TECHNICAL REPORT

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Intelligent transport systems — Mobility integration — Digital infrastructure service role and functional model for urban ITS service applications

Systèmes de transport intelligents - Intégration de la mobilité - Rôle des services d'infrastructure numérique et modèle fonctionnel pour les applications de services ITS urbains

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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).

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).

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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*.

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

Currently, more than 70 % of the world's people live in cities. The proportion of people living in cities is rising around the world as civilizations develop and congregate around the areas where employment opportunity most arises. Societies develop more innovatively and more rapidly in cities, adding to their attraction. Finally, cities present better entertainment opportunities. These points all add to their attraction and popularity, hence the continuing trend. It has recently been forecast that by 2045, an additional 2 billion people will live in urban areas.[4] Due to the concentration of the population that this causes, various issues arise, such as road congestion due to increases in vehicle population and environmental pollution due to exhaust gas and tyre erosion. This has been attributed to increases in the amount of delivery trucks, taxis and town centre traffic and is further exacerbated by obstacles to effective use of urban space due to private ownership of cars (parking lots, street parking).

In line with scientific advice that significant action and change of behaviour is needed to ameliorate the adverse effects of climate change, more environmentally-friendly use of the transport system is required.

It is also recognized that within cities, there is a general deterioration in road infrastructure, lack of provision of information on the use of public transportation, driver shortages (due to an increase in the number of elderly people) and inconvenience of multimodal fare payments. Action to improve this situation is urgently needed.

Therefore, in recent years, in Europe, studies on the development of mobility integration standards have been active in solving urban problems. There are also various movements around the world making efforts to address such issues. In the United States, for example, intelligent transport system (ITS) technology is used to try to solve urban problems in the Smart City Pilot Project. Important key factors here are the core architectural elements of smart cities and urban ITS sharing of probe data (also called sensor data), connected cars and automated driving. In addition, new issues have been recognized with the introduction of the connected car to the real world regarding privacy protection, the need to strengthen security measures, big data collection and processing measures, which are becoming important considerations.

In terms of effective use of urban space, it is hoped that the introduction of connected cars and automated driving can significantly reduce the requirements for urban parking lots (redistribution of road space). If technology can eliminate congestion, city road area usage can also be minimized or reallocated (space utilization improvement) to improve the living environment and quality of life in the city. In addition, the environment around the road will be improved by improving enforcement (e.g. overloaded vehicles). It is possible, even in rural areas, to introduce automated driving robot taxis and other shared mobility that saves labour (and is therefore more affordable) and improves the mobility of elderly people.

To achieve this, the following points will need to be achieved:

— cooperation in the harmonization of International Standards and other industry standards;

— recognition of the significance of international standardization (for example, in reducing implementation costs);

— recognition of the significance of harmonization activities by countries around the world;

— cooperation and contribution between ISO/TC 22 for in-vehicle systems and ISO/TC 204 for ITS technology.

ITS technology is an important element for realizing smart cities, and it is important to clearly understand the role model of ITS service applications when developing standards to achieve these objectives.

ISO/TR 4445 is already an important resource for this objective, providing consideration of the emerging direction of mobility electrification, automated driving and the direction of an environmentally friendly

society, whilst also incorporating other urban data such as traffic management into city management within the context of improving the mobility of urban society.

This document, ISO/TR 7872, describes how ITS sensor data can be integrated into a valuable data cluster presented on map data, so that ITS service providers can provide services such as automated driving, parking, kerb operations, etc.

This document does not describe smart city use cases for ITS data in detail, nor does it describe in detail any specific ITS use-cases; it is instead focussed on the generic role model for digital infrastructure service.

Intelligent transport systems — Mobility integration — Digital infrastructure service role and functional model for urban ITS service applications

1 Scope

This document describes a basic role and functional model of digital infrastructure service for urban intelligent transport system (ITS) service applications. It provides an extension of the information given in ISO/TR 4445. It lays out a paradigm describing:

a)   a framework for the provision of digital infrastructure for cooperative ITS service application;

b)   a description of the concept of roles and functional models for such services;

c)   a conceptual architecture between actors involved in the provision/receipt of digital infrastructure services;

d)   references for the key documents on which the architecture is based; and

e)   a taxonomy of the organization of generic procedures.

2 Normative references

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

ISO/TS 14812, *Intelligent transport systems — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TS 14812 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/

4 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

AI	artificial intelligence
AVPS	automated valet parking system
AV	automated vehicle
CAV	connected and automated vehicle
CONOPS	concept of operations

EFC   electronic fee collection

EV   electric vehicles

ExVe   extended vehicle

FCV   fuel cell vehicles

GDD   graphic data dictionary

GDF   geographic data files

HD   high definition

ITS   intelligent transport system

LSAD   low-speed automated driving

MaaS   mobility as a service

METR   management for electronic traffic regulations

NDS   Navigation Data Standard

OBE   on-board equipment

OEM   original equipment manufacturer

QoS   quality of service

RV   road vehicle

RVU   road vehicle user

SCMS   security credentials management system

SPaT-MAP   signal phase and timing (SPaT) and map (MAP)

WIM   weigh in motion

5 General overview and framework

5.1 Objective

Emerging ITS service applications such as parking (including AVPS: automated valet parking systems), CAV (connected and automated vehicle, including LSAD: low-speed automated driving) and kerb operations require infrastructure supports for secured and safety operations. Several ongoing standardization work items exist within ISO/TC 204, including:

— high definition (HD) maps,

— management for electronic traffic regulations (METR), and

— graphic data dictionary (GDD).

