INTERNATIONAL STANDARD

ISO 37181

First edition
2022-06

Smart community infrastructures — Smart transportation by autonomous vehicles on public roads

Infrastructures urbaines intelligentes — Transport intelligent par véhicules autonomes sur la voie publique

Reference number
ISO 37181:2022(E)

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Foreword

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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 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

Various countries are facing critical issues as their population ages, often at a rate higher than expected. One of the challenges is the shortage of manpower, where many sectors, including transportation, face constraints. At the same time, as their economic activities expand, travel demands have also become more diversified, thus imposing additional demand on transportation networks. These challenges are especially acute for cities, where increased transportation needs have brought about traffic congestion and led to a lower quality of life.

To overcome such challenges, cities have tried to improve transportation systems in a variety of ways, investing in mass transit ranging from light rail transit to metro as well as public bus services. In mass transit, Automatic Train Operation (ATO) has been widely used for decades. ATO are mostly deployed at grade of automation 4, i.e. Unattended Train Operation (UTO), where the system is fully run without any staff on board, as introduced in the metro systems in Barcelona, Copenhagen, Hong Kong, Sao Paulo, Singapore, Tokyo and Vancouver.

Beyond mass transit, transportation services on public roads have potential to be automated as well. Autonomous shuttle services are in operation as a means to provide first and last mile connectivity between transport nodes and homes or workplaces as well as transport services within designated areas such as campuses, parks and neighbourhoods. Such services have already been deployed in Beijing, Las Vegas, Melbourne, Nice and Singapore.

Smart transportation by autonomous vehicles will work as a solution to transportation issues and concerns in cities. However, the outcomes can be achieved only when autonomous vehicles are applied under organised conditions with safety as a top priority. This document describes the concept of smart transportation and aims to accelerate the proper introduction of autonomous vehicles onto public roads.

NOTE 1 As of November 2021, there are no international or national standards published on the basic behaviour and safety of autonomous vehicles operating on public roads except for the Singapore Technical Reference (TR) 68 series, the summaries of which are available in Annex A for information.

NOTE 2 For autonomous vehicle introduction into on-demand responsive passenger services with shared vehicles, ISO 37168 can be useful.

Smart community infrastructures — Smart transportation by autonomous vehicles on public roads

1 Scope

This document describes the concept and goals of smart transportation by autonomous vehicles on public roads. It provides guidelines for the successful introduction and organisation of autonomous vehicles, with the aim of enhancing the safety of public road transportation and addressing the challenges to cities such as an aging population and diverse travel demands.

This document focuses on the deployment of autonomous vehicles as an operational system for actual use on public roads. This document is intended for those in academia, autonomous vehicle developers, policy makers, research institutions, road infrastructure operators, public road administrators, testing inspection and certification bodies, and vehicle manufacturers.

NOTE 1 This document targets autonomous vehicle services except on-demand responsive services with shared vehicles. For on-demand responsive passenger services with shared vehicles, see ISO 37168.

NOTE 2 A bus vehicle is shared by different passenger groups and can be chartered. A taxi vehicle is hired and can, if local regulations permit, be shared by different passenger groups.

2 Normative references

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

SAE J3016, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*

Singapore TR 68-1, *Autonomous vehicles — Part 1: Basic behaviour*

Singapore TR 68-2, *Autonomous vehicles — Part 2: Safety*

Singapore TR 68-3, *Autonomous vehicles — Part 3: Cybersecurity principles and assessment framework*

Singapore TR 68-4, *Autonomous vehicles — Part 4: Vehicular data types and formats*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in SAE J3016 and the following apply.

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

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

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

3.1
autonomous vehicle
vehicle that is capable of sensing its environment and moving safely with no direct human input and designed to be operated by automated driving systems

Note 1 to entry: Automated driving system in this document means no human intervention system characterised as SAE levels 4 and 5 as defined by SAE J3016.

