of CCTV Cameras, assuming monitoring the camera image is done at the Regional Main Center or at the Road Management Office.

Have CCTV cameras set up every 2 km on the road section length of 80 km, so the number of cameras will be 40 units in case of ideal condition. Also have many cameras installed in Interchanges and Junctions.

Have PTZ camera complete with Zooming, Tilting and Panning functions for efficient monitoring.

In actual situations, exhaustive monitoring observations will be made without using PTZ functions, since continuous monitoring by the operator is already complex.

Without Zooming function, the maximum range of surveillance is 192.5 m with 4.7 mm lens, or 204.8 m with a 5.0 mm lens (using a 60-inch display). Thus, for approx. 1,800 m distances, it is not able to always observed, in case of installing the camera for every 2 km.

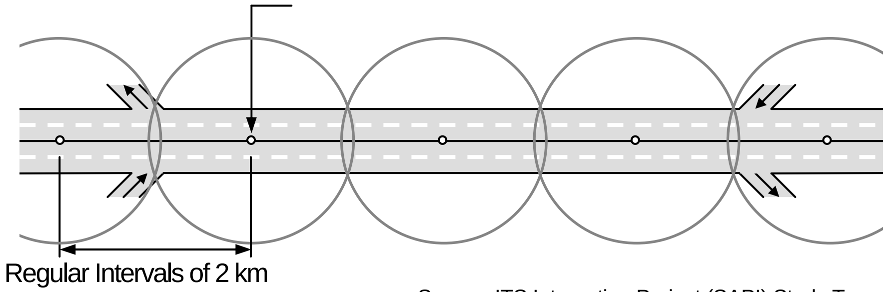
Therefore, the operation / monitoring by CCTV cameras are not constant in the event something occurs, and confirmation will usually be based on incidence reports from drivers and operators.

Hence, in camera location design of our study, to identify the occurrence of incidents reported by telephone, and to identify the severity of incidents by CCTV cameras at any place on the expressway.

(2) Location of CCTV Camera on Through Lanes

CCTV cameras need to be installed continuously along the expressway and are to be utilized only for identifying the severity of incidents through manual panning/zooming of camera. As shown in the foregoing table, if alignment of the expressway can be assumed as completely straight, 2 km spacing between two cameras can perform monitoring using 20-inch display by combination of panning/zooming of camera. If 50-inch display can be used, 2 km spacing can be covered only by zooming.

Figure 5.14 Normal Range of CCTV Camera along the Expressway

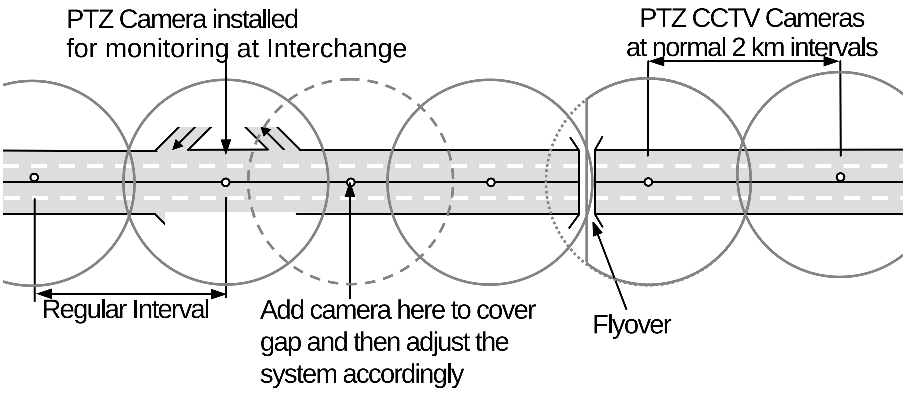


Source: ITS Integration Project (SAPI) Study Team

However, in consideration of the actual installation intervals, it is necessary to consider if there are things disrupting the surveillance view of the camera. For example, a physical condition such as longitudinal gradient of road, horizontal alignment of road, flyover bridge and so on.

For example, see Figure 8.6, if there is an Interchange requiring the camera to be installed at its center or if there is a Flyover, then CCTV camera range of surveillance would be insufficient. To solve this situation, another camera should be installed to cover the gap.

Figure 5.15 Adjust CCTV Camera Installation based on actual conditions



Source: ITS Integration Project (SAPI) Study Team

Additionally, taking images of distant objects is technically possible by using CCTV camera in case of ideal condition. However, there are many interferences in real condition, such as hard rain, dust, heat haze, damp haze, fog and so on.

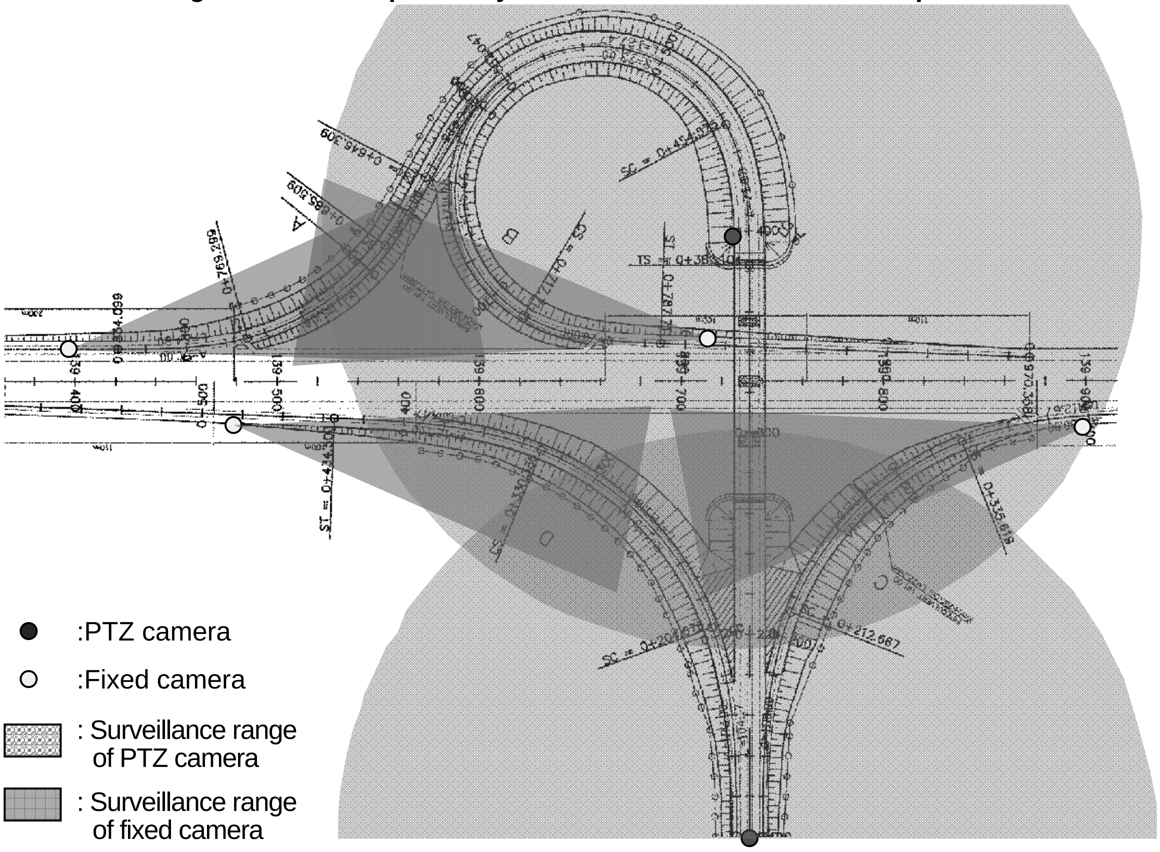
(3) Location of CCTV Camera on Ramp

At the ramp of Interchanges and Junctions, there is a relatively high probability of incident occurrence (such as traffic accidents). The incidents often occur at ramps due to congestion since the ramp has only one lane.

Therefore, CCTV cameras should be installed at the merging and diverging points of Interchanges and Junctions for observation of road traffic.

In addition, there are two types of camera such as Fixed and PTZ Camera. To the consideration as to which camera is capable for observation at ramp of Interchange and Junction. The surveillance range is significant differences in PTZ and Fixed camera as shown figure as follows.

Figure 5.16 Example of Layout for CCTV Camera on the ramp

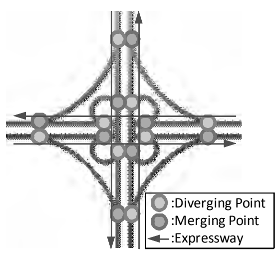
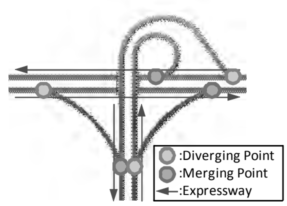


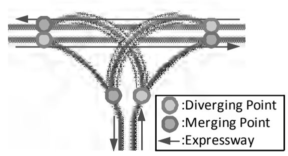
Source: ITS Integration Project (SAPI) Study Team

(4) Location of CCTV Camera around Interchange/Junction

Locate a CCTV camera (Fixed type) at each ramp of Junctions.

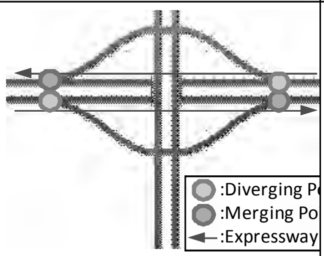
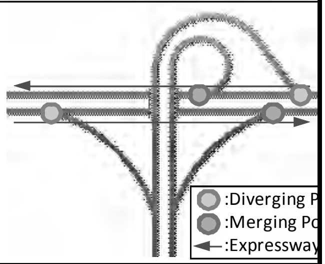
Table 5.6 Location of CCTV Cameras around Interchange/Junction (1)

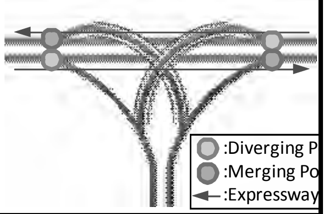
	Junction Type	
	Cloverleaf	Trumpet
		
CCTV Camera (Fixed Type)	16	6

	Junction Type
	Directional T
	
CCTV Camera (Fixed Type)	6

Source: ITS Integration Project (SAPI) Study Team

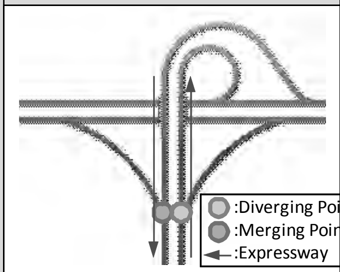
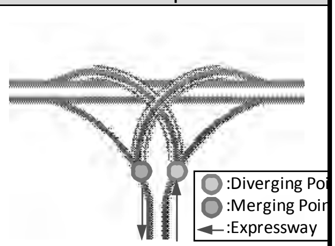
Table 5.7 Location of CCTV Cameras around Interchange/Junction (2)

	Interchange Type	
	Diamond	Trumpet
		
CCTV Camera (Fixed Type)	4	4

	Interchange Type
	Directional T
	
CCTV Camera(Fixed Type)	4

Source: ITS Integration Project (SAPI) Study Team

Table 5.8 Location of CCTV Cameras around Interchange/Junction (3)

	Interchange Type (Starting/Ending Point)	
	Diamond	Trumpet
		
CCTV Camera (Fixed Type)	2	2

Source: ITS Integration Project (SAPI) Study Team

5.7 Display for CCTV Monitoring at Regional Main Center

(1) Human Machine Interfaces

Video images for traffic surveillance shall be taken by CCTV cameras controlled by the operator using a camera control console in the Main Center. These video images shall be put up on the displays selected automatically or manually in turn by using a monitor console which shall be capable control NVR (Network Video Recorder), and shall be capable being put up on other man-machine displays. The video images shall be monitored also in the road management office and put up on the displays selected manually in turn by using a monitor console at road management office.

Recommended size of monitor screen shall be (approx.) 20 inches or over. All camera images shall be capable of being displayed on Monitor Screen for the operating staff to monitor the traffic conditions.

However, there may be some issues as follows:

- The space of monitoring room may not be sufficient to house all necessary monitor screens
- The number of operators may not be enough for monitoring all CCTV images displayed on Monitor Screens

Therefore, number of monitors should be considered as follows:

- Multi images shall be separately displayed on the same Monitor Screen
- Images of different cameras shall be displayed on the same Monitor Screen in defined rotating interval

(2) Video Data

Since the CCTV camera's picture is standardized by International Standard such as Mpeg 2 and Mpeg 4, shared usage of equipment from different manufacturers is possible.

Especially, since most commercially available IP cameras have video image output based on MPEG-4, the introduction of CCTV cameras complying with ISO/IEC 14496-2 is recommended.

(3) Camera Control Signal

Regarding the control protocol of CCTV camera functions such as zooming, panning, tilting, the following three standards (ONVIF, PSIA, SIA Standards committee) are in competition with each other. At present, there is no one International Standard. They are all discussed below.

Therefore, the CCTV camera can be controlled by the method which is shown in section 2.6 Transmission Design for the time being.

ONVIF: Leaders are Axis, Bosch and Sony; they seem motivated to protect the interests of the largest selling camera manufactures

PSIA: Leader is Cisco and supported by a half dozen camera manufacturers; they seem motivated to protect the interests of manufacturers with lower IP camera market share

SIA Standards Committee:, this committee, the oldest of the three, has actually published standards and looks to be the least political (though not an industry alliance like PSIA and ONVIF, SIA could be the organization that eventually manages the process of standardizing the winning specification)

(4) Transmission Design

The establishment of three Main Centers is considered: one in Hanoi for the northern area, one in Danang for the central area, and one in Ho Chi Minh city for the southern area. In case of monitoring roads using CCTV cameras in Main Center, there are some possible issues regarding transmission as follows;

Potential Issues

- If all the Video images from CCTV installed within the area are observed in the Main Center at the same time, the volume of communication online would be excessive
- It is being contemplated that a different manufacturer's CCTV is installed by each road operators for competition. There is no International Standard for Protocol of controlling CCTV functions including Zooming, panning, tilting, it is difficult to control all CCTVs installed within the Main Center Area

Potential Solutions

NVR (Network Video Recorder) is one possible solution. NVR is an internet protocol-based device that sits on network. Because it is IP based, NVR can be managed remotely via LAN or over the Internet giving the user greater flexibility. The basic function of an NVR is the simultaneous recording and remote access of live video streams from IP camera. NVR will feature flexible recording and playback capability, an intuitive remote control unit, a user-friendly GUI, intelligent motion detection, and Panning-Tilting-Zooming camera control.

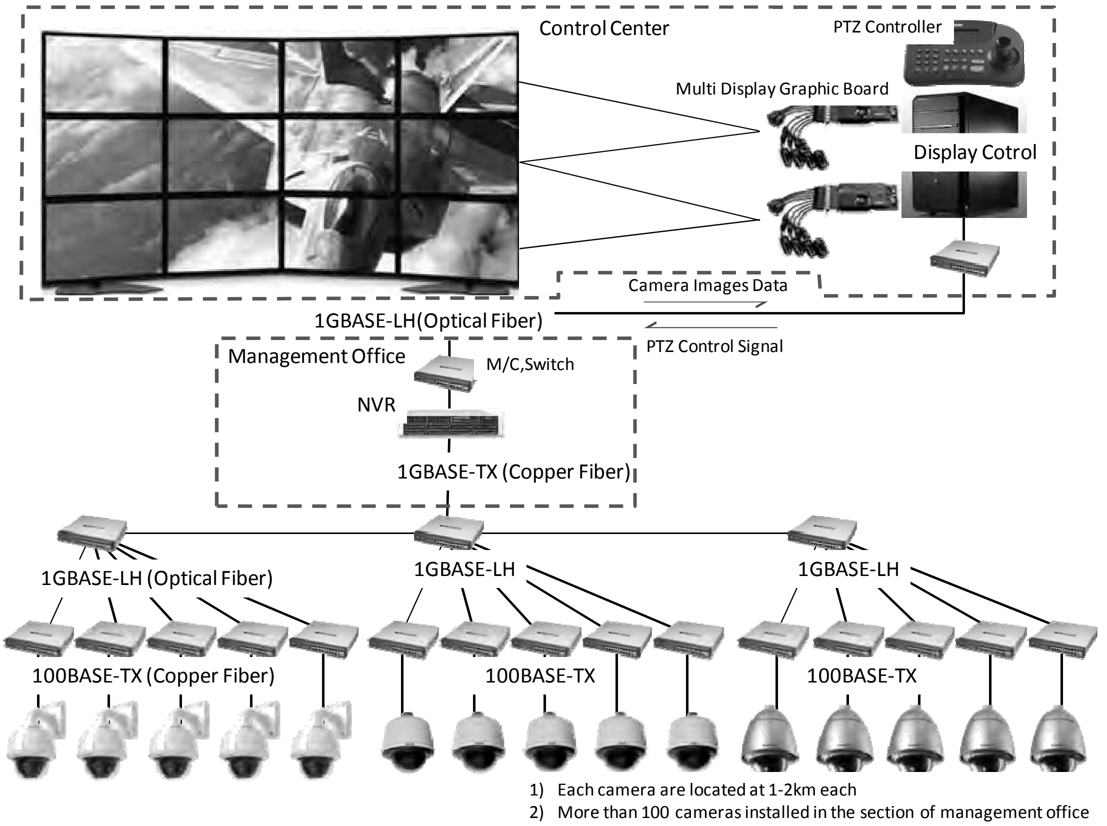
Therefore, by installing one NVR in each interval between Interchanges (or between administrative areas of road operator), the observation of NVR video image from the Main Center and the control of functions such as Panning-Tilting-Zooming are possible. In this case, it is crucial to secure the interoperability of CCTV controlled by different NVRs. (refer to Figure 9.6)

5.8 Display for CCTV Monitoring at Road Management Office

Console equipment is needed for traffic management at Road Management Office. It is implemented for each function of traffic management such as CCTV monitoring, Traffic event management. Normally, the monitoring is not needed at Road Management Office however, it is needed when the incident occur such as traffic accident, disaster, vandalization as so on.

Especially for CCTV monitoring, the console is needed for monitor and PTZ control. At least 2 consoles to be installed for the multiple monitoring and PTZ control at the same time. Additionally, multi display is optional for the monitoring at Road Management Office.

Figure 5.17 Relation of Main Center and NVR on Network

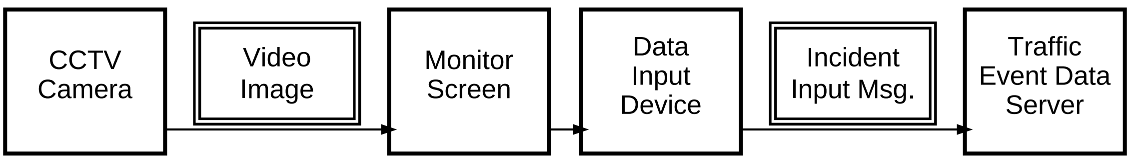


Source: ITS Integration Project (SAPI) Study Team

5.9 Data Set for CCTV Image

Major Message Exchanges for generating incident data is shown in the following figure.

Figure 5.18 Major Message Exchanges for Generating Incident Data



Source: ITS Integration Project (SAPI) Study Team

1) Video Data

Since the CCTV camera's picture is standardized by International Standard such as Mpeg 2, Mpeg 4, the shared usage of equipment by different manufacturers is possible.

Especially, since most of commercial available IP cameras have video image output based on MPEG-4, the introduction of CCTV cameras complying with ISO/IEC 14496-2 is recommended.

2) Camera Control Signal

Regarding the control protocol of CCTV camera functions such as zooming, panning, tilting, the following 3 standards (ONVIF, PSIA, SIA Standards committee) are in competition with each other. Therefore, at the present stage, it hasn't been standardized by International Standard.

Therefore, the CCTV camera can be controlled by the method which is shown in 2.6 Transmission Design for the time being.

ONVIF: Lead by Axis, Bosch and Sony, they seem motivated to protect the interests of the largest selling camera manufactures

PSIA: Lead by Cisco and supported by a half dozen camera manufacturers, they seem motivated to protect the interests of manufacturers with lower IP camera market share

SIA Standards Committee: the oldest of the 3, this committee has actually published standards and looks to be the least political (though not an industry alliance like PSIA and ONVIF, SIA could be the organization that eventually manages the process of standardizing the winning specification)

3) Incident Data Input

Referring to video image indicated on the monitor screen, a message for generating incident data is to be input by an operator to the traffic event data server.

Table 5.9 Data Set/Elements in Event Input Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Incident Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Roadside Equipment ID	INT*	4	1		
	Incident Status	INT*	2	1		
	Date/Time	Datetime	≥14	1		
Event Image Data Set <G - Server>	Road Management Office ID	INT*	4	1	When an event is checked	1 year
	Roadside Equipment ID	INT*	4	1		
	Place ID	INT*	4	1		
	Video Image ID	INT	8	1		
	Event Video Image	IMG	var	1		
	Traffic Event Data ID	INT	8	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

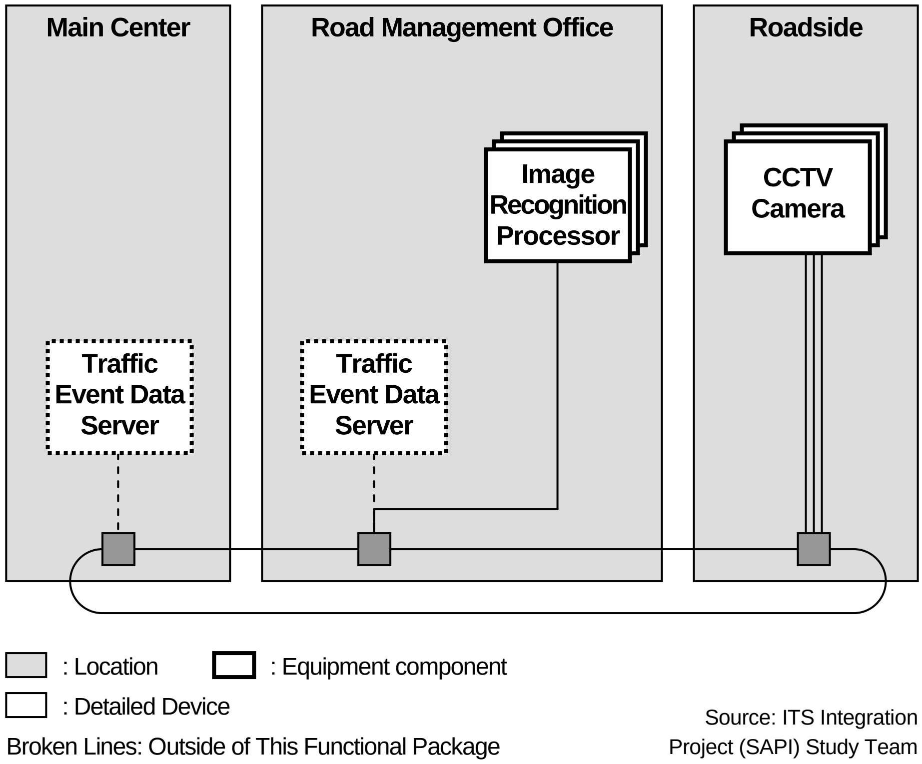
Source: ITS Integration Project (SAPI) Study Team

6. Event Detection (by Image)

6.1 Outline and System Architecture

notification to the Regional Main Centres and road management offices by analyzing video images from cameras installed at bottleneck spots where traffic can be easily stuck and at long tunnel sections.

Figure 6.1 System Architecture for Event Detection



Source: ITS Integration Project (SAPI) Study Team

6.2 Traffic Event to be Detected

Event detection equipment is capable of automatically detecting the occurrence of an accident, a broken vehicle or a falling object and give notice to Regional Main Centre and Road Management Office by analyzing pictures taken by cameras which are installed in road side. At the ramp of Interchanges and Junctions, there is a relatively high probability of incident occurrence (such as broken down vehicle, traffic accidents). The incidents often occur at ramps due to congestion since the ramp has only one lane.

Therefore, CCTV cameras should be installed at the merging and diverging points of Interchanges and Junctions with Event detection. Then, shall be capable detection Stopped Vehicle, Wrong-way Vehicle and Speed drop vehicle.

Therefore, CCTV cameras should be installed at the merging and diverging points of Interchanges and Junctions with Event detection. Then, shall be capable detection Stopped Vehicle, Wrong-way Vehicle and Speed drop vehicle.

6.3 Detection Algorithm by Image Recognition

There are multi-categories of analyzing image system. Analyzing image system on highway requires vehicle detection position on the road, and the system requires that the vehicle identification technique shows a suitable image. Image analysis techniques for the last 10 years have met with difficulties in analyzing when having both vehicle and motorcycle objects move on one screen in many different ways. However, with present analysis technique, there is improved accuracy when analyzing image and for many vehicle types.

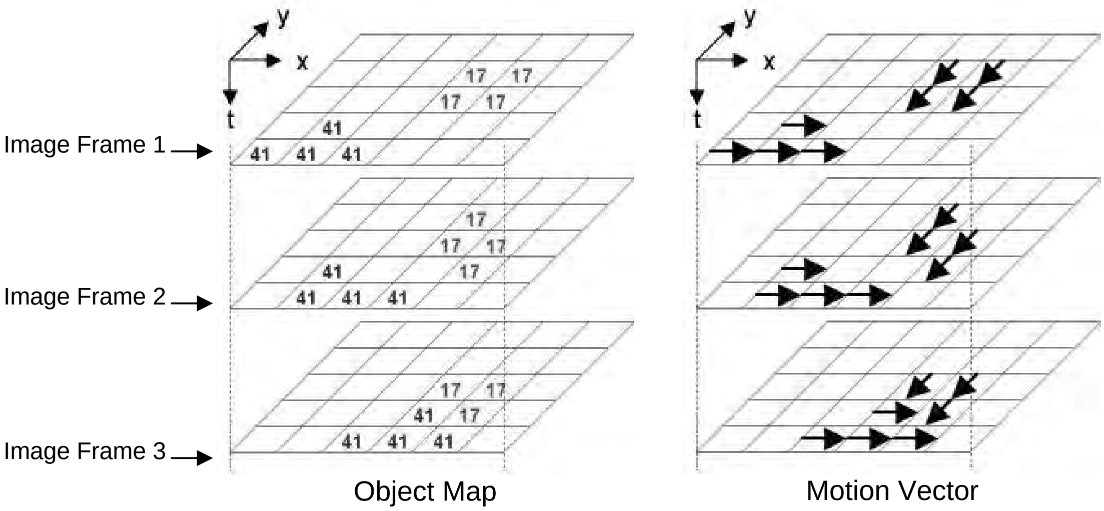
(1) Example of the method

For example, this section presents general information about one image analysis method called ”S-T MRF Model (Space-time Markov Random Field Model)”. S-T MRF Model is the technology which is invented by Dr.Kamijo laboratory of Institute of Industrial Science, University of Tokyo. (http://kmj.iis.u-tokyo.ac.jp/e_index.html)

The method is a probability model to divide the Space-time image area. S-T MRF Model focus on mutual relationship between time-scale directions of Space-time images enlarged as Space-time model. Normal MRF Model often divides area according to pixels. There is only one principle in S-T MRF Model; however, in case of comparing image frames, a vehicle moves from a few pixels to dozens of pixels; therefore the dividing area according to pixel is very difficult.

Therefore, S-T MRF Model divides the area according to block unit which is defined as 8 × 8 pixels, and as mutual relationship between time scale directions after consulting motion vector of each block by comparing image frames.

Figure 6.2 Recognition Imagery of S-T MRF Model



※Processing image that change gradually of Image Frames1 to 3, analysing, comparing, detecting movement and existing position of object

Source: Dr.Kamijo laboratory of Institute of Industrial Science, University of Tokyo.

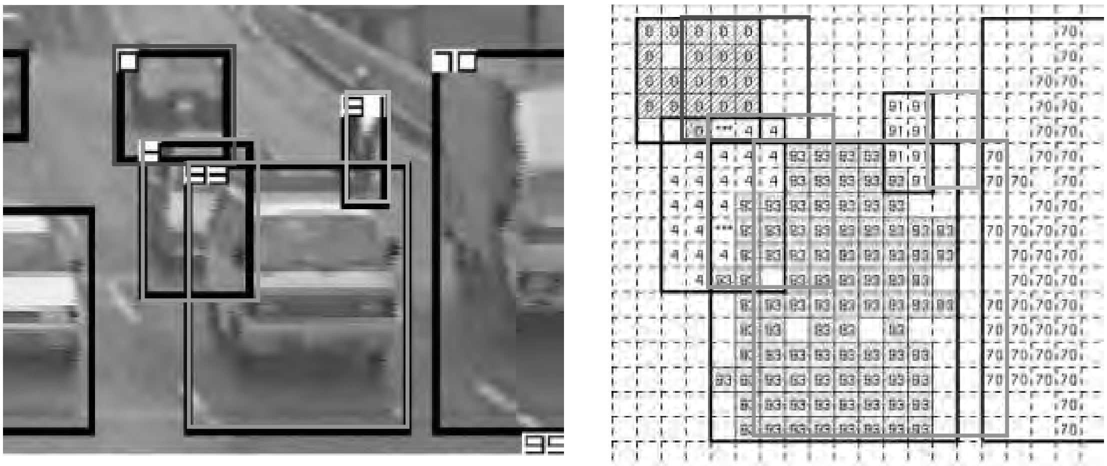
In addition, by applying probabilistic relaxation model, in case of occlusion due to different vehicles, still it is able to analyze the moving object line most suitably. Time/space MRF model only focuses on moving vectors of object in order to divide the area, but not as category of object.

Example: In case monitor is constructed as 640 × 480 pixels then divide into blocks with 8 × 8 pixels, and after that distribute into 80 × 60 blocks.

Followings figure show processing of image on the left, and then status of object identification by object map on the right. Vehicle in green frame is identified in range of 5 x 7 blocks (shown on Object Map as No.4) is overlapped vehicle in blue frame (shown on Object Map as No.93). In spite of occlusion here, exact detection is made.

This image analyzes by improved vehicle detection technique. The received image information can detect incident occurrence by reduced speed or unexpected stopping of vehicle. Therefore, it is possible to detect what happened by image analyzing; however, it is impossible to analyze the reason for the incident such as traffic accident or broken down vehicles. Hence it is necessary to confirm by CCTV or patroller.

Figure 6.3 Recognition Sample of S-T MRF Model



CCTV Image Object Map

Source: Dr.Kamijo laboratory of Institute of Industrial Science, University of Tokyo.

(2) Notandum in Image Recognition

The accuracy of image processing device depends on angle of view of CCTV camera. In short, images that are difficult to see by human eye also affect the accuracy when analyzing. In order to maintain accuracy of measurement/detector, it is necessary to investigate a site completely before installing event detector to avoid installing at places yielding same image as before installation.

For example, image in the left, a small passenger car is hiding beside the truck. This angle of view is undesirable. On the right image, the skyline may be affected by sunshine depending on time of day or camera direction.

Figure 6.4 Sample of Undesirable Angle of View

Source: SOHATSU System Institute Co., LTD.

Therefore, if PTZ camera is used for surveillance with image recognition, then you need to set image recognition settings each time when resetting the direction of the camera in order to ensure the recognition accuracy. Fixed camera, always the direction is fixed, so it is relatively easy to apply.

There are pros and cons for either type, so the best one should be selected according to the conditions such as the grade of the road, the frequency of patrol and the frequency of incident occurrence and so on.

Table 6.1 Advantage/Disadvantage of Fixed/PTZ Camera

	Fixed Camera	PTZ Camera
Applicability of image recognition for reducing human errors	++ Applicable	+ Impractical
Proper installation point around interchange	Applicable at Diverging and Merging point of the Ramp	Applicable for observation to whole of the Ramp at interchange
Evaluation Grade	Adopted for Event Detection	Insufficient for Event Detection

Source: ITS Integration Project (SAPI) Study Team

6.4 Required Function/Performance of CCTV Camera

In case of incident detection by recognition of the camera image, the image recognition is able to perform while PTZ functions are in use according to manufacturer product. Fixed camera is recommended for the accuracy control.

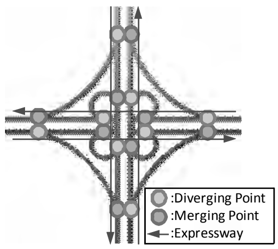
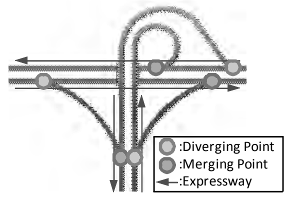
The camera is installed at outdoor, should be capable done waterproof, dustproof. Therefore, the camera should be equipped an ingress protection based on IP66 more, according to ISO/IEC60529.

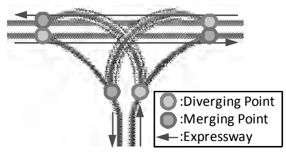
6.5 Location of CCTV Camera

(1) Location of CCTV Camera around Interchange/Junction

Locate a CCTV camera (Fixed type) at each ramp of Interchange. The number of CCTV cameras depends on the connection directions of the main road.

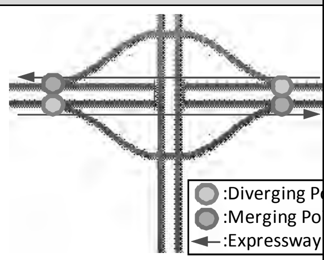
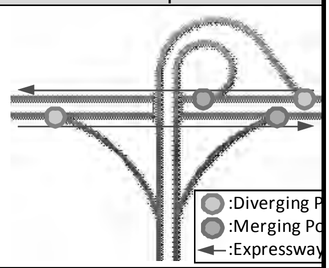
Table 6.2 Location of CCTV Cameras around Interchange/Junction (1)

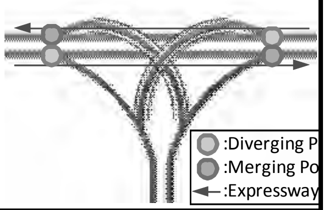
	Junction Type	
	Cloverleaf	Trumpet
		
CCTV Camera (Fixed Type)	16	6

	Junction Type
	Directional T
	
CCTV Camera (Fixed Type)	6

Source: ITS Integration Project (SAPI) Study Team

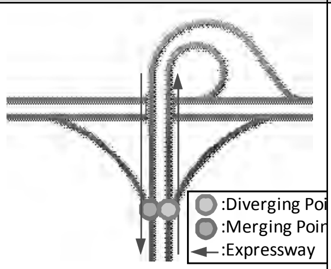
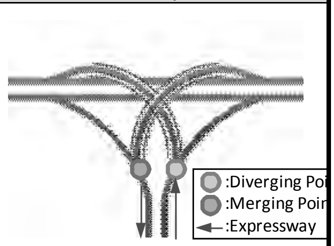
Table 6.3 Location of CCTV Cameras around Interchange/Junction (2)

	Interchange Type	
	Diamond	Trumpet
		
CCTV Camera (Fixed Type)	4	4

	Interchange Type
	Directional T
	
CCTV Camera(Fixed Type)	4

Source: ITS Integration Project (SAPI) Study Team

Table 6.4 Location of CCTV Cameras around Interchange/Junction (3)

	Interchange Type (Starting/Ending Point)	
	Diamond	Trumpet
		
CCTV Camera (Fixed Type)	2	2

Source: ITS Integration Project (SAPI) Study Team

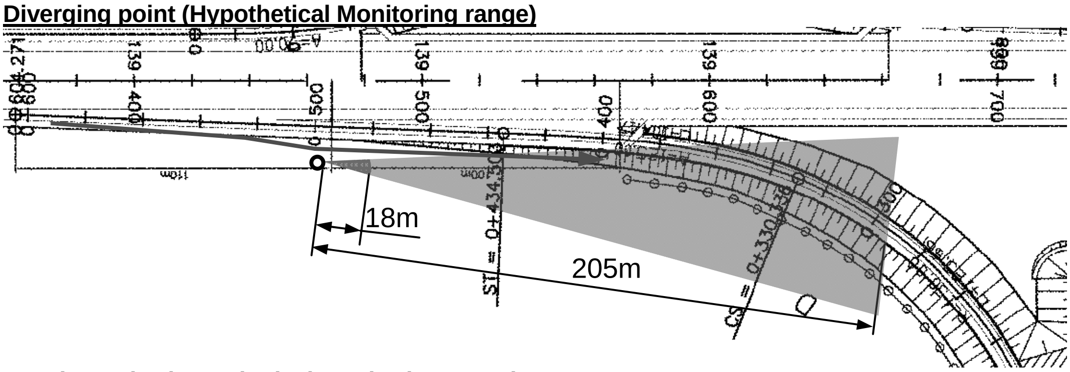
(2) Arrangement of CCTV Camera

Event detection cameras should be installed at the merging and diverging points of the ramp. Then, shall be capable detection Stopped Vehicle, Wrong-way Vehicle and Speed drop vehicle. According to Table 4.2, maximum surveillance range is approx. 200 m long, it is possible by using 60-inch display and the camera has got functions such as 1/4" inch image sensor and 5.0 mm focal length of lens.

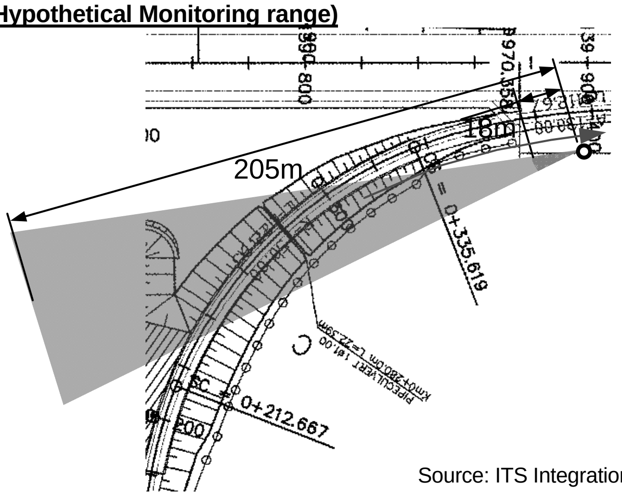
Therefore, the CCTV camera shall be installed on the median or roadside at around begin or end of the curve.

Figure 6.5 Maximum surveillance range of Fixed Camera in an ideal condition

<u>Diverging point (Hypothetical Monitoring range)</u>



<u>Merging point (Hypothetical Monitoring range)</u>

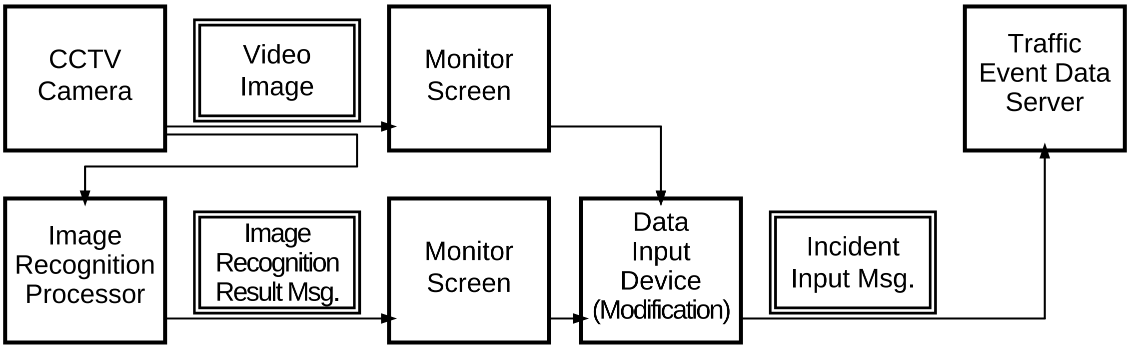


Source: ITS Integration Project (SAPI) Study Team

6.6 Data Set for Event Detection

Major Message Exchanges for generating incident data is shown in the following figure.

Figure 6.7 Major Message Exchanges for Generating Incident Data



Source: ITS Integration Project (SAPI) Study Team

Captured image by CCTV camera is to be sent automatically to the image recognition processor, analyzed results are to be shown to an operator and a message for generating incident data is to be input to the traffic event data server.

Figure 6.5 Data Set/Elements in Image Recognition Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Image Recognition Result Data Set <G - Image Processor>	Road Management Office ID	INT*	4	1	When an event occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Image Recognition Result Status	INT*	2	1		
	Video Image Address	TXT	60	1		
	Date/Time	Datetime	≥14	1		
Incident Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Roadside Equipment ID	INT*	4	1		
	Incident Status	INT*	2	1		
	Date/Time	Datetime	≥14	1		
Event Image Data Set <G - Server>	Road Management Office ID	INT*	4	1	When an event is checked	1 year
	Roadside Equipment ID	INT*	4	1		
	Place ID	INT*	4	1		
	Video Image ID	INT	8	1		
	Event Video Image	IMG	var	1		
	Traffic Event Data ID	INT	8	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

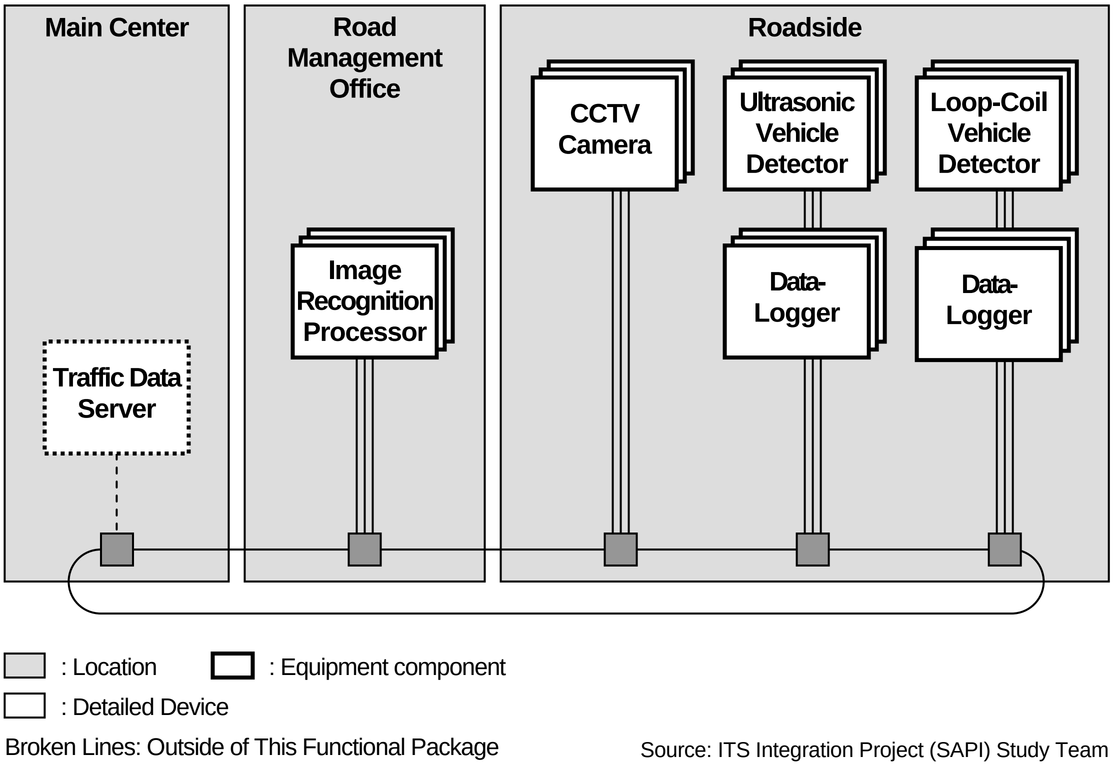
Source: ITS Integration Project (SAPI) Study Team

7. Vehicle Detection

7.1 Outline and System Architecture

This functional package allows road operators to measure actual traffic volume, heavy vehicle ratio and vehicle velocity on the expressways for developing road operation/ improvement plans by using vehicle detectors installed at important points on the throughway and the tollgates.

Figure 7.1 System Architecture for Vehicle Detection



Source: ITS Integration Project (SAPI) Study Team

7.2 Vehicles/Classes to be Identified

(1) Measurement Data by using Vehicle Detection

Vehicle detection shall be capable detection the traffic volume, vehicle speed and length of vehicle of all vehicles on expressway. Detection for motor cycle is optional function.

At least, following items of measurement is required;

- Number of vehicle
- Vehicle Length
- Vehicle Speed

(2) Method of calculation for required traffic data

a) Average vehicle speed per unit of time

The calculation of average speed per unit of time, it is calculated from the past data of the total number of vehicle and vehicle speed by using following formula;

$AV_{ut} = (Vv_{(1)} + Vv_{(2)} + \cdots\cdots Vv_{(N)}) / Q_{ut}$

AV_{ut} : Average vehicle speed per unit of time
$Vv_{(1)\text{-}(N)}$: Vehicle Speed of each vehicle
Q_{ut} : Number of Vehicle per unit of time (Σ from 1 to N)
N : Number of data per unit of time (it is should be the same of Q_{ut})

b) Occupancy per unit of time

The calculation of occupancy per unit of time, it is calculated from the past data of the vehicle length and vehicle speed by using following formula;

$OC_{ut} = (VLv_{(1)} / Vv_{(1)} + VLv_{(2)} / Vv_{(2)} + \cdots\cdots + VLv_{(N)} / Vv_{(N)}) / UT \times 100$

OC_{ut} : Occupancy per unit of time
$Vv_{(1)\text{-}(N)}$: Vehicle Speed of each vehicle
$VLv_{(1)\text{-}(N)}$: Vehicle Length of each vehicle
UT : Unit of time (ordinary, it is 1 minute and 5 minutes)
N : Number of data per unit of time

c) Calculation Vehicle Speed and Vehicle Length by using Loop-coil data

In case of measuring vehicle velocity, it’s necessary to install two loop coils, calculate vehicle velocity by dividing the distance between two loop coils by the time difference between vehicle detection timing of each loop coil.

$V_V = L_S / TD_S$

V_V : Vehicle Speed
L_S : Distance between each loop coils
TD_S : Time difference between detection timing of each loop coils

In addition, regarding vehicle length, it is necessary to calculate the vehicle length by calculated vehicle velocity multiplied by the reaction of detection time of loop coil.

$VL_V = V_V \times RT_S$

VL_V : Vehicle Length
V_v : Vehicle Speed
RT_S : Reaction Time of loop coil

(3) Vehicle Class for Detecting Traffic Volume

Vehicle class for detecting traffic volume is defined as shown in the table below.

Table 7.1 Vehicle Class for Detecting Traffic Volume

Vehicle Class	Definition
Ordinary Vehicle	Detected Length ≤ 6 m
Large Vehicle	6 m< Detected Length ≤ 12 m
Traler Vehicle	12 m < Detected Length

Source: ITS Integration Project (SAPI) Study Team

7.3 Types of Vehicle Detector

There are many types of vehicle detectors which can be categorized into in-road sensors and over-road sensors. a) Loop-coil type is mainly used in in-road sensors whereas b) Ultrasonic type and c) Image recognition type are mainly used in over-road sensors. Characteristics for each type of vehicle detector are described in following Tables.

The focus of attention in this paragraph is on a) Loop-coil type, b) Ultrasonic type and c) Image recognition.

(1) Loop-coil Type

This type detects vehicles passing by using electromagnetic induction. Number of vehicles can be counted with relatively high accuracy. However, it is difficult to install in bridge sections because of difficulty to secure a sufficient distance from steel to the loop-coil.

Advantages: The operation of inductive loop-coil type is well understood and their application for providing basic traffic parameters (volume, presence, occupancy, speed, headway, and gap) represents a mature technology. The equipment cost of loop-coil type may be low when compared to over-road sensors. Another advantage of loop-coil type is their suitability for a large variety of applications due to their flexible design.

Disadvantages: The drawbacks of loop-coil type detectors include disruption of traffic for installation and repair, and failures associated with installations in poor road surfaces and use of substandard installation procedures. In addition, resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors. The wire loops are also subject to the stresses of traffic and temperature. Therefore, installation and maintenance costs significantly increase the life-cycle cost of loop-coil type detectors. In many instances multiple detectors are required to instrument a location.

(2) Ultrasonic Type

This type detects vehicles passing by using arrival time difference of ultrasonic waves reflected from objects on the road and from the road. Number of vehicles can be counted with relatively high accuracy. However, it is difficult to distinguish the vehicles from the other objects on the road.

Advantages: Installation of ultrasonic type does not require an invasive pavement procedure.

Disadvantages: Temperature change and extreme air turbulence may affect the performance of ultrasonic type. Temperature compensation is built into some models. Large pulse repetition periods may degrade occupancy measurement on road with vehicles travelling at moderate to high speeds.

(3) Image Recognition Type

This type detects moving objects in images captured from video cameras according to preset size/speed of the object. The image recognition can be conducted using higher quality images in comparison with that for visual inspection. Number of detected vehicles also can be counted in the system.

Advantages: Allows to detection multiple lanes and multiple detection zones/lane. Easy to add and modify detection zones by setting of recognition processor. Provides wide-area detection when information gathered at one camera location can be linked to another.

Disadvantages: Some disadvantages of the image recognition include its vulnerability to viewing obstructions; inclement weather; shadows; vehicle projection into adjacent lanes; occlusion; day to night transition; vehicle/road contrast; water; salt grime; and cobwebs on camera lens that can affect performance. Image recognition arrangement is generally cost effective only if many detection zones are required within the field of view of the camera.

Table 7.2 Traffic output data of Vehicle Detection

Type	Output Data			Multiple Lane Detection
	Count	Speed	Length	
a) Loop-coil type	Capable	On condition 1)	On condition 2)	
b) Ultrasonic type	Capable	—	—	
c) Image Recognition type	Capable	Capable	Capable	Capable

1) Speed can be measured by using two sensors a known distance apart.
2) Length can be calculated from speed and detected time of sensor.

Source: ITS Integration Project (SAPI) Study Team

Accordingly, we recommend that to install vehicle detection by using image recognition type. Additionally, install Loop-coil type at one cross-section for the evaluation of the measured data of image recognition.

Table 7.3 Advantages and Disadvantages of Type of Vehicle Detectors

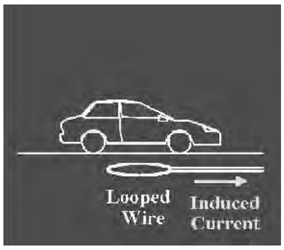
Type	Advantages	Disadvantages
a) Loop-coil type	1) Flexible design to satisfy large variety of applications. 2) Mature, well understood technology. Large experience base. 3) Provides basic traffic parameters (e.g., volume, presence, occupancy, speed, headway, and gap). 4) Insensitive to inclement weather such as rain, fog, and snow. 5) Provides best accuracy for count data as compared with other commonly used techniques. 6) Common standard for obtaining accurate occupancy measurements. 7) High frequency excitation models provide classification data.	1) Installation requires pavement cut. 2) Decreases pavement life. 3) Installation and maintenance require lane closure. 4) Wire loops subject to stresses of traffic and temperature. 5) Multiple detectors usually required to monitor a location. 6) Detection accuracy may decrease when design requires detection of a large variety of vehicle classes.
b) Ultrasonic type	1) Multiple lane operation available. 2) Capable of over-height vehicle detection. 3) Large Japanese experience base.	1) Environmental conditions such as temperature change and extreme air turbulence can affect performance. 2) Temperature compensation is built into some models. 3) Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles travelling at moderate to high speeds.
c) Image Recognition type	1) Monitors multiple lanes and multiple detection zones/lane. 2) Easy to add and modify detection zones. 3) Rich array of data available. 4) Provides wide-area detection when information gathered at one camera location can be linked to another.	1) Installation and maintenance, including periodic lens cleaning, require lane closure when camera is mounted over roadway. (lane closure may not be required when camera is mounted at side of roadway) 2) Performance affected by inclement weather such as fog, rain, and snow; vehicle shadows; vehicle projection into adjacent lanes; occlusion; day-tonight transition; vehicle/road contrast; and water, salt grime, icicles, and cobwebs on camera lens. 3) Some models susceptible to camera motion caused by high winds or vibration of camera mounting structure. 4) Generally cost-effective when many detection zones within the field-of view of the camera or specialized data are required. 5) Reliable nighttimes signal actuation requires street lighting.

Source: ITS Integration Project (SAPI) Study Team

There are pros and cons for every type; however, a) Loop-coil type is the most common sensor used in traffic management, and a mature technology. Also, b) Ultrasonic type is common sensor used in traffic management in Japan. Recently, c) Image recognition type is applied in traffic management; however, availability and accuracy of the image recognition is affected from vulnerability to obstructions. Some products avoid the vulnerability. In fact, it is developing technology so, requires further validation.

Therefore, mainly a) Loop-coil type is adopted in this study, also c) Image recognition type is in trial to implement at some point with a) Loop-coil for providing an opportunity for validation.

Table 7.4 Comparison of Vehicle Detection

	a) Loop-coil type	b) Ultrasonic type	c) Image Recognition type
Outline			
Installation	Being buried in a sufficient distance from steels	Being fixed on the structure securing clearance of the road	Being fixed on the stable structure securing sight path
Unsuitable Location	+ Metal bridge section	++ None	++ None
Implementation Cost	+++ Low	++ Average	+ High
Applicability to Traffic Swerved from Lanes	+ Incapable	+ Incapable	++ Capable
Secondary Usage for Visual Judgment	+ Incapable	+ Incapable	++ Capable
Availability	+++ High	+++ High	++ Average
Serviceability	+ Low	++ Average	++ Average
Endurance	++ Average	+++ High	++ Average
Maintenance	Necessary to work on the pavement for mechanical trouble caused by heat	Very rare and not necessary to work on the pavement	Not necessary to work on the pavement
Grading	Adopted	Applicable	Adopted

Grade: +++ = best, ++ = average, + = worst. Source: ITS Integration Project (SAPI) Study Team

7.4 Detection Algorithm by Image Recognition

There are multi-categories of analyzing image system. Analyzing image system on highway requires vehicle detection position on the road, and the system requires that the vehicle identification technique shows a suitable image. Image analysis techniques for the last 10 years have met with difficulties in analyzing when having both vehicle and motorcycle objects move on one screen in many different ways. However, with present analysis technique, there is improved accuracy when analyzing image and for many vehicle types.

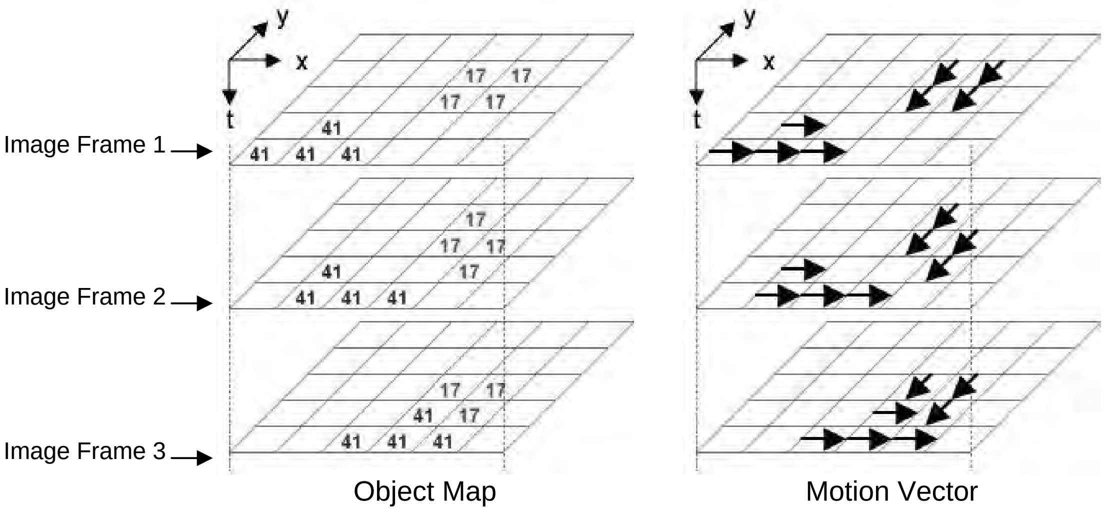
(1) Example of the method

For example, this section presents general information about one image analysis method called "S-T MRF Model (Space-time Markov Random Field Model)". S-T MRF Model is the technology which is invented by Dr.Kamijo laboratory of Institute of Industrial Science, University of Tokyo. (http://kmj.iis.u-tokyo.ac.jp/e_index.html)

The method is a probability model to divide the Space-time image area. S-T MRF Model focus on mutual relationship between time-scale directions of Space-time images enlarged as Space-time model. Normal MRF Model often divides area according to pixels. There is only one principle in S-T MRF Model; however, in case of comparing image frames, a vehicle moves from a few pixels to dozens of pixels; therefore the dividing area according to pixel is very difficult.

Therefore, S-T MRF Model divides the area according to block unit which is defined as 8 × 8 pixels, and as mutual relationship between time scale directions after consulting motion vector of each block by comparing image frames.

Figure 7.2 Recognition Imagery of S-T MRF Model



※Processing image that change gradually of Image Frames1 to 3, analysing, comparing, detecting movement and existing position of object

Source: Dr.Kamijo laboratory of Institute of Industrial Science, University of Tokyo.

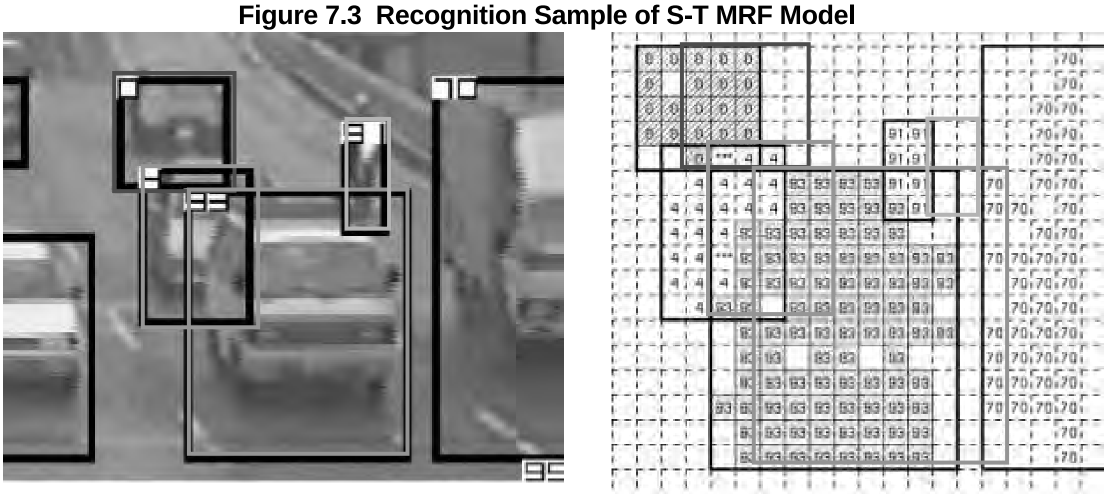
In addition, by applying probabilistic relaxation model, in case of occlusion due to different vehicles, still it is able to analyze the moving object line most suitably. Time/space MRF model only focuses on moving vectors of object in order to divide the area, but not as category of object.

Example: In case monitor is constructed as 640 × 480 pixels then divide into blocks with 8 × 8 pixels, and after that distribute into 80 × 60 blocks.

Followings figure show processing of image on the left, and then status of object identification by object map on the right. Vehicle in green frame is identified in range of 5 x 7 blocks (shown on Object Map as No.4) is overlapped vehicle in blue frame (shown on Object Map as No.93). In spite of occlusion here, exact detection is made.

This image analyzes by improved vehicle detection technique. The received image information can detect incident occurrence by reduced speed or unexpected stopping of vehicle. Therefore, it is possible to detect what happened by image analyzing; however, it is impossible to analyze the reason for the incident such as traffic accident or broken down vehicles. Hence it is necessary to confirm by CCTV or patroller.

Figure 7.3 Recognition Sample of S-T MRF Model



CCTV Image

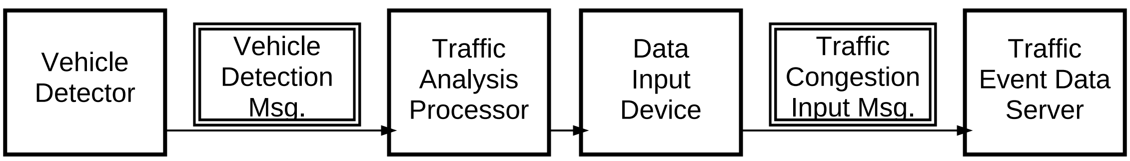
Object Map

Source: Dr.Kamijo laboratory of Institute of Industrial Science, University of Tokyo.

7.5 Data Set for Vehicle/Classes

Major message exchanges for generating traffic congestion data is shown in the following figure.

Figure 7.4 Major Message Exchanges for Generating Traffic Congestion Data



Source: ITS Integration Project (SAPI) Study Team

Vehicle category is divided by the vehicle length. It is assumed that if the vehicle length is more than 5.5m then the vehicle is full-sized car. The system be capable of discretionarily setting the unit time of recording volume, average speed, occupancy and traffic flow speed.

Additionally, the system shall have video image output interface to adjust angle of view of camera and control signal receiving interface to check camera operations for setting-up at installation site.

Data set of Vehicle Detection is shown in the table below.

Table 7.5 Data Set/Elements in Vehicle Detection Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Image Recognition Result Data Set <G - Image Processor>	Road Management Office ID	INT*	4	1	When an event occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Image Recognition Result Status	INT*	2	1		
	Video Image Address	TXT	60	1		
	Date/Time	Datetime	≥14	1		
Vehicle Detection Data Set <G - Vehicle Detector>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Cumulative Number of Vehicles	INT*	4	1		
	Vehicle Speed	FLOAT	5	N		
	Vehicle Length	FLOAT	4			
	Date/Time	Datetime	≥14	1		
Traffic Congestion Data Set <G - Traffic Analysis Processor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Cumulative Number of Vehicles	INT*	4	1		
	Average Vehicle Speed	INT*	4	1		
	Traffic Congestion Status	INT*	2	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

7.6 Required Function/Performance of CCTV Camera

The system shall be capable of monitoring vehicles on the expressway and identifying types of the vehicles by their appearances, shall be capable of taking an image of vehicle license number plate upon control signal. CCTV system shall be capable of automatically correcting brightness of captured image. (That is called the iris function.)

Measurement object speed shall be 0~160 km/h or more.

The system shall be capable of controlling the lens aperture per the brightness of the subject and of outputting suited good video image, shall be capable of zooming, correcting brightness and focusing of the camera according to the control signal.

7.7 Location/Installation of CCTV Camera

(1) Installation / Operation Policies of Vehicle Detector

Vehicle Detection makes it possible for the road operators to measure actual traffic volume, heavy vehicle ratio and vehicle velocity on the expressways based on type of detection technology. Collected data will be utilized for developing road operation / improvement plans.

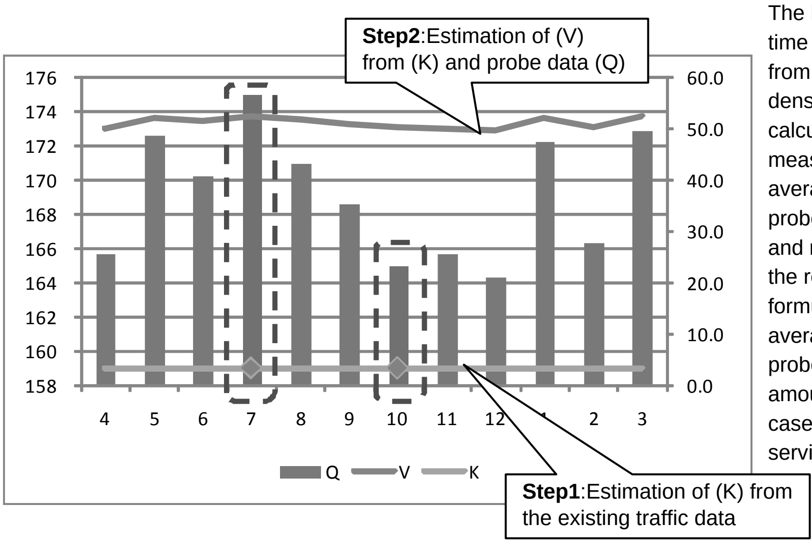
Therefore, traffic data is very important for road operation and management. There are many types and methods of traffic data collection.

The current method of traffic data collection is based on Probe data obtained using GPS equipment installed in the vehicle. However, in order to measure based on the Probe data, true value must be measured as the accumulation of traffic data over a long time.

Of course, it is possible to use the full Probe data; however, first a fixed detection method needs to be implemented for accumulation of traffic data.

Therefore, attention in this paragraph is focused on fixed detection method.

Figure 7.5 Example of utilization of Probe data



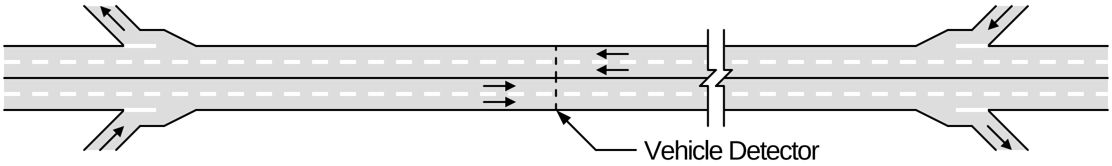
The link travel speed data continuous time and space can be calculated from the probe data. The traffic density of reference value (K) is calculated from the true value of measured traffic volume (V) and the average speed is obtained from the probe data (Q) for each level of road and region. Subsequently the setting the reference value (K), by the formula V = Q / K applied to the average velocity is obtained from the probe data (Q). Then, calculate the amount of link traffic volume (V), in case of "the current situation of road service level" possibly.

(2) Arrangement of Vehicle Detectors

a) Vehicle Detector Arrangement for Policy 1

In the case of the Policy 2, vehicle detectors need to be installed at a midway point between a pair of interchanges on the expressway in order to measure traffic volume on a section between them.

Figure 7.6 Vehicle Detector Installation at Midway between a Pair of Interchanges

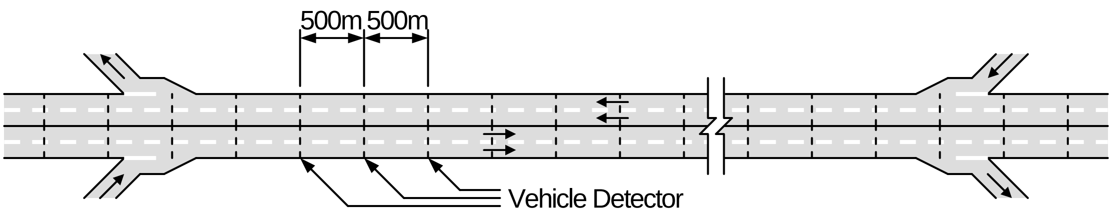


Source: ITS Integration Project (SAPI) Study Team

b) Vehicle Detector Arrangement for Policy 2

In the case of the Policy 2, vehicle detectors need to be installed continuously at small spacing (e.g. 500 m) along the expressway in order to measure vehicle velocity at any section on the expressway and positively to identify traffic congestion.

