INTERNATIONAL STANDARD

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

Part 1:
General framework

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 1: Cadre général

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Contents

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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 the development and deployment of the ADB has been accelerated in recent years, exceeding the speed of automated passenger vehicles.

The overall purpose of this document is to provide technical standards at the international level to ensure the safety and connectivity of the ADB operating as a public transport mode. The objectives of this document include building a framework for operating ADBs in public transit networks, developing performance test methods and procedures in terms of safety and connectivity of ADBs that require communication with roadside infrastructure and with the monitoring and control centre, and providing the service framework and use cases as references for field applications.

From the connectivity perspective, the ADB needs to be connected with traffic signal networks for vehicles and pedestrians, with the monitoring and control centre for bus operation, and with other relevant infrastructure to ensure its effectiveness as a public transport mode. In terms of safety, the ADB needs to be embedded with automated vehicle functions to connect with the wireless signal control system and to be ready to respond to unexpected situations involving other road users such as pedestrians and bicyclists.

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

Therefore, this document is intended to benefit public transport operators, relevant governing authorities of public transport, and industrial stakeholders.

This document provides the basis for the development of performance testing for connectivity and safety functions of ADB on a national and international level.

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

Part 1:
General framework

1 Scope

This document specifies the general framework and the automated driving bus (ADB) system components for operating ADBs in public transport networks, including:

a) the general framework and the operation scheme for public transport systems in cooperation with ADBs;

b) definitions of system components for operating ADBs; and

c) definitions of functions and requirements of each system component for providing transport services with ADBs.

This document is applicable to bodies in public transport systems and services including transportation operators, public transport governing authorities and relevant industries.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

3.1.2
operation safety
set of minimum safety requirements ensuring an automated driving bus's expected functions as a public transport mode when operating in cooperation with road infrastructure

Note 1 to entry: Road infrastructure includes exclusive bus lanes, bus stations, signalized and non-signalized intersections, crosswalks for pedestrians and bicyclists, general traffic signals, bus priority signals, and monitoring and control centres.

3.1.3
safety function
set of minimum functions related to the safety of an automated driving bus (ADB) as a public transport mode, facilitating passengers on board, at bus stations and responding to emergency events that can arise both inside and outside of ADBs

3.1.4
connectivity of ADB
connectivity performance of an automated driving bus (ADB) system that ensures the stable and reliable provision of the information feed required to provide safe public transport services

3.1.5
transport information
set of information required for automated driving buses (ADBs) to function as a public mode

Note 1 to entry: This includes operation information exchanged between road infrastructure and ADBs themselves, bus priority signal information, passengers' boarding and alighting information, roadside signage equipment information, battery charge and discharge information (if the bus is an electric bus), etc.

3.1.6
ADB system framework
framework for ensuring stability and safety of automated driving bus system operations through interactions among automated driving bus (ADB) system components

3.1.7
ADB system components
required components for operating an automated driving bus (ADB) system

Note 1 to entry: The components include the ADB, the monitoring and control centre, Internet of Things infrastructure, smart bus stations and users.

3.1.8
ADB service framework
framework for transport services provided by the automated driving bus (ADB) system through interactions among the ADB service components, consisting of the ADB, the monitoring and control centre, passengers, smart bus stations and Internet of Things infrastructure

3.1.9
monitoring and control centre
MC centre
system that ensures the safe operation of the automated driving bus (ADB) system by monitoring and controlling the fleet through collecting data from each component (the ADB, ADB users, Internet of Things infrastructure, smart bus stations), processing the data, and providing comprehensive information to each component

3.1.10
IoT infrastructure
Internet of Things infrastructure
sensor system collecting road traffic and environment data at intersections, pedestrian crosswalks and smart bus stations

Note 1 to entry: The collected data is transmitted to the monitoring and control centre and automated driving buses (ADBs) directly through communication networks.

3.1.11
smart bus station
facility where an automated driving bus stops and passengers safely board, alight, and wait for an automated driving bus

Note 1 to entry: The smart bus station is installed with a station kiosk and Internet of Things infrastructure to communicate with the monitoring and control centre.

3.1.12
station kiosk
device that is installed at a smart bus station and assists passengers with their boarding reservations, the payments and ticketing

3.1.13
pickup station
smart bus station which is designated by the monitoring and control centre and at which it is intended that an automated driving bus (ADB) will pick up passengers when operating a demand-responsive route

3.1.14
routine station
fixed smart bus station that is designated for automated driving buses (ADBs) as a location to stop at for picking up and dropping off passengers

3.1.15
one-time boarding ticket
boarding ticket that is used for one round trip

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

3.1.16
ADB users
general passengers who are the primary party receiving mobility services and legal entities providing mobility services to the passengers including local authorities and private bus operators

3.1.17
passenger
one of the automated driving bus (ADB) users receiving ADB mobility services

3.1.18
operator
one of the users who is responsible for operating and managing the automated driving bus (ADB) systems

3.1.19
operation manager
person responsible for monitoring the automated driving bus (ADB) fleet operation and responding to emergencies in the monitoring and control centre

3.1.20
in-vehicle operation manager
person responsible for monitoring automated driving bus operations and responding to emergencies in an automated driving bus (ADB) vehicle

3.1.21
on-demand route
operating measure with flexible schedule and route to respond to passengers' demands within the delineated service area

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

Note 2 to entry: An automated driving bus (ADB) can deviate from a fixed route to an on-demand route in response to the passengers' demand. However, the automated driving bus should stop at a smart bus station.

3.1.22
automated driving message
ADM
message carrying data collected by a suite of automated driving bus (ADB) sensors

Note 1 to entry: The types of messages and the data each message includes are as follows:

3

— ADB driving messages include speed, acceleration and deceleration, angular acceleration, etc.

— ADB positioning messages include latitude, longitude, global navigation satellite system mode, etc.

— Route messages include a route ID, stopovers, the destination, etc.

— Route following messages include orientation control, control speed, acceleration, brake, mission, etc.

— Object messages include object type, distance to object, etc.

— Decision messages include system decision messages such as departure, stop, waiting, transmission information, etc.

— Sensor messages include fail or safe, rerun message, etc.

— Automated driving status messages include fail or safe, passenger information, etc.

3.1.23
automated driving service message
ASM
service message such as automated driving control, road driving and pedestrian protection, and the collected information which includes service unique ID, service purpose and service provision location, etc.

3.1.24
basic safety message
BSM
message providing basic information for safe driving such as communication status, weather information, system status, etc.

3.1.25
emergency event message
EEM
message providing information for responding to the vehicle emergency and driving requirements when operating

Note 1 to entry: The collected information includes emergency event ID, location, time of the emergency, etc.

3.1.26
routine data set
data set that the two components (automated driving bus and monitoring and control centre) regularly exchange without a request from each side

3.1.27
event data set
data set provided when requested by automated driving buses (ADBs) or the monitoring and control centre

3.1.28
backup data set
data sets stored once the automated driving buses (ADBs) finish one round of the route

3.1.29
target location
specific point on an automated driving bus route where an automated driving bus is aiming to move on

3.1.30
target vehicle
vehicle that can form a conflict with an automated driving bus by driving in opposite directions or merging into the same lane, at the same location, and at the same time

3.1.31
target object
pedestrian, bicycle rider and other non-human object that can potentially form a conflict with an automated driving bus (ADB)

3.2 Abbreviated terms

BIS   bus information system

BMS   bus management system

BRT   bus rapid transit

DSRC   dedicated short range communication

GNSS   global navigation satellite system

IoT   Internet of Things

LTE   long term evolution

RSE   roadside equipment

RSU   roadside unit

SOH   state of health for electric vehicle battery

TOD   transport-oriented development

V2I   vehicle to infrastructure

V2X   vehicle to everything

WAVE   wireless access for vehicle environment

4 General information

4.1 ISO 21734 series overview and structure

The ISO 21734 series specifies documents and standards related to the connectivity and safety functions required to support the implementation of the ADB system in the public transport network. Unlike autonomous driving vehicles which make operation manoeuvres based on their own sensor data, ADBs are connected with the MC centre and Internet of Things (IoT) infrastructure for obtaining information that is critical for ensuring safety but undetectable by their own sensors.