There is a need for the creation of a document describing how these standardization items fit into a prospected digital infrastructure service role and functional model for smart city ITS service applications.

This will lead to a digital twin operation for smart cities: creation of a digitality formed society connecting real (physical world) society to processing and analysing big data and sending out a data stream to the real world.

In actual deployment, distributed security technology such as block chain will be introduced for efficient and speedy transactions.

This document suggests investigating ITS as a component of a smart city and that the ITS data can focus on data originating from ITS components and available for sharing with other smart city services and commercial interests.

This clause describes a generic framework for the provision of digital infrastructure services for cooperative telematics application services for ITS service applications.

(Clause 6 provides the general concept of operations for which this architecture is designed. Clause 7 provides a framework, role definition and summary of the architecture at a conceptual level.)

5.2 National variations

The instantiation of interoperable on-board platforms for ITS service applications with common features is expected to vary from country to country, as will the provision of regulated, or supported, services.

5.3 Mandatory, optional, and cooperative issues

5.3.1 This document does not impose any requirements on Nations in respect of which services for ITS service applications countries will require, or which they will support as an option, but provides a generic common framework architecture within which countries can achieve their own objectives in respect of application services for ITS-supported service applications in cities, and can provide standardized sets of requirements descriptions for the exchange of data to enable consistent and cost efficient implementations where instantiated.

5.3.2 Cooperative ITS application, in this context, is the use of a common platform to meet both regulated and commercial service provision providing collaboration between transport systems and smart cities.

5.4 Specification of service provision

Cooperative ITS applications for ITS service applications (both commercial services and regulated services) are specified in terms of the service provision, and not in terms of the hardware and software.

5.5 Architecture options

Architecturally, it needs to be possible for a vehicle user/on-board equipment (OBE) to use the services of different application services. The in-vehicle system can be a vehicle-original equipment specification option, in-built at the time of manufacture of the vehicle, with the service provider selection being a subsequent service-user choice. Alternatively, it can be after-market equipment that has access rights to the required data. An ITS application service will be based in the infrastructure. Other options are possible and can be supported within the conceptual architecture. The objective of this role model is the accessibility of the use of ITS data generated in ITS application services in smart city application services.

6 Concept of operations

6.1 General

This clause describes the characteristics of a proposed system from the viewpoint of an individual who will use that system. Its objective is to communicate the quantitative and qualitative system characteristics to all stakeholders.

ISO/TR 4445 describes the roles and responsibilities of the classes and actors involved in the provision of digital infrastructure for ITS services for ITS service applications using a secure vehicle interface.

This document recognizes that there will be variations between jurisdictions, a role in ISO/TR 4445. It does not attempt, nor recommend, homogeneity between jurisdictions. It is simply designed to provide common standard features to enable equipment of common specification, that supports a standardized 'Secure ITS Interface', to be used, and to enable the common features of service provision to be able to be referenced simply by reference to an ISO deliverable (requiring detailed specification of only the additional requirements of a jurisdiction).

A 'concept of operations' (CONOPS) generally evolves from a concept and is a description of how a set of capabilities will be employed to achieve desired objectives.

6.2 Statement of the goals and objectives of the system

The overall objective of the ITS service application in smart cities is the seamless exchange of data between transport applications and smart city service applications.

These services are provided to meet the smart city requirements using common 'Secure ITS interface' communications between ITS systems (including in-vehicle systems, infrastructure-based systems, and personal ITS stations) and smart city applications.

6.3 Strategies, tactics, policies and constraints affecting the system

Strategies, tactics, policies and constraints, and indeed, the services that are regulated as mandatory or optionally supported, will vary from jurisdiction to jurisdiction. Clause 7 provides detail of the options of such aspects.

6.4 Organizations, activities and interactions among participants and stakeholders

The classes, attributes and key relationships are described in Clause 7. High-level conceptual architectural detail is elaborated in Clause 8.

6.5 Clear statement of responsibilities and authorities delegated

Clause 6 describes the high-level options and issues. The actors, their responsibilities and authorities are described in Clause 7.

6.6 Operational processes for the system

The following description of operational processes is at a high abstracted level (above that of any application service). Specific services will have additional requirements not described herein.

6.6.1 Service requirements definition

A smart city application service provides a service (a benefit that a service user receives or a duty that a service user provides) to a service user using exchanges of data, in this case using a secure ITS interface. Smart cities can also use other communications means appropriate to the context of their use. The interface will be wired or wireless, but is likely to be the latter, in which case the latency of the system will limit the ability to provide/capabilities of the application service.

