Technical Report

ISO/TR 21734-3

First edition
2024-06

Intelligent transport systems — Performance testing for connectivity and safety functions of automated driving buses in public transport —

Part 3: Service framework and use cases

Systèmes de transport intelligents — Essais de performance pour les fonctions de connectivité et de sécurité des bus à conduite automatisée dans les transports publics —

Partie 3: Cadre de service et cas d'usage

Reference number
ISO/TR 21734-3:2024(en)

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Foreword

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This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

A list of all parts in the ISO 21734 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Automated vehicle technology has been developing rapidly in recent years as one of the measures for reducing automobile accidents caused by human errors and for promoting the automobile industry. The automated driving bus (ADB) is a new type of public transport mode embedded with automated vehicle technologies. The progress of development and deployment of ADBs has accelerated in recent years, exceeding that of automated passenger vehicles.

From the connectivity perspective, to ensure its effectiveness as a public transport mode, ADBs need to connect with:

— traffic signal networks both for vehicles and pedestrians;

— the monitoring and control centre for bus operation; and

— other relevant infrastructure.

In terms of safety, the ADB needs to:

— be embedded with automated vehicle functions to connect with the wireless signal control system; and

— be ready to respond to unexpected situations involving other road users such as pedestrians and bicyclists.

With secured connectivity and safety, ADBs can provide stable services.

Along with stable service provision, an ADB deviates its operational measures from conventional ones. This document describes basic components for providing transport services and service framework based on ADB. It also explains use-cases of ADB services, including structure of service components, operational route management, fare payment, emergency response, and provision of operational information along with service procedures for each service use-case.

Furthermore, public transport authorities need technical reference points to measure the service performance of ADB for enhancing public safety on roads.

This document provides the basis for the development of performance testing for connectivity and safety functions of ADB on a national and international level. It is intended to benefit public transport operators, relevant governing authorities and industrial stakeholders.

Intelligent transport systems — Performance testing for connectivity and safety functions of automated driving buses in public transport —

Part 3:
Service framework and use cases

1 Scope

This document specifies the general service framework and components for operating automated driving buses (ADBs) in public transport networks. It includes:

a) a description of the ADB service components which consist of ADBs, the monitoring and control (MC) centre, Internet of Things (IoT) infrastructure, the smart bus stations and the passengers.

b) a description of the use cases for the ADB service operation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21734-1, *Intelligent transport systems — Performance testing for connectivity and safety functions of automated driving buses in public transport — Part 1: General framework*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21734-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1
automated driving bus
ADB
bus designed for public transport and embedded with automated driving functions based on SAE level 4 or higher

Note 1 to entry: definitions of autonomous vehicle can be found in the SAE document SAE J3016.

3.1.2
automated driving bus service framework
ADB service framework
framework for transport services provided by the automated driving bus (ADB) system through interactions among the system components consisting of ADB, Internet of Things (IoT) infrastructure, passengers, smart bus stations and the monitoring and control centre

3.1.3
monitoring and control centre
MC centre
system that can ensure the safety of automated driving bus (ADB) operations by monitoring and controlling the fleet through the collection of data from the ADB system

3.1.4
IoT infrastructure
sensor-equipped transport infrastructure such as traffic signals at intersections and smart bus stations that recognize road traffic conditions and ADBs

3.1.5
smart bus station
facility where an automated driving bus (ADB) stops and passengers safely board, alight and wait for an ADB

Note 1 to entry: Smart bus stations include a station kiosk and Internet of Things (IoT) infrastructure to communicate with the monitoring and control (MC centre).

3.1.6
passenger
one of the automated driving bus (ADB) users provided with ADB transport services

3.1.7
operator
one of the users who is responsible for operating and managing automated driving bus (ADB) systems

3.1.8
on-demand operation
operating measure with a flexible schedule and route that responds to the passengers' demand within the delineated service area

Note 1 to entry: Passengers are only permitted to board and alight at a smart bus station.

3.1.9
station kiosk
device that is installed at a smart bus station and that provides boarding reservation, payment and billing services to passengers

3.1.10
mobile application
software program supporting automated driving bus (ADB) passengers in making their boarding reservation and payment with a mobile device

3.1.11
operation manager
person who is responsible for monitoring the operation of the automated driving bus (ADB) fleet and responding to emergencies in the MC centre

3.1.12
in-vehicle operation manager
individual who is responsible for monitoring automated driving bus (ADB) operation and responding to emergencies in an ADB while it is in operation

3.1.13
one-time boarding ticket
ticket used for one round trip

Note 1 to entry: Depending on reservation methods, tickets can be either paper or electronic.

3.2 Abbreviated terms and symbols

A	fare
ADM	automated driving message
ASM	automated driving service message
BIS	bus information system
BSM	basic safety message
EEM	emergency event message
IoT	Internet of Things
JPY	Japanese yen
KRW	South Korea won
MRT	mass rapid transit
N	deposit for the additional amount to pay when the reservation information differs from destination
NFC	near field communication
R	deposit of calculation of purchase cost of a one- time ticket
r_F	refund false
r_T	refund true
SGD	Singapore dollar
T	ticket

4 ADB service framework

4.1 ADB service components

4.1.1 General

The ADB service component consists of five components including the ADB, the MC centre, IoT infrastructure, the smart bus station and the ADB passenger. These components are shown in Figure 1.

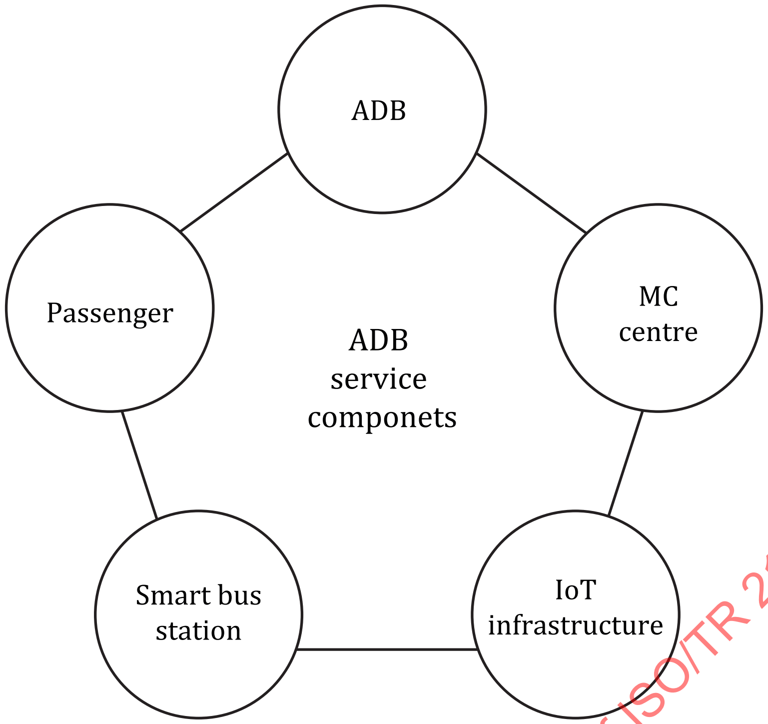


Figure 1 — Five components of ADB service

4.1.2 Automated driving bus (ADB)

An ADB is a vehicle designed for the carriage of passengers with a capacity of more than 9 persons. It can provide safe transport services by communicating with traffic signals and IoT infrastructure that are installed on the roadside and can transmit messages to the MC centre. An ADB can also allow the MC centre to manage its driving functions when necessary.

