INTERNATIONAL STANDARD

ISO

37168

First edition
2022-06

Smart community infrastructures — Guidance on smart transportation by Electric, Connected and Autonomous Vehicles (eCAVs) and its application to on-demand responsive passenger services with shared vehicles

Infrastructures urbaines intelligentes — Recommandations relatives au transport intelligent par véhicules électriques, connectés et autonomes et application aux services de transport de passagers à la demande avec des véhicules partagés

COPYRIGHT PROTECTED DOCUMENT

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 268, *Sustainable cities and communities*, Subcommittee SC 2, *Sustainable cities and communities - Sustainable mobility and transportation*.

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

Public transport using Electric, Connected and Autonomous Vehicles (eCAVs) will be a solution to a range of problems, including passenger need for flexible, demand-responsive transport options and a shortage of drivers in ageing societies.

5G cellular and WLAN technologies provide the necessary vehicle-to-network (V2N), vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications that assist the navigation of autonomous buses.

However, autonomous buses that are wirelessly connected and driverless also address key environmental and road safety considerations in busy and polluted urban areas and therefore are likely to have a significant role in a future transport system. In particular, they can:

— provide comfortable and convenient transport for everyone, especially the young, elderly and disabled;

— reduce congestion and time lost to slow moving traffic, increasing efficiency;

— manage travel demand, relieve parking and optimise the use of road space;

— reduce carbon emissions, pollution and noise in and between cities, promoting health and well-being;

— make cities more attractive and productive places, able to grow sustainably.

Technology that supports small autonomous vehicles such as pods, one of the Low-Speed Autonomous Transport Systems (L-SATS), for intra-city passenger transport also lends itself to local delivery services. Autonomous delivery pods are designed to carry parcels, groceries and food, making local distribution faster and more cost-efficient.

Key obstacles to the introduction of autonomous bus and delivery pod services include the ability to introduce autonomous vehicles among regular bus services and manually driven vehicles. Therefore, many autonomous experiments have been increasingly sophisticated bus services on fixed, short routes around safe, off- and on-road spaces.

While trials and pilot schemes exist, they have not been at a scale that really demonstrates the extent to which eCAVs can form the basis of a genuine public transport service.

Nevertheless, a strategic city focus plus open innovation should form the basis of intelligent demand-responsive mobility that offers seamless journeys across multi-modal travel options that include autonomous buses. Key advantages of such transport systems, include:

— adaptability, i.e. eCAVs fit the environment and travel needs of passengers;

— flexible routing and demand responsive journeys;

— real-time information across transport infrastructures;

— city-scale functionality and integration;

— safer and more accessible public transportation.

Rapidly developing pilot projects on autonomous buses can serve the development of smart transportation that helps reach these goals. This document aims to signpost the way towards these goals and offer some focus for the collaborative development of international standards for autonomous public transport services.

ISO Guide 82 has been taken into account in the development of this document with regards to addressing sustainability issues.

Smart community infrastructures — Guidance on smart transportation by Electric, Connected and Autonomous Vehicles (eCAVs) and its application to on-demand responsive passenger services with shared vehicles

1 Scope

This document provides guidance on the staged implementation of Electric, Connected and Autonomous Vehicle (eCAV) passenger and delivery services, with a special focus on on-demand responsive passenger services with shared vehicles. This document aims to accelerate innovation and deliver smart transportation by eCAV, in and between cities.

Note 1 to entry   This document does not designate the technical details of eCAVs, including pods, which are Low-Speed Autonomous Transport System (L-SAT) vehicles. These technical details are provided by ISO 22737.

Note 2 to entry   This document targets on-demand responsive passenger services with shared vehicles. ISO 37181 also mentions the advantages of eCAV applications to public transportation.

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
autonomous bus
shared vehicle used for public transport services for passengers provided by Electric, Connected and Autonomous Vehicles (eCAVs)

Note 1 to entry: A taxi vehicle is hired and can, if local regulations permit, be shared by different passenger groups. In contrast, a bus vehicle is shared and can be chartered.