Figure 7.7 Vehicle Detector Installation Continuously at a Short Spacing along the Expressway

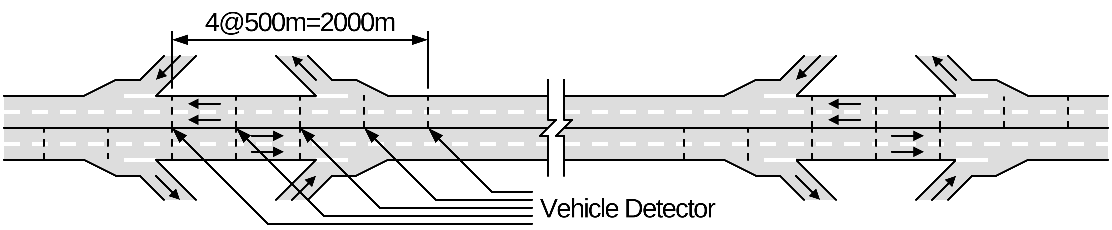


Source: ITS Integration Project (SAPI) Study Team

c) Vehicle Detector Arrangement for Policy 3

In the case of the policy 3, vehicle detectors need to be installed at small spacing (e.g. 500 m) in congestion-prone sections on the expressway in order to measure vehicle velocity at the sections and positively to identify traffic congestion.

Figure 7.8 Vehicle Detector Installation at Congestion-prone Sections on the Expressway

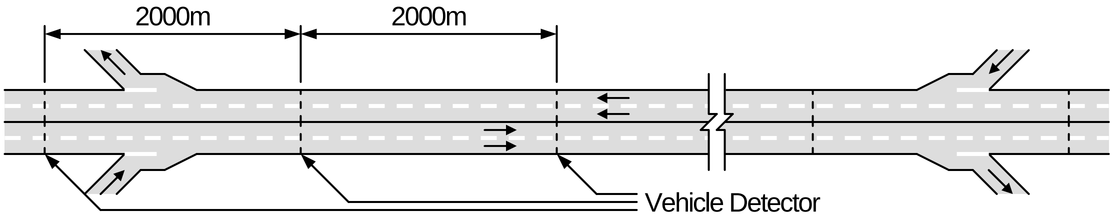


Source: ITS Integration Project (SAPI) Study Team

d) Vehicle Detector Arrangement for Policy 4

In the case of the policy 4, vehicle detectors need to be installed continuously along the expressway in order to measure vehicle velocity throughout the expressway and roughly to identify traffic congestion.

Figure 7.9 Vehicle Detector Installation Continuously along the Expressway



Source: ITS Integration Project (SAPI) Study Team

(3) Comparison of Installation/Operation Policies

Advantages/disadvantages of the four installation/operation policies of vehicle detector are summarized in the table below.

Table 7.6 Advantages/Disadvantages of Installation/Operation Policies of Vehicle Detector

		Policy 1	Policy 2	Policy 3	Policy 4
Measurement of traffic volume on a section		Capable	Capable	Capable	Capable
Identification of traffic congestion	At any section on the expressway	+ Incapable	+++ Capable (QL=0.5–1km)	+ Incapable	++ Capable (QL>2km)
	At congestion-prone sections on the expressway	+ Incapable	+++ Capable (QL=0.5–1km)	+++ Capable (QL=0.5–1km)	++ Capable (QL>2km)
Required number of equipment implementation for 80km length of the expressway network		** ++++ 12 set	** + 640 set	** +++ 80 set	** ++ 160 set
Evaluation Grading		Adopted	Not suitable	Adopted (2nd Stage)	Applicable

Grade: +++ = best, ++ = average, + = worst.
Note: QL: Minimum detectable queue length.
**: In the case of using Loop-coil type, number of interchange is 4, 1 set has two Loop-coil sensors, Number of merging/diverging point is 8, number of lane is 2 lanes each way.

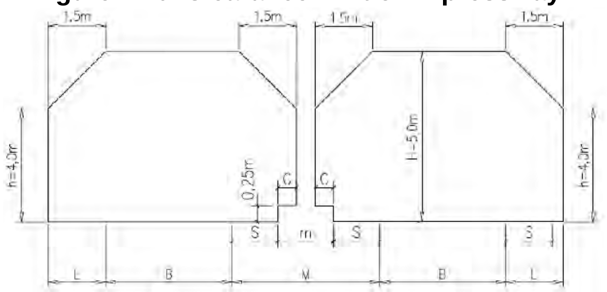
Source: ITS Integration Project (SAPI) Study Team

At first stage, Policy 1 is adopted for collection of traffic data and reducing the cost of implementation. However, as shown in the table above, Policy 2 requires large numbers of equipment to be implemented and is not suitable. Policy 4 is can be applicable only to the road sections with large traffic over their length. Hence, according to this comparison, Policy 1 is adopted in this study of 1st stage, and then Policy 2 is adopted in 2nd stage based on the vehicle detector installation at congestion-prone sections on the expressway.

(5) Policy of height of CCTV Camera and the Field of view

The height of CCTV camera for vehicle detection by image, the camera is should Fixed type. Therefore, the height of installation 7-8m above ground level according to CCTV monitoring. It is consider that sometimes Fixed camera and PTZ camera are attached the same pole therefore, ,make a margin 1.0m from the height of PTZ camera installation.

Figure 7.10 Clearance limit of Expressway



Source: TCVN5729 Expressway Standard Design

Figure 7.11 Height of CCTV camera

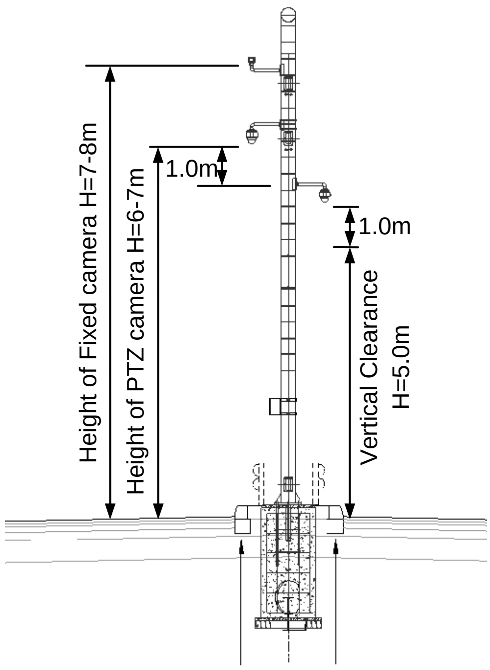


Table 7.7 Height of CCTV Camera

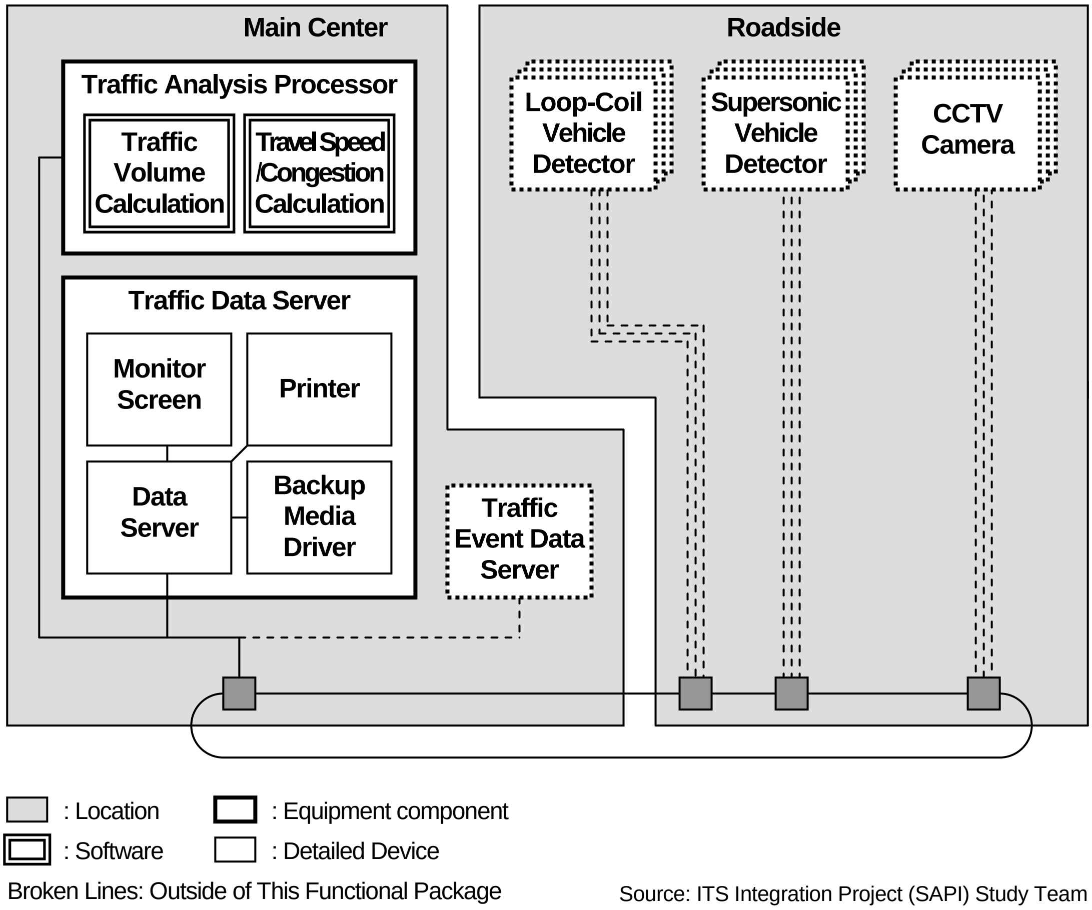
Type of Camera	Height
Fixed Camera	7-8m above Ground level

8. Traffic Analysis

8.1 Outline and System Architecture

This functional package allows the road operators to keep track of traffic conditions on the expressways, such as crowdedness and vehicle velocity, by processing and analyzing the data captured by vehicle detectors.

Figure 8.1 System Architecture for Traffic Analysis



Source: ITS Integration Project (SAPI) Study Team

8.2 Values on Traffic/Congestion to be Estimated

Normally, traffic congestion arises when traffic volume increasing beyond the traffic capacity of lane of the road. However, traffic congestion can be caused by an incident, such as a traffic accident, that obstructs the traffic of one or more than one lane. Traffic congestion caused by incident can take place even in the condition the traffic volume is smaller than usual traffic volume.

Hence, it is necessary to measure the traffic volume around congested section for identifying the cause of traffic congestion. It is necessary to catch traffic volume of congestion section before and after arising congestion as catch above content. CCTV cameras need to be installed every 2km in order to monitor incidents.

Table 8.1 Categories/Classes of Traffic Congestion

Traffic Event Category	Traffic Event Class	Definition
Traffic Congestion	Congestion	Condition that an average speed detected in each minute for each lane is ≤40km/h and a vehicle queuing more than 1km at such low speed continues to exist ≥15 minutes.
	Crowdedness	Condition that an average speed detected in each minute for each lane is ≤50km/h and such low speed situation continue to exist ≥15 minutes.
	Normal	Condition without any congestion and crowdedness.

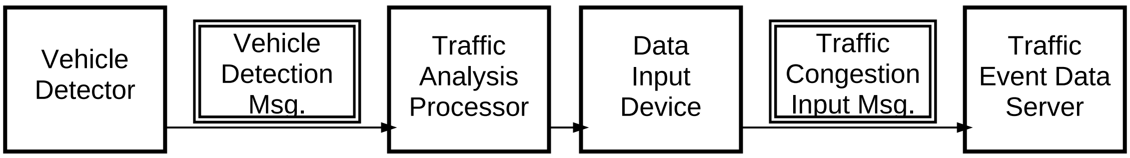
Note: INT* : Short integer; I: Input; G: Generated; C:Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

8.3 Data Set for Traffic Analysis

Major Message Exchanges for generating traffic congestion data is shown in the following figure.

Figure 8.2 Major Message Exchanges for Generating Traffic Congestion Data



Source: ITS Integration Project (SAPI) Study Team

The results of vehicle detection are to be sent automatically to the traffic analysis processor, and the results of traffic analysis to be indicated on the monitor screen. Referring to that, a message for generating traffic congestion data is to be input by an operator to the traffic event data server.

Table 8.2 Data Set/Elements in Traffic Congestion Input Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Vehicle Detection Data Set <G - Vehicle Detector>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Cumulative Number of Vehicles	INT*	4	1		
	Vehicle Speed	FLOAT	5	N		
	Vehicle Length	FLOAT	4			
	Date/Time	Datetime	≥14	1		
Image Recognition Result Data Set <G - Image Processor>	Road Management Office ID	INT*	4	1	When an event occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Image Recognition Result Status	INT*	2	1		
	Video Image Address	TXT	60	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

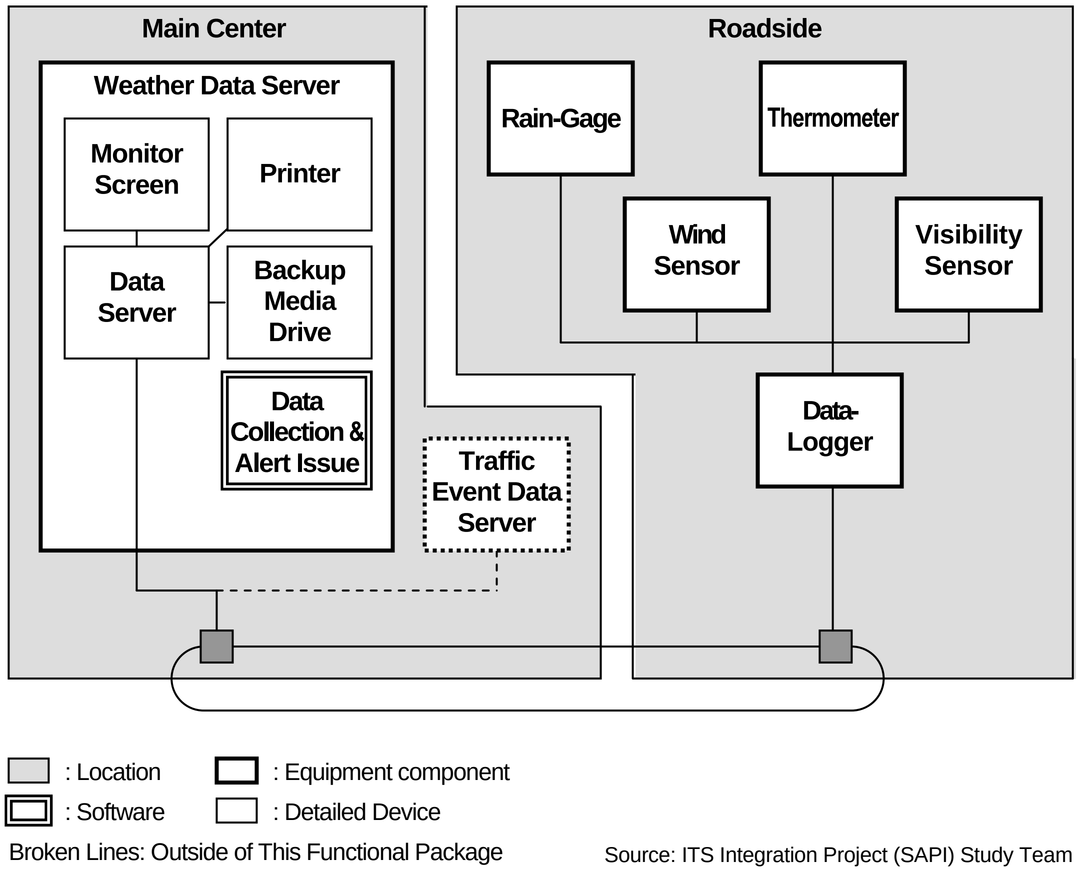
Source: ITS Integration Project (SAPI) Study Team

9. Weather Monitoring

9.1 Outline and System Architecture

This functional package allows the road operators to estimate dangerous conditions for road traffic on the expressways by using data acquired by the sensors installed at the interchanges and at the road sections where undesired weather conditions for traffic safety frequently take place.

Figure 9.1 System Architecture for Weather Monitoring



Source: ITS Integration Project (SAPI) Study Team

9.2 Observation Elements for Weather Monitoring

The observation element and observation range of each sensor are shown below.

Table 9.1 Observation Elements and Observation Method

Elements	Observation method				Remarks
	Device	Observation range	Unit	Height	
Rainfall	Rain gauge	Enable to measure min. 200mm/h	0.5 mm	Approx. 3.0-3.5 m	Tipping-Bucket Rain Gage
Wind speed	Anemometer	2 ~ 50 m/s	0.1 m/s	3.5 – 5.0 m	
Visibility	Visibility sensor	10 – 2000 m	–	1.5 – 2.5m	MOR[1]
Temperature	Thermometer	-10~60 °C	0.1 °C	1.5 – 2.0 m	Electric thermometer

As for accuracy of censers, it should be verified before delivery.

9.3 Bad Weather Categories

Alert is to be detected in case observed data exceeds the preset threshold. According to the “Standard of issuing traffic restriction” specified in the item of Traffic Event Data Management, the following alert criteria are configured on significant weather.

Table 9.2 Criteria/Levels of Enforcing Traffic Restriction

Traffic Event Categories	Observed Data or Processed Data	Restriction Levels		
		Closure	Lane Closure or Speed Restriction	Warning Information
Heavy rain	Accumulated precipitation	250mm or more	200mm or more	–
	Hourly rainfall	40mm or more after reaching 100mm rainfall in 1 hour	20mm or more	10mm or more
High wind	10 min. average wind speed	25 m/s or more	15 m/s or more	10 m/s
Dense fog	Visibility	50m or less	100m or less	200
High temperature	10 min. average temperature	–	–	40 degree centigrade

Note, Accumulated precipitation is accumulation of precipitation starting from observation of rain fall and continuous rain fall is observed without interruption up to the observing time.
Hourly rainfall is calculated by conversion of 10 minutes accumulated precipitation. It is corresponding to what is called rainfall intensity.

Each threshold is required to configure properly based on the above criteria. The weather data server to be installed at main center collects and updates weather observation data every 5 minutes from data logger of each site. If processed data calculated from the collected data exceeds above threshold for precipitation, wind speed, and temperature, and become lower than above thresholds for visibility, it is required to detect this condition.

The detected result is required to be categorized into corresponding Traffic Event Category and Traffic Event Class shown in the following table. The following table is the extraction of significant weather part from the original one stipulated in item 14 Traffic Event Data

[1] Meteorological Optical Range

Management.

Table 9.3 Categories/Class of Bad Weather

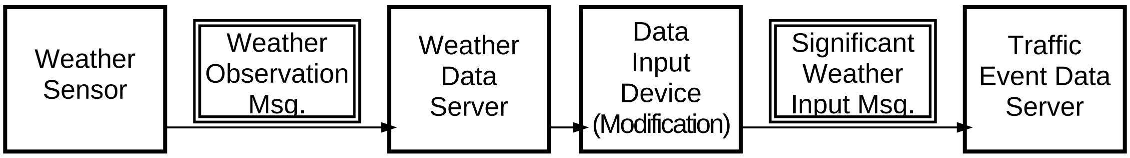
Traffic Event Category	Traffic Event Class		Definition
Significant Weather	Heavy Rain	1	Significantly heavy rain with issuing closure
		2	Heavy rain with issuing lane/speed restriction
		3	Heavy rain with issuing warning information
	High Wind	1	Significantly high wind with issuing closure
		2	High wind with issuing lane/speed restriction
		3	High wind with issuing warning information
	Dense Fog	1	Significantly dense fog with issuing closure
		2	Dense fog with issuing lane/speed restriction
		3	Dense fog with issuing warning information
	High Temperature		High temperature with issuing warning information

Source: ITS Integration Project (SAPI) Study Team

9.4 Data Set for Weather Observation and Bad Weather

Major Message Exchanges for generating significant weather data is shown in the following figure.

Figure 9.2 Major Message Exchanges for Generating Significant Weather Data



Source: ITS Integration Project (SAPI) Study Team

The weather observation message is to be sent to and stored in the weather data server automatically and the message shall include data shown in the table below.

Table 9.4 Data set/Elements in Weather Observation Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Weather Monitoring Data Set <G - Weather Sensor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Precipitation	FLOAT	2	1		
	Wind Speed	FLOAT	2	1		
	Visibility	FLOAT	2	1		
	Temperature	FLOAT	2	1		
	Alarm Status of Precipitation	INT*	2	1		
	Alarm Status of Wind Speed	INT*	2	1		
	Alarm Status of Visibility	INT*	2	1		
	Alarm Status of Temperature	INT*	2	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

Referring to alert status indicated by weather data server, message for generating significant weather data shown below is to be input by an operator to the traffic event data server.

Table 9.5 Data set/Elements in Bad Weather Input Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Bad Weather Data Set <G - Weather Server>	Road Management Office ID	INT*	4	1	When a bad weather occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Precipitation	FLOAT	2	1		
	Wind Speed	FLOAT	2	1		
	Visibility	FLOAT	2	1		
	Temperature	FLOAT	2	1		
	Heavy Rain Status	INT*	2	1		
	High Wind Status	INT*	2	1		
	Low Visibility Status	INT*	2	1		
	High Temperature Status	INT*	2	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

9.5 Required Function/Performance of Weather Sensors

(1) Rain Gauge

Performance of rain gauge shall be as per the following conditions;

a) Observation range : measurable min. 200 mm/h
b) Sensitivity : 0.5 mm
c) Accuracy : max. +/- 0.5mm (up to 20mm/h)
: max. +/- 3% (more than 20mm/h up to 100mm/h)
d) Funnel diameter : 200mm – 260mm

(2) Wind Sensor

Performance of wind speed sensor shall be as per the following conditions;

a) Measuring range : 2 to 50 m/sec
b) Resolution : 0.1 m/sec
c) Accuracy : within +/- 3%

(3) Visibility Sensor

Performance of visibility sensor shall be as per the following conditions;

a) Measuring range : MOR[2] 10m – 2,000m
b) Accuracy : +/- 10 % (up to 2,000m)

(4) Thermometer

Performance of thermometer shall be as per the following conditions;

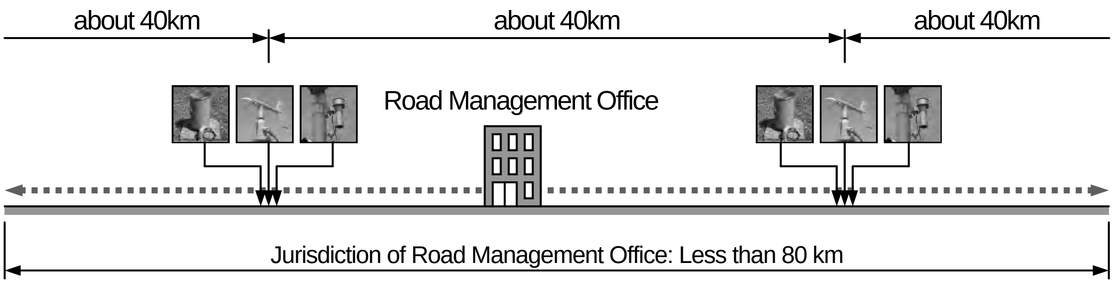
a) Measuring range : -10 to 60 degree centigrade
b) Resolution : 0.1 degree -10 to 60 degree centigrade
c) Accuracy : +/- 0.2 degree centigrade (at +20 degree centigrade)
d) Type : Pt 100

[2] MOR: Meteorological Optical Range

9.6 Location of Weather Sensors

In the manual on global observing system published by WMO (World Meteorological Organization), it is recommended to apply a meteorological observation network of 100 km mesh or less for observation of small-scale weather phenomena, such as thunderstorms. According to this concept, a set of weather sensors is to be installed every 40 km along the expressway network, which is corresponding to 2 sets for a jurisdiction of the road management office as shown below.

Figure 9.3 Illustration of Advanced Road Operation Using ITS



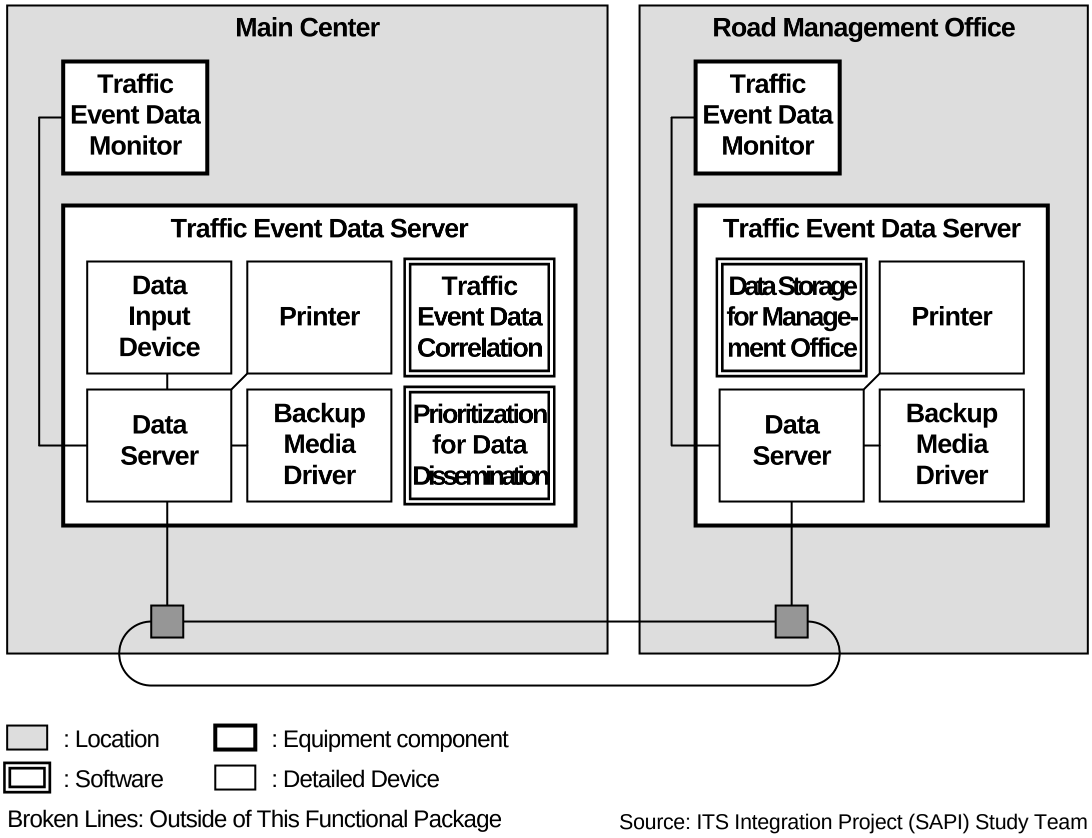
Source: ITS Integration Project (SAPI) Study Team

10. Traffic Event Data Management

10.1 Outline and System Architecture

This functional package allows the road operators to conduct traffic control, restriction and information dissemination on the expressway, in the unified/integrated form, by categorizing the results acquired through emergency telephones, mobile radio communication, event detection, traffic analysis and weather monitoring and by organizing them as the data of traffic events corresponding to the place/time of occurrence and the priority.

Figure 10.1 System Architecture for Traffic Event Management



Source: ITS Integration Project (SAPI) Study Team

10.2 Enforcement of Traffic Restriction

One of important activities of the road operator is to enforce appropriate traffic restriction responding to the occurrences of traffic events.

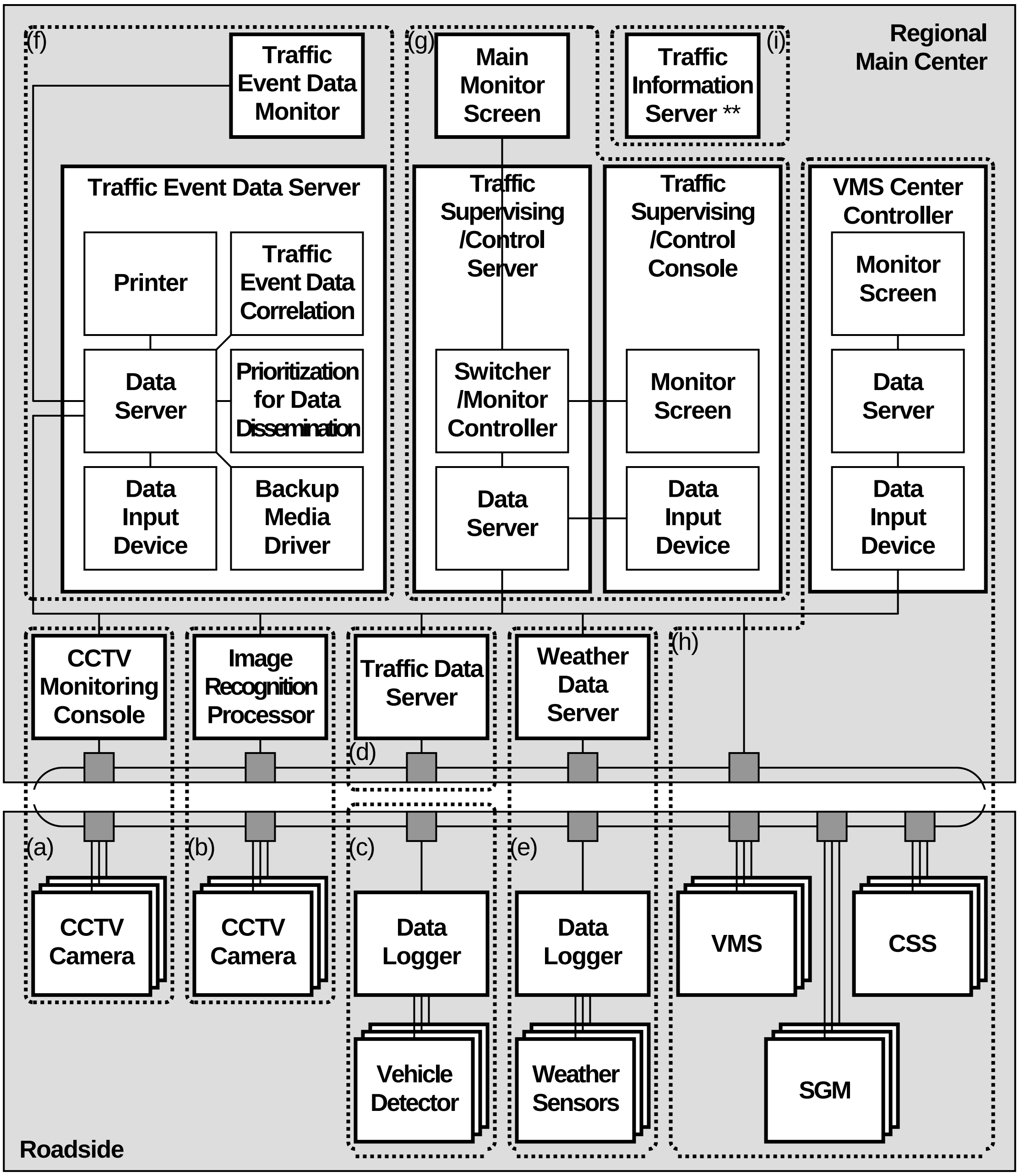
Criteria and levels of enforcing traffic restriction in the case of bad weather mentioned in the foregoing chapter. Levels of enforcing traffic restriction in case of an incident or a construction work depends on each condition.

10.3 System for Traffic Information/Control

Traffic information/control is to be conducted totally from the Regional Main Center using the following functional packages:

(a) CCTV Monitoring
(b) Event Detection (by Image)
(c) Vehicle Detection
(d) Traffic Analysis
(e) Weather Monitoring
(f) Traffic Event Data Management
(g) Traffic Supervision
(h) VMS Indication
(i) Traffic Information

Figure 10.2 System for Traffic Information/Control



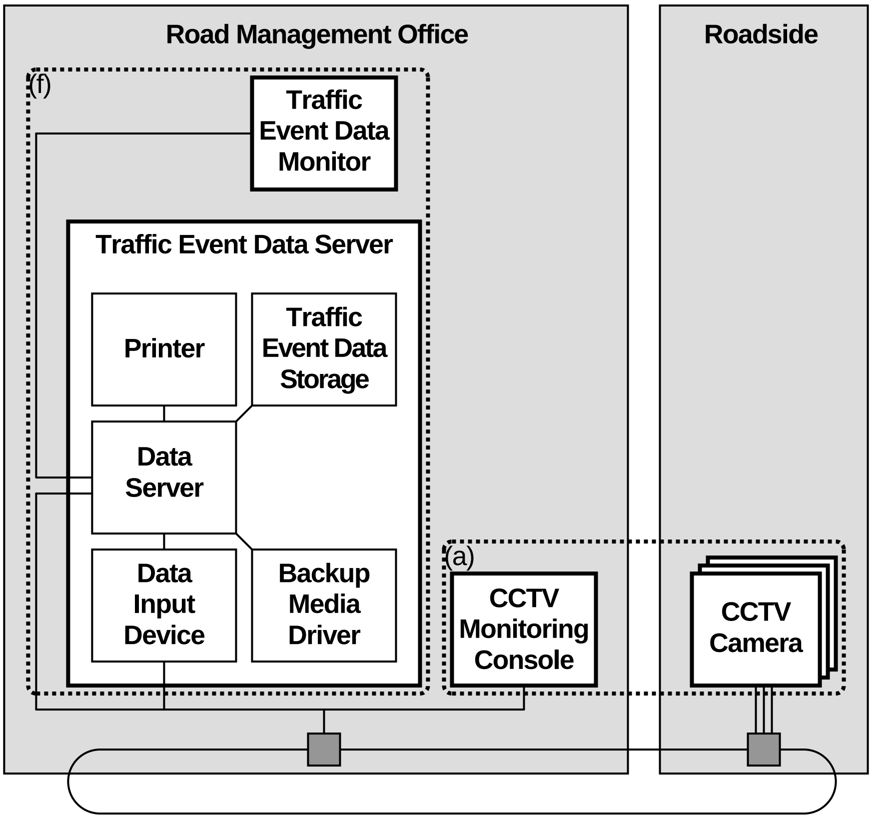
Note, [dotted box]: Functional package, ** : Protected by a firewall for connecting to the Internet and stored data in it is to be copied from the traffic event data server.

Source: ITS Integration Project (SAPI) Study Team

Consequently, vehicle detectors, weather sensors and VMSs need to be controlled directly from the Regional Main Center for integrating traffic information dissemination.

A part of center equipment is to be installed in the road management offices for expressway operation. CCTV cameras are to be controlled and the traffic event data are to be input from the road management office as well for handling and clearing incidents. The traffic event data can be input from the road management office; however, prioritisation of the traffic event data is to be done in the Regional Main Center and the result is to be sent directly to the VMS, SGM or CSS.

Figure 10.3 System for Traffic Information/Control



Note: : Functional package

Source: ITS Integration Project (SAPI) Study Team

10.4 Definition of Traffic Events

Incidents and other affairs on the expressway network need to be segmentalized as the traffic events for the traffic information/control. Definitions of the traffic events are shown in the table in the following page:

Table 10.1 Definition of Traffic Events including Correlations

Category	Traffic Event		Definition	Traffic Event to be Correlated												
Special Event	Special Event		Special event which may prevent vehicle traffic	X	X	X	X	X	X	X	X	X	X	X	X	X
Incident	Traffic Accident		Serious traffic accident	X	X	X	X	X	X	X	X	X	X	X	X	X
	Incident in Tunnel		Incident in tunnel including fire	X	X	X	X	X	X	X	X	X	X	X	X	X
	Reverse Driving		Vehicle driven in the reverse direction	X	X	X	X	X	X	X	X	X	X	X	X	X
	Broken-down Vehicle		Vehicle stopping on the road	X	X	X	X	X	X	X	X	X	X	X	X	X
	Left Obstacle		Object * on the road which may prevents vehicle traffic	X	X	X	X	X	X	X	X	X	X	X	X	X
	Natural Disaster		Natural disaster which may prevent vehicle traffic	X	X	X	X	X	X	X	X	X	X	X	X	X
	Vandalism		Wilful destruction of facilities or obstruction to traffic on the road	X	X	X	X	X	X	X	X	X	X	X	X	X
Construction Work	Construction Work		Construction work which may prevent vehicle traffic	X	X	X	X	X	X	X	X	X	X	X	X	X
Bad Weather	Heavy Rain	1	Heavy rain more than 40 mm/h**	X	X	X	X	X	X	X	X	X				
		2	Heavy rain more than 20 mm/h**	X	X	X	X	X	X	X					X	
		3	Heavy rain more than 10 mm/h**	X	X	X	X	X	X	X						X
	High Wind	1	High wind more than 25 m/sec** on average	X	X	X	X	X	X	X	X	X				
		2	High wind more than 20 m/sec** on average	X	X	X	X	X	X	X					X	
		3	High wind more than 10 m/sec** on average	X	X	X	X	X	X	X						X
	Dense Fog	1	Dense fog with visibility less than 50 m**	X	X	X	X	X	X	X	X	X				
		2	Dense fog with visibility less than 100 m**	X	X	X	X	X	X	X					X	
		3	Dense fog with visibility less than 200 m**	X	X	X	X	X	X	X						X
	High Temperature		High temperature more than 40 degrees C**													
Traffic Congestion	Congestion on Trough Lanes	1	VS continuously slower than 40 km/h*** on av. with VQ longer than 4 km													
		2	VS continuously slower than 40 km/h*** on av. with VQ longer than 2 km													
		3	VS continuously slower than 40 km/h*** on av. with VQ longer than 1 km													
	Crowdedness on Trough Lanes		VS slower than 50 km/h*** on av. with no or short VQ													
	Congestion at Exit	1	VS continuously slower than 40 km/h*** on av. with VQ longer than 4 km at exit													
		2	VS continuously slower than 40 km/h*** on av. with VQ longer than 2 km at exit													
		3	VS continuously slower than 40 km/h*** on av. with VQ longer than 1 km at exit													
Traffic Restriction	Entry Closure		Restriction to stop inflow traffic at entrance													
	Closure		Restriction to stop traffic on through lanes													
	Exit Closure		Restriction to stop traffic at exit													
	Lane Closure		Restriction to stop through traffic partially on some lanes													
	Speed Limitation	1	Restriction to limit the fastest vehicle speed less than 50 km/h													
		2	Restriction to limit the fastest vehicle speed less than 80 km/h													

Note: VS: Vehicle speed, VQ : Vehicle queueing, * : Excluding vehicles, ** : Specific definition is shown Table 9.2, *** : Specific definition is shown Table 8.1.

Source: ITS Integration Project (SAPI) Study Team

10.5 Correlation between Traffic Events

The correlated traffic events in the table below are to be generated by the software "Traffic Event Data Correlation" mainly for indication on VMS.

Table 10.2 Correlated Traffic Event for Indication

Traffic Event	Data	Correlated Traffic Event for Indication																		
Special Event	M																			
Traffic Accident	M																			
Incident in Tunnel	M																			
Reverse Driving	M																			
Broken-down Vehicle	M																			
Left Obstacle	M																			
Natural Disaster	M																			
Vandalism	M																			
Construction Work	M																			
Heavy Rain 1	A																			
Heavy Rain 2	A																			
Heavy Rain 3	A																			
High Wind 1	A																			
High Wind 2	A																			
High Wind 3	A																			
Dense Fog 1	A																			
Dense Fog 2	A																			
Dense Fog 3	A																			
High Temperature	A																			
Emergency 1	M											X	X						X
Emergency 2	M																X	X	
Bad Weather 1	M				X			X			X									
Bad Weather 2	M		X	X		X	X		X	X										
Warning 1	M											X			X	X	X			
Warning 2	M											X	X	X	X	X	X	X	X	X
Warning 3	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Warning 4	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Congestion on TL	M		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Congestion at Exit	M		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Entry Closure	M				X			X			X	X	X	X	X	X	X	X	X	X
Closure	M				X			X			X	X	X	X	X	X	X	X	X	X
Exit Closure	M											X	X	X	X	X	X	X	X	X
Lane Closure	M											X	X	X	X	X	X	X	X	X
Speed Limitation 1	M			X			X			X		X	X	X	X	X	X	X	X	X
Speed Limitation 2	M		X			X			X			X	X	X	X	X	X	X	X	X

Note: TL: Through lanes, M: Manually input, A: Automatically generated.

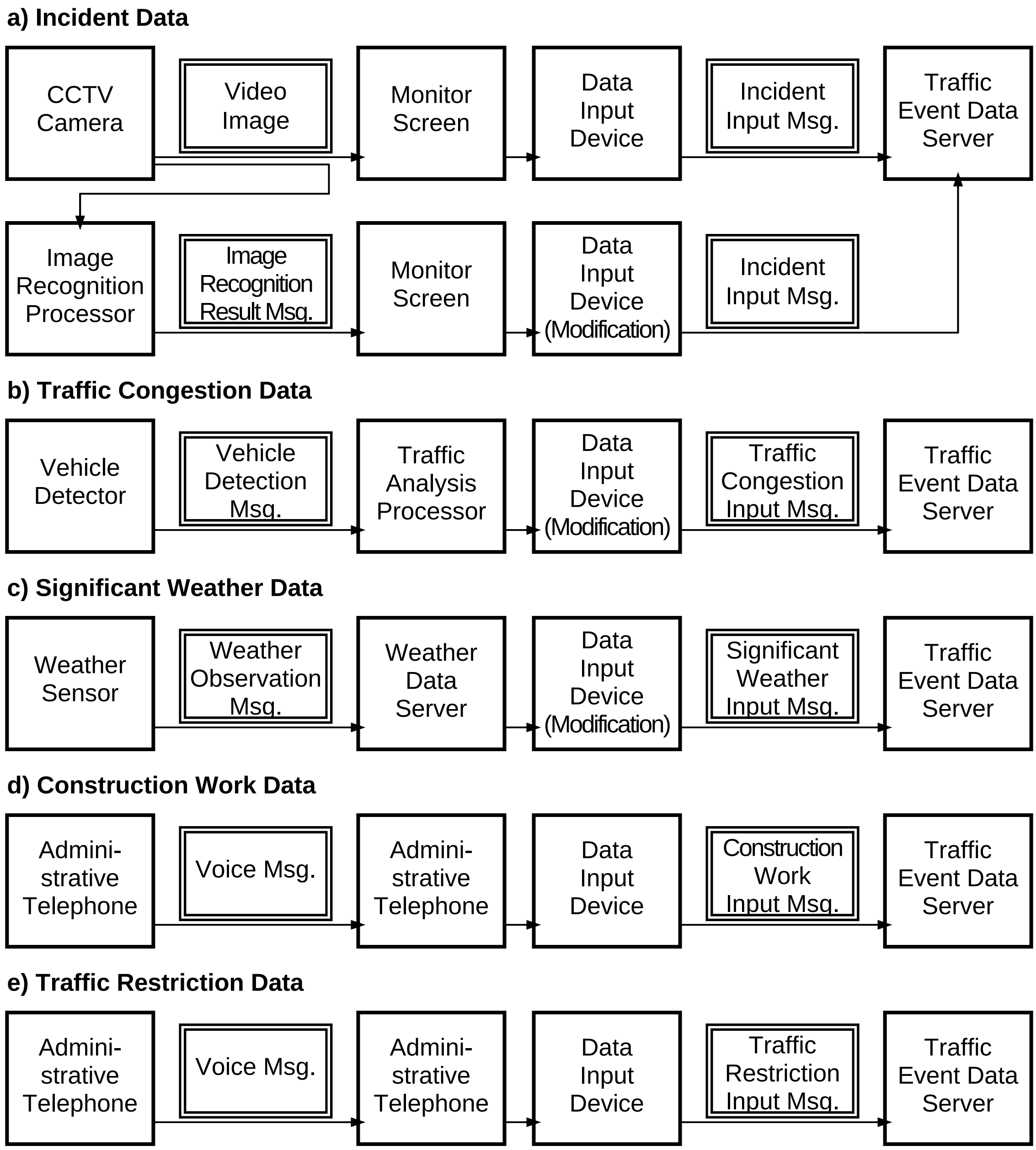
Source: ITS Integration Project (SAPI) Study Team

10.6 Data Set for Traffic Events

Traffic event data can be categorized into the following five and the flows of message exchange for generating them can be illustrated as shown in the figure below.

- Incident
- Traffic congestion
- Significant weather
- Construction work
- Traffic restriction

Figure 10.3 Major Message Exchanges for Generating Traffic Event Data



Source: ITS Integration Project (SAPI) Study Team

Through the message exchange the traffic event data shown in the following table are to be generated and stored in the traffic event data server.

Table 10.3 Data Sets/Elements in Generated Traffic Event Data

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Image Recognition Result Data Set <G - Image Processor>	Road Management Office ID	INT*	4	1	When an event occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Image Recognition Result Status	INT*	2	1		
	Video Image Address	TXT	60	1		
	Date/Time	Datetime	≥14	1		
Incident Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Roadside Equipment ID	INT*	4	1		
	Incident Status	INT*	2	1		
	Date/Time	Datetime	≥14	1		
Vehicle Detection Data Set <G - Vehicle Detector>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Cumulative Number of Vehicles	INT*	4	1		
	Vehicle Speed	FLOAT	5	N		
	Vehicle Length	FLOAT	4			
	Date/Time	Datetime	≥14	1		
Traffic Congestion Data Set <G - Traffic Analysis Processor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Cumulative Number of Vehicles	INT*	4	1		
	Average Vehicle Speed	INT*	4	1		
	Traffic Congestion Status	INT*	2	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Date/Time	Datetime	≥14	1		
Construction Work Data Set <I - Server>	Road Management Office ID	INT*	4	1	When a construction work is scheduled	1 month after end of construction
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Construction Work Status	INT*	2	1		
	Number of document	TXT	20	1		
	Permission Date	TXT	8	1		
	Date/Time Begin	TXT	≥14	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		
Traffic Restriction Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month after end of restriction
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Construction Work Status	INT*	2	1		
	Permission Date	TXT	8	1		
	Date/Time Begin	TXT	≥14	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

From the traffic event data above, data set/elements for traffic event dissemination are to be generated automatically and stored in the traffic event data server, which is shown in the following table.

Table 10.4 Data Set/Elements for Traffic Event Dissemination

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Traffic Event Data Set <G/C - Server>	Traffic Event Data ID	INT	8	1	When an event occurs	1 year
	Road Management Office ID	INT*	4	1		
	Road Section ID	INT*	4	1		
	Road Link ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Traffic Event Category ID	INT*	4	1		
	Traffic Event Class ID	INT*	4	1		
	Causal Traffic Event Data ID	INT	8	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Input Person	TXT	32	1		
	Event Status	TXT	4	1		
	Video Image address	TXT	60	1		
	Main Center Check Status	INT*	4	1		
	Road Management Office Check Status	INT*	4	1		
	Status of Traffic Event	INT*	2	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

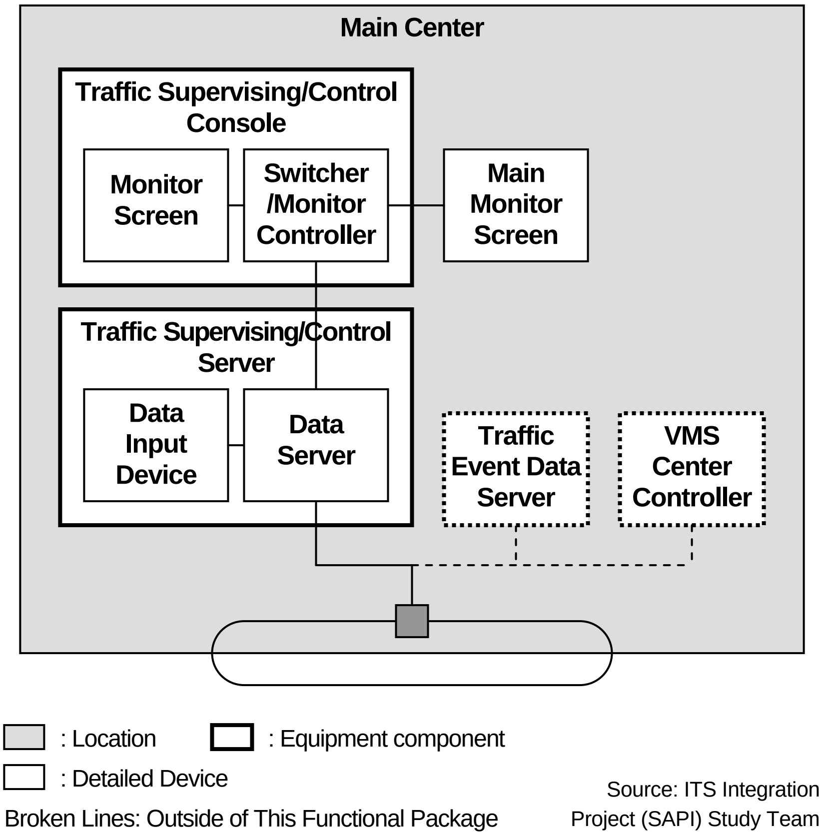
Source: ITS Integration Project (SAPI) Study Team

11. Traffic Supervision

11.1 Outline and System Architecture

This functional package allows the road operators at the Main Center and road management office to supervise totally and visually the current traffic conditions on the expressways and the information organized as traffic events

Figure 11.1 System Architecture for Traffic Supervision

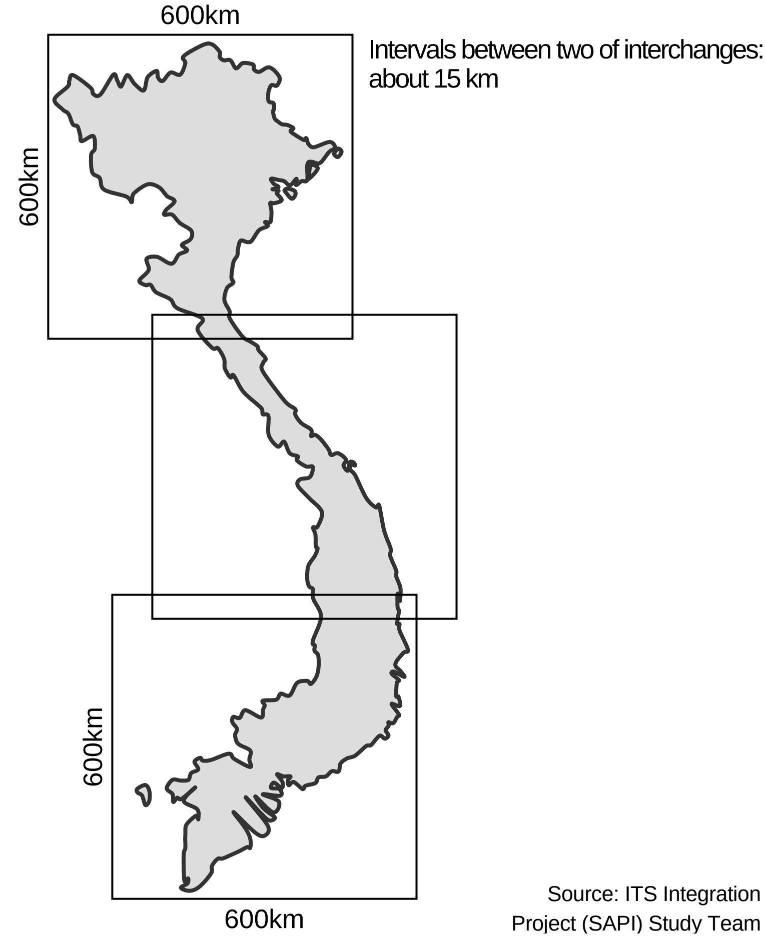


Source: ITS Integration Project (SAPI) Study Team

11.2 Required Functions/Performance of Main Monitor Screen

The scope of the main monitor screens in the 3 Main Centers is to be as wide as about 600 km x 600 km on the nationwide scale as shown below.

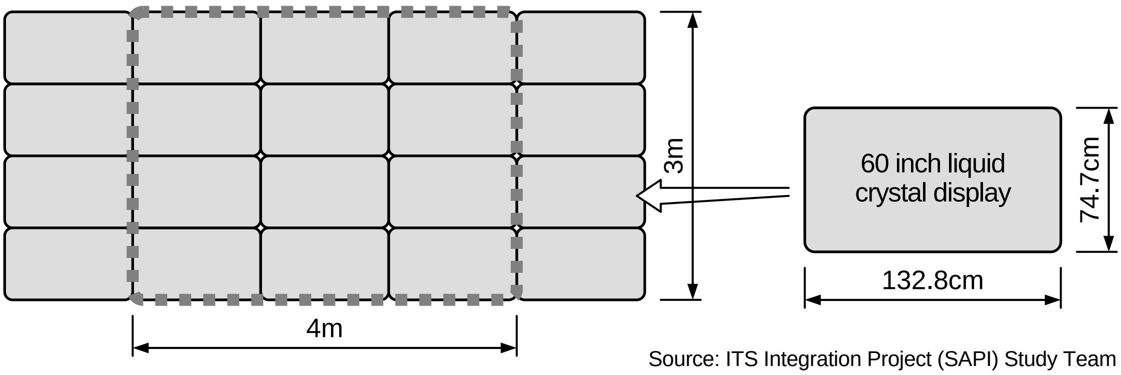
Figure 11.2 Required Size of Required Main Monitor Screen



Source: ITS Integration Project (SAPI) Study Team

On the other hand, the interval of interchanges, which can be assumed as 15km, needs to be indicated longer than 10 cm on the main monitor screen in order to show the traffic conditions and restrictions between interchanges. Hence, the main monitor screen's side should be about 4 m.

Figure 4.2 Structure of Main Monitor Screen



Source: ITS Integration Project (SAPI) Study Team

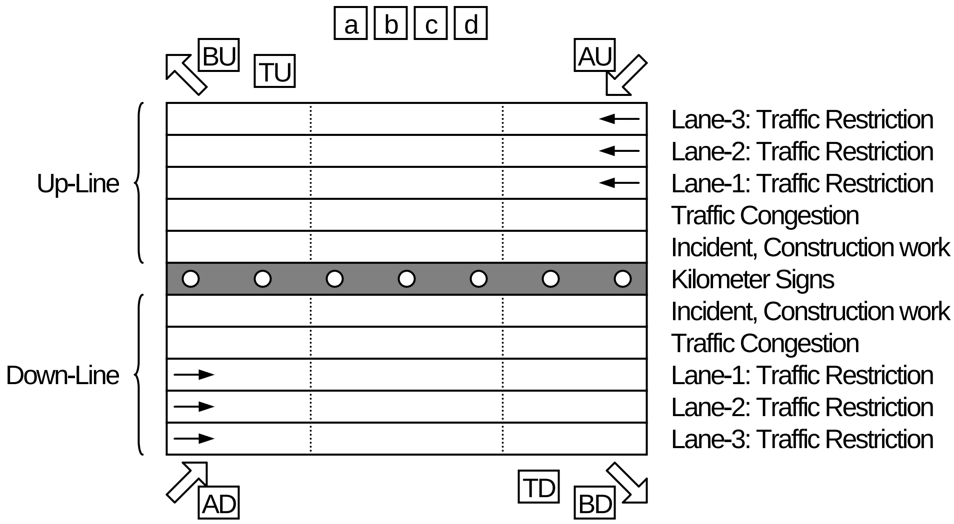
As the expressway network will be patterned on the main monitor screen, the height of patterned network can be compressed to about 75% as compared to the width. Therefore, the main monitor screen can be constructed by combining 60-inch liquid crystal display as shown below.

11.3 Indication Items on Main Monitor Screen

On the main monitor, the expressway network under the jurisdiction is to be divided into sections between two of interchanges, junctions, sections or tollgates and to be indicated with kilometer-posts. In the displayed expressway network or in appropriate places, the following information needs to be indicated.

- Conditions of incident occurrence
- Conditions of traffic congestion
- Conditions of significant weather
- Conditions of conducting construction works
- Conditions of enforcing traffic restriction.

Figure 11.3 Indication Items on Main Monitor Screen (for Each Section)



a: Conditions of heavy rain
b: Conditions of high wind
c: Conditions of dense fog
d: Conditions of high temperature

Conditions of significant weather

TU: Conditions of traffic congestion on the up-line (1 or more points)
TD: Conditions of traffic congestion on the down-line (1 or more points)
AU: Indication of VMS short of entrance on the up-line
BU: Indication of VMS short of exit/junction on the up-line
AD: Indication of VMS short of entrance on the down-line
BD: Indication of VMS short of exit/junction on the down-line

Source: ITS Integration Project (SAPI) Study Team

Table 11.1 Indicating Methods on Main Monitor Screen

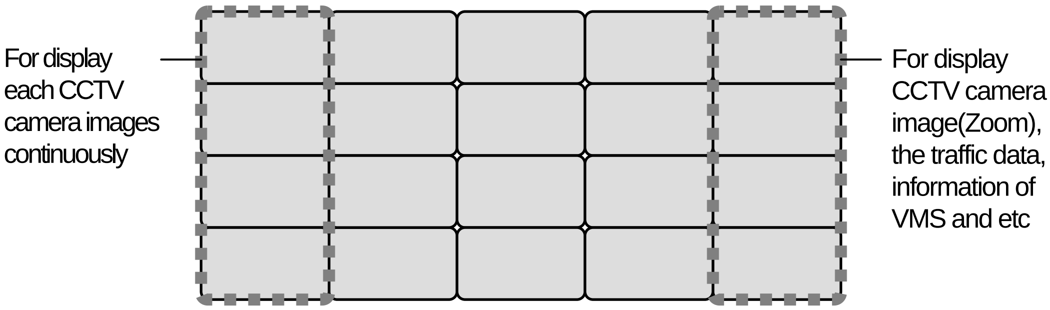
Traffic Event Category	Traffic Event Class	Indicating Methods
Incident	Traffic Accident	1: R (BLK), 2: Y (BLK), 3: G (BLK)
	Broken-down Vehicle	Y
	Left Obstacle	Y
	Reversing Vehicle	Y
	Vandalism	Y
	Natural Disaster	R
Traffic Congestion	Congestion	R
	Crowdedness	Y
Significant Weather	Heavy Rain	1: R, 2: Y, 3: G
	High Wind	1: R, 2: Y, 3: G
	Dense Fog	1: R, 2: Y, 3: G
	High Temperature	G
Construction Work	Construction Work	G
Traffic Restriction	Closure	R
	Entry Closure	R
	Lane Closure	R
	Speed Limitation	Y
	Warning Information	G

Note, R: Red, Y: Yellow, G: Green, BLK: Blinking

Source: ITS Integration Project (SAPI) Study Team

In addition, in consideration of the display of CCTV camera images, traffic data, information of VMS into the Main Monitor Screen, example of main monitor screens should be as shown in the following figure.

Figure 11.4 Structure of Main Monitor Screen



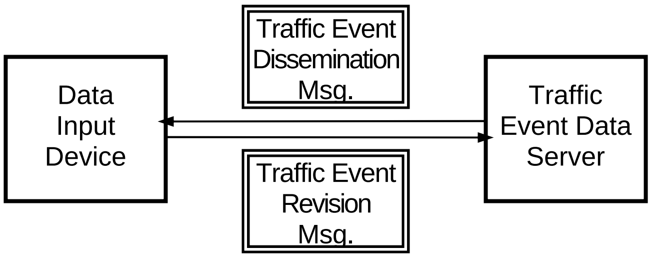
Source: ITS Integration Project (SAPI) Study Team

Main monitor screen shall be capable action like one display. CCTV camera images, Traffic Data, the information of VMS, the expressway network are shown at wherever on the display by using moving the window of each information.

11.4 Data Set for Traffic Supervision

Major Message Exchanges for checking/revising traffic event data is shown in the following figure.

Figure 11.5 Major Message Exchanges for Checking/Revising Traffic Event Data



Source: ITS Integration Project (SAPI) Study Team

A traffic event data dissemination message is to be sent to and indicated on the data input device. The data elements in the indicated message are to be checked and revised by an operator, and to be sent back to and stored in the traffic event data server.

Table 11.2 Data Set/Elements in Traffic Event Dissemination/Revision Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Traffic Event Data Set <G/C - Server>	Traffic Event Data ID	INT	8	1	When an event occurs	1 year
	Road Management Office ID	INT*	4	1		
	Road Section ID	INT*	4	1		
	Road Link ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Traffic Event Category ID	INT*	4	1		
	Traffic Event Class ID	INT*	4	1		
	Causal Traffic Event Data ID	INT	8	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Input Person	TXT	32	1		
	Event Status	TXT	4	1		
	Video Image address	TXT	60	1		
	Main Center Check Status	INT*	4	1		
	Road Management Office Check Status	INT*	4	1		
	Status of Traffic Event	INT*	2	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

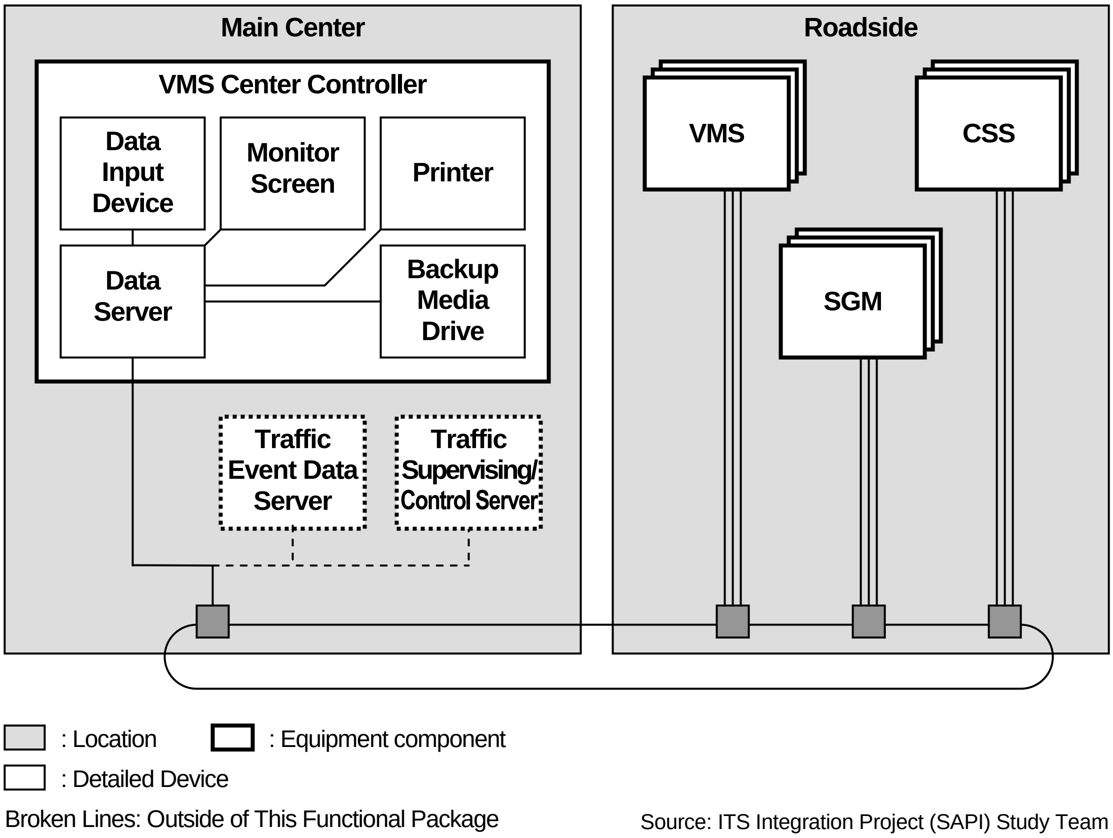
Source: ITS Integration Project (SAPI) Study Team

12. VMS Indication

12.1 Outline and System Architecture

This functional package allows the road operators to provide road users on the expressways with the information organized as traffic events by using VMS (Variable Message Sign) installed at the place short of entrances, exits, tollgates, junctions and tunnels.

Figure 12.1 System Architecture for VMS Indication



Source: ITS Integration Project (SAPI) Study Team

12.2 Equipment for Indicating Information on Expressway

(1) VMS

VMS allows the road operators to provide road users on the expressways with traffic event information. VMS shall disseminate the traffic situation in the forward direction for road users.

Therefore, it is located near where the users will select and decide their forward direction, such as before merging point where the artery road enters the expressway, before diverging point on the expressway, before Toll barrier on the expressway, or on the main route between Interchanges.

(2) SGM

SGM allows the road operators to provide road users on the expressways with traffic event information. SGM shall disseminate the traffic situation in the forward direction for road users.

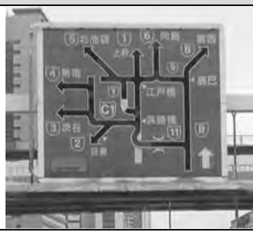
When the road network is complex, it will be installed before the connection to a complex road network. Therefore, it would be located before the junction between inter-city and urban expressway on the main route of inter-city expressway.

(3) CSS

CSS allows the road operators to dynamicaly provide road users on the expressways with spped limit information. CSS shall disseminate the speed limit in the forward direction for road users in case dense fog or heavy rains occurs, and the regulatory speed limit needs to be changed.

The regulatory speed would be applied to the section between Interchanges. Therefore, it is located after the merging point on expressway, on the main route between the Interchanges.

Table 12.1 Reference Data for VMS, SGM and CSS

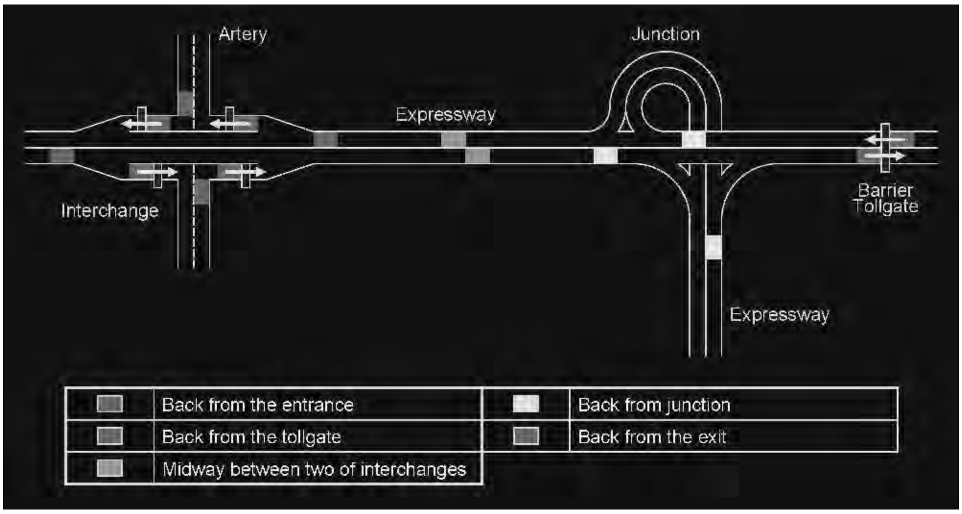
Name	Variable Message Sign	Simple Graphical Message	Changeable Speed limit Sign
Abbreviation	VMS	SGM	CSS
Appear-ance			
Function	Disseminate the Status of traffic and restrictions (such as traffic accidents and other occurrences) on the expressway using text.	Disseminate the Status of traffic and restrictions (such as traffic accidents and other occurrences) on the expressway using graphics.	Disseminate the speed limit, in case of dense fog and heavy rains, needs to change the regulatory speed.
Location	- Before merging point where the artery road enters the expressway - Before diverging point on the expressway - Before Toll barrier on the expressway - On the main road between the Interchanges.	- Before the junction between inter-city and urban expressway on the main route of inter-city expressway.	- After the merging point on expressway - On the main road between the Interchanges

Source: ITS Integration Project (SAPI) Study Team

12.3 Location and Contents to be Indicated on VMS

VMS allows road operators to disseminate traffic information to drivers on the road mainly for assisting their route selection. For this purpose, VMS is to be installed in front of the diversing point where drivers select the direction. VMS arrangement criteria are defined responding to the locations of sections for information dissemination shown in the figure below.