An ITS application service provides an ITS service (a benefit that a service user receives or a duty that a user provides) to a service user using a secure ITS interface. The interface will be wired or wireless, but is likely to be the latter, in which case the latency of the system will limit the ability to provide/ capabilities of the application service.

Wireless communications between a vehicle and its original equipment manufacturer (OEM), commonly known as "ExVe" (extended vehicle) are separate and complementary to, and out of the scope of, this document.

6.7 Appointment of an approval authority (regulatory)

This document is based on the premise that a smart city will develop its own regulation base (in consort with national government and other smart cities). The term used in this document to describe this organization and its regulation base is the 'jurisdiction', and this body creates or appoints an authority to approve and audit the 'process'. The 'process' in this context is a smart city application service. The assumption is made that there will be some form of approval process to control smart city application services and their cybersecurity (at the least to protect privacy and avoid fraud, and to minimize risks of terrorism or other disruption). The structure of that authority is a matter for the jurisdiction, and it will be a separate appointed organization, or a department of the jurisdiction. Within the context of this document, it is the actor 'role' of 'approval authority' that is important, not its structure, ownership or business model.

An approval authority (regulatory) will only preside over the instantiation and operation of one application service or will preside over the instantiation and operation of many application services (at the discretion of the jurisdiction).

The approval authority (regulatory) will, where appropriate, approve service providers (or delegate approval of service providers), and will provide audit as described in Clause 5, in accordance with the requirements of the jurisdiction.

6.8 In-vehicle system

In ITS service applications, the OBE that provides the application service is an ITS trusted device that meets the requirements of ISO 5616.

6.9 User

An ITS application service provides a service to a service user using a secure ITS interface. Within the context of mobility integration, while most ITS services are provided to/from a road vehicle/road vehicle user (RV/RVU) to another RV/RVU, or between an RV/RVU and a service provider or service receiver, the application service will also be between the RV/RVU and another transport system using entity, such as a vulnerable road user, micro mobility user, public transport service provider, mobility as a service (MaaS) service provider, etc.

6.10 Application service

An application service will be provided on request or will be cyclical to a pre-agreed cycle.

In an 'on request' implementation, an ITS trusted device, offering the appropriate credentials via the secure ITS interface will request pre-specified information from the client OBE, which, on confirmation of the credentials of the requestor for the requested information, will provide it via the secure ITS interface.

An OBE will or will not be set up to deal with one or both cyclical and on request demands for information.

The nature and definition of the information supplied will be the subject of a specification or regulation.

6.11 Big data management entity

6.11.1 Big data management

This big data will be connected to other smart city data entities and share the data for the efficient smart city operation in a manner approved and authorized by the jurisdiction. This role is required to support privacy requirements and to fairly manage any business case issues.

6.12 Data aggregator

The data aggregator will provide timely and value-added data to service provider for its ITS service application provisioning. Data collected for sharing is generally not forwarded in the same formats or data timing so there is a need to have an entity that can provide standardized data to service provider in a standard data format and data timing. This role is like a role between ITS entities as described in ISO 21184, but in this case is between ITS entities and smart city entities. Artificial intelligence (AI) can be deployed to create such structured value-added data for service providers.

NOTE   This document does not attempt to describe the role of big data/data aggregation in smart cities.

6.13 Map service providers

The open architecture platform map data will be assumed as being map data that anyone can use for free, map data that is charged but has no usage restrictions, map data that anyone can modify and re-provide, etc.

The map service will provide an open architecture platform map data and it receives probe data, OEM cloud data, etc. from a data aggregator. It combines such data into a map and provides map data (such as HD map) cluster in a standard format such as geographic data files (GDF), Navigation Data Standard (NDS), etc. to digital infrastructure service provider for ITS application services.

6.14 Digital infrastructure service provider

The digital infrastructure service provider will receive the map data cluster in a standard format from the map service provider and receive public infrastructure and enforcing regulation data, such as METR, GDD, etc. from jurisdictions/road authority/municipals. It combines such data into a map as a data cluster, digital infrastructure data which consist of dynamic and static data. The digital infrastructure service provider provides these to the service provider, who performs provisioning of ITS services such as CAV, parking (AVPS), kerb, etc. The service provider will utilize AI/edge computing tools in some use cases for low-latency safety service applications.

7   Conceptual architecture framework

7.1   General

Clause 6 provided the generic concept of operations which the relevant actors and classes enact to provide the application service(s). To specify a generic framework standard of the ITS service platform exchange of data with smart cities, this framework standardization deliverable identifies core actors and classes as described in 7.2 to 7.4, which are described as elements which are independent of any specific application. Examples of digital infrastructure service are listed in Annex A for reference.

7.2   Actors

ISO/TR 4445 describes a role model where the roles and responsibilities of three key actor classes are defined to provide an entity known as an 'application service':

a)   the service users;

b)   the service provider;

and, for any regulated applications:

c)   the jurisdiction(s).