Note 2 to entry: A pod, which is a Low-Speed Autonomous Transport System (L-SAT) vehicle and is characterized by being a small vehicle with low capacity, autonomously transports passengers in different or the same groups and delivers items. Thus, a pod is a bus vehicle.

4 Common considerations for smart transportation by autonomous buses

4.1 Goals of smart transportation

Automobile transportation is on the cusp of the biggest revolution in public roads since the advent of the internal combustion engine. eCAVs will spearhead the development of radically new mobility services. Vehicle-to-everything connectivity improves road safety, enables collaboration between CAVs and allows authorities to orchestrate traffic flow in real time via wireless connectivity with strict assurance for security and privacy.

This vision of ubiquitous autonomous public transport services requires fully fledged autonomous driving technologies and legal frameworks that are still years away.

However, in the meantime, there is a demand for a set of guidelines and standard approaches:

— to enable both the commercial development and public deployment of eCAVs;

— to provide a policy framework for the provision of tailored and on-demand responsive transportation services using eCAVs;

— to establish broad use cases for eCAVs such as:

— low speed urban transit;

NOTE eCAV is one suitable vehicle that is adaptable to smart transportation for compact cities designated in ISO 37157.

— intercity transfers;

— tailored transport solutions to suit the needs of the young, elderly and people with disabilities and special needs;

— to promote optimal and efficient public transport and delivery services through the shared use of eCAVs that can act in either a conventional mode, such as scheduled bus and freight services, or a demand-responsive mode, such as taxis and couriers;

— to understand the roles and responsibilities of transport authorities in the planning and development of eCAVs;

— to focus on control systems necessary for eCAV services, including the exchange and interoperability of shared vehicle and passenger data;

— to accelerate the development and integration of supporting digital and physical infrastructures;

— to assure approaches to passenger and pedestrian safety and the security of personal data and build public trust;

— to offer an overview of recent developments;

— to shape and influence testing to ensure that trials also complement other key objectives of city transport strategies, such as active travel and greater reliance upon public and shared transport.

Smart transportation aims to satisfy the following United Nations Sustainable Development Goals (UN SDGs): goal 3 "Good Health and Well-being", goal 7 "Affordable and Clean Energy", goal 8 "Decent Work and Economic Growth", goal 9 "Industry, Innovation and Infrastructure", goal 11 "Sustainable Cities and Communities", goal 12 "Responsible Consumption and Production", goal 13 "Climate Change" and goal 15 "Life on Land".

4.2 Basic characteristics of eCAVs

eCAV services take many forms:

— large vehicles (conventionally sized buses);

— smaller vehicles for typically 6 to 14 passengers;

— urban pods for 2 to 6 passengers for intracity transit in compact cities and centres;

— autonomous saloon cars for intercity transit (e.g. provision of snacks and drinks for long distance travel, sightseeing);

— eCAV freight that has a particular application in compact urban centres;

— small-delivery vehicles, designed for pavements and home delivery.

A critical aim of autonomous buses is the ability to offer an on-demand responsive passenger service in dense urban spaces, while larger intercity buses can continue providing a scheduled service. Autonomous public transport in urban spaces is in its very early stages of development. Therefore, to shape the implementation and the transformative impact upon urban life, deep engagement with all relevant transport stakeholders, citizens and passengers should be a priority.

Much collaborative discussion and public engagement will be required to understand the future of road design, traffic management and the adaptation of the rules of the road that would support the adoption of autonomous bus services. It is important to take account of new autonomous technologies and develop user-friendly interaction with the public, leading to trust and acceptance among passengers.

4.3 eCAV as integrated intelligent mobility

4.3.1 General

eCAVs combine three key characteristics that are driverless, electric-powered and remotely connected.