Figure 12.2 Location of Sections for Information Dissemination



Source: ITS Integration Project (SAPI) Study Team

(1) Entrance Gate

Entrance VMS shall be installed in the place on the access road to the expressway within 100m back from the diverging point of entrance gate. The distance to the diverging point is longer than the length of deceleration lane. However, considering the fact that the access road is outside of the expressway, VMS can be installed in the nearer place to the expressway depending on the conditions of land aquisition.

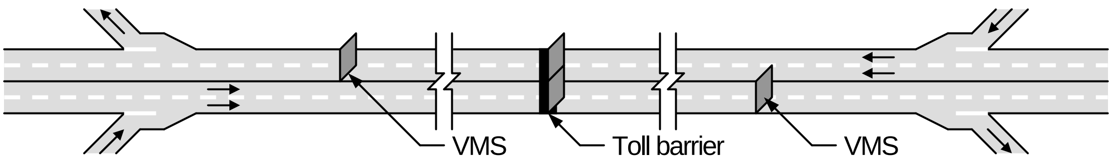
(2) Exit Gate

Exit VMS shall be installed in the place on the expressway about 200m back from the diverging point of exit gate. The distnace to the diverging point is nearly equal to the length of deceleration lane including taper length. It is consideration to be capable change direction in safe when the exit from the interchange by the information of VMS.

(3) Barrier Tollgate and Mid-point (in Future: Next Stage)

Additional VMS shall be installed at the barrier tollgate and at the mid-point between a pair of neighboring interchanges on the through lanes, if necessary in the future: the next stage.

Figure 12.3 VMS Installation at Mid-point between a Pair of Interchanges

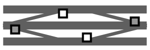
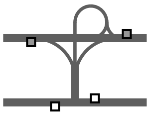
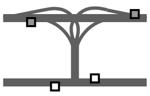
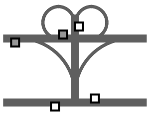
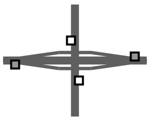
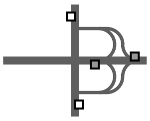
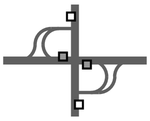
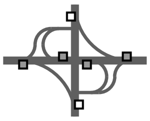
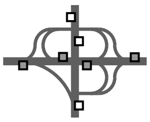
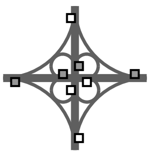
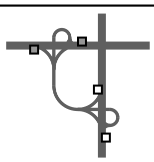


Source: ITS Integration Project (SAPI) Study Team

(4) Interchange

VMS is to be installed around interchange as shown below:

Table 12.2 Arrangement of VMS at Interchange

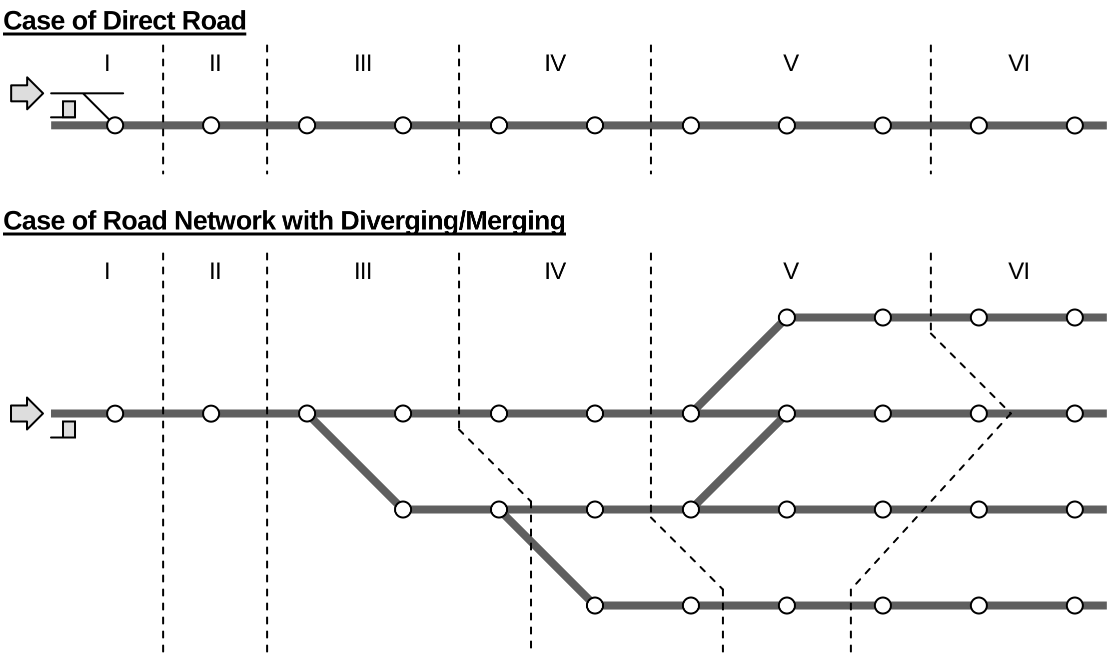
Type of Interchange/ Arrangement of VMS		Number of Entrance	Number of Exit	Number of VMS around Interchange
Diamond		2	2	4
Trumpet		2	2	4
Directional T		2	2	4
Half Clover		2	2	4
Diamond		2	2	4
Folded Diamond		2	2	4
Partial Cloverleaf		2	2	4
6 Ramp Partial Cloverleaf		2	4	6
7 Ramp Partial Cloverleaf		3	4	7
Cloverleaf		4	4	8
Double Trumpet		2	2	4

Source: ITS Integration Project (SAPI) Study Team

12.4 Prioritisation on Traffic Event for VMS Indication

Priority on the traffic event for VMS indication is to be generated by the software "Prioritisation for Data Dissemination".

Figure 12.4 Priority on Traffic Event for VMS Indication



Traffic Event	Designated VMS	Ordinary VMS					
		I	II	III	IV	V	VI
Emergency 1		$F_{01}(p_C,p_D,p_V)$ →					
Emergency 2	Tunnel VMS	$F_{02}(p_C,p_D,p_V)$ →					
Bad Weather 1		$F_{03}(p_C,p_D,p_V)$ →					
Bad Weather 2		$F_{04}(p_C,p_D,p_V)$ →					
Warning 1		$F_{05}(p_C,p_D,p_V)$ →					
Warning 2		$F_{06}(p_C,p_D,p_V)$ →					
Warning 3		$F_{07}(p_C,p_D,p_V)$ →					
Warning 4		$F_{08}(p_C,p_D,p_V)$ →					
Congestion on TL		$F_{09}(p_C,p_D,p_V)$ →					
Congestion at Exit	Exit VMS	$F_{10}(p_C,p_D,p_V)$ →					
Entry Closure	Entrance VMS	$F_{11}(p_C,p_D,p_V)$ →					
Closure	Exit VMS	$F_{12}(p_C,p_D,p_V)$ →					
Exit Closure	Exit VMS	$F_{13}(p_C,p_D,p_V)$ →					
Lane Closure		$F_{14}(p_C,p_D,p_V)$ →					
Speed Limitation 1		$F_{15}(p_C,p_D,p_V)$ →					
Speed Limitation 2		$F_{16}(p_C,p_D,p_V)$ →					

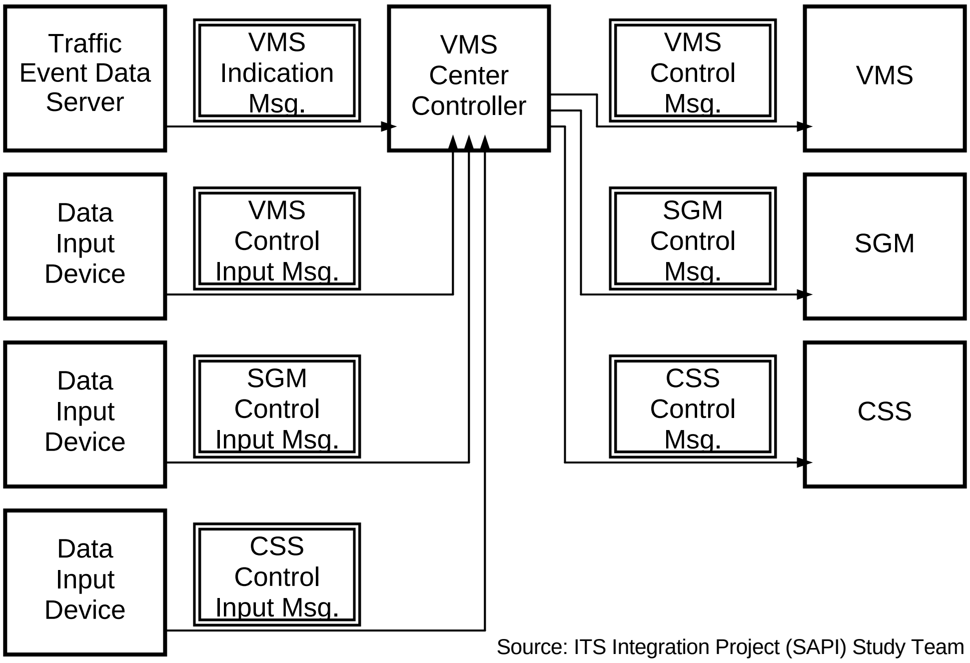
Note: TL: Through lanes.
F_{ii}: Function for generating priority on traffic event for indicating it on VMS in the zones of I, II, III, IV, V, VI
p_C: Parameters for priority depending on the kind of correlated traffic events
p_D: Parameters for priority depending on the distance from VMS to the site of traffic event
p_V: Parameters for priority depending on the traffic volume that will stumble across the traffic event

Source: ITS Integration Project (SAPI) Study Team

12.5 Data Set for VMS Indication

Data to be displayed on VMS is generated through the message exchanges shown below.

Figure 12.5 Major Message Exchanges for Generating Data for Indication



Source: ITS Integration Project (SAPI) Study Team

The details of these messages are to be mentioned in this section. However, in the Master Plan, SGM is defined to be installed in the later stages, so hereby the details of the messages only for VMS and CSS are shown in the following.

Table 12.3 Data Set/Elements for VMS Indication Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
VMS Check /Indication Data Set <G/C - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month
	Roadside Equipment ID	INT*	4	1		
	Traffic Event Class ID	INT*	4	1		
	Place ID	INT*	4	1		
	Place Name	TXT	28	1		
	Traffic Event ID	INT	8	1		
	Traffic Event Name	TXT	20	1		
	Causal Place ID	INT*	4	1		
	Causal Place Name	TXT	28	1		
	Date/Time	Datetime	≥14	1		
VMS Input/Indication Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month
	Roadside Equipment ID	INT*	4	1		
	Traffic Event Class ID	INT*	4	1		
	Place ID	INT*	4	1		
	Place Name	TXT	28	1		
	Traffic Event ID	INT	8	1		
	Traffic Event Name	TXT	20	1		
	Causal Place ID	INT*	4	1		
	Causal Place Name	TXT	28	1		
	Free Text	TXT	var	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

Table 12.4 Data Set/Elements for CSS Indication Message

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
CSS Indication Data Set <G/C - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month
	Roadside Equipment ID	INT*	4	1		
	Speed Limit	INT*	3	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

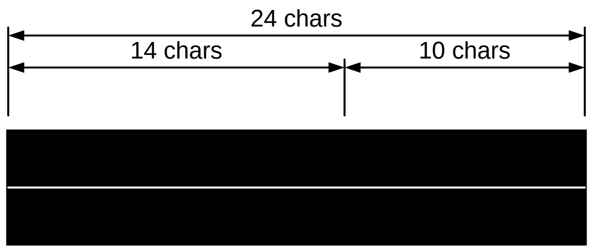
12.6 Indication Layout on VMS

(1) Standard VMS

Standard VMS is composed of two lines to indicate information on board in the consideration of the technical and economic issues in the case installed on the expressway.

- A name of the place where a traffic event of heist priority occurs and the traffic event are to be indicated within 14 and 10 characters each on the first line
- A subsidiary traffic event such as traffic restriction is to be indicated within 10 characters on the second line

Figure 12.6 Indication Layout of Standard VMS



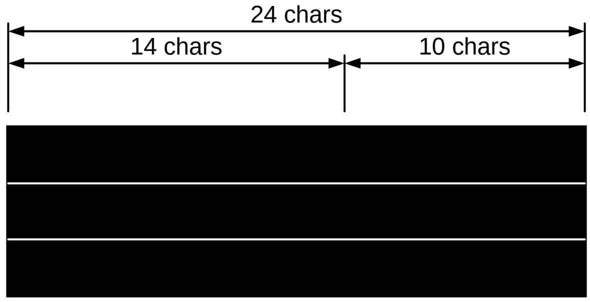
Source: ITS Integration Project (SAPI) Study Team

(2) Large VMS

Standard VMS is composed of two lines to indicate information on board in the consideration of the technical and economic issues in the case installed on the expressway.

- A name of the place where a traffic event of heist priority occurs and the traffic event are to be indicated within 14 and 10 characters each on the first line
- A subsidiary traffic event such as traffic restriction is to be indicated within 10 characters on the second line
- A name of the place where a traffic event of second priority occurs and the traffic event are to be indicated within 14 and 10 characters each on the third line

Figure 12.7 Indication Layout of Large VMS



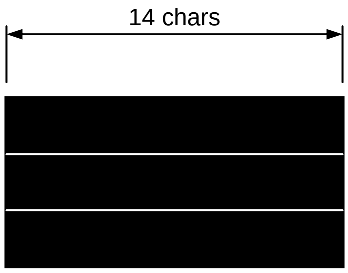
Source: ITS Integration Project (SAPI) Study Team

(3) VMS for Viaduct Section

VMS for viaduct section is composed of three lines to indicate information on board in the consideration of the structural conditions in the case installed at viaducts on the expressway.

- A name of the place where a traffic event of heist priority occurs is to be indicated within 14 characters on the first line
- The traffic event is to be indicated within 10 characters on the second line
- A subsidiary traffic event such as traffic restriction is to be indicated within 10 characters on the third line

Figure 12.8 Indication Layout of VMS for Viaducts Section



Source: ITS Integration Project (SAPI) Study Team

12.7 Traffic Events and Name of Place to be Indicated on VMS

The contents and the words are chosen to display on VMS need to be considered with the compatibility and suitable of technical and economical issues in VMS installing progress.

The contents and the words need be enough easy to understand and they also need can be shorten to be able to be display with two types of above VMS. With these requirements and with the collection data. This table is proposed as the referent dictionary for words which be shown on VMS.

Table 12.5 Traffic Events and Name of Place to be Indicated on VMS

No	English	Vietnamese	Abbreviation/ Indication
Traffic Event ≤ 10 characters			
1	Special Event	Sự kiện đặc biệt	Sk.Đặc biệt
2	Traffic Accident	Tai nạn giao thông	Tai nạn
3	Incident in Tunnel	Sự cố trong hầm	Sự cố
4	Reverse Driving	Xe đi ngược chiều	Xe Ng.Chiều
5	Broken-down Vehicle	Xe hỏng	Xe hỏng
6	Left Obstacle	Vật cản trên đường – Chướng ngại	Vật cản
7	Natural Disaster	Thiên tai	Thiên tai
8	Vandalism	Trang thiết bị đường bị phá hoại	ĐB.Phá hại
9	Construction Work	Công trường	C.Trường
10	Heavy Rain	Mưa lớn	Mưa lớn
11	High Wind	Gió mạnh	Gió mạnh
12	Dense Fog	Sương mù dầy	Sương dầy
13	High Temperature	Nhiệt độ cao	Nh.độ cao
14	Congestion on Through lane	Tắc trên làn cao tốc	Tắc đường
15	Crowdedness on Trough Lanes	Mật độ cao trên làn cao tốc	Mật độ cao
16	Congestion at Exit	Nghẽn tại lối ra	Tắc lối ra
17	Entry close	Đóng lối vào	Đóng-Vào
18	Closure	Đóng	Đóng
19	Exit Closure	Đóng lối ra	Đóng-Ra
20	Lane Closure	Đóng làn	Đóng làn
21	Speed Limitation	Giới hạn tốc độ	Giới hạn V

Location on Expressway ≤ 3 characters			
1	Expressway	Tên Đường Cao Tốc	CT
2	National Highway	Tên Quốc Lộ	QL.
3	Interchange	Nút giao khác mức	N
4	Junction	Nút giao cao tốc	NC
5	Entrance Gate	Lối vào đường cao tốc	VCT
6	Exit Gate	Lối ra đường cao tốc	RCT
7	Tollgate	Trạm Thu Phí	TTP
8	Parking Area	Khu vực có thể đỗ xe	PA
9	Rest Area	Trạm dừng nghỉ	T.N
10	Bus Station	Vị trí Trạm xe buýt	XB
11	Petrol Station	Trạm xăng	P
12	Medical Station	Trạm y tế - Bệnh viện	Ytế
13	Rescue Station	Trạm cứu hộ	C.H
Name of Place ≤ 14 character			
Expressway			
1	Expressway Ring Road No3	Cao Tốc Vành đai 3 Hà Nội	CTVĐ3
2	Expressway 1A	Cao Tốc 1A (Pháp Vân – Ninh Bình)	CT1A
3	Expressway 1B	Cao Tốc 1B (Hà Nội – Lạng Sơn)	CT1B
4	Expressway 2	Cao Tóc 2 (Nội Bài – Lào Cai)	CT2
5	Expressway 3	Cao Tốc 3 (Hà Nội – Thái Nguyên)	CT3
6	Expressway 5	Cao Tốc 5 (Hà Nội – Hải Phòng)	CT5
7	Expressway 6B	Cao Tốc 6B (Láng – Hoà Lạc)	CT6B
National Highway			
1	National Highway No1	Quốc Lộ 1	QL1
2	National Highway No1A	Quốc Lộ 1A	QL1A
3	National Highway No2	Quốc Lộ 2	QL2
4	National Highway No2A	Quốc Lộ 2A	QL2A
5	National Highway No2B	Quốc Lộ 2B	QL2B
6	National Highway No3	Quốc Lộ 3	QL3
7	National Highway No5	Quốc Lộ 5	QL5
8	National Highway No6	Quốc Lộ 6	QL6
9	National Highway No10	Quốc Lộ 10	QL10
10	National Highway No18	Quốc Lộ 18	QL18
11	National Highway No21	Quốc Lộ 21	QL21

12	National Highway No23	Quốc Lộ 23	QL23
13	National Highway No32	Quốc Lộ 32	QL32
14	National Highway No32C	Quốc Lộ 32C	QL32C
15	National Highway No38	Quốc Lộ 38	QL38
Interchange			
1	Trung Hoa IC	Nút giao Trung Hòa	N.Trung Hòa
2	Thanh Xuan IC	Nút giao Thanh Xuân	N.Thanh Xuân
3	Phap Van IC	Nút giao Pháp Vân	N.Pháp Vân
4	Tam Trinh IC	Nút giao Tam Trinh	N.Tam Trinh
5	Linh Nam IC	Nút giao Lĩnh Nam	N. Lĩnh Nam
6	North Thanh Tri IC	Nút giao Bắc Thanh Trì	N. B.Thanh Trì
7	NH5 IC	Nút giao Quốc Lộ 5 – Sài Đồng	N. QL5-S.Đồng
8	Dai Mo IC	Nút giao Đại Mỗ	N. Đại Mỗ
9	Dong Mo IC	Nút giao Đồng Mô	N. Đồng Mô
10	Phu Cat IC	Nút giao Phú Cát	N. Phú Cát
11	Hoa Lac IC	Nút giao Hòa Lạc	N. Hòa Lạc
12	Khe Hoi IC	Nút giao Khê Hội	N. Khê Hội
13	Van Diem IC	Nút giao Vạn Điểm	N. Vạn Điểm
14	Dai Xuyen IC	Nút giao Đại Xuyên	N. Đại Xuyên
15	Vuc Vong IC	Nút giao Vực Vòng	N. Vực Vòng
16	Liem Tuyen IC	Nút giao Liêm Tuyền	N. Liêm Tuyền
17	Cao Bo IC	Nút giao Cao Bồ	N. Cao Bồ
18	South Bac Ninh IC	Nút giao Nam Bắc Ninh	N.N.Bắc Ninh
19	Lien Bao IC	Nút giao Liên Bảo	N. Liên Bảo
20	Tien Son IC	Nút giao Tiên Sơn	N. Tiên Sơn
21	Tu Son IC	Nút giao Từ Sơn	N. Từ Sơn
22	Den Do IC	Nút giao Đền Đô	N. Đền Đô
23	Thang Long-Noi Bai IC	Nút giao Thăng Long -Nội Bài	N.TL-Nội Bài
24	NH3-Phu Lo IC	Nút giao Quốc lộ 3-Phủ Lỗ	N.QL3-Phủ Lỗ
25	PR295-Cho IC	Nút giao Tỉnh lộ 295-Chờ	N.TL295-Chờ
26	Binh Xuyen IC	Nút giao Bình Xuyên	N. Bình Xuyên
27	NH2B-Kim Long IC	Nút giao Quốc lộ 2B-Kim Long	N. QL2B-KL
28	PR305-Van Quan IC	Nút giao Tỉnh lộ 305-Văn Quán	N. TL305-VQ
29	NH2-Phu Ninh IC	Nút giao Quốc lộ 2-Phù Ninh	N.QL2-P.Ninh
30	NH32C-Sai Nga IC	Nút giao Quốc lộ 32C-Sai Nga	N. QL32C-SN

Junction			
1	Phap Van Junction	Nút Cao tốc Pháp Vân	NC.Pháp Vân
Tollgate			
1	Linh Nam TG	Trạm thu phí Lĩnh Nam	TTP Lĩnh Nam
2	Phuong Nhi TG	Trạm thu phí Phương Nhị	TTP P.Nhị
3	Khe Hoi TG	Trạm thu phí Khê Hội	TTP Khê Hội
4	Van Diem TG	Trạm thu phí Vạn Điểm	TTP Vạn Điểm
5	Dai Xuyen TG	Trạm thu phí Đại Xuyên	TTP Đại Xuyên
6	Vuc Vong TG	Trạm thu phí Vực Vòng	TTP Vực Vòng
7	Liem Tuyen TG	Trạm thu phí Liêm Tuyền	TTP Liêm Tuyền
8	Cao Bo TG	Trạm thu phí Cao Bồ	TTP Cao Bồ
9	Phuc Loi TG	Trạm thu phí Phúc Lợi	TTP Phúc Lợi
10	Ca Lo TG	Trạm thu phí Cà Lồ	TTP Cà Lồ
11	Tan Dan TG	Trạm thu phí Tân Dân	TTP Tân Dân
12	Binh Xuyen TG	Trạm thu phí Bình Xuyên	TTP Bình Xuyên
13	NH2B-Kim Long TG	Trạm thu phí Quốc lộ 2B-Kim Long	TTP QL2B-KL
14	PR305-Van Quan TG	Trạm thu phí Tỉnh lộ 305-Văn Quán	TTP TL305-VQ
15	NH2-Phu Ninh TG	Trạm thu phí Quốc lộ 2-Phù Ninh	TTP QL2-P.Ninh
16	NH32C-Sai Nga TG	Trạm thu phí Quốc lộ 32C-Sai Nga	TTP QL32C-SN
Parking Area			
Rest Area			
Bus Station			
Petrol Station			
Medical Station			
Rescue Station			

Airport			
1	Noi Bai Airport	Sân bay Nội Bài	SB.Nội Bài
2	Gia Lan Airport	Sân bay Gia Lâm	SB.Gia Lâm
Port			
1	Hai Phong Port	Cảng Hải Phòng	C.Hải Phòng
2	Lach Huyen Port	Cảng Lạch Huyện	C.Lạch Huyện
City/District			
1	Bac Ninh City	Thành phố Bắc Ninh	TP.Bắc Ninh
2	Ha Noi Capital	Thành phố Hà Nội	TP.Hà Nội
3	Nam Dinh City	Thành phố Nam Định	TP.Nam Định
4	Ninh Binh City	Thành phố Ninh Bình	TP.Ninh Bình
5	Phu Ly City	Thành phố Phủ Lý	TP.Phủ Lý
6	Viet Tri City	Thành phố Việt Trì	TP.Việt Trì
7	Hai Phong City	Thành phố Hải Phòng	TP.Hải Phòng
8	Hoa Lac	Hòa Lạc	Hòa Lạc
9	Hoa Binh	Hòa Bình	Hòa Bình
10	Hung Yen	Hưng Yên	Hưng Yên
11	Binh Xuyen	Bình Xuyên	Bình Xuyên
12	Huong Canh	Hương Canh	Hương Canh
13	Phuc Yen	Phúc Yên	Phúc Yên
14	Cau Giay	Cầu Giấy	Cầu Giấy
15	Ha Dong	Hà Đông	Hà Đông
16	Hoa Binh	Hòa Bình	Hòa Bình
17	Phu Ly	Phủ Lý	Phủ Lý
18	Giai Phong	Giải Phóng	Giải Phóng
19	Hoang Mai	Hoàng Mai	Hoàng Mai
20	Gia Lam	Gia Lâm	Gia Lâm
21	Cau Chui	Cầu Chui	Cầu Chui
22	My Dinh	Mỹ Đình	Mỹ Đình
23	Nhon	Nhổn	Nhổn
24	Quoc Oai	Quốc Oai	Quốc Oai
25	Thach That	Thạch Thất	Thạch Thất
26	Son Tay	Sơn Tây	Sơn Tây
27	Xuan Mai	Xuân Mai	Xuân Mai
28	Thuong Tin	Thường Tín	Thường Tín
29	Van Tao	Vân Tảo	Vân Tảo
30	Van Diem	Vạn Điểm	Vạn Điểm
31	Phu Minh	Phú Minh	Phú Minh

32	Dong Van	Đồng Văn	Đồng Văn
33	Hoa Mac	Hòa Mạc	Hòa Mạc
34	Liem Tuyen	Liêm Tuyền	Liêm Tuyền
35	Lien Bao	Liên Bảo	Liên Bảo
36	Tien Son	Tiên Sơn	Tiên Sơn
37	Phat Tich	Phật Tích	Phật Tích
38	Tu Son	Từ Sơn	Từ Sơn
39	Phu Chan	Phù Chẩn	Phù Chẩn
40	Tan Dan	Tân Dân	Tân Dân
41	Van Quan	Văn Quán	Văn Quán
42	Sai Dong	Sài Đồng	Sài Đồng
43	Phu Cat	Phú Cát	Phú Cát
44	Dai Xuyen	Đại Xuyên	Đại Xuyên
45	Vuc Vong	Vực Vòng	Vực Vòng
46	Cao Bo	Cao Bồ	Cao Bồ
47	Cho	Chờ	Chờ
48	Soc Son	Sóc Sơn	Sóc Sơn
49	Phu Lo	Phù Lỗ	Phù Lỗ
50	Phu Ninh	Phù Ninh	Phù Ninh
51	Sai Nga	Sai Nga	Sai Nga

Source: ITS Integration Project (SAPI) Study Team

12.8 Required Functions/Performance of VMS Indication

(1) Examples of letter size on traffic sign board on highways in other countries.

-USA-
Letter height: >250 mm
Letter width: 50-100% of letter height
Line thickness: 10-20 % of letter height (15% is ideal)
-Germany-
Letter height: >280 mm
-Japan-
Letter height: 450 mm
Letter width: 84% of letter height
Line 44thickness: 10% of letter height

(2) Letter height of traffic sign in Vietnam

Letter height on traffic sign in Viet Nam is expected to be “22-TCN-331-05 BIỂN CHỈ DẪN TRÊN ĐƯỜNG CAO TỐC”

According to the guideline, drivers would recognize the traffic sign, understand and start action 10 seconds before the sign.

Table 12.6 Correlation with Decipher required distance and Letter height

Decipher required distance	250m	325m	400m
Letter height (Vietnamese)	200mm	300mm	400mm

Source: 22-TCN-331-05 BIỂN CHỈ DẪNTRÊN ĐƯỜNG CAO TỐC

When driving at 120 km/h on Vietnam highway, 10 seconds would require 333.33 m distance from the sign, thus from the Table, letter height needs to be more than 400 mm. However, since VMS displays letters by LED (Light Emitting Diode) dots, letter height should be more than 450 mm considering Vietnamese circumflex representation.

(3) Letter width of traffic sign in Vietnam

Character width on traffic signs in Vietnam must comply with the standard "22-TCN-331-05 ROAD SIGNS ON HIGHWAY which is illustrated in the Table 11 and 12
Width of numbers 0-9 must be 25%-72% of their heights. Letters A-Z comprise circumflex with the width of 16%~86% of their heights.
Therefore, in the case of applying this standard for the width of character on VMS then character height on VMS is 450mm, the width of each character is illustrated in column "For VMS" in the Table 11 and 12.

Table 12.7 Letter Width of Number

	Letter width (mm)							
	22TCN331-05 BIẾN CHỈ DÂN TRÊN ĐƯỜNG CAO TỐC						For VMS / CSS	
Letter height (mm)	**200**	Ratio to Letter Height	**300**	Ratio to Letter Height	**400**	Ratio to Letter Height	**450**	Ratio to Letter Height
1	50	25%	74	25%	98	25%	108	24%
2	137	69%	205	68%	274	69%	306	68%
3	137	69%	205	68%	274	69%	306	68%
4	149	75%	224	75%	298	75%	306	68%
5	137	69%	205	68%	274	69%	306	68%
6	137	69%	205	68%	274	69%	306	68%
7	137	69%	205	68%	274	69%	306	68%
8	137	69%	205	68%	274	69%	306	68%
9	137	69%	205	68%	274	69%	306	68%
0	143	72%	214	71%	286	72%	324	72%
Average	130	65%	195	65%	260	65%	288	64%

Table 12.8 Letter width of Alphabet

	Letter width (mm)							
	22TCN331-05 BIỂN CHỈ DẪN TRÊN ĐƯỜNG CAO TỐC						For VMS	
Letter Height (mm)	200	Ratio to Letter Height	300	Ratio to Letter Height	400	Ratio to Letter Height	450	Ratio to Letter Height
A, Â	170	85%	225	75%	340	85%	378	84%
B	137	69%	205	68%	274	69%	306	68%
C	137	69%	205	68%	274	69%	306	68%
D	137	69%	205	68%	274	69%	306	68%
Đ	155	78%	232	77%	310	78%	342	76%
E, Ê	124	62%	186	62%	248	62%	279	62%
F	124	62%	186	62%	248	62%	279	62%
G	137	69%	205	68%	274	69%	306	68%
H	137	69%	205	68%	274	69%	306	68%
I	32	16%	48	16%	64	16%	72	16%
J	127	64%	190	63%	254	64%	279	62%
K	140	70%	210	70%	280	70%	315	70%
L	124	62%	186	62%	248	62%	279	62%
M	157	79%	236	79%	314	79%	351	78%
N	137	69%	205	68%	274	69%	306	68%
O, Ô, Ơ	143	72%	214	71%	286	72%	315	70%
P	137	69%	205	68%	274	69%	306	68%
Q	143	72%	214	71%	286	72%	315	70%
R	137	69%	205	68%	274	69%	306	68%
S	137	69%	205	68%	274	69%	306	68%
T	124	62%	186	62%	248	62%	279	62%
U	137	69%	205	68%	274	69%	306	68%
Ư	167	84%	250	83%	334	84%	378	84%
V	152	76%	229	76%	304	76%	342	76%
X	137	69%	205	68%	274	69%	306	68%
Y	171	86%	257	86%	342	86%	387	86%
Z	137	69%	205	68%	274	69%	306	68%
Average	133	67%	198	66%	267	67%	297	68%

(4) Distance between disappearance point and sign

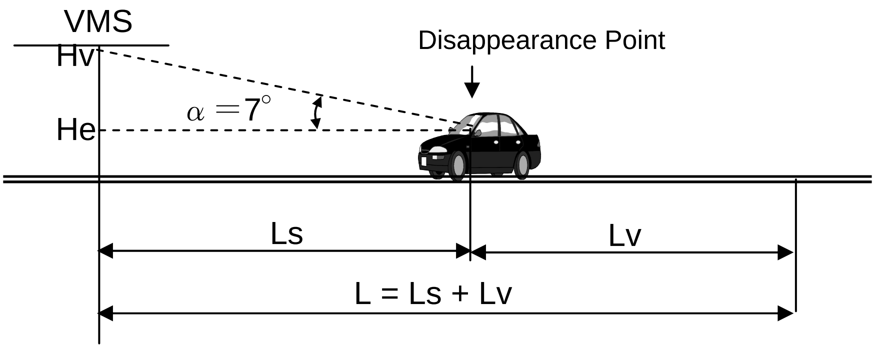
Distance between disappearance point and sign (Ls) can be calculated from driver's visual limit, position of traffic sign (VMS), and size of VMS.

When vertical visual limit is $\alpha = 7°$, eye-level of the driver is 1.2m, height of VMS is 6.25 m, Ls can be calculated to be about 51 m.
The upper-edge of the VMS board was set at 6.25 m to fulfil structural height limit of 4.75 m determined by local guideline, and VMS board height is 1.50 m (3 rows of 450 mm high letters).

Ls = (Hv – He) / tan α

Where Hv: Upper-edge of the VMS board (m)
He: Eye-level of the driver (m)
α: Vertical visual limit (degree)

Figure 12.9 Relation between Hv, He, Ls, Lv and L



(4) Decipher required distance (Lv)

Decipher required distance (Lv) is calculated from decipher required time (or number of letters) and running speed. When decipher required time is t, and running speed is V=120 km/h, Lv would become Lv＝120× t ／3.6＝33.3 t .

Lv = V x t / 3.6
Where V: Running Speed (km/h)
t: Decipher Required Time (sec)

(5) Visual recognition distance (L)

From (3) and (4), visual recognition distance can be calculated from below:
L=Ls + Lv
Thus, L = 51m + 33.3t

(6) Decipherable letter number

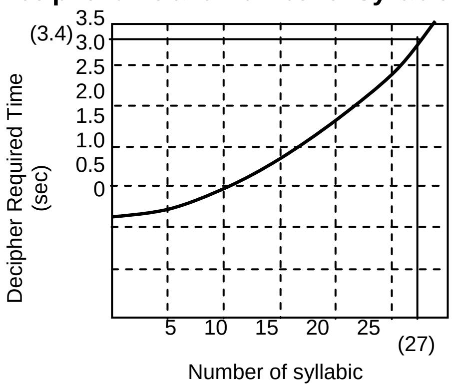
According to Germany standard from the table, the following formulae can be given by the fact 167 m sight distance required at letter height of 450 mm.

t = (L – 51m) / 33.3 = (167m – 51m) / 33.3
= 3.48 sec = 3.5 sec (approx.)
From the Figure graph below, 30 letters are legible in 3.5 second decipher time.

Table 12.9 Relation between Character Height and sight Distance

Alphabet Font Type	Character Height to Sight Distance	Character Height		
		30cm	45cm	60cm
Narrow	300h	90cm	130cm	180cm
Normal	370h	111	167	222
Wide	450h	135	203	270

Figure 12.10 Relation between Decipher time and Number of Syllabic



(7) Examination on longevity elongation of LED element

LED element takes 35,000-50,000 hours for its light intensity to decrease for 50%.

The picture represents the example of letter display, assuming the resolution to be 30 pixels vertical vs 16 pixels horizontal.

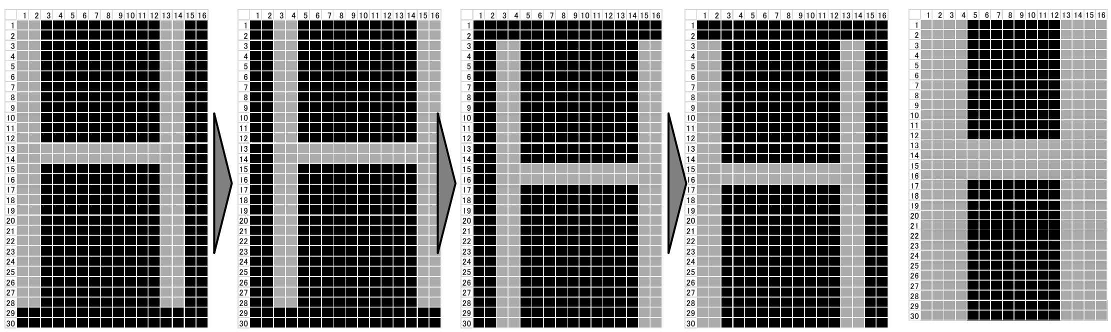
In case of Vietnamese, display will employ alphabets from A to Z, and circumflex in addition. On the display there will be highly frequently used LED elements, and others rarely used.

When LED elements burn out, the replacement will be made not by individual elements but by a unit of certain number of LED elements. For example, if the display is made by 160 x 160 mm LED element unit with 15 mm pitch, replacement is done by unit of 144 dots (12 x 12).

Individual LED elements are ideally degraded equally for VMS to last longer.

For such purpose, shifting lighting LED elements by time to time can equalize the frequency of lighting time of each element. However, it is not the case when all elements are lit for picture display.

Figure 12.11 Example for Longevity elongation of LED element

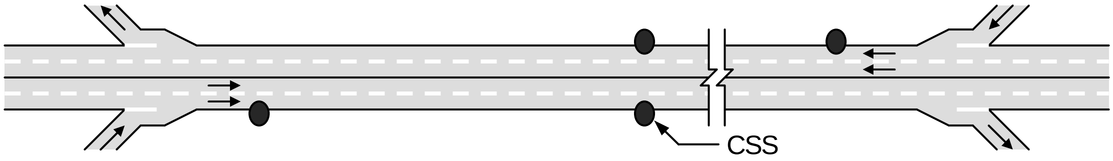


Move 2 columns to right | Move 2 rows downward | Move 2 columns to left | Total LED use

12.9 Location and Indication Criteria of CSS

Locate the CSS after the merging point on expressway, on the main road between the Interchanges.

Figure 12.12 CSS Installation at Mid-point between a Pair of Interchanges



Source: ITS Integration Project (SAPI) Study Team

12.10 Required Functions/Performance of CSS Indication

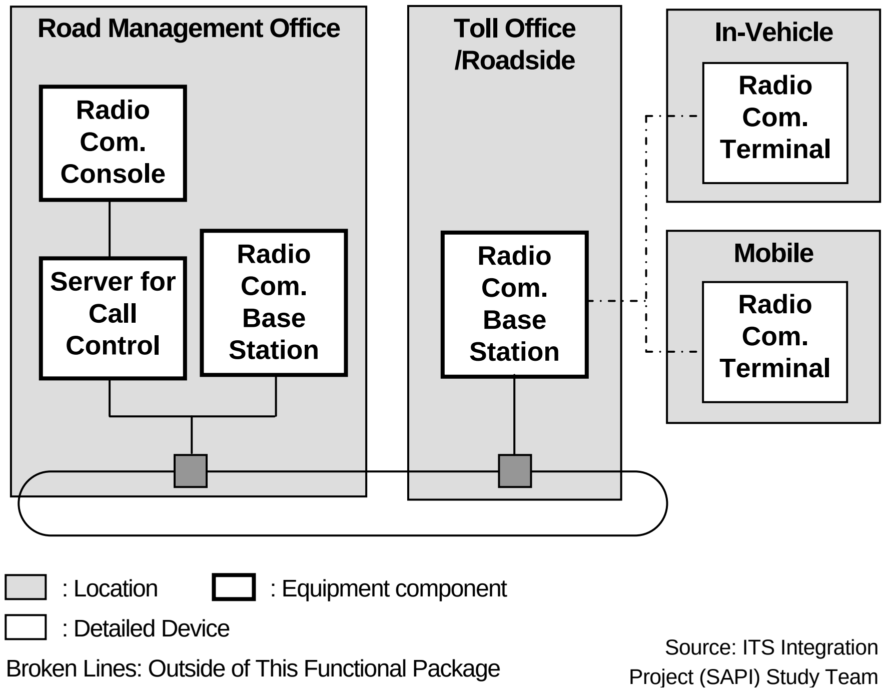
Numerical character for showing speed limit is indicated on CSS in the same performance as the characters on VMS.

13. Mobile Radio Communication

13.1 Outline and System Architecture

This functional package allows the road operators to exchange information between road operation vehicles/workers on the expressway and the road management office by using radio communication.

Figure 13.1 System Architecture for Mobile Radio Communication



Source: ITS Integration Project (SAPI) Study Team

13.2 Required Function of Mobile Radio Communication

Mobile Radio communication system is able to actualize interactive voice communication between console in road management office and terminal equipment component holders, and among terminal equipment component holders.

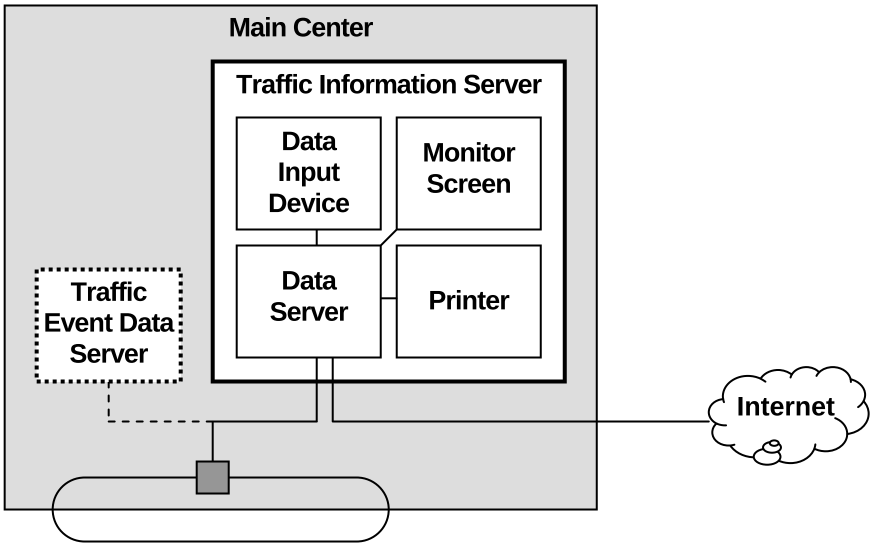
The coverage area of mobile radio communication for expressway operation and maintenance shall be capable to communicate on the expressway and related facility areas along the expressway such as outside area within the premises of road management office, interchanges, toll areas, rest areas, parking areas and other premises along the expressway. However it should not be caused interference due to unnecessarily expanded coverage areas.

14. Traffic Information

14.1 Outline and System Architecture

This functional package allows the road operators to provide other organizations with the information organized as traffic events on the expressways by using the Internet.

Figure 14.1 System Architecture for Traffic Information



: Location : Equipment component
: Detailed Device
Broken Lines: Outside of This Functional Package

Source: ITS Integration Project (SAPI) Study Team

14.2 Contents of Traffic Information

System is to disseminate information on traffic and road condition of the expressway network to the Internet Users based on the traffic event data stored in the server.

- Incidents
- Traffic conditions
- Traffic congestion
- Bad weather
- Construction works on the expressways
- Traffic restrictions.

Details of each contents are shown in the definition of traffic events aforementioned.

14.3 Data Set for Traffic Information

Table 14.1 Data Set/Elements for Traffic Information

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Traffic Event Data Set <G/C - Server>	Traffic Event Data ID	INT	8	1	When an event occurs	1 year
	Road Management Office ID	INT*	4	1		
	Road Section ID	INT*	4	1		
	Road Link ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Traffic Event Category ID	INT*	4	1		
	Traffic Event Class ID	INT*	4	1		
	Causal Traffic Event Data ID	INT	8	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Input Person	TXT	32	1		
	Event Status	TXT	4	1		
	Video Image address	TXT	60	1		
	Main Center Check Status	INT*	4	1		
	Road Management Office Check Status	INT*	4	1		
	Status of Traffic Event	INT*	2	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

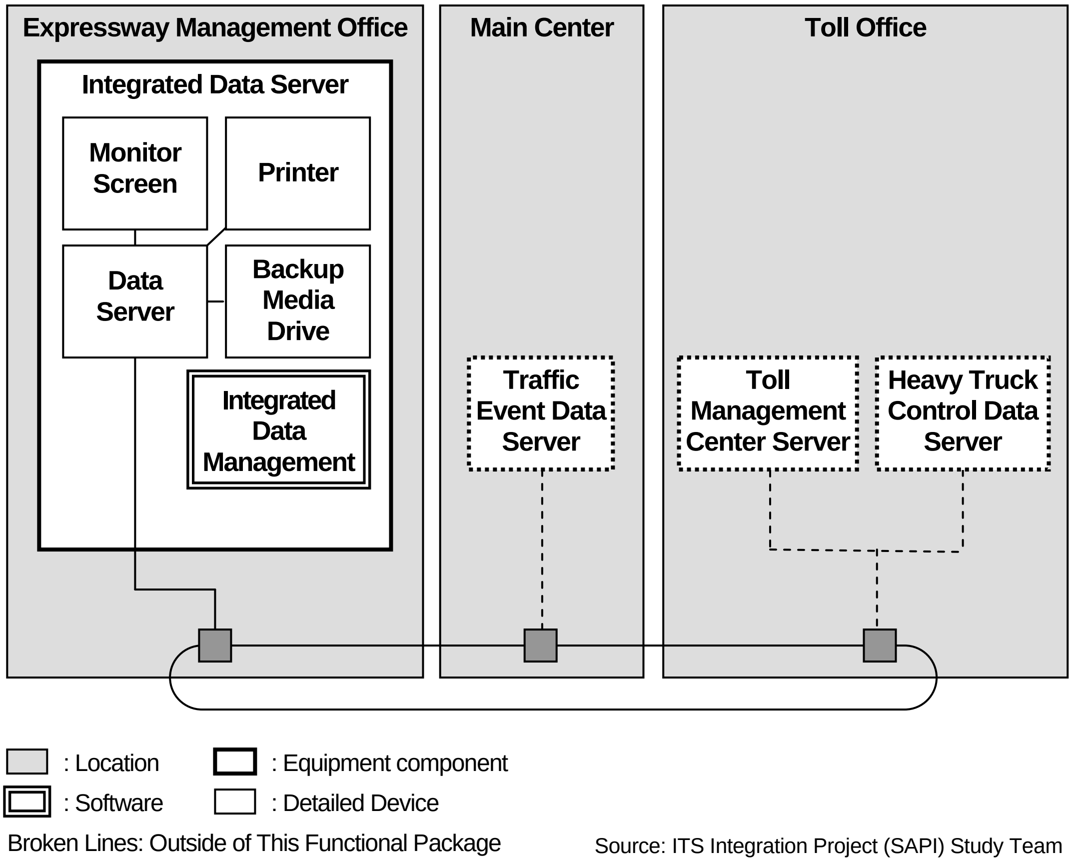
Source: ITS Integration Project (SAPI) Study Team

15. Integrated Data Management

15.1 Outline and System Architecture

This functional package allows road operators to utilize acquired data such as traffic events, traffic volume, large vehicle ratio and measured axle loads of heavy trucks for developing inspection and budget plan of road maintenance and to check validity of toll revenue in comparison with traffic data.

Figure 14.1 System Architecture for Traffic Information



Source: ITS Integration Project (SAPI) Study Team

15.2 Required Function for Integrated Data Management

The system is to compile the following data set corresponding to date/time and kilo-meter post of a road section:

- Incident data set
- Traffic volume data set
- Traffic congestion data set
- Bad weather data set
- Construction work data set
- Traffic restriction data set
- Traffic event data set
- Hourly toll collection data set
- Axle load management data set

15.3 Data for Traffic Information/Control

Table 15.1 Data Sets for Traffic Information Control

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Incident Data Set <I -Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Roadside Equipment ID	INT*	4	1		
	Incident Status	INT*	2	1		
	Date/Time	Datetime	≥14	1		
Traffic Volume Data Set <G -Traffic Analysis Processor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Total Traffic Volume per Day	INT	5	1		
	Large Vehicle Ratio	FLOAT	5	1		
	Traffic Volume per Day of vehicle class 1	INT	5	1		
	Traffic Volume per Day of vehicle class 2	INT	5	1		
	Traffic Volume per Day of vehicle class 3	INT	5	1		
	Traffic Volume per Day of vehicle class 4	INT	5	1		
	Traffic Volume per Day of vehicle class 5	INT	5	1		
	Total Traffic Volume per Hour	INT*	4	1		
	Large Vehicle Ratio	FLOAT	5	1		
	Traffic Volume per Hour of vehicle class 1	INT*	4	1		
	Traffic Volume per Hour of vehicle class 2	INT*	4	1		
	Traffic Volume per Hour of vehicle class 3	INT*	4	1		
	Traffic Volume per Hour of vehicle class 4	INT*	4	1		
	Traffic Volume per Hour of vehicle class 5	INT*	4	1		
	Total Traffic Volume per 15 minutes	INT*	3	1		
	Traffic Volume per 15 minutes of vehicle class 1	INT*	3	1		
	Traffic Volume per 15 minutes of vehicle class 2	INT*	3	1		
	Traffic Volume per 15 minutes of vehicle class 3	INT*	3	1		
	Traffic Volume per 15 minutes of vehicle class 4	INT*	3	1		
	Traffic Volume per 15 minutes of vehicle class 5	INT*	3	1		
	Date/Time	Datetime	≥14	1		
Traffic Congestion Data Set <G -Traffic Analysis Processor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest
	Roadside Equipment ID	INT*	4	1		
	Cumulative Number of Vehicles	INT*	4	1		
	Average Vehicle Speed	INT*	4	1		
	Traffic Congestion Status	INT*	2	1		
	Beginning Kilometer Post	TXT	6	1		

	Ending Kilometer Post	TXT	6	1		
	Date/Time	Datetime	≥14	1		
Bad Weather Data Set <G -Weather Server>	Road Management Office ID	INT*	4	1	When a bad weather occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Precipitation	FLOAT	2	1		
	Wind Speed	FLOAT	2	1		
	Visibility	FLOAT	2	1		
	Temperature	FLOAT	2	1		
	Heavy Rain Status	INT*	2	1		
	High Wind Status	INT*	2	1		
	Low Visibility Status	INT*	2	1		
	High Temperature Status	INT*	2	1		
	Date/Time	Datetime	≥14	1		
Construction Work Data Set <I -Server>	Road Management Office ID	INT*	4	1	When a constructio n work is scheduled	1 month after end of constructio n
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Construction Work Status	INT*	2	1		
	Number of document	TXT	20	1		
	Permission Date	TXT	8	1		
	Date/Time Begin	TXT	≥14	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		
Traffic Restriction Data Set <I -Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month after end of restriction
	Road Section ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Construction Work Status	INT*	2	1		
	Permission Date	TXT	8	1		
	Date/Time Begin	TXT	≥14	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		
Traffic Event Data Set <G/C-Server>	Traffic Event Data ID	INT	8	1	When an event occurs	1 year
	Road Management Office ID	INT*	4	1		
	Road Section ID	INT*	4	1		
	Road Link ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Place ID	INT*	4	1		
	Traffic Event Category ID	INT*	4	1		
	Traffic Event Class ID	INT*	4	1		
	Causal Traffic Event Data ID	INT	8	1		
	Beginning Kilometer Post	TXT	6	1		
	Ending Kilometer Post	TXT	6	1		
	Input Person	TXT	32	1		
	Event Status	TXT	4	1		
	Video Image address	TXT	60	1		
	Main Center Check Status	INT*	4	1		
	Road Management Office Check Status	INT*	4	1		
	Status of Traffic Event	INT*	2	1		
	Date/Time End	TXT	≥14	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

15.4 Data for Toll Collection/Management

Table 15.2 Data Sets for Toll Collection/Management

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Daily Toll Collection Data Set <G/C-Server>	Road Owner ID	INT*	4	1	Daily	1 year
	Toll Office ID	INT*	4	1		
	Date of Toll Amount	TXT	8	1		
	Sum of Toll Amount	FLOAT	12	1		
	Number of Vehicle Passage	INT	8	1		
	Sum of Toll of Vehicle Class 1	FLOAT	12	1		
	Number of Vehicle of Class 1	INT	8	1		
	Sum of Toll of Vehicle Class 2	FLOAT	12	1		
	Number of Vehicle of Class 2	INT	8	1		
	Sum of Toll of Vehicle Class 3	FLOAT	12	1		
	Number of Vehicle of Class 3	INT	8	1		
	Sum of Toll of Vehicle Class 4	FLOAT	12	1		
	Number of Vehicle of Class 4	INT	8	1		
	Sum of Toll of Vehicle Class 5	FLOAT	12	1		
	Number of Vehicle of Class 5	INT	8	1		
	Sum of Toll of Vehicle Class 6	FLOAT	12	1		
	Number of Vehicle of Class 6	INT	8	1		
	Sum of Toll of Vehicle Class 7	FLOAT	12	1		
	Number of Vehicle of Class 7	INT	8	1		
	Sum of Toll of Vehicle Class 8	FLOAT	12	1		
	Number of Vehicle of Class 8	INT	8	1		
	Sum of Toll of Vehicle Class 9	FLOAT	12	1		
	Number of Vehicle of Class 9	INT	8	1		
	Sum of Toll of Vehicle Class 10	FLOAT	12	1		
	Number of Vehicle of Class 10	INT	8	1		
	Sum of Toll of Vehicle Class 11	FLOAT	12	1		
	Number of Vehicle of Class 11	INT	8	1		
	Sum of Toll of Vehicle Class 12	FLOAT	12	1		
	Number of Vehicle of Class 12	INT	8	1		
	Sum of Toll of Vehicle Class 13	FLOAT	12	1		
	Number of Vehicle of Class 13	INT	8	1		
	Sum of Toll of Vehicle Class 14	FLOAT	12	1		
	Number of Vehicle of Class 14	INT	8	1		
	Sum of Toll of Vehicle Class 15	FLOAT	12	1		
	Number of Vehicle of Class 15	INT	8	1		
	Sum of Toll of Vehicle Class 16	FLOAT	12	1		
	Number of Vehicle of Class 16	INT	8	1		
	Sum of Toll of Vehicle Class 17	FLOAT	12	1		
	Number of Vehicle of Class 17	INT	8	1		
	Sum of Toll of Vehicle Class 18	FLOAT	12	1		
	Number of Vehicle of Class 18	INT	8	1		
	Sum of Toll of Vehicle Class 19	FLOAT	12	1		
	Number of Vehicle of Class 19	INT	8	1		
	Sum of Toll of Vehicle Class 20	FLOAT	12	1		
	Number of Vehicle of Class 20	INT	8	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

15.5 Data for Vehicle Weighing

Table 15.3 Data Sets for Vehicle Weighing

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Axle Load Management Data Set <G/C-Server>	Road Owner ID	INT*	4	1	Daily	1 year
	Road Section ID	INT*	4	1		
	Axle Load Scale Location ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Date of Record	TXT	8	1		
	Number of Heavy Trucks	INT	5	1		
	Number of Suspicious Trucks	INT	5	1		
	Number of Overloaded Trucks	INT	5	1		
	Axle Load Measurement Data Set	Set	var	N		
	Axle Load Status	INT*	2			
	Serial Number of Vehicle	INT	5			
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

15.6 Data to be Compiled/Generated for Integration

The following data sets are to be integrated being corresponded by data set ID to date/time and kilo-meter post of a road section:

- Data Set ID=1: Incident data set
- Data Set ID=2: Traffic volume data set
- Data Set ID=3: Traffic congestion data set
- Data Set ID=4: Bad weather data set
- Data Set ID=5: Construction work data set
- Data Set ID=6: Traffic restriction data set
- Data Set ID=7: Traffic event data set
- Data Set ID=8: Hourly toll collection data set
- Data Set ID=9: Axle load management data set

Table 15.4 Data Sets for Integration

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Integrated Data Sed <G - Server>	Date/Time	TXT	≥14	1	Every 1 hour	1 year
	Road Section ID	INT*	4	1		
	Kilo-meter Post	TXT	6	1		
	Lane ID	INT*	2	1		
	Data Set ID	INT*	2	1		
	Data Set	Set	var	1		

AUTOMATED TOLL COLLECTION/MANAGEMENT SYSTEM

TABLE OF CONTENTS

1. Introduction

Service descriptions:

This service enables toll collection without stopping vehicles: ETC (Electronic Toll Collection). This service relieves bottlenecks at the tollgates and allows smooth incoming and outgoing at the interchanges. This service reduces the number of tollbooths and solves the problem of land acquisition for the tollgates in suburban areas where traffic congestion will become an issue in near future. This service realizes simple vehicle inspection at the border crossings, and provides road or vehicle operators with the time of vehicle passage at the tollgates. Computerized toll management can vastly reduce uncollected toll revenue due to the failure in counting/classifying vehicles and can realize appropriate sharing of the toll revenue among different road operators.

Functional packages to be included in the system:

(13) Tollgate Lane monitoring
(14) Vehicle/class identification
(15) Lane control
(16) Road-to-vehicle communication
(17) IC-card recording
(18) Toll data management
(19) OBU management.

2. Use Case and General System Architecture

Use cases and general system architecture are illustrated for the following implementation packages of toll collection/management:

(1) Toll collection
(2) Center-to-Center Data Exchange.

Relationships between the system and users/operators/other-systems are illustrated by the following use case diagrams in the design drawings:

Road traffic supervision

- Toll collection
- Lane control for ETC
- Handling of balance shortage vehicle
- Toll data management
- Toll settlement
- OBU management
- Toll enforcement assistance.

The general system architecture is sown using collaboration diagrams and message sequence diagrams titled as below in the design drawings:

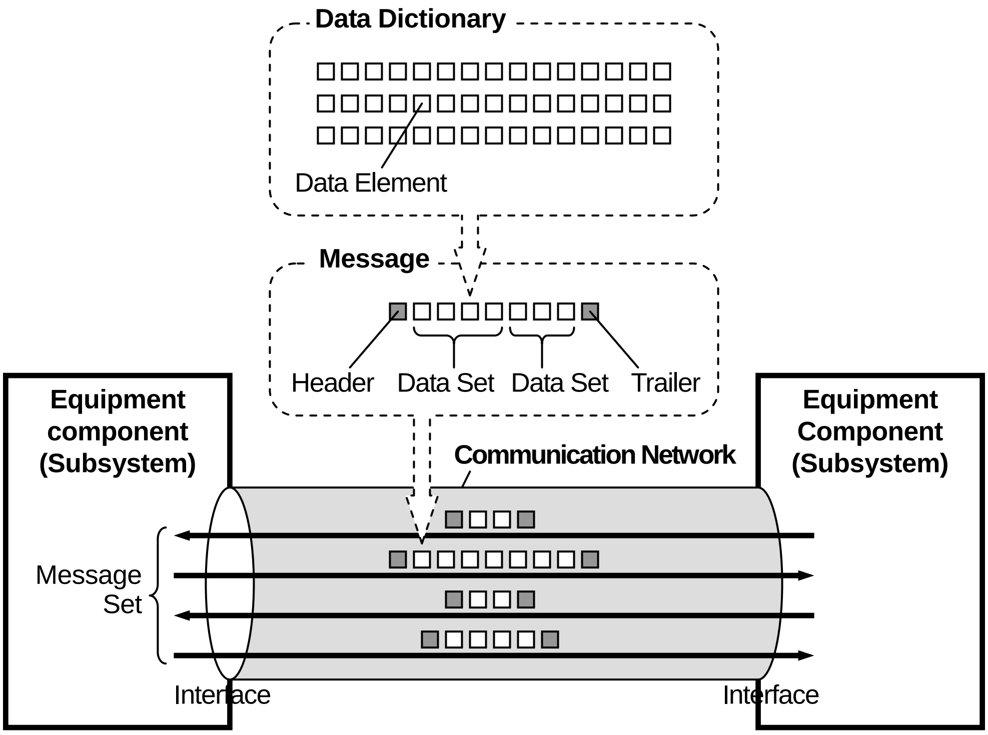
(1) Toll collection by touch&go/manual
(2) Toll collection by ETC at toll-island (2-piece type OBU)
(3) Center-to-center data exchange for toll settlement
(4) Center-to-center data exchange for IC-card operation
(5) Center-to-center data exchange for OBU management.

3. Message/Data Design

3.1 General

ITS consists of many pieces of equipment, which are illustrated as the equipment components in the diagrams of system architecture. The equipment components need to be connected with each other by communication network in order to exchange messages and data between them, to actualise the system and to provide intended services.

Figure 3.1 Conceptual Illustration of Message/Data Exchange



Source: ITS Integration Project (SAPI) Study Team

3.2 Major Message List

The major message list for automated toll collection/management system is shown in the following table.

Table 3.1 Major Message List of Automated Toll Collection/Management System

Name of Message	A Pair of Equipment Components on Both Side of Interface through Which Message is Exchanged		Name of Include Data Sets
Toll Price Input Message	Data Input Device	Toll Management Server	Toll Price Information Data Set
Toll Price Message	Toll Management Server	Lane Server	Toll Price Data Set
Toll Price Message	Lane Server	Roadside Controller	Toll Price Data Set
ETC Message	OBU	Roadside Controller	OBU Registration Data Set OBU Passage Data Set IC-Card Contract Data Set IC-Car Passage Data Set Transaction Data Set
Touch & Go Message	IC-Card R/W	Lane Server	IC-Card Contract Data Set IC-Car Passage History Data Set Transaction Data Set
IC-Card recharge Message	IC-Card	IC-Card Recharger	IC-Card Recharge Data Set
Transaction Collection Message	Lane Server	Toll Management Server	Transaction Collection Data Set
Toll Collection Message	Toll Management Server	Toll Management Center Server	Toll Collection Data Set
Invalidation ID Message	Bank Server	Toll Office Server	Invalidation List Data Set
Invalidation ID Message	Toll Office Server	Lane Server	Invalidation List Data Set
Traffic Volume Massage	Toll Office Server	Integrated Data Server	Traffic Volume Data Set
License plate message	License Plate Scanner	Lane Server	License Plate Recognition Data Set
Toll Fare Message	Toll Management Server	Bank Server	Toll Fare Data Set
Traffic Volume Massage	Regional Main Center	Crosscheck Organization	Traffic Volume Data Set
Toll Fare Message	Toll Management Server	Crosscheck Organization	Toll Fare Data Set
Toll Validity Message	Crosscheck Organization	Bank Server	Validity Result Data Set
Toll Settlement Message	Head Office Server	Bank Server	Toll Settlement Data

Source: ITS Integration Project (SAPI) Study Team

3.3 Primary Data Dictionary

Primary data dictionary for automated toll collection/management system is shown in the table below.