The ISO/TR 4445 role model provides the general attributes and the responsibilities of the parties. These aspects are further described within this document. Figure 1 illustrates a conceptual role model architecture for application service provision.

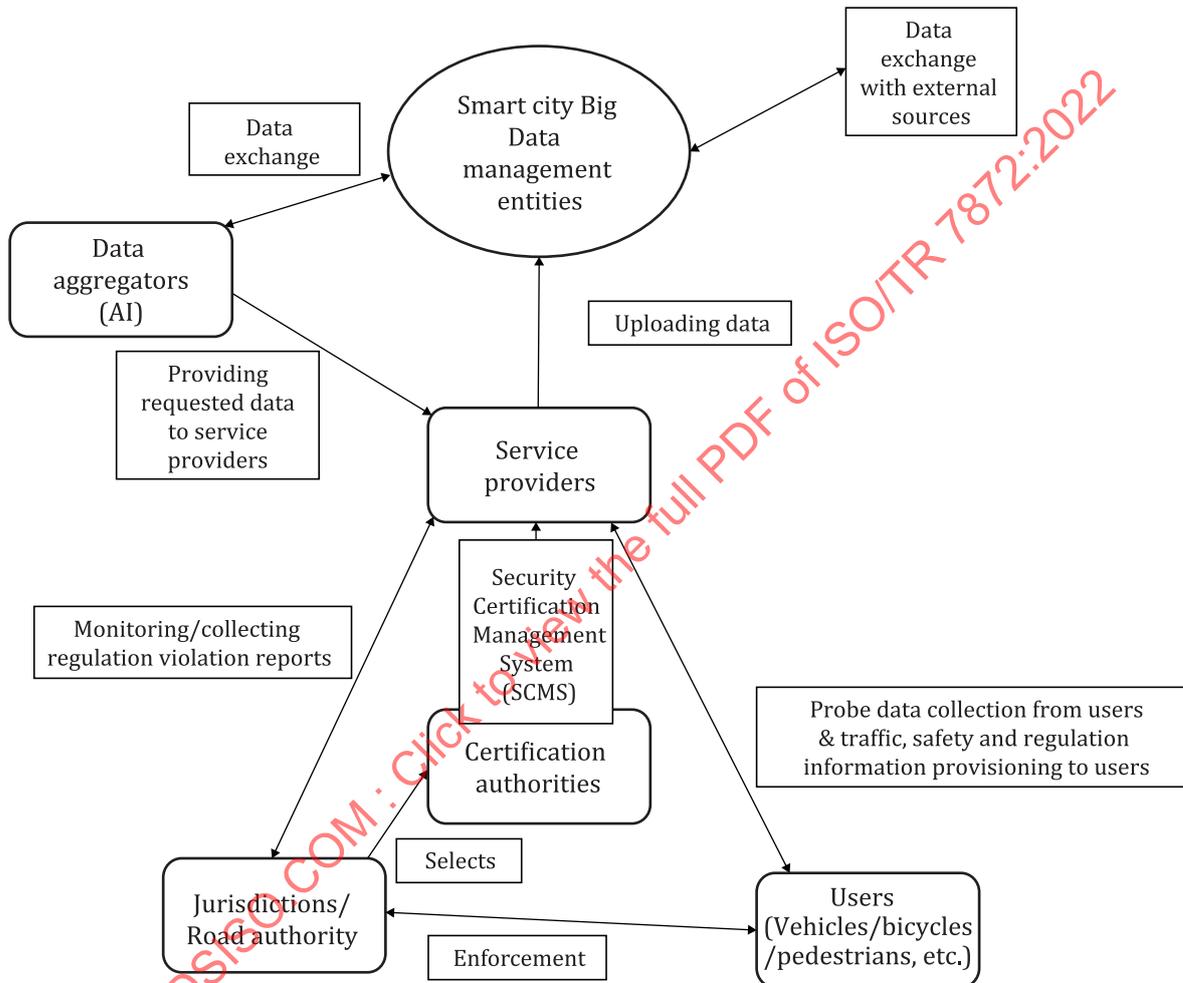**Figure 1 — Role model conceptual architecture**

7.3   Role model and functional model of digital infrastructure servicer

This document defines a role and functional model where the roles and responsibilities of two key actor classes are defined to provide an entity known as a digital infrastructure service:

a)   the map service provider(s), and

b)   the digital infrastructure service provider.

This document provides the general attributes and the responsibilities of these parties. Figure 2 illustrates a conceptual role model architecture for application service provision.