These characteristics reflect critical changes ongoing in the automobile market. Cars are increasingly connected for purposes of geo-positioning, navigation and the monitoring of driving quality. Responding to public concern about air quality, particularly in urban environments, vehicles are increasingly electric powered. And while not yet a consumer trend, around the world much work and investment support the development of autonomous and robotic technologies that drive vehicles autonomously.

4.3.2 Examples of development of autonomous technologies

4.3.2.1 Pods in Milton Keynes, UK

As part of the UK autodrive project, self-driving pods have been undergoing trials on pavements in Milton Keynes. The Milton Keynes Council has been working to test out a new first/last mile transport solution for local people, shoppers and visitors to the city.

The pods can travel up to 24 km per hour and last up to 100 km off one charge, operating in the city centre from the central railway station. There are plans for the pods to continue to operate in the city, with a service being offered to residents.

4.3.2.2 Driverless taxi service

What autonomous taxi services have demonstrated is the potential for this technology to develop into a public transport service. This can enable first and last mile mobility options that can help people move around for their business in an efficient and safe way with improved travel options for those who cannot drive or can find it difficult to either use regular buses, cycle or walk.

4.3.3 Framework of four features

These trials bring together the electric, connected and driverless characteristics, but they also have to take into account the context in which they must operate. That framework consists of four features: human behaviour, vehicle requirements, digital infrastructure, and the design and state of roads.

The interventions needed to make these contextual features fit for eCAV services are indicated in Figure A.1, and cover:

— data management and exchange, which are central to the connected characteristic, and relevant to human behaviour and digital infrastructure;

— establishing the mobile connectivity and a suitable operating environment, which are relevant to the road and digital infrastructure;

— the safe operation and insurance of vehicles bring together aspects of human behaviour and technical vehicle safety of eCAVs.

Therefore, relevant interventions can include rules on:

— personal data protection and privacy;

— security standards on the exchange of data;

— ensuring sufficient fibre backhaul networks to support the edge computing and IoT roadside infrastructures;

— safety standards for autonomous buses and the insurance and liability rules underpinning their services.

Putting in place the right interventions that address the context in which eCAV services operate should support the public and commercial development of autonomous buses and public acceptance of this paradigm shift in urban mobility.

4.4 Key considerations

4.4.1 General

For the development and trials of eCAV transportation services in an actual city, key considerations include the role of transport authorities, legal and regulatory frameworks and service typologies.

4.4.2 Role of transport authorities

Governments (e.g. city, state, nation) are often the providers of 'infrastructure' and facilitator of trials, particularly when it comes to granting permissions and licenses for eCAV activities and installations.

The development and operation of vehicles is driven largely by industry and technology, often in collaboration with centres of research and expertise, such as universities with specialities in robotics and artificial intelligence.

Universities also provide objective impact assessments and technical and non-technical advice based upon a pool of expertise and experience, for example, simulating eCAV impacts on existing transport networks.

The collaborative research and development between industry and universities also supports the development of business cases and implementation plans.

There will be a critical role for transport authorities to guide and lead the development of autonomous public transport:

— to be up to date and engaged in all trial activities;

— to provide assurance with regards to safety and testing;

— to shape development of eCAVs to complement other urban transport policy objectives.

Fiscal measures and tax incentives can be offered by governments to encourage research and development and make viable the production of eCAVs for public transport.

4.4.3 Legal and regulatory framework

Essential elements of the legal regulatory requirements are insurance and liability issues, especially who is liable for an accident involving an eCAV and what are the 'meet and greet' rules of the road.

Common and consistent rules of the road are necessary to enable the widespread commercial development and adoption of services:

— the legal framework for autonomous public transport should be consistent everywhere albeit developed to take account of different terrains and environments and applied technologies in different places;

— regulators and testing organisations need to ensure vehicles are road legal and insured;

— a suitably trained and licenced test driver or test operator should supervise the vehicle at all times and be able to over-ride automated operation if necessary.

4.4.4 Service typology

Services morph and grow over time as a result of innovation and passenger preferences, however, in the short-term, services that are likely to develop include:

— testing, maintenance and repair facilities

— safe spaces in which to develop and test vehicles;

— autonomous bus services

NOTE   ISO 37154 describes passenger services provided by smart transportation in a general meaning.