Figure 3.2 Primary Data Dictionary for Automated Toll Collection/Management System

	Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin	Definition
16	Toll Rate Information Data Set <R - Server>	Number of tollgate pair	INT	8	1	Daily	1 year	The number of tollgate pair (N)
		Tollgate Pair ID	INT	8	N			An unique identifier of a pair of tollgate
		Entrance Tollgate ID	INT*	4				An unique identifier of the entrance tollgate
		Exit Tollgate ID	INT*	4				An unique identifier of the exit tollgate
		Toll Rate of Vehicle Class 1	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses
		Toll Rate of Vehicle Class 2	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons
		Toll Rate of Vehicle Class 3	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons
		Toll Rate of Vehicle Class 4	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries
		Toll Rate of Vehicle Class 5	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries
		Toll Rate of Vehicle Class 6	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 6: Military vehicles in the missions
		Toll Rate of Vehicle Class 7	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 7: Public security vehicles in the missions
		Toll Rate of Vehicle Class 8	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 8: Reserved
		Toll Rate of Vehicle Class 9	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 9: Reserved
		Toll Rate of Vehicle Class 10	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 10: Reserved
		Toll Rate of Vehicle Class 11	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 11: Reserved
		Toll Rate of Vehicle Class 12	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 12: Reserved
		Toll Rate of Vehicle Class 13	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 13: Reserved
		Toll Rate of Vehicle Class 14	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 14: Reserved
		Toll Rate of Vehicle Class 15	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 15: Reserved
		Toll Rate of Vehicle Class 16	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 16: Reserved
		Toll Rate of Vehicle Class 17	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 17: Reserved
		Toll Rate of Vehicle Class 18	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 18: Reserved
		Toll Rate of Vehicle Class 19	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 19: Reserved
		Toll Rate of Vehicle Class 20	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 20: Reserved
		Number of document	TXT	20				Official number of permission document
		Date of Toll Rate Table	TXT	8				Day/month/year of the toll rate information for the pair of tollgate
17	Bar-code Data Set <G - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	1 month	An unique identifier of a toll office
		Tollgate ID	INT*	4	1			An unique identifier of a tollgate
		Lane ID	INT*	2	1			An unique identifier of the lane where a construction work applied (Numbered from the median)
		Deposit Terminal ID	INT*	4	1			An unique identifier of the deposit terminal
		Ticket Type	INT*	4	1			Type of ticket
		Vehicle Class	INT*	2	1			Vehicle class: - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		Serial Number	INT	12	1			Serial number of the ticket
		Date Issue	Date	8	1			Day/month/year of issuing ticket
		Date of Expiry	Date	8	1			Day/month/year of ticket expiration
18	IC-card Issue Data Set <R - IC-card>	Issuer ID	INT*	4	1	IC-card issue	Permanent	An unique identifier of an issuer organization
		Issue Terminal ID	INT	12	1			An unique identifier of an issue terminal equipment
		IC-card ID	INT	12	1			An unique identifier of an IC-card
		IC-card Owner ID	INT	18	1			An unique identifier of IC-card owner
		Amount of Deposit	FLOAT	8	1			The amount of electric money deposited to the account (unit: thousand VND)
		Date/Time of Issue	TXT	≥14	1			Day/month/year/hour/minutes/second of issuing IC-card
		Date/Time of Expiry	TXT	≥14	1			Day/month/year/hour/minutes/second of expiring IC-card
19	IC-card Recharge Data Set <R - IC-card>	Issuer ID	INT*	4	N	Each recharge	Permanent	An unique identifier of an issuer organization
		Deposit Terminal ID	INT	12				An unique identifier of a terminal device
		Amount of Deposit	FLOAT	8				The amount of electric money deposited to the prepared account (unit: thousand VND)
		Prepaid Balance	FLOAT	8				The remaining amount of electric money in an IC-card (unit: thousand VND)
		Date/Time	Datetime	≥14				Year/ month/day/hour/minutes/second of generating data set
20	IC-card Passage Data Set	Toll Office ID	INT*	4	N	Each passage at tollgate	Latest	An unique identifier of a toll office
		Tollgate ID	INT	8				An unique identifier of a toll gate
		Lane ID	INT	12				An unique identifier of a lane (Numbered from the median)

	<R - IC-card>	Toll Amount	FLOAT	8				A toll charge collected by the system when a vehicle passing through a tollgate using ETC, Touch&Go toll collection or Manual toll collection. (unit: thousand VND)
		Prepaid Balance	FLOAT	8				The remaining amount of electric money in an IC-card (unit: thousand VND)
		Date/Time	Datetime	≥14				Year/ month/day/hour/minutes/second of generating data set
21	IC-card Invalidation List Data Set <G - Server>	Issuer ID	INT*	4	1	Daily	1 year	An unique identifier of an issuer organization
		Issue Terminal ID	INT	12	N			An unique identifier of an issue terminal equipment
		IC-card ID for Invalidation	INT	12				An unique identifier of an IC-card of invalidation
		IC-card Owner ID	INT	18				An unique identifier of IC-card owner
		Amount of Deposit	FLOAT	8				The amount of electric money deposited to the account (unit: thousand VND)
		Date/Time of Issue	TXT	≥14				Day/month/year/hour/minutes/second of issuing IC-card
		Date/Time of Expiry	TXT	≥14				Day/month/year/hour/minutes/second of expiring IC-card
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
22	OBU Registration Data Set <R - OBU>	Management Organization ID	INT	12	1	OBU registration	Permanent	An unique identifier of OBU management organization
		OBU ID	INT	12	1			An unique identifier of an OBU
		OBU Owner ID	INT	18	1			An unique identifier of OBU owner
		License Plate Number	TXT	12	1			License plate number recorded in OBU
		Vehicle Class	TXT	2	1			Vehicle class recorded in OBU: - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		Date of Issue	TXT	8	1			Day/month/year of issuing OBU
		Date of Expiry	TXT	8	1			Day/month/year of OBU expiration
23	OBU Passage Data Set <R - OBU>	Toll Office ID	INT*	4	3	Each passage at tollgate	Latest	An unique identifier of a toll office
		Tollgate ID	INT*	4				An unique identifier of a tollgate
		Lane ID	INT*	4				An unique identifier of a lane (Numbered from the median)
		IC-card ID	INT	12				An unique identifier of an IC-card
		Toll Amount	FLOAT	4				A toll charge collected by the system when a vehicle passing through a tollgate using ETC, Touch&Go toll collection or Manual toll collection. (unit: thousand VND)
		Prepaid Balance	INT	8				Prepaid balance copied from an IC-card
		Date/Time	Datetime	≥14				Year/ month/day/hour/minutes/second of generating data set
24	OBU Invalidation List Data Set <G - Server>	Management Organization ID	INT	12	1	Daily	1 year	An unique identifier of OBU management organization
		OBU ID for Invalidation	INT	12	N			An unique identifier of an OBU of invalidation
		OBU Owner ID	INT	18				An unique identifier of OBU owner
		License Plate Number	TXT	12				License plate number recorded in OBU
		Vehicle Class	TXT	2				Vehicle class recorded in OBU - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		Date of Issue	TXT	8				Day/month/year of issuing OBU
		Date of Expiry	TXT	8				Day/month/year of OBU expiration
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
25	Toll Collection License Plate Data Set <G - Image Processor>	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months	An unique identifier of a toll office
		Tollgate ID	INT*	4	1			An unique identifier of a tollgate
		Lane ID	INT*	4	1			An unique identifier of a lane (Numbered from the median)
		Roadside Equipment ID	INT*	4	1			An unique identifier of a license recognition device
		Captured License Plate Number	TXT	12	1			License plate number recognized by image processor
		Captured License Plate Image	IMG	var	1			The license plate image captured by CCTV camera
		Serial Number of Vehicle	INT*	5	1			Daily serial number for a vehicle passing through tollgate. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
26	Transaction Data Set <R - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months	An unique identifier of a toll office
		Tollgate ID	INT	8	1			An unique identifier of a toll gate
		Lane ID	INT*	4	1			An unique identifier of a lane (Numbered from the median)
		OBU ID	INT	12	1			An unique identifier of OBU
		Vehicle Class in OBU	INT*	2	1			Vehicle class recorded in OBU - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		License number in OBU	TXT	12	1			License number recorded in OBU

		IC-card ID	INT	12	1			An unique identifier of an IC-card
		Toll Amount	INT	8	1			A toll charge collected by the system when a vehicle passing through a tollgate using ETC, Touch&Go toll collection or Manual toll collection. (unit: thousand VND)
		Prepaid Balance	FLOAT	8	1			The remaining amount of electric money in an IC-card (unit: thousand VND)
		Termination Status	INT*	2	1			Data for indicating a toll collection procedure has finished successfully or not
		Serial Number of Vehicle	INT	5	1			Daily serial number for a vehicle passing through tollgate. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
27	Toll Collection Data Set <G - Lane Server>	Road Owner ID	INT*	4	1	Every 10 minutes	6 months	An unique identifier of a road owner
		Toll Office ID	INT*	4	1			An unique identifier of a toll office
		Date of Toll Amount	TXT	8	1			Day/month/year of the toll amount
		Sum of Toll Amount	INT*	12	1			A sum of colleted toll amount of vehicles passing through the tollgate
		Number of Vehicle Passage	INT	8	1			Number of vehicles passing through the tollgate
		<u>Transaction Data Set</u>	Set	var	N			Transaction data set of a vehicle passing through the tollgate
		Enforcement Status	TXT	2				Status for indicating the enforcement status: - 0: Successful. - 1: Vehicle passage that has different scanned license plate number compared to OBU. Suspicion of spoofing. - 2: Vehicle passage with continuously negative balance in IC-card. Suspicion of cheating. - 3: Vehicle passage without OBU and/or IC-card.
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
28	Hourly Toll Collection Data Set <G/C - Server>	Road Owner ID	INT*	4	1	Hourly	1 year	An unique identifier of a road owner
		Toll Office ID	INT*	4	1			An unique identifier of a toll office
		Date/Hour of Record	TXT	10	1			Day/month/year/hour of the record
		Sum of Toll Amount	FLOAT	12	1			Total toll amount of vehicles passing through the tollgate (unit: thousand VND)
		Number of Vehicle Passage	INT	8	1			Number of vehicles passing through the tollgate
		Sum of Toll of Vehicle Class 1	FLOAT	12	1			Total toll amount of class 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses (unit: thousand VND)
		Number of Vehicle of Class 1	INT	8	1			Number of vehicles of class 1
		Sum of Toll of Vehicle Class 2	FLOAT	12	1			Total toll amount of class 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons (unit: thousand VND)
		Number of Vehicle of Class 2	INT	8	1			Number of vehicles of class 2
		Sum of Toll of Vehicle Class 3	FLOAT	12	1			Total toll amount of class 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons (unit: thousand VND)
		Number of Vehicle of Class 3	INT	8	1			Number of vehicles of class 3
		Sum of Toll of Vehicle Class 4	FLOAT	12	1			Total toll amount of class 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 4	INT	8	1			Number of vehicles of class 4
		Sum of Toll of Vehicle Class 5	FLOAT	12	1			Total toll amount of class 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 5	INT	8	1			Number of vehicles of class 5
		Sum of Toll of Vehicle Class 6	FLOAT	12	1			Total toll amount of class 6: Military vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 6	INT	8	1			Number of vehicles of class 6
		Sum of Toll of Vehicle Class 7	FLOAT	12	1			Total toll amount of class 7: Public security vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 7	INT	8	1			Number of vehicles of class 7
		Sum of Toll of Vehicle Class 8	FLOAT	12	1			Total toll amount of class 8: Reserved(unit: thousand VND)
		Number of Vehicle of Class 8	INT	8	1			Number of vehicles of class 8
		Sum of Toll of Vehicle Class 9	FLOAT	12	1			Total toll amount of class 9: Reserved(unit: thousand VND)
		Number of Vehicle of Class 9	INT	8	1			Number of vehicles of class 9
		Sum of Toll of Vehicle Class 10	FLOAT	12	1			Total toll amount of class 10: Reserved(unit: thousand VND)
		Number of Vehicle of Class 10	INT	8	1			Number of vehicles of class 10
		Sum of Toll of Vehicle Class 11	FLOAT	12	1			Total toll amount of class 11: Reserved(unit: thousand VND)
		Number of Vehicle of Class 11	INT	8	1			Number of vehicles of class 11
		Sum of Toll of Vehicle Class 12	FLOAT	12	1			Total toll amount of class 12: Reserved(unit: thousand VND)
		Number of Vehicle of Class 12	INT	8	1			Number of vehicles of class 12
		Sum of Toll of Vehicle Class 13	FLOAT	12	1			Total toll amount of class 13: Reserved(unit: thousand VND)
		Number of Vehicle of Class 13	INT	8	1			Number of vehicles of class 13
		Sum of Toll of Vehicle Class 14	FLOAT	12	1			Total toll amount of class 14: Reserved(unit: thousand VND)
		Number of Vehicle of Class 14	INT	8	1			Number of vehicles of class 14
		Sum of Toll of Vehicle Class 15	FLOAT	12	1			Total toll amount of class 15: Reserved(unit: thousand VND)
		Number of Vehicle of Class 15	INT	8	1			Number of vehicles of class 15
		Sum of Toll of Vehicle Class 16	FLOAT	12	1			Total toll amount of class 16: Reserved(unit: thousand VND)
		Number of Vehicle of Class 16	INT	8	1			Number of vehicles of class 16
		Sum of Toll of Vehicle Class 17	FLOAT	12	1			Total toll amount of class 17: Reserved(unit: thousand VND)
		Number of Vehicle of Class 17	INT	8	1			Number of vehicles of class 17
		Sum of Toll of Vehicle Class 18	FLOAT	12	1			Total toll amount of class 18: Reserved(unit: thousand VND)
		Number of Vehicle of Class 18	INT	8	1			Number of vehicles of class 18
		Sum of Toll of Vehicle Class 19	FLOAT	12	1			Total toll amount of class 19: Reserved(unit: thousand VND)
		Number of Vehicle of Class 19	INT	8	1			Number of vehicles of class 19
		Sum of Toll of Vehicle Class 20	FLOAT	12	1			Total toll amount of class 20: Reserved(unit: thousand VND)
		Number of Vehicle of Class 20	INT	8	1			Number of vehicles of class 20
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
29	Toll Revenue Data Set <G/C - Server>	Road Owner ID	INT*	4	1	Monthly	1 year	An unique identifier of a road owner
		Fiscal Month	TXT	6	1			Number of fiscal month
		Toll Revenue of The Month/Week	FLOAT	16	1			Toll revenue of the fiscal period (unit: thousand VND)
		Number of Vehicle Passage	INT	8	1			Number of vehicles passing through the tollgate

		Sum of Toll of Vehicle Class 1	FLOAT	12	1			Total toll amount of class 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses (unit: thousand VND)
		Number of Vehicle of Class 1	INT	8	1			Number of vehicles of class 1
		Sum of Toll of Vehicle Class 2	FLOAT	12	1			Total toll amount of class 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons (unit: thousand VND)
		Number of Vehicle of Class 2	INT	8	1			Number of vehicles of class 2
		Sum of Toll of Vehicle Class 3	FLOAT	12	1			Total toll amount of class 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons (unit: thousand VND)
		Number of Vehicle of Class 3	INT	8	1			Number of vehicles of class 3
		Sum of Toll of Vehicle Class 4	FLOAT	12	1			Total toll amount of class 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 4	INT	8	1			Number of vehicles of class 4
		Sum of Toll of Vehicle Class 5	FLOAT	12	1			Total toll amount of class 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 5	INT	8	1			Number of vehicles of class 5
		Sum of Toll of Vehicle Class 6	FLOAT	12	1			Total toll amount of class 6: Military vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 6	INT	8	1			Number of vehicles of class 6
		Sum of Toll of Vehicle Class 7	FLOAT	12	1			Total toll amount of class 7: Public security vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 7	INT	8	1			Number of vehicles of class 7
		Sum of Toll of Vehicle Class 8	FLOAT	12	1			Total toll amount of class 8: Reserved(unit: thousand VND)
		Number of Vehicle of Class 8	INT	8	1			Number of vehicles of class 8
		Sum of Toll of Vehicle Class 9	FLOAT	12	1			Total toll amount of class 9: Reserved(unit: thousand VND)
		Number of Vehicle of Class 9	INT	8	1			Number of vehicles of class 9
		Sum of Toll of Vehicle Class 10	FLOAT	12	1			Total toll amount of class 10: Reserved(unit: thousand VND)
		Number of Vehicle of Class 10	INT	8	1			Number of vehicles of class 10
		Sum of Toll of Vehicle Class 11	FLOAT	12	1			Total toll amount of class 11: Reserved(unit: thousand VND)
		Number of Vehicle of Class 11	INT	8	1			Number of vehicles of class 11
		Sum of Toll of Vehicle Class 12	FLOAT	12	1			Total toll amount of class 12: Reserved(unit: thousand VND)
		Number of Vehicle of Class 12	INT	8	1			Number of vehicles of class 12
		Sum of Toll of Vehicle Class 13	FLOAT	12	1			Total toll amount of class 13: Reserved(unit: thousand VND)
		Number of Vehicle of Class 13	INT	8	1			Number of vehicles of class 13
		Sum of Toll of Vehicle Class 14	FLOAT	12	1			Total toll amount of class 14: Reserved(unit: thousand VND)
		Number of Vehicle of Class 14	INT	8	1			Number of vehicles of class 14
		Sum of Toll of Vehicle Class 15	FLOAT	x	1			Total toll amount of class 15: Reserved(unit: thousand VND)
		Number of Vehicle of Class 15	INT	8	1			Number of vehicles of class 15
		Sum of Toll of Vehicle Class 16	FLOAT	12	1			Total toll amount of class 16: Reserved(unit: thousand VND)
		Number of Vehicle of Class 16	INT	8	1			Number of vehicles of class 16
		Sum of Toll of Vehicle Class 17	FLOAT	12	1			Total toll amount of class 17: Reserved(unit: thousand VND)
		Number of Vehicle of Class 17	INT	8	1			Number of vehicles of class 17
		Sum of Toll of Vehicle Class 18	FLOAT	12	1			Total toll amount of class 18: Reserved(unit: thousand VND)
		Number of Vehicle of Class 18	INT	8	1			Number of vehicles of class 18
		Sum of Toll of Vehicle Class 19	FLOAT	12	1			Total toll amount of class 19: Reserved(unit: thousand VND)
		Number of Vehicle of Class 19	INT	8	1			Number of vehicles of class 19
		Sum of Toll of Vehicle Class 20	FLOAT	12	1			Total toll amount of class 20: Reserved(unit: thousand VND)
		Number of Vehicle of Class 20	INT	8	1			Number of vehicles of class 20
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

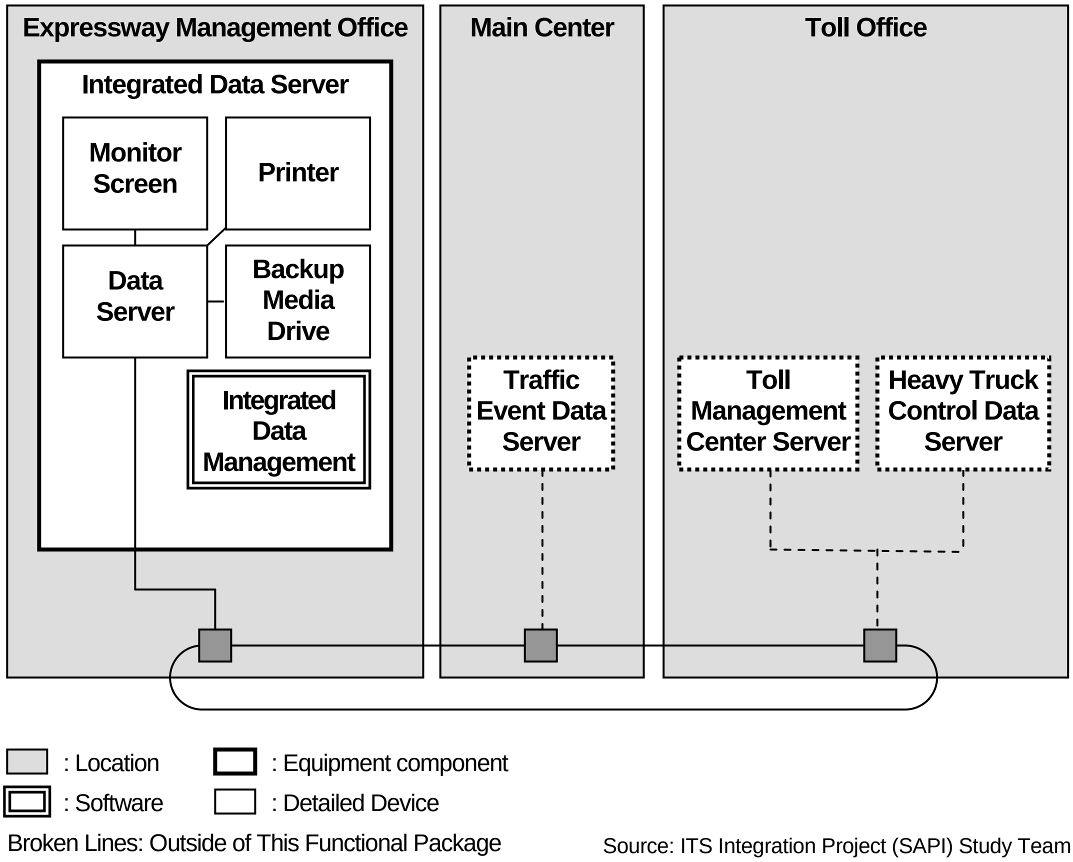
Source: ITS Integration Project (SAPI) Study Team

4. Tollgate Lane Monitoring

4.1 Outline and System Architecture

This functional package allows the road operators to monitor current conditions of vehicle passage and operations by workers by using cameras installed in a separated lane such as a tollgate lane of the expressway.

Figure 4.1 System Architecture for Toll Lane Monitoring



Source: ITS Integration Project (SAPI) Study Team

4.2 Conditions to be Monitored

CCTV camera is to give assistance for operator to monitor the following conditions:

- Vehicle coming into the tollgate lane
- Class and appearance of the vehicle
- Activities of the driver and the toll collector
- Occurrence of trouble and response to it in the tollgate lane
- Vehicle going out from the tollgate lane

4.3 Required Functions/Performance of CCTV Camera

(1) Types of Camera

There is 1 types of CCTV camera: PTZ Type and Fixed Type. PTZ Type has the functions Panning, Tilting and Zooming. Fixed Camera does not have these functions.

In addition, sometime Fixed Type has zooming function but they do not have the capability of Tilting and Panning. Therefore, a focal point is one point only, which is not good for surveillance.

The following table shows an example of the Specification for Fixed Camera and PTZ Type.

Figure 4.2 Type of CCTV camera

Fixed camera PTZ camera

Source: ITS Integration Project (SAPI) Study Team

PTZ Camera: The camera shall have mechanical capability of panning, tilting and zooming for focusing the objective of interest for traffic surveillance.

Fixed camera: The camera does “Not” have mechanical capability of panning and tilting for focusing the objective of interest for traffic surveillance.

(2) Mechanical Functions

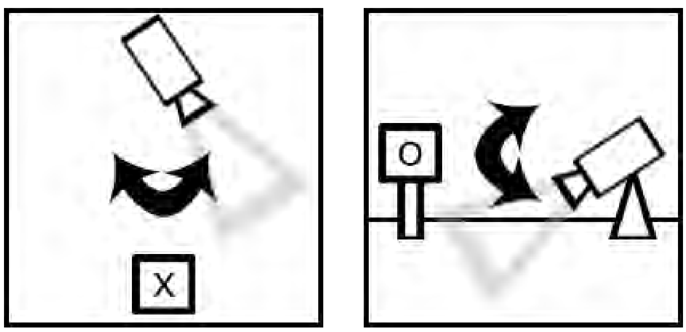
Panning:

Panning refers to the rotation in a horizontal plane of a video camera. Panning a camera results in a motion similar to that of someone shaking their head "no”.

Tilting:

Tilting refers to the stationary and rotation in a vertical plane (or tilting plane). A rotation in a horizontal plane is known as panning. Tilting the camera results in a motion similar to someone nodding their head "yes".

Figure 4.3 Panning and Tilting



Panning function Tilting function

Source: ITS Integration Project (SAPI) Study Team

Zooming:

Zoom adjusts the Angle of View. It is a magnification of image as a result. The function of zooming, there are two type of zoom such as Digital Zoom and Optical Zoom. For our purpose, digital zoom is not really zoom, in the strictest definition of the term. What digital zoom does is enlarge a portion of the image, thus ‘simulating’ optical zoom. In other words, the camera crops a portion of the image and then enlarges it back to size.

Against that, optical zoom is really zoom, It is capable a magnification of image by extend the focal length of between lens and image sensor. Optical zoom doesn’t make a deterioration of images compare with Digital zoom.

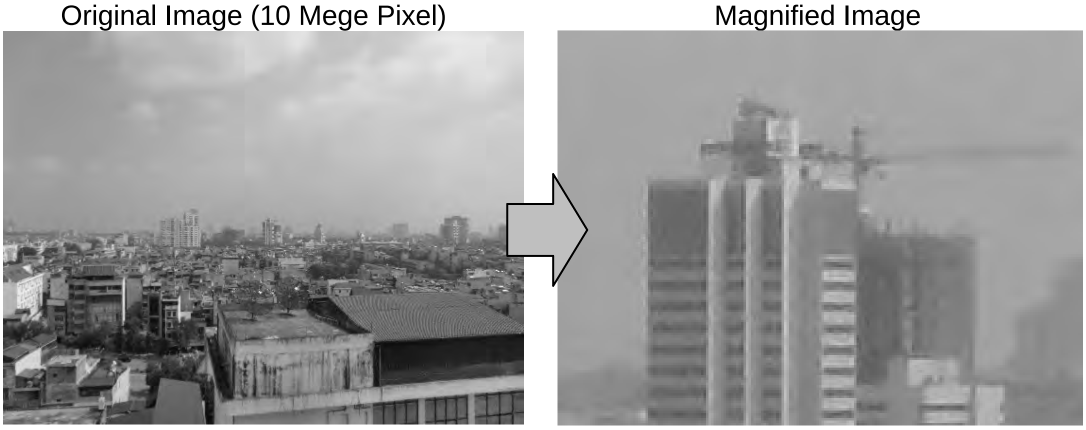
For example, see Figure 4.6. Upper stand, show the magnification of image (10 mega pixel) by using digital zoom function. Lower stand, show the magnification of image (1 mega pixel) by using optical zoom function.

Resolution of the original image is 10 mega pixels on Digital zoom whereas, resolution of the original image is 1 mega pixel on Optical zoom. Optical zoom image is 1/10 times the resolution however, the quality of the image after the magnification is more clear than Digital zoom.

Figure 4.4 Comparison for Digital Zoom and Optical Zoom

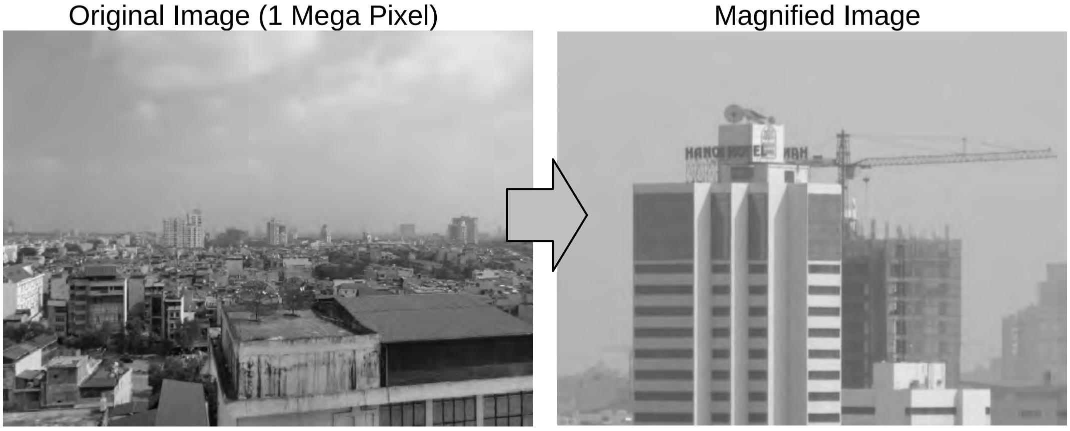
Digital zoom

Original Image (10 Mege Pixel) Magnified Image



Optical zoom

Original Image (1 Mega Pixel) Magnified Image



Source: ITS Integration Project (SAPI) Study Team

(3) Optical Functions/Performance

Width of image sensor :

There are two type of image sensor, such as CCD image sensor and CMOS sensor. Both types of sensor accomplish the same task of capturing light and converting it into electrical signals. In previous time, CCD image sensor was better than CMOS sensor. However, CMOS sensor is advance by means of technological innovation in today. CMOS sensor can potentially be implemented with use less power, faster reboot and cheaper than CCD. Therefore, most of CCTV camera are using CMOS sensor.

The meaning of the image Sensor are large, the camera has a larger area per 1pixel in case of the number of pixel is the same. Then, a larger amount of light to be received on 1pixel, collect the light efficiency is increased. Then, there are a lot of light coming into the image sensor, can be stayed on top of the subsequent of image processing, there will be less noise as a result. In other words, it is possible to record images of a more natural state.

Focal length of lens:

It is effect to surveillance range. The focal length of a lens determines the magnification at which it images distant objects. It is equal to the distance between the image plane and a pinhole that images distant objects the same size as the lens in question.

Resolution:

Resolution is the term used to describe the number of pixels, used to display an image. Higher resolutions mean that more pixels are used to create the image, resulting in a crisper, cleaner image. The number of pixel is to provide a more accurate figure for the resolution of the CCTV camera. Recently, the resolution is more than 1 mega pixel in general.

Minimum Illumination:

Minimum illumination is a way to measure the sensitivity of a camera. In another word It is mean, how dark the camera can still see usable image. There is the Day/Night function that colour video image at daytime, switch to black and white video image at night, to provide the best image automatically by determine the brightness of the day or night.

(4) Data and Interface

Encoding:

Encoding is a compression method of video images by using codec. There are several type of codec such as MPEG-2, MPEG-4, H.264 and so on. The quality the codec can achieve is heavily based on the compression format the codec uses. A codec is not a format, and there can be multiple codec that implement the same compression specification. For example, MPEG-1 codec typically do not achieve quality/size ratio comparable to codec that implement the more modern H.264 specification. But quality/size ratio of output produced by different implementations of the same specification can vary.

Frame rate:

Frame rate is the frequency at which an imaging device produces unique consecutive images called frames. Frame rate is most often expressed in frames per second (fps). In case of there are many more frames per second image becomes video image smoothly, as the data size of the video image becomes larger.

Ingress Protection:

The ingress protection or IP Code consists of the letters IP followed by two digits or one digit and one letter and an optional letter. As defined in international standard IEC 60529, IP Code classifies and rates the degrees of protection provided against the intrusion of solid objects, dust, accidental contact, and water in mechanical casings and with electrical enclosures.

CCTV camera shall be protected against dust and water ingress, where it will be installed outdoors in typical road section in accordance with IP66 of the international standards IEC 60529 or equivalent.

First Digit:

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.

Table 4.1 Meaning of First Digit in IPXX

Level	Object Size Protected against	Effective against
0	-	No protection against contact and ingress of objects
1	>50 mm	Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part
2	>12.5 mm	Fingers or similar objects
3	>2.5 mm	Tools, thick wires, etc.
4	>1 mm	Most wires, screws, etc.
5	Dust protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact
6	Dust tight	No ingress of dust; complete protection against contact

Source: ITS Integration Project (SAPI) Study Team

Second Digit:

Protection of the equipment inside the enclosure against harmful ingress of water.

Table 4.2 Meaning of Second Digit in IPXX

Level	Protected against	Details
0	Not protected	-
1	Dripping water	Test duration: 10 minutes Water equivalent to 1mm rainfall per minute
2	Dripping water when tilted up to 15°	Test duration: 10 minutes Water equivalent to 3mm rainfall per minute
3	Spraying water	Test duration: 5 minutes / Water volume: 0.7 litres per minute Pressure: 80–100 kN/m²
4	Splashing water	Test duration: 5 minutes / Water volume: 10 litres per minute Pressure: 80–100 kN/m²
5	Water jets	Test duration: at least 3 minutes Water volume: 12.5 litres per minute Pressure: 30 kN/m² at distance of 3m
6	Powerful water jets	Test duration: at least 3 minutes Water volume: 100 litres per minute Pressure: 100 kN/m² at distance of 3m
7	Immersion up to 1 m	Test duration: 30 minutes / Immersion at depth of 1m
8	Immersion beyond 1 m	Test duration: continuous immersion in water Depth specified by manufacturer

Source: ITS Integration Project (SAPI) Study Team

Interface:

Each device is assumed to be connected to Ethernet. The device is required to equip Ethernet interface. In addition, in order to streamline the piping and wiring of communication cable and power cable therefore, in order, the device is equipped the PoE (Power over Ethernet) what is power supply through the Ethernet cable. However, in case of the PTZ camera should be equipped a High PoE. It is capable supply a large amount of Power.

(5) Ambient Conditions and Others

Operating temperature / humidity range:

An operating temperature / humidity is the temperature / humidity at which an electrical or mechanical device operates. The device will operate effectively within a specified temperature / humidity range which varies based on the device function and application context, and ranges from the minimum to the maximum operating temperature / humidity.

Consumed power:

That is the amount of power consumed when the device is operating. Keeping the guideline value of the power consumption of the device on the specification, consideration to be required and ensured that electrical equipment does not exceed the electric capacity provided from the road side.

4.4 Location/Installation of CCTV Camera

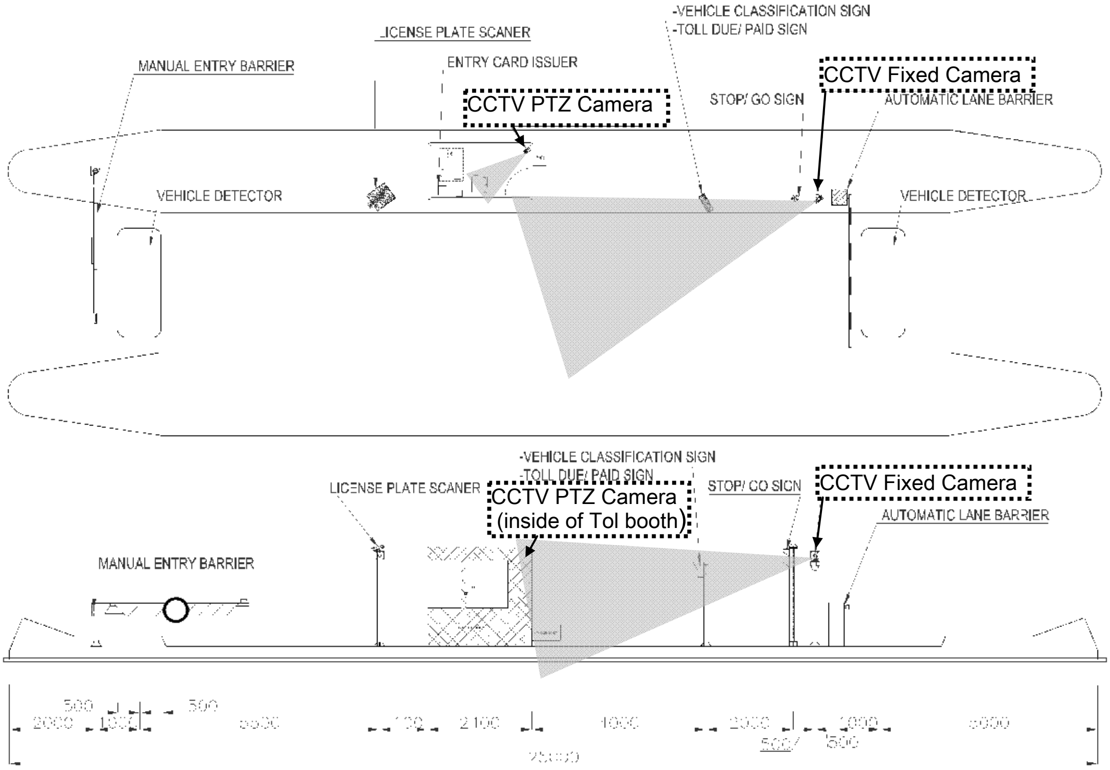
There are 2 types of camera for Tollgate Lane Monitoring. One camera should be installed on Toll Island for the Vehicle coming into and going out the tollgate, confirmation of class and appearance of the vehicle. Other one camera should be installed in Toll booth for the inspection of transfer of fee. And, the camera shall be has PTZ functions for watch toll collector’s hands especially. Type of camera, Intended Purpose and Location are showing as follows,

Additionally, need the communication between toll collector and toll office, to transmit various types of messages, information of card replacement, communication in case of trouble, and warning in case of detecting fraudulent behaviour of toll collector from toll office during operation and management of toll collection. Therefore, Headset communication device has better to be installed for the verbally communication.

Table 4.3 Type of Camera for Tollgate Lane Monitoring

Type	Intended purpose of Monitoring	Location
Fixed Camera	- Vehicle coming into the tollgate lane - Class and appearance of the vehicle - Occurrence of trouble and response to it in the tollgate lane - Vehicle going out from the tollgate lane	Toll Island
PTZ Camera (Indoor type)	- Activities of the driver and the toll collector	Toll Booth

Figure 4.5 Layout Plan of CCTV Camera for Tollgate Lane Monitoring



4.5 Data Set for Toll Lane Monitoring

Table 4.4 Principal Data Elements for Toll Lane Monitoring

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Image Recognition Result Data Set <G - Image Processor>	Road Management Office ID	INT*	4	1	When an event occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Image Recognition Result Status	INT*	2	1		
	Video Image Address	TXT	60	1		
	Date/Time	Datetime	≥14	1		
Event Image Data Set <G - Server>	Road Management Office ID	INT*	4	1	When an event is checked	1 year
	Roadside Equipment ID	INT*	4	1		
	Place ID	INT*	4	1		
	Video Image ID	INT	8	1		
	Event Video Image	IMG	var	1		
	Traffic Event Data ID	INT	8	1		
	Date/Time	Datetime	≥14	1		
Transaction Data Set <R - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months
	Tollgate ID	INT	8	1		
	Lane ID	INT*	4	1		
	OBU ID	INT	12	1		
	Vehicle Class in OBU	INT*	2	1		
	License number in OBU	TXT	12	1		
	IC-card ID	INT	12	1		
	Toll Amount	INT	8	1		
	Prepaid Balance	FLOAT	8	1		
	Termination Status	INT*	2	1		
	Serial Number of Vehicle	INT	5	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

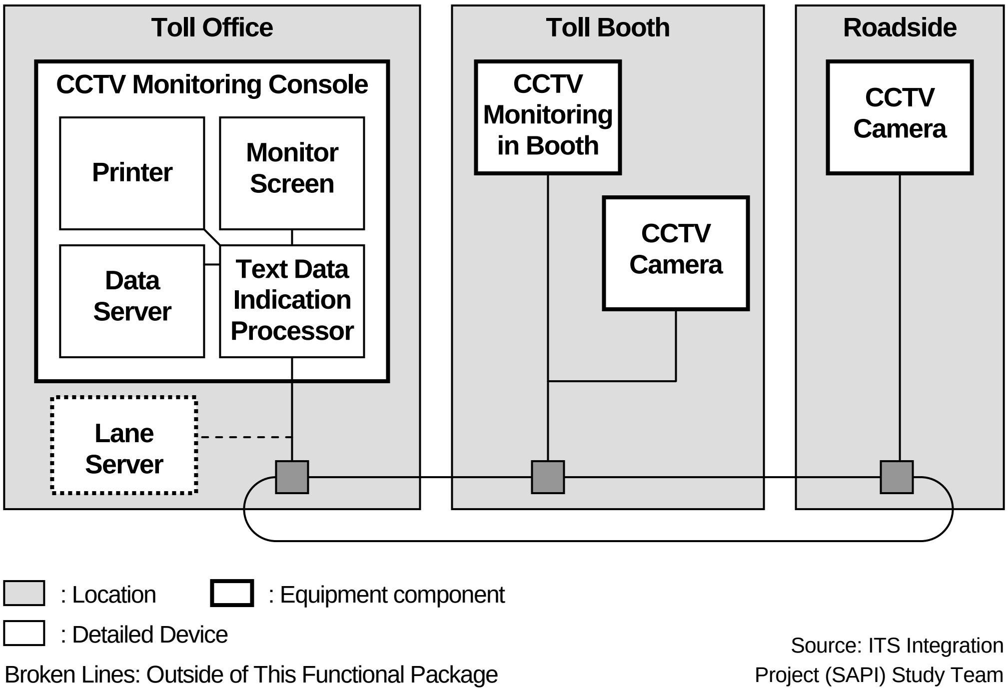
Source: ITS Integration Project (SAPI) Study Team

5. Vehicle/Class Identification

5.1 Outline and System Architecture

This functional package allows the road operators to identify individual vehicle by using a license plate scanner and other equipment installed in a separated lane such as a tollgate lane of the expressway.

Figure 5.1 System Architecture for Vehicle/Class Identification



Source: ITS Integration Project (SAPI) Study Team

5.2 Identifying Method of Vehicle/Class

Vehicle classification for roll rate of epxressway is based on the Circular No.14/2012/TT-BTC of MOF shown in the table below. The vehicle classification is defined by the combination of the number of seats and the loading capacity, focusing on the benefits provided by road use. This classification is to be identified by scanning license plate based on the following license plate system.

Table 5.1 Vehicle Classification in VIETNAM

Vehicle Class		Definition
Ordinary Vehicle	1	Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses
	2	Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons
	3	Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons
	4	Trucks with a capacity between 10 and 18 tons, 20ft-container lorries
	5	Trucks with a capacity of 18 tons or more, 40ft-container lorries
MOD Vehicle	6	Military vehicles in the missions
Police Vehicle	7	Public security vehicles in the missions

Source: ITS Standards & Operation Plan Study Team

In Vietnam, there is standard for License Plate such as "Decree No. 136/ 2003MD-CP". According to the standards, type of License Plate in Vietnam as follows;

- Vehicles of state administrative agencies, state-power bodies, judicial bodies, procurator offices; police; Communist Party bodies, socio-politic organizations:
  Base colour: blue
  Character and Number: white
  Serial No.: A, B, C, D, E

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- Vehicles of enterprises of all economic sectors; Vehicles of State offices, none-business organization, none-business organization with revenue; Private Vehicle:
  Base colour: white
  Character and Number: black
  Serial No.: F, H, K, L, M, N, P, R, S, T, U, V, X, Y, Z,

30 K - 2358

- Except following special cases:
  Vehicles of economic military bodies: KT
  Vehicles of 100% foreign companies, foreign joint ventures, rental vehicles from foreign companies (having Investment Certificate): LD
  Vehicles of projects funded by foreign fund: DA
  Semi-trailer, trailer: R
  Temporary registered vehicle: T
  Tractor: MK
  Electric motorbike: MĐ

30 LB - 2358

- Vehicles of Specific Economic Zone following the Government Regulation: the symbol of province where that vehicle registered and 2 initial letters of that Zone;
  Base colour: yellow
  Character and Number: Red

- Vehicle of foreign organizations, offices and individuals:

- Diplomatic representative offices, consulate offices and foreign officers who are granted with diplomatic immunity, consulate immunity, working for such organizations and offices:
  Base colour: white
  Number: black
  Serial No.: NG in red colour
  Especially, the vehicles of Ambassador and General Consular: strike line on the middle of letter showing Nationality and Registration Order.

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- Representative offices of international organizations, foreign officers who are granted with diplomatic immunity, consulate immunity, working for such organizations:
  Base colour: white
  Number: black
  Serial No.: QT in red colour
  Especially, the vehicles of Chief Representative of international organizations belong to UNDP: strike line on the middle of letter showing that organization vehicle symbol and Registration Order.

30 QT - 2358

- Vehicle of foreign organizations, representative offices, individuals (including foreign students):
  Base colour: white
  Number: black
  Serial No.: NN

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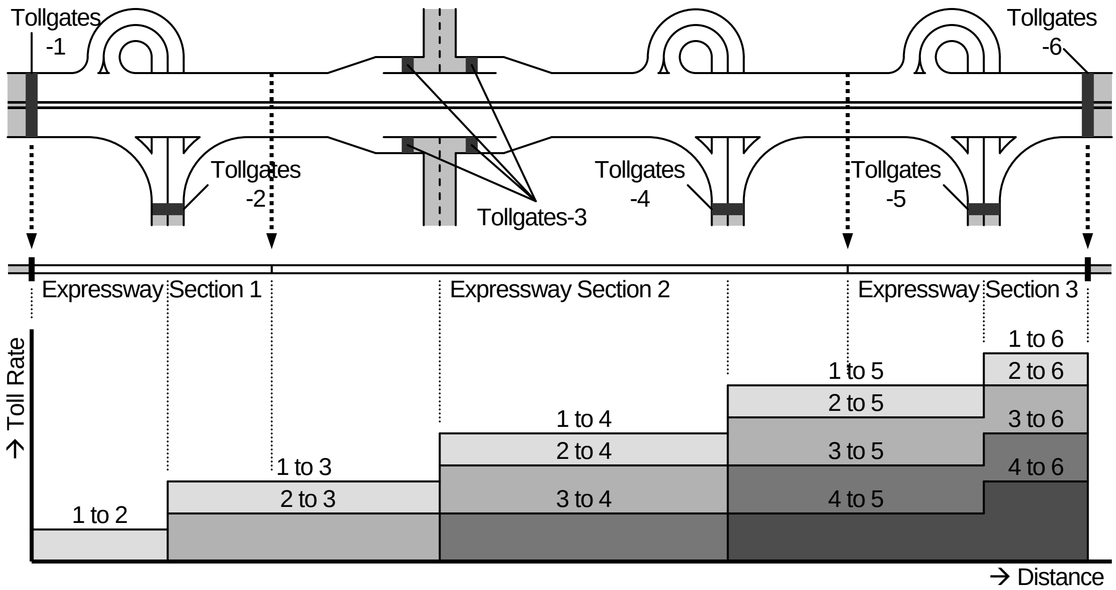
Figure 5.2 Example of Number Plate

Upper: Individuals
Lower Left:
Government Agencies
Lower Right: Foreign

Source: ITS Integration Project (SAPI) Study Team

5.3 Calculation of Toll Rate

Figure 5.3 Toll Rate Table for Whole Inter-city Expressway Network



Toll Rate Table		Exit					
		Tollgates-1	Tollgates-2	Tollgates-3	Tollgates-4	Tollgates-5	Tollgates-6
Entrance	Tollgates-1	--	1 to 2	1 to 3	1 to 4	1 to 5	1 to 6
	Tollgates-2	2 to 1	--	2 to 3	2 to 4	2 to 5	2 to 6
	Tollgates-3	3 to 1	3 to 2	--	3 to 4	3 to 5	3 to 6
	Tollgates-4	4 to 1	4 to 2	4 to 3	--	4 to 5	4 to 6
	Tollgates-5	5 to 1	5 to 2	5 to 3	5 to 4	--	5 to 6
	Tollgates-6	6 to 1	6 to 2	6 to 3	6 to 4	6 to 5	--

Note: A tollgate-ID is to be defined by using a pair of an expressway-ID and a number of kilometer post.

Source: ITS Integration Project (SAPI) Study Team

A method using a toll rate table for the whole expressway network is to be prepared for the expressway network. The figure foregoing shows an example of this method applied to an expressway network consists of three adjacent sections. In the toll rate table, toll amounts are defined respectively for all pairs of tollgates on the whole expressway network.

For this method, the toll rate table shall be revised and maintained when a new expressway section comes into service. Correlation between driving distance and toll rate is to be defined based on the unit toll rate shown in the table below.

Table 5.2 Vehicle Classification in VIETNAM

Vehicle Class		Definition	Unit Toll Rate (VND/km)
Ordinary Vehicle	1	Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses	1000
	2	Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons	1500
	3	Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons	2200
	4	Trucks with a capacity between 10 and 18 tons, 20ft-container lorries	4000
	5	Trucks with a capacity of 18 tons or more, 40ft-container lorries	8000

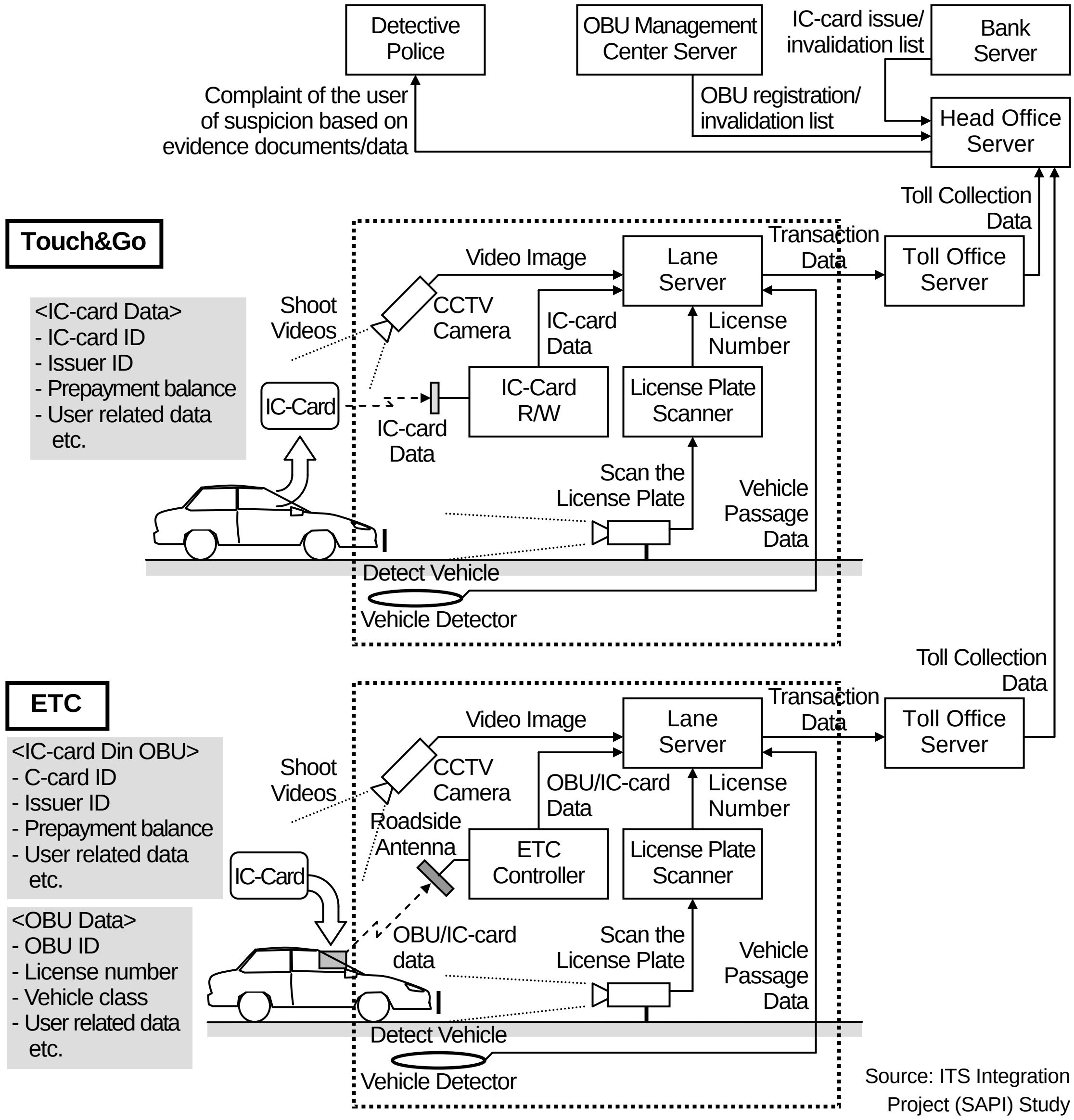
5.4 Data Set for Vehicle/Class Identification

Vehicle class data and vehicle identification data such as licence plate number are primary data for enforcement assistance.

Enforcement shall be conducted based on the data obtained by four ways as shown in figure below. These are the license number data in received from OBU through roadside antenna, the license number obtained by license plate scanner, and the vehicle passage data obtained by vehicle detector.

- Video image of vehicle appearance captured by CCTV
- Vehicle class data received from OBU through roadside antenna
- License number data received from OBU through roadside antenna
- License number data obtained by license plate scanner
- Vehicle passage data obtained by vehicle detector.

Figure 5.4 Major Message Exchanges for Enforcement Assistance



Source: ITS Integration Project (SAPI) Study

Data frame and principal data elements for toll enforcement are shown in the table below.

Table 5.3 Principal Data Elements for Enforcement Assistance

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Toll Rate Information Data Set <R - Server>	Number of tollgate pair	INT	8	1	Daily	1 year
	Tollgate Pair ID	INT	8	N		
	Entrance Tollgate ID	INT*	4			
	Exit Tollgate ID	INT*	4			
	Toll Rate of Vehicle Class 1	FLOAT	12			
	Toll Rate of Vehicle Class 2	FLOAT	12			
	Toll Rate of Vehicle Class 3	FLOAT	12			
	Toll Rate of Vehicle Class 4	FLOAT	12			
	Toll Rate of Vehicle Class 5	FLOAT	12			
	Toll Rate of Vehicle Class 6	FLOAT	12			
	Toll Rate of Vehicle Class 7	FLOAT	12			
	Toll Rate of Vehicle Class 8	FLOAT	12			
	Toll Rate of Vehicle Class 9	FLOAT	12			
	Toll Rate of Vehicle Class 10	FLOAT	12			
	Toll Rate of Vehicle Class 11	FLOAT	12			
	Toll Rate of Vehicle Class 12	FLOAT	12			
	Toll Rate of Vehicle Class 13	FLOAT	12			
	Toll Rate of Vehicle Class 14	FLOAT	12			
	Toll Rate of Vehicle Class 15	FLOAT	12			
	Toll Rate of Vehicle Class 16	FLOAT	12			
	Toll Rate of Vehicle Class 17	FLOAT	12			
	Toll Rate of Vehicle Class 18	FLOAT	12			
	Toll Rate of Vehicle Class 19	FLOAT	12			
	Toll Rate of Vehicle Class 20	FLOAT	12			
	Number of document	TXT	20			
	Date of Toll Rate Table	TXT	8			

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

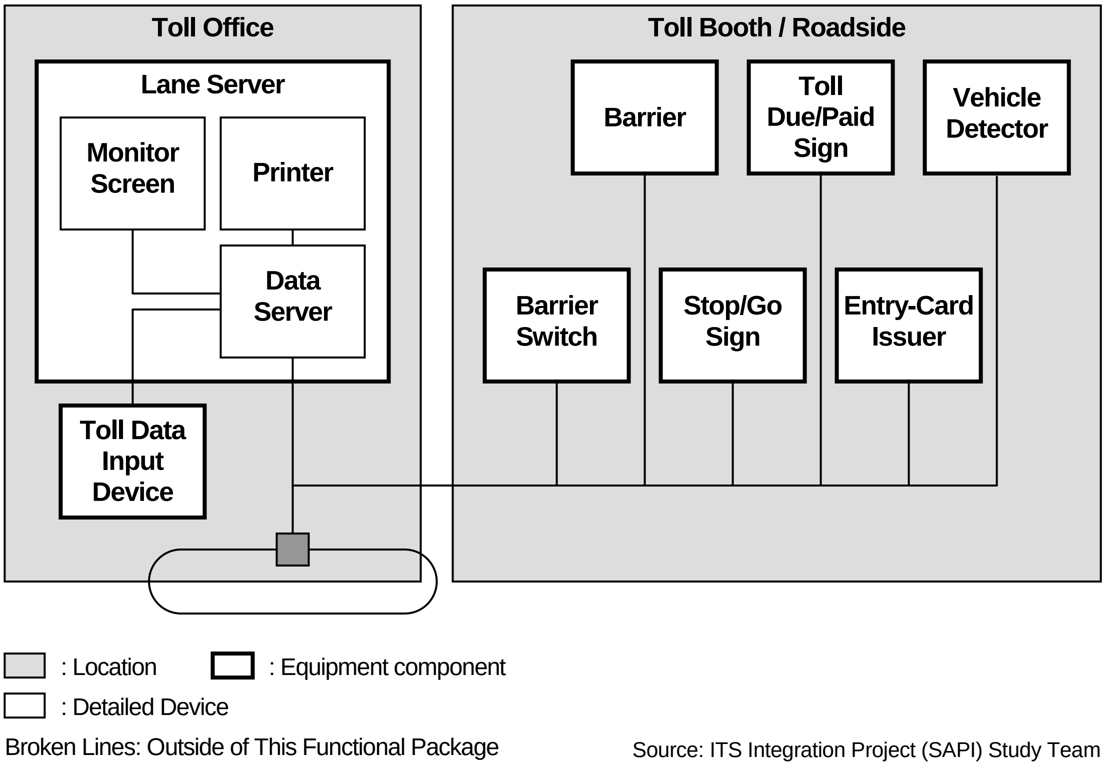
Source: ITS Integration Project (SAPI) Study Team

6. Lane Control

6.1 Outline and System Architecture

This functional package allows the road operators to eliminate the vehicle passages without adequate toll collection by using a computer, vehicle detectors, signs and a barrier installed in a separated tollgate lane of the expressway.

Figure 6.1 System Architecture for Lane Control

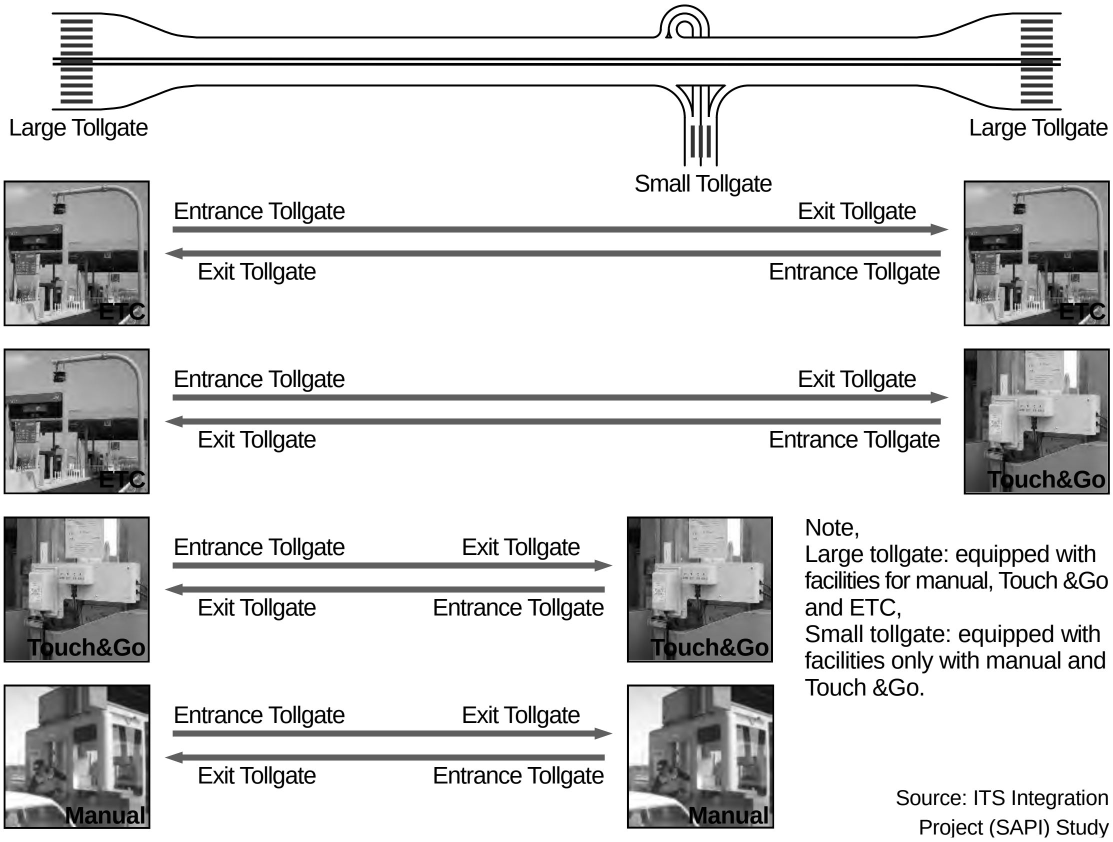


Source: ITS Integration Project (SAPI) Study Team

6.2 Tollbooth Arrangement at Tollgate

Available combination of toll collection methods at entrance and exit is shown in the figure below. For reducing the cost of roadside equipment implementation, combination use of ETC and Touch&Go is available.

Figure 6.2 Available Combination of Toll Collection Methods at Entrance/Exit



Note,
Large tollgate: equipped with facilities for manual, Touch &Go and ETC,
Small tollgate: equipped with facilities only with manual and Touch &Go.

Source: ITS Integration Project (SAPI) Study

Arrangement criteria of tollbooths are defined responding to design traffic volume passes through the tollgate and according to the basic policy that heavy vehicles are to be processed in the tollgate lanes near roadside.

Table 6.1 Arrangement Criteria of Tollbooths for Toll Collection

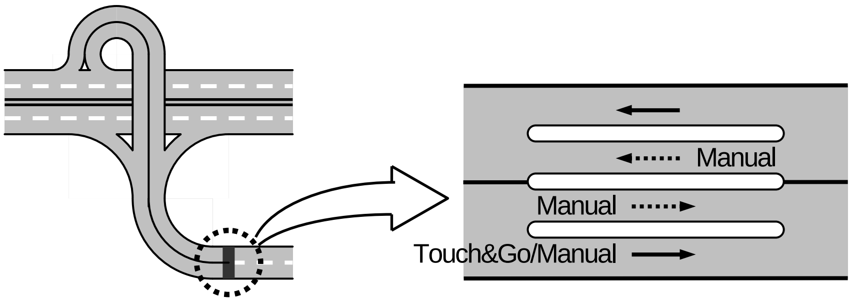
	Small Traffic Volume	Average Traffic Volume	Large Traffic Volume	
For Toll Collection	Tollbooth Arrangement Criteria 1	Tollbooth Arrangement Criteria 2	Tollbooth Arrangement Criteria 3	Tollbooth Arrangement Criteria 4

Source: ITS Integration Project (SAPI) Study Team

(1) Tollbooth Arrangement Criteria 1

As the standard arrangement for the tollgate consists of two lanes in each direction at a trumpet-type interchange for small traffic volume, Touch& Go is to be installed in a lane on the roadside as shown in the figure below. Two kinds of processing of toll collection: Touch&Go and manual are to be carried out in the same lane.

Figure 6.3 Tollbooth Arrangement at Trumpet-Type Interchange for Small Traffic Volume

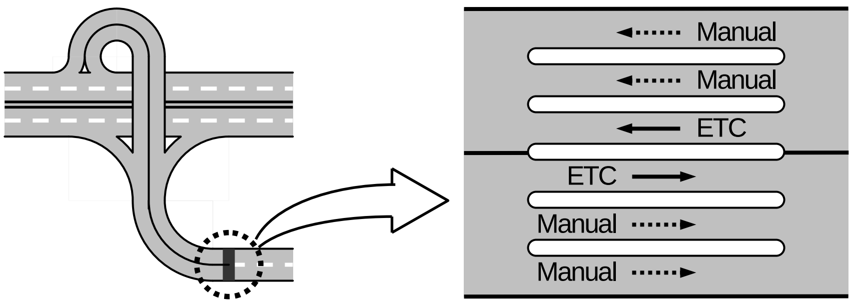


Source: ITS Integration Project (SAPI) Study Team

(2) Tollbooth Arrangement Criteria 2

As the standard arrangement for the tollgate consists of three lanes in each direction at a trumpet-type interchange for middle traffic volume, ETC is to be installed in the center lane as shown in the figure below. Only the vehicles equipped for ETC are to be processed at the median-side lane exclusively. In the later stage, when many vehicles equipped for ETC and toll processing capacity is not sufficient, ETC is to be installed additionally in other lane.

Figure 6.4 Tollbooth Arrangement at Trumpet-Type Interchange for Middle Traffic Volume

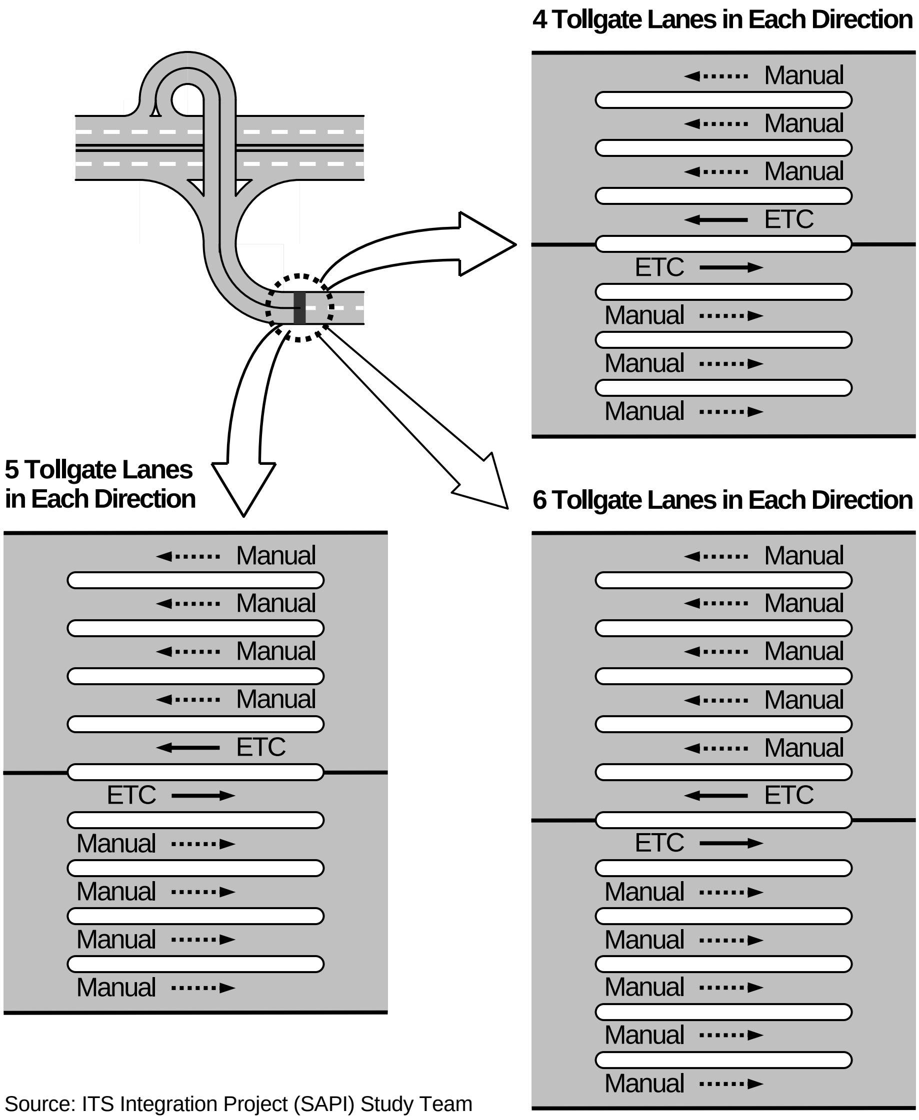


Source: ITS Integration Project (SAPI) Study Team

(3) Tollbooth Arrangement Criteria 3

As the standard arrangement for the tollgate consists of four, five or six lanes in each direction at a trumpet-type interchange for large traffic volume, ETC is to be installed in the median-side lane as shown in the figure below. Only the vehicles equipped for ETC are to be processed at these lanes exclusively. In the later stage, when many vehicles equipped for ETC and toll processing capacity is not sufficient, ETC is to be installed additionally in other lane.

Figure 6.5 Tollbooth Arrangement at Trumpet-Type Interchange for Large Traffic Volume

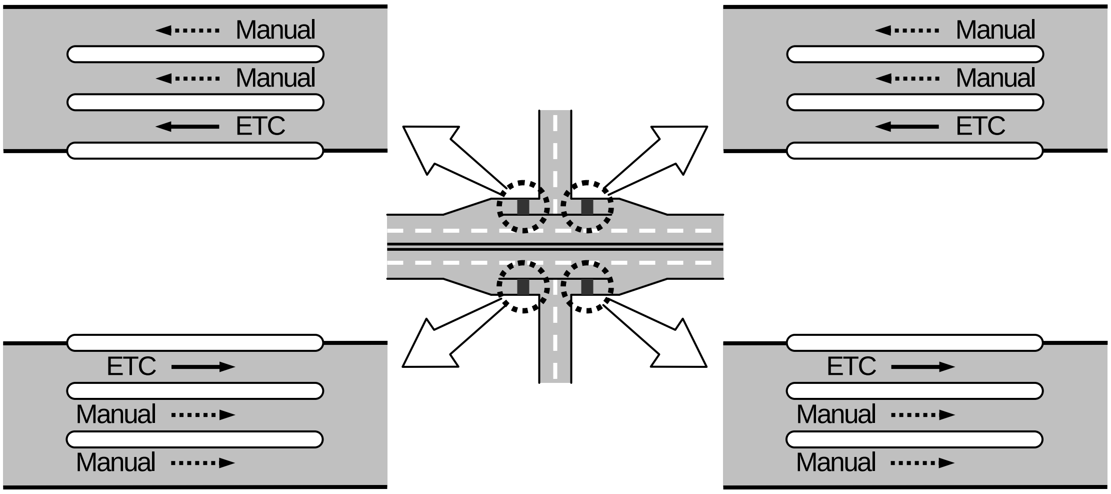


Source: ITS Integration Project (SAPI) Study Team

(4) Tollbooth Arrangement Criteria 4

As the standard arrangement for the tollgate consists of three lanes in each direction at a diamond-type interchange for large traffic volume, ETC is to be installed in the left-hand lane as shown in the figure below. Only the vehicles equipped for ETC are to be processed at these lanes exclusively. In the later stage, when many vehicles equipped for ETC and toll processing capacity is not sufficient, ETC is to be installed additionally in other lane.

Figure 6.6 Tollbooth Arrangement at Diamond-Type Interchange for Large Traffic Volume



Source: ITS Integration Project (SAPI) Study Team

6.3 Capacity and Calculating Number of Tollgate Lanes

(1) Variation of Tollgates

Tollgate is classified into two types according to its installation location.

- Barrier tollgate: The tollgate installed on the through lanes
- Interchange tollgate: The tollgate installed in an interchange

(2) Precautions for Design

Tollgate is a facility which is installed on the road in order to stop vehicles, since it is contradictory by nature to road which is a facility aiming at smooth vehicle traffic, it is necessary to pay special attention to the following precautions in designing tollgate square:

- The existence of a tollgate shall not be the obstacle to safety. In case of a tollgate inside an interchange, the tollgate must avoid any influence on traffic especially in the through lanes. In case of a toll barrier, besides giving prior notice and caution from adequate distance to the coming traffic at the speed on the through lanes, the tollgate must be installed so that it can be seen from long distance. It is necessary to take efforts to avoid installing the tollgate in places where the speed is likely to increase such as on the bottom of a vertical concave line shape.
- The tollgate must be installed in such a way as not be a bottleneck in traffic. This can be achieved only by preparing adequate number of lanes for handling traffic at peak hour. Besides, in case the distance between exit tollgate and connecting road is short, since the congestion in the intersection may surpass the tollgate and results in the congestion on the through lanes, there should be adequate space for tollgate as well as intersection.
- The tollgate must be safe and facile for vehicles to stop or start moving, and convenient for collecting toll. This will require the tollgate square to be as flat and straight as possible.

- It is necessary to consider and implement plan on many issues such as traffic management and toll collection.