The messages an ADB provides to the MC centre include its real time locations, the number of empty seats, its expected arrival time at a smart bus station, the number of boarding passengers, passengers' identities, and traffic conditions. Additionally, an ADB provides the MC centre with emergency messages with the occurrence of an event such as system errors or accidents. Furthermore, information protection policies and technologies are applied for operating an ADB.

4.1.3 Monitoring and control centre

The functions of the MC centre component consist of delivering ADB mobility services, managing information for reservations and fare payments, and responding to emergencies.

For delivering the ADB mobility services, the functions of the MC centre include the provision of information for facilitating bus operations and serving passengers. The provision of information includes the number of boarding/alighting passengers at the next station, optimum paths to their destinations, traffic conditions and signal phases along their routes, and weather and road conditions. The passenger service information includes an ADB's current location, its expected arrival time, and the number of remaining seats.

Additionally, the MC centre manages information for the passengers' boarding reservations and payments through in-vehicle equipment, station kiosks and passengers' mobile applications. A station kiosk and a mobile application identify passengers' intentions to board on an ADB along with their designated stations for boarding and alighting, fares for their trips, and their payment status information. It further manages the issuance of a one-time ticket and the refunding of deposits upon return, and imposes a penalty fare if necessary.

For responding to emergencies, the MC centre operation manager is informed of emergency situations by ADBs, passengers or IoT infrastructure. The MC centre operation manager is responsible for communicating with first responders including hospitals, police and the fire stations, if necessary, based on information on the emergency type, time and location, and emergency handling procedures.

When collecting and utilizing passengers' personal information for the delivery of these functions, the MC centre complies with regulations for protecting privacy.

4.1.4 IoT infrastructure

The IoT infrastructure directly detects road and traffic conditions in real time, collects real-time operational data from ADBs, and transmits the collected data to ADBs and the MC centre. The data that IoT infrastructure collects includes traffic, road and weather conditions, along with information for ADBs to identify safety gaps when passing through intersections within a scheduled time.

4.1.5 Smart bus station

The smart bus station provides passengers with shelters while waiting for their ADBs. It also provides operational information concerning the ADBs through devices such as bus information system (BIS) monitors and kiosks at the station. The operational messages of an ADB include route information, current locations, the number of remaining empty seats, and the remaining time for arrival at the station. The smart bus station also identifies passengers' boarding intentions through kiosks installed at the station and provides the MC centre with the messages including the number of passengers who intend to board and ADBs' arrival and departure time at a stop lot.

4.1.6 ADB passenger

The ADB passenger is a person using an ADB by making their boarding reservations at a station kiosk or with their own mobile application before boarding an ADB and paying the fare for their trip. When making a reservation, an ADB passenger provides a station kiosk or a mobile application with the messages designating their departure and destination stations, the number of accompanying passengers and the boarding time. An ADB passenger touches one-time boarding ticket on the tagging devices installed in the vehicle upon boarding and before alighting or at a smart bus station to provide boarding information. Passengers can respond to in-vehicle information in case of emergency.

4.1.7 Summary

Table 1 provides a summary of the roles of each ADB service component.

Table 1 — Summary of roles for each ADB service component

Component	Summary of roles
ADB	— Provision of real time operational information.
MC centre	— Collection and provision of real-time data for ADB operations. — Storage and management of data collected from the components. — Management of passenger's boarding reservations and payments. — Responses to emergency events.
IoT infrastructure	— Provision of information including traffic, road and weather conditions to the MC centre. — Provision of information to ADBs for making decisions as to whether to pass through an intersection.
Smart bus station	— Provision of ADBs' operational messages for passengers. — Provision of a space for a kiosk instalment. — Arrival and departure time of ADBs at the smart stations.
Passengers	— Utilization of ADB services. — Boarding reservations and payments. — Provision of boarding information. — Sounding of emergency alarm and evacuation.

4.2 Fare management system

The fare management system component functions according to ISO 24014-1. The fare management system derives data and statistics required to calculate the transport operator's profit share. Within the context of ADB, fare management systems comply with regulations on data protection and financial services and are capable of protecting customer's privacy.

Tickets or transit cards are used by ADB passengers when boarding and alighting an ADB. Issuing an ADB ticket as a medium for a payment would reduce waiting time for ADBs when passengers are boarding or alighting.

Two types of fare systems can be applied, including a uniform fare system that pays an equal amount of fare across sectors, or a variable fare system where the fare varies with distance, sector and zone.

4.3 Identification

The identification component functions according to ISO 24014-1. Identification is a method of clarifying a specific person, an object, or a thing and of assigning a series of attributes for it. Each component is identified by assigning unique IDs such as ADBs, the MC Centre, IoT infrastructure, smart bus stations, and passengers. Reasons for identification include the following:

— security: unique IDs assigned to components are used for component certification procedures;

— message exchange handling: unique IDs are assigned for handling a large volume of messages that components exchange as a message sender and receiver;

— inspection: unique IDs are used for inspecting the details of a problem and for locating a point at which a problem occurs while exchanging messages.

4.4 Security

4.4.1 General

The security policy of an ADB service protects the system's public interest and assets. The security of public interest, assets to protect, and general security is covered by ISO 24014-1.

4.4.2 Public interest

General principles concerning public interest are as follows:

— service quality: the ADB service is used as a tool for achieving the strategic goal of national public transport service;

— fair payment: the ADB service confirms for customers that they pay the correct amount of fare according to the valid custom principle;

— public trust: the ADB service confirms for customers that they pay the correct amount of fare for the service they want;

— public ethics: any deliberate disruption is regarded as an illegal act which is concerned with the principle of fairness and public trust;

— privacy: the information generated by the ADB service is protected according to the relevant law.

International, European and regional regulations concerned with the protection of personal information impose limitations on the collection, storage, processing and distribution of data related to individuals and their actions. Some countries or regions require a complete anonymity system when dealing with personal data. Therefore, the ADB services comply with the relevant regulations in terms of protecting the passengers' personal information. To achieve this, at least the following regulations are applied.

— Only the personal information that is required for an ADB service operation is requested of the customers.

— The ADB service actors are obliged not to disclose customers' personal information to third parties without specified confirmation of the customer.