This document (ISO 21734-1) defines five components of the ADB system that are required for safe operations, the objectives and scopes of performance tests in terms of connectivity and safety for ADB operations, and service framework and use cases.

ISO 21734-2:—[1] specifies the performance requirements and test procedures for ADBs to operate in existing public transport systems. It specifies appropriate types of test methods and performance standards to ensure the overall safety of public transport operations.

ISO/TR 21734-3:—[2] specifies the service framework and uses cases as a technical reference for field applications. The service framework is composed of software that utilizes components of ADBs,

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1) Under preparation. Stage at the time of publication: ISO/AWI 21734-2:2022.

2) Under preparation. Stage at the time of publication ISO/DTR 21734-3:2022.

passengers, IoT infrastructure, smart bus stations, the MC centre and other elements for serving passengers.

4.2 Purpose of the ISO 21734 series

The overall purpose of ISO 21734 series is to set performance standards, testing methods and procedures for operating ADBs when adopted for a conventional bus system.

The purpose of ISO 21734–1 (this document) is to provide general information on the ISO 21734 series, including the basic structure of the series. It further specifies five ADB system components that are required for ADBs to operate in existing bus system and use cases.

The purpose of ISO 21734-2 is to specify performance requirements to be adopted safely as an ADB system in terms of safety and connectivity and to specify test procedures for ensuring safety and connectivity of the ADB system operation.

The purpose of ISO 21734-3 is to specify the ADB system service framework and use cases as a reference for application.

5 ADB system Components

5.1 Overview

The ADB system shall consist of five components as shown in Figure 1: ADBs, the MC centre, IoT Infrastructure, smart bus stations and ADB users.
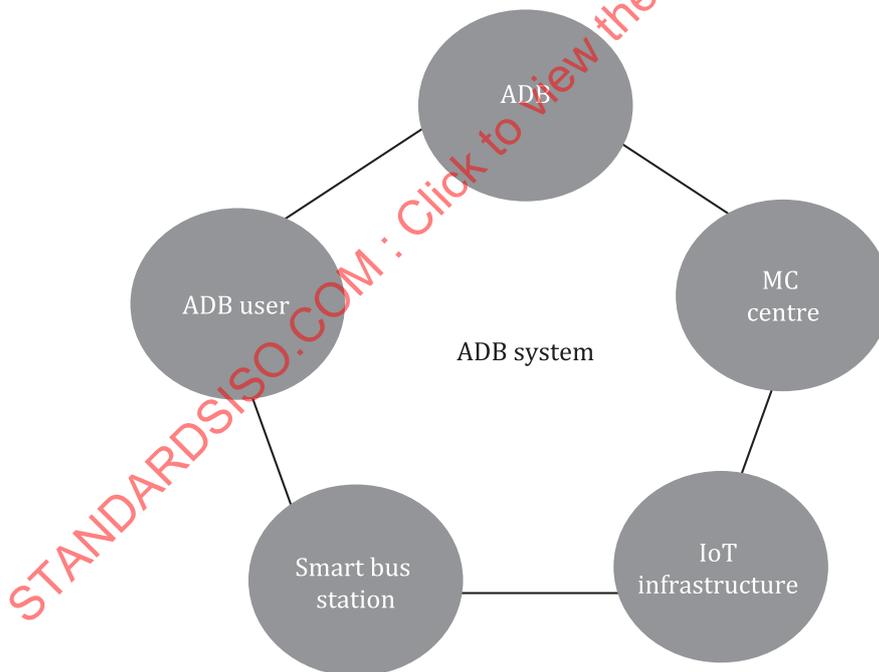
Figure 1 — Five components of ADB system

5.2 ADB component

The ADB component is the most important component; all others except ADB user are supporting the safe driving of ADBs. An ADB vehicle shall be designed for carriage of passengers with capacity of more than nine persons and shall be embedded with level 4 automated vehicle technologies or higher based on SAE J3016.

The ADB shall be capable of operating on fixed and on-demand routes, communicating with the MC centre and IoT infrastructure, detecting traffic signals and other objects that may deter its safe operation, allowing passengers to board and alight at a smart bus station regardless of the existence of a driver on the ADB, along with emergency response features.

5.3 MC centre component

The MC centre is specified as a system that ensures the safe operation of the ADB system by monitoring and controlling the fleet. This is achieved by collecting data from each component (ADB, ADB users, IoT infrastructure and smart bus station), processing the data, and providing comprehensive information back to each component.

From the controlling perspective, the MC centre shall be equipped with a bus information system (BIS) and a bus management system (BMS) that collect real time bus operation data at smart bus stations and provide bus information to the passengers. The real time bus information data includes traffic signal information, fleet and fare management information and passenger information.

From the monitoring perspective, the ADB system is required to manage not only bus schedules but also payments, passenger boarding and alighting and emergency responses. For responding to emergency events, an ADB system is required to control the site both inside and outside of the vehicle by connecting emergency first responders including medical centres, police office and fire stations.

Therefore, the MC centre shall be able to collect data from and provide information back to ADBs, ADB users, smart bus stations and IoT infrastructure through communication networks.

5.4 IoT infrastructure component

The IoT infrastructure is specified as a complementary system that enhances safe operation of ADBs. It is installed on roadside infrastructure and facilities for collecting relevant environment data including road, traffic, and weather conditions through direct sensing and being fed from other components. The data collected by the IoT infrastructure is then provided to ADBs and the MC centre (if necessary).

IoT infrastructure shall be able to update information on ADB operation and the relevant surroundings in real time.

5.5 Smart bus station component

The smart bus station is specified as a physical space with relevant systems that enable passengers to board and alight to ADBs and enhance passenger services. It shall be able to allow passengers to get on board and alight an ADB at a smart bus station they planned for and provide arrival and departure information.

With the ADB system, the bus station shall be able to provide passenger information including a count of how many passengers expressed their intention to board a specific ADB at a specific station, fare and payment as they expressed their intention to board, etc. It also serves to provide ADBs with road traffic conditions as supplementary information when making decisions for departure from the station and merging into the main lane, as well as managing stop lots by assigning a proper lot to a specific ADB if necessary. To carry out such functions, the smart bus station shall be equipped with the stop sign, passenger facilities, and a device that receives and presents bus information, as well as sensor devices to detect road traffic conditions and kiosk devices for allowing passengers to express their intention to board an ADB and to collect their fares.

5.6 ADB user component

The ADB user is specified as general passengers who are the primary party receiving mobility services and legal entities providing mobility services to the passengers including local authorities and private bus operators.

Passengers should be able to express their departure and destination stations prior to boarding or upon boarding. They should also be able to evacuate by themselves if an emergency event occurs. Therefore, the passengers are provided with equipment and appropriate guidance allowing them to carry out such functions.

The legal entities serving public mobility services with the ADB system shall provide passengers with equipment or tools for route scheduling, self-payment systems and emergency response guidelines.

6 ADB system framework

6.1 Overview

While operating ADB vehicles in the public bus system, ADB system components should cooperate with each other to ensure the stability and safety of the system. Within the ADB system framework, the major role of connectivity for the five ADB components is exchanging information that facilitates operational safety. This clause explains which part of the ADB system should be tested and evaluated for safe operation in terms of safety and connectivity.

6.2 Safety aspect of ADB system framework

6.2.1 General

The safety aspect of the ADB system is specified as the ADB's operational performance cooperating with the system hardware including ADBs, the MC centres, IoT infrastructure, smart bus stations, and passenger devices. The focus of the safety performance test is to evaluate the operational safety of the ADBs in the transport system. Therefore, safety standards for ADB systems are related to the operational performance of ADBs with the hardware of the four other components: MC centre, IoT infrastructure, smart bus station, and ADB user.

Furthermore, an ADB system can encounter humans throughout their operation, including passengers, pedestrians, bicycle riders and other manual drivers. Since the major objective of the ADB is to increase public transport safety by minimizing human errors, an ADB should be able to effectively cope with any constraints with other road user throughout its operation. Examples include interactions with manual bus drivers on the network, interactions with pedestrians and manual bus drivers at smart bus stations, and interactions with manually driven passenger vehicles and other road users when passing along the routes.

The following subclauses explain the ADB system framework that composes safety of the system.