(3) Number of Tollgate Lanes

The required number of tollgate lanes can be obtained from Table 17-1 if the traffic volume (interval between coming-in vehicles), average service time and service criteria (average number of queuing vehicles) are determined. Upon separating shuttling roadway (into entry interchange and exit interchange), the required number of lanes adequate for traffic volume of the direction with busy traffic during peak hour must be built in each side.

In case an entry interchange and an exit interchange are located in one place and the lane in central part is utilized as reversible lane, the required number of lanes for entry interchange and exit interchange is calculated based on the direction with busy traffic in case of long service time, or the traffic volume of direction with less traffic in case of short service time, then the total calculated number of lanes shall be built.

Traffic volume, average service time and service criteria are based on following standards:

Standard Hourly Traffic Volume

The traffic volume is determined based on the design hourly traffic volume (DHV), however, the 30th hour is used in this case. The 30th hour traffic volume can be obtained from the following formula with annual average daily traffic volume (ADT):

$$\text{DHV} = \text{ADT} \times K \times D$$

In the formula above, K (the ratio of the 30th hour traffic volume to ADT) and D (the ratio of the traffic volume of direction with busy traffic during the 30th hour to total traffic volume of both directions) conform to "The design traffic volume of an interchange" in principal. In some other special cases, K and D can be determined by using other factors as reference such as the actual measured value of a similar region.

Service Time

In order to calculate required number of lanes, service time is defined in principal as 6 seconds for entry interchange and 14 seconds for exit interchange in case of sectional tariff system, or as 8 seconds in case of flat tariff system. However, in places where these values are anticipated to be obviously different, other average service time can be used.

Service Criteria

Service criteria are determined by average number of queuing vehicles, but in principal it is defined as 1.0 vehicle. In the case it is difficult to base on this value due to some other reasons such as geological formation, and if the traffic is smooth, other value can be used.

Table 6.2 Number of Tollgate Lanes, Service Time, Average Number of Queuing Vehicles and Vehicle Processing Capacity (vehicles/hr)

	Service Time											
	6 sec		8 sec		10 sec		14 sec		18 sec		20 sec	
	1	3	1	3	1	3	1	3	1	3	1	3
1	300	450	230	340	180	270	130	190	100	150	90	140
2	850	1,040	640	780	510	620	360	440	280	350	250	310
3	1,420	1,630	1,070	1,230	850	980	610	700	480	550	430	490
4	2,000	2,230	1,500	1,670	1,200	1,340	860	960	670	740	600	670
5	2,590	2,830	1,940	2,120	1,550	1,700	1,110	1,210	860	940	780	850
6	3,180	3,430	2,380	2,570	1,910	2,060	1,360	1,470	1,060	1,140	950	1,030
7	3,770	4,020	2,830	3,020	2,260	2,410	1,620	1,720	1,260	1,340	1,130	1,210
8	4,360	4,630	3,270	3,470	2,620	2,780	1,870	1,980	1,450	1,540	1,310	1,390
9	4,960	5,220	3,720	3,920	2,980	3,130	2,130	2,240	1,650	1,740	1,490	1,570
10	5,560	5,820	4,170	4,370	3,330	3,490	2,380	2,490	1,850	1,940	1,670	1,750
11	6,150	6,420	4,610	4,820	3,690	3,850	2,640	2,750	2,050	2,140	1,850	1,930
12	6,740	7,020	5,050	5,270	4,040	4,210	2,890	3,010	2,250	2,340	2,020	2,110
13	7,340	7,620	5,510	5,720	4,400	4,570	3,150	3,270	2,450	2,540	2,200	2,290
14	7,940	8,220	5,954	6,170	4,760	4,930	3,400	3,520	2,650	2,740	2,380	2,470
15	8,530	8,820	6,400	6,620	5,120	5,290	3,660	3,780	2,840	2,940	2,560	2,650

(4) Calculation Method of the Number of Tollgate Lanes

The required number of tollgate lanes can be determined upon knowing 3 factors: traffic volume, necessary service time for toll collection, and service criteria (criteria for judging whether the service is good or bad based on average time for keeping customers waiting).

If the traffic volume is high, the larger number of gates shall be needed and if the service time is long, similarly, the larger number of gates shall be needed. In case number of gate is comparatively less than traffic volume, customers shall have to wait longer. In other words, in order to upgrade service criteria and to shorten average waiting time, the number of gates must be increased.

Thus, the issue of handling each coming vehicle one after another can be defined as the waiting line or the issue of keeping waiting in mathematics. It is common sense that the status of waiting line can be obtained based on the relation between above mentioned 3 factors, or to be more accurate, that is the relation between the following 3 factors:

- The statistic distribution of coming vehicles toward the gate in a certain period of time (Interval between coming vehicles)
- The statistic distribution relevant to the time that each vehicle occupies the gate in order to pay the toll (service time)
- The relation between the number of vehicles coming into the tollgate in a certain time and the time that a vehicle occupies the tollgate to pay toll (the interval between coming vehicles and service time)

Now, if a: average interval between vehicles (second)

b: average service time (second)

s: number of lanes (number of gates)

in general, the relation between coming vehicles and service time is defined as follows:

$\rho = b/a$ (traffic intensity)

then, gate per lane is defined as follows:

$u = b/sa$ (traffic intensive of per lane)

In the formula above, $u \geq 1$, this means if service time is longer than incoming interval per lane, of course the tollgate can not handle all coming vehicles and this shall result in endless line of queuing vehicles. Therefore, upon knowing a and *b, s* must be defined so that *u* becomes less than 1. If *u* is less than 1, the incoming vehicle shall pass the gate after an average time of waiting, but that situation differs according to the status of statistic distribution of coming car interval and service time

The interval between coming vehicles conforms to Poisson distribution law, in case the service time complies with index distribution, (it is common sense that this has been applied in practice based on the actual measurement); however, its relation is given as follows:

Average waiting time: $\omega = \dfrac{\rho^s}{s.s!} \bullet \dfrac{b}{(1-u)^2} \bullet k$

Average number of vehicles (Service criteria): $q = \dfrac{1}{(1-u)^2} \bullet \dfrac{\rho}{s!} \bullet k = \dfrac{\omega}{k} \bullet s$

Average number of queuing vehicles per lane (the length of line) $= \dfrac{q}{s} = \dfrac{\omega}{b}$

However,

$\dfrac{3,600}{b} u \bullet s$ (the possibility that there is no vehicle in the gate)

The average number of queuing vehicles per lane (*q / s*) can be obtained from service criteria, but the relation between this and the traffic intensity per lane (*u*) and number of gates (*s*) can be determined by above mentioned formulas and it is given in Table 17 -2. According to this Table (or Graph 17-1), regarding similar average number of queuing vehicles (service criteria), the larger number of lanes is, the higher the traffic intensity per lane gets. In other words, the vehicle processing capacity per lane is increased. This is because in case one gate is occupied, the next incoming vehicle may take advantage of the other vacant gate, and the efficiency is improved.

The required number of lanes is determined by giving specific values to traffic volume (interval between incoming vehicles) and average service time, then the required number of lanes corresponding to service criteria can be obtained. The determination method of those values and calculation method are given below.

Traffic Volume

The traffic volume, similar to the cases of the through lane and ramp design, shall apply design hourly traffic volume. The design hourly traffic volume is obtained by multiplying Annual average daily traffic volume (ADT) of calculated year by *K* and *D*. However, the determination method of these values varies a great deal so the design hourly traffic volume based on it also varies widely. Since this design hourly traffic volume is the most important factor in determining the number of gates, determination of this factor requires discretion. In determining the final necessary volume, attention must be paid so that the value is not excessive but a certain leeway for period of phased construction must be foreseen.

Service Time

The service time differs according to toll collection method and types of vehicle, but it takes usually an average time of 8 ~ 14 seconds to collect toll. Nowadays, according to experience in many routes such as Meishin, Tomei and Central Road, service time in entry interchange takes 6 seconds (only for card delivery), that in exit interchange takes 14 seconds (in case of sectional tariff system and the tariff system which toll differs according to types of vehicle) as a standard. Besides, in case of flat tariff system, in general, service time is defined as 8 seconds (for toll payment).

Service Criteria

Service criteria are built based on average number of queuing vehicles per gate, as being mentioned in the formula above, average waiting time is the value obtained by multiplying average number of queuing vehicles by average service time. If this standard value (q / s) gets bigger, when the temporary traffic volume increases, it is likely to result in long line of queuing vehicles. Besides, according to the assumption of theoretical calculation, vehicles are distributed evenly among all gates, but in fact, vehicle has a character of direction selection, there are many instances where even in situation of busy traffic, vehicles mostly gather in the central gate, both sides of the tollgate are comparatively empty. Therefore, in case of large number of gates, the number of queuing vehicles in the central part is higher than theoretical value. From those aspects, the appropriate standard value of service criteria is defined as 1.0. However, in case it is difficult to base on this value due to some other reasons such as geological formation, and if the traffic is smooth, the value up to 3.0 can be used.

Calculating the Required Number of Lanes

The traffic intensity (ρ) can be obtained from design hourly traffic volume (DHV) and service time (b). This means

$$\rho = \frac{b}{a} = \frac{DHV}{3,600} b$$

Since the traffic intensity of one lane u is ρ / s, the value of s in such a way as to keep the traffic intensity not to exceed the values given in Table 17-12 is the required number of lanes.

The relation between number of tollgate lanes, average number of queuing vehicles and the traffic intensity per lane, which are calculated by above formulas, is given in Table 14.2 and Table 14.3.

Besides, if the traffic intensity per lane (u), service time (b), number of lanes (s) and service criteria (q / s) are stipulated by these calculations, the hypothesis of calculation changes, but

$$\frac{3,600}{b} u \bullet s$$

is the number of process able vehicles per hour of that tollgate.

Table 6.3 Number of Tollgate Lanes (s), Average Number of Queuing Vehicles (q) and Traffic Intensity for a Tollgate Lane (u)

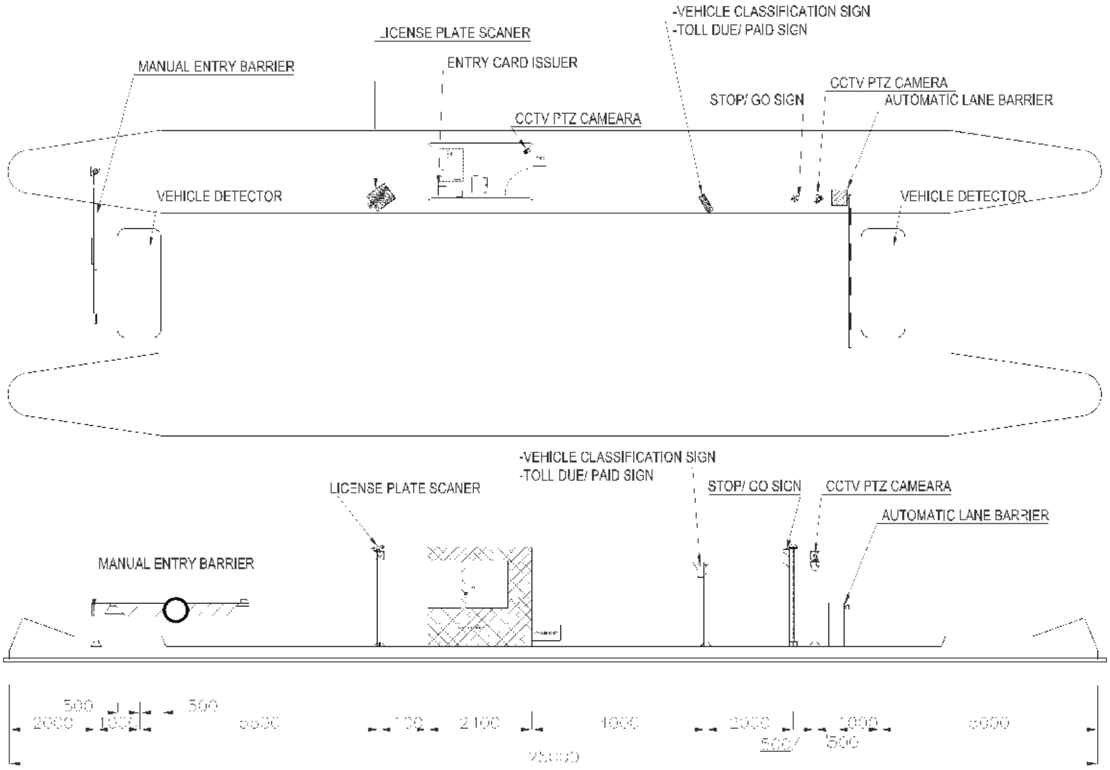
Number of Tollgate Lanes	Average Number of Queuing Vehicles (q/s)							
	0.5	1.0	1.5	2.0	3.0	4.0	5.0	10.0
1	0.333	0.500	0.600	0.667	0.750	0.800	0.833	0.909
2	0.577	0.706	0.775	0.817	0.863	0.895	0.913	0.953
3	0.686	0.791	0.841	0.872	0.908	0.928	0.940	0.969
4	0.748	0.835	0.876	0.902	0.929	0.945	0.955	0.976
5	0.787	0.863	0.899	0.919	0.942	0.955	0.963	0.981
6	0.817	0.883	0.914	0.932	0.952	0.962	0.969	0.984
7	0.838	0.898	0.925	0.940	0.958	0.968	0.974	0.986
8	0.854	0.909	0.933	0.948	0.964	0.972	0.977	0.988
9	0.868	0.919	0.941	0.953	0.967	0.975	0.980	0.989
10	0.878	0.926	0.946	0.957	0.970	0.977	0.982	0.990
11	0.888	0.932	0.950	0.961	0.973	0.979	0.983	0.991
12	0.896	0.936	0.954	0.964	0.975	0.981	0.984	0.992
13	0.903	0.941	0.958	0.967	0.977	0.982	0.986	0.992
14	0.908	0.945	0.961	0.969	0.979	0.983	0.987	0.993
15	0.913	0.948	0.962	0.971	0.980	0.984	0.988	0.993

6.4 Arrangement of Roadside Equipment at Tollgate

(1) Manual Lane

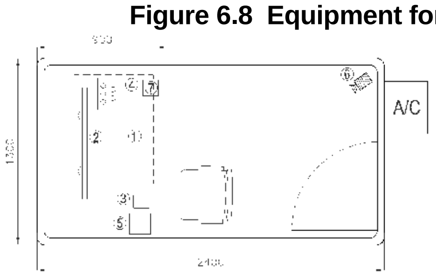
The most of lane type is manual at toll gate. For toll collection, it is done the delivery and receipt operation by using radio-frequency transmission instead of human labour forth in both ETC and Touch&Go. Therefore, the same roadside equipments are installed at the lane, except DSRC antenna, Contactless IC card reader / writer. Layout of roadside equipment at Manual lane is shown in the figures below.

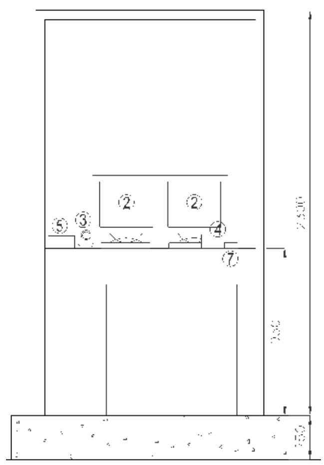
Figure 6.7 Arrangement at Manual Lane



Source: ITS Integration Project (SAPI) Study Team

Figure 6.8 Equipment for Tollbooth





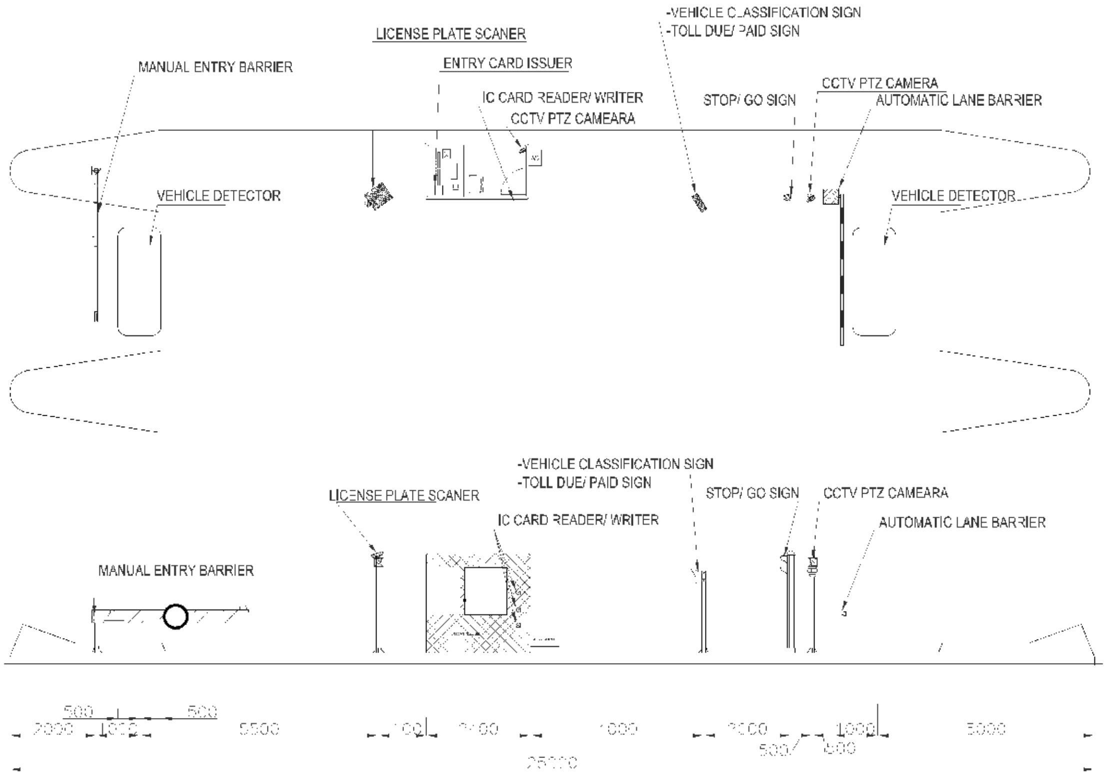
① Toll collection Console (Keyboard)
② Toll collection Console (LCD Monitor)
③ Barcode Scanner
④ Manual Booth Controller
⑤ Intercom Unit
⑥ CCTV PTZ camera

Source: ITS Integration Project (SAPI) Study Team

(1) Touch&Go Lane

Touch&Go (by using Contactless IC-Card) toll collection should be used in a first step. Therefore, we recommend that Touch&Go is installed on at least 1 lane at each tollgate / toll barrier. Layout of roadside equipment at Touch and Go lane is shown in the figure below.

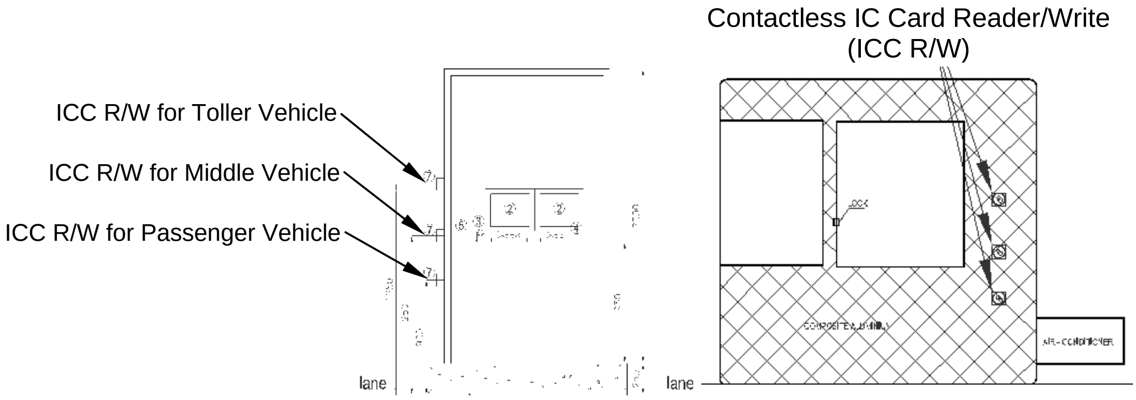
Figure 6.9 Arrangement at Touch&Go Lane



Source: ITS Integration Project (SAPI) Study Team

Contactless IC Card Reader / Writer (ICC R/W) are installed at Touch and Go lane. The ICC R/W are attached on the outside wall of toll booth, it is installed three height according to the height of driver seat. The installation is shown in the figure below.

Figure 6.10 IC-card Reader/Writer

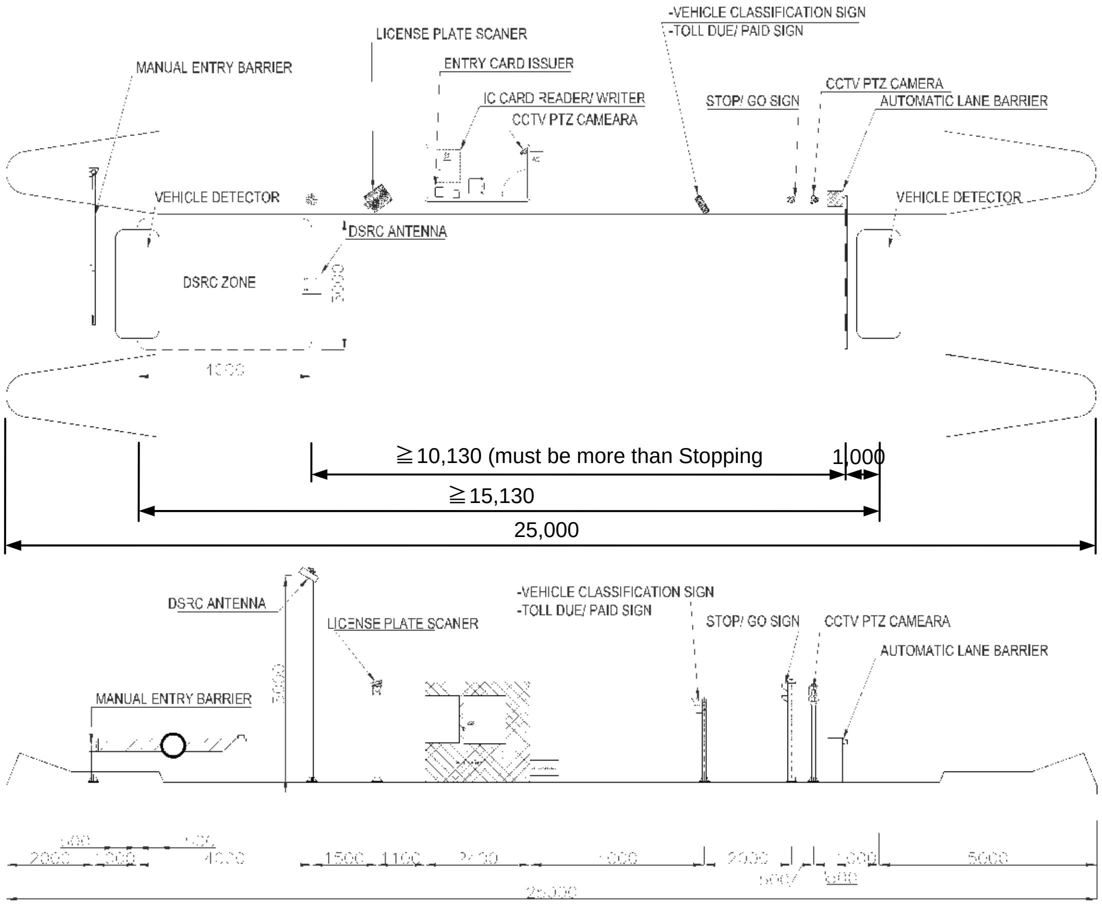


Source: ITS Integration Project (SAPI) Study Team

(2) ETC Lane

For distance-based toll collection, the toll amount is calculated by the distance from the entrance interchange to the exit interchange based on which entrance interchange is passed through. The same is true in the case of Electric Toll Collection (ETC) . Therefore, ETC is should be installed at both the interchange entrances and exits. Thus, we recommend that ETC is installed on at least 1 lane at each tollgate / toll barrier. Layout of roadside equipment at ETC lane is shown in the figure below.

Figure 6.11 Arrangement at ETC Lane



Source: ITS Integration Project (SAPI) Study Team

The length of toll island is 25m mainly in existing design or existing toll gate. In case of the speed of passing vehicles 25km/h at toll lane, layout of toll equipment at the toll island is as shown in Figure as follows, it is sufficient to the length of toll island is 25m.

Table 6.4 Vehicle Speed and Stopping Distance

Vehicle Speed (km/h)	10	15	20	25	30	35	40
Stopping Distance (m)	2.87	4.90	7.32	10.13	13.34	16.94	20.93

Source: ITS Integration Project (SAPI) Study Team

6.5 Required Functions of Roadside Equipment

Roadside equipment of toll collection is consists of the following components and functions.

Table 6.5 Components/Functions of Roadside Equipment of Toll Collection

Component	Function
Lane server	Toll fee calculation and control various types of equipment related to toll collection
Data Input Console *	Terminal equipment for input the data such as classification of vehicles, collected toll amount and etc.
IC-card R/W **	To communicate with contact-less IC card, to write/read the entrance gate information, to read/rewrite the balance in the card.
Roadside Antenna ***	To communicate with OBU installed in the vehicle, to receive the recorded information from OBU, to send the information to OBU
ETC Controller ***	To control roadside antenna
License Plate Scanner	To recognize license plate information by image
Barrier	To prevent the entry of vehicles into the lane during maintenance, it is operated by manual.

Note, * : Component for manual toll collection, ** : Component for Touch&Go, *** : Component for ETC

6.6 Data Set for Lane Control

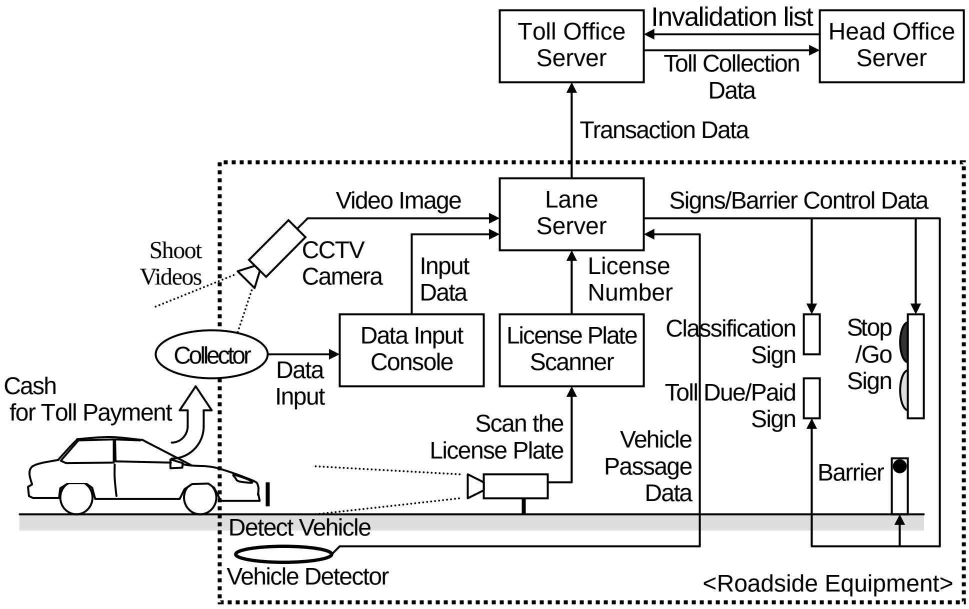
In this chapter the message exchange for lane control is to be illustrated based on the following three toll collection methods.

- Manual Toll Collection
- Touch&Go
- ETC

(1) Manual Toll Collection

Major messages for manual toll collection are to be exchanged as shown in the following figure, and tollgate lanes are to be controlled according to these message exchanges.

Figure 6.12 Major Message Exchanges for Manual Toll Collection

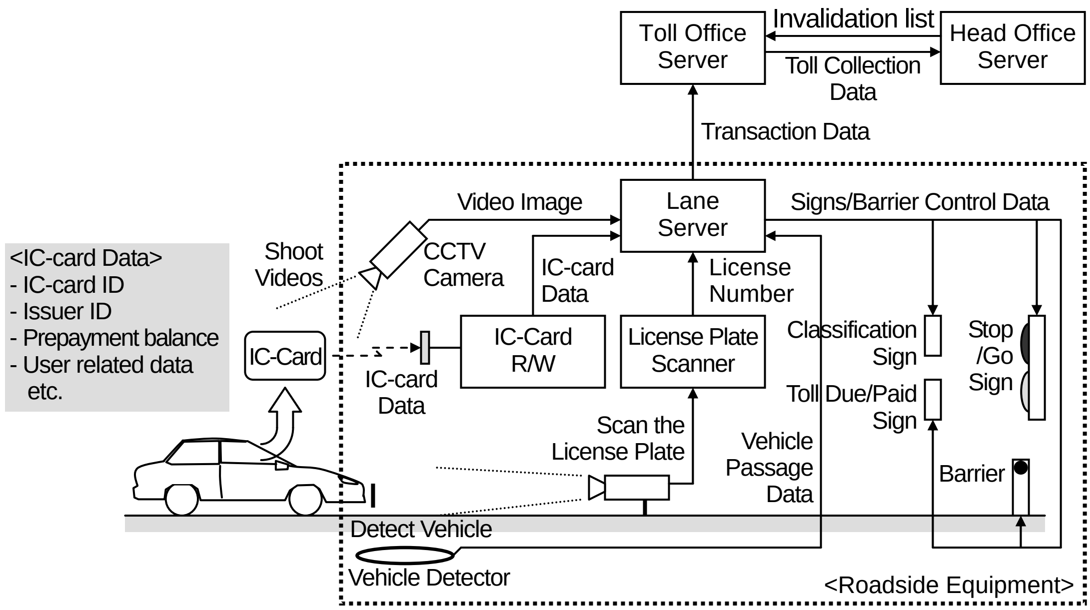


Source: ITS Integration Project (SAPI) Study

(2) Touch&Go

Major messages for Touch&Go are to be exchanged as shown in the following figure, and tollgate lanes are to be controlled according to these message exchanges.

Figure 6.13 Major Message Exchanges for Touch&Go

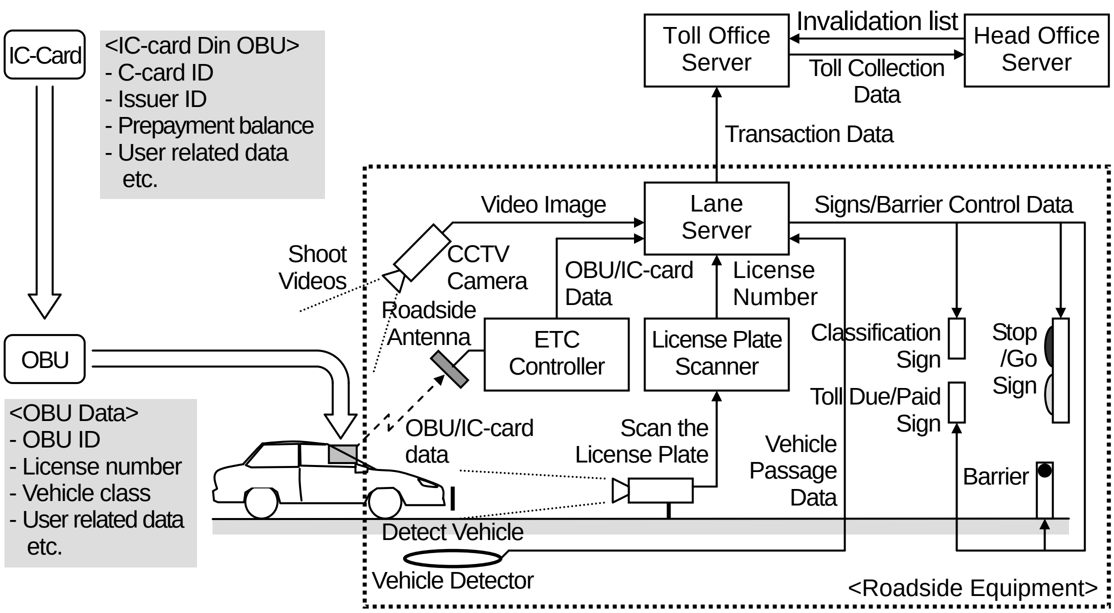


Source: ITS Integration Project (SAPI) Study

(3) ETC

Major messages for ETC are to be exchanged as shown in the following figure, and tollgate lanes are to be controlled according to these message exchanges.

Figure 6.14 Major Message Exchanges for ETC



Source: ITS Integration Project (SAPI) Study

(4) Data Set

Data frame and principal data elements for lane control are shown in the table below.

Table 6.5 Principal Data for Lane Control

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Bar-code Data Set <G - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	1 month
	Tollgate ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Deposit Terminal ID	INT*	4	1		
	Ticket Type	INT*	4	1		
	Vehicle Class	INT*	2	1		
	Serial Number	INT	12	1		
	Date Issue	Date	8	1		
	Date of Expiry	Date	8	1		
IC-card Invalidation List Data Set <G - Server>	Issuer ID	INT*	4	1	Daily	1 year
	Issue Terminal ID	INT	12	N		
	IC-card ID for Invalidation	INT	12			
	IC-card Owner ID	INT	18			
	Amount of Deposit	FLOAT	8			
	Date/Time of Issue	TXT	≥14			
	Date/Time of Expiry	TXT	≥14			
	Date/Time	Datetime	≥14	1		
OBU Invalidation List Data Set <G - Server>	Management Organization ID	INT	12	1	Daily	1 year
	OBU ID for Invalidation	INT	12	N		
	OBU Owner ID	INT	18			
	License Plate Number	TXT	12			
	Vehicle Class	TXT	2			
	Date of Issue	TXT	8			
	Date of Expiry	TXT	8			
	Date/Time	Datetime	≥14	1		
Transaction Data Set <R - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months
	Tollgate ID	INT	8	1		
	Lane ID	INT*	4	1		
	OBU ID	INT	12	1		
	Vehicle Class in OBU	INT*	2	1		
	License number in OBU	TXT	12	1		
	IC-card ID	INT	12	1		
	Toll Amount	INT	8	1		
	Prepaid Balance	FLOAT	8	1		
	Termination Status	INT*	2	1		
	Serial Number of Vehicle	INT	5	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

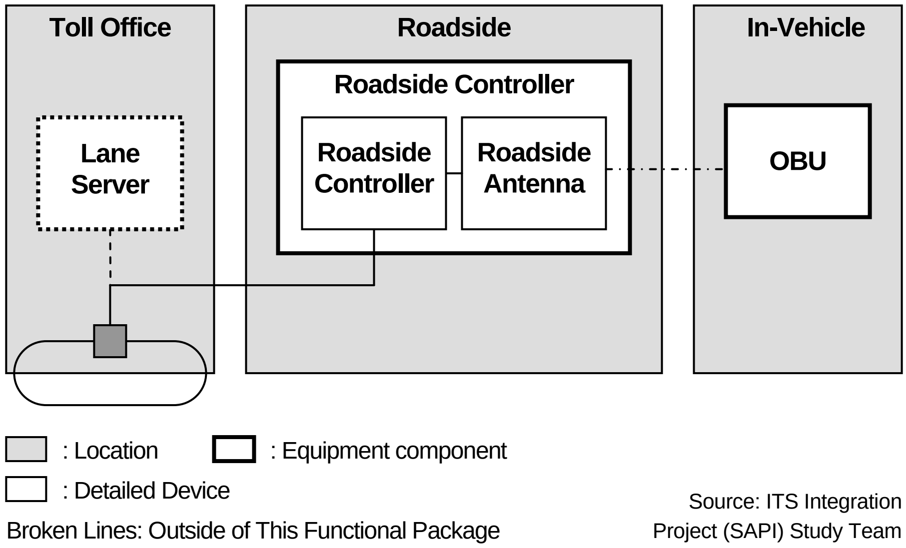
Source: ITS Integration Project (SAPI) Study Team

7. Road-to-vehicle Communication

7.1 Outline and System Architecture

This functional package allows the road operators to exchange data for toll collection and other services on the expressways by using radio communication between antennas installed at roadside and on-board units installed in the vehicles.

Figure 7.1 System Architecture for Road-to-Vehicle Communication

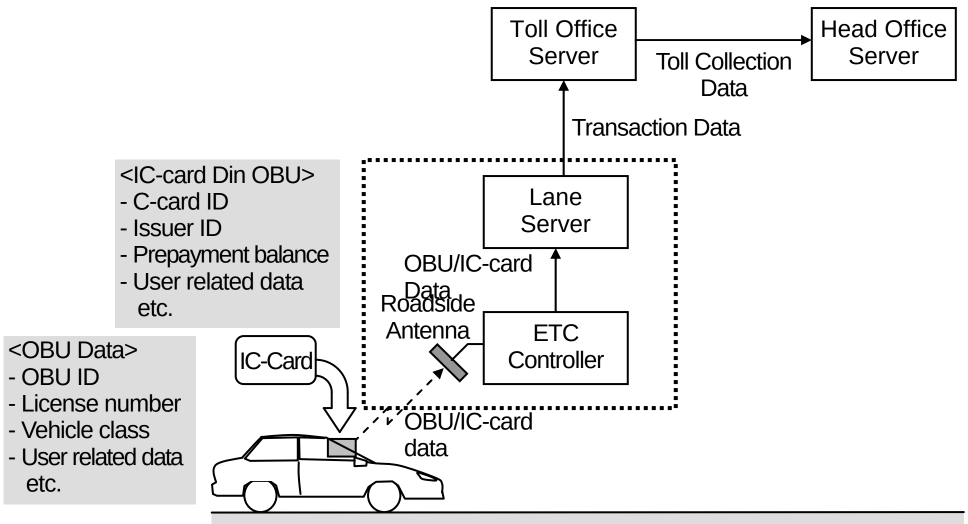


Source: ITS Integration Project (SAPI) Study Team

7.2 Procedure of Toll Collection by ETC

Major messages for ETC are to be exchanged as shown in the figure below.

Figure 7.2 Major Message Exchanges for ETC



Source: ITS Integration Project (SAPI) Study

7.3 Installation of OBU and Roadside Antenna

(1) OBU

OBU communicate the ID number, IC Card ID, Entrance-gate ID and Vehicle classification and etc with Roadside Antenna by using the wireless communication such as Dedicated Short Range Communication (DSRC). Especially, two-piece type OBU should be installed on the front side of the vehicle at dashboard for a favourable environment of wireless communication. The recommendable location is shown below.

Figure 7.3 Installation of OBU in Vehicle

(2) Roadside Antenna

The roadside antenna should be capable of exchange toll transaction data with the On Board Unit (OBU) over the wireless communication. The communication zone for a single lane operation should cover 4m in the longitudinal direction and 3m in the lateral direction at a height of 1m from the road surface. The height and width of the installation area of roadside antenna should be decided by considering the conditions of tollgate.

The design process for the roadside antenna installation is divided into the following steps,

(1) Determine communication areas
(2) Communication zone design
(3) Channel layout in the new system (in the case of multiple lane at the same tollgate)
(4) Verify interference with other systems
(5) Re-design communication zone

An example of installation of roadside antenna is shown in the following page.

Figure 7.4 Communication Zone of Roadside Antenna at Tollgate

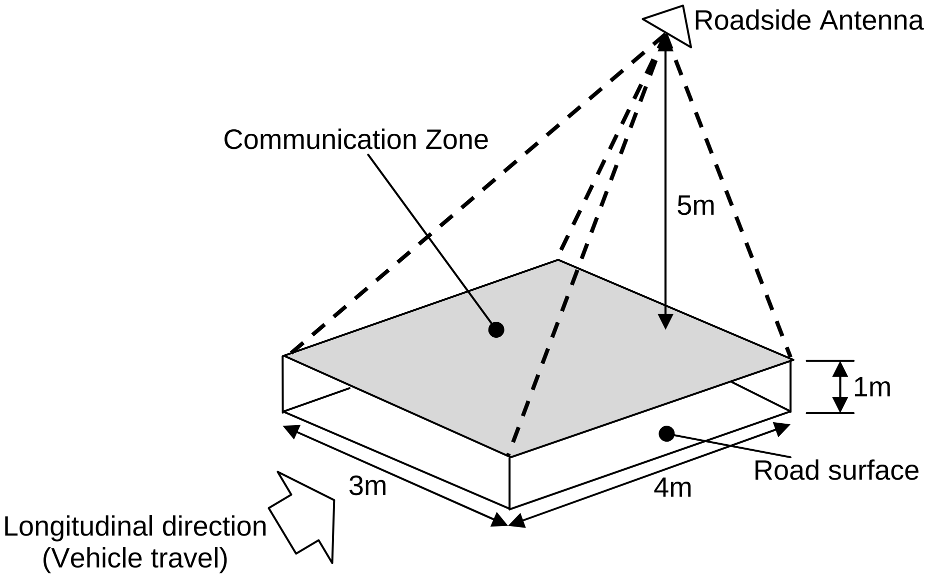
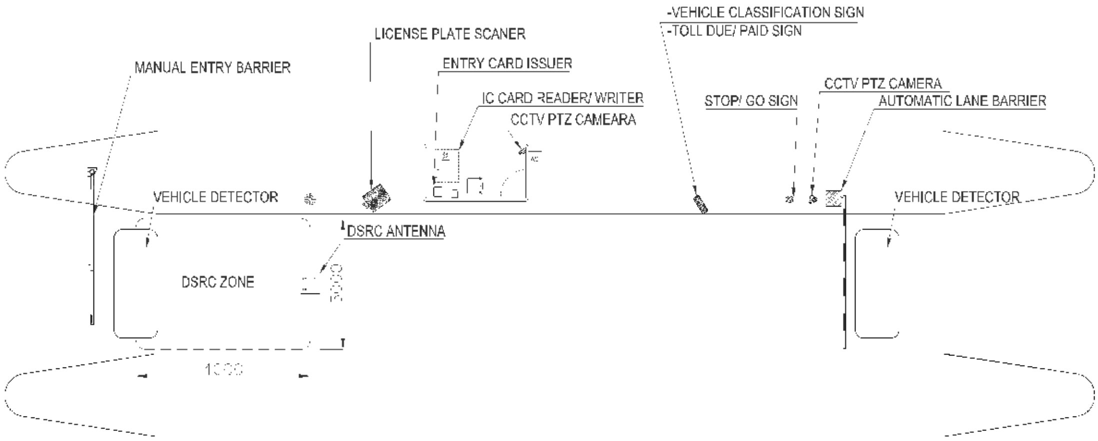


Figure 7.5 Installation of Roadside Antenna at Tollgate Lane



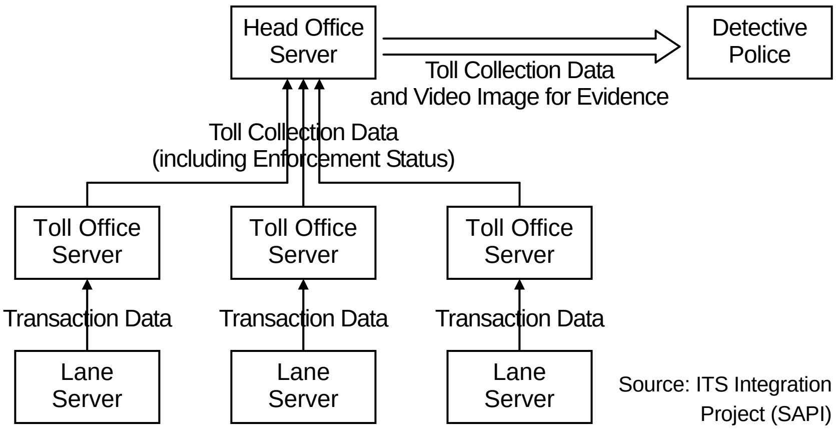
7.4 Procedure of Toll Enforcement Assistance

The following cases are to be considered in the discussion of toll enforcement in the system.

- Spoofing: vehicle passing tollgates by re-installation of OBU
- Cheating: vehicle passing tollgates habitually with negative balance in the IC-card
- Violation: vehicle passing tollgates without OBU.

These unlawful passages are to be checked making comparison among the data received through a vehicle detector, a roadside antenna and a license plate scanner at the tollgate, and enforcement status is to be generated in the toll office server based on the check and to be handover to the detective police as an evidence through the head office. Procedure of enforcement shall be established with completely different meaning of invalidation of an OBU or an IC-card aforementioned.

Figure 7.6 Major Message Exchanges for Toll Enforcement



Source: ITS Integration Project (SAPI)

7.5 Data Set for Toll Enforcement Assistance

Enforcement status can be estimated by verifying the data in the table below.

Table 7.1 Enforcement Status by Estimated Verifying Data

Vehicle Detector	Roadside Antenna				License Plate Scanner		Enforcement Status	CCTV Camera
Vehicle Passage	OBU ID	LN in OBU	IC-card ID	Positive balance	LN	LN Image	Successful	Video Image
Vehicle Passage	OBU ID	LN in OBU	IC-card ID	Positive balance	Different LN	LN Image	Spoofing? *	Video Image
Vehicle Passage	OBU ID	LN in OBU	IC-card ID	Negative balance	LN	LN Image	Cheating? **	Video Image
Vehicle Passage	-	-	-	-	LN	LN Image	Violation? ***	Video Image

Note, LN : License number

* : Suspicion of spoofing: vehicle passing by re-installation of OBU shall be checked making comparison between license plate numbers in OBU received through the roadside antenna and that captured by the license plate scanner.

** : Suspicion of cheating: vehicle passing tollgates habitually with negative balance in the IC-card shall be checked referring to the historical data of IC-card balance stored in the toll office server.

*** : Suspicion of violation: vehicle passing without OBU shall be checked making comparison between data from the vehicle detector and from the roadside antenna.

Source: ITS Integration Project (SAPI) Study

Table 7.2 Enforcement Status by Estimated Verifying Data

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
IC-card Passage Data Set <R - IC-card>	Toll Office ID	INT*	4	N	Each passage at tollgate	Latest
	Tollgate ID	INT	8			
	Lane ID	INT	12			
	Toll Amount	FLOAT	8			
	Prepaid Balance	FLOAT	8			
	Date/Time	Datetime	≥14			
OBU Passage Data Set <R - OBU>	Toll Office ID	INT*	4	3	Each passage at tollgate	Latest
	Tollgate ID	INT*	4			
	Lane ID	INT*	4			
	IC-card ID	INT	12			
	Toll Amount	FLOAT	4			
	Prepaid Balance	INT	8			
	Date/Time	Datetime	≥14			
Transaction Data Set <R - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months
	Tollgate ID	INT	8	1		
	Lane ID	INT*	4	1		
	OBU ID	INT	12	1		
	Vehicle Class in OBU	INT*	2	1		
	License number in OBU	TXT	12	1		
	IC-card ID	INT	12	1		
	Toll Amount	INT	8	1		
	Prepaid Balance	FLOAT	8	1		
	Termination Status	INT*	2	1		
	Serial Number of Vehicle	INT	5	1		
	Date/Time	Datetime	≥14	1		
Toll Collection Data Set <G - Lane Server>	Road Owner ID	INT*	4	1	Every 10 minutes	6 months
	Toll Office ID	INT*	4	1		
	Date of Toll Amount	TXT	8	1		
	Sum of Toll Amount	INT*	12	1		
	Number of Vehicle Passage	INT	8	1		
	Transaction Data Set	Set	var	N		
	Enforcement Status	TXT	2			
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

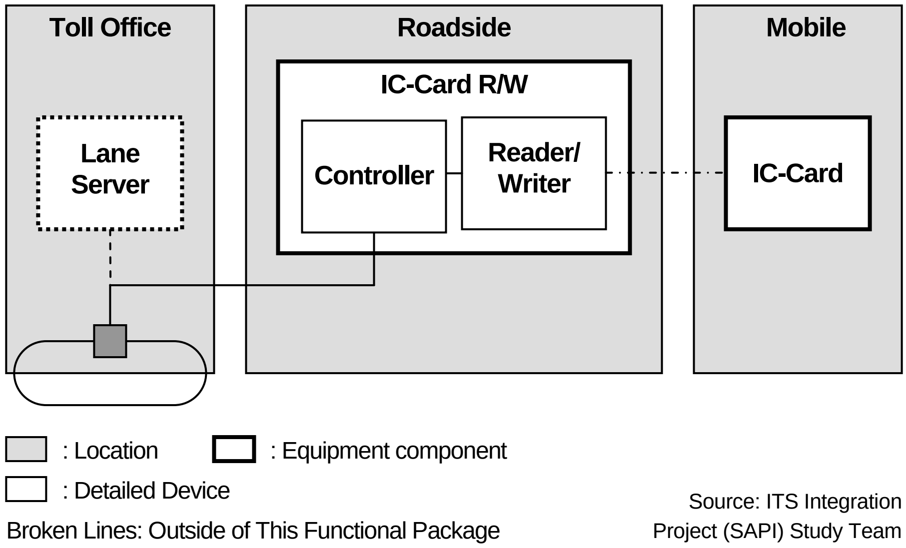
Source: ITS Integration Project (SAPI) Study Team

8. IC-card Recording

8.1 Outline and System Architecture

This functional package allows the road operators to deduct prepaid balance of IC-cards for collecting toll by using equipment installed at tollgates on the expressways.

Figure 8.1 System Architecture for IC-Card Recording

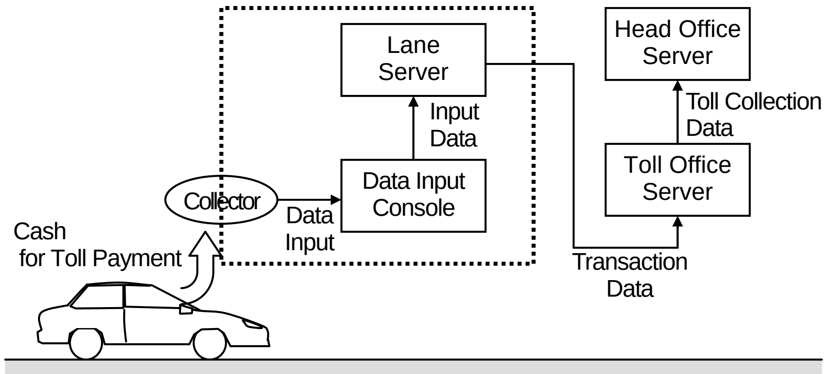


Source: ITS Integration Project (SAPI) Study Team

8.2 Procedure of Toll Collection by Manual

Major messages for manual toll collection are to be exchanged as shown in the figure below.

Figure 8.2 Major Message Exchanges for Manual Toll Collection

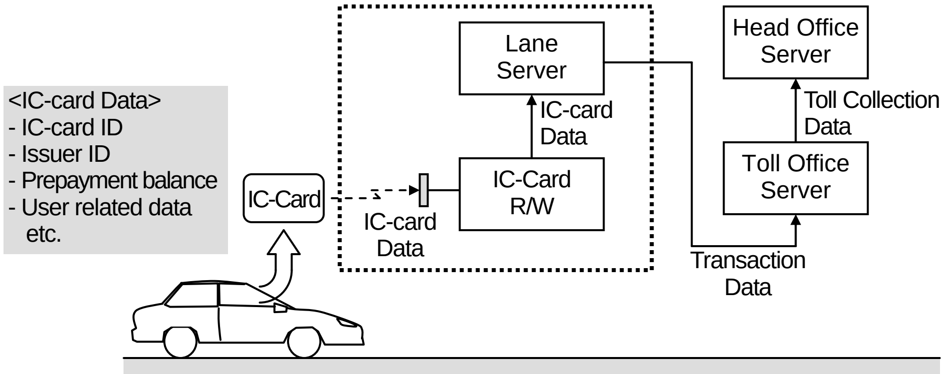


Source: ITS Integration Project (SAPI) Study

8.3 Procedure of Toll Collection by Touch&Go

Major messages for Touch&Go are to be exchanged as shown in the figure below.

Figure 8.3 Major Message Exchanges for Touch&Go



Source: ITS Integration Project (SAPI) Study

8.4 Data Set for IC-Card Recording

The data set and principal data elements to be recorded in IC-card are shown in the table below.

Table 8.1 Principal Data to be Recorded in IC-card

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
IC-card Issue Data Set <R - IC-card>	Issuer ID	INT*	4	1	IC-card issue	Permanent
	Issue Terminal ID	INT	12	1		
	IC-card ID	INT	12	1		
	IC-card Owner ID	INT	18	1		
	Amount of Deposit	FLOAT	8	1		
	Date/Time of Issue	TXT	≥14	1		
	Date/Time of Expiry	TXT	≥14	1		
IC-card Recharge Data Set <R - IC-card>	Issuer ID	INT*	4	N	Each recharge	Permanent
	Deposit Terminal ID	INT	12			
	Amount of Deposit	FLOAT	8			
	Prepaid Balance	FLOAT	8			
	Date/Time	Datetime	≥14			
IC-card Invalidation List Data Set <G - Server>	Issuer ID	INT*	4	1	Daily	1 year
	Issue Terminal ID	INT	12	N		
	IC-card ID for Invalidation	INT	12			
	IC-card Owner ID	INT	18			
	Amount of Deposit	FLOAT	8			
	Date/Time of Issue	TXT	≥14			
	Date/Time of Expiry	TXT	≥14			
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

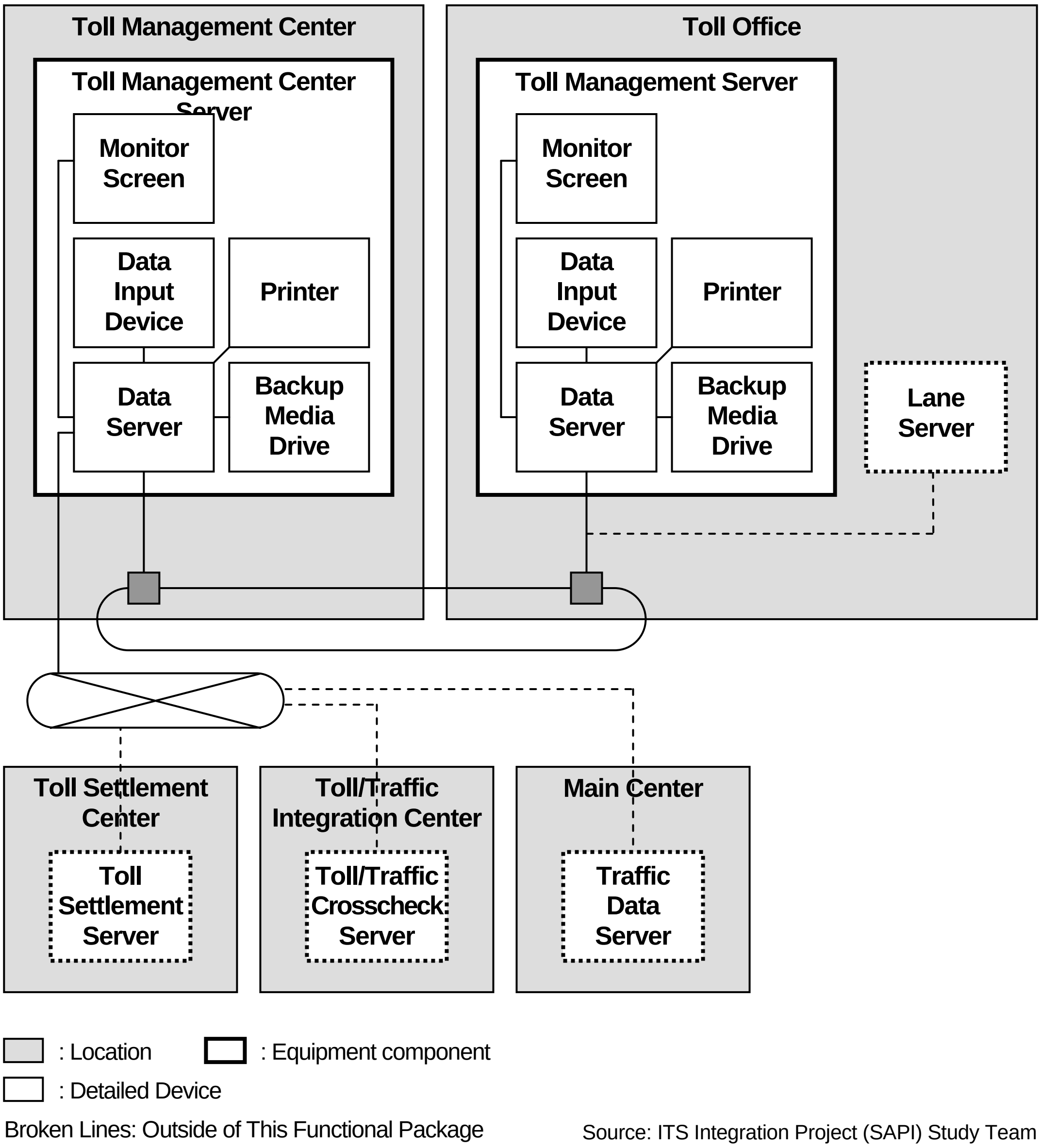
Source: ITS Integration Project (SAPI) Study Team

9. Toll Data Management

9.1 Outline and System Architecture

This functional package allows the road operators to keep all data of toll collection, to manage the invalidation list on the usage of on-board units and IC-cards, and to manage toll revenue of the expressways with a high reliability by using computers and software installed in the road management office.

Figure 9.1 System Architecture for Toll Data Management



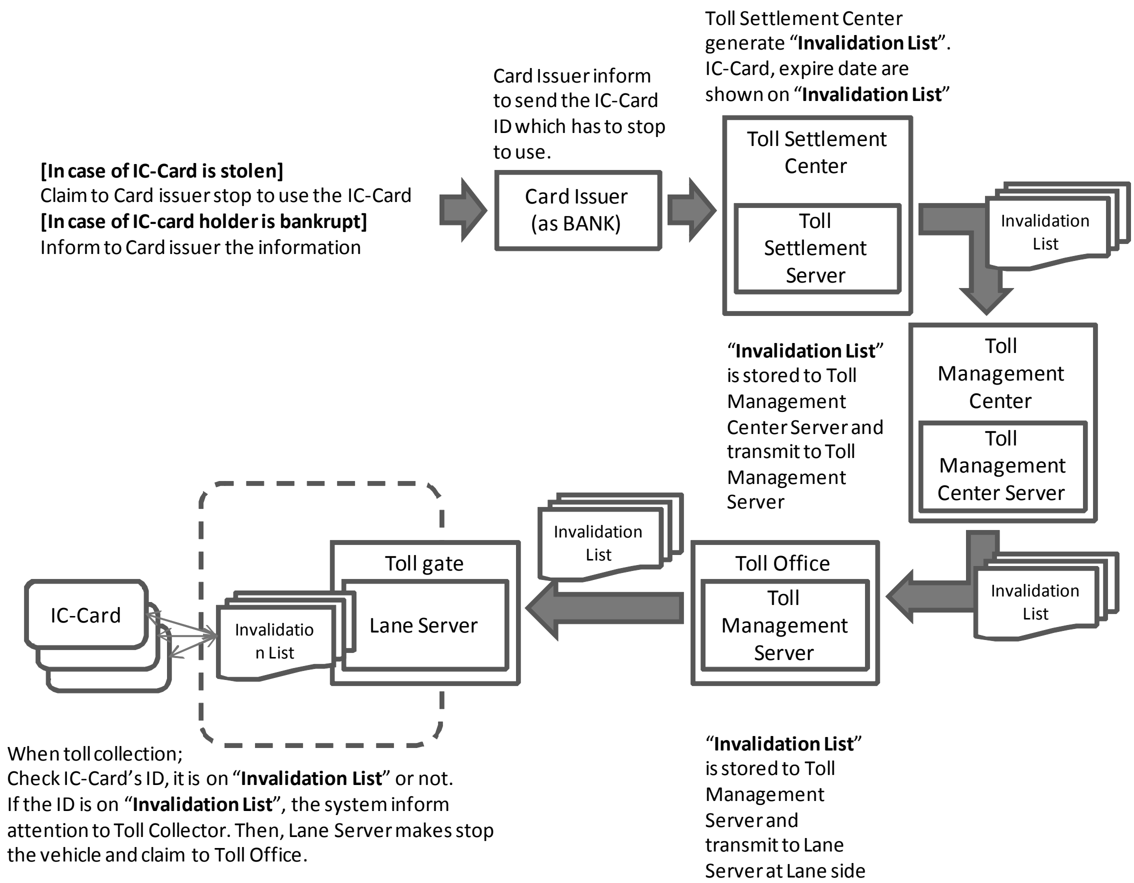
Source: ITS Integration Project (SAPI) Study Team

9.2 Procedure of Toll Data Management

(1) Checking using "Invalidation list"

Invalidation list is for checking the card which shall be invalidated such as stolen and so on. If the invalidated card is used on toll, the fee is not collected from bank. Therefore, we have to consider the card shall not be capable of using for toll collection. The process is shown in the figure below.

Figure 9.2 Process of using Invalidation list



(2) Checking using "License number"

The toll fee amount of each car is depended on type of vehicle according to degree of Ministry of Finance standard; the vehicle class is recorded in OBU when set up OBU. If the OBU is moved to from car to different type of car, the ETC system charge the incorrect fee. For secure toll collection, we have to compare between the vehicle class and actual vehicle type using License number.

Therefore, Licence number shall be recorded in OBU and Vehicle Identification system (such as License Plate scanner) shall be installed on toll lane. Then the toll management system shall be check that the Licence number is the same or not due to comparison of between Licence number (by OBU) in Transaction data set and License number (by scan) in Toll collection data set; refer to Table 13.1 Data Set and Principal Data Elements for Toll Management.

(3) Checking using "Termination sign"

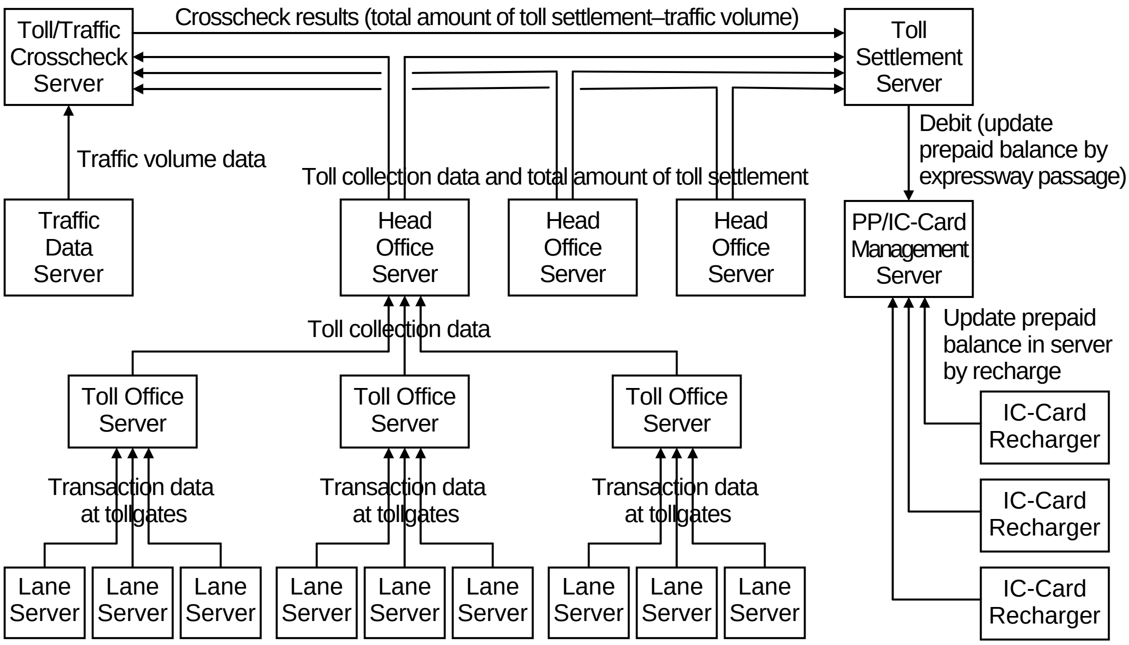
In sometime, the communication between Roadside and Vehicle is not termination properly due to affected by the disorder outside and the being overheard. The system shall not be capable of settlement completely the error.

Therefore, Transaction data set include "Termination sign" which is for checking the communication is terminated properly or not. If the sign is not recorded, the meaning is the communication is not terminated properly. Refer to Table 13.1 Data Set and Principal Data Elements for Toll Management.

9.3 Data Set for Toll Data Management

Major messages for toll management are to be exchanged as shown in the following figures.

Figure 9.3 Major Message Exchanges for Toll Management



Source: ITS Integration Project (SAPI) Study

Data set and principal data elements for toll management are shown in the table below.