4.4.3 Assets to protect

ADB services protect assets related to the ADB system for service provisions. Assets can be classified as follows:

— physical assets: the communication system, the customer's medium, kiosk ticket vending machines, ticket identification devices, smart bus stations, ADBs, IoT infrastructure, etc.;

— software assets: all kinds of software related to the ADB operational system;

— Information assets: databases, operation procedures and plans, personal information, security keys, etc.

4.4.4 General criteria for security

The following general criteria for security can be applicable to ADB services.

— The ADB services provide the confidence that the service does not provide or disclose the information to unauthorized individuals and parties.

— The ADB services provide the confidence that the information is not altered or damaged without the owners' permission (information integrity).

— The ADB services provide the confidence that the identity of the agent or the resource is guaranteed. (fidelity)

— The ADB services provide the confidence of protection from false information.

— The ADB services provide the confidence that each piece of the information is unique.

— The ADB services administer the security keys for data generation, registration, certification, distribution, installation, and storage according to the security policy of ADB service.

5 ADB service and use cases

5.1 Overview

An ADB defined in this document is based on SAE level 4 or higher. Therefore, the goal is to provide safe and convenient mobility services by ADBs, including:

— ADB operation services;

— passenger payment handling services;

— ADB emergency response services;

— transport information provision services.

This document gives an account for services and use cases in detail to standardize the services of ADBs. Figure 2 illustrates ADB services and associated use cases which are drawn from field test cases developed by the Republic of Korea and described in Annex A. It provides an overview of the different use case categories. The use cases are grouped into four ADB services. Detailed definitions for each service are defined in Subclauses 5.2. to 5.5.

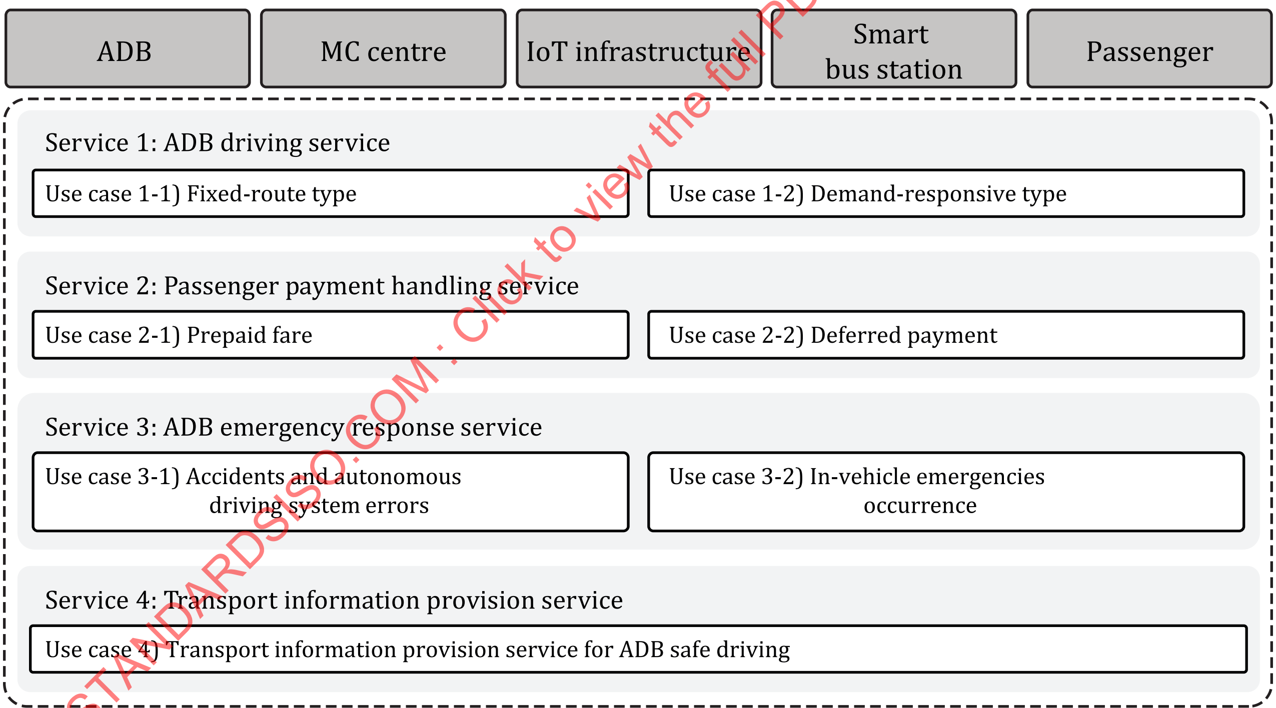


Figure 2 — ADB service use cases

5.2 ADB operation service

5.2.1 General

As for conventional buses, the human drivers monitor the vehicle vicinity and support passengers to board and alight. However, an ADB lets vehicle sensors, instead of a human driver, monitor the vehicle vicinity and identify the passengers' information. An ADB also lets IoT infrastructure identify traffic conditions.

In terms of ADB service operation types, there are two types of use cases, as illustrated in Figure 3:

1) predefined route; and

2) on-demand route type.

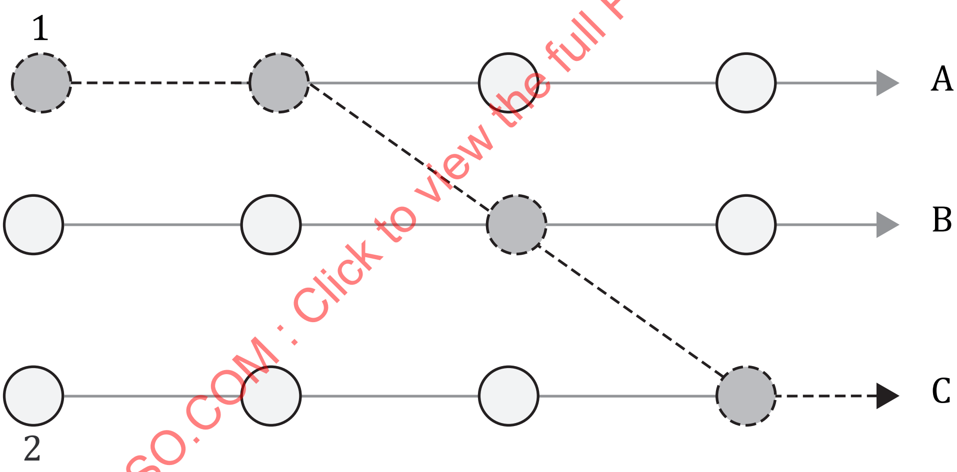
In a predefined route service operation type, an ADB operates along the predefined routes by schedule, whereas an on-demand route service type has more flexibility regarding route choices: the ADB operates within a service area with a planned destination and stops at smart bus stations, but it can change routes while operating based on the requests from passengers (provided that the requests fit an optimal travel plan).