6.2.2 Road infrastructure

6.2.2.1 General

Road infrastructure that can be included in bus routes are intersections (three-way, four-way and roundabout), pedestrian crosswalks, overpasses, tunnels, exclusive bus lanes, etc. Within this context, this document mainly focuses on intersections, pedestrian crosswalks and smart bus stations that are related to the ADB operation.

6.2.2.2 Intersections

The intersections are categorized by types of traffic signalization and the road geometry. Depending on the traffic signal provisions, the intersections are specified as signalized or non-signalized intersections. Depending on the road geometry, they are specified as three-way, four-way or roundabout intersections. The safety performance evaluation of an ADB on intersections tests its general driving manoeuvres passing through an intersection and responding to emergency events between pedestrians and other vehicles by sensing the physical structure of the intersection itself and by being fed traffic signal information from the MC centre.

6.2.2.3 Pedestrian crosswalks

The pedestrian crosswalk is specified as signalized and non-signalized crosswalks. Pedestrian crosswalks can be installed with IoT infrastructure as optional safety equipment. The safety performance of an ADB on crosswalks is tested by evaluating its behaviour on crosswalks in sensing physical structure and objects including pedestrians and bicycle riders as well as traffic signals fed by the MC centre and IoT infrastructure.

6.2.2.4 Smart bus station

The smart bus station is specified as a place where passengers board and alight from an ADB. Smart bus stations are located on the roadside or on exclusive bus lanes with or without a bay. The safety performance of an ADB at a smart bus station is tested by evaluating its capability to select a stop lot and to avoid conflicts that can arise between passengers, other buses both in front and behind during boarding and alighting, and other vehicles when merging into main lanes.

A smart bus station shall be able to provide passenger information through the MC centre and traffic condition information surrounding the smart bus station through IoT infrastructure to assist ADBs for choosing their driving manoeuvres.

6.2.3 Safety performance test elements of the ADB operation

ADBs shall be able to safely operate on the intersections, pedestrian crosswalks and at smart bus stations. The ADB operation manoeuvres with this road infrastructure include but are not limited to:

— making left and right turns on a signalized intersection and driving straight forward on a signalized intersection;

— stopping and moving forward at pedestrian crosswalks, regardless of traffic signalization;

— stopping at and departing from a smart bus station both with and without a bus bay and merging into the main lane;

— identifying emergency events and responding properly.

Figure 2 outlines ADB system performance test elements for ADB operation.
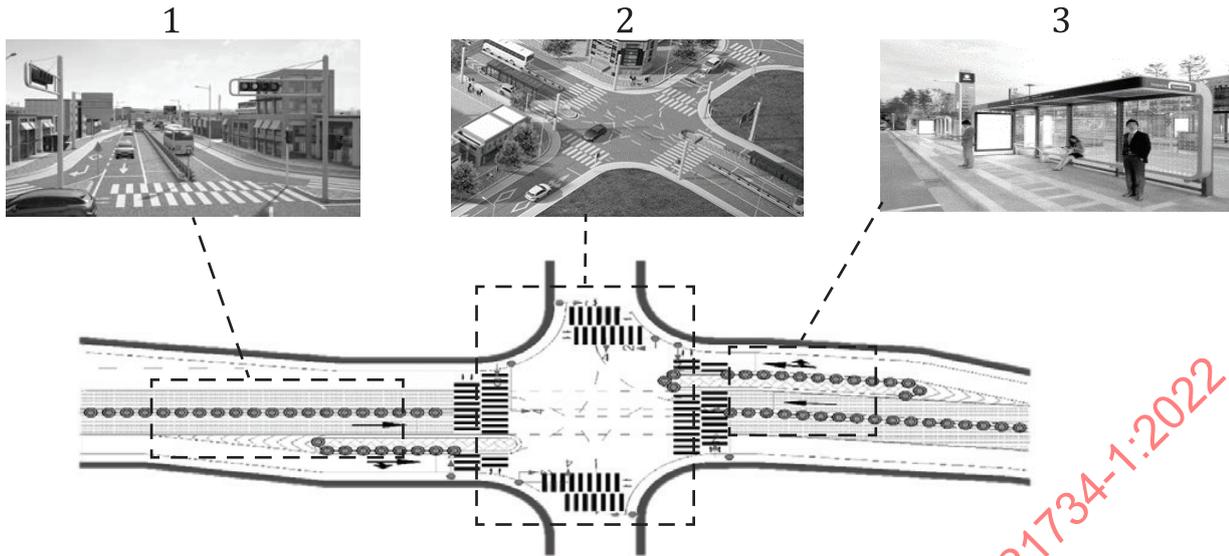
Key

1 exclusive bus lane

2 signalized intersection

3 smart bus station

Figure 2 — System performance test elements for ADB operation

6.3 Connectivity aspect of the ADB system framework

6.3.1 General

The connectivity aspect of the system component is related to information simultaneously exchanged between each component for safe ADB operation. The information exchanged includes traffic signal information, dynamic road and traffic information, weather and road conditions, etc.

The evaluation of the connectivity performance of an ADB system is specified so as to test the stability of V2I interactions among the ADB components through communication networks to support ADBs making an operational decision considering information fed from the MC centre and IoT infrastructure. The following subclauses explain the framework composing the connectivity of the ADB system.

6.3.2 Connectivity infrastructure

The connectivity infrastructure is specified as the hardware and software that ensure the stable and accurate exchange of information required for the ADB operation between the MC centre and IoT infrastructure. This includes GNSS for vehicle positioning and wireless communication networks including LTE, WAVE, and/or Wi-fi for IoT infrastructure, etc. The following points apply:

— The traffic signal control infrastructure shall include the authority and entity of traffic signal controllers (the MC centre, local signal controller, road RSU), types of traffic signal controls (actuated traffic signal/TOD), types of pedestrian and bicycle signal controllers (TOD, demand-responsive by pedestrian).

— Types of signal operations shall include bus priority signals (buses, emergency vehicles), provisions of traffic signals (communications, traffic lights), types of V2I communication (DSRC, LTE, etc.).

— Types of information provision shall include message types, the data architecture and types of data sets for exchange among ADB components.

— IoT infrastructure shall include types of smart bus station signal provisions and required equipment.

— The ADB is required to provide vehicle operation information to the MC centre. In some cases, road infrastructure plays a role as a medium for connecting the MC centre with the ADBs.

6.3.3 Connectivity performance test elements of ADB operation

The performance of connectivity is specified as the quality of information exchanged among ADB components, including frequency and accuracy, which is required for ADB operations, as well as their fallback measure for responding to emergency events. The required information for the ADB operation includes traffic signal operations, the ADB's operational information (including service intervals, number of occupants in the vehicle, fare managements, etc.) and recognition and warning messages for emergency events and their responsive procedure information, etc.

The test elements for connectivity performance shall include, but not be limited to:

— the ADBs' operational information from/to the MC centre per second;

— traffic signal information from the MC centre to ADBs per second;

— smart bus station information including number of passengers for boarding and alighting from the MC centre to ADBs per second;

— smart bus station information for vehicles around the station from IoT infrastructure to ADBs; and

— emergency event information from ADBs to the MC centre.