Table 9.1 Data Set and Principal Data Elements for Toll Management

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Toll Collection Data Set <G - Lane Server>	Road Owner ID	INT*	4	1	Every 10 minutes	6 months
	Toll Office ID	INT*	4	1		
	Date of Toll Amount	TXT	8	1		
	Sum of Toll Amount	INT*	12	1		
	Number of Vehicle Passage	INT	8	1		
	Transaction Data Set	Set	var	N		
	Enforcement Status	TXT	2			
	Date/Time	Datetime	≥14	1		
Hourly Toll Collection Data Set <G/C - Server>	Road Owner ID	INT*	4	1	Hourly	1 year
	Toll Office ID	INT*	4	1		
	Date/Hour of Record	TXT	10	1		
	Sum of Toll Amount	FLOAT	12	1		
	Number of Vehicle Passage	INT	8	1		
	Sum of Toll of Vehicle Class 1	FLOAT	12	1		
	Number of Vehicle of Class 1	INT	8	1		
	Sum of Toll of Vehicle Class 2	FLOAT	12	1		
	Number of Vehicle of Class 2	INT	8	1		
	Sum of Toll of Vehicle Class 3	FLOAT	12	1		
	Number of Vehicle of Class 3	INT	8	1		
	Sum of Toll of Vehicle Class 4	FLOAT	12	1		
	Number of Vehicle of Class 4	INT	8	1		
	Sum of Toll of Vehicle Class 5	FLOAT	12	1		
	Number of Vehicle of Class 5	INT	8	1		
	Sum of Toll of Vehicle Class 6	FLOAT	12	1		
	Number of Vehicle of Class 6	INT	8	1		
	Sum of Toll of Vehicle Class 7	FLOAT	12	1		
	Number of Vehicle of Class 7	INT	8	1		
	Sum of Toll of Vehicle Class 8	FLOAT	12	1		
	Number of Vehicle of Class 8	INT	8	1		
	Sum of Toll of Vehicle Class 9	FLOAT	12	1		
	Number of Vehicle of Class 9	INT	8	1		
	Sum of Toll of Vehicle Class 10	FLOAT	12	1		
	Number of Vehicle of Class 10	INT	8	1		
	Sum of Toll of Vehicle Class 11	FLOAT	12	1		
	Number of Vehicle of Class 11	INT	8	1		
	Sum of Toll of Vehicle Class 12	FLOAT	12	1		
	Number of Vehicle of Class 12	INT	8	1		
	Sum of Toll of Vehicle Class 13	FLOAT	12	1		
	Number of Vehicle of Class 13	INT	8	1		
	Sum of Toll of Vehicle Class 14	FLOAT	12	1		
	Number of Vehicle of Class 14	INT	8	1		
	Sum of Toll of Vehicle Class 15	FLOAT	12	1		
	Number of Vehicle of Class 15	INT	8	1		
	Sum of Toll of Vehicle Class 16	FLOAT	12	1		
	Number of Vehicle of Class 16	INT	8	1		
	Sum of Toll of Vehicle Class 17	FLOAT	12	1		
	Number of Vehicle of Class 17	INT	8	1		
	Sum of Toll of Vehicle Class 18	FLOAT	12	1		
	Number of Vehicle of Class 18	INT	8	1		
	Sum of Toll of Vehicle Class 19	FLOAT	12	1		
	Number of Vehicle of Class 19	INT	8	1		
	Sum of Toll of Vehicle Class 20	FLOAT	12	1		
	Number of Vehicle of Class 20	INT	8	1		
	Date/Time	Datetime	≥14	1		

Toll Revenue Data Set <G/C - Server>	Road Owner ID	INT*	4	1	Monthly	1 year
	Fiscal Month	TXT	6	1		
	Toll Revenue of The Month/Week	FLOAT	16	1		
	Number of Vehicle Passage	INT	8	1		
	Sum of Toll of Vehicle Class 1	FLOAT	12	1		
	Number of Vehicle of Class 1	INT	8	1		
	Sum of Toll of Vehicle Class 2	FLOAT	12	1		
	Number of Vehicle of Class 2	INT	8	1		
	Sum of Toll of Vehicle Class 3	FLOAT	12	1		
	Number of Vehicle of Class 3	INT	8	1		
	Sum of Toll of Vehicle Class 4	FLOAT	12	1		
	Number of Vehicle of Class 4	INT	8	1		
	Sum of Toll of Vehicle Class 5	FLOAT	12	1		
	Number of Vehicle of Class 5	INT	8	1		
	Sum of Toll of Vehicle Class 6	FLOAT	12	1		
	Number of Vehicle of Class 6	INT	8	1		
	Sum of Toll of Vehicle Class 7	FLOAT	12	1		
	Number of Vehicle of Class 7	INT	8	1		
	Sum of Toll of Vehicle Class 8	FLOAT	12	1		
	Number of Vehicle of Class 8	INT	8	1		
	Sum of Toll of Vehicle Class 9	FLOAT	12	1		
	Number of Vehicle of Class 9	INT	8	1		
	Sum of Toll of Vehicle Class 10	FLOAT	12	1		
	Number of Vehicle of Class 10	INT	8	1		
	Sum of Toll of Vehicle Class 11	FLOAT	12	1		
	Number of Vehicle of Class 11	INT	8	1		
	Sum of Toll of Vehicle Class 12	FLOAT	12	1		
	Number of Vehicle of Class 12	INT	8	1		
	Sum of Toll of Vehicle Class 13	FLOAT	12	1		
	Number of Vehicle of Class 13	INT	8	1		
	Sum of Toll of Vehicle Class 14	FLOAT	12	1		
	Number of Vehicle of Class 14	INT	8	1		
	Sum of Toll of Vehicle Class 15	FLOAT	x	1		
	Number of Vehicle of Class 15	INT	8	1		
	Sum of Toll of Vehicle Class 16	FLOAT	12	1		
	Number of Vehicle of Class 16	INT	8	1		
	Sum of Toll of Vehicle Class 17	FLOAT	12	1		
	Number of Vehicle of Class 17	INT	8	1		
	Sum of Toll of Vehicle Class 18	FLOAT	12	1		
	Number of Vehicle of Class 18	INT	8	1		
	Sum of Toll of Vehicle Class 19	FLOAT	12	1		
	Number of Vehicle of Class 19	INT	8	1		
	Sum of Toll of Vehicle Class 20	FLOAT	12	1		
	Number of Vehicle of Class 20	INT	8	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

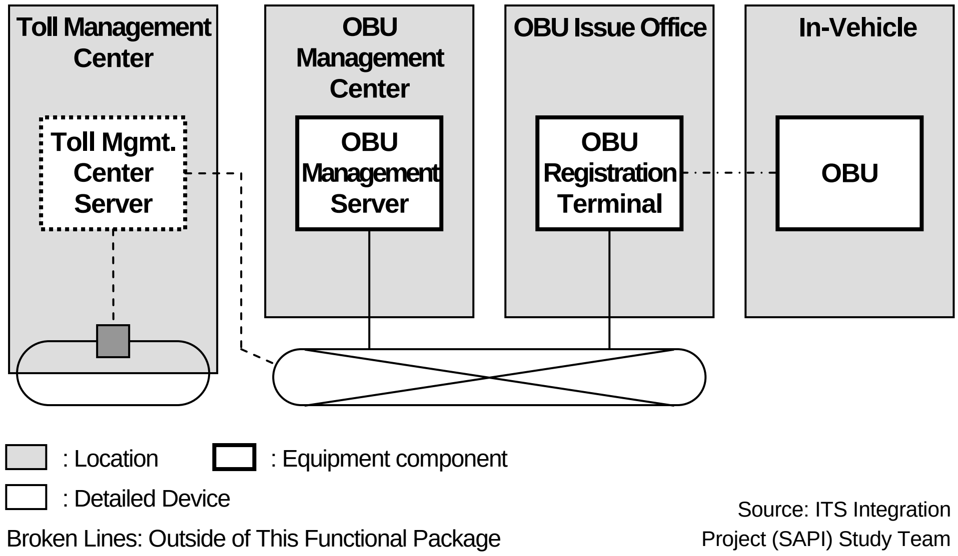
Source: ITS Integration Project (SAPI) Study Team

10. OBU Management

10.1 Outline and System Architecture

This functional package allows to register on-board units by using equipment installed in OBU issue offices, and allows to generate/manage the registration list and the invalidation list of on-board units by using computers and software installed in the OBU registration center.

Figure 10.1 System Architecture for OBU Management



Source: ITS Integration Project (SAPI) Study Team

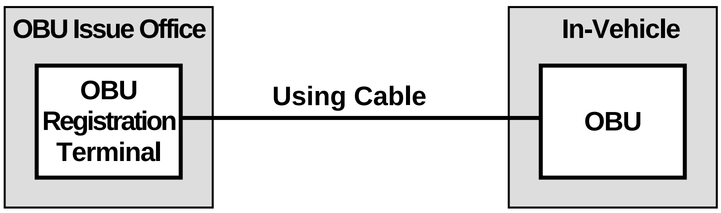
10.2 Procedure of OBU Management

There is some method for the set up. For example; a) connect cable, b) using the same as DSRC antenna, c) using IC-Card. The characteristic of each method as follows;

(1) Using cable

Cost: Cheapest (OBU shall be equipped the interface of cable connection)
Re-set up: Inconvenient (user should go to OBU Issue Office and bring the OBU)

Figure 10.2 Set up using Cable

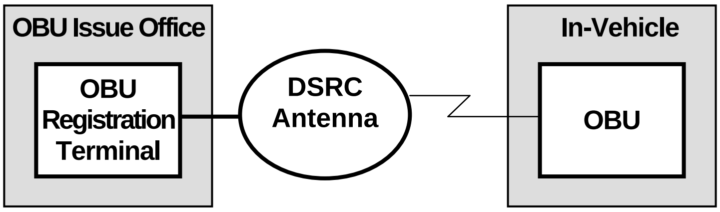


Source: ITS Integration Project (SAPI) Study

(2) Using DSRC antenna

Cost: Expensive (DSRC antenna shall be installed on each OBU Issue Office)
Re-set up: Convenient (can be set up at OBU Issue Office and Tollgate)

Figure 10.3 Set up OBU using DSRC antenna



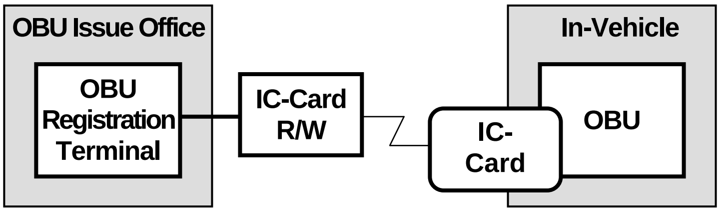
Source: ITS Integration Project (SAPI) Study

(3) Using IC-Card

Cost: Cheaper (OBU shall be 2 piece type and IC-Card R/W shall be installed on each OBU Issue Office)

Re-set up: Convenient (can be set up at OBU Issue Office and Tollgate)

Figure 10.4 Set up OBU using IC-Card



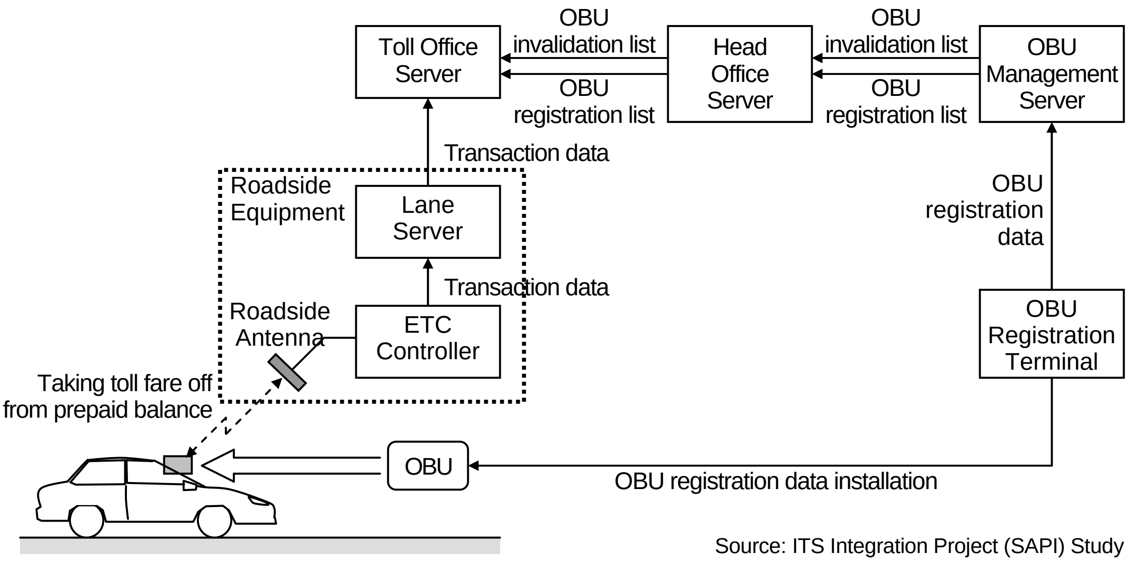
Source: ITS Integration Project (SAPI) Study

10.3 Data Set for OBU Management

(1) OBU Registration/Invalidity

Major messages for OBU in the procedures of registration, toll collection and invalidity management are to be exchanged as shown in the following figures.

Figure 10.5 Major Message Exchanges of OBU



Source: ITS Integration Project (SAPI) Study

The data set and principal data elements to be recorded in OBU are shown in the table below.

Table 10.1 Data Set and Principal Data Elements to be Recorded in OBU

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
OBU Registration Data Set <R - OBU>	Management Organization ID	INT	12	1	OBU registration	Permanent
	OBU ID	INT	12	1		
	OBU Owner ID	INT	18	1		
	License Plate Number	TXT	12	1		
	Vehicle Class	TXT	2	1		
	Date of Issue	TXT	8	1		
	Date of Expiry	TXT	8	1		
OBU Passage Data Set <R - OBU>	Toll Office ID	INT*	4	3	Each passage at tollgate	Latest
	Tollgate ID	INT*	4			
	Lane ID	INT*	4			
	IC-card ID	INT	12			
	Toll Amount	FLOAT	4			
	Prepaid Balance	INT	8			
	Date/Time	Datetime	≥14			
OBU Invalidation List Data Set <G - Server>	Management Organization ID	INT	12	1	Daily	1 year
	OBU ID for Invalidation	INT	12	N		
	OBU Owner ID	INT	18			
	License Plate Number	TXT	12			
	Vehicle Class	TXT	2			
	Date of Issue	TXT	8			
	Date of Expiry	TXT	8			
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

VEHICLE WEIGHING SYSTEM

TABLE OF CONTENTS

1. Introduction

Service descriptions:

This service eliminates overloading of heavy trucks by automatic execution of vehicle weighing at interchanges. It restrains damage to the road structure and extends its durable lifetime. This service restrains congestion caused by heavy trucks and allows freight trans-port to improve safety by eliminating overloading. This service allows prompt action of the road operator at the occurrence of serious accidents caused by heavy trucks and hazardous-material trucks and appropriate vehicle operation by keeping track of the trucks on the expressway network.

Functional packages to be included in the system:

(20) Axle load measurement
(21) Measurement lane monitoring.

2. Use Case and General System Architecture

Use cases and general system architecture are illustrated for the following implementation packages of vehicle weighing:

(1) Vehicle weighing
(2) Center-to-Center Data Exchange.

Relationships between the system and users/operators/other-systems are illustrated by the following use case diagrams in the design drawings:

Road traffic supervision
- Axle load measurement
- Axle load data management
- Overloading regulation assistance.

The general system architecture is sown using collaboration diagrams and message sequence diagrams titled as below in the design drawings:

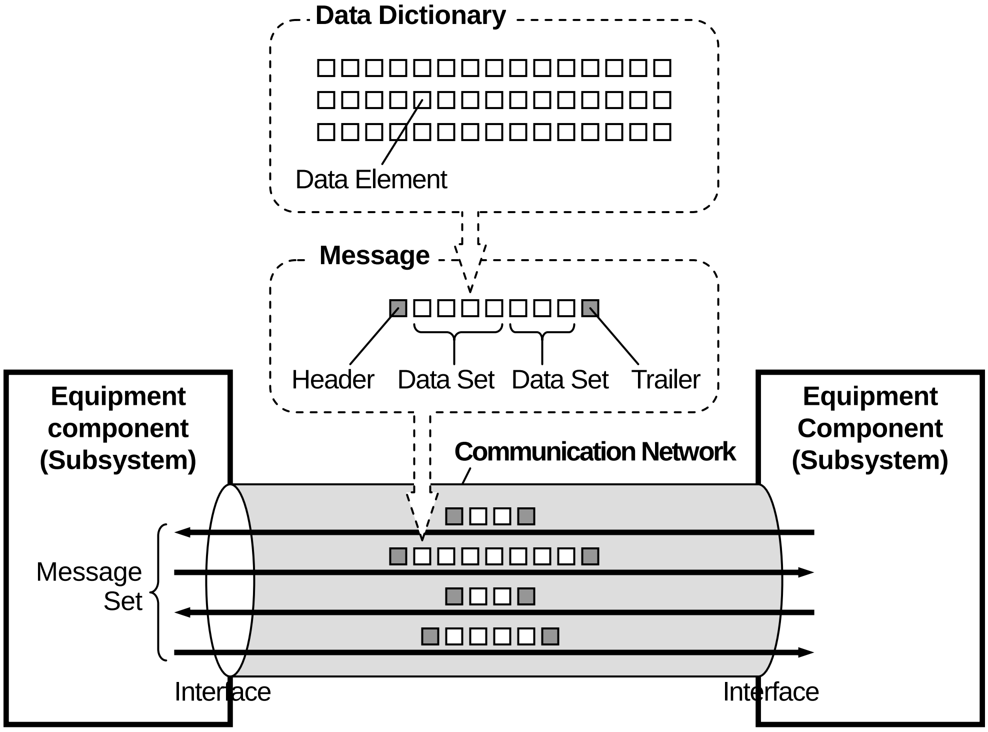
(1) Vehicle weighing by axle load scale
(2) Center-to-center data exchange for heavy truck control.

3. Message/Data Design

3.1 General

ITS consists of many pieces of equipment, which are illustrated as the equipment components in the diagrams of system architecture. The equipment components need to be connected with each other by communication network in order to exchange messages and data between them, to actualise the system and to provide intended services.

Figure 3.1 Conceptual Illustration of Message/Data Exchange



Source: ITS Integration Project (SAPI) Study Team

3.2 Major Message List

The major message list for vehicle weighing system is shown in the following table.

Table 3.1 Major Message List of Vehicle Weighing System

Name of Message	A Pair of Equipment Components on Both Side of Interface through Which Message is Exchanged		Name of Include Data Sets
Over Loading Message	Heavy Truck Control Data Server	Traffic Event Data Server	Axle Load Measurement Data Set Over Loading Vehicle Data Set
License Plate Message	Vehicle Detector	Heavy Truck Control data Server	License Plate Recognition Data Set
Axle Load Measurement Data Set	Axle Load Scale	Heavy Truck Control data Server	Axle Load Measurement Data Set

Source: ITS Integration Project (SAPI) Study Team

3.3 Primary Data Dictionary

Primary data dictionary for vehicle weighing system is shown in the table below.

Figure 3.2 Primary Data Dictionary for Vehicle Weighing System

	Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin	Definition
30	Axle Load Measurement Data Set <G -Axle Load Scale>	Road Section ID	INT*	4	1	When overloading data detected	6 months	An unique identifier of the road section where the axle load scale installed
		Axle Load Scale Location ID	INT*	4	1			An unique identifier of install location of axle load scale
		Lane ID	INT*	2	1			An unique identifier of the lane of axle load scale (Numbered from the median)
		Vehicle Class	INT*	2	1			Vehicle class categorized for axle load: - 1: Single-unit truck with 2 axles - 2: Single-unit truck with 3 axles - 3: Single-unit truck with 4 axles - 4: Single-unit truck with 5 or more axles - 5: Tractor with trailer/semi-trailer, 3 axles - 6: Tractor with trailer/semi-trailer, 4 axles - 7: Tractor with trailer/semi-trailer, 5 or more axles - 8: 2-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles - 9: 3-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles - 10: 4-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles - 11: 5-or-more-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles
		Number of Axles	INT*	2	1			Number of axles (less than or equal to 10)
		Axle Load	INT*	2	10			Measurement data of load of an axle (unit: Ton)
		Maximum Axle Load	INT*	2	1			Maximum value of measured axle loads of a vehicle (unit: Ton)
		Axle Load Status	INT*	2	1			Status of the axle load scale: - 0: Normal - 1: Suspicious at overloading - 2: Overloaded
		Serial Number of Vehicle	INT	5	1			Daily serial number for a vehicle passing through the axle load scale. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
31	Axle Load License Plate Data Set <G -Image Processor>	Road Section ID	INT*	4	1	When overloading data detected	6 months	An unique identifier of the road section where the axle load scale installed
		Axle Load Scale Location ID	INT*	4	1			An unique identifier of install location of axle load scale
		Lane ID	INT*	2	1			An unique identifier of the lane of axle load scale (Numbered from the median)
		Roadside Equipment ID	INT*	4	1			An unique identifier of a license recognition device
		Captured License Plate Number	TXT	12	1			License plate number recognized by image proccessor
		Captured License Plate Image	IMG	var	1			The license plate image captured by CCTV camera
		Serial Number of Vehicle	INT	5	1			Daily serial number for a vehicle passing through the axle load scale. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
32	Axle Load Management Data Set <G/C-Server>	Road Owner ID	INT*	4	1	Hourly	1 year	An unique identifier of a road owner
		Road Section ID	INT*	4	1			An unique identifier of the road section where the axle load scale installed
		Axle Load Scale Location ID	INT*	4	1			An unique identifier of install location of axle load scale
		Lane ID	INT*	2	1			An unique identifier of the lane of axle load scale (Numbered from the median)
		Date/Hour of Record	TXT	10	1			Day/month/year/hour of the record
		Number of Heavy Trucks	INT	5	1			Number of heavy trucks measured
		Number of Suspicious Trucks	INT	5	1			Number of heavy trucks suspicious at overloading
		Number of Overloaded Trucks	INT	5	1			Number of heavy trucks overloaded
		Axle Load Measurement Data Set	Set	var	N			Axle load measurement data set of vehicle passing through axle load scale
		Axle Load Status	INT*	2				Status of the axle load scale: - 0: Normal - 1: Suspicious at overloading - 2: Overloaded
		Serial Number of Vehicle	INT	5				Daily serial number for a vehicle passing through the axle load scale. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

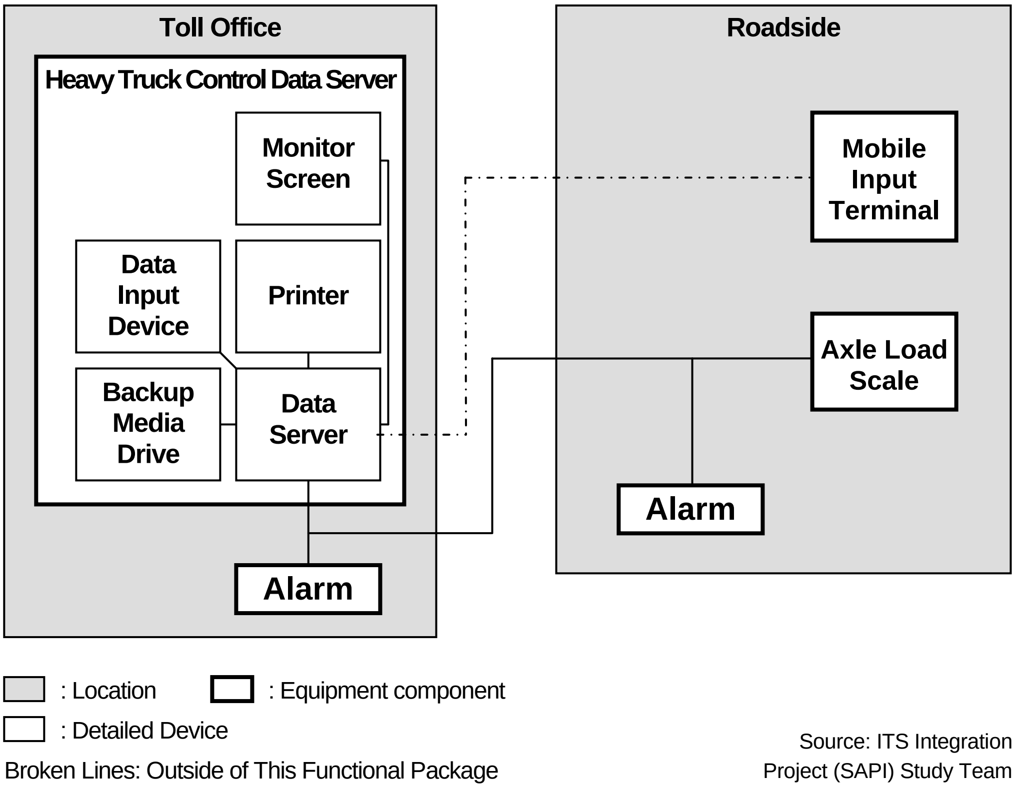
Source: ITS Integration Project (SAPI) Study Team

4. Axle Load Measurement

4.1 Outline and System Architecture

This functional package allows the road operators to detect/regulate overloaded heavy trucks on the expressways by using axle load scale installed in the exit tollgate lane exclusive for large-size vehicles.

Figure 4.1 System Architecture for Axle Load Measurement



Source: ITS Integration Project (SAPI) Study Team

4.2 Procedure of Axle Load Measurement

(1) General

Axle load measurement function is measuring and recording functions of the axle load of heavy trucks which drive low speed. The judgement is made whether the measured result exceed the limited load or not with combination of other functions.

(2) Objective Heavy Trucks to be Measured

The objective heavy trucks to be measured are all vehicles which pass the axle load measurement system zone to be located after passing entrance toll gate of expressway dedicated only for heavy trucks.

(3) Measuring Item and Measuring Range

Measuring item and measuring range is shown in the following table.

Table 4.1 Measuring Item and Measuring Range

No.	Measuring Item	Measuring range	Resolution
1	Axle load	1.0 – 20 ton	0.1 ton
2	Number of Axles	2 – 7 axles	
3	—	40 km/h	

Source: ITS Integration Project (SAPI) Study Team

- Gross weight of the heavy truck is calculated by summation of each axle load
- Number of axles more than 7 is deemed as 7, and the load for more than 8th axle should be added to 7th axle load basically
- Although the driving speed of heavy truck is not measurement item, it is assumed that there will be a sign board showing max 20km/h. However since the location of axle load measurement system zone is after the entrance toll gate, the condition for measurable speed is 40km/h

4.3 Required Functions/Performance of Equipment

The allowable measurement error of the equipment component is considered within 10% for 95% of measured heavy trucks based on the condition shown in the previous measurement range, and also under the condition of installation of equipment component shown in the following item.

4.4 Location of Axle Load Scale

Axle load scale for the overloading regulation can be installed in the following three locations:

- Location alternative 1: Closely back from entrance tollgates
- Location alternative 2: Closely behind entrance tollgates
- Location alternative 3: Closely back from exit tollgates.

The location closely back from exit tollgates is recommended for axle load scale comparing advantages and disadvantages of three alternatives above as summarized in the table below.

Table 4.2 Comparison on Location Alternatives of Axle Load Scale

	Location Alternative 1	Location Alternative 2	Location Alternative 3
Securing of Conformance to Jurisdiction of Road Operator	Difficult	Capable	Capable
Measuring Accuracy by Controlling Vehicle Trail in a Tollgate Lane	Capable (within Tollgate Lane)	Capable (within Tollgate Lane)	Capable (within Tollgate Lane)
Necessity of Large Land Acquisition for Rejecting Overloaded Vehicles	Necessary	Necessary	Not Necessary
Installation into Every Tollgate for Preventing Avoidance/Unfairness	Difficult	Difficult	Possible
Effects of Rejecting Overloaded Vehicles from the Expressway	Average	Average	High
Grading	Not Suitable	Comparable	Recommended

Source: ITS Integration Project (SAPI) Study Team

4.5 Axle Load Scale Arrangement at Tollgate

Arrangement criteria of axle load scale are defined responding to design traffic volume passes through the tollgate and according to the basic policy that heavy vehicles are to be processed in the tollgate lanes near roadside.

Table 4.3 Arrangement Criteria of Axle Load Scale

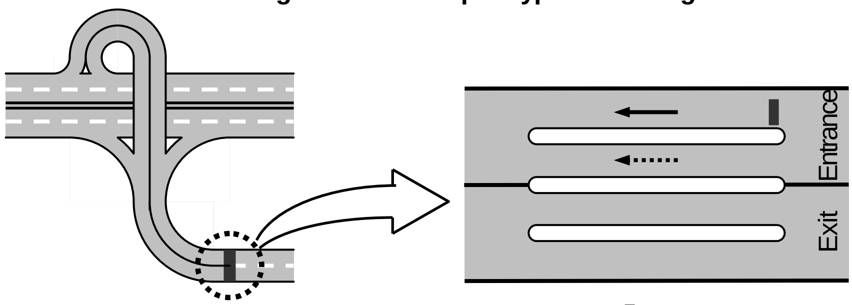
	Small Traffic Volume	Average Traffic Volume	Large Traffic Volume	
For Overloading Regulation	Axle Load Scale Arrangement Criteria 1	Axle Load Scale Arrangement Criteria 2	Axle Load Scale Arrangement Criteria 3	Axle Load Scale Arrangement Criteria 4

Source: ITS Integration Project (SAPI) Study Team

(1) Axle Load Scale Arrangement Criteria 1

As the standard arrangement for the tollgate consists of two lanes in each direction at a trumpet-type interchange for small traffic volume, an axle load scale is to be installed in a lane on the roadside for entrance as shown in the figure below. Two kinds of processing of toll collection: Touch&Go and manual can be carried out in the lane.

Figure 4.2 Axle Load Scale Arrangement at Trumpet-Type Interchange for Small Traffic Volume



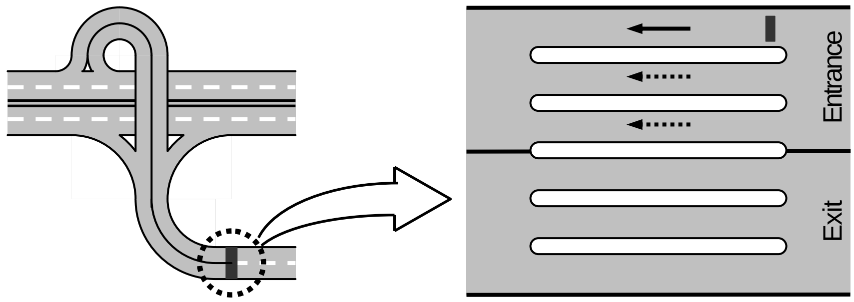
Manual or ETC   Touch&Go/Manual   Axle Load Scale

Source: ITS Integration Project (SAPI) Study Team

(2) Axle Load Scale Arrangement Criteria 2

As the standard arrangement for the tollgate consists of three lanes in each direction at a trumpet-type interchange for middle traffic volume, axle load scales are to be installed in a roadside lane of entrance tollgate as shown in the figure below. Two kinds of processing of toll collection: Touch&Go and manual can be carried out in the lane. In the later stage, when overloaded trucks increase, axle load scale is to be installed additionally in other lane.

Figure 4.3 Axle Load Scale Arrangement at Trumpet-Type Interchange for Small Traffic Volume



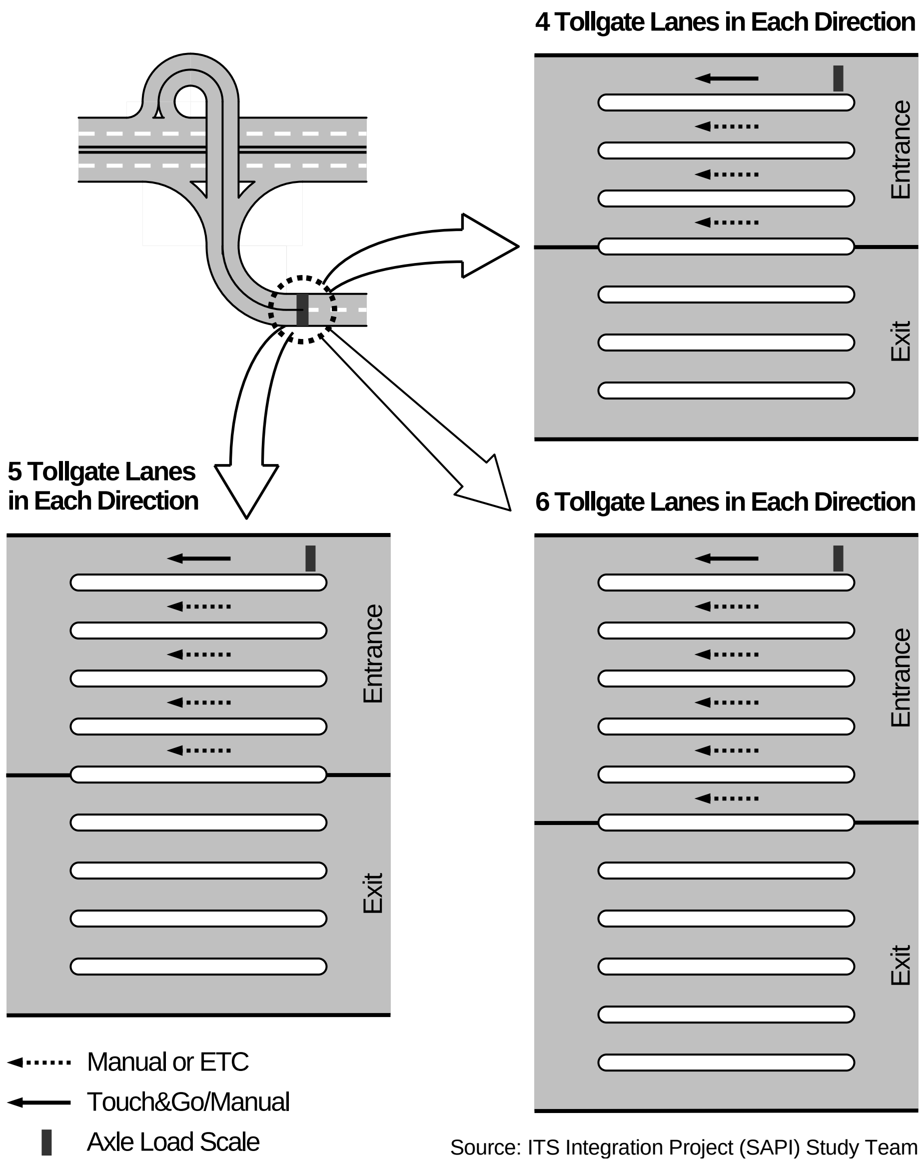
Manual or ETC   Touch&Go/Manual   Axle Load Scale

Source: ITS Integration Project (SAPI) Study Team

(3) Axle Load Scale Arrangement Criteria 3

As the standard arrangement for the tollgate consists of more than four lanes in each direction at a trumpet-type interchange for large traffic volume, axle load scales are to be installed in a roadside lane of entrance tollgate as shown in the figure below. Two kinds of processing of toll collection: Touch&Go and manual can be carried out in the lane. In the later stage, when overloaded trucks increase, axle load scale is to be installed additionally in other lane.

Figure 4.4 Axle Load Scale Arrangement at Trumpet-Type Interchange for Small Traffic Volume

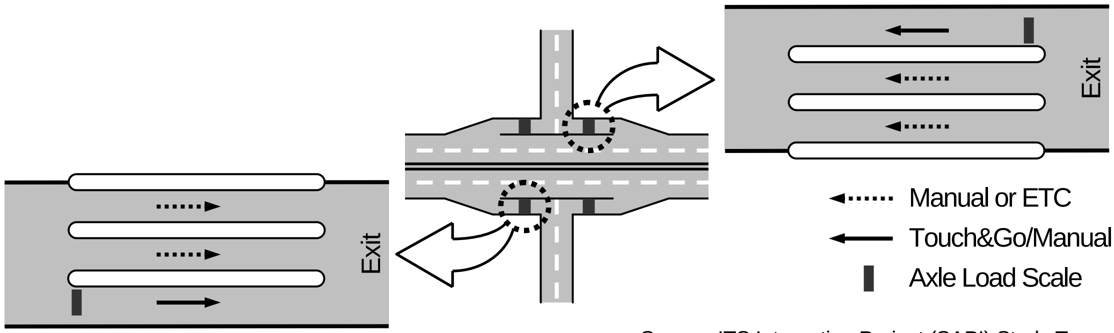


Source: ITS Integration Project (SAPI) Study Team

(4) Axle Load Scale Arrangement Criteria 4

As the standard arrangement for the tollgate consists of three lanes in each direction at a diamond-type interchange for middle traffic volume, axle load scales are to be installed in a roadside lane of entrance tollgate as shown in the figure below. Two kinds of processing of toll collection: Touch&Go and manual can be carried out in the lane. In the later stage, when overloaded trucks increase, axle load scale is to be installed additionally in other lane.

Figure 4.5 Axle Load Scale Arrangement at Diamond-Type Interchange for Large Traffic Volume



Source: ITS Integration Project (SAPI) Study Team

(5) Installation of Major Equipment Components

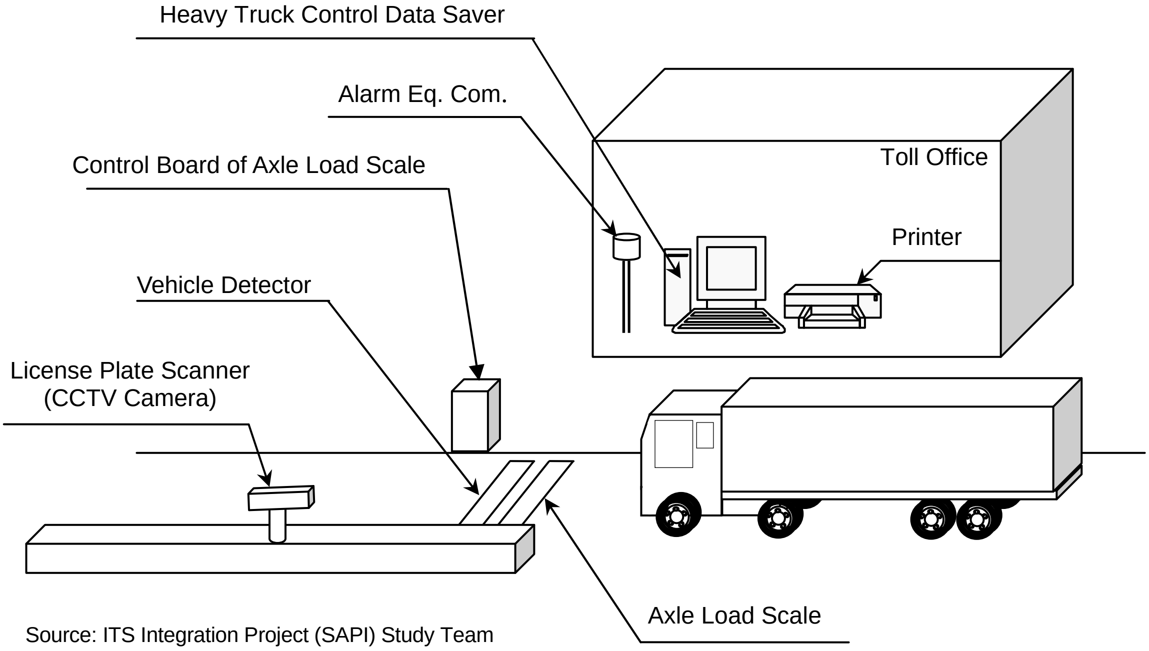
This functional package is implemented for toll office and related roadside only. For project implementation, specific location is required to be specified in detail.

The major equipment components are described in the following items;

- **Axle Load Sensor :**
  Measure the axle weight of vehicle
- **Control Board for Axle Load Scale :**
  Control the axle load scale, receive the measured data from the scale and transmit the data to the Heavy Truck Control Data Server
- **Heavy Truck Control Data Server :**
  It is the center item of axle load measurement for organize collection of the axle weight data, calculate the total weight of the vehicle, detect the overloading from calculated data, control alarm equipment when detect the overloading vehicle
- **Alarm Equipment :**
  Calling for attention when detect the overloading vehicle. It is should be installed in the tollbooth and the toll office
- **Vehicle Detector :**
  Detect the vehicle coming into the measurement lane
- **License Plate Scanner :**
  Recognize for the license plate information by image

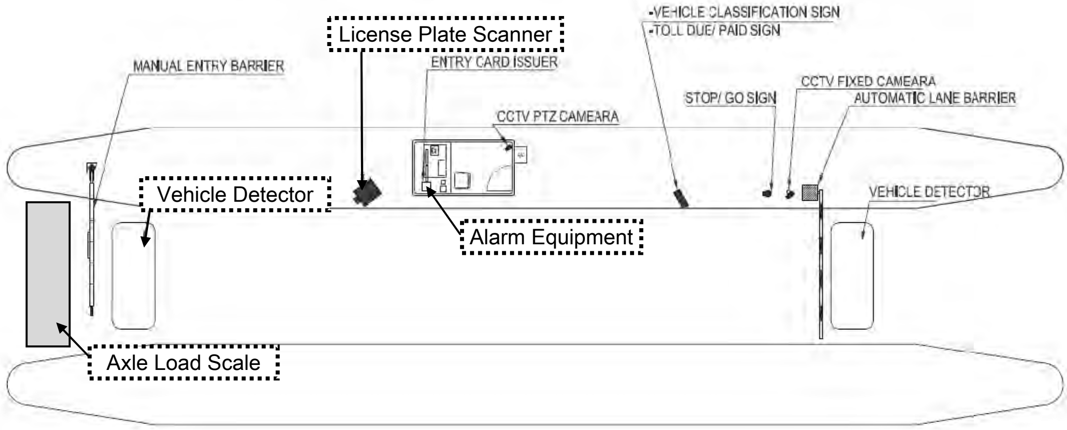
General equipment component location is shown in the following figure as a typical case.

Figure 4.6 Major Equipment Components Arrangement



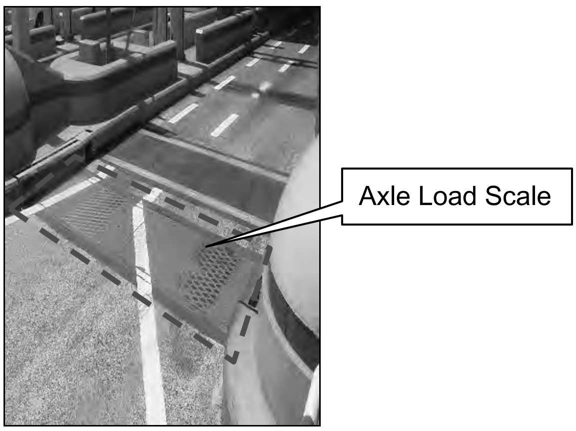
Source: ITS Integration Project (SAPI) Study Team

Figure 4.7 Layout of relevant equipment for Axle Load measurement on Tollgate



Source: ITS Integration Project (SAPI) Study Team

Figure 4.8 Installation example of Axle Load Scale at Tollgate



Source: NEXCO

Above these figure is conceptual ones, and it is not shown precise system or combination of equipment components. As for the software to be realized necessary functions, as mentioned above, it may be installed in another equipment component under the conditions that total necessary functions are covered by others.

(6) Installation Condition of Equipment Component

The equipment installation condition to be guaranteed for the previous error rate is shown below;

- Gradient Ratio: Cross and longitudinal slope ratio should be within 2%
- Road surface dent due to track: The road surface should be well maintained that there should not be observerved apparent rolling or pitching of the heavy truck visually

4.6 Data Set for Axle Load Measurement

The measurement data is composed of the following items:

Table 4.4 Data Set List for Axle Load Measurement

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Axle Load Measurement Data Set <G -Axle Load Scale>	Road Section ID	INT*	4	1	When overloading data detected	6 months
	Axle Load Scale Location ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Vehicle Class	INT*	2	1		
	Number of Axles	INT*	2	1		
	Axle Load	INT*	2	10		
	Maximum Axle Load	INT*	2	1		
	Axle Load Status	INT*	2	1		
	Serial Number of Vehicle	INT	5	1		
	Date/Time	Datetime	≥14	1		
Axle Load License Plate Data Set <G -Image Processor>	Road Section ID	INT*	4	1	When overloading data detected	6 months
	Axle Load Scale Location ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Roadside Equipment ID	INT*	4	1		
	Captured License Plate Number	TXT	12	1		
	Captured License Plate Image	IMG	var	1		
	Serial Number of Vehicle	INT	5	1		
	Date/Time	Datetime	≥14	1		
Axle Load Management Data Set <G/C-Server>	Road Owner ID	INT*	4	1	Hourly	1 year
	Road Section ID	INT*	4	1		
	Axle Load Scale Location ID	INT*	4	1		
	Lane ID	INT*	2	1		
	Date/Hour of Record	TXT	10	1		
	Number of Heavy Trucks	INT	5	1		
	Number of Suspicious Trucks	INT	5	1		
	Number of Overloaded Trucks	INT	5	1		
	Axle Load Measurement Data Set	Set	var	N		
	Axle Load Status	INT*	2			
	Serial Number of Vehicle	INT	5			
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

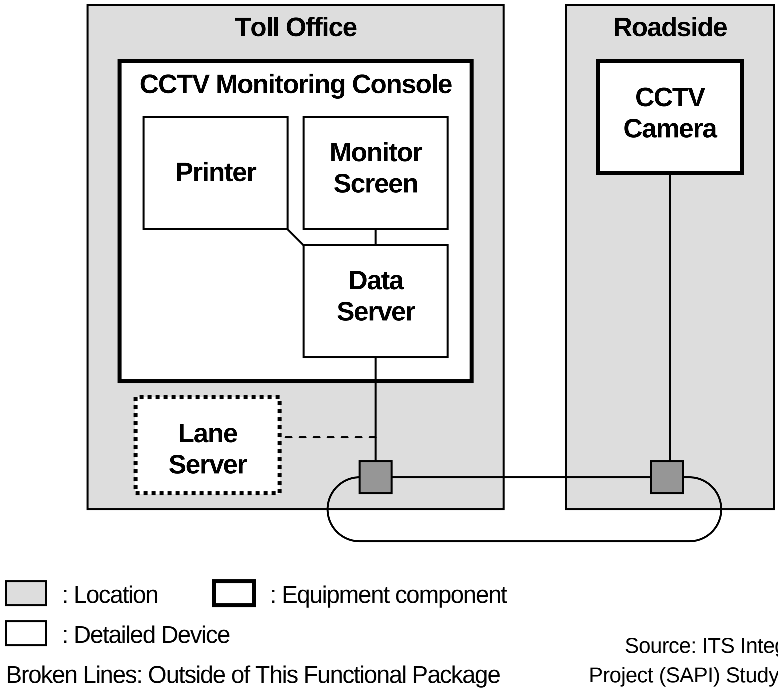
Source: ITS Integration Project (SAPI) Study Team

5. Measurement Lane Monitoring

5.1 Outline and System Architecture

This functional package allows the road operators to store/retrieve data of the heavy trucks overloaded on the expressways by using computers and software installed in the road management office.

Figure 5.1 System Architecture for Measurement Lane Monitoring



Source: ITS Integration Project (SAPI) Study Team

5.2 Conditions to be Monitored

CCTV camera is to give assistance for operator to monitor the following conditions:

- Vehicle coming into the measurement lane
- Class and appearance of the vehicle
- Activities of the driver and the operator
- Occurrence of trouble and response to it in the measurement lane
- Vehicle going out from the measurement lane

5.3 Data Set for Measurement Lane Monitoring

Table 5.1 Data Set List for Management Lane Monitoring

Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin
Image Recognition Result Data Set <G - Image Processor>	Road Management Office ID	INT*	4	1	When an event occurs	Latest
	Roadside Equipment ID	INT*	4	1		
	Image Recognition Result Status	INT*	2	1		
	Video Image Address	TXT	60	1		
	Date/Time	Datetime	≥14	1		
Event Image Data Set <G - Server>	Road Management Office ID	INT*	4	1	When an event is checked	1 year
	Roadside Equipment ID	INT*	4	1		
	Place ID	INT*	4	1		
	Video Image ID	INT	8	1		
	Event Video Image	IMG	var	1		
	Traffic Event Data ID	INT	8	1		
	Date/Time	Datetime	≥14	1		
Transaction Data Set <R - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months
	Tollgate ID	INT	8	1		
	Lane ID	INT*	4	1		
	OBU ID	INT	12	1		
	Vehicle Class in OBU	INT*	2	1		
	License number in OBU	TXT	12	1		
	IC-card ID	INT	12	1		
	Toll Amount	INT	8	1		
	Prepaid Balance	FLOAT	8	1		
	Termination Status	INT*	2	1		
	Serial Number of Vehicle	INT	5	1		
	Date/Time	Datetime	≥14	1		

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF TRANSPORT, VIETNAM

SPECIAL ASSISTANCE FOR PROJECT IMPLEMENTATION (SAPI)
FOR ITS INTEGRATION PROJECT ON
NEW NATIONAL HIGHWAY NO.3 & NORTHERN AREA OF VIETNAM

DRAFT ITS MESSAGE/DATA STANDARDS (REVISED VERSION)

FINAL REPORT IN AUGUST 2012

ORIENTAL CONSULTANTS CO., LTD
NEXCO EAST ENGINEERING CO., LTD
NIPPON KOEI CO., LTD
TRANSPORTATION RESEARCH INSTITUTE CO., LTD
LANDTEC JAPAN INC.

DRAFT ITS MESSAGE/DATA STANDARDS

TABLE OF CONTENTS

1. Introduction

ITS consists of many equipment components, which are illustrated in the diagrams of system architecture in the Draft Design Standards and the Draft General Specifications. Provisions for securing compatibility of the equipment components are defined in the Draft General Specifications.

The equipment components need to be connected with each other by communication network in order to exchange messages and data among them, to realize the system and to provide intended services. For this purpose, inter-operability of message/data and connectability of interfaces need to be secured by preparing the standards for ITS as follows:

- Draft General Specifications → Compatibility of equipment components
- Draft Message/Data Standards → Inter-operability of message/data
- Draft Communication System Plan → Connectability of interfaces.

The Draft Message/Data Standards are developed in the Study in order to define a message list and a data dictionary and establish inter-operability of message and data.

1) Message List

A multitude of messages need to be exchanged among equipment components for implementing services of ITS. Major messages are shown in the document by respectively specifying the items below.

- Name of message
- Equipment component on one side of interface
- Equipment component on the other side of interface
- Names of Included data sets
- Names of Major Included data elements.

2) Data Dictionary

Messages include a number of data sets consisting of data elements. Major data elements are shown in the document by respectively specifying the attributes below.

- Name of data element
- Definition
- Presentation category
- Form of representation
- Data type of data element values.

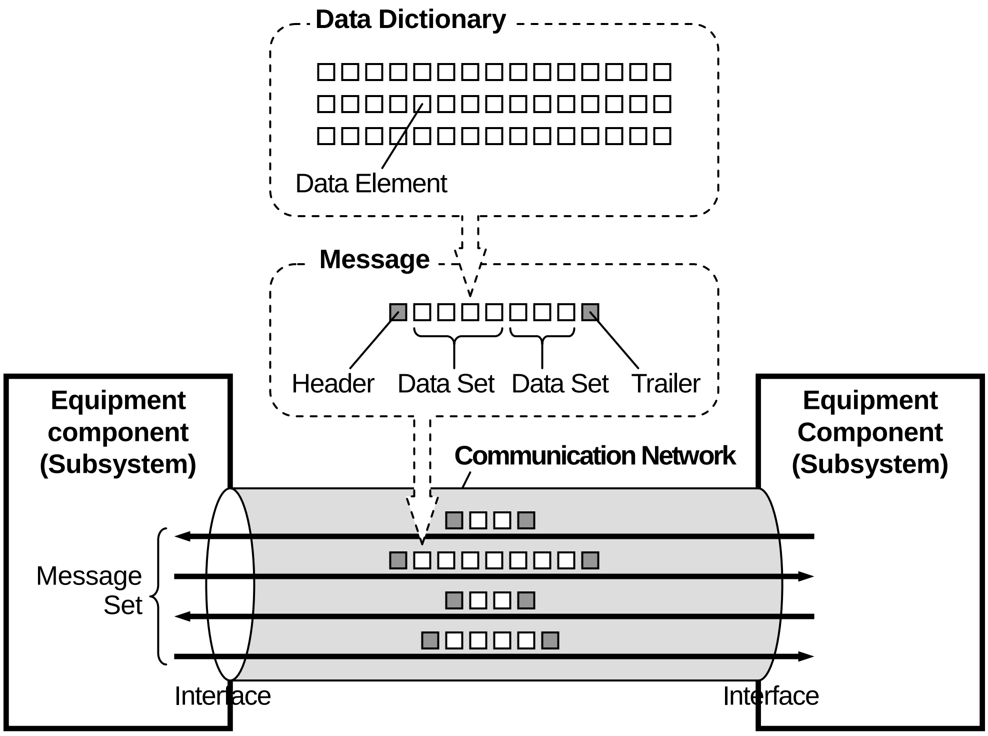
The attributes above are defined as mandatory in ISO/IEC 11179. In ISO/IEC 11179, three additional attributes listed below also are defined as mandatory; however, these are not included in the data dictionary because of insufficient discussion on them.

- Maximum size of data element values
- Minimum size of data element values
- Permissible data element Values

2. General

ITS consists of many pieces of equipment, which are illustrated as the equipment components in the diagrams of system architecture. The equipment components need to be connected with each other by communication network in order to exchange messages and data between them, to actualise the system and to provide intended services.

Figure 2.1 Conceptual Illustration of Message/Data Exchange



Source: ITS Integration Project (SAPI) Study Team

3. Message/Data Design for Traffic Information/Control System

3.1 Major Message List

The major message list for traffic information/control system is shown in the following table.

Table 3.1 Message List of Traffic Information/Control System

Name of Message	A Pair of Equipment Components on Both Side of Interface through Which Message is Exchanged		Name of Include Data Sets
Event Input Message	Data Input Device	Traffic Event Data Server	Traffic Event Data Set Image Recognition Result Data Set
	Traffic Event Data Server	Traffic Information Server	Traffic Event Data Set Image Recognition Data Set
Vehicle Detection Message	Vehicle Detector	Traffic Analysis Processor	Vehicle Detection Data Set
	Traffic Analysis Processor	Traffic Event Data Server	Vehicle Detection Data Set
Traffic Congestion Message	Traffic Analysis Processor	Traffic Event Data Server	Traffic Congestion Data Set
Traffic Congestion Input Message	Data Input Device	Traffic Event Data Server	Traffic Congestion Data Set
Image Data Message	CCTV Center Control Server	Traffic Supervising/Control Server	Event Image Data Set
Weather Observation Message	Weather Sensor	Weather Monitor Server	Weather Monitoring Dataset
Bad Weather Input Message	Data Input Device	Traffic Event Data Server	Bad Weather Data Set
	Traffic Event Data Server	Traffic Information Server	Bad Weather Data Set
	Weather Monitor Server	Traffic Event Data Server	Bad Weather Data Set
Weather Observation Message	Weather Monitor Server	Traffic Event Data Server	Weather Monitoring Dataset
Construction Work Input Message	Data Input Device	Traffic Event Data Server	Construction Work Data Set
	Traffic Event Data Server	Traffic Information Server	Construction Work Data Set
Traffic Restriction Input Message	Data Input Device	Traffic Event Data Server	Traffic Restriction Data Set
	Traffic Event Data Server	Traffic Information Server	Traffic Restriction Data Set
Traffic Event Message	Traffic Supervising/Control Server	Traffic Event Data Server	Traffic Event Data Set
VMS Indication Message	Traffic Event Data Server	VMS Center Controller	VMS Indication Data Set
	Traffic Event Data Server	Traffic Information Server	VMS Indication Data Set
VMS Control Input Message	Data Input Device	VMS Center Controller	VMS Control Input Data Set
VMS Control Message	VMS Center Controller	VMS	VMS Control Data Set

CSS Control Input message	Data Input Device	VMS Center Controller	CSS Control Input Data Set
CSS Control message	VMS Center Controller	CSS	CSS Control Data Set

Source: ITS Integration Project (SAPI) Study Team

3.2 Primary Data Dictionary

Primary data dictionary for traffic information/control system is shown in the table below.

Figure 3.1 Primary Data Dictionary for Traffic Information/Control System

	Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin	Definition
1	Incident Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where an incident occurred (Jurisdiction of a Road Management Office)
		Lane ID	INT*	2	1			An unique identifier of the lane where an incident occurred (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where an incident occurred (For information dissemination)
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where an incident occurred
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where an incident occurred
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Incident Status	INT*	2	1			Class of incident input referring to the video image: - 1: Traffic Accident - 2: Incident in Tunnel - 3: Reverse Driving - 4: Broken-down Vehicle - 5: Left Obstacle - 6: Natural Disaster - 7: Vandalism
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
2	Image Recognition Result Data Set <G - Image Processor>	Road Management Office ID	INT*	4	1	When an event occurs	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Image Recognition Result Status	INT*	2	1			Status analyzed by image recognition processor (Values are to be proposed by contractor including traffic accidents, breakdown vehicles, left obstacles, reverse driving, vandalism and natural disaster)
		Video Image Address	TXT	60	1			The network address of where the video image file is stored
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
3	Vehicle Detection Data Set <G - Vehicle Detector>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Cumulative Number of Vehicles	INT*	4	1			Cumulative number of vehicles detected by vehicle detector
		Vehicle Speed	FLOAT	5	N			Vehicle speed detected by vehicle detector (unit: km/h)
		Vehicle Length	FLOAT	4				Vehicle length detected by vehicle detector (unit:: m)
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
4	Traffic Volume Data Set <G - Traffic Analysis Processor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Total Traffic Volume per Day	INT	5	1			Total traffic volume per day
		Large Vehicle Ratio	FLOAT	5	1			Percentage of large vehicles to the total number of vehicles
		Traffic Volume per Day of vehicle class 1	INT	5	1			Traffic volume per day vehicle class 1: Ordinary vehicle
		Traffic Volume per Day of vehicle class 2	INT	5	1			Traffic volume per day vehicle class 2: Large vehicle
		Traffic Volume per Day of vehicle class 3	INT	5	1			Traffic volume per day vehicle class 3: Trailer vehicle
		Traffic Volume per Day of vehicle class 4	INT	5	1			Traffic volume per day vehicle class 4: Reserved
		Traffic Volume per Day of vehicle class 5	INT	5	1			Traffic volume per day vehicle class 5: Reserved
		Total Traffic Volume per Hour	INT*	4	1			Total traffic volume in the latest one hour
		Large Vehicle Ratio	FLOAT	5	1			Percentage of large vehicles to the total number of vehicles
		Traffic Volume per Hour of vehicle class 1	INT*	4	1			Traffic volume in the latest one hour of vehicle class 1: Ordinary vehicle
		Traffic Volume per Hour of vehicle class 2	INT*	4	1			Traffic volume in the latest one hour of vehicle class 2: Large vehicle
		Traffic Volume per Hour of vehicle class 3	INT*	4	1			Traffic volume in the latest one hour of vehicle class 3: Trailer vehicle
		Traffic Volume per Hour of vehicle class 4	INT*	4	1			Traffic volume in the latest one hour of vehicle class 4: Reserved
		Traffic Volume per Hour of vehicle class 5	INT*	4	1			Traffic volume in the latest one hour of vehicle class 5: Reserved
		Total Traffic Volume per 15 minutes	INT*	3	1			Total traffic volume in the latest 3 sets of 5 minutes
		Traffic Volume per 15 minutes of vehicle class 1	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 1: Ordinary vehicle
		Traffic Volume per 15 minutes of vehicle class 2	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 2: Large vehicle

		Traffic Volume per 15 minutes of vehicle class 3	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 3: Trailer vehicle
		Traffic Volume per 15 minutes of vehicle class 4	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 4: Reserved
		Traffic Volume per 15 minutes of vehicle class 5	INT*	3	1			Traffic volume in the latest 3 sets of 5 minutes of vehicle class 5: Reserved
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
5	Traffic Congestion Data Set <G - Traffic Analysis Processor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Cumulative Number of Vehicles	INT*	4	1			Cumulative number of vehicles detected by vehicle detector in the latest 3 sets of 5 minutes
		Average Vehicle Speed	INT*	4	1			Average value of detected vehicle speed in the latest 3 sets of 5 minutes
		Traffic Congestion Status	INT*	2	1			Class of traffic congestion generated referring to the results - 1: Congestion on Trough Lanes 1 - 2: Congestion on Trough Lanes 2 - 3: Congestion on Trough Lanes 3 - 4: Crowdedness on Trough Lanes - 5: Congestion at Exit 1 - 6: Congestion at Exit 2 - 7: Congestion at Exit 3
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of vehicle queuing
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of vehicle queuing
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
6	Weather Monitoring Data Set <G - Weather Sensor>	Road Management Office ID	INT*	4	1	Every 5 minutes	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a weather monitoring device
		Precipitation	FLOAT	2	1			Accumulated precipitation during specific 5 minutes (unit:: mm)
		Wind Speed	FLOAT	2	1			Average, minimum, and maximum observed wind speed during specific 5 minutes (unit:: m/s)
		Visibility	FLOAT	2	1			Average, minimum, and maximum observed visibility during specific 5 minutes (unit:: m)
		Temperature	FLOAT	2	1			Average, minimum, and maximum observed temperature during specific 5 minutes (unit:: Celsius degree)
		Alarm Status of Precipitation	INT*	2	1			Alarm to be issued when specific level of precipitation aforementioned is detected
		Alarm Status of Wind Speed	INT*	2	1			Alarm to be issued when specific level of wind speed aforementioned is detected
		Alarm Status of Visibility	INT*	2	1			Alarm to be issued when specific level of visibility aforementioned is detected
		Alarm Status of Temperature	INT*	2	1			Alarm to be issued when specific level of temperature aforementioned is detected
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
7	Bad Weather Data Set <G - Weather Server>	Road Management Office ID	INT*	4	1	When a bad weather occurs	Latest	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a weather monitoring device
		Precipitation	FLOAT	2	1			Precipitation (converted from 10 min. data) measured by rain gauge. (unit:: mm/h)
		Wind Speed	FLOAT	2	1			Wind speed (10 min. average) measured by wind sensor (unit:: m/s)
		Visibility	FLOAT	2	1			Visibility (10 min. average) measured by visibility sensor (unit:: m)
		Temperature	FLOAT	2	1			Temperature (10 min. average) measured by thermometer (unit: Celsius degree)
		Heavy Rain Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of heavy rain in traffic event class: - 1: Heavy Rain 1 - 2: Heavy Rain 2 - 3: Heavy Rain 3
		High Wind Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of high wind in traffic event class: - 1: High Wind 1 - 2: High Wind 2 - 3: High Wind 3
		Low Visibility Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of lowering of visibility in traffic event class: - 1: Dense Fog 1 - 2: Dense Fog 2 - 3: Dense Fog 3
		High Temperature Status	INT*	2	1			Specifying bad weather in traffic event category and corresponding class of high temperature in traffic event class: - 1: High Temperature
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
8	Construction Work Data Set <I - Server>	Road Management Office ID	INT*	4	1	When a construction work is scheduled	1 month after end of construction	An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where a construction work applied (Jurisdiction of a Road Management Office)
		Lane ID	INT*	2	1			An unique identifier of the lane where a construction work applied (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where a construction work applied (For information dissemination)
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where a construction work applied
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where a construction work applied
		Construction Work Status	INT*	2	1			Status of construction work: - 1: Scheduled - 2: Under construction - 3: Finished
		Number of document	TXT	20	1			Official number of permission document

		Permission Date	TXT	8	1			The date (Day/month/year) of permission of construction work
		Date/Time Begin	TXT	≥14	1			The begin time (Day/month/year/hour/minutes/second) of construction work
		Date/Time End	TXT	≥14	1			The end time (Day/month/year/hour/minutes/second) of construction work
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
9	Traffic Restriction Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month after end of restriction	An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where a construction work applied (Jurisdiction of a Road Management Office)
		Lane ID	INT*	2	1			An unique identifier of the lane where a construction work applied (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where a construction work applied (For information dissemination)
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where a traffic restriction applied
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where a traffic restriction applied
		Construction Work Status	INT*	2	1			Status of construction work: - 1: Scheduled - 2: Under construction - 3: Finished
		Permission Date	TXT	8	1			The date (Day/month/year) of permission of traffic restriction
		Date/Time Begin	TXT	≥14	1			The begin time (Day/month/year/hour/minutes/second) of traffic restriction
		Date/Time End	TXT	≥14	1			The end time (Day/month/year/hour/minutes/second) of traffic restriction
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
10	Traffic Event Data Set <G/C - Server>	Traffic Event Data ID	INT	8	1	When an event occurs	1 year	An unique identifier of the traffic event data
		Road Management Office ID	INT*	4	1			An unique identifier of a road management office
		Road Section ID	INT*	4	1			An unique identifier of the road section where a traffic event occurred (Jurisdiction of a Road Management Office)
		Road Link ID	INT*	4	1			An unique identifier of a segmentation of road network divided by diverging/ merging points at interchanges/ junctions or barrier tollgates
		Lane ID	INT*	2	1			An unique identifier of the lane where a traffic event occurred (Numbered from the median)
		Place ID	INT*	4	1			An unique identifier of the place where a traffic event occurred (For information dissemination)
		Traffic Event Category ID	INT*	4	1			An unique identifier of traffic event data category: - 1: Special Event - 2: Incident - 3: Construction Work - 4: Bad Weather - 5: Traffic Congestion - 6: Traffic - 7: Restriction
		Traffic Event Class ID	INT*	4	1			An unique identifier of traffic event data class 01: Special Event 19: High Temperature 02: Traffic Accident 20: Congestion on Trough Lanes 1 03: Incident in Tunnel 21: Congestion on Trough Lanes 2 04: Reverse Driving 22: Congestion on Trough Lanes 3 05: Broken-down Vehicle 23: Crowdedness on Trough Lanes 06: Left Obstacle 24: Congestion at Exit 1 07: Natural Disaster 25: Congestion at Exit 2 08: Vandalism 26: Congestion at Exit 3 09: Construction Work 27: Entry Closure 10: Heavy Rain 1 28: Closure 11: Heavy Rain 2 29: Exit Closure 12: Heavy Rain 3 30: Lane Closure 13: High Wind 1 31: Speed Limitation 1 14: High Wind 2 32: Speed Limitation 2 15: High Wind 3 16: Dense Fog 1 17: Dense Fog 2 18: Dense Fog 3
		Causal Traffic Event Data ID	INT	8	1			An unique identifier of the causal traffic event data
		Beginning Kilometer Post	TXT	6	1			The beginning kilometer post of the place where a traffic event occurred
		Ending Kilometer Post	TXT	6	1			The ending kilometer post of the place where a traffic event occurred
		Input Person	TXT	32	1			Name of the person who input traffic event data set
		Event Status	TXT	4	1			Status of traffic event
		Video Image address	TXT	60	1			The network address of where the Video image file is stored
		Main Center Check Status	INT*	4	1			Approval status by the main center: - 0: Not yet approved - 1: Approved
		Road Management Office Check Status	INT*	4	1			Approval status by the road management office: - 0: Not yet approved - 1: Approved
		Status of Traffic Event	INT*	2	1			Status of traffic event: - 1: Occurred and existing - 2: Removed
		Date/Time End	TXT	≥14	1			Day/month/year/hour/minutes/second of the traffic event input by operator
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
11	Event Image Data Set <G - Server>	Road Management Office ID	INT*	4	1	When an event is checked	1 year	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CCTV camera
		Place ID	INT*	4	1			An unique identifier of the place where the traffic event occurred (For information dissemination)
		Video Image ID	INT	8	1			An unique identifier of the video image
		Event Video Image	IMG	var	1			Video image data during time interval from 5 min before incident to 10 min after incident
		Traffic Event Data ID	INT	8	1			An unique identifier of the traffic event data

		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
12	Integrated Data Sed <G - Server>	Date/Time	TXT	≥14	1	Every 1 hour	1 year	Date and time for the reference of a data set
		Road Section ID	INT*	4	1			An unique identifier for the reference of a data set (Jurisdiction of a Road Management Office)
		Kilometer Post	TXT	6	1			Kilometer post for the reference of a data set
		Lane ID	INT*	2	1			An unique identifier of the lane for the reference of a data set (Numbered from the median)
		Data Set ID	INT*	2	1			An unique identifier of the kind for the reference of a data set - 1: Incident Data Set - 2: Traffic Volume Data Set - 3: Traffic Congestion Data Set - 4: Bad Weather Data Set - 5: Construction Work Data Set - 6: Traffic Restriction Data Set - 7: Traffic Event Data Set - 8: Hourly Toll Collection Data Set - 9: Axle Load Management Data Set
		<u>Data Set</u>	Set	var	1			A data set corresponding to Date/time, Road Section ID, Kilometer Post, Lane ID and Data Set ID
13	VMS Check /Indication Data Set <G/C - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a VMS
		Traffic Event Class ID	INT*	4	1			An unique identifier of the traffic event class
		Place ID	INT*	4	1			An unique identifier of the place where a traffic event occurred (For information dissemination)
		Place Name	TXT	28	1			Name of the place where a traffic event occurred
		Traffic Event ID	INT	8	1			An unique identifier of the traffic event (including indication of "Under Repair")
		Traffic Event Name	TXT	20	1			Name of the traffic event occurred
		Causal Place ID	INT*	4	1			An unique identifier of the place where the causal traffic event occurred (For information dissemination)
		Causal Place Name	TXT	28	1			Name of the place where the causal traffic event occurred
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
14	VMS Input/Indication Data Set <I - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a VMS
		Traffic Event Class ID	INT*	4	1			An unique identifier of the traffic event class
		Place ID	INT*	4	1			An unique identifier of the place where a traffic event occurred (For information dissemination)
		Place Name	TXT	28	1			Name of the place where a traffic event occurred
		Traffic Event ID	INT	8	1			An unique identifier of the traffic event (including indication of "Under Repair")
		Traffic Event Name	TXT	20	1			Name of the traffic event occurred
		Causal Place ID	INT*	4	1			An unique identifier of the place where the causal traffic event occurred (For information dissemination)
		Causal Place Name	TXT	28	1			Name of the place where the causal traffic event occurred
		Free Text	TXT	var	1			The characters input using data input device
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set
15	CSS Indication Data Set <G/C - Server>	Road Management Office ID	INT*	4	1	When an event occurs	1 month	An unique identifier of a road management office
		Roadside Equipment ID	INT*	4	1			An unique identifier of a CSS
		Speed Limit	INT*	3	1			The limit speed input using data input device
		Date/Time	Datetime	≥14	1			Year/month/day /hour/minutes/second of generating data set

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

4. Message/Data Design for Automated Toll Collection/Management System

4.1 Major Message List

The major message list for automated toll collection/management system is shown in the following table.