— fixed short routes, e.g. last mile journeys into and out of urban centres that can be scheduled or demand responsive;

— autonomous, shared, demand-responsive, safe and user-friendly passenger services

— hop on and hop off at designated points and times based upon algorithmic routes that respond to passenger requests;

— intercity autonomous journeys

— faster scheduled vehicles between city pick up and drop off points, which connect with local autonomous services;

— pods

— subscription-based services for small vehicles to pick up and drop off passengers at various locations;

— autonomous taxi services

— on-demand transport services supported by a learning algorithm into which road data are fed.

4.4.5   Public engagement and the dissemination of findings

Dissemination of findings from the early adoption of eCAV services, along with public engagement, is another key role that should be led by authorities related to or in charge of transportation, public roads and city governments. They should work closely with private and public stakeholders in wider communications to inform people about the introduction of such innovation.

eCAVs co-exist with conventional vehicles on public roads. This means that eCAVs are operated under the current regulations and rules (e.g. highway codes, road traffic rules, traffic signs, signals and facilities).

4.5 Applicable city issues and expected advantages

To promote the holistic planning and uptake of eCAV services, it is important to have a comprehensive understanding of their long-term benefits and impacts. The benefits and impacts of autonomous bus and delivery pod services are economic, environmental and social.

a) Economic impacts centre around convenient and available services that improve connectivity and mobility in and between neighbourhoods. Such impacts include:

— encouraging visitors and inward investment;

— increasing transport efficiency;

— integrating traffic management;

— lowering transport costs;

— promoting tourism;

— resolving labour shortages;

— stimulating enterprise, innovation and new services.

> NOTE   eCAVs can also be utilised to provide mesh network to support the 5G-backbone network. This would enhance the telecommunication services in the city, while at the same time rental creating revenues for the eCAV operators.

b) Environmental impacts of eCAV services promote a cleaner less polluted local environment. Such impacts include:

— improving air quality;

NOTE 1   eCAVs are driven with motors that are powered. If green energy is supplied as the power, eCAVs realize perfect zero emission. ISO 37158:2019, Annex A describes the positive effectiveness of motor-driven vehicles to the atmospherics environment.

NOTE 2   If the eCAV production chain is organized, it can mitigate negative impacts to the environment and contributes thereto from another aspect.

— promoting green growth;

— reducing congestion;

NOTE 3   When almost all vehicles on public roads are replaced with eCAVs, no traffic congestion is expected, theoretically.

— reducing noise.

c) Social benefits focus on inclusion and a more equitable spread of opportunities across diverse populations, with better access to sites and places for learning, leisure, well-being and work. Such benefits include:

— offering easier journeys;

— creating inclusive mobility for all;

— realizing healthier quality of life;

— providing quicker journeys;

— leading to quieter streets;

— securing safer roads;

— leading to cyber infrastructures.

4.6 Service issues and challenges

There is a range of service issues and challenges for city planners to consider, from public engagement and education to collecting autonomous fares and managing and policing passenger behaviours in eCAVs.

Another key area is designing streets to make them fit for autonomous buses including pods and autonomous taxis. Road and kerbside space need to be managed flexibly to support multi-modal transport options. The space needs to best facilitate the co-existence of eCAVs with other road users.

An important aspect of standardised approaches to autonomous bus services is that they should serve a range of urban environments, from new towns, eco districts, 'smart cities' and older industrial and de-industrialized urban areas.

Other service issues include continuous monitoring to ensure timely and incident-free operations.

Consequently, cyber infrastructure safety and data protection are also concerns. However, they are not unique to autonomous bus services and apply to well organized ticketing systems, regular public transport and even private car journeys using geo-positioning and satellite navigation.

5 Technical requirements for adoption of eCAV transportation

5.1 Target operating environments

Two key operating environments for autonomous bus services are within dense urban areas and on highways between cities.