Specific test elements for evaluating connectivity performance are outlined on Figure 3.
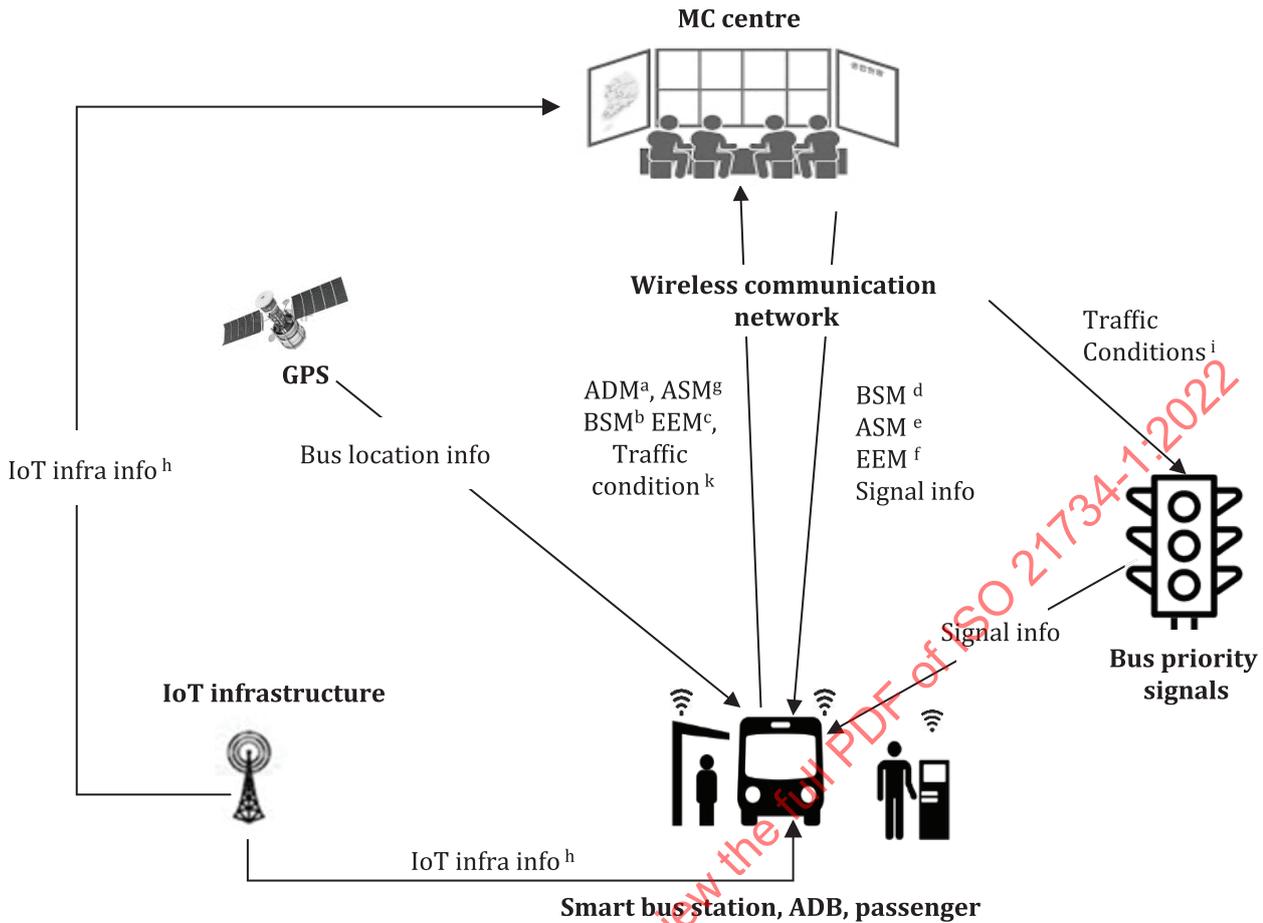
a   Vehicle driving info, positioning info, route message, steering control message, sensed objects, sensor message fail or safe, ADB driving status messages fail or safe.

b   Communication status fail or safe, weather info, system status fail or safe.

d   Communication status fail or safe, weather info, system status fail or safe.

e   ADB operation information, number of passengers boarding/alighting, fare payment information, service ID, service purpose, service provision location.

g   ADB operation information, number of passengers boarding/alighting, fare payment information, service purpose, service provision location.

c   Emergency event ID and location, etc.

f   Emergency event ID and location, responding manoeuvre, etc.

h   Traffic conditions including road driving condition, traffic volume, incidents on the roads, etc.

i   Traffic conditions including road driving condition, traffic volume, incident on the roads, etc.

Figure 3 — Connectivity performance test elements of the ADB operation

6.4   ADB system framework requirements

6.4.1   ADB component requirements

6.4.1.1   Safety aspect of ADBs

ADBs shall be properly functioning automated driving vehicles and shall be equipped with devices for serving passengers as a public transport mode so that the role of human driver in an ADB can become minimal or obsolescence.

The human drivers' role in operating a public bus should be assumed by other components of the ADB system, such as passengers or the system itself if the technical level of the adopted ADB fleet is higher than SAE level 4. The roles of the human driver in the public bus system, other than driving, includes constant monitoring of the surrounding environment on route, maintenance of in-vehicle safety, monitoring passenger payments, observing the location of bus stations and stop lots, providing information to passengers such as bus route, fare level and time schedules, responding to emergency events, providing notifications of bus locations, etc.

To allocate to ADB components such functions as those carried out by a conventional driver, an ADB shall:

— be informed of the number of passengers boarding and alighting at each station and the number of available seats for each bus station to take passenger reservations, etc.;

— be equipped with devices to allow passengers to provide notification of their destination when boarding;

— be equipped with devices to identify emergency events and respond to them;

— be equipped with a manual system for opening and closing doors in response to physically vulnerable passengers (to provide enough time for them) and also for emergency responses; and

— stop with a notification of passengers who change their destination prior to arrival at their initial destination.

6.4.1.2 Connectivity aspect of ADBs

An ADB shall be connected wirelessly with the MC centre, smart bus stations and IoT infrastructure to exchange operational information. The information an ADB exchanges with the MC centre shall include the routine data set, the event data set, and the backup data set.

The routine data set an ADB shall provide to the MC centre includes the functional status of communication between an ADB and other components, the current speed of an ADB and geographic location on the route, the next bus station location, and the status of automated driving. The data the MC centre shall provide to ADBs includes the functional status of communication between an ADB and the MC centre and the status of automated driving.

The event data set an ADB shall provide to the MC centre includes the occupancy of an ADB, camera views of the inside and outside of the vehicle, information when approaching and leaving a smart bus station, passenger boarding and alighting data, emergency events and unplanned stops. The event data set the MC centre shall provide to an ADB includes guidance on emergency response, general notices and in-vehicle camera views.

An ADB shall provide the backup data set to the MC centre regularly, depending on its technical and operational purpose.

The information that an ADB shall exchange with IoT infrastructure is specified as event information directly sensed from the road traffic environment. The IoT infrastructure shall provide an ADB with the signal device ID, the IoT device identification, and the IoT information and data.

6.4.2 MC centre component requirements

In the current BRT system, manually driven bus operational data is collected and processed at the BIS and BMS centre. Then the bus information is fed back to bus stations and passengers' mobile devices. However, the ADB operation system is largely different to the current operation systems as an ADB requires more functions involving the MC centre in terms of collecting information and monitoring and controlling the system.

The MC centre consists of a big-data platform, cloud server and data analysis centre. The MC centre can also provide passengers with various transport information services based on analysed and processed data along with road infrastructure data provided by ADBs.

The information the MC centre collects shall include:

— the ADB's operational data, such as their dynamic locations and vision sensor data captured both from the interior and exterior of ADBs;

— passenger information, such as the number of passengers at a smart bus station for boarding and alighting and fare collection status;

— road traffic and weather conditions on road surfaces, etc.