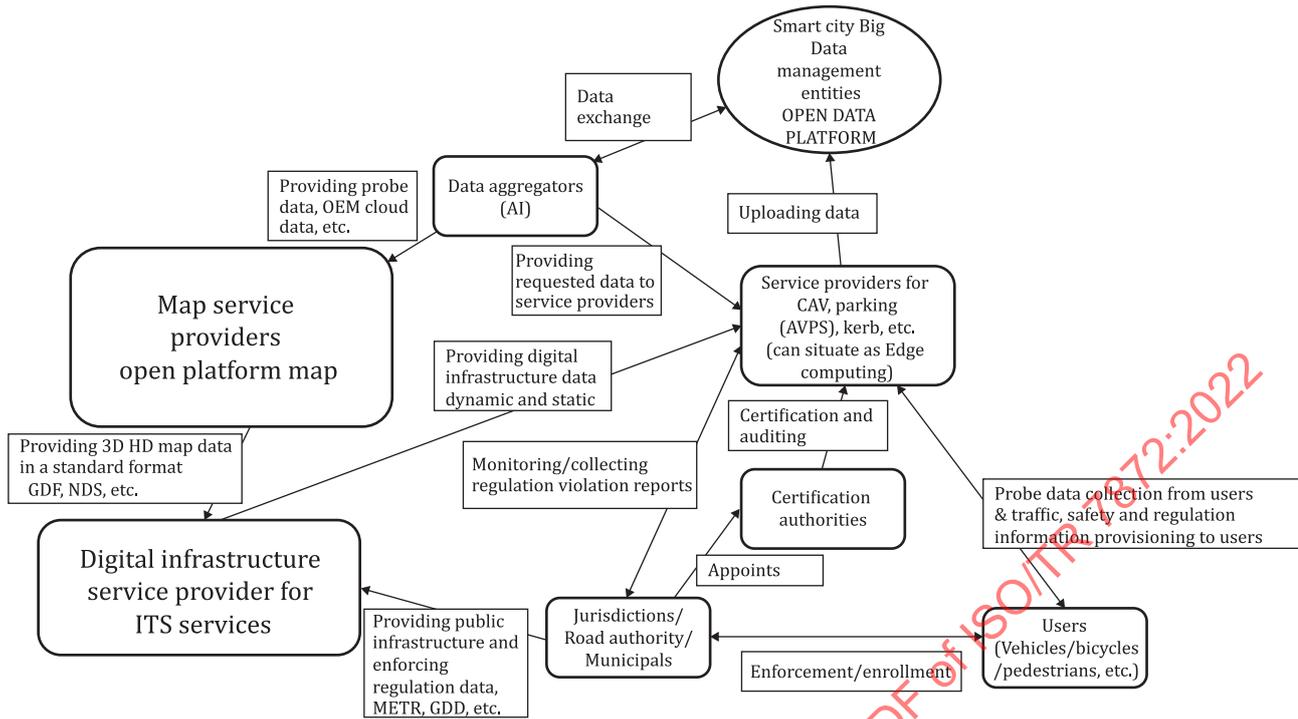**Figure 2 — Role model and functional model of digital infrastructure servicer**

The conceptual view of the digital infrastructure of a role and functional model is as shown in Figure 3.
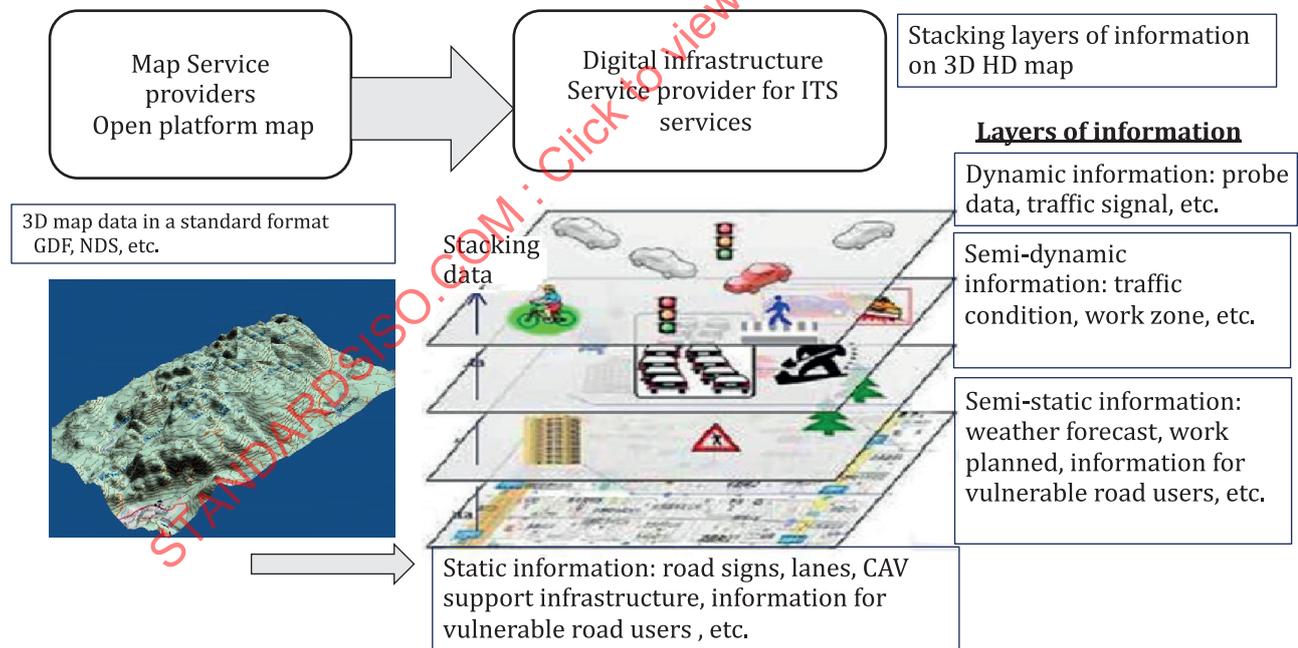