Both types of service operation allow passengers to board and alight at smart bus stations due to boarding reservation and passenger safety. However, the on-demand type differs from the predefined type in that an ADB can flexibly bypass stations along the optimum routes derived from passengers' demands, real-time traffic conditions collected from IoT infrastructure and other ADBs, and information provided by the MC centre.

The optimum route is the optimal travel plan derived by matching desired routes of ADBs and passengers. With optimum routes, passengers can travel between routes without making transfer stops to their destination, while ADBs can switch routes to pick up passengers at smart bus stations. The optimum routes are determined by the MC centre utilizing information on passenger reservations and road and traffic conditions. They are transmitted to the ADBs in real time.

For on-demand operation, the fundamental equipment for an ADB is a route map that specifies all the possible routes that can be taken and IoT infrastructure that can identify traffic conditions within the service area. Message sets that ADBs exchange with the MC centre during driving refer ISO 17185.

ADB passengers make boarding reservations by using station kiosks or mobile applications in advance.



Key

1 on-demand type

2 predefined-route type

A line A

B line B

C line C

○ smart bus station

Figure 3 — Predefined route type and on-demand type

5.2.2 Use case 1-1: Predefined route type

Table 2 describes a predefined route type use case (Use case 1-1) for ADB services.

Table 2 — Use case 1-1: Predefined route type

Item	Predefined route type
Definition	An ADB operates with predefined routes and schedules.
Actors	— ADB — The MC centre — IoT infrastructure — Smart bus station — Passenger
Premise	A passenger intends to use an ADB.
Description	
1)	An ADB starts driving according to the predefined operation schedule and transmits messages for starting to drive to the MC centre. — Messages that the ADB transmits to the MC centre: — ADB's time for entry to/departure from the garage.
2)	An ADB drives along the predefined route. — Messages that the ADB transmits to the MC Centre during driving: — the location message (GPS), GPS collection time, current number of empty seats, expected arrival time at the next station, travel speed. — Message that the MC centre transmits to the ADB and passengers: — location of the ADB. — Messages that the MC centre transmits to smart bus station: — ADB's current number of empty seats, location, expected arrival time.
3)	IoT infrastructure (such as signal controller) transmits messages to the MC centre of the ADB's status if it passes through the intersection and of traffic conditions. — Messages that IoT infrastructure transmits to the MC centre: — ADB's operational status if it passes the intersection, traffic conditions, road conditions.
4)	Passengers input their boarding reservation information for an ADB by using a station kiosk or a mobile application. — Boarding reservation messages that passengers input to the station kiosk: — destination, the number of passengers boarding with the reservation. — Boarding reservation messages that passengers input to their mobile applications: — boarding and alighting stations, the number of passengers on board, boarding time.
5)	A station kiosk or a mobile application transmits boarding reservation messages to the MC centre. — Boarding reservation messages that the station kiosk or the mobile application transmit to MC centre: — station IDs (boarding and destination), the number of passengers boarding, the number of passengers alighting.
6)	The MC centre collates passenger reservation messages transmitted from station kiosks and mobile applications and provides ADBs with the messages for the number of passengers boarding and alighting at their next station. — Messages that the MC centre transmits to an ADB: — next station ID, the number of passengers boarding and alighting at the next station.
7)	An ADB arrives at the smart bus station, and the station and the ADB transmit the arrival messages to the MC centre. — Message that the smart bus station and the ADB transmit to the MC centre: — the ADB's arrival time at the station.
8)	An ADB opens its door and transmits the message that indicate the door is open to the MC centre. — Message that the ADB transmits to MC centre: — status of the ADB's door operation.

Table 2 *(continued)*

9) An alighting passenger tags a prepaid ticket or a deferred payment card on the in-vehicle ticket identification device and alights the ADB.
- — Messages that the alighting passenger transmits to the ADB:
  - — alighting date and time, alighting station ID.

10) A boarding passenger tags a prepaid ticket or a deferred payment card on the in-vehicle ticket identification device and boards the ADB.
- — Messages that the boarding passenger transmits to the ADB:
  - — boarding date and time, alighting station ID.

11) An ADB examines passengers' information agreements between transmitted ones from the MC centre and those of tagged ones for the identification and the number of passengers boarding/alighting.
- — Message that the ADB transmits to the MC centre:
  - — passenger identification.

12) An ADB identifies the number of boarding and alighting passengers in relation to the number of taken seats by using the ticket identification device, calculates the number of empty seats, and informs the MC centre, station kiosk, and passengers at stations with the number of available seats until the next station.

13) An ADB closes the door and starts driving to the next station.
- — Message that the station transmits to the MC centre:
  - — departure time of the ADB from the station.
- — Message that the ADB transmits to the MC centre:
  - — status of the ADB's door operation.

14) An ADB announces the next station to in-vehicle passengers.

5.2.3 Use case 1-2: on-demand type

Table 3 describes an on-demand route type use case (Use case 1-2) for ADB services.

Table 3 — Use case 1-2: On-demand type

Item	On-demand type
Definition	The ADB drives flexibly regarding operation time and station in response to passengers' demands.
Actor	— The ADB — The MC centre — IoT infrastructure — Smart bus station — Passengers
Premise	Passengers intend to use an ADB.

Description

1) Passengers input their boarding reservation information for an ADB by using the station kiosk or their mobile application.
- — Boarding reservation messages that passengers input to a station kiosk:
  - — destination station, the number of passengers on board.
- — Boarding reservation messages that passengers input to their mobile application.
  - — boarding and alighting station, the number of passengers on board, boarding date and time.

2) The MC centre collates passenger reservation messages provided by station kiosks and mobile applications and instructs the ADB nearest to the passengers' reserved pick-up station and capable of accommodating the reserved passengers to drive to the pick-up station.
- — Messages that the MC centre transmits to the ADB:
  - — pick-up station ID, the number of passengers boarding at the pick-up station, the number of passengers alighting at the pick-up station.