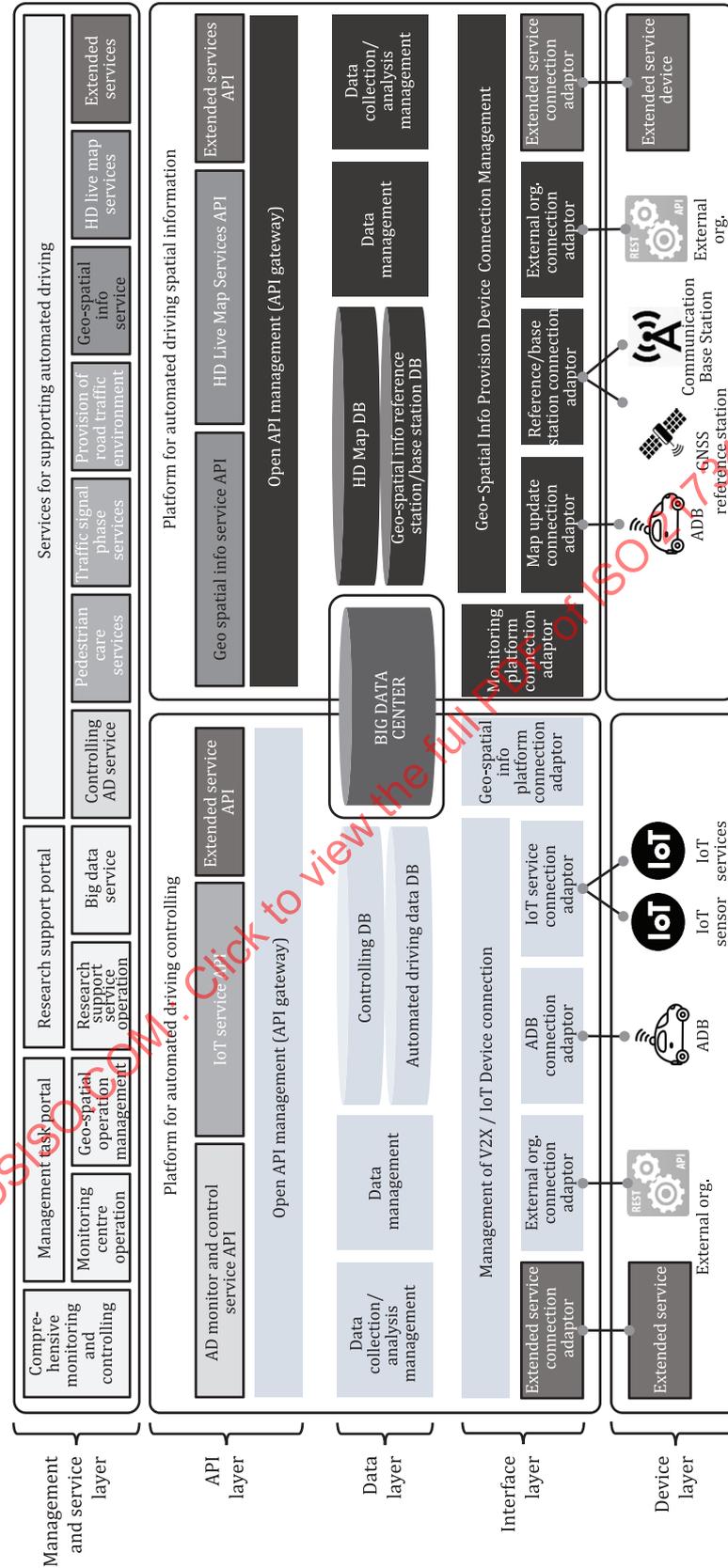The system architecture of the MC centre is provided in Figure 4.

Figure 4 — System architecture of the MC centre

6.4.2.1 Controlling aspect of the MC centre

In terms of control, the MC centre manages the operation of the ADB fleet and takes responsibilities for emergency response. To carry out such roles, the MC centre should be able to connect with other components for providing relevant information.

In terms of control, the MC centre shall:

— provide ADBs with traffic signal information, and static and dynamic map information;

— provide ADBs with information regarding the number of passengers at a specific bus station;

— provide route operation information to ADBs and passengers; and,

— provide operators with ADB operational information and fare revenue.

6.4.2.2 Monitoring aspect of the MC centre

When in an emergency, passengers should be able to evacuate the site and be transported with a substitute mode of transport to their destination or be assisted by other care providers in case of casualties. To deal with such events, the MC centre should be able to detect emergency events, evaluate the site for casualties, and request appropriate first responders for handling of the emergency sites.

In terms of monitoring, the MC centre shall:

— be able to evaluate and analyse event notifications;

— be able to respond to emergency events based on scenarios such as e-call system;

— be able to communicate or connect to ADBs and emergency first responders (police, hospitals and fire stations); and

— be equipped with emergency guidance for passenger evacuations.

6.4.3 IoT infrastructure requirements

The functions of IoT infrastructure are to collect local data through direct sensing and to provide this to ADBs and MC centres. Therefore, the IoT infrastructure shall be able to sense pedestrians, bicycle riders, motorbike riders and other manually driven vehicles. It shall also be able to send data to ADBs through V2X communication.

NOTE   In each use case, an ADB cooperates with an MC centre and the available IoT infrastructure that is providing sensor information via V2X communication. However, roadside equipment (RSE) as described in ISO/TS 19091 transmits sensor information through DSRC for signalized intersection use cases.

The IoT infrastructure shall be:

— installed on the road infrastructure, including roadside, of exclusive bus lanes (if necessary as an option), smart bus stations (regardless of bus bays), pedestrian crosswalks (if necessary as an option), intersections (regardless of traffic island), etc.;

— able to sense pedestrians, bicycle riders, motorbike riders and manually driven vehicles within the coverage of the area;

— able to transmit information to ADBs and pedestrians (if necessary as an option) through a communication network such as DSRC, LTE, Wi-fi, etc.

6.4.4 Smart bus station requirements

The smart bus station infrastructure shall include bus shelter, waiting facilities for passengers, conventional bus information provision equipment, and ADB bus information provision equipment for functioning as a bus station in the public transport system.

In terms of connectivity, the bus station shall be equipped with:

— V2X communication devices to exchange information between ADBs and the MC centre;

— IoT infrastructure for communicating with ADBs;

— vision sensors for detecting passengers and vehicles;

— passenger service devices allowing passengers to express their intention to use an ADB manually; and

— passenger service devices providing ADBs with passenger information.

6.4.5 ADB user requirements

6.4.5.1 Passengers

To receive traffic and ADB operational information that is processed at the MC centre, passengers, ADBs and smart stations are required to install receptive devices and software. Passengers are required to install software on their mobile devices. An ADB is required to install in-vehicle equipment and relevant software. The smart bus station is required to install bus station equipment and relevant software on the station kiosk.

Passengers' mobile device software shall be able to allow passengers to reserve or cancel a seat at a specific smart bus station for boarding and alighting and make a payment for their ride along with provision of other bus operational information.

Smart bus station equipment and relevant software shall be able to facilitate reserving or cancelling a seat for passengers to their destination and shall facilitate making a payment through touch screen or button. Additional services shall be available where required by passengers, such as voice and braille guidance and menu.

In-vehicle equipment and relevant software shall be able to facilitate stating a destination and paying a fare for passengers.

6.4.5.2 Operators

6.4.5.2.1 General

The operators provide ADB services including appropriate public transport services, response to emergencies, and guidance for passengers.

6.4.5.2.2 Types of public transport provision

— **Fixed/flexible route**: In a fixed-route service, an ADB shall operate on regular, pre-determined routes. In a flexible route, an ADB can change routes responding to passengers' demands. In both cases, ADBs shall stop at routine stations.

— **Reservation and cancellation for boarding and alighting**: Passengers shall be provided with reservation methods through passenger mobile devices, station kiosks and in-vehicle equipment.

— **Details of passenger information provision**: Passengers shall be provided with ADB information including expected arrival and departure time, announcement for arrival and departure at pickup stations or routine stations, announcement for in-vehicle safety warnings, and vehicle IDs for reservations.

— **Payment and withdrawal methods**: Passengers shall be provided with payment and withdrawal methods through passengers' mobile devices, bus station kiosks and in-vehicle equipment.

6.4.5.2.3   Methods for emergency response

— **In-vehicle emergency response**: Emergency alarm to relevant ADB components (connecting the MC centre and bus operator, connecting occupants, regional police, fire station and medical centre).

— **External emergency response**: Emergency alarm to ADB system elements caused by vehicle accidents between vehicles, pedestrian, bicycles, road facilities.

— **Vehicle defect and malfunction**: Connecting the MC centre, ADB operator, in-vehicle passengers, and relevant public service authorities when sensing mechanical defect and malfunction.

6.4.5.2.4   Consideration of physically vulnerable passengers

— Managing boarding and alighting time or allowing passengers to control them considering physically vulnerable passengers, including blindness, wheelchair users, people with other physical disabilities, elderly people and parents with strollers.

6.5   ADB service framework

The ADB service framework is specified as public transport services and requirements in cooperation with ADB system components. Therefore, the ADB service framework consists of ADB service components including:

— ADBs,

— the MC centre,

— IoT infrastructure,

— smart bus stations,

— ADB passengers,

— fare management systems,

— identification,

— security measures including measures for public interest, asset protection and general requirements.

The services that ADBs provide are classed as follows (see Figure 5).

— **ADB operational service**: specified as services that are provided by ADBs for passengers with predefined route and on-demand routes, passenger board/alignment, indication of destination and payment of fare, and safe transport to passengers' destinations. The medium of transport services includes kiosks at bus stations, in-vehicle equipment and passengers' mobile devices.

— **Passenger payment handling service**: specified as services that are provided by the MC centre to passengers for taking trip reservations, charging and collecting the correct fare, and issuing one-time boarding tickets (if necessary) through kiosks at smart bus stations and through passenger mobile phones. Fare systems are categorized into four types depending on uniform or various fare systems with prepaid or deferred payment.