Table 4.1 Major Message List of Automated Toll Collection/Management System

Name of Message	A Pair of Equipment Components on Both Side of Interface through Which Message is Exchanged		Name of Include Data Sets
Toll Price Input Message	Data Input Device	Toll Management Server	Toll Price Information Data Set
Toll Price Message	Toll Management Server	Lane Server	Toll Price Data Set
Toll Price Message	Lane Server	Roadside Controller	Toll Price Data Set
ETC Message	OBU	Roadside Controller	OBU Registration Data Set OBU Passage Data Set IC-Card Contract Data Set IC-Car Passage Data Set Transaction Data Set
Touch & Go Message	IC-Card R/W	Lane Server	IC-Card Contract Data Set IC-Car Passage History Data Set Transaction Data Set
IC-Card recharge Message	IC-Card	IC-Card Recharger	IC-Card Recharge Data Set
Transaction Collection Message	Lane Server	Toll Management Server	Transaction Collection Data Set
Toll Collection Message	Toll Management Server	Toll Management Center Server	Toll Collection Data Set
Invalidation ID Message	Bank Server	Toll Office Server	Invalidation List Data Set
Invalidation ID Message	Toll Office Server	Lane Server	Invalidation List Data Set
Traffic Volume Massage	Toll Office Server	Integrated Data Server	Traffic Volume Data Set
License plate message	License Plate Scanner	Lane Server	License Plate Recognition Data Set
Toll Fare Message	Toll Management Server	Bank Server	Toll Fare Data Set
Traffic Volume Massage	Regional Main Center	Crosscheck Organization	Traffic Volume Data Set
Toll Fare Message	Toll Management Server	Crosscheck Organization	Toll Fare Data Set
Toll Validity Message	Crosscheck Organization	Bank Server	Validity Result Data Set
Toll Settlement Message	Head Office Server	Bank Server	Toll Settlement Data

Source: ITS Integration Project (SAPI) Study Team

4.2 Primary Data Dictionary for Automated Toll Collection/Management System

Primary data dictionary for automated toll collection/management system is shown in the table below.

Figure 4.1 Primary Data Dictionary for Automated Toll Collection/Management System

	Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin	Definition
16	Toll Rate Information Data Set <R - Server>	Number of tollgate pair	INT	8	1	Daily	1 year	The number of tollgate pair (N)
		Tollgate Pair ID	INT	8	N			An unique identifier of a pair of tollgate
		Entrance Tollgate ID	INT*	4				An unique identifier of the entrance tollgate
		Exit Tollgate ID	INT*	4				An unique identifier of the exit tollgate
		Toll Rate of Vehicle Class 1	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses
		Toll Rate of Vehicle Class 2	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons
		Toll Rate of Vehicle Class 3	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons
		Toll Rate of Vehicle Class 4	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries
		Toll Rate of Vehicle Class 5	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries
		Toll Rate of Vehicle Class 6	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 6: Military vehicles in the missions
		Toll Rate of Vehicle Class 7	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 7: Public security vehicles in the missions
		Toll Rate of Vehicle Class 8	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 8: Reserved
		Toll Rate of Vehicle Class 9	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 9: Reserved
		Toll Rate of Vehicle Class 10	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 10: Reserved
		Toll Rate of Vehicle Class 11	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 11: Reserved
		Toll Rate of Vehicle Class 12	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 12: Reserved
		Toll Rate of Vehicle Class 13	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 13: Reserved
		Toll Rate of Vehicle Class 14	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 14: Reserved
		Toll Rate of Vehicle Class 15	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 15: Reserved
		Toll Rate of Vehicle Class 16	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 16: Reserved
		Toll Rate of Vehicle Class 17	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 17: Reserved
		Toll Rate of Vehicle Class 18	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 18: Reserved
		Toll Rate of Vehicle Class 19	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 19: Reserved
		Toll Rate of Vehicle Class 20	FLOAT	12				Toll rate from Ent to Exit for Vehicle Class 20: Reserved
		Number of document	TXT	20				Official number of permission document
		Date of Toll Rate Table	TXT	8				Day/month/year of the toll rate information for the pair of tollgate
17	Bar-code Data Set <G - Lane Server>	Toll Office ID	INT*	4	1	Each passage at tollgate	1 month	An unique identifier of a toll office
		Tollgate ID	INT*	4	1			An unique identifier of a tollgate
		Lane ID	INT*	2	1			An unique identifier of the lane where a construction work applied (Numbered from the median)
		Deposit Terminal ID	INT*	4	1			An unique identifier of the deposit terminal
		Ticket Type	INT*	4	1			Type of ticket
		Vehicle Class	INT*	2	1			Vehicle class: - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		Serial Number	INT	12	1			Serial number of the ticket
		Date Issue	Date	8	1			Day/month/year of issuing ticket
		Date of Expiry	Date	8	1			Day/month/year of ticket expiration
18	IC-card Issue Data Set <R - IC-card>	Issuer ID	INT*	4	1	IC-card issue	Permanent	An unique identifier of an issuer organization
		Issue Terminal ID	INT	12	1			An unique identifier of an issue terminal equipment
		IC-card ID	INT	12	1			An unique identifier of an IC-card
		IC-card Owner ID	INT	18	1			An unique identifier of IC-card owner
		Amount of Deposit	FLOAT	8	1			The amount of electric money deposited to the account (unit: thousand VND)
		Date/Time of Issue	TXT	≥14	1			Day/month/year/hour/minutes/second of issuing IC-card
		Date/Time of Expiry	TXT	≥14	1			Day/month/year/hour/minutes/second of expiring IC-card
19	IC-card Recharge Data Set <R - IC-card>	Issuer ID	INT*	4	N	Each recharge	Permanent	An unique identifier of an issuer organization
		Deposit Terminal ID	INT	12				An unique identifier of a terminal device
		Amount of Deposit	FLOAT	8				The amount of electric money deposited to the prepared account (unit: thousand VND)
		Prepaid Balance	FLOAT	8				The remaining amount of electric money in an IC-card (unit: thousand VND)
		Date/Time	Datetime	≥14				Year/ month/day/hour/minutes/second of generating data set

20	IC-card Passage Data Set <R - IC-card>	Toll Office ID	INT*	4	N	Each passage at tollgate	Latest	An unique identifier of a toll office
		Tollgate ID	INT	8				An unique identifier of a toll gate
		Lane ID	INT	12				An unique identifier of a lane (Numbered from the median)
		Toll Amount	FLOAT	8				A toll charge collected by the system when a vehicle passing through a tollgate using ETC, Touch&Go toll collection or Manual toll collection. (unit: thousand VND)
		Prepaid Balance	FLOAT	8				The remaining amount of electric money in an IC-card (unit: thousand VND)
		Date/Time	Datetime	≥14				Year/ month/day/hour/minutes/second of generating data set
21	IC-card Invalidation List Data Set <G - Server>	Issuer ID	INT*	4	1	Daily	1 year	An unique identifier of an issuer organization
		Issue Terminal ID	INT	12	N			An unique identifier of an issue terminal equipment
		IC-card ID for Invalidation	INT	12				An unique identifier of an IC-card of invalidation
		IC-card Owner ID	INT	18				An unique identifier of IC-card owner
		Amount of Deposit	FLOAT	8				The amount of electric money deposited to the account (unit: thousand VND)
		Date/Time of Issue	TXT	≥14				Day/month/year/hour/minutes/second of issuing IC-card
		Date/Time of Expiry	TXT	≥14				Day/month/year/hour/minutes/second of expiring IC-card
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
22	OBU Registration Data Set <R - OBU>	Management Organization ID	INT	12	1	OBU registration	Permanent	An unique identifier of OBU management organization
		OBU ID	INT	12	1			An unique identifier of an OBU
		OBU Owner ID	INT	18	1			An unique identifier of OBU owner
		License Plate Number	TXT	12	1			License plate number recorded in OBU
		Vehicle Class	TXT	2	1			Vehicle class recorded in OBU: - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		Date of Issue	TXT	8	1			Day/month/year of issuing OBU
		Date of Expiry	TXT	8	1			Day/month/year of OBU expiration
23	OBU Passage Data Set <R - OBU>	Toll Office ID	INT*	4	3	Each passage at tollgate	Latest	An unique identifier of a toll office
		Tollgate ID	INT*	4				An unique identifier of a tollgate
		Lane ID	INT*	4				An unique identifier of a lane (Numbered from the median)
		IC-card ID	INT	12				An unique identifier of an IC-card
		Toll Amount	FLOAT	4				A toll charge collected by the system when a vehicle passing through a tollgate using ETC, Touch&Go toll collection or Manual toll collection. (unit: thousand VND)
		Prepaid Balance	INT	8				Prepaid balance copied from an IC-card
		Date/Time	Datetime	≥14				Year/ month/day/hour/minutes/second of generating data set
24	OBU Invalidation List Data Set <G - Server>	Management Organization ID	INT	12	1	Daily	1 year	An unique identifier of OBU management organization
		OBU ID for Invalidation	INT	12	N			An unique identifier of an OBU of invalidation
		OBU Owner ID	INT	18				An unique identifier of OBU owner
		License Plate Number	TXT	12				License plate number recorded in OBU
		Vehicle Class	TXT	2				Vehicle class recorded in OBU - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		Date of Issue	TXT	8				Day/month/year of issuing OBU
		Date of Expiry	TXT	8				Day/month/year of OBU expiration
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
25	Toll Collection License Plate Data Set <G - Image Processor>	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months	An unique identifier of a toll office
		Tollgate ID	INT*	4	1			An unique identifier of a tollgate
		Lane ID	INT*	4	1			An unique identifier of a lane (Numbered from the median)
		Roadside Equipment ID	INT*	4	1			An unique identifier of a license recognition device
		Captured License Plate Number	TXT	12	1			License plate number recognized by image processor
		Captured License Plate Image	IMG	var	1			The license plate image captured by CCTV camera
		Serial Number of Vehicle	INT*	5	1			Daily serial number for a vehicle passing through tollgate. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
26	Transaction Data Set <R - Lane	Toll Office ID	INT*	4	1	Each passage at tollgate	6 months	An unique identifier of a toll office
		Tollgate ID	INT	8	1			An unique identifier of a toll gate
		Lane ID	INT*	4	1			An unique identifier of a lane (Numbered from the median)
		OBU ID	INT	12	1			An unique identifier of OBU

	Server>	Vehicle Class in OBU	INT*	2	1			Vehicle class recorded in OBU - 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses - 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons - 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons - 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries - 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries - 6: Military vehicles in the missions - 7: Public security vehicles in the missions
		License number in OBU	TXT	12	1			License number recorded in OBU
		IC-card ID	INT	12	1			An unique identifier of an IC-card
		Toll Amount	INT	8	1			A toll charge collected by the system when a vehicle passing through a tollgate using ETC, Touch&Go toll collection or Manual toll collection. (unit: thousand VND)
		Prepaid Balance	FLOAT	8	1			The remaining amount of electric money in an IC-card (unit: thousand VND)
		Termination Status	INT*	2	1			Data for indicating a toll collection procedure has finished successfully or not
		Serial Number of Vehicle	INT	5	1			Daily serial number for a vehicle passing through tollgate. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
27	Toll Collection Data Set <G - Lane Server>	Road Owner ID	INT*	4	1	Every 10 minutes	6 months	An unique identifier of a road owner
		Toll Office ID	INT*	4	1			An unique identifier of a toll office
		Date of Toll Amount	TXT	8	1			Day/month/year of the toll amount
		Sum of Toll Amount	INT*	12	1			A sum of colleted toll amount of vehicles passing through the tollgate
		Number of Vehicle Passage	INT	8	1			Number of vehicles passing through the tollgate
		<u>Transaction Data Set</u>	Set	var	N			Transaction data set of a vehicle passing through the tollgate
		Enforcement Status	TXT	2				Status for indicating the enforcement status: - 0: Successful. - 1: Vehicle passage that has different scanned license plate number compared to OBU. Suspicion of spoofing. - 2: Vehicle passage with continuously negative balance in IC-card. Suspicion of cheating. - 3: Vehicle passage without OBU and/or IC-card.
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
28	Hourly Toll Collection Data Set <G/C - Server>	Road Owner ID	INT*	4	1	Hourly	1 year	An unique identifier of a road owner
		Toll Office ID	INT*	4	1			An unique identifier of a toll office
		Date/Hour of Record	TXT	10	1			Day/month/year/hour of the record
		Sum of Toll Amount	FLOAT	12	1			Total toll amount of vehicles passing through the tollgate (unit: thousand VND)
		Number of Vehicle Passage	INT	8	1			Number of vehicles passing through the tollgate
		Sum of Toll of Vehicle Class 1	FLOAT	12	1			Total toll amount of class 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses (unit: thousand VND)
		Number of Vehicle of Class 1	INT	8	1			Number of vehicles of class 1
		Sum of Toll of Vehicle Class 2	FLOAT	12	1			Total toll amount of class 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons (unit: thousand VND)
		Number of Vehicle of Class 2	INT	8	1			Number of vehicles of class 2
		Sum of Toll of Vehicle Class 3	FLOAT	12	1			Total toll amount of class 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons (unit: thousand VND)
		Number of Vehicle of Class 3	INT	8	1			Number of vehicles of class 3
		Sum of Toll of Vehicle Class 4	FLOAT	12	1			Total toll amount of class 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 4	INT	8	1			Number of vehicles of class 4
		Sum of Toll of Vehicle Class 5	FLOAT	12	1			Total toll amount of class 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 5	INT	8	1			Number of vehicles of class 5
		Sum of Toll of Vehicle Class 6	FLOAT	12	1			Total toll amount of class 6: Military vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 6	INT	8	1			Number of vehicles of class 6
		Sum of Toll of Vehicle Class 7	FLOAT	12	1			Total toll amount of class 7: Public security vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 7	INT	8	1			Number of vehicles of class 7
		Sum of Toll of Vehicle Class 8	FLOAT	12	1			Total toll amount of class 8: Reserved(unit: thousand VND)
		Number of Vehicle of Class 8	INT	8	1			Number of vehicles of class 8
		Sum of Toll of Vehicle Class 9	FLOAT	12	1			Total toll amount of class 9: Reserved(unit: thousand VND)
		Number of Vehicle of Class 9	INT	8	1			Number of vehicles of class 9
		Sum of Toll of Vehicle Class 10	FLOAT	12	1			Total toll amount of class 10: Reserved(unit: thousand VND)
		Number of Vehicle of Class 10	INT	8	1			Number of vehicles of class 10
		Sum of Toll of Vehicle Class 11	FLOAT	12	1			Total toll amount of class 11: Reserved(unit: thousand VND)
		Number of Vehicle of Class 11	INT	8	1			Number of vehicles of class 11
		Sum of Toll of Vehicle Class 12	FLOAT	12	1			Total toll amount of class 12: Reserved(unit: thousand VND)
		Number of Vehicle of Class 12	INT	8	1			Number of vehicles of class 12
		Sum of Toll of Vehicle Class 13	FLOAT	12	1			Total toll amount of class 13: Reserved(unit: thousand VND)
		Number of Vehicle of Class 13	INT	8	1			Number of vehicles of class 13
		Sum of Toll of Vehicle Class 14	FLOAT	12	1			Total toll amount of class 14: Reserved(unit: thousand VND)
		Number of Vehicle of Class 14	INT	8	1			Number of vehicles of class 14
		Sum of Toll of Vehicle Class 15	FLOAT	12	1			Total toll amount of class 15: Reserved(unit: thousand VND)
		Number of Vehicle of Class 15	INT	8	1			Number of vehicles of class 15
		Sum of Toll of Vehicle Class 16	FLOAT	12	1			Total toll amount of class 16: Reserved(unit: thousand VND)
		Number of Vehicle of Class 16	INT	8	1			Number of vehicles of class 16
		Sum of Toll of Vehicle Class 17	FLOAT	12	1			Total toll amount of class 17: Reserved(unit: thousand VND)
		Number of Vehicle of Class 17	INT	8	1			Number of vehicles of class 17

		Sum of Toll of Vehicle Class 18	FLOAT	12	1			Total toll amount of class 18: Reserved(unit: thousand VND)
		Number of Vehicle of Class 18	INT	8	1			Number of vehicles of class 18
		Sum of Toll of Vehicle Class 19	FLOAT	12	1			Total toll amount of class 19: Reserved(unit: thousand VND)
		Number of Vehicle of Class 19	INT	8	1			Number of vehicles of class 19
		Sum of Toll of Vehicle Class 20	FLOAT	12	1			Total toll amount of class 20: Reserved(unit: thousand VND)
		Number of Vehicle of Class 20	INT	8	1			Number of vehicles of class 20
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
29	Toll Revenue Data Set <G/C - Server>	Road Owner ID	INT*	4	1	Monthly	1 year	An unique identifier of a road owner
		Fiscal Month	TXT	6	1			Number of fiscal month
		Toll Revenue of The Month/Week	FLOAT	16	1			Toll revenue of the fiscal period (unit: thousand VND)
		Number of Vehicle Passage	INT	8	1			Number of vehicles passing through the tollgate
		Sum of Toll of Vehicle Class 1	FLOAT	12	1			Total toll amount of class 1: Cars with seats of 12 or less, trucks with a capacity less than 2 tons, mass transit buses (unit: thousand VND)
		Number of Vehicle of Class 1	INT	8	1			Number of vehicles of class 1
		Sum of Toll of Vehicle Class 2	FLOAT	12	1			Total toll amount of class 2: Cars seats between 12 and 30, trucks with a capacity between 2 and 4 tons (unit: thousand VND)
		Number of Vehicle of Class 2	INT	8	1			Number of vehicles of class 2
		Sum of Toll of Vehicle Class 3	FLOAT	12	1			Total toll amount of class 3: Cars with seats of 30 or more, trucks with a capacity between 4 and 10 tons (unit: thousand VND)
		Number of Vehicle of Class 3	INT	8	1			Number of vehicles of class 3
		Sum of Toll of Vehicle Class 4	FLOAT	12	1			Total toll amount of class 4: Trucks with a capacity between 10 and 18 tons, 20ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 4	INT	8	1			Number of vehicles of class 4
		Sum of Toll of Vehicle Class 5	FLOAT	12	1			Total toll amount of class 5: Trucks with a capacity of 18 tons or more, 40ft-container lorries (unit: thousand VND)
		Number of Vehicle of Class 5	INT	8	1			Number of vehicles of class 5
		Sum of Toll of Vehicle Class 6	FLOAT	12	1			Total toll amount of class 6: Military vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 6	INT	8	1			Number of vehicles of class 6
		Sum of Toll of Vehicle Class 7	FLOAT	12	1			Total toll amount of class 7: Public security vehicles in the missions (unit: thousand VND)
		Number of Vehicle of Class 7	INT	8	1			Number of vehicles of class 7
		Sum of Toll of Vehicle Class 8	FLOAT	12	1			Total toll amount of class 8: Reserved(unit: thousand VND)
		Number of Vehicle of Class 8	INT	8	1			Number of vehicles of class 8
		Sum of Toll of Vehicle Class 9	FLOAT	12	1			Total toll amount of class 9: Reserved(unit: thousand VND)
		Number of Vehicle of Class 9	INT	8	1			Number of vehicles of class 9
		Sum of Toll of Vehicle Class 10	FLOAT	12	1			Total toll amount of class 10: Reserved(unit: thousand VND)
		Number of Vehicle of Class 10	INT	8	1			Number of vehicles of class 10
		Sum of Toll of Vehicle Class 11	FLOAT	12	1			Total toll amount of class 11: Reserved(unit: thousand VND)
		Number of Vehicle of Class 11	INT	8	1			Number of vehicles of class 11
		Sum of Toll of Vehicle Class 12	FLOAT	12	1			Total toll amount of class 12: Reserved(unit: thousand VND)
		Number of Vehicle of Class 12	INT	8	1			Number of vehicles of class 12
		Sum of Toll of Vehicle Class 13	FLOAT	12	1			Total toll amount of class 13: Reserved(unit: thousand VND)
		Number of Vehicle of Class 13	INT	8	1			Number of vehicles of class 13
		Sum of Toll of Vehicle Class 14	FLOAT	12	1			Total toll amount of class 14: Reserved(unit: thousand VND)
		Number of Vehicle of Class 14	INT	8	1			Number of vehicles of class 14
		Sum of Toll of Vehicle Class 15	FLOAT	x	1			Total toll amount of class 15: Reserved(unit: thousand VND)
		Number of Vehicle of Class 15	INT	8	1			Number of vehicles of class 15
		Sum of Toll of Vehicle Class 16	FLOAT	12	1			Total toll amount of class 16: Reserved(unit: thousand VND)
		Number of Vehicle of Class 16	INT	8	1			Number of vehicles of class 16
		Sum of Toll of Vehicle Class 17	FLOAT	12	1			Total toll amount of class 17: Reserved(unit: thousand VND)
		Number of Vehicle of Class 17	INT	8	1			Number of vehicles of class 17
		Sum of Toll of Vehicle Class 18	FLOAT	12	1			Total toll amount of class 18: Reserved(unit: thousand VND)
		Number of Vehicle of Class 18	INT	8	1			Number of vehicles of class 18
		Sum of Toll of Vehicle Class 19	FLOAT	12	1			Total toll amount of class 19: Reserved(unit: thousand VND)
		Number of Vehicle of Class 19	INT	8	1			Number of vehicles of class 19
		Sum of Toll of Vehicle Class 20	FLOAT	12	1			Total toll amount of class 20: Reserved(unit: thousand VND)
		Number of Vehicle of Class 20	INT	8	1			Number of vehicles of class 20
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

5. Message/Data Design for Vehicle Weighing System

5.1 Major Message List

The major message list for vehicle weighing system is shown in the following table.

Table 5.1 Major Message List of Vehicle Weighing System

Name of Message	A Pair of Equipment Components on Both Side of Interface through Which Message is Exchanged		Name of Include Data Sets
Over Loading Message	Heavy Truck Control Data Server	Traffic Event Data Server	Axle Load Measurement Data Set Over Loading Vehicle Data Set
License Plate Message	Vehicle Detector	Heavy Truck Control data Server	License Plate Recognition Data Set
Axle Load Measurement Data Set	Axle Load Scale	Heavy Truck Control data Server	Axle Load Measurement Data Set

Source: ITS Integration Project (SAPI) Study Team

5.2 Primary Data Dictionary

Primary data dictionary for vehicle weighing system is shown in the table below.

Figure 5.1 Primary Data Dictionary for Vehicle Weighing System

	Data Set <Origin>	Data Elements	Type	Digit	Set	Update Cycle	Storage Period for Origin	Definition
30	Axle Load Measurement Data Set <G -Axle Load Scale>	Road Section ID	INT*	4	1	When overloading data detected	6 months	An unique identifier of the road section where the axle load scale installed
		Axle Load Scale Location ID	INT*	4	1			An unique identifier of install location of axle load scale
		Lane ID	INT*	2	1			An unique identifier of the lane of axle load scale (Numbered from the median)
		Vehicle Class	INT*	2	1			Vehicle class categorized for axle load: - 1: Single-unit truck with 2 axles - 2: Single-unit truck with 3 axles - 3: Single-unit truck with 4 axles - 4: Single-unit truck with 5 or more axles - 5: Tractor with trailer/semi-trailer, 3 axles - 6: Tractor with trailer/semi-trailer, 4 axles - 7: Tractor with trailer/semi-trailer, 5 or more axles - 8: 2-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles - 9: 3-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles - 10: 4-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles - 11: 5-or-more-axle single-unit truck with trailer/semi-trailer that has 1, 2 or 3 axles
		Number of Axles	INT*	2	1			Number of axles (less than or equal to 10)
		Axle Load	INT*	2	10			Measurement data of load of an axle (unit: Ton)
		Maximum Axle Load	INT*	2	1			Maximum value of measured axle loads of a vehicle (unit: Ton)
		Axle Load Status	INT*	2	1			Status of the axle load scale: - 0: Normal - 1: Suspicious at overloading - 2: Overloaded
		Serial Number of Vehicle	INT	5	1			Daily serial number for a vehicle passing through the axle load scale. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
31	Axle Load License Plate Data Set <G -Image Processor>	Road Section ID	INT*	4	1	When overloading data detected	6 months	An unique identifier of the road section where the axle load scale installed
		Axle Load Scale Location ID	INT*	4	1			An unique identifier of install location of axle load scale
		Lane ID	INT*	2	1			An unique identifier of the lane of axle load scale (Numbered from the median)
		Roadside Equipment ID	INT*	4	1			An unique identifier of a license recognition device
		Captured License Plate Number	TXT	12	1			License plate number recognized by image processor
		Captured License Plate Image	IMG	var	1			The license plate image captured by CCTV camera
		Serial Number of Vehicle	INT	5	1			Daily serial number for a vehicle passing through the axle load scale. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set
32	Axle Load Management Data Set <G/C-	Road Owner ID	INT*	4	1	Hourly	1 year	An unique identifier of a road owner
		Road Section ID	INT*	4	1			An unique identifier of the road section where the axle load scale installed
		Axle Load Scale Location ID	INT*	4	1			An unique identifier of install location of axle load scale

	Server>	Lane ID	INT*	2	1			An unique identifier of the lane of axle load scale (Numbered from the median)
		Date/Hour of Record	TXT	10	1			Day/month/year/hour of the record
		Number of Heavy Trucks	INT	5	1			Number of heavy trucks measured
		Number of Suspicious Trucks	INT	5	1			Number of heavy trucks suspicious at overloading
		Number of Overloaded Trucks	INT	5	1			Number of heavy trucks overloaded
		<u>Axle Load Measurement Data Set</u>	Set	var				Axle load measurement data set of vehicle passing through axle load scale
		Axle Load Status	INT*	2	N			Status of the axle load scale: - 0: Normal - 1: Suspicious at overloading - 2: Overloaded
		Serial Number of Vehicle	INT	5				Daily serial number for a vehicle passing through the axle load scale. (For reference to other data set)
		Date/Time	Datetime	≥14	1			Year/ month/day/hour/minutes/second of generating data set

Note: INT* : Short integer; I: Input; G: Generated; C: Checked; R: Recorded

Source: ITS Integration Project (SAPI) Study Team

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF TRANSPORT, VIETNAM

SPECIAL ASSISTANCE FOR PROJECT IMPLEMENTATION (SAPI)
FOR ITS INTEGRATION PROJECT ON
NEW NATIONAL HIGHWAY NO.3 & NORTHERN AREA OF VIETNAM

DRAFT ITS COMMUNICATION SYSTEM PLAN (REVISED VERSION)

FINAL REPORT IN AUGUST 2012

ORIENTAL CONSULTANTS CO., LTD
NEXCO EAST ENGINEERING CO., LTD
NIPPON KOEI CO., LTD
TRANSPORTATION RESEARCH INSTITUTE CO., LTD
LANDTEC JAPAN INC.

Introduction

The revised version of the Draft Communication System Plan includes the General Plan and the Draft Design Standards of communication system in order to establish connectability of communication network.

- General Plan of Communication System
- Draft Design Standards of Communication System.

The General Plan of Communication System shows the discussion results on the items below.

- Locations of Main Centers and network structure
- Communication network management
- Terminal layer for roadside equipment
- Basic procedure of expressway operation
- Integration of roadside equipment control
- Transmission method.

COMMUNICATION SYSTEM

TABLE OF CONTENTS

1. Introduction

1.1 Basic Policy of Communication Network

As for the Basic Policy for Communication Network for ITS, the following points are required.

(1) Securing of redundancy of backbone network

The backbone communication network shall be redundant by combination of ring network configuration so as not to disconnect due to incident or other reasons. If necessary, the back up by communication network carrier is also considered.

(2) Monitoring of fault or failure of the network

In case failure or fault occurs on the specific position of backbone communication network such as disconnection or malfunction, it shall be detected such failure or fault and its location by Regional Main Center or road management office with monitoring function of the network using hardware or software before switch over to the redundant equipment component or network. All such log shall be recorded for recovery of fault.

(3) Securing of QoS for directive communication in emergency case

In case severe incident occurs, it is supposed that communication traffic increases or specific system functions are utilized bursty. In addition, it should be considered that the communication network failure of the related part due to maintenance mistake. Even under such situation, Quality of Service (QoS) for important communication, such as directive of voice communication, shall be secured logically or physically.

1.2 Network Layers

The network for expressway ITS is recommended to composed of the following layers taking actual expressway construction conditions into consideration.

(1) National Layer Network

Communication network among the Regional Main Centers

(2) Integration Layer Network

Communication network among one Regional Main Center and its related road management offices

(3) Road Section Layer Network

Communication network among one road management office and its related terminal nodes

(4) Terminal Layer Network

Communication network between one terminal node and its related Layer 2 Switch which is connected with roadside equipment component(s)

1.3 Communication Traffic

The communication traffic for ITS operation will be voice, data and moving image, and details are shown below;

(1) Voice Communication

The Traffic for directive communication and administrative telephone

(2) Data and moving image

Moving image monitored by CCTV camera, data obtained by roadside equipment components such as vehicle detector, event detector and weather sensor, and data to the VMS and controlling data for roadside equipment components

(3) Forecasted Communication Traffic

The major communication traffic for considering transmission capacity is moving image to be transmitted from roadside CCTV cameras to Road Management Center and Regional Main Center. The forecasted communication traffic for upstream and downstream is shown in the following table.

Table 1.1 Communication Traffic (Upstream)

No.	Communication Traffic Category	Traffic for Road Section Layer Network	Traffic for Integration Layer Network
1	Moving Images from CCTV Cameras	Approx. 640Mbps (including cameras for Vehicle Detection and Event Detection)	128 Mbps (for 20 cameras)
2	Event Detector	None (Note a)	Approx. 0.001Mbps (Note b)
3	Vehicle Detector	None (Note a)	Approx. 20Mbps
4	Voice Communication	Approx. 2Mbps	Approx. 1.5Mbps
5	Weather Data	Approx. 0.0016 Mbps	Approx. 0.032Mbps
	Total	Approx. 650Mbps	Approx. 150Mbps

Note: a) Communication traffic for Event Detection and Vehicle Detection will not be originated in the Road Section Layer Network since image recognition sensor will be installed in Road Management Office.
b) This communication traffic is originated only upon the event is detected.

Source: ITS Integration Project (SAPI) Study Team

Table 1.2 Communication Traffic (Downstream)

No.	Communication Traffic Category	Traffic for Road Section Layer Network	Traffic for Integration Layer Network
1	Voice Communication	Approx. 2Mbps	Approx. 12Mbps
2	VMS (including CSS)	Approx. 21Mbps	Approx. 384Mbps
	Total	Approx. 30Mbps	Approx. 400Mbps

Source: ITS Integration Project (SAPI) Study Team

The communication traffic calculation basis is shown below;

(a) One Road Management Office covers 80km expressway section is assumed to include 6 interchanges.

(b) One Regional Main Center assumed to cover approximately 1600km expressway section including 20 Road Management Offices.

(c) Network Video Recorder (NVR) will be installed in Road Management Office for recording moving images obtained by CCTV camera including event detection and vehicle detection, and not to be installed in Terminal Node.

(d) Equipment for Image Recognition will be installed in Road Management Office and not to be installed in Roadside. Therefore moving image will be transmitted from roadside cameras to NVR located in Road Management Office.

(e) Communication traffic for moving image obtained by one CCTV Camera is assumed approximately 6.4Mbps.

(f) Communication traffic for event detection will be originated only when the event is detected. The approximate traffic for one event detector is assumed 0.001Mbps.

(g) Communication traffic for one vehicle detector will be approximately 5kbyte per 1 minute data for 1 vehicle detector. Therefore the data volume of approximately 0.04Mbps is assumed for one vehicle detector.

(h) In 80km expressway section managed under one Road Management Office, approx. 50 CCTV cameras for through lane, 24 fixed type cameras for event detection, and 24 fixed type cameras for vehicle detection will be assumed to be installed. (In total approximately 100 moving images obtained by CCTV cameras are transmitted from roadside to Road Management Office.)

(i) In one Regional Main Center, one directive communication console and 20 sets administrative telephone is assumed to be installed.

(j) Under one Road Management Office, 8 sets directive telephone and 20 sets administrative telephone is assumed to be installed.

(k) One weather station which includes data for temperature, wind speed, precipitation and visibility is assumed to be approx. 100 byte. Therefore communication traffic will be approximately 800 bps per station.

(l) Under one Road Management Office, approximately 24 sets VMS and 18 sets of CSS will be estimated to install. Traffic for one VMS and CSS will be approximately 100Kbyte and 10Kbyte respectively.

(m) As for dissemination of Traffic Information/Control from Regional Main Center, it is assumed under the worst case, information will be disseminated to all Road Management Offices. In total, it is assumed that approximately 384Mbps will be required as maximum traffic of VMS.

1.4 Appropriate Transmission System for ITS

Basic concept is IP based network and G-Ethernet is to be applied due to the following reasons;

(1) Consistency with the basic policy of communication network for ITS

The G-Ethernet meets three requirements of the basic policy of communication network for ITS mentioned above.

(2) Connectivity with ITS related equipment components

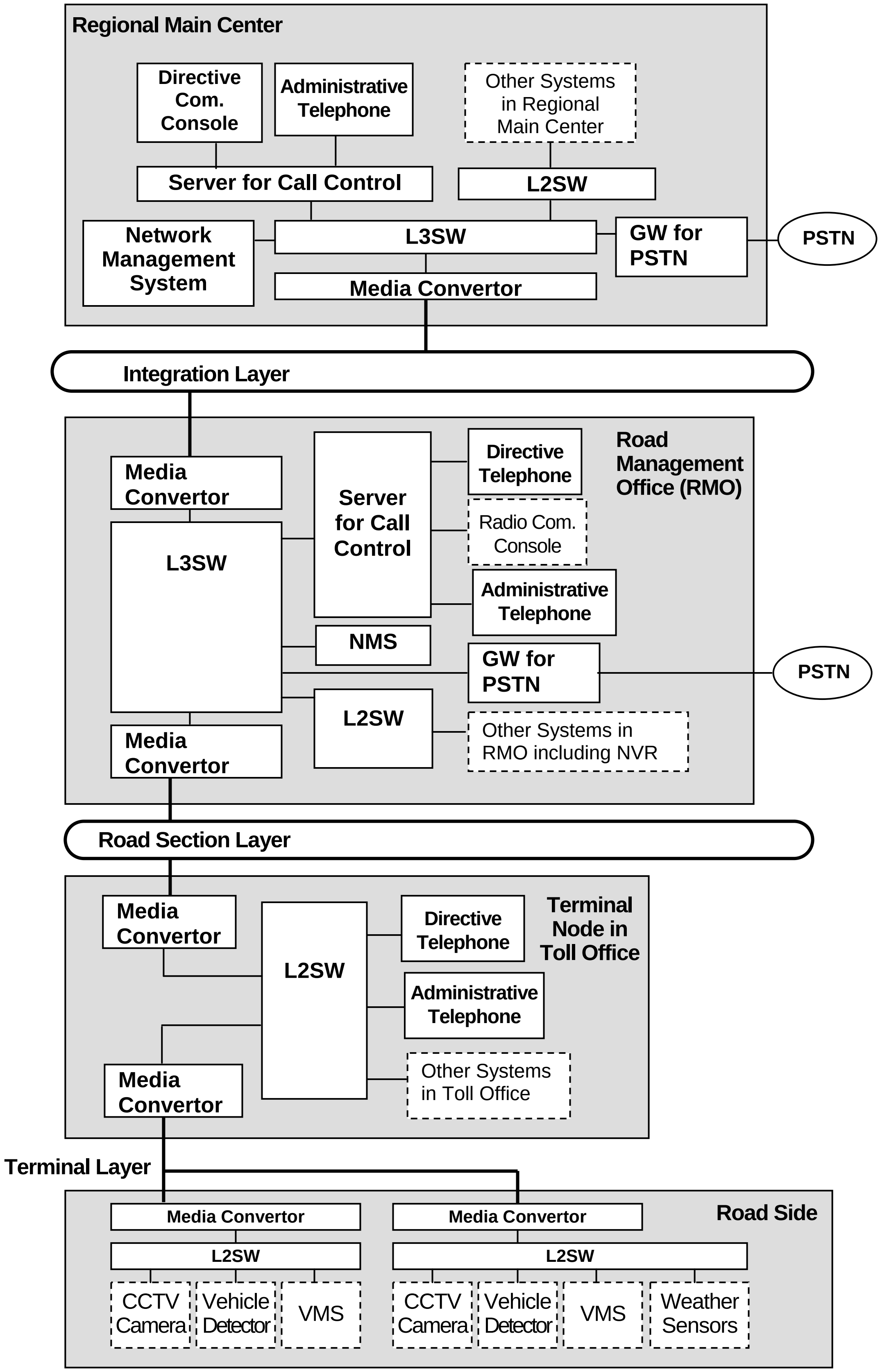
There are no equipment components or systems to be introduced under ITS related project, which is impossible to connect with G-Ethernet.

(3) Availability

Availability of equipment component or spare parts of G-Ethernet related products is widely available currently and this condition will not change in near future. Therefore, such kind of equipment component is expected to utilize longer period.

The Equipment Component of Communication Network for ITS is shown in the Figure 6.1 below;

Figure 1.1 Equipment Component of Communication Network



Source: ITS Integration Project (SAPI) Study Team

1.5 Basic Communication Equipment Component

The basic communication Equipment component for ITS is shown below;

(1) Layer 3 Switch (L3SW)

Layer 3 Switch (L3SW) is required for the connection between different LANs. In the ITS Integration Project, L3SW is applied for the connection between Northern Regional Main Center and Road Management Offices.

(2) Layer 2 Switch (L2SW)

Layer 2 Switch (L2SW) is required for the connection within LAN. In the ITS Integration Project, L2SW is applied for the network under L3SW such as connection between L3SW in Road management office and Terminal Node, L3SW in Road Management Office and equipment components in the same office, and connection between Terminal Node and Roadside Equipment components.

(3) Media Converter (M/C)

Media Converter (M/C) is required where optical/electrical conversion is needed.

(4) Server for Call Control

Server for call control is required to control voice communication. The directive communication should be connected without calling loss.

(5) Gateway for Public Switched Telephone Network (GW for PSTN)

Gateway for PSTN is required to connect voice communication using administrative telephone to Public Switched Telephone Network (PSTN) and vice versa.

(6) Directive Communication Console

Directive Communication Console is needed for disseminating directive from Regional Main Center to others. It is required in operating room for Traffic Information/Control in Regional Main Center.

(7) Directive Telephone

Directive telephone is required for Regional Main Center, Road Management Offices and Toll Offices. The detailed number is shown later.

(8) Administrative Telephone

Administrative Telephone is required for Regional Main Center, Road Management Offices and Toll Offices. The detailed number is shown later.

(9) Optical Fiber Cable

Optical Fiber Cable is required for connecting network equipment components.

(10) Network Management System (NMS)

Network Management System (NMS) is required for monitoring network operating conditions including fault or failure detection.

1.6 Applicable Protocol

As for the communication network for ITS, IP is recommended to apply as layer 3 for all transmitting data, moving image, and voice communication except for the communication between roadside equipment and data logger/controller. For layer 4, TCP is recommended to apply for data and moving image transmission, and UDP is recommended to apply for voice communication.

1.7 IP Version

IP version 6 is recommended to apply for National Layer and Integration Layer Network. At the project implementation time, most of the Roadside equipment is stall not fully compatible to IPv6. Therefore IPv4/IPv6 Translator is required in the network.

1.8 Network Configuration Overview for ITS Integration Project

The communication traffic necessary for expressway ITS, such as moving image, data and voice, is planed to transmit through the fiber optic transmission system using optical fiber cable basically.

In the target road sections of the project, the section between Noi Bai and Mai Dich through Thang Long Bridge is planned to construct as expressway in future, however this section is ordinary road with open system without access control currently. This section is a part of ring configuration road which is composed of this section, Ring Road 3, Ha Noi – Bac Ninh Expressway Section, and Noi Bai – Bac Ninh Expressway Section. In this ring configuration road, the communication network called Integration Layer which connects Northern Regional Main Center and individual Road Management Offices will be installed, and in the view point to secure redundancy of the important communication network called integration layer, the network route is planned to install along the ring road in order to secure communication route redundancy. However, considering current condition and near future expressway construction plan, the following alternatives are appropriate for the section between Road Management Office of Noi Bai – Viet Tri and Road Management Office in Lang – Hoa Lac.

(1) Borrowing existing optical fiber cores for the mentioned section from telecommunications carrier

(2) Borrowing existing duct from telecommunications carrier and installing optical fiber cable under ITS Integration Project

(3) Utilization of communication services such as leased line, VPN or others provided by the telecommunications carrier

Among the options mentioned above, the most suitable option should be selected based on the following point of view;

- Reasonable initial cost is recommended
- Low operation and maintenance cost is recommended

- Higher reliability is recommended
- Necessary transmission capacity is 1 Gbps considering the communication traffic for integration layer network shown above

In future, when expressway is constructed to this section, it is recommended to install necessary conduit and cables, and change over to the newly installed facilities.

The expressway construction project takes long period basically compared to the procurement of ITS equipment component, and there will be the case to make a communication plan for the expressway sections which includes partially uncompleted section. In such case, the fiber optic transmission system is recommended to apply for the expressway section to be completed, and for the section to be uncompleted, above options are recommended to apply. It is important to adopt the suitable combination of the communication systems taking actual expressway construction progress into consideration.

2. Voice Communication

2.1 General

The communication network of ITS will be developed on the basis of Internet Protocol, therefore interactive voice communication will be realized with Voice over IP with in the ITS network.

In the planned voice communication, two types are recommended to introduce. The one is directive and the other is administrative telephone.

The directive is used for the communication under event occurrence and so on. The directive is made from Regional Main Center to all Road Management Offices and Toll Offices simultaneously or used from Regional Main Center to concerned Road Management Offices and Toll Offices simultaneously. The directive communication should be connected 100% whenever required without calling loss.

In Regional Main Center, the Directive Communication Console is required to install, and directive telephone set is required to install for all Road Management Offices and Toll Offices. The detailed number of telephone set is to be mention later.

As for the administrative telephone, it is used for normal expressway operation and maintenance business activities, and it is realized to connect among Regional Main Center, Road Management Offices, Toll Offices, and Public Switched Telephone Network (PSTN). For the administrative telephone, the calling loss is allowed. The detailed number of administrative telephone is also to be shown later.

The call control is made with Server for Call Control and connection with PSTN is realized with Gateway for PSTN.

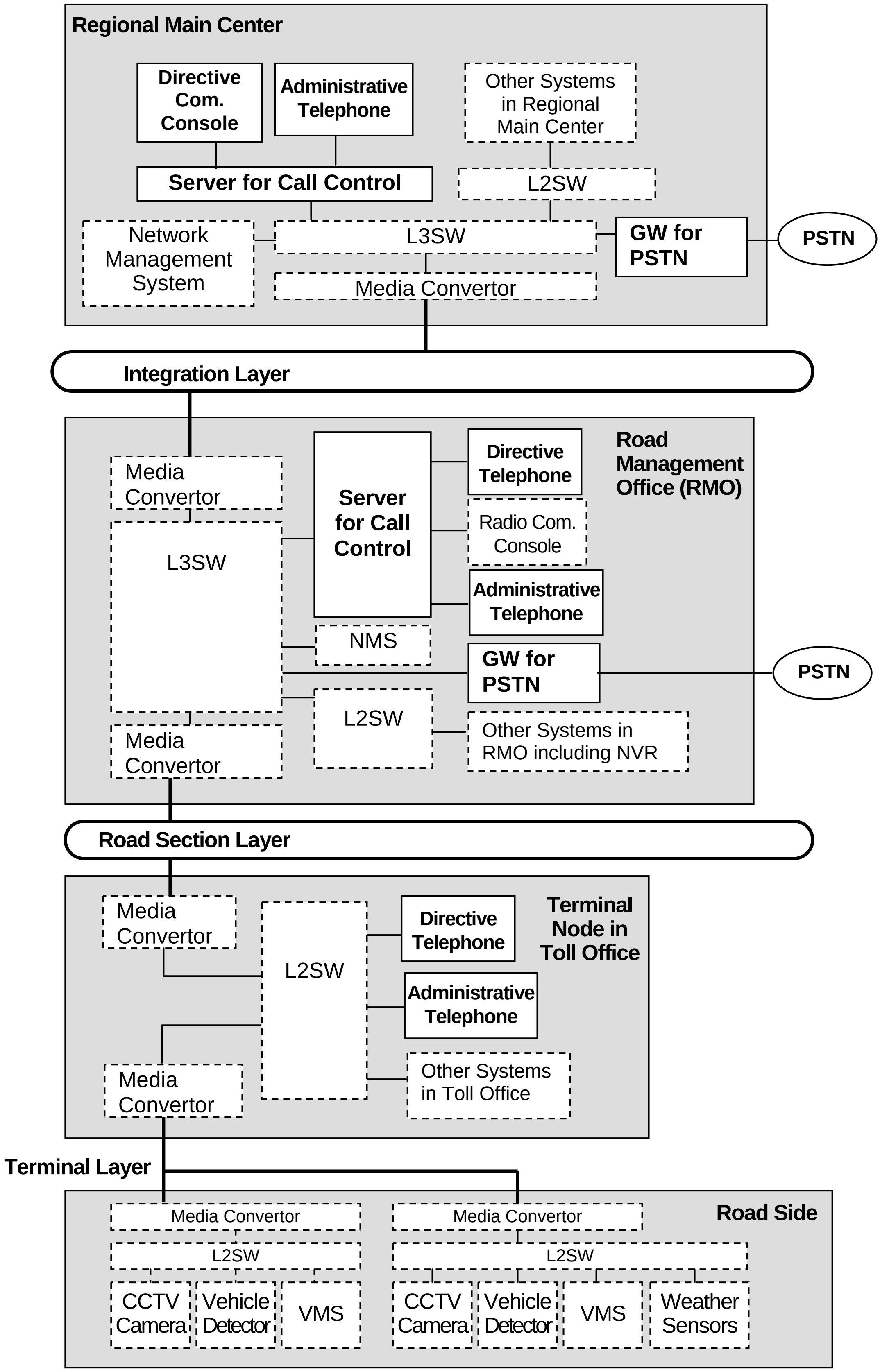
The Server for Call Control should equip the function of registrar, proxy server and redirect server. The Server is also required to control Gateway for PSTN.

The Gateway for PSTN is required to convert voice packet which can be transmit in IP network, into voice traffic in PSTN which is encoded into digital signal, and vice versa. In addition, it is also required to convert call control signal in PSTN into call control signal in IP network, and vice versa, and it is required to interconnecting between administrative telephone in ITS network and telephone set in PSTN.

The Equipment Component of Voice Communication is shown below;

2.2 Equipment Component of Voice Communication

Figure 2.1 Equipment Component of Voice Communication



Source: ITS Integration Project (SAPI) Study Team

2.3 Numbering Plan

(1) General

There are two different numbering plan for Directive Telephone and Administrative Telephone shown as follows. The code allocation such as office code is required to determine referring the following samples.

As for the connection of the Road management Offices which are implemented prior to effectiveness of this Design Standard, the connection may be made through the public switched telephone network for temporary basis. If such implementation will be made for the specific road management office, it is recommended to connect according to the code to be determined when the timing of equipment component renewal of such road management office.

(2) Numbering Plan for Directive Telephone

Directive Telephone number is composed of the following five (5) digits. The Directive Telephone is effective only One Regional Main Center Area. Therefore there is no number to distinguish another Regional Main Center.

L AB CD

Where

L: Directive Class (The specific number is shown as sample.)

8: Downstream directive from Directive Communication Console in Regional Main Center to individualized Directive Telephone

6: Downstream directive from Directive Communication Console in the Regional Main Center to ALL Directive Telephones

3: Upstream directive from Directive Telephone in the Road Management Office to Directive Communication Console in Regional Main Center

AB: Office Code for Regional Main Center and Road Management Offices (The specific number is shown as sample.)

Specific number is allocated for Regional Main Center and individual Road Management Offices. The number is recommended to utilize commonly with Administrative Telephone number. The sample is shown below;

20: Ha Noi Regional Main Center

21 – 39: Road Management Offices under management of Ha Noi Regional Main Center

40: Da Nang Regional Main Center

41 – 69: Road Management Offices under management of Da Nang Regional Main Center

60: Ho Chi Ming Regional Main Center

61 – 79: Road Management Offices under management of HCM Regional Main Center

C: Interchange Number

The Interchange number is required to allocate for the expressway section managed by one (1) Road Management Office. The number is recommended to allocate from North or East to South or West in ascending order.

D: Duty category Number (The specific number is shown as sample.)

1: Road Management Office (Administrative Office)

2: Operator in charge who monitor the traffic condition

3: Traffic Management (manager of patrolling staff and vehicles)

4: Toll Office

5: Information Desk (it will be required when Service Area is developed.)

6-9: spare number

(3) Numbering Plan for Administrative Telephone

Administrative Telephone number is composed of the following seven (7) digits.

A B CD EFG

Where

A: Calling Category (The specific number is shown as sample.)

1: Reserved as special number

8: Outgoing call number for Other Regional Main Center Management Region

9: Reserved as maintenance use

0: Outgoing call connecting to PSTN

B: Number for Regional Main Center Management Region (The specific number is shown as sample.)

2: Ha Noi Region

4: Da Nang Region

6: Ho Chi Ming Region

CD: Office Code for Regional Main Center and Road Management Offices (The specific number is shown as sample.)

Specific number is allocated for Regional Main Center and individual Road Management Offices. Code C is able to allocate from 2 to 7 except for 0, 1, 8, 9, and Code D is able to allocate from 0 to 9 respectively. The applicable number for code C and D is shown in the following tale. One Road Management Office will manage approx. 80 km expressways section, and in future, the number of Road Management Offices will be estimated approx. 60. Therefore the code CD from 20 to 79 is considered to be enough to cover future developed conditions. The allocatable number as CD code is shown in the following table.

Figure 2.2 Number Allocation Plan for Administrative Telephone

C╲D	0	1	2	3	4	5	6	7	8	9
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										

Allocatable Area of CD Code

The sample CD code is shown below;
20: Ha Noi Regional Main Center
21–39: Road Management Offices under management of Ha Noi RMC
40: Da Nang Regional Main Center
41-69: Road Management Offices under management of Da Nang RMC
60: Ho Chi Ming Regional Main Center
61–79: Road Management Offices under management of HCM RMC

E: Interchange Number
The Interchange number is allocated for the expressway section managed by one (1) Road Management Office. The number is recommended to allocate from North or East to South or West in ascending order.

FG: Extension Number
Extension number required for One Road Management Office including its related Toll Office is allocated.

(4) Connection Method of Administrative Telephone

The administrative telephone should be capable to connect in the following method;

(i) Call within One Road Management Office

It should be capable to connect by sending the number of EFG.

(ii) Call between Regional Main Center and Road Mnagement Office or between Road Management Offices under One Regional Main Center Management Region

It should be capable to connect by sending the number of CDEFG.

(iii) Call from a Regional Main Center to another Regional Main Center or between Road Management Offices under different Regional Main Centers

It should be capable to connect by sending the number of ABCDEFG.

(iv) Call to PSTN

It should be capable to connect by sending the number of 0+(the number of PSTN).

2.4 Directive Telephone Set

The number of telephone set and installation location of Directive Telephone is shown in the following table.

Table 2.1 Location/Quantity of Directive Telephones

Location	Q'ty	Remarks
Regional Main Center		
General Director Room	1	
Others (Police Officer Room, Meeting Room, Resting Room, Mess Hall, etc)	6	
Road Management Office		
Administrative Office	1	
Operator in charge who monitor the traffic condition	1	
Manager desk for patrolling staff and vehicles	1	
Traffic Police Office	1	
Toll Office		
Manager	1	
Service Area		Assumption of future development condition
Information Desk	2	To be installed one set for each direction.

The Directive Telephone set shall be capable to notify it to the receiver as directive by buzzer or flashing light.

It is also required to equip the function to transmit the acknowledgement to the sender of directive.

2.5 Administrative Telephone Set

The number of telephone set and installation location of Administrative Telephone is shown in the following table.

Table 2.2 Location/Quantity of Administrative Telephone

Location	Q'ty	Remarks
Regional Main Center		
General Director Room	2	
Traffic Control Operating Room	3	
Server Room	1	
Police Room	1	
Meeting Room	1	
Machine Room	1	
Visitor Room	1	
Depositary	1	
Resting Room	2	
Mess Hall	1	
Others		
Road Management Office		
Administrative Office	1+N	N: Except for the manager, one set per two staff is to be planned.
Traffic Condition Monitoring Room	2	
Manager desk for patrolling staff and vehicles	1	
Traffic Police Office	1	
Ambulance Office	1	
Rest Area in Road Management Office	2	
Toll Office		
Administrative Office	1+N	N: Except for the manager, one set per two staff is to be planned.
Rest Area	2	
Service Area		Assumption of future development condition
Administrative Office	2	To be installed one set for each direction.
Information Desk	2	To be installed one set for each direction
Rest Area for staff	2	To be installed one set for each direction

3. Mobile Radio Communication

3.1 Outline of Mobile Radio Communication System

(i) Mobile Radio communication system is absolutely required not only for normal operation and maintenance purpose such as patrol, but also for communication method between the site and road management office under emergency cases such as accident or disaster.

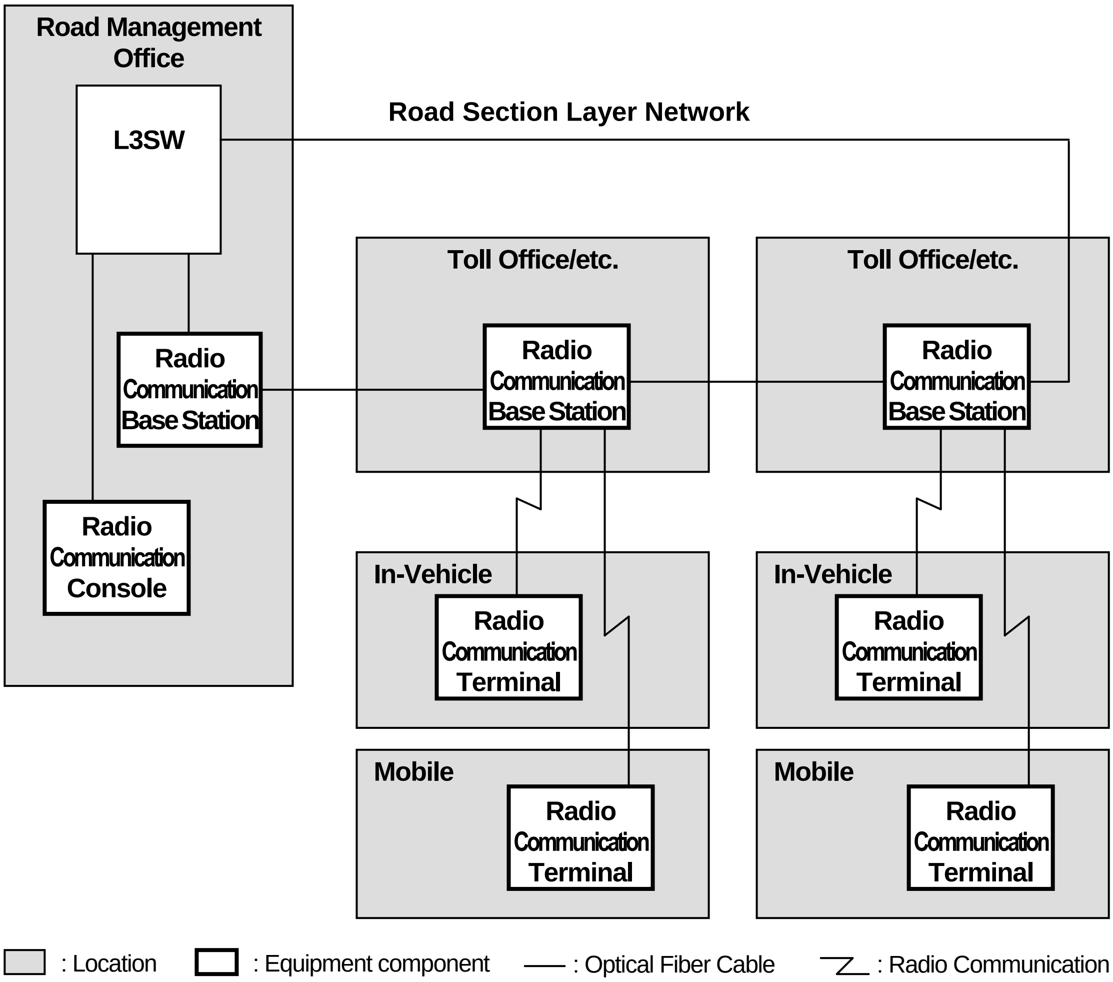
(ii) Mobile Radio communication system is able to actualize interactive voice communication between console in road management office and terminal equipment component holders, and among terminal equipment component holders.

(iii) Mobile radio communication system means the facilities and equipment components from land mobile station such as terminal equipment components to the console in road management office through the base station.

(iv) The interference should be considered to minimize as much as possible.

3.2 Equipment Component of Mobile Radio Communication

Figure 3.1 Equipment Component of Mobile Radio Communication



Source: ITS Integration Project (SAPI) Study Team

3.3 System Design Conditions

(1) Coverage Area of Mobile Communication

The coverage area of mobile radio communication for expressway operation and maintenance shall be capable to communicate on the expressway and related facility areas along the expressway such as outside area within the premises of road management office, interchanges, toll areas, rest areas, parking areas and other premises along the expressway. However it should not be caused interference due to unnecessarily expanded coverage areas.

(2) Circuit Configuration

(i) Between base station and mobile terminal under one road management office area, circuit frequency is required two (2) waves.

(ii) The circuit frequency for mobile terminal is needed three (3) waves for communication between console in road management office and terminal, and for receiving directives.

(iii) The base station is able to be controlled from the console of the road management office. However if the coverage area of several consecutive base stations are limited due to several short tunnels, those base stations may be controlled as a group.

(3) Location of Base Station

Base station location within the own road management section is selected in the following priority order. It is preferable to be determined by the characteristics of the radio wave propagation theoretically.

(i) Within the premises of road management office

(ii) Within the premises of toll office

(iii) Within the premises of inter change or toll gate area

(iv) Within the premises of rest area, service area, or parking areas

(v) Other necessary locations

If the base station is required to be outside of the premises of road management office, the site ownership should be clarified or agreement related to land lease should be made in writing, prior to commencement of installation work at site.

(4) Assignment of mobile terminal equipment component

In-vehicle mobile terminal equipment components are to be utilized for expressway patrol vehicles, maintenance vehicles, and vehicles for installation work on the expressway.

The mobile terminals which are to be utilized not in-vehicle purpose, at least four (4) set are required for one road management office.

Necessary number of terminals should be surveyed and determined basically, however, in ITS integration Project, it is planned to deliver 10 sets per one road management office.

(5) Standby of the Radio Equipment Component

Since the transceiver of the base station is core component of the station and it is required to avoided long time operation down due to the component failure, standby transceiver shall be equipped.

(6) Leaky Coaxial Cable

Inside of the tunnel in which the minimum receiving power of the radio wave is not able to be obtained by antenna, leaky coaxial cable installation should be considered.

(7) Backup Electric Power Supply Facility

In order to keep the radio communication functions during commercial power failure, the backup electric power supply facility such as UPS, battery and engine generator shall be equipped for the base station equipment component. The backup power supply facility shall be covered the capacity of the necessary power of the radio communication system and the conditions are shown below;

- In case the base station equipped engine generator: ten (10) minutes
- In case the base station not equipped engine generator: six (6) hours

The engine generator shall be kept the good conditions and amount of fuel for six (6) hours continuous operation shall be stocked within the same premises.

(8) Functions related to Directive communication

Directive communication console located in the road management office which is required to control the base stations shall be equipped the following functions;

(i) Selection function of base station to transmit the directive

(ii) Displaying function (such as flashing light) of reception of directive

(iii) Directive buzzer (twice of approx. 1 sec buzzer)

3.4 Radio Communication System

(1) Radio Frequency Band

Frequency band for expressway mobile radio communication system is recommended to be VHF or UHF, and it is required to be licensed by Radio Frequency Directorate of Ministry of Information and Communication in Vietnam prior to the operation.

(2) Communication Method

Full duplex communication method is to be applied for the mobile radio communication system for the following reasons;

- Simultaneous transmission and reception is available
- No proficiency is required for terminal usage

For information sharing purpose, the voice communication made by mobile radio communication system is preferable to be heard by the operator at console and other terminal holders within one road management office area as much as possible.

3.5 Speech Quality

(1) Consideration of Speech Quality

The speech quality design and threshold should be considered as follows;

(i) The speech quality on the expressway should be within 25dB of S/N (Signal-to-Noise) ratio for normal modulation. It means that “the degree of clear voice can be head fully with some degree of noise”.

(ii) During design stage, in order to secure the above S/N ratio, speech quality should be checked by the site survey taking necessary margins into consideration. For example, an obstacle margin of sound abatement shield along the expressway should be considered.

(iii) The terminology of “normal modulation” in item (i) above means ±1.75KHz frequency modulation due to 1 KHz input signal.

(iv) The specified S/N ratio in item (i) is the threshold for the measurement result specified in the next item (v) and taking necessary margins mentioned above item (ii) into account.

(2) Measurement method of input signal strength of receiver and noise intensity

Input signal strength of receiver and noise intensity are measured with the following procedure;

(i) Measurement of input signal strength of the receiver should be made under the condition of transmitting from base station and receiving of mobile terminal.

(ii) Whole measurement result of input signal strength of receiver is required to record along each 100m interval of expressway, and data analysis should be made for lower 25% measured result. In addition, elevated section of expressway such as inter change, road management office area, toll office, rest area, and parking areas is also required to measure.

(iii) Measurement of noise intensity should be made for 10 minutes duration in accordance with the CISPR standard for the above 25% lower signal strength points, and at the same time, number of passing vehicles also should be counted. The noise intensity measurement for base station should be made under the similar conditions of actual antenna installation conditions such as height and location. As for noise intensity measurement for mobile terminal is also made under the similar conditions of actual operation such as utilization of vehicle mounted antenna and parking shoulder part of the expressway.

If there is very few vehicle passage observed during measurement, it is able to refer to the measurement result of in-service expressway section's measurement record.

(iv) Analysis of measurement result of noise intensity is made based on the recorded data, and required to obtain to calculate 50%-value (medium value) and 95%-value. As for 95% -value of noise intensity is obtained based on the condition that the 95% measured data is equal to or less than other measured data of one specific location.

(v) The S/N ratio is obtained for the location where the measured result of input signal strength of receiver is rather low mentioned above item (ii), and the 95%-value of noise intensity explained above item (iv) at the same location is utilized.

3.6 Radio Wave Propagation

After completion of installation of the radio communication equipment component, radio wave propagation from antenna and leaky coaxial cable shall be confirmed with the conditions specified coverage area in item 7.3 2) (1) under the quality specified in the item 7.3 4) through the measuring method specified in the item 7.3 4) (2).

3.7 Antenna Supporting Pole

Antenna supporting pole should be designed taking following conditions into account;

(i) Necessary antenna height is able to set

(ii) Platform for maintenance work of the antenna is necessary to equip at the place where maintenance staff is able to reach the antenna easily

(iii) Enough strength should be kept against the prospective load to the pole

(iv) Counter measures shall be taken to the various environment conditions of Vietnam, such as lightning strike and surge, flood, and storm

4. Communication System

4.1 General

The communication network for ITS Integration Project is planned to be developed on the basis of Ethernet as mentioned above. The equipment component for communication network is planned to consist of L2SW, L3SW, Media Converter and Optical Fiber Cable mainly. In addition, Network Management System (NMS) is planned to introduce to monitor the network.

The communication traffic for ITS is composed of moving image, data and voice. The quality of service for the traffic is required to secure based on the timing required under the expressway operation conditions or international standard such as ITU-T Recommendation Y1541.

4.2 Planned Network Equipment Component

The Communication Network within one Road Management Office is planned to develop as one Local Area Network. The component to be included in one LAN is all network related equipment components which will be installed in Road Management Office, Terminal Node, Toll Office, and network equipment connected with roadside equipment components. It means that one road section layer network under one road management office and terminal layer network under that road section layer network is planned to be developed as one LAN.

In addition, the network between Regional Main Center and Road Management Office and the network within Regional Main Center is planned to be developed as one LAN.

Within individual LANs, all communication traffic is planned to switch with L2SW.

In between different LANs, all communication traffic is planned to switch or route with L3SW as routing with referring to IP is required. L3SW is planned to install in Regional Main Center and each Road Management Offices.