Table 3 *(continued)*

3)	The MC centre informs passengers of the allocated ADB ID and the expected arrival time. — Messages that the MC centre transmits to passengers (via station kiosks or mobile applications): — allocated ADB ID, expected arrival time of the ADB.
4)	The ADB drives to the pick-up station as informed by the MC centre. — Messages that the ADB transmits to the MC centre while driving: — ADB location message (GPS), GPS collection time, number of empty seats, expected arrival time at the pick-up station, travel speed. — Messages that the MC centre transmits to in-vehicle passengers: — the ADB's location message, the next station. — Messages that the MC centre transmits to the smart bus station: — ADB ID, number of empty seats, expected arrival time.
5)	IoT infrastructure (such as signal controller) transmits to the MC centre the messages of ADB's location status at the intersection and of traffic conditions. — Messages that IoT infrastructure transmits to the MC centre: — ADB's location status at the intersection, traffic conditions.
6)	The MC centre informs the ADB of the optimum route determined using the traffic condition messages transmitted from IoT infrastructure and other ADBs. — Message that the MC centre transmits to the ADB: — the optimum route.
7)	An ADB transmits to in-vehicle passengers an announcement for the next station.
8)	An ADB arrives at the pick-up/routine station and the smart bus station transmits to the MC centre the messages of the ADB's arrival. — Message that the smart bus station transmits to the MC centre: — the ADB's arrival time at the station.
9)	An ADB opens the door and transmits the message that the door is open to the MC centre. — Message that ADB transmits to the MC centre: — status of the ADB's door operation.
10)	Alighting passengers tag a prepaid ticket or a deferred payment card on the in-vehicle ticket identification device and alight the ADB. — Messages that alighting passengers transmit to the ADB: — alighting date and time, alighting station ID.
11)	Boarding passengers tag a prepaid ticket or a deferred payment card on the in-vehicle ticket identification device and board the ADB. — Messages that boarding passengers transmit to the ADB: — boarding date and time, boarding station ID, alighting station ID.
12)	An ADB examines the agreement of the passengers' information between transmitted ones from the MC centre and those of tagged ones for the identification and the numbers of passengers boarding/alighting. — Message that the ADB transmits to the MC centre: — passenger identification.
13)	An ADB identifies the number of boarding and alighting passengers in relation to the number of taken seats by using the ticket identification device, calculates the number of empty seats, and informs the MC centre, smart bus station, and passengers at stations with the number of available seats.
14)	An ADB closes the door and starts driving to the next station referred to by the MC centre. — Messages that smart bus station transmits to the MC centre: — departure time at the station, time at which the ADB skipped the station. — Message that the ADB transmits to the MC centre: — status of the ADB's door operation.
15)	An ADB announces the next station to in-vehicle passengers.

Figure 4 illustrates the data exchange flow for Use case 1-2.

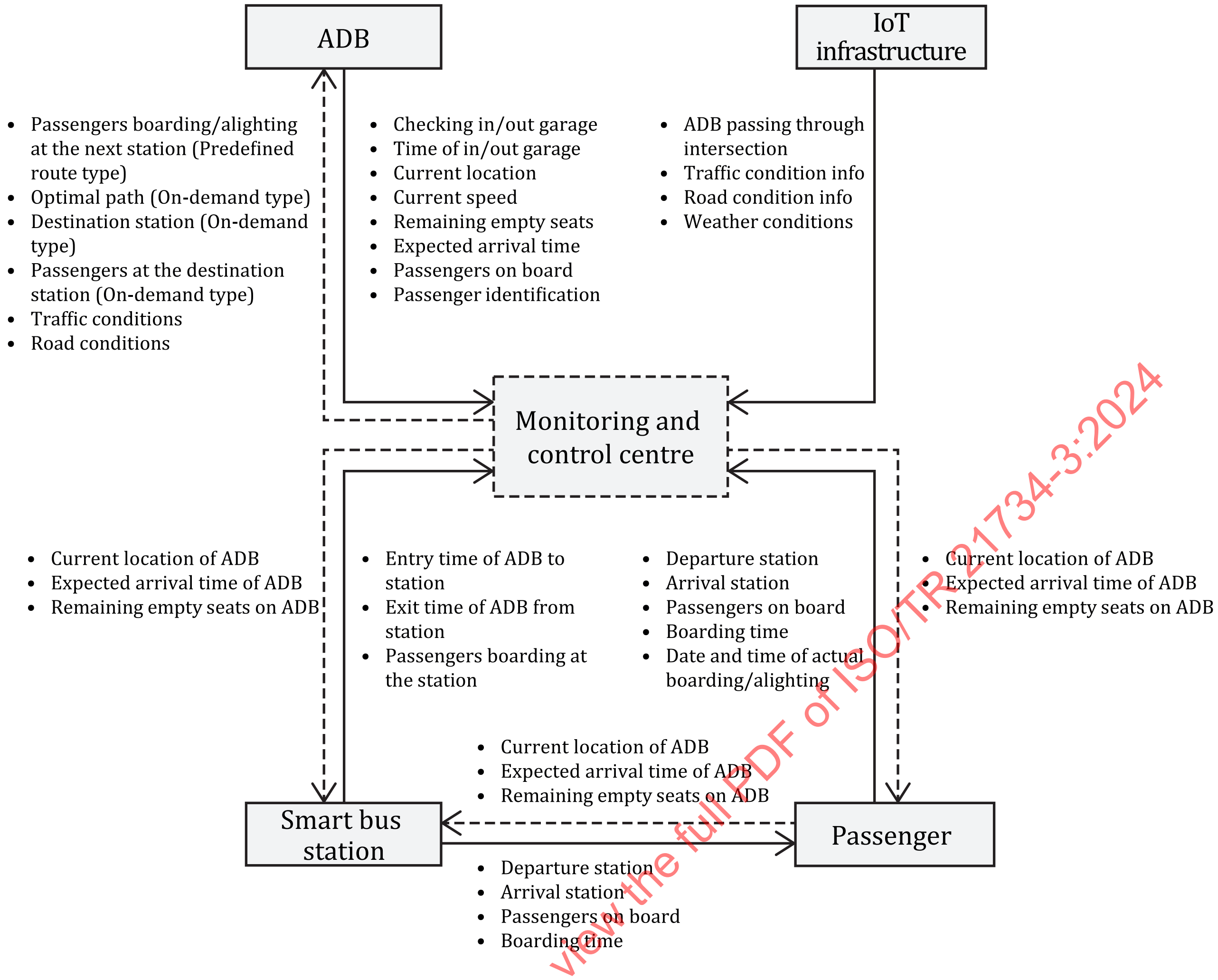


Figure 4 — ADB on-demand driving service use case

5.3 Passenger payment handling service

5.3.1 General

In conventional buses, the bus driver identifies the passenger's destination and informs them of their fares. The passengers then pay their fare by cash or a transit card. With the ADB service operations, a station kiosk, a mobile application, and a ticket vending machine can take charge of the driver's fare management role while the MC centre manages the fare calculation and related data. The station kiosk is a device installed at the smart bus station for boarding reservations and fare collection; mobile application is a software program that can carry out a boarding reservation and fare collection by mobile device.

The ADB fare system can adopt either a uniform fare system, in which a fare applies equally across sectors, or a variable fare system in which the fare varies depending on distance, sector and zone. Prepayment or deferred payment is applicable depending on the payment system. With the prepaid method, passengers who pay the fare in advance using a station kiosk or a mobile application prior to boarding an ADB, will be issued with a one-time ticket or a one-time mobile ticket. With the deferred payment method, the passengers tag a contact transit card (credit card, mobile phone NFC) on the transit card terminal when boarding and alighting an ADB. The total fare amount is then billed to the passenger. The ADB payment types can be classified as shown in Table 4.