Inner urban eCAVs used in public transport are likely to be located within the L-SATS sector because of safety considerations in densely populated areas, such as city centres.

L-SATS vehicles have the potential to be used on public pavements, streets and on private land making them versatile. L-SATS vehicles are typically electric and have sufficient spatial awareness to enable future driving to be free from fuel, emissions and accidents. For cities that suffer from congestion issues, the use of such vehicles would open-up new public transport opportunities.

Vehicles, such as pods, can be customised to carry a range in the number of passengers and be applied to locations, for example:

— new towns and older cities, with a variety of transport infrastructures;

— eco towns;

— transportation facilities, e.g. rail and bus stations, ferry terminals, airports, freight yards;

— shopping centres and malls;

— university campuses;

— buildings (e.g. offices), hotels and hospitals;

— industrial and residential complexes.

5.2 Technical objectives

The adoption and implementation of autonomous bus services should be performed by following the staged implementation processes set out in 5.3.

The implementation also requires standardised approaches to the following:

a) Operational control

— defined zones of operation;

— simple tasks of pick-up and drop-off;

— anywhere-to-anywhere demand responsive service.

b) Communications technology

— communications vehicle-to-individual and vehicle-to-device;

— communications V2I, V2N and V2V;

— data exchange among a fleet of vehicles and with an operations centre to

   — operate effectively and efficiently;

   — facilitate continuous monitoring and inspection of vehicles;

   — enable an entire environment for autonomous buses.

c) Commercial operations

— customer booking and payment;

— supporting infrastructure (e.g. charging, maintenance, servicing).

   NOTE 1   For charging batteries equipped on electric vehicles, IEC 61851-1 provides general requirements.

d) Vehicle specifications

— dimensions, agility, range and speed;

— electric charging and battery requirements;

— passenger access and comfort.

e) Emergency systems and safety planning

— breakdown and recovery;

— compensating for the behaviour of others;

— emergency intervention procedures;

— integrity of constituent systems and safety;

NOTE 2   BS PAS 11281 describes constituent systems and safety for eCAVs.

— maintaining safe distance between eCAVs, other vehicles and pedestrians;

— maximum acceleration, gradient and stopping distance.

f) Operating environment

— pedestrian alerts;

— road space management;

— segregation and coexistence of eCAV and conventional vehicles.

g) Dynamic scheduling

— pick-up of a set of passengers;

— assign time of pick-up to vehicle;

— communication on the vehicle information with passengers.

NOTE 3   ISO 37167 describes energy saving operations of scheduled transportation services.

5.3 Technical prerequisites

There is a range of technical matters that should be discussed, settled and arranged for the adoption of autonomous buses. They include transport modelling and planning, artificial intelligence (AI) platforms, wireless communications, and the digital backhaul and infrastructure needed to support eCAVs at scale. Gigabit bandwidths over dense wireless networks with low latency, capable of maintaining continuous communications between many vehicles, are needed to allow vehicles to interact with their monitors, passengers, sensors, surroundings and each other.

a)   Transport modelling and planning

eCAVs can be deployed as public transportation to beat congestion and solve environmental issues in the city such as air quality.

Modelling and planning should include different types of eCAVs. If the types are limited, urban mobility problems cannot be effectively solved.

This should include road infrastructure guidance with developed use-cases and design recommendations.

b)   AI platform

Key pieces of supporting infrastructure for autonomous public transport include platforms and systems to predict and respond to travel conditions upon the road network.

Such platforms would empower local transport authorities to use predictive AI controls to nudge vehicle behaviours, optimise the routing of an autonomous fleet and improve local traffic flows.

Where autonomous buses and vehicles built by different manufacturers coexist, the algorithmic calculations and rules that determine their behaviours should be standardised so that the rules of the road are commonly respected and understood by AI platforms.

c)   5G and eCAV connectivity

To support the connectivity of autonomous buses, a heterogeneous hybrid Low Power Wide Area Network (LPWAN) and/or 5G networks are needed to allow vehicles to interact with their monitors, passengers, sensors, surroundings and each other.