Note 2 to entry: Autonomous vehicles in this document exclude those applied to on-demand responsive passenger services with shared vehicles, which are designated in ISO 37168.

4 Autonomous vehicles as smart transportation

4.1 General

ISO 37154 provides general guidance on smart transportation that aims to solve specific city issues. The deployment of autonomous vehicles on public roads is considered one of the ways to introduce smart transportation systems.

NOTE Any transportation technologies or services cannot be used for smart transportation systems, if their performance is not confirmed, formally documented or published as international or official standards.

4.2 Autonomous vehicles used in smart transportation

This document describes smart transportation using autonomous vehicles that have been validated for public road operations based on the Singapore Technical Reference (TR) 68 series, Parts 1 to 4. Singapore TR 68-1, Singapore TR 68-2, Singapore TR 68-3 and Singapore TR 68-4 shall be applied to the validation when using autonomous vehicles as smart transportation.

NOTE Autonomous vehicles have been deployed on public roads and the experiences have been documented. For example, public trials were conducted for on-demand autonomous shuttles at Sentosa, Singapore in 2019[8].

5 Concept of smart transportation by autonomous vehicles

5.1 Objectives

The smart transportation system of autonomous vehicles can be introduced into a city in order to improve connectivity, mainly first and last mile, and accessibility to mass transit and other transportation networks, reduce traffic congestion levels, free up land used for roads and parking lots for other purposes, alleviate manpower constraints, contribute to traffic accident avoidance and lead to improving the quality of life of citizens.

5.2 Concept and target city issues of smart transportation

Autonomous vehicles can enhance the efficiency of transportation services in a variety of ways. They help improve the regularity of conventional bus services plying fixed routes and optimise dispatching dynamically routed shuttle fleets and delivery item/freight services. Autonomous vehicles can improve the accessibility and inclusivity of public transport systems. Commuters that need point-to-point mobility, such as the elderly or people with disabilities, can hail an autonomous shuttle on demand, which can bring them to transport nodes.

Efficiently organised and highly accessible public transportation systems can reduce reliance on privately owned or personally used vehicles that are often with single occupancy and encourage a shift to public transportation, thereby reducing congestion on public roads. Goods delivery and municipal services such as street cleaning, can be automated with autonomous vehicles operating during off-peak hours, enabling the dispersion of traffic over the course of the entire day.

Reducing the number of vehicles will enable the use of roads for other purposes (i.e. parking lot removal). This would be beneficial for dense and land-scarce cities. Autonomous vehicles relieve the manpower constraints faced by cities when it comes to drivers, thanks to their automated operation. In addition, the number of traffic accidents can be reduced, as autonomous vehicles are designed to achieve non-collision operation. In addition, people no longer need to drive their vehicles by themselves, thus freeing them for productive use of their time while riding.

5.3 Application

Smart transportation can be applied to:

- private transportation (e.g. automobiles, trucks);
- public transportation (e.g. taxis, scheduled/chartered buses, scheduled/chartered trucks).

NOTE Private and public transportation are defined in ISO 37154:2017, 3.8 and 3.9.

5.4 United Nations Sustainable Development Goals (UN SDGs)

This smart transportation aims to satisfy the following UN SDGs: goal 7 “Affordable and clean energy”, goal 8 “Decent work and economic growth”, goal 9 “Industry, innovation and infrastructure”, goal 10 “Reduced inequalities”, goal 11 “Sustainable cities and communities”, goal 12 “Responsible consumption and production”, goal 13 “Climate action” and goal 17 “Partnerships for the goals”.

6 Features of autonomous vehicles as smart transportation

6.1 General

Autonomous vehicles, which partly or fully replace conventional vehicles on public roads, should satisfy the features described in 6.2 to 6.6 for safe deployment and operation on public roads where other road users operate. There should be no changes with the current operation of conventional vehicles on public roads, which are to be shared with autonomous vehicles.

Smart transportation is applicable to any road vehicle independent of a vehicle’s energy sources (e.g. internal combustion engines, onboard batteries, catenary cables powering) and vehicle type (e.g. automobile, bus, truck).