Figure 3 — Conceptual view of digital infrastructure

7.4 Service definition

The service definition for each application service comprises:

a) a clear description of the service provided and its inputs, outputs and results;

b) basic vehicle data content and quality that an OBE is required to deliver;

c) core application data content to meet the requirements of the service and meet any requirements of the jurisdiction;

d) any additional application-specific data content for the provision of that service;

e) service elements (such as "retrieve data from OBE", "map data to a map with access conditions", "report non-compliance", etc.):

f) rules for the approval of OBEs and application services.

7.5 Role model architecture

7.5.1 General

This subclause considers the roles of the actors defined in 7.2 and 7.3 and their interrelationship in greater detail, as well as their relationship to the provision of the applications service(s).

7.5.2 Application service actors

Application services, whether or commercial or regulated, need clear definition in terms of the requirements on the OBE.

It also falls to the service provider to provide sufficiently accurate specification of what is required from the vehicle to enable the OEM, or after-market provider, to design the OBE.

Application services can be architecturally described as involving seven further classes/subclasses of actors in addition to the jurisdiction:

— the security credentials management system (SCMS);

— the certificate issuer;

— the OBE;

— the equipment installer (subclass);

— the OBE equipment maintainer (subclass);

— the approval authority (regulatory);

— the service user.

Single entities will perform the roles of multiple classes of actor. For example, the SCMS and the certificate authority will be the same actor. Other actors will also be embraced within these key roles, such as a communications provider, but these will be regarded as additional subclasses that support one of the key actor roles.

7.5.3 Service provider(s)

A service provider, within the context of this deliverable, can be described as a party which is providing safety, commercial or regulated ITS or smart city services. Application services will be certified by the certification authority (regulatory) as suitable.

8 Quality of service requirements

This document contains no specific requirements concerning quality of service. Such aspects will be determined by a jurisdiction.

9 Test requirements

There are no test requirements within This document.

10 Marking, labelling and packaging

Attention is drawn to ISO/TR 12859 in this respect. Regulation EU 2016/679, "General Data Protection Regulation"[24] can also be relevant for implementers in Europe.

11 Declaration of patents and intellectual property

This document contains no known patents or intellectual property other than that which is implicit in the media standards referenced.

12 Definition of service domains utilizing digital infrastructure

12.1 General

Digital infrastructure will support the implementation of emerging service applications needed for smart city services. For example, such infrastructure could eventually be implemented to assess physical infrastructure needs and improve safety within cities.

Possible service applications can include:

— critical safety information provision;

— safety driving support;

— infrastructure planning;

— dynamic traffic management;

— traffic rule enforcement;

— dynamic map updates;

— emergency evacuation support.

Where applicable, digital infrastructure definition already defined by the local authority can be utilized.

For deployment, further research or development of digital infrastructure is recommended.

12.2 Referenced target use cases

ITS service applications largely rely upon the big data collected through applications. Services consist of a smart city that are held and maintained by smart city data management entity. Those ITS services can be grouped into two categories: the services provided by jurisdiction or the road operator; and the services by the public and private service providers. The applications offered and managed by the jurisdiction, or the road operator can be classified in four groups as "infrastructure operation management", "traffic management", "road traffic operation management" and "enforcement". The applications provided by the service providers can be offered through public or private sectors. The classification of an ITS service and applications can be shown in Figure 4 below.
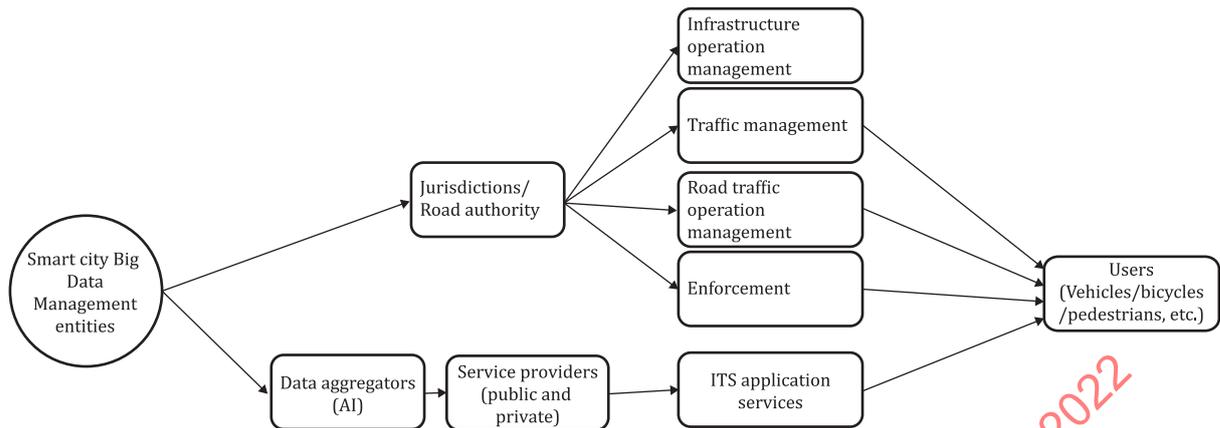
Figure 4 — Classification of smart city ITS service and its applications