— **Transport information provision service:** specified as service provision among ADB system components including ADM, ASM, BSM, EEM and traffic condition messages. For example, the MC centre provides information to passengers including the number of occupancies of an ADB (number of passengers boarding/alighting for each station in real time), arrival time at a specific station, boarding reservation, or cancellation (destination selection), etc. The medium of information services includes kiosks at bus stations and passengers' mobile devices.

— **Monitoring and control service:** provided by the MC centre to the ADB for its safe operation for providing transport services. Monitoring services include the number of occupancies (number of passengers for boarding/alighting at a specific station), bus operation interval, estimated time to

arrival at a specific station, traffic signal phase, monitoring in-vehicle safety, guiding passengers in response to emergency and any disturbances. The medium of monitoring services includes V2I communications and voice announcement for passengers provided from the MC centre.

— **Emergency response service:** specified as services that are provided to passengers and ADBs from the MC centre. When emergency events occur, the MC centre operation manager or in-vehicle operation manager should contact appropriate institutions to request support for guiding passengers.
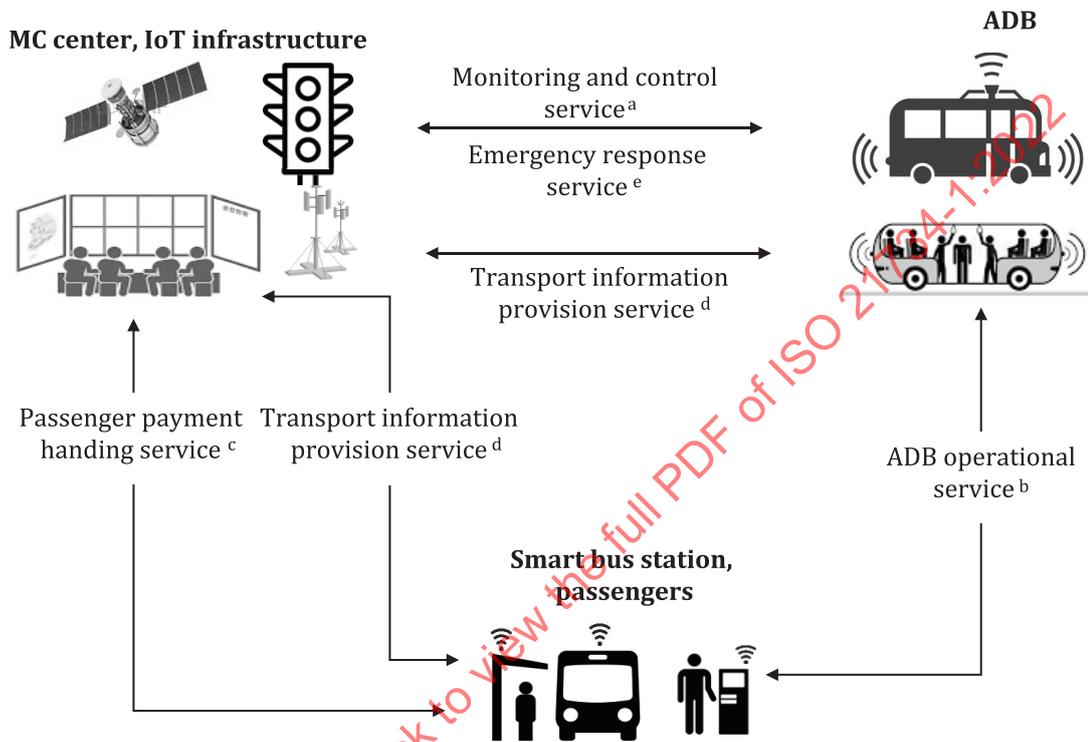
a   Monitoring and control services include number of occupancies (boarding/alighting), expected arrival and departure time, monitoring in-vehicle safety, emergency response to ADB and passengers via V2I communication.

b   ADB operational services are provided to passengers with predefined or on-demand routes and other services that ensuring safe trips to destinations. Trip reservations are made via passenger mobile devices, station kiosks and in-vehicle equipment.

c   Passenger payment handling services include charging and collecting fares and issuing one-time tickets for reserved trips by the MC centre and station kiosk.

d   Provision of transport information includes ADM, ASM, BSM, EEM and traffic condition among ADB components via V2X communications.

e   Emergency response services include emergency occurrence, passenger guidance, etc. via V2I communications or telecommunication if necessary.

Figure 5 — ADB service framework

7 Required data sets

7.1 General

In this clause, data sets for safety and connectivity are described for three cases according to operation area points: signalized intersection, crosswalk and bus stop.

7.2 Operation

7.2.1 Signalized intersection case

The data set described in Table 1 is essential for ensuring that the safety and connectivity of ADB operation and data are achieved from each component of the ADB systems.

Table 1 — Data set for ADB system operation at a signalized intersection

Data source	Data	Purpose	Attributes
MC centre	ID of signalized intersection	Safety	Static
	Direction of approaching leg	Safety	Static
	Type of signal operation	Safety	Static
	Common cycle length	Safety	Static
	Time of offset	Safety	Static
	Order of signal phase	Safety	Static
	Signal timing plan for each approach	Safety	Static
	Green time for corresponding phase for ADB	Safety	Static
	Yellow time for corresponding phase for ADB	Safety	Static
	Red time for corresponding phase for ADB	Safety	Static
	Road construction plan on ADB route	Safety	Static
	Road work plan on ADB route	Safety	Static
	Accident occurrence information on ADB route	Safety	Dynamic
	Road condition on ADB route	Safety	Dynamic
	Weather condition on ADB route	Safety	Dynamic
	Traffic condition on ADB route	Safety	Dynamic
ADB	Link ID for heading	Safety	Static
	Lane ID on running	Safety	Static
	Crosswalk ID	Safety	Static
	Operation type of crosswalk	Safety	Static
	Position (x,y) of ADB	Safety	Dynamic
	Speed of ADB	Safety	Dynamic
	Acceleration rate of ADB	Safety	Dynamic
	Deceleration rate of ADB	Safety	Dynamic
	Operation condition of ADB	Safety	Dynamic
	Position (x,y) of approaching vehicle ID	Safety	Dynamic
	Speed of approaching vehicle ID	Safety	Dynamic
	Acceleration rate of approaching vehicle ID	Safety	Dynamic
	Deceleration rate of approaching vehicle ID	Safety	Dynamic
	Battery SOH	Safety	Dynamic
	Battery capacity	Safety	Static
	Object existence within screen line on route	Safety	Dynamic
	Pedestrian existence within screen line on route	Safety	Dynamic
	Bicycle user existence within screen line on route	Safety	Dynamic
	Time to detect object on route	Safety	Dynamic
	Distance of detected object from ADB	Safety	Dynamic

Table 1 *(continued)*

Data source	Data	Purpose	Attributes
IoT infrastructure	Type of IoT	Connectivity	Static
	ID of IoT	Connectivity	Static
	Location of IoT	Connectivity	Static
	Road condition at IoT	Safety	Dynamic
	Weather condition at IoT	Safety	Dynamic
	Traffic condition at IoT	Safety	Dynamic
User (Management)	Location of ADB	Safety	Dynamic
	Operation condition of ADB	Safety	Dynamic
	Road condition on route of ADB	Safety	Dynamic
	Emergency condition on route of ADB	Safety	Dynamic
	Number of passengers in ADB	Safety	Dynamic
	Operation condition at intersection ID	Safety	Dynamic
	Object at intersection ID	Safety	Dynamic
	Arrival time at intersection ID	Safety	Dynamic
	Departure time at intersection ID	Safety	Dynamic
	Speed of ADB on route	Safety	Dynamic
	Request call from intersection ID	Connectivity	Dynamic

7.2.2 Crosswalk case

The data set for the crosswalk case is categorized in two cases: with signalized pedestrian operation and without signalized operation. Table 2 shows the required data set for the ADB system operation.