Low latency, high bandwidth radio and mobile communications infrastructures, will enable the roadside sensing and mobile edge computing to organize smart transportation by autonomous buses for on-demand responsive services.

The development of new technologies and standards in mobile communications, offering the next generation of high capacity and low latency connectivity, should be aligned with field trials of eCAV services and light freight delivery robots.

Enhanced mobile communications, such as 5G, are central to the development of AI, safety and control applications and systems for eCAV operations with minimal human intervention.

Wide availability of the next generation communications will help accelerate the commercial development and public deployment of autonomous bus and delivery pod services.

d)   Dynamic scheduling platform

A critical component of the autonomous public transport is the scheduling platform that aggregates the passenger requests and coordinates the movement of eCAVs.

In particular, the platform should determine the set of passengers that ride together in a vehicle and assign a time of departure for the vehicles. The assignments should be performed in a manner that optimizes the travel time for passengers and operating costs. The platform should have the ability to adapt the scheduling based on the congestion and operating costs to deliver the same quality of service.

e)   autonomous bus battery charging/replacement infrastructure

Replenishing vehicle batteries is necessary to ensure the continuous operation of autonomous bus services. With a growing number of electric vehicles on the road, another key technical requirement is a power grid infrastructure that can cope with growing vehicle-to-grid demands and provide necessary local load balancing.

f)   Monitoring and evaluation

A consistent methodology and approach is required in the collection of monitoring and evaluation data and information, which will be provided through a combination of information exchange, wireless communications and surveillance.

This has implications for the protection and security of personal data and commercial information, however this is important not just for the day to day operations of eCAVs but also for their rapid development and improvement.

5.4   Procedure to adopt smart transportation

Smart transportation by autonomous buses can be adopted into a city and on public roads between cities by following the procedure:

a)   Stage 0

Operation controls and safety are planned by:

— city, state and national governments;

— manufacturers;

— system operators;

— regulators.

b)   Stage 1

Technical performance is observed, especially on:

— simple tasks of pick-up and drop-off under the control of manufacturer;

— demonstration exercises;

— finalising operation control and safety plans.

c)   Stage 2

Transfer of control is tried by:

— trials using pseudo-customers;

— transition of control to systems operators;

— testing of use cases;

— testing of Emergency Intervention Centres (EIC).

d)   Stage 3

Limited operations are carried out by:

— fully operational control systems and dynamic scheduling by operator;

— EIC fully operational;

— transition from pseudo-customers to the public;

— customer booking and payment apps operational.

e) Stage 4

Full operations are performed, including:

— continuous operation;

— anywhere-to-anywhere demand responsive service within a zone of operation.

f) Stage 5

After adoption, the operations are monitored and evaluated.

5.5   Continuous oversight and governance

Continuous oversight of eCAV services also implies a power to intervene and forms the basis of crisis planning.

The role of fallback systems that initiate should wireless communication fail between the autonomous buses and the control centre, are considered on a systematic basis.

The maintenance of continuous communication is also a public concern regarding the potential abuse of user and trip data.

Consequently, managing public awareness, civic engagement and people's expectations of eCAV services is an important aspect of oversight and governance.

6   Quality maintenance of smart transportation by autonomous buses

6.1   General

To maintain the performance of smart transportation by autonomous buses, the parameters in 6.2 should be observed regularly and corresponding evaluations should be made to improve the quality and control the risk of the smart transportation services.

6.2   Parameters to be observed

The parameters can be used to compare smart transportation performance, which indicate the conditions listed below. Use appropriate units for observation.

a) Environmental impacts

— the natural environment (e.g. air quality);

— the built environment.

b) Economic impacts

— availability and convenience of autonomous bus services;

— transport capacity (e.g. passenger numbers, journey numbers, distances travelled);

— the differential effects of deregulated and public models of eCAV services;