Table 4 — Payment types

Item	Fare system	Payment method	Fare adjustment
type 1	uniform fare	prepaid	×
type 2	uniform fare	deferred payment	×
type 3	variable fare	prepaid	○
type 4	variable fare	deferred payment	×

If the passengers board and alight differently from their initial reservation, the prepayment of the uniform fare system does not cause a fare-related problem. However, the prepayment of the variable fare system requires the passenger to pay or redeem the difference between the fares for the initially planned trips and changed final trips. Therefore, a fare adjustment measure is needed for the fare system that differs between countries and regions.

In the case of additional trips, a predetermined deposit amount can be added on top of the ticket price when purchasing a prepaid one-time ticket. The deposit would then be fully refunded when the passenger alights at the station they originally reserved. While some penalties would be debited from the deposit as additional fares when the passenger deviated from their initial travel reservation, what is remaining would be refunded. Therefore, the calculation of a prepaid one-time ticket price results in the sum of the ADB fare, the deposit for a one-time ticket reuse, and the deposit for the additional amount.

1) Calculation of the initial one-time ticket purchase cost is as follows:

$$T=A+R+N$$

where

T is the ticket price;

A is the fare;

R is the deposit of calculation of purchase cost of a one-time ticket;

N is the deposit for the additional amount to pay when the reservation information differs from destination.

2) Refund when the passenger alights as the reservation information states is calculated as follows:

$$r_T=R+N$$

where r_T is "refund true".

3) Refund when the passenger alights differently from what the reservation information states is calculated as follows:

$$r_F=R$$

where r_F is "refund false".

As a summary, Table 5 describes an example calculation of the purchase cost of a one-time ticket.

Table 5 — Example calculation of the purchase cost of a one-time ticket

Item		Amount (KRW)
Fare		1 500
Deposit	Deposit for the reuse of one-time ticket	500
	Deposit for the additional amount to pay when the reservation information differs from the destination	700
Total		2 700

An example of the transit fare penalty described in the use case in 5.3.2 is as follows.

The Republic of Korea's Gyeonggi-do bus system charges fare proportionately to distance travelled. It charges a basic tariff within the basic section (10 km) and then charges an additional amount of KRW 100 for every 5 km up to KRW 700. Passengers' travel distance is measured with the tagging of the transit card when boarding and alighting. If a passenger forgets to tag a transit card when alighting, the exact travel distance is not known. The maximum additional fare of KRW 700 is charged because the passenger is assumed to have travelled the longest distance possible.

An example of the transit ticket deposit described in the use case in 5.3.3 is as follows.

The Republic of Korea's subway system charges a deposit of KRW 500 in addition to the ticket price when a passenger purchases a one-time ticket. The deposit of KRW 500 is refunded when the passenger returns a transit card at the end of their subway trip. With Japan's Suica, a prepaid rechargeable transit card, JPY 500 is debited from the charged fare as a deposit and refunded when the passenger returns the card after the trip. In Singapore, the subway (MRT) charges a deposit of SGD 1 in addition to the ticket price when a passenger purchases a one-time ticket. The deposit of SGD 1 is refunded to the passenger when the passenger returns the transit card within a month after the subway trip.

5.3.2 Use case 2-1: Prepaid fare system

Table 6 describes a prepaid fare system use case (Use case 2-1), including definition, actors, premise and description of the use case.

Table 6 — Use case 2-1: Prepaid fare system

Item	Prepaid fare
Definition	Passenger prepays the ADB fare.
Actor	— The ADB — Smart bus station — Station kiosk — The MC centre — The passenger
Premise	A passenger intends to use an ADB.
Description	
1) Passengers enter the boarding information of an ADB by using a station kiosk or a mobile application. — Information that passengers provide to the station kiosk for the boarding ticket: — alighting station, the number of passengers on board, boarding time. — Information that passengers provide to the mobile application for the boarding ticket: — boarding and alighting stations, the number of passengers on board, boarding time. 2) Passengers are notified of the fare by the message appearing on the station kiosk or the mobile application. 3) When the fare is confirmed, passengers pay it using the station kiosk with a transit card or cash or using the mobile application with mobile authorization.	

Table 6 *(continued)*

4)	When the station kiosk confirms the passenger's payment, the passenger is given a one-time paper ticket. A passenger using the mobile application would receive a one-time mobile ticket. The number of one-time tickets provided is the same as the number of boarding passengers.
5)	A station kiosk and a mobile application transmit the passengers' information to the MC centre. — Messages that the station kiosk and the mobile application transmit to the MC centre: — boarding and alighting stations, the number of passengers on board, boarding time.
6)	The MC centre transmits to ADBs the passenger information obtained from station kiosks and mobile applications. — Messages that the MC centre transmits to the ADB: — the number of passengers boarding and alighting.
7)	The ADB arrives at the smart bus station and opens the door
8)	Alighting passengers tag their tickets on the terminal device in the vehicle and alight. — Messages that alighting passengers transmit to the ADB: — actual alighting date and time, actual alighting station.
9)	Boarding passengers board the ADB and tag their tickets on the terminal device. — Messages that boarding passengers transmit to the ADB: — actual boarding date and time, actual boarding station.
10)	An ADB examines the agreement of the passengers' information between the MC centre transmitted ones and those of tagged ones for passengers' identification and passenger numbers for boarding and alighting. Then the ADB provides the MC centre with the messages of passenger identification. — Messages that an ADB transmits to the MC centre: — the identified information on the number of passengers boarding and alighting at the station
11)	A passenger requests a refund of their deposit from a station kiosk or a mobile application. — Transmitted messages to the station kiosk and the mobile application regarding passenger's trip with the ticket: — boarding reservation information (boarding and alighting stations), actual boarding and alighting information (actual boarding and alighting stations).
12)	The station kiosk or the mobile application compare the passenger's originally planned boarding and alighting stations reservation as transmitted by the MC centre with the tagged actual boarding and alighting stations. Then the station kiosk or mobile application refunds the deposit if identical to the reservation or imposes the calculated penalty if different from the passenger's reservation.

5.3.3 Use case 2-2: Deferred payment system

Table 7 describes a deferred payment system use case (Use case 2-2), including definition, actors, premise and description of the use case.

Table 7 — Use case 2-2: Deferred payment system

Item	Deferred payment
Definition	Passenger prepays the ADB fare.
Actor	— The ADB — Smart bus station — The passenger
Premise	A passenger intends to use an ADB.
Description	
1)	A passenger enters the boarding information for an ADB by using a station kiosk or a mobile application. — Information that the passenger provides to the station kiosk for a boarding ticket: — alighting station, the number of passengers on board, boarding time. — Information that the passenger provides to the mobile application for a one-time boarding ticket: — boarding and alighting stations, the number of passengers on board, boarding time.