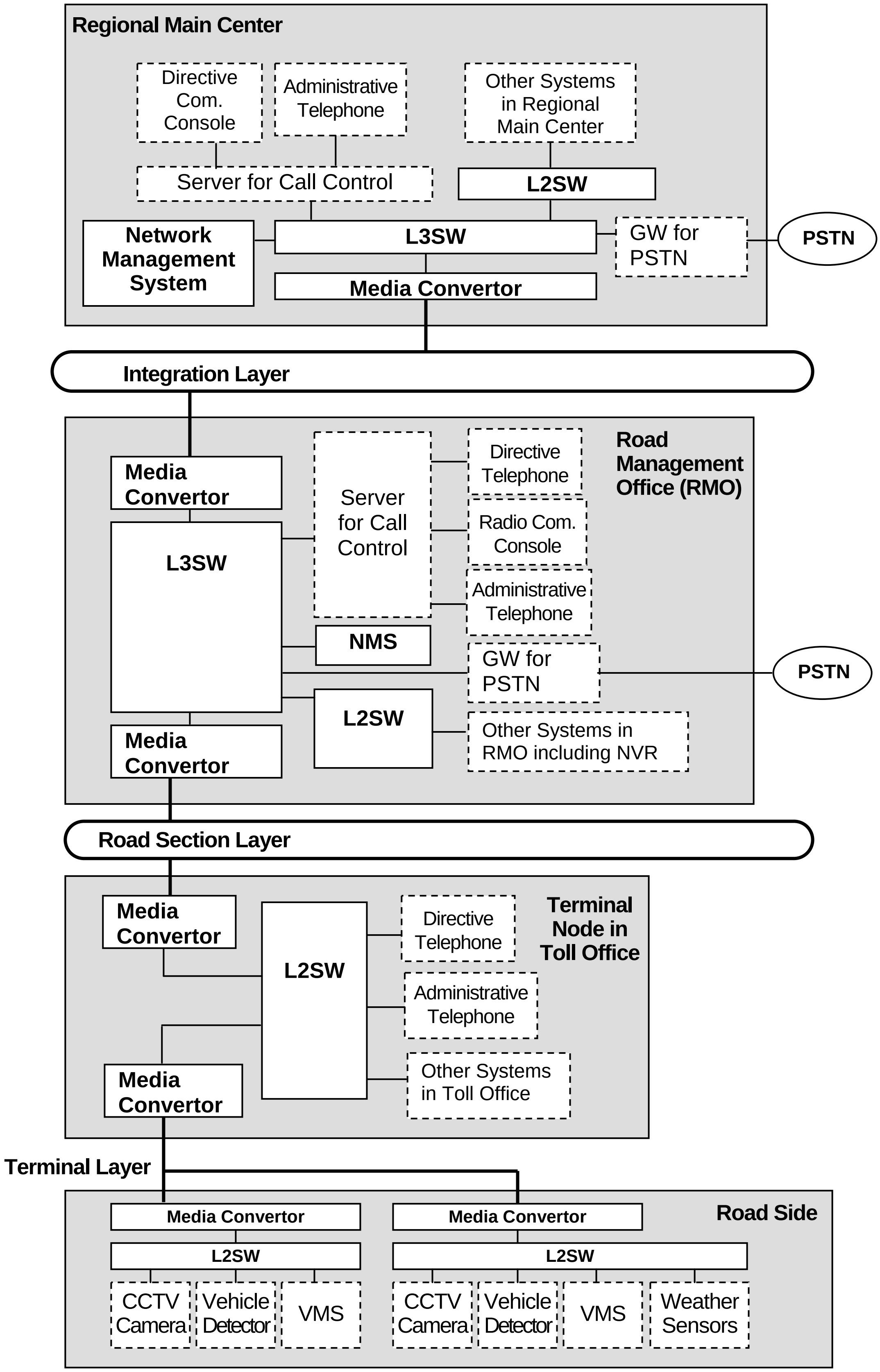
The transmission distance required for ITS related equipment is located relatively far, and appropriate transmission system is fiber optic transmission system which is composed of optical fiber cable and media comverter.

In addition, in order to monitor the network within one LAN, Network Management System (NMS) is planned to install. The detail on NMS is described later.

The equipment component of communication network is shown below.

4.3 Equipment Component of Communication System

Figure 4.1 Equipment Component of Communication System



Source: ITS Integration Project (SAPI) Study Team

4.4 Transmission Distance

The transmission distance of the optical fiber cable is limited based on the receivable optical signalling level, and it is different from the optical fiber characteristics, however in the design of ITS Integration Project, the maximum transmission distance is planed 40 km. If the transmission distance exceeds 40 km, repeater is planned to install.

4.5 Number of Optical Fiber Cores

(1) Integration Layer Network

Although the communication traffic from one road management office to the regional main center is small compared to its transmittable capacity of one optical fiber cable as it is shown in the communication traffic mentioned above, 4 cores are recommended to connect between the Regional Main Center and the Road Management Office taking necessary construction years of the expressway into consideration. The breakdown of 4 cores is active 2 cores for upstream and downstream respectively, and another 2 cores for redundancy of the active cores. In addition to the above 4 cores, additional 2 cores are reserved for future necessity. Therefore in total 6 cores are recommended to connect between the Regional Main Center and the Road Management Office.

(2) Road Section Layer Network

The 4 cores are planned to connect between road management office and terminal node basically. The breakdown of 4 cores is active 2 cores for upstream and downstream respectively, and another 2 cores for redundancy of the active cores.

In most cases, as ring configuration is applied with one optical fiber cable, it will be required to utilize 8 cores for operation and redundancy, and 4 cores for future reservation.

Therefore in total 12 cores are recommended to allocate between Road Management Office and Terminal Nodes.

(3) Terminal Layer Network

In Terminal Layer, there are mainly two methods to connect the equipment to the Terminal Node as follows;

1) Applying one wave into one optical fiber core and connecting two fiber cores between Terminal Node and roadside equipment component
2) Applying more than two waves into one optical fiber core and commonly use fiber core between Terminal Node and roadside equipment components

If we select alternative 2), we need to install multiplexer between one end of optical fiber core and Terminal Node, and between another end of fiber core and roadside equipment. If additional roadside equipment will be installed in future, the additional multiplexer is required to procure only the product of the same company of the existing one, as different manufacturer’s product does not compatible. Therefore we recommend the above alternative 1) connection method.

The expressway elongation to be covered by one Terminal Node is approximately 15 km. If there is an interchange within this 15km, the roadside equipment to be installed within the 15km will be CCTV Camera (PTZ), Fixed CCTV Camera for Event Detection, and VMSs. The number of equipment components to be connected to one Terminal Node will be 16 sets except for the special type of interchange. Therefore the number of optical fiber cores for terminal layer is 48 cores (16x2+spare cores) taking spare cores into consideration.

However the case of special type interchange, necessary number of optical fiber cores should be considered individually. In addition, if there is no interchange in one Terminal Node covering area, the number of roadside equipment components will be minimum 8 CCTV Camera (PTZ) only, and in such case, minimum 24 fiber cores (8x2+spare core) are required.

4.6 Number of Optical Fiber Cables

The operation and maintenance of the communication system is recommended to outsource from the road operator to communication service company, and the possibility to be different communication service company for integration layer network and road section layer network is also need to consider.

Based on the mentioned operation and maintenance conditions, the optical fiber core for integration layer and road section layer should not combined into one cable and should be separated. The necessary number of cables is planned on the basis of above condition.

The cables to be installed in the individual expressway section and number of fiber cores are shown in the table below;

The number of cores shown in the following table is rough target. During project implementation time, installation drawings should be approved taking type of interchange, number of roadside equipment to be installed, and future spare cores into consideration.

Table 4.1 Number of Optical Fiber Cables and its Number of Cores

Expressway Section	Number of Optical Fiber Cores for Integration Layer Cable	Number of Optical Fiber Cores for Road Section Layer and Terminal Layer	Number of Optical Fiber Cable for the specified expressway section
Lang – Hoa Lac	6	60(12+48)	2
Phap Van – Cau Gie – Ninh Binh	6	60(12+48)	2
RR3	36	60(12+48)	2
Ha Noi – Bac Ninh	36	60(12+48)	2
Noi Bai – Bac Ninh	36	60(12+48)	2
Noi Bai – Viet Tri	(24)	60(12+48)	(2)
Ha Noi – Thai Nguyen	6	To be installed under NH3 Project	2
Ha Noi – Hai Phong	(12) + (6)**	(60) for each section	(2)
Bac Ninh – Ha Long	(6)	60(12+48)	(2)
Bac Ninh – Lang Son	(6)	60(12+48)	(2)
Viet Tri – Lao Cai	(18)+(12)+(6)***	(60) for each section	(2)

Note: The figure in parenthesis is out of scope of ITS Integration Project
* The road management office is supposed to be established two along Ha Noi – Hai Phong
** The road management office is supposed to be established three along Viet Tri – Lao Cai
**** The specified number of fiber core should be checked for special type interchange or the expressway section where no interchange is located within one Terminal Node coverage area

5. Network Management System

5.1 Outline of NMS

Operation condition of the communication network is to be monitored by introducing Network Management System (NMS). The outline of NMS is summarized in the following table.

Table 5.1 Outline of NMS

Network Layer	Location of NMS Display	Supervision Framework
Integration Layer	Communication Equipment Components Room in Regional Main Center	Round the Clock
Road section and Terminal Layer	Monitoring Room in Road Management Office	Monitoring Alert

The Network Management System to be located in a Road Management Office shall be capable to monitor Road Section and Terminal Layer Network under the Road Management Office. The NMS to be located in a Regional Main Center shall be capable to monitor Integration Layer Network under the Regional Main Center.

All network equipment components shall be capable to be monitored by at least one of the above Network Management Systems.

5.2 Functions of NMS

NMS is required to equip the following functions;

(1) Monitoring Alert and Notification Function

Function for detection of origination and recovery of various types of alert and monitoring L3SW, L2SW, transmission equipment/route, roadside equipment is required. Recording function of alert log is necessary, and displaying/printing out function is also required whenever required. Notification function to the operating staff by buzzer or flashing light is also required.

(2) Resource Management Function

Function of monitoring operation condition of L3SW, L2SW, transmission equipment/route, roadside equipment which is connected to the network are required. When system configuration is modified, the function of adding system, registration and modification of the equipment component should be also equipped. During replacement of the equipment component, it should be distinguished “Operating Condition” and “under installation”.

(3) Performance Monitoring Function

The function to monitor the communication traffic on the network is required.

(4) Testing Function

Testing function of Communication line and connecting conditions of communication equipment should be equipped.

(5) Switching Function to the Redundant Equipment Component

The switching function to the redundant equipment component should be equipped automatically basically when failure is detected, and it should be capable to distinguish operation conditions of equipment components such as “Normal” or “Trouble” for both in operation and redundant equipment components. If it is not switched over to the redundant equipment component, NMS should be equipped to switch it over manually on mandatory basis.

5.3 Monitoring Target of NMS

Monitoring target of NMS is shown below;

(1) Transmission equipment components

(2) Switches

(3) Communication cables

Necessary monitoring items are required to select to detect fault location and faulty conditions.

5.4 Installation Location of NMS

Alert terminal of the NMS is recommended to install in the traffic control room in the Regional Main Center so as to share such information with traffic control operator on duty.

COMMUNICATION DUCTS

TABLE OF CONTENTS

1. Communication Ducts Design

1.1 General

Communication Ducts design should be performed by selecting a rational and economical route as well as method of construction in consideration of various related facilities. Furthermore, “Communication Ducts” is the collective term for communication duct cable rack, cable chamber. etc.

- As duct design is mutually related to earthworks, pavement works, viaduct section works, tunnel section works, etc., its designing should be performed with sufficient understanding of such related regulations and this document.
- Communication ducts means the duct used for communication cables.

1) Installation Location of Ducts

Basically the ducts should be laid underground in earthwork area and should be supported by superstructure at the bridge.

In earthwork area, using the median is better than using the shoulder for easy construction, maintenance and economical considerations. So in case the median is wider than 2.0 m (possible to install chamber), the ducts should be laid in the median.
For other cases in earthwork area, they should be laid in the shoulder.

In case of bridge, the ducts should be set on the outer side of the bridge not in median for easy construction and maintenance. However, in case of Ha Noi Ring Road 3, the ducts must be set in the median due to structural difficulty for setting on the outer side and with regard for aesthetics.

1) Number of Ducts

The required number of ducts should be considered on the basis of one cable for one duct. The number of ducts is calculated that the number of proposed cables plus spare duct(s) for the cables to be installed in future and empty duct which is used only for emergency cable installation for damaged cable replacement. As for the spare duct(s), it is necessary to consider cable for national layer between regional main centers.

In addition, the duct for electric power supply cable is needed to consider. It should be 2 ducts in addition to the communication ducts.

Number of cables to be installed and proposed number of ducts in RR3, Ha Noi – Bac Ninh, and Noi Bai – Bac Ninh is shown in the following table.

Table 1.1 Proposed Number of Ducts and its Calculation Basis for RR3, Ha Noi – Bac Ninh and Noi Bai – Bac Ninh Expressway Section

Layer/Expressway Section	Number of Cable to be installed	Proposed Number of Ducts
Cable for Integration Layer	1	1
Cable for Road Section Layer including Terminal Layer	1	1
Spare ducts for future cable installation (Expressway Extension beyond Hoa Lac, Ha Long, and Ninh Binh including cable for National Layer)	3	3
Empty duct for emergency cable replacement	-	1
Electric Power Supply Cable	1 or 2	2
Total	6 or 7	8

Source: ITS Standards & Operation Plan Study Team

Number of cables to be installed and proposed number of ducts in Lang – Hoa Lac and Noi Bai – Viet Tri is shown in the following table.

Table 1.2 Proposed Number of Ducts and its Calculation Basis for Lang – Hoa Lac, Phap Van – Ninh Binh Expressway Section

Layer/Expressway Section	Number of Cable to be installed	Proposed Number of Ducts
Cable for Integration Layer	1	1
Cable for Road Section Layer including Terminal Layer	1	1
Spare ducts for future cable installation (Expressway Extension beyond Hoa Lac, Ha Long, and Ninh Binh including cable for National Layer)	3*	3*
Empty duct for emergency cable replacement	-	1
Electric Power Supply Cable	1 or 2	2
Total	6 or 7	8

Note: The expansion of Expressway which will be managed under Road Management Office under future project is assumed 3 offices in individual expressway route under the coverage of Northern Regional Main Center.

Source: ITS Standards & Operation Plan Study Team

2) Diameter of Duct

The maximum number of fiber cores required for this project will be 60 cores for Road Section and Terminal Layer Network. However considering future necessity, it should be considered that the cables with higher number of cores should be possible to install. Therefore it is recommended to consider 2 to 3 times of necessary number of cores. In general, available number of fiber cores depends on the manufacturer's cable design, however, widely available number of cores are 48, 72, 96, 144, etc.

The outer diameter of optical fiber cable with 144 cores is considered as 2 to 3 times of necessary number of fiber cores. The outer diameter of the cable with 144 cores for installing in duct is approximately 19mm. The inner diameter of the duct is needed to determine at least 1.7 times of outer diameter of cables. On the basis of this requirement, the inner diameter of duct should be 19 x 1.7 = 32.3 mm, therefore the duct of D40mm with 36 mm inner diameter is recommended to utilize for ITS Integration project

In general, diameter of ducts shall be considered and determined as follows;

3) General Provisions related to Communication Ducts Design

(1) Number of Cables in a Duct

- Communication main cablr (optical fiber cable) shall be 1 cable for each duct
- Cables other than above shall be maximum 3 per 1 duct
- Control cables less than 60V and the cables which may affect the signal of the control cable shall not be installed together within same duct

(2) Number of Duct

When cables are to be installed into duct, cable jacket might be damaged due to friction heat, or cable might be damaged due to excessive pulling force. In order to avoid such cases, and taking necessary number of cables to be installed into account, required number of ducts should be considered.

The number of duct is composed of necessary number and spare number of ducts. The reference is made to the following table.

Table 1.3 Number of Ducts

Number	Breakdown	Criterion
Required	Initial stage	Initial number of ducts estimated/calculated based on the required number of cables to be installed..
	Future stage	For sections uneconomical to construct ducts in future, such required number to be estimated and included in the required number of duct.
Reserved for Emergency	Reserve	One duct is to be required for cable replacement for emergency case

(3) Necessary Diameter of Duct

Necessary diameter of a duct when cables are installed should be obtained by the following method

(a) One cable per duct

$D \geqq d+15$ (In this case $d \geqq 30$)
$D \geqq 1.7d$ (In this case $d < 30$)

Note 1: D is inner diameter of duct, d is outside diameter of cable

(b) Laying 2 cables within 1 duct

$D \geqq 1.5(d_1 + d_2)$

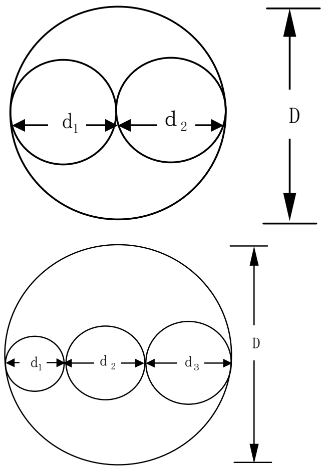
Note: D is inner diameter of duct, d_1, d_2 are outside diameters of cables.

(c) Laying 3 cables within 1 duct
Select inner diameter 2.85 times that of maximum diameter of cable to be inserted and make its numerical value 2.85 times as much as possible.

In case $d_3 \geqq d_2 \geqq d_1$
$D > 2.85 \times d_3$

Note: D is inner diameter of duct, d_1, d_2 and d_3 are outside diameter of cables.

Diameter of cable and duct



(4) Linearity of Duct

Communication duct is recommended to install linearly as much as possible. When it is required to install curve section, radius of the duct run should be as large as possible. If the curved section is required to apply, it shall be minimum 2.5 m in a two cable chambers.

4) Cable Chamber Span

The Cable Chamber which is required for cable installation, jointing, and cable branch, is required to be located cable branch point such as interchange. In normal expressway section, at least one (1) cable chamber should be installed for maximum 333m span taking metal cable installation case into consideration.

1.2 Plan Arrangement

The planning of each project is discussed below.

(1) Ring Road 3

Ring Road 3 is viaduct in all target areas, so the ducts should be supported by superstructure. As mentioned above, they will be set in the median.

From the starting point of Thanh Tri Bridge (the ending point of Ring Road 3) to KM 1 + 120, the ducts should be set in the median sequentially from Ring Road 3.

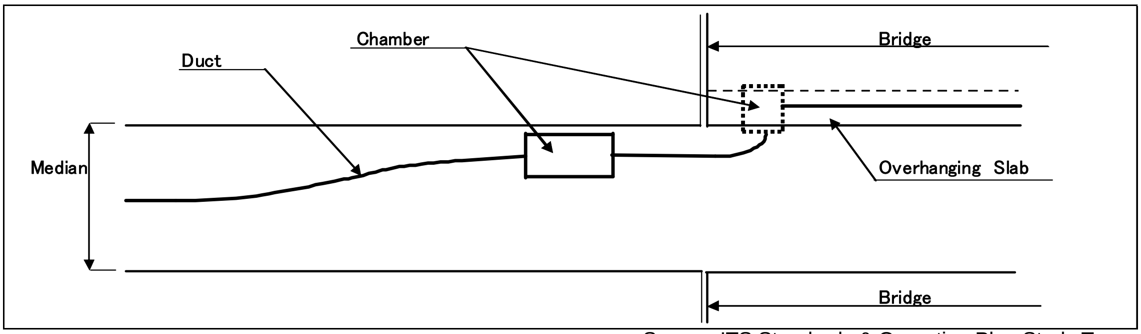
At the abutment (KM 1+120), the ducts will be shifted to the north side shoulder. From this point the ducts should be set in the shoulder in the earthwork area and be set on the outer side of bridges.

(2) Lang – Hoa Lac

The width of median is 20.0 m, so the ducts should be laid in the underground area of the median in the earthwork area.

Before the bridge, the ducts will be shifted to shoulder side smoothly and be set on the outer side of the bridge as shown in Figure 1.1.

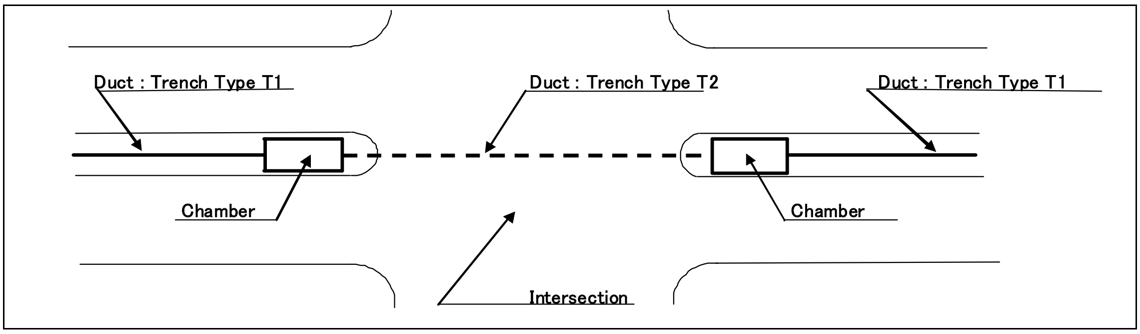
Figure 1.1 Lang-Hoa Lac Duct Arrangement



Source: ITS Standards & Operation Plan Study Team

At the intersection, the ducts cross the intersection from median to the opposite side median changing the Type of duct as shown in Figure 1.2. Type of duct will be explained in section 1.3.

Figure 1.2 Duct Arrangement at the Intersection



Source: ITS Standards & Operation Plan Study Team

(3) Phap Van – Cau Gie

Ducts and Chambers were already designed by CADPRO.
Some equipment that must be added was designed in this project.
Hence ducts and new chambers also were designed in this project.

(4) Cau Gie – Ninh Binh

Ducts and Chambers were already designed by CADPRO.
Some equipment that must be added was designed in this project.

Hence ducts and new chambers also were designed in this project.

(5) Ha Noi – Bac Ninh

The width of median is 3.0 m, so the ducts should be laid underground in the median in earthwork area.

Before the bridge, the ducts will be shifted to the shoulder side and be set on the outer side of the bridge.

(6) Noi Bai – Bac Ninh

There is no median in this area, so the ducts should be laid underground on the shoulder in the earthwork area. When there is widening to south according to the plan in the future, the ducts will be set on the north side shoulder to avoid being any obstruction against to the widening working.

In the bridge, the ducts will be set on the northern outer side of the bridge

(7) Noi Bai – Viet Tri (for Reference)

The width of median is 1.5 m which is not sufficient for setting a chamber in it, so the ducts should be laid underground in the shoulder in the earthwork area.

North side shoulder will be used for setting ducts because of the connection to the Noi Bai-Bac Ninh project.

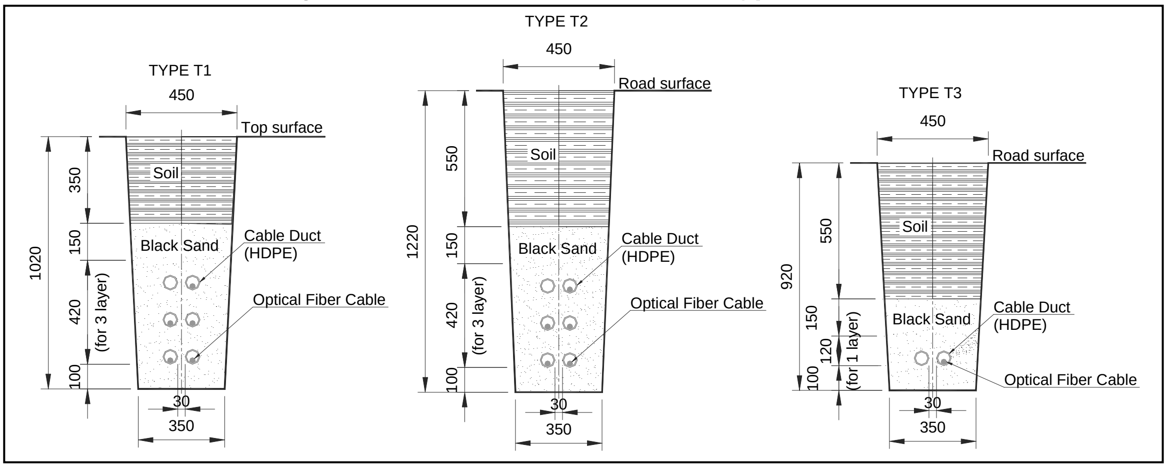
In the bridge, the ducts will be set on the northern outer side of the bridge.

1.3 Earthwork Sections

Ducts should be laid underground in the median or in the shoulder.

In case of using the median, trench type T1 is adopted if there is no effect by vehicle load. In case of using the shoulder, trench type T2 is adopted that does consider vehicle load. In the part connecting to CCTV or VMS, type T3 is adopted as shown in Figure 1.3.

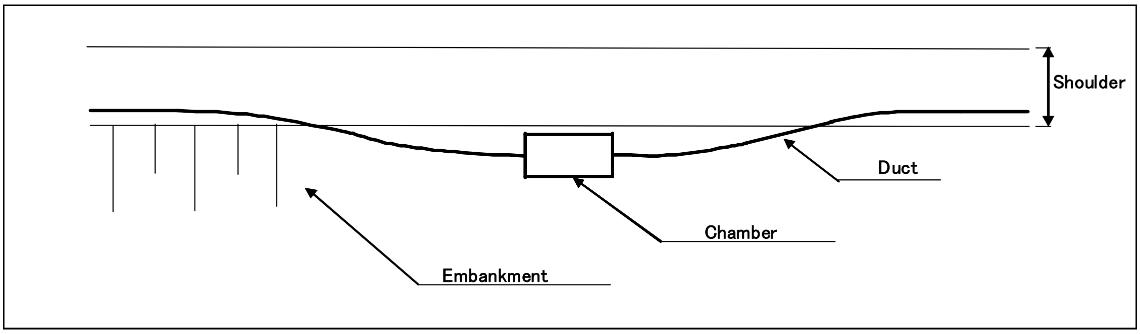
Figure 1.3 Earthwork Area Trench Types



Source: ITS Standards & Operation Plan Study Team

In the case of using the shoulder, the chamber should be set outside of the shoulder in consideration for driver safety. Hence, the ducts must be sifted smoothly to the chamber as shown in Figure 1.4.

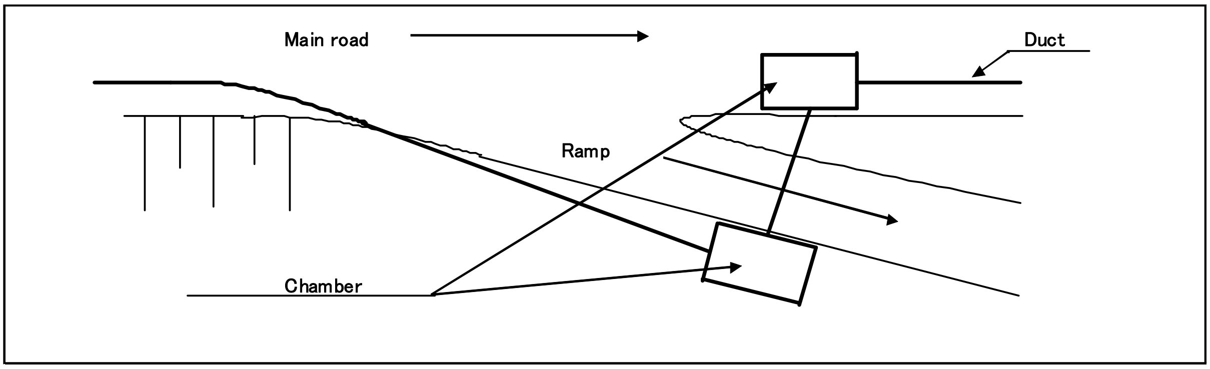
Figure 1.4 Shifting Ducts to a Chamber



Source: ITS Standards & Operation Plan Study Team

In the interchange, the ducts cross ramps, so it is desirable that the ducts cross the ramp along the shortest possible route because of easy and safe maintenance as shown in Figure 1.5.

Figure 1.5 Ducts at Interchanges with the shortest possible route



Source: ITS Standards & Operation Plan Study Team

1) General Provisions related to Communication Ducts Installation in earthwork section

Location of embedded ducts in earthwork sections should be where specified covering depth and linearity can be secured, difficulty of installation due to other existing underground utilities and structures is negligible and design is required to be performed in consideration of safety of duct, work efficiency, economical efficiency, etc.

(1) Ducts are recommended to be buried within the same cross section of earthwork of expressway during road construction time simultaneously. The ductt is required to be installed at a depth and location to keep its strength, where it is not endangered during and after construction and considering the depth and location preventing damage from vehicle accident.

(2) In case duct is installed in road shoulder part, clearance from ancillary structures such as drainage, etc. shall be kept by standardized means of construction wherever

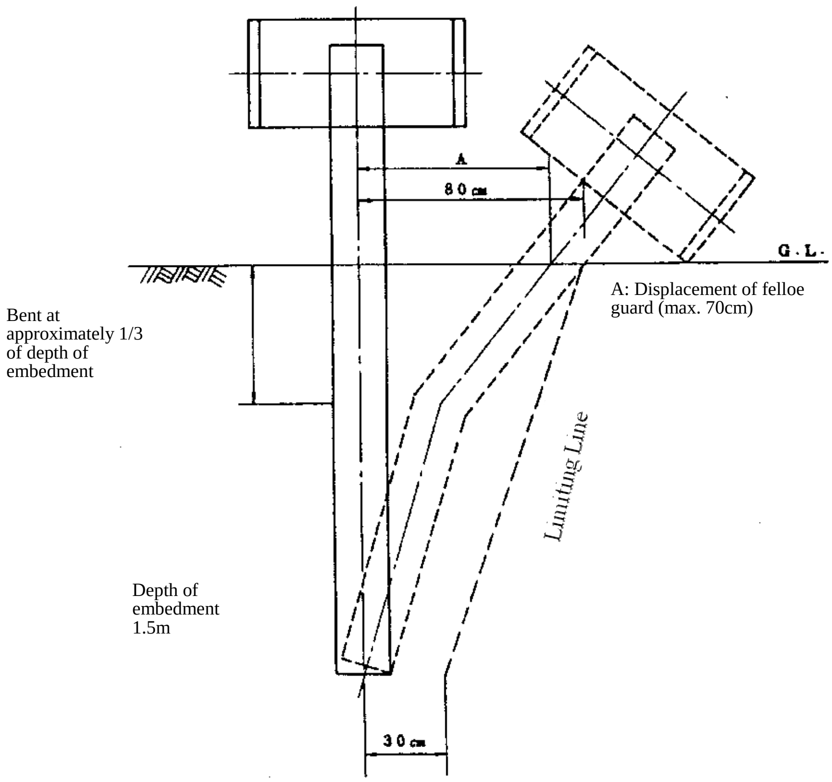
possible.

(3) Location of installation of ducts should be considered to prevent damage accidents and alleviating burden caused by maintenance and improvement works at maintenance stage. In principle, the ducts should be installed in shoulder part of expressway road where the location will not affect the pavement, or be installed in the roadbed located at the bottom end of the slope of earthwork. As for the bridge and tunnel section, the ducts should be installed at shoulder part or center divider.

(4) To avoid danger caused by impact of drilling of guard-rail and impact of driving vehicles onto guard-rail posts, ducts should, in principle, be installed away from affection limit line as per following figure.

(5) Ducts crossing roads should be crossed at right angles to road center lines.

Deformed Guard-rail Post



1.4 Box Culverts and Crossing Pipes

There are many box culverts for vehicles crossing pipes everywhere.

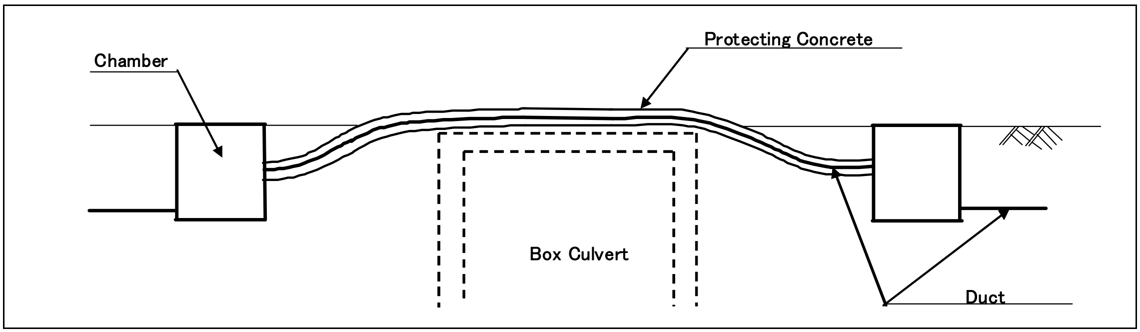
In case of crossing pipes the clearance between top of pipe and the bottom of ducts should be made so the ducts can cross over the pipes without any countermeasures.

In case of box culvert, the clearance between surface of culvert slab and the bottom of ducts depends on many factors for each box culvert. The clearance must be checked in the stage of Detail Design and Construction.

In case of small clearance, protecting concrete is adopted as a countermeasure.

Ducts in the median will cross over the box culvert as shown in Figure 1.6.

Figure 1.6 Protecting Concrete Countermeasure in case of small clearance

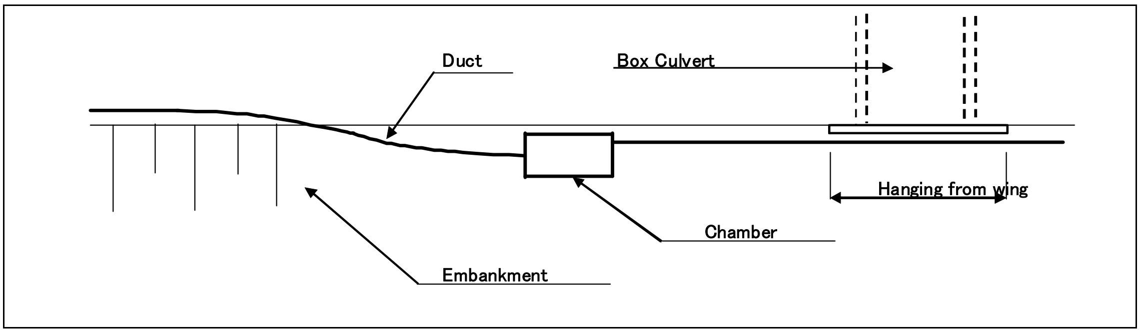


Source: ITS Standards & Operation Plan Study Team

Ducts in the shoulder will be shifted to outside of shoulder smoothly and cross the culvert using the wing of culvert the same as for bridge type A as shown in Figure 1.7. Bridge type A will be explained in section 1.5.

If there is space between the shoulder and the wing of box culvert, the ducts can cross over the box culvert using the space as shown in Figure 1.6.

Figure 1.7 Use of wing of culvert



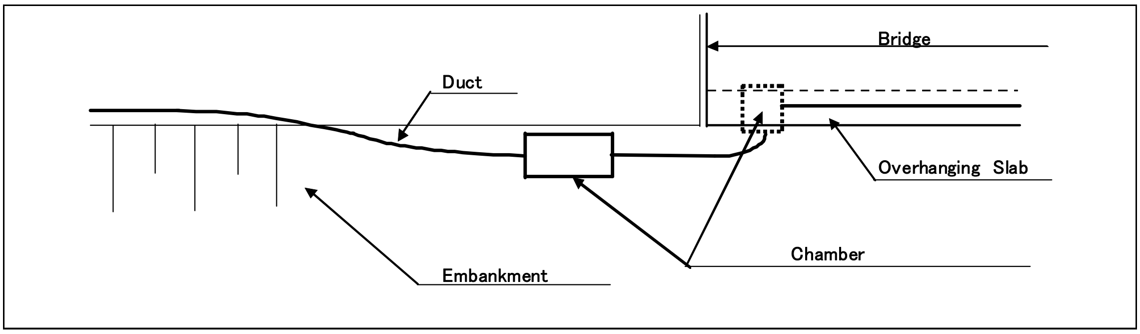
Source: ITS Standards & Operation Plan Study Team

1.5 Bridge Sections

From the chamber behind abutment, the ducts will access to the bridge as shown in Figure 1.8.

In case of using the median, the ducts should be shifted to the shoulder-side chamber behind abutment and then access to the bridge.

Figure 1.8 Access to Bridge from chamber behind abutment



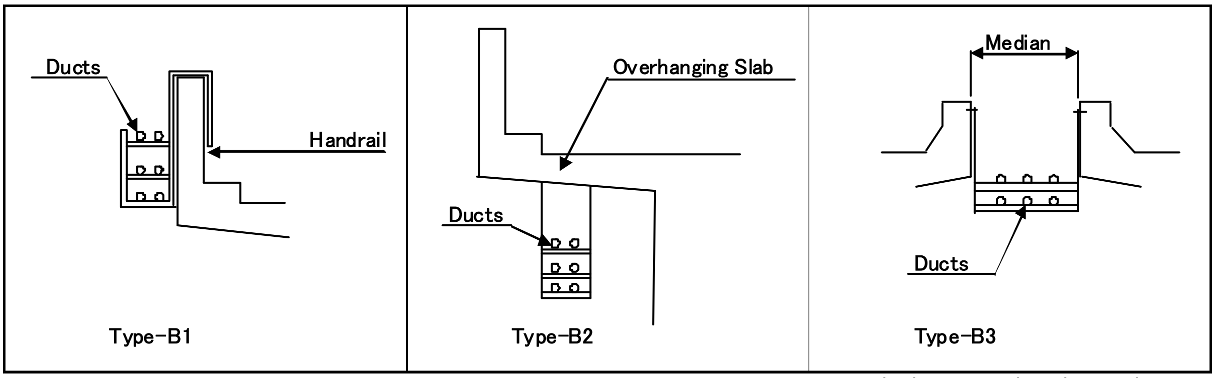
Source: ITS Standards & Operation Plan Study Team

There are three types of supporting methods for ducts on bridges as shown in Figure 1.9.

Basically Type-B should be adopted because of easy construction and maintenance as well as large track record. Type-A is adopted in case of an old bridge in order to protect the old concrete without using much anchoring.

Type-C is a special case, only adopted in Ha Noi Ring Road 3 because of the structural difficulty for setting on bridge outer side and with regard for aesthetics.

Figure 1.9 Types of supporting methods for ducts on bridges



Source: ITS Standards & Operation Plan Study Team

1) General Provisions related to Communication Ducts Installation in bridge section

(1) Location to install duct

Ducts to be installed on viaduct section or bridges are required to design proper location taking future cable installation work and maintenance/inspection work into account.

Duct material for bridge part should, in principle, be steel.

(a) Duct installation location should be selected considering easy cable installation work and maintenance /inspection work.

(b) For the protection of cables from fires from the lower part of bridge elevated segments or duct due to aging deterioration, embedded ducts should, in principle, be located as per the cases shown in Figure 1.10 or a case in Figure 1.11.

(c) Bridges on which wheel guard or wall type bridge railings were constructed in advance without installing duct for communication cables, the duct is required to be installed as attachment or suspension method.

(d) If duct is located the position to be embedded, the concrete will be casted in the form surrounding the duct. In order to protect duct deformation from heat of the concrete solidification or vibrator during casting of concrete, the duct type should be steel. On the other hand, if the duct is attached to the bridge or suspended from the bridge, the steel duct is also applied to protect from deterioration due to sunlight exposure or fire from lower part of brides. The duct installation location (5) in Figure 1.11 allows to be applied synthetic resin pipes.

Figure 1.10 Location of duct installation (1)

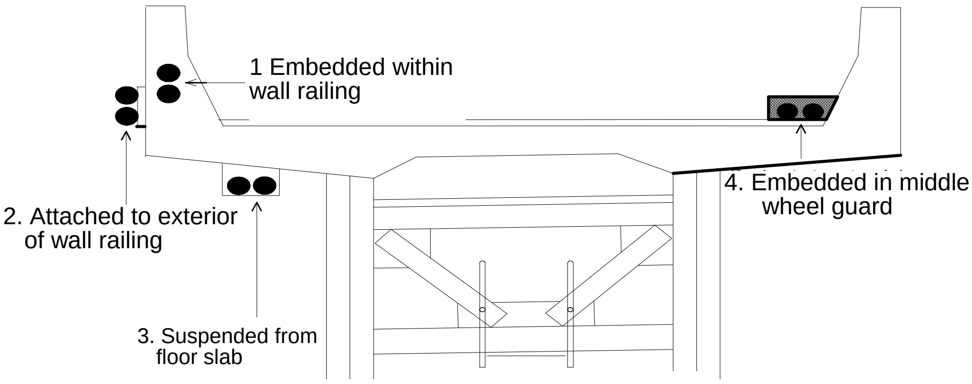
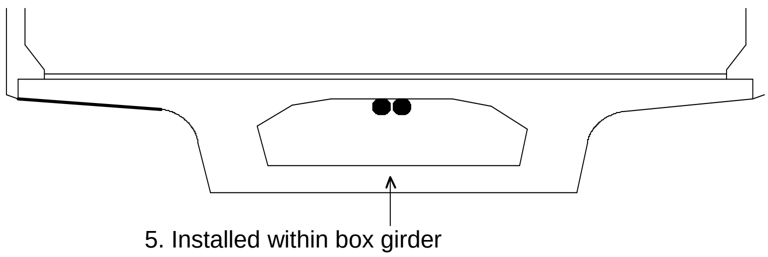


Figure 1.11 Location of duct installation (2)



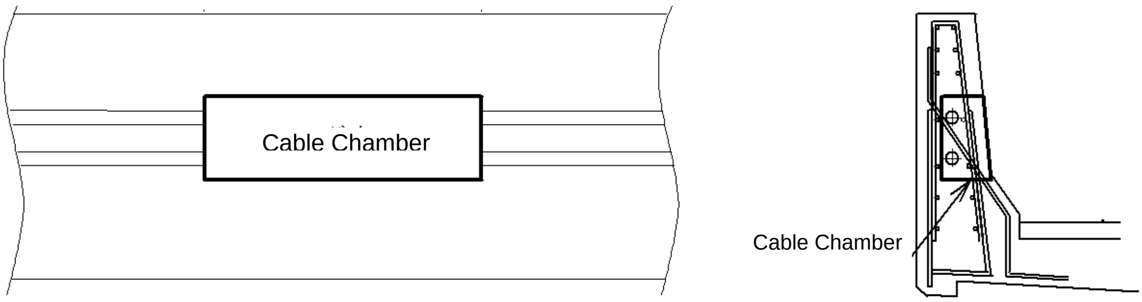
(2) Embedded duct

In case duct is embedded in wheel guard concrete or concrete wall railing, it should be designed taking into account several factors such as influence of structural strength of wall, workability of concrete encasement, and available space for other facility such as vehicle noise barriers to be installed in future in concrete wall railing.

(a) Embedded duct should be designed to prevent damage due to vibrator at time of casting of concrete (when vinyl duct is used in particular,) lack of concrete filling, and deviation of duct location.

(b) When embedding in wall railing, connections with other structures such as vehicle noise barriers should be considered in the design. As for sections at which noise barriers will initially not be installed, available space for noise barriers should be considered for future needs, and straightness of duct is required to be secured as much as possible.

Figure 1.12 Piping embedded in concrete wall railing



(3) Attached duct

Duct installed by attachment method should be executed so as not to impair the appearance of the structure, and it should be located for easy maintenance and inspection of duct and cables.

Supports for attachment should not only sufficiently support its own load and vibration with margin of safety but also expansion and contraction of duct will have to be taken into consideration.

(a) In order to avoid uncoupling of jointed duct due to duct extension or contraction, fixed support is required to install in specific intervals.

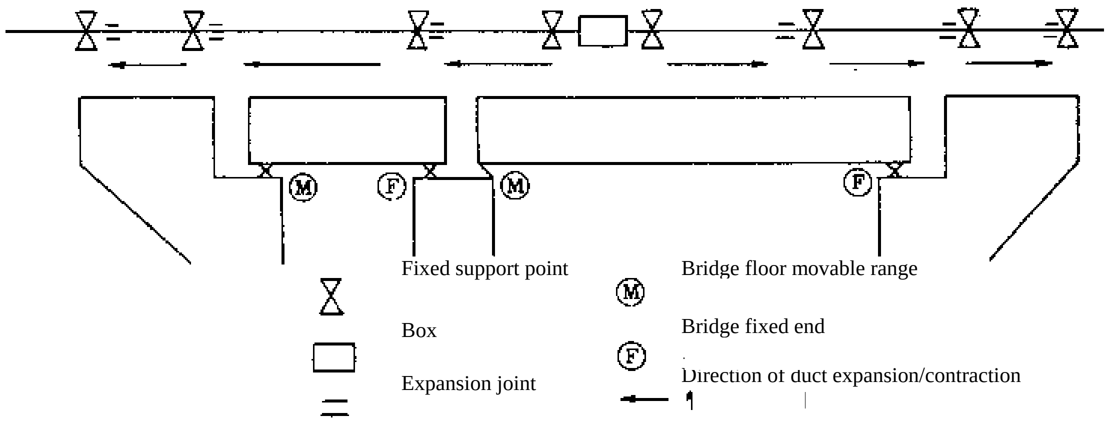
(b) The interval between supporting points to attach steel pipes is as per Table 9.18 and specific supporting point and supporting type should be determined taking following points into account;

(i) Fixed support points (for expansion joint side only) should be fixed 1m from bridge floor separation point or abutment.
(ii) When box which accommodates equipment component exists, fixed support should be installed 1m away from the box.
(iii) When expansion joint is installed at bridge floor intermediate point, fixed support point is required 1m away from the intermediate expansion joint.
(iV) General support points are required to be located between fixed support points within 4m intervals with equal distances as much as possible.

Table 1.4 Interval of supporting points in general

Supporting type	Supporting interval for steel pipe
General support	4m
Fixed support	50m

Figure 1.13 Supporting points in general



(c) When there is a possibility of fire below bridge elevated segment and attached ducts in the vicinity of abutment, required duct protection measures against fire is required to be taken in consideration of importance of cable. zones at which measures are to be taken are as follows:

(i) Barrier to prevent entry does not exist, places whereby entry is easy (excluding road crossings,) shortest height to duct is less than 5m and sections where risk of telecommunication cables being damamged by fire is high. (Figure 1.13)

(ii) Regardless of whether a barrier exists or not, shortest height to duct is less than 5m and slope is protected with grass. (Figure 1.14)

(iii) Places where duct is attached on wall of culvert (Figure 1.15). However, where slopes are of stone or concrete blocks, duct protection against fire is not required.

Figure 1.14 Places of side attachment of duct and less than 5m height

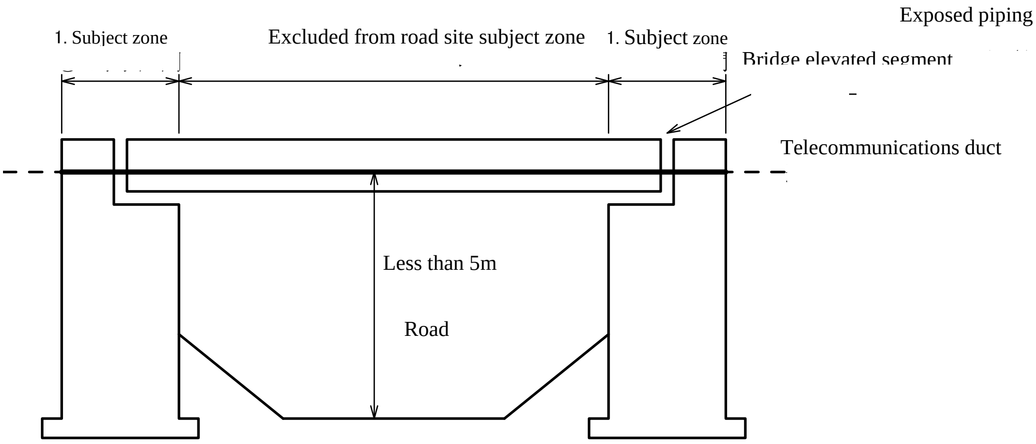


Figure 1.15 Less than 5m height to duct and where slope with grass space outside road site could be exposed to spreading fire

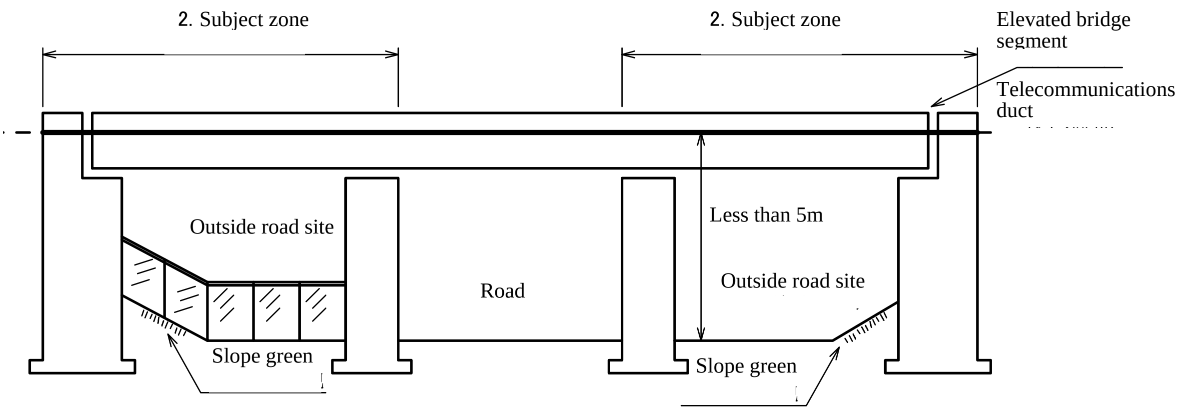
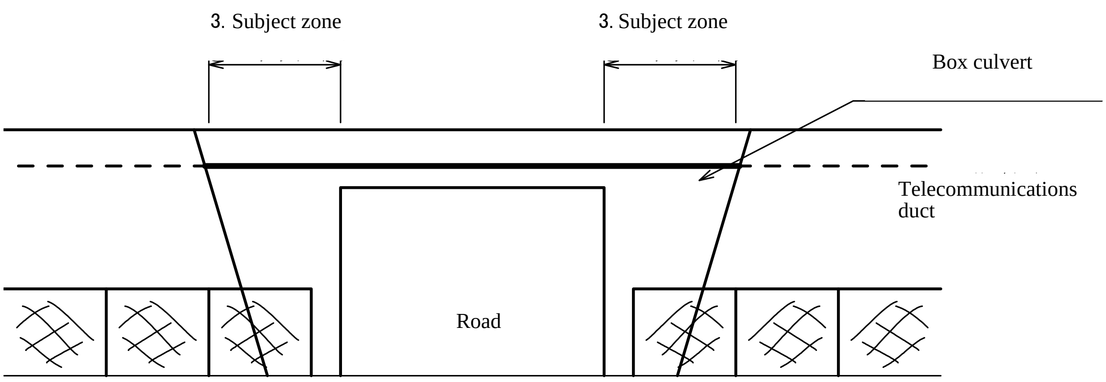


Figure 1.16 Box culvert where slope with grass could be exposed to spreading fire



(4) Expansion joint

Expansion joints are required to be installed at points of bridge floor separation and at abutment connections.

When no expansion joints are installed over a span exceeding 50m of steel pipe installation, an expansion joint is to be installed in the span next to the fixed support point.

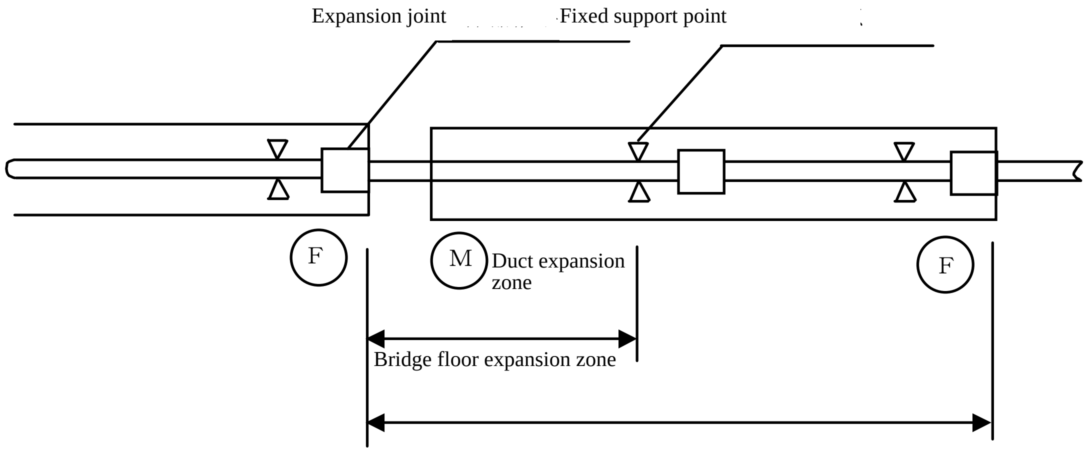
Appropriate and economical expansion joint is required to be selected taking into account the conditions such as movable length of expansion/contraction, and moveable direction of the joint.

In addition to the above, expansion/contraction due to thermal characteristics of steel pipe, and movable direction and length of expansion joint for road bridge is also need to be considered.

(a) For protection of pipe body and supports from pipe's thermal stress, expansion joints are required to install at bridge elevated part for embedded duct and attached duct.

(b) Expansion joint of the bridge attached duct is to be applied at separation point of bridge floor and between abutment and bridge floor considering sufficient absorb length to cover total expansion/contraction for the section.

Figure 1.17 Expansion zone of attached duct section



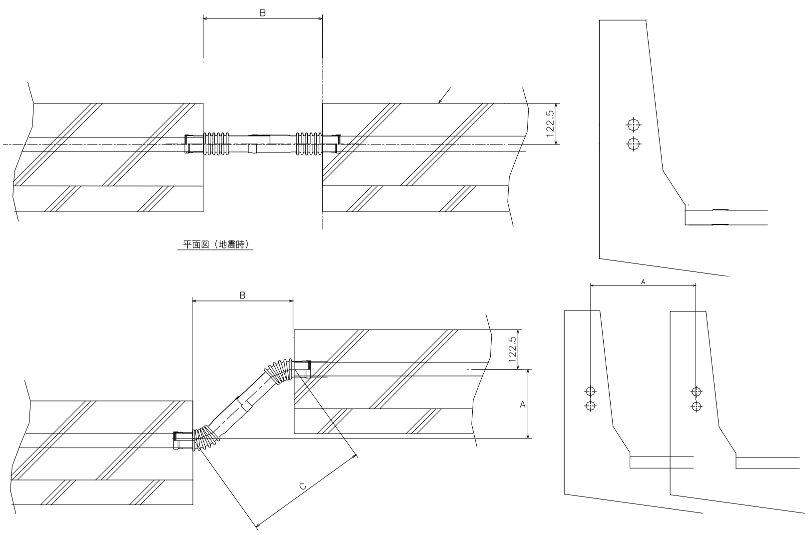
(c) Rust-proof expansion joints is needed to be used for attached ducts or corrosion protection applied at site.

(d) Expansion/contraction length of duct is required to consider the bridge expansion/ contraction basically. In the bridge expansion/contraction is considered following factors mainly:

(i) Expansion/contraction due to thermal characteristics of bridge
(ii) Displacement due to earthquake ground motion

The expansion joint is required to absorb the expansion/contraction due to above factors. The sample calculation method in item b) above is shown in Figure 1.17.

Figure 1.18 Horizontal displacement during an earthquake



A= Horizontal displacement
B=Normal expansion spacing width
C＝Maximum expansion/contraction (C＝ $\sqrt{A^2 + B^2}$)

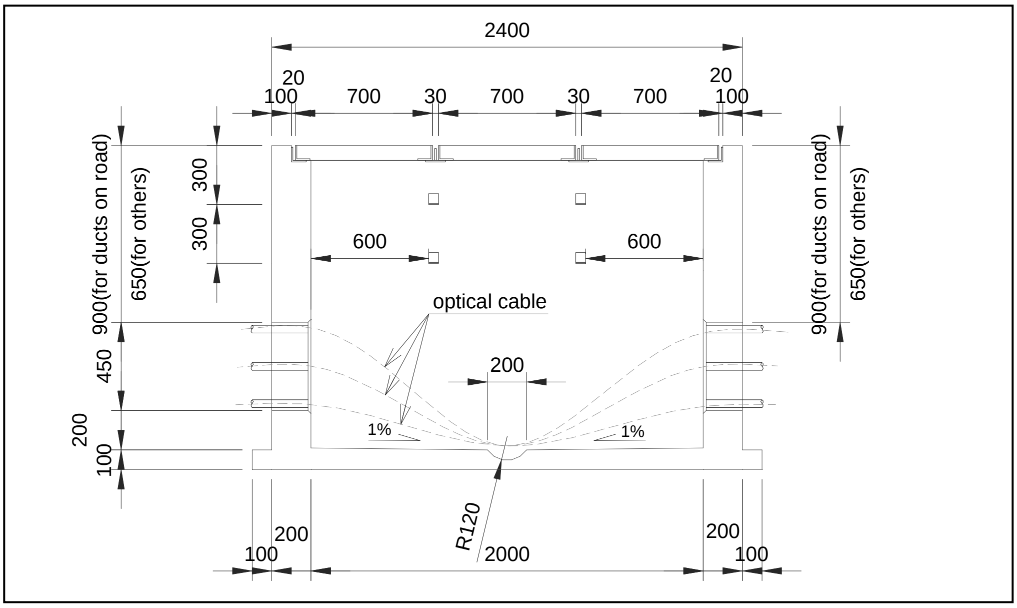
(5) Surplus length of cable to meet the expansion joint selected in accordance with above items is required to confirm in cable installation design.

1.6 Chamber

Of six main types of chamber shown in Figures 8.10 ~ 8.15, M1~M4 made by concrete are adopted in earthwork areas and M5~M6 made by steel are adopted on bridges.

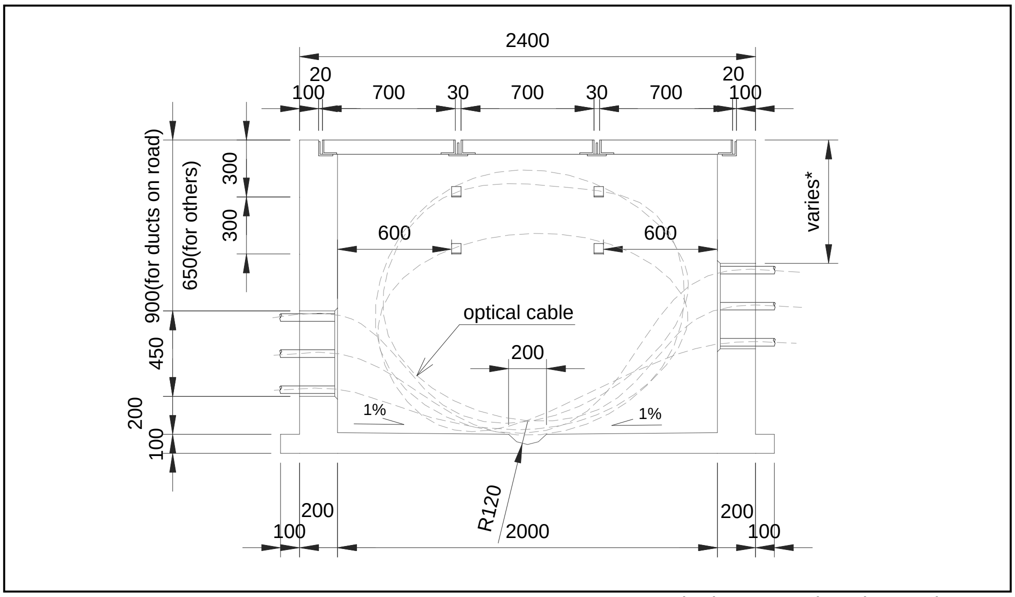
* M1 : This chamber handles cables and for keeping them slack.
Regular interval is approximately 333 m.
* M2 : This chamber connects the ducts in earthwork area to the bridge.
It is set behind abutment.
* M3 : This chamber is for installing and connecting cables.
Regular interval is approximately 2.0 km.
* M4 : This chamber is set at changing point of cable direction both horizontally and vertically. For example, Figures 1.5 and 1.6 are M4 type.
* M5 : This chamber is set at bridge section. It is for maintaining cables slack against expansion and contraction of bridge. Regular interval is approximately 100 m.
For bridges which its length is over 2.0km or M5 chamber which needs to connect to roadside equipment, a closure shall be installed in the chamber.

Figure 1.19 Main types of chambers M1



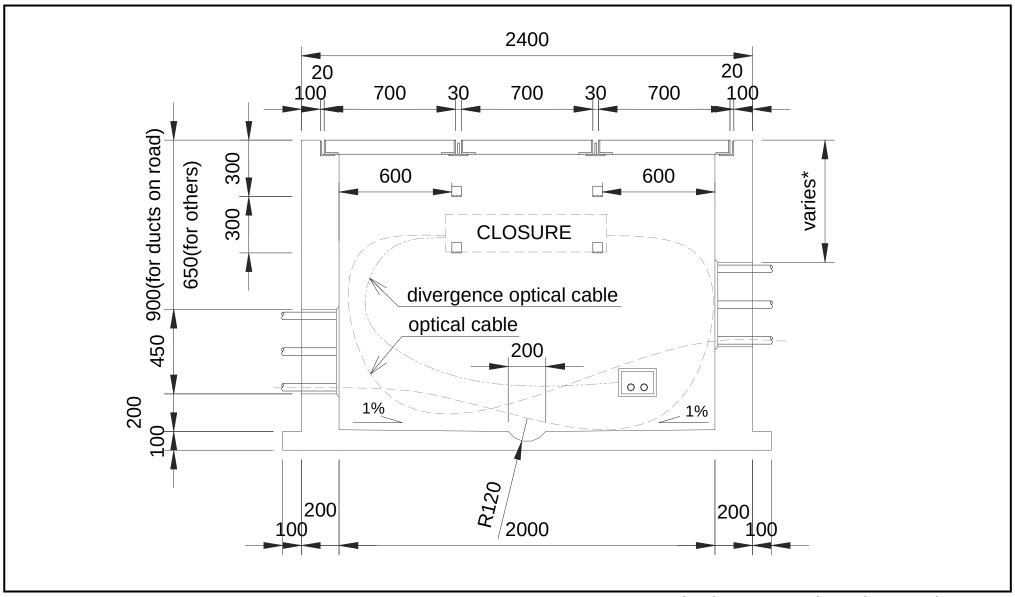
Source: ITS Standards & Operation Plan Study Team

Figure 1.20 Main types of chambers M2



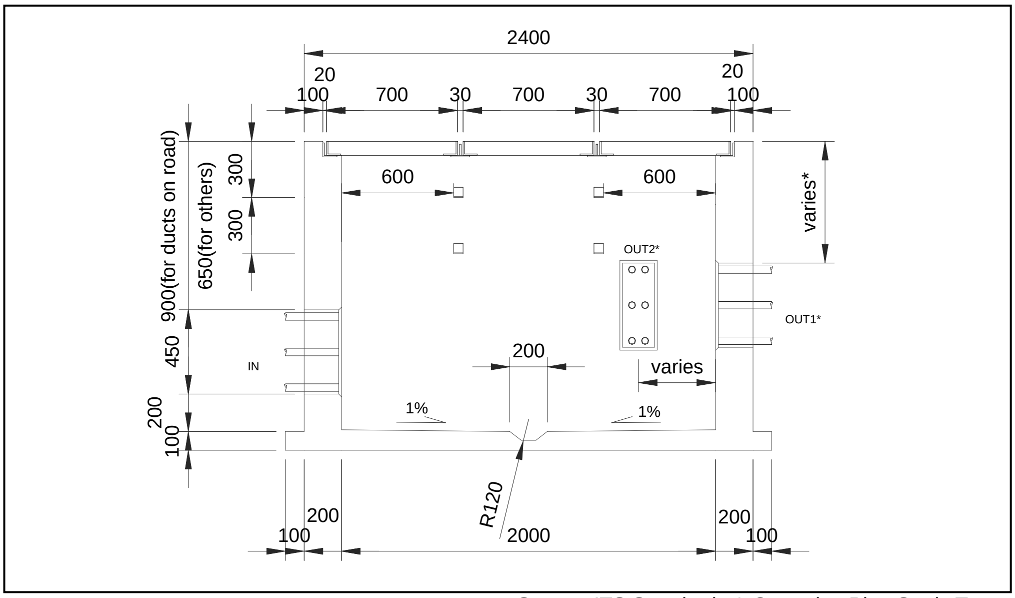
Source: ITS Standards & Operation Plan Study Team

Figure 1.21 Main types of chambers M3



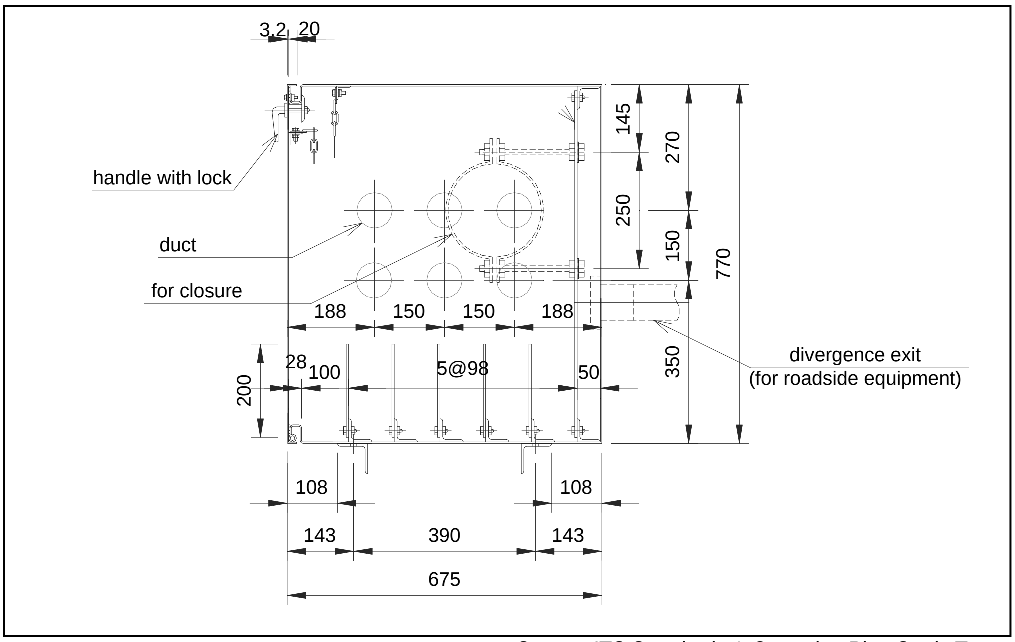
Source: ITS Standards & Operation Plan Study Team

Figure 1.22 Main types of chambers M4



Source: ITS Standards & Operation Plan Study Team

Figure 1.23 Main types of chambers M5



Source: ITS Standards & Operation Plan Study Team

1) General Provisions related to Cable Chamber

(1) General information

(a) Cable Chambers are required to be installed at locations/points where cables are connected or installed and where small radius bending is required.

(b) Size of a cable chamber is considered necessary factors of cable and cable joint accommodation capacity and cable installation work space.

(c) Strength of cable chamber is required to withstand cable pulling force, live load caused by earth pressure and traveling vehicles at time of construction and after commencement of service.

(2) Required Dimensions of MH/HH

The dimensions of Cable chambers are to be determined taking occupied space of cables and splicing points and cable installation working space into account.

(3) Locations of installment and span

(a) Cable chamber is to be installed where cables are joined, at road crossings, where small radius bends exist in roads, etc. Concerning its locations on viaduct section and within tunnels, location shall be considered taking other supporting facilities location into account. Moreover, they shall be installed at equal distances wherever possible.

(b) When connections are to be made with the room in building structures such as electric room, communication equipment component room, etc., the cable chamber should not be located close to the building foundation and installed exterior of the cat walk.

(c) Cable Chamber is not considered to be located those places where it will be expressway driving lane, unequal external pressure being applied, and the location where there is a possibility of ground subsidence, however when installation of such location is unavoidably required, sufficient protection should be made to cable chamber cover and its duct connection part.

(4) Number indication

Name and number plate for cable chamber is required to be indicated inside of cable chamber.

(a) The name plate is required to include the nearest interchange names, serial numbers starting from one side interchange, and others as shown below."

(b) In case cable chamber is to be added between existing cable chambers after completion of installation work, "supplementary number" to be added to serial number.

(c) Plant record for each cable chamber is required to prepare and periodically needed to update for operation and maintenance. The plant record includes the information of cable chamber number, connected ducts, installed cables, installed cable joint and other necessary information to manage cable facilities.

Figure 1.24 Cable Chamber Nameplate Example