It is necessary to carry out tests in a controlled environment to verify the behaviour of autonomous vehicles coexisting with conventional vehicles.

6.2 Basic behaviour of autonomous vehicles

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

- have an object detection range always exceeding a safe stopping distance dependent on running speed;

NOTE 1 Stopping distance is the distance travelled for the vehicle to come to a complete stop upon detection of an obstacle.

- have an object detection range that is always sufficiently greater than a braking distance, which includes another distance required for extra factors of safety when human visibility range is limited by weather conditions;

NOTE 2 Braking distance is the distance from the point when applying a brake to the point where the vehicle stops.

- be able to interpret the likelihood of pedestrians entering into a road unexpectedly, independently of personal characteristics such as gender, ethnicity and disability;
- detect, interpret and appropriately respond to signals (e.g. by hand, with indicators) given by other road users (e.g. cyclists);
- detect and accordingly respond to hand traffic signals by authorised persons (e.g. directions by police officers);

— detect and respond to informal traffic signs indicated temporarily for convenience or safety (e.g. school patrol warden showing signs such as “STOP-Children” and “Stop/Go” at construction sites);

— be capable of interpreting and responding to emergency vehicles.

Under any condition, including adverse weather, the autonomous vehicle should prevent harm and facilitate free traffic movement. The vehicle should enter a minimum risk condition when not being able to complete its intended journey due to reasons such as running out of fuel and battery charge. The manoeuvre for risk minimization is taken by reducing operating speeds, entering a limp-home mode or going into a safe stop depending on the situations and environment where the vehicle is operating.

Autonomous vehicles deployed on roads will not be reliant on any off-vehicle systems to provide safe operation. The smart transportation system can be connected via wireless communication to external systems to receive deployment commands or enhance performance. However, in the event of disruption or improper operation of external systems (e.g. malfunction, power loss, cyberattacks), smart transportation should not present any unacceptable risk to its occupants or other road users.

6.3 Safety of autonomous vehicle driving

Safety is a top priority when deploying smart transportation with autonomous vehicles.

A quality management system should be in place to ensure the safety of smart transportation and its fitness for intended usage through uniform interpretation of procedural and quality measures.

The delineation of roles and responsibilities for all stakeholders should be clearly defined in smart transportation deployment. This ensures clear traceability in the legal structure of smart transportation.

Even while smart transportation can exclude safety roles for humans, the interface between humans and vehicles should be considered for interactions with passengers during the journey, for example, responding to emergency situations. Such considerations should involve other road users.

6.4 Cybersecurity principles, framework and requirements

For successful and safe operation of autonomous vehicles that are connected, cybersecurity is one of the most important and indispensable technical imperatives. Two tiers of cybersecurity safeguards serve to provide an enhanced cybersecurity framework for autonomous vehicles deployed on public roads, which are organized based on cybersecurity principles and independent cybersecurity assessment as mentioned in ISO/SAE 21434.

The cybersecurity principles are for autonomous vehicle developers/operators to manage cybersecurity for the full life cycle of an autonomous vehicle, including design, development, operations, maintenance and decommissioning. This culminates in a security-by-design system and secure operations, which are verified by a full internal and independent cybersecurity assessment. The system design and its implementation should provide adequate cybersecurity safeguards against cybersecurity threats.

The independent cybersecurity assessment framework by third parties consists of a system review, threat risk analysis and cybersecurity validation, which are described in Singapore TR 68-3.

NOTE A connected vehicle means, as described in ISO 37168, a vehicle that is wirelessly connected to facilitate data exchanges.

6.5 Data types and formats

Standardising the data type and format will enable the different entities in the smart transportation system to communicate and operate efficiently. The message design philosophy takes into consideration the communications between the entities in the smart transportation system, which are carried out in various types of wired and wireless communication channels. Due to possible bandwidth and resource constraints, messages are designed to be compactly represented.