The number of emerging ITS service applications for smart city deployment are growing rapidly in recent years. The list below provides examples of those applications:

— Traffic management applications to ease traffic congestion and maintain safety in urban areas.

— Road traffic operation applications to realize efficient and safer use of infrastructure.

— Electronic fee collection (EFC) support for urban ITS traffic management to realize dynamic road pricing.

— Weigh in motion to ease heavy good transport vehicles.

— Dangerous goods/hazardous materials transport management to enforce geo-fencing.

— Disaster information provisioning systems for safer and timely evacuation activities

— Infrastructure services applications for efficient and automated maintenance works.

— Access control in urban area to enhance vehicle entry to certain area.

— Traffic signal (SPaT-MAP): signal phase and timing and road topology messages information provisioning for safer and efficient traffic flow in the urban area.

— Law enforcement applications to regulated freight vehicles such as overloaded vehicle shut out from certain urban area.

— Remote digital tachograph monitoring to maintain safe freight transport vehicle movement.

— Heavy vehicle air quality controls and geo-fencing in certain urban area.

— Emission control of vehicle entering certain urban area to enforce geo-fencing in certain area of the smart city.

— Autonomous vehicle applications such as monitoring, emergency controls, override command, regulated information provisioning.

— Urban/suburban/expressways mobility mode-specific safety information provisioning and traffic monitoring.

— Dynamic map management including probe data collection, data aggregation, managing digital twin in the cloud and provisioning of safety information.

— EFC from services such as parking, event admission, car sharing.

— Vehicle remote maintenance applications such as over the air software updates.

— Freight vehicle management applications supporting efficient and safer transport fleet operations.

— Electric vehicle charging applications such as booking, monitoring, fee collections with security management.

— Fuel cell vehicle charging applications.

— Intelligent parking such as automated ballet parking supporting systems.

— Car sharing management including booking, matchmaking between user and driver, safety information provisioning.

— Public transit information provisioning to users in timely and dynamic real time basis.

— Taxi fleet management applications such as booking, matchmaking between users and drivers, safety information provisioning.

— Dynamic map utilizing service applications for automated driving buses, shuttles, freight vehicles for efficient and safer operations.

— Tourist information/advice provisioning service applications to inbound users.

— Bicycle/motor cyclist's ITS service applications such as vulnerable road user safety information provision services.

Major use cases and business cases for smart city ITS service applications (those currently available and future ones) are shown here for information only. The example uses cases shown in this document are each referenced with a URL link information; however there is no intention to promote those use cases as a standard but for reference only. Further applications can be expected to be developed in the future depending on how the smart city ITS regulators can implement their initiative with the local government.

The example use cases are grouped according to the classifications shown in Figure 4.

12.3 Infrastructure operation management

The use cases fall into the "Infrastructure operation management" category shown in Figure 5 are infrastructure service applications focusing on service vehicle operational efficiency and automated maintenance.

> Infrastructure
> operation management

Figure 5 — Infrastructure operation management use case

Infrastructure operation management services applications are effective for efficient and automated maintenance works.

Example can be found at Reference [5].

In this case, road maintenance service vehicles such as a snowplough dispatching operation becomes safer and more efficient with proper monitoring and controlling from adding back-office management.

12.3.1 Traffic management

The "traffic management" use case can be applied to all vehicles, freight vehicles and automated vehicles. See Figure 6.
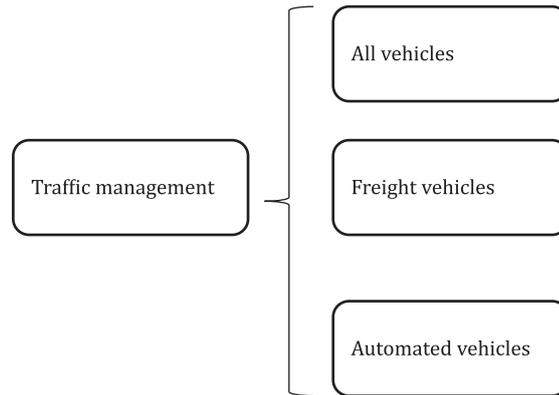
Figure 6 — Traffic management use cases

For all vehicles, traffic management applications to ease traffic congestions and maintain safety in urban area can be effective.