Table 7 *(continued)*

2)	The station kiosk or the mobile application transmits the passenger's information to the MC centre. — Messages that the station kiosk or the mobile application transmits to the MC centre: — boarding and alighting stations, the number of passengers on board, boarding time.
3)	The MC centre transmits to the ADB with the passengers' information obtained from the station kiosk or the mobile application. — Messages that the MC centre transmits to an ADB: — the number of passengers boarding and alighting at the station.
4)	An ADB arrives at the smart bus station and opens its door.
5)	When the passenger tags their ticket on the transit card terminal device in an ADB for board, the basic fare is charged to the passenger. — Messages that the boarding passenger transmit to the ADB: — actual boarding date and time, actual boarding station.
6)	An ADB examines the agreement of the passenger information (comparing information transmitted by the MC centre with information transmitted through tagged tickets) for the boarding and alighting passenger identification and the number of passengers. — Messages that the ADB transmits to the MC centre: — passenger identification.
7)	An ADB departs for the next station.
8)	An ADB arrives at the station and opens the door.
9)	When the passenger tags their ticket on the transit card terminal device in the ADB for alighting, the additional fare is charged to the passenger if the passenger deviated from their original destination. — Messages that the alighting passenger transmits to the ADB: — actual alighting date and time, actual alighting station ID.

Figure 5 illustrates the data exchange flow for Use case 2-2.

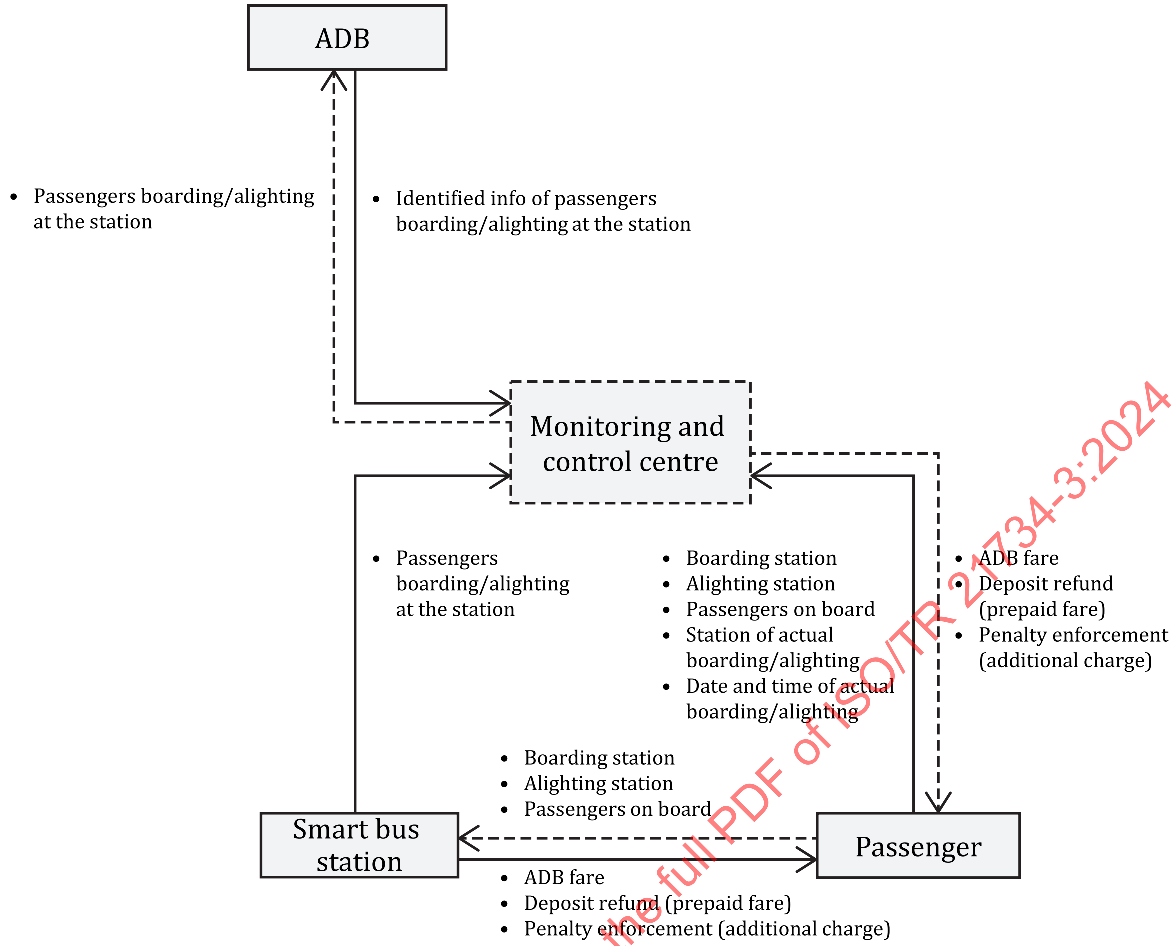


Figure 5 — Passenger payment service use case

5.4 ADB emergency response service

5.4.1 General

Types of emergency events that could occur during an ADB's operation include traffic accidents (vehicle to vehicle, vehicle to person, etc., and vehicle alone), automated driving system error, passengers' emergencies due to health problems or conflicts between passengers, for example.

When in an emergency event, if the ADB is incapable of handling the emergency, the right of automated driving control is given to the in-vehicle operation manager or the operation manager at the MC centre. If an ADB has an in-vehicle operation manager on board in preparation for emergencies, the manager directly identifies the situation, helps passengers to evacuate, and calls first responders such as police officers or fire fighters for support. When the in-vehicle operation manage is absent, the MC centre manager handles the emergency.

5.4.2 Use case 3-1: Occurrences of accidents and autonomous driving system errors

Table 8 describes the use case of occurrences of accidents and autonomous driving system errors (Use case 3-1), including definition, actors, premise and the description of the case.

Table 8 — Use case 3-1: Occurrences of accidents and autonomous driving system errors

Item	Accidents and autonomous driving system errors
Definition	Response to the occurrence of an accident or a system error during ADB driving.
Actor	— The ADB — The MC centre — IoT infrastructure — Smart bus station — Passengers
Premise	Occurrence of accident during ADB driving
Description	
1)	An accident or a system error occurs during the ADB driving.
2)	An ADB transmits to the MC centre the messages of an accident or a system error and hands over the vehicle control to the in-vehicle operation manager or the MC centre. — Messages that the ADB provides to the MC centre: — ID of the ADB that an accident or a system error has occurred, time of the ADB accident or error, location of the accident or error, time of the system error, location of the system error.
3)	The MC centre detects an emergency event using interior and exterior vehicle cameras and sensors and calls for supports from a medical centre, police station, fire station, etc. (relevant to the emergency situation).
4)	If the ADB does not identify the occurrence of an accident, passengers inform the MC centre of the emergency event through in-vehicle emergency events devices. — Message that the passenger provides to the MC centre: — accident occurrence alarm.
5)	The MC centre transmits emergency event messages to smart bus stations, passengers and ADBs. — Messages that the MC centre provides to stations, passengers and ADBs: — ADB emergency event type, time of emergency occurrence, location of emergency occurrence, emergency event handling.