Table 2 — Data set for ADB system operation at a crosswalk

Data Source	Data	Purpose	Attributes
MC centre	ID of crosswalk	Safety	Static
	Direction of vehicle movement	Safety	Static
	Type of operation	Safety	Static
	Common cycle length	Safety	Static
	Order of pedestrian signal phase	Safety	Static
	Signal timing plan for pedestrian signal phase	Safety	Static
	Green time for corresponding phase for ADB	Safety	Static
	Yellow time for corresponding phase for ADB	Safety	Static
	Red time for corresponding phase for ADB	Safety	Static
	Green time for pedestrian signal phase	Safety	Static
	Yellow time for pedestrian signal phase	Safety	Static
	Red time for pedestrian signal phase	Safety	Static

Table 2 *(continued)*

Data Source	Data	Purpose	Attributes
ADB	Link ID for heading	Safety	Static
	Lane ID on running	Safety	Static
	Crosswalk ID	Safety	Static
	Operation type of crosswalk	Safety	Static
	Speed of ADB	Safety	Dynamic
	Acceleration rate of ADB	Safety	Dynamic
	Deceleration rate of ADB	Safety	Dynamic
	Operation condition of ADB	Safety	Dynamic
	Position (x,y) of approaching vehicle ID	Safety	Dynamic
	Speed of approaching vehicle ID	Safety	Dynamic
	Acceleration rate of approaching vehicle ID	Safety	Dynamic
	Deceleration rate of approaching vehicle ID	Safety	Dynamic
	Battery SOH	Safety	Dynamic
	Battery capacity	Safety	Static
	Pedestrian existence within screen line on route	Safety	Dynamic
	Bicycle user existence within screen line on route	Safety	Dynamic
	Time to detect object at crosswalk	Safety	Dynamic
	Distance of detected object from ADB	Safety	Dynamic
IoT infrastructure	Type of IoT	Connectivity	Static
	ID of IoT	Connectivity	Static
	Location of IoT	Connectivity	Static
	Object detected from IoT	Safety	Dynamic
	Position of detected object	Safety	Dynamic
	Speed of detected object	Safety	Dynamic
	Road condition at IoT	Safety	Dynamic
	Weather condition at IoT	Safety	Dynamic
	Traffic condition at IoT	Safety	Dynamic
User (Management)	Location of ADB	Safety	Dynamic
	Operation condition of ADB	Safety	Dynamic
	Road condition on route of ADB	Safety	Dynamic
	Emergency condition on route of ADB	Safety	Dynamic
	Number of passengers in ADB	Safety	Dynamic
	Operation condition at crosswalk ID	Safety	Dynamic
	Object at crosswalk ID	Safety	Dynamic
	Arrival time at crosswalk ID	Safety	Dynamic
	Departure time at crosswalk ID	Safety	Dynamic
	Speed of ADB on route	Safety	Dynamic
	Request call from crosswalk ID	Connectivity	Dynamic

7.2.3 Bus stop case

The data set at a bus stop is highly associated with passengers who get in or get off from a bus. There is also an undetected area spot when a bus is attempting to merge into a lane from a bus stop. For enhancing the safety around the bus stop, an IoT facility is required to be installed at the merging point for detecting a vehicle in an upstream. Table 3 shows the required data set for the ADB system operation at a bus stop.

Table 3 — Data set for ADB system operation at a bus stop

Data source	Data	Purpose	Attributes
MC centre	ID of bus stop	Safety	Static
	Direction of vehicle movement	Safety	Static
	Operation condition at bus stop ID	Safety	Static
ADB	Link ID for heading	Safety	Static
	Lane ID on running	Safety	Static
	Bus stop ID	Safety	Static
	Speed of ADB	Safety	Dynamic
	Acceleration rate of ADB	Safety	Dynamic
	Deceleration rate of ADB	Safety	Dynamic
	Operation condition of ADB	Safety	Dynamic
	Position (x,y) of approaching vehicle ID	Safety	Dynamic
	Speed of approaching vehicle ID	Safety	Dynamic
	Acceleration rate of approaching vehicle ID	Safety	Dynamic
	Deceleration rate of approaching vehicle ID	Safety	Dynamic
	Battery SOH	Safety	Dynamic
	Battery capacity	Safety	Static
	Pedestrian existence around bus stop	Safety	Dynamic
	Time to detect object at bus stop	Safety	Dynamic
	Distance of detected object from ADB	Safety	Dynamic
IoT infrastructure	Type of IoT	Connectivity	Static
	ID of IoT	Connectivity	Static
	Location of IoT	Connectivity	Static
	Object detected from IoT	Safety	Dynamic
	Position of detected object	Safety	Dynamic
	Speed of detected object	Safety	Dynamic
	Road condition at IoT	Safety	Dynamic
	Weather condition at IoT	Safety	Dynamic
	Traffic condition at IoT	Safety	Dynamic
User (Management)	Location of ADB	Safety	Dynamic
	Operation condition of ADB	Safety	Dynamic
	Road condition on route of ADB	Safety	Dynamic
	Emergency condition on route of ADB	Safety	Dynamic
	Number of passengers in ADB	Safety	Dynamic
	Operation condition at bus stop ID	Safety	Dynamic
	Object at bus stop ID	Safety	Dynamic
	Arrival time at bus stop ID	Safety	Dynamic
	Departure time at bus stop ID	Safety	Dynamic
	Speed of ADB on route	Safety	Dynamic
	Request call from bus stop ID	Connectivity	Dynamic

7.3 ADB service

The data set shown in Table 4 is collected from the ADB, the MC centre, the smart bus station, the IoT infrastructure and users. The data is used for providing various services defined in the ADB service framework.

Table 4 — Data set for ADB system service by source

Data source	Data	Purpose	Attributes	Target of information provision
ADB	Checking in/out garage	Service	Dynamic	MC centre
	Time of in/out garage	Service	Dynamic	MC centre
	Current location	Service	Dynamic	MC centre
	Current speed	Service	Dynamic	MC centre
	Remaining empty seats	Service	Dynamic	MC centre
	Expected arrival time	Service	Dynamic	MC centre
	Passengers on board	Service	Dynamic	MC centre
	Passenger identification	Service	Dynamic	MC centre
	Identified information of passengers boarding/alighting at the station	Service	Dynamic	MC centre
	Accident info	Service	Dynamic	MC centre
	System error info	Service	Dynamic	MC centre
	ADB operation info	Service	Dynamic	MC centre
	ADB service info	Service	Dynamic	MC centre
	ADB basic security info	Service	Dynamic	MC centre
	ADB emergency response info	Service	Dynamic	MC centre
	Traffic condition	Service	Dynamic	MC centre
MC centre	Current location of ADB	Service	Dynamic	Station, user
	Expected arrival time of ADB	Service	Dynamic	Station, user
	Remaining empty seats of ADB	Service	Dynamic	Station, user
	Passengers boarding/alighting at the next station (Ffixed route type)	Service	Dynamic	ADB
	Optimal path (demand responsive type)	Service	Dynamic	ADB
	Destination station (demand responsive type)	Service	Dynamic	ADB
	Passengers at the destination station (demand responsive type)	Service	Dynamic	ADB
	Traffic condition	Service	Dynamic	ADB
	Road condition	Service	Dynamic	ADB
	ADB fare	Service	Dynamic	Station, user
	Deposit refund (prepaid fare)	Service	Dynamic	Station, user
	Penalty enforcement (additional charge)	Service	Dynamic	Station, user
	System error identification	Service	Dynamic	ADB
	ADB accident identification	Service	Dynamic	ADB
	In-vehicle emergency identification	Service	Dynamic	ADB
	Centre personnel support	Service	Dynamic	ADB
	Call for support from policy and fire station	Service	Dynamic	ADB
	Emergency type	Service	Dynamic	Station, user
	Emergency occurrence time	Service	Dynamic	Station, user
	Emergency occurrence location	Service	Dynamic	Station, user
	Emergency handling status	Service	Dynamic	Station, user
	Weather condition	Service	Dynamic	ADB
	Emergency event of ADB	Service	Dynamic	Station, user