For automated vehicles, automated driving vehicle support applications such as monitoring, emergency control, override command, regulated information provisioning can be effective.

EFC support for urban-ITS traffic management can be effective for realizing dynamic road pricing.

Examples include:

a) Traffic management applications to ease traffic congestions and maintain safety in urban areas, in which the smart city ITS traffic centre monitors traffic conditions and controls both signals and road signs to ease traffic congestions.

b) EFC support for smart city ITS traffic management to realize dynamic road pricing, in which the smart city traffic centre controls traffic by changing toll fees dynamically to divert traffic flows to other road networks. In such cases, the traffic centre also provides feedback to the toll operator to adjust toll fees to maintain the quality of service (QoS) of the toll road operations.

   An example can be found at Reference [5].

c) Autonomous vehicle support applications, which, to monitor road conditions, assist emergency control, respond to override command and update regulated information provisioning. In such an example, the automated driving vehicle relies mainly on its own sensor data, but the safety level can be increased with the supports from the infrastructure.

   An example can be found at Reference [6].

12.4 Road traffic management

In the road traffic management use case, the road traffic operation applications improve efficiency and make it safer to use the infrastructure by allowing the road authority to control the traffic volume of the road, especially on the expressways. See Figure 7.
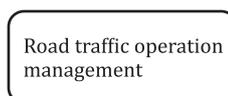

Figure 7 — Road traffic operation management use case

Road traffic operation management applications can be effective for realizing efficient and safer use of infrastructure.

They are normally implemented through controlling the volume of the vehicles entering the road with ramp metering.

An example can be found at Reference [5].

12.5 Enforcement

Enforcement is a broad subject for smart city ITS. This subject can be further divided into two categories: enforcement for all vehicles and enforcement for freight vehicles as shown in Figure 8.
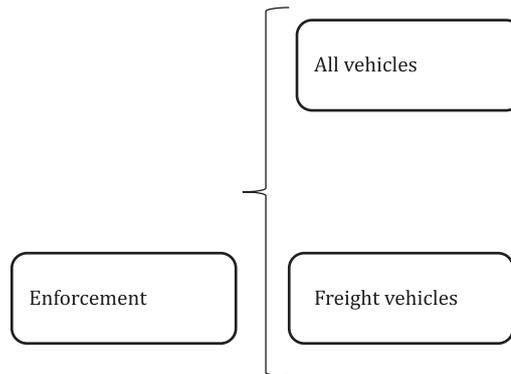

Figure 8 — Enforcement use cases

For all vehicles, access control in urban areas to enforce vehicle entry to certain areas can be effective.

For freight vehicles, weigh in motion (WIM) to enforce heavy goods transport vehicles, dangerous goods/hazardous materials transport management to enforce geo-fencing and law enforcement applications to regulated freight vehicles such as overloaded vehicle shutout from urban area can be effective.

Application such as remote digital tachograph monitoring to maintain safe freight transport vehicles movement, and heavy vehicle air quality controls and geo-fencing in urban areas and emission control of vehicles entering urban areas to enforce geo-fencing in certain area of the city can also be effective.

The use cases include:

a)   Access control in urban area to enforce vehicle entry to certain area, in which the smart city ITS enforcement controls the traffic volume by controlling the access to the city centre of each vehicle.

b)   Emission control of vehicles entering urban areas by enforcing geo-fencing in restricted areas of the city, in which the smart city ITS enforcement centre monitors and controls the traffic volume to keep the air clean near the city centre.

An example can be found at Reference [7].

c)   WIM to enforce heavy goods transport vehicles, in which the smart city ITS enforcement agency monitors or detects overloaded vehicles to keep road traffic safe.

An example can be found at Reference [8].

d)   Dangerous goods or hazardous materials transport management to enforce geo-fencing, in which the smart city ITS enforcement agency monitors and controls the vehicles carrying dangerous goods or hazardous cargos and keeps those vehicles away from entering the city centre for safety reasons. Furthermore, by monitoring those vehicles, the first responders can be despatched in a timely manner to the accident site in case of emergency.

e) Law enforcement applications to regulated freight vehicles such as overloaded vehicle shutout from smart city ITS area, in which the smart city ITS enforcement agency monitors or controls the speed, size and load of the vehicle to keep the road traffic safe.

f) Remote digital tachograph monitoring to maintain safe freight transport vehicle movement, in which the smart city ITS enforcement agency monitors or controls the commercial vehicle and ensures that the operator of the vehicle complies with the regulations and laws, such as maintaining minimum resting time, to keep the road traffic safe.

An example can be found at Reference [9].

g) Heavy vehicle air quality controls and geo-fencing in smart city areas, in which the smart city ITS enforcement agency monitors or controls the emission of the monitored heavy vehicle to keep high polluting vehicles out of the city.

An example can be found at Reference [10].

12.6 The role of service providers

The role of service providers, public or private, can be examined in the four categories as shown in Figure 9.