5.4.3 Use case 3-2: Occurrences of in-vehicle emergencies

Table 9 explains the use case of occurrences of in vehicle emergencies (Use case 3-2), including definition of the use case, actors, premise and description of the case.

Table 9 — Use case 3-2: Occurrences of in-vehicle emergencies

Item	In-vehicle emergencies occurrence
Definition	Response to the occurrence of in-vehicle emergencies (passenger emergency events, safety problems, etc.) during ADB driving.
Actor	— The ADB — The MC centre — Smart bus station — Passengers
Premise	In-vehicle emergencies occur during ADB driving.
Description	
1)	An in-vehicle emergency (passengers' emergency, safety problem, etc) occurs when an ADB is in operation.

Table 9 *(continued)*

2)	The MC centre identifies an in-vehicle emergency event through interior cameras and sensors and emergency response personnel (operation manager) call police stations and fire stations for support.
3)	The passenger in the vehicle provides the emergency information to the MC centre with the in-vehicle emergency alarm call. — Message that a passenger provides to the MC centre: — in-vehicle emergency alarm.
4)	The MC centre transmits emergency messages to stations, passengers and ADBs. — Messages that the MC centre provides to stations, passengers and ADBs: — ID of an ADB in which an emergency occurs, time and location of the ADB in-vehicle emergency and in-vehicle emergency handling, accident occurrence alarm.

Figure 6 illustrates the data exchange flow for Use case 3-2.

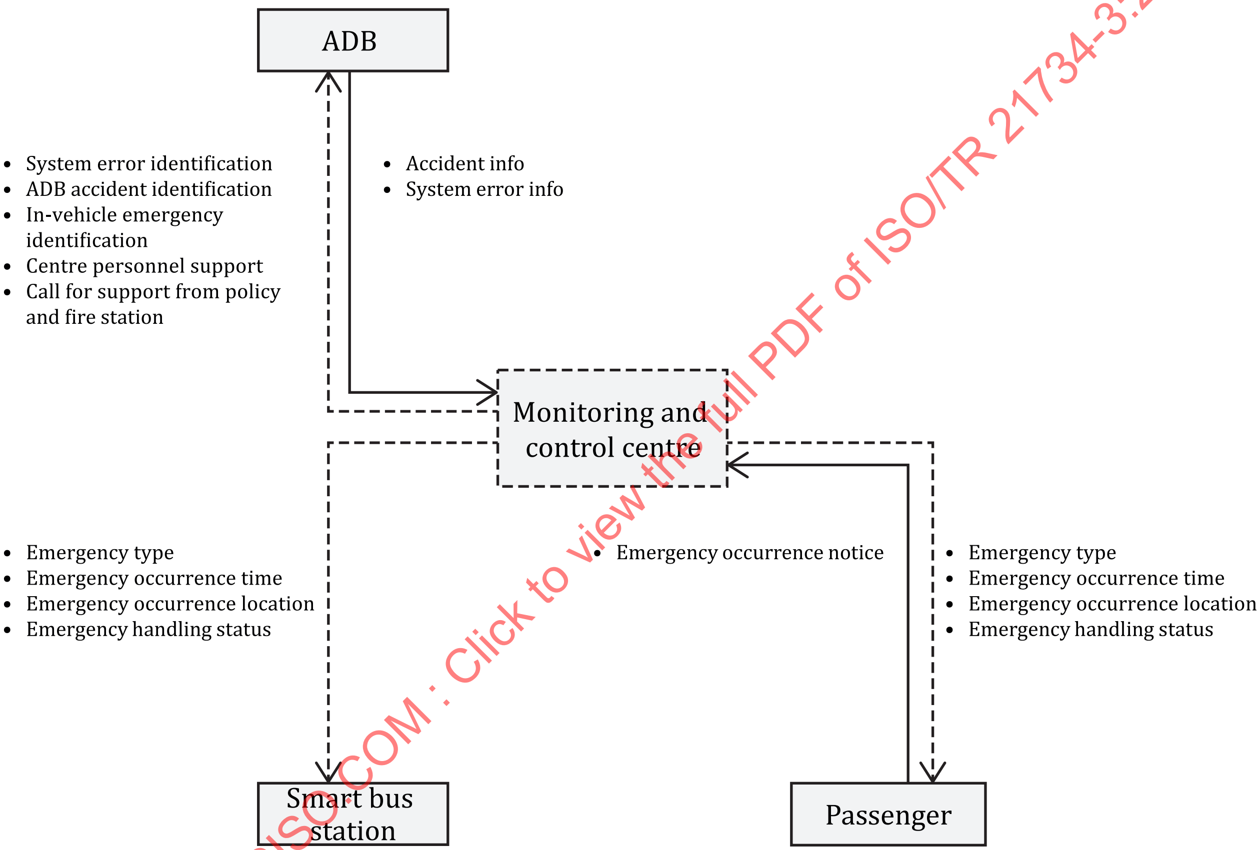


Figure 6 — ADB emergency response service use cases

5.5 Transport information provision service

5.5.1 General

The information collected by the sensor attached to the ADB is specified as autonomous driving message, autonomous driving service message, autonomous driving basic safety message and autonomous driving emergency event message.

The ADM (autonomous driving message) is the message carrying data collected by the ADB sensors. Types of ADM and the data sets are as follow:

— vehicle driving message: speed, acceleration/deceleration, angular acceleration, etc.;

— vehicle positioning message: latitude, longitude, GNSS mode, etc.;

— route message: route ID, stopover, destination, etc.;

— steering control message: steering direction control, steering speed, acceleration, brake, etc.;

— sensed object message: object type, distance to object, etc.;

— decision message: system decision message (departure, stop, waiting, transmission information, etc.);

— sensor message: fail/safe, re-run message, etc.;

— autonomous driving status message: fail/safe, passenger information, etc.

The ASM (autonomous driving service message) refers to service messages such as automated driving control, road driving and pedestrian protection. The collected information includes the following:

— service unique ID;

— service purpose;

— service provision location, etc.

The BSM (basic safety message) refers to the basic information for safe driving such as communication and system status. The types of messages and carrying data include the following:

— communication status: fail/safe;

— weather information: clean, rainy, cloudy, etc.;

— system status: fail/safe.

The EEM (emergency event message) refers to the information for responding to the vehicle emergency and driving requirements during ADB operating. The collected information includes the following:

— emergency event ID;

— emergency occurrence location, etc.;

Traffic condition messages refer to the information on the traffic condition that can be collected from ADB sensors or IoT infrastructure. The collected information includes the following:

— road driving condition;

— traffic volume;

— incident on the road, etc.

5.5.2 Use case 4: Transport information provision service for safe operation of ADBs

Table 10 explains the use case of transport information provision services for safe operation of ADBs (Use case 4), including definition of the use case, actors, premise and description of the case.