Table 4 *(continued)*

Data source	Data	Purpose	Attributes	Target of information provision
Bus station	Entry time of ADB to station	Service	Dynamic	MC centre
	Exit time of ADB from station	Service	Dynamic	MC centre
	Passengers boarding at the station	Service	Dynamic	MC centre
	ADB fare	Service	Dynamic	User
	Deposit refund (prepaid fare)	Service	Dynamic	User
	Penalty enforcement (additional charge)	Service	Dynamic	User
IoT infrastructure	ADB passing through intersection	Service	Dynamic	MC centre
	Traffic condition info	Service	Dynamic	MC centre
	Road condition info	Service	Dynamic	MC centre
	Weather condition	Service	Dynamic	MC centre
User (Management)	Departure station	Service	Dynamic	MC centre
	Arrival station	Service	Dynamic	MC centre
	Passengers on board	Service	Dynamic	MC centre
	Boarding time	Service	Dynamic	MC centre
	Station of actual boarding/alighting	Service	Dynamic	MC centre
	Date and time of actual boarding/alighting	Service	Dynamic	MC centre
	Emergency occurrence notice	Service	Dynamic	MC centre

8 Use cases

8.1 General

This clause contains use cases for performance requirements and test procedures while manoeuvring at intersections, smart bus stations, etc. Although this document is mainly focused on right-hand driving, major performance and test elements in terms of the safety and connectivity shall hold the same with left-hand driving.
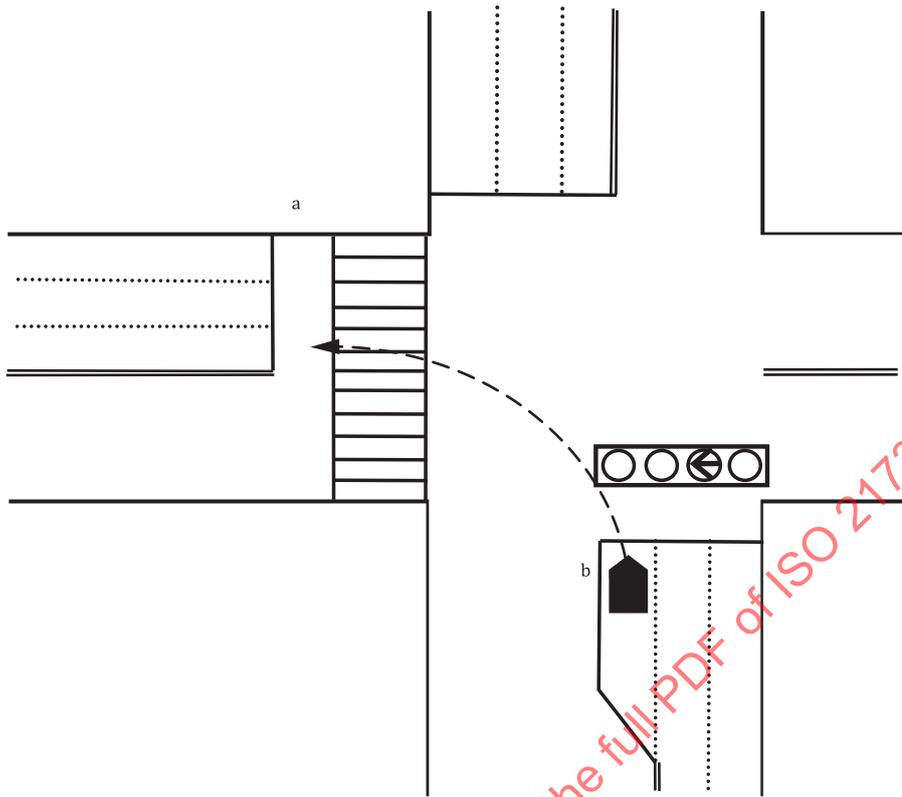
8.2 Left turn on intersection

8.2.1 Use case 1-1: Protected left turn on intersection

An ADB is making a protected or unprotected left turn on a four-way signalized intersection. When the protected left turn signal is on, the pedestrian signal on the target location is red. See Figure 6.

— Description: An ADB is making an unprotected left-turn on a four-way signalized intersection. The vehicle signal is on green, representing the protected left-turn light; the pedestrian signal is on red.

— Intersection type: Four-way signalized intersection.

— Traffic signal operation type: Fixed-time signalization.

— Infrastructure: MC centre.

— Required data set for the ADB:

— signalization phase for the intersection,

— signal time plans for ADBs (protected left turn/green),

— location and speed of target vehicle, and

— location and speed of target objects (pedestrian and/or bicycle riders).


Key

⬛ ADB

a   Pedestrian crosswalk signal is on red.

b   ADB makes left turn with protected green signal.

Figure 6 — Protected left turn on intersection

8.2.2   Use case 1-2: Permitted left turn on intersection

An ADB is making a permitted left turn on a four-way signalized intersection. When the permitted left turn signal is on, the green light is on, the pedestrian signal on the target location is in green and a target vehicle can potentially be approaching with its green signal from the opposite side. See Figure 7.

— Description: An ADB is making an unprotected left-turn on a four-way signalized intersection with the unprotected green light; pedestrian signal is on green.

— Intersection type: Four-way signalized intersection.

— Traffic signal operation type: Fixed-time signalization.

— Infrastructure: MC centre.

— Required data set for the ADB:

   — signalization phase for the intersection,

   — signal time plan for the ADB (protected left turn/green),

   — location and speed of target-vehicle, and

   — location and speed of target objects (pedestrian and/or bicycle riders).
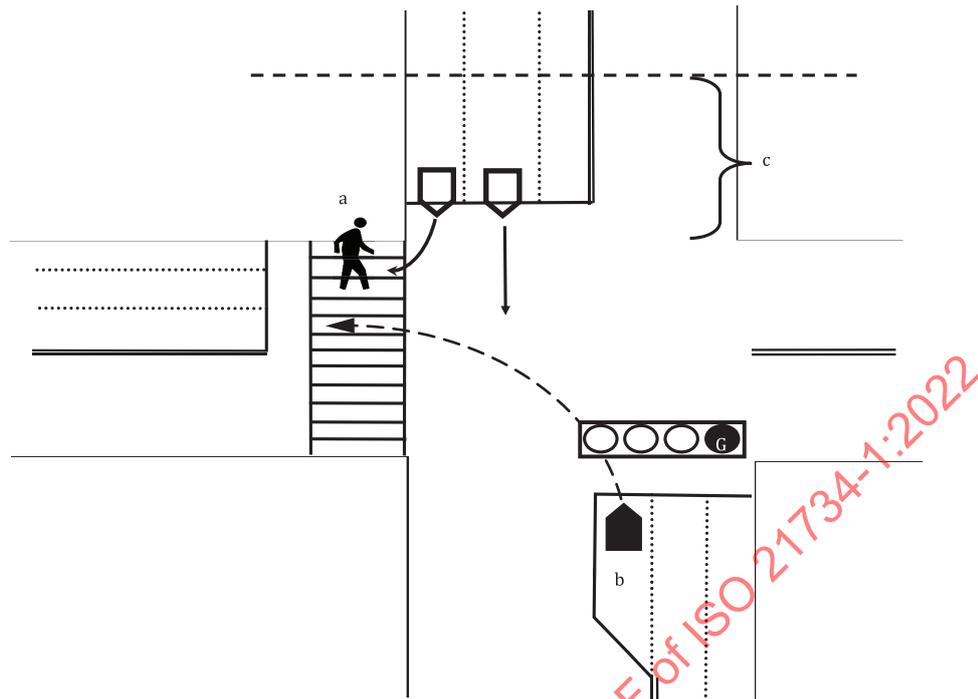
key

⬛   ADB

⬗   target vehicle

a   Pedestrian crosswalk signal is on green.
b   ADB makes permitted left turn on green signal.
c   Minimum sensing distance by ADB when making permitted left turn.

Figure 7 — Permitted left turn on intersection

8.3 Straight forward on intersection

8.3.1 Use case 2: Straight forward on intersection

An ADB is driving straight forward on a four-way signalized intersection with green signal. The pedestrian crosswalk signals are on red on both the near and far side of the intersection. See Figure 8.

— Description: An ADB is driving straight forward on a four-way signalized intersection with green signal; pedestrian signals are on red on both the near and far side crosswalk.

— Intersection type: Four-way signalized intersection.

— Operation type: Fixed-time signalization.

— Infrastructure: MC centre.

— Required data set for the ADB:

    — signalization phase for the intersection,

    — signal time plan for ADB (remaining red/yellow/green time), and

    — location and speed of target objects (pedestrian and/or bicycle riders) on the crosswalks near the current position and/or target position across the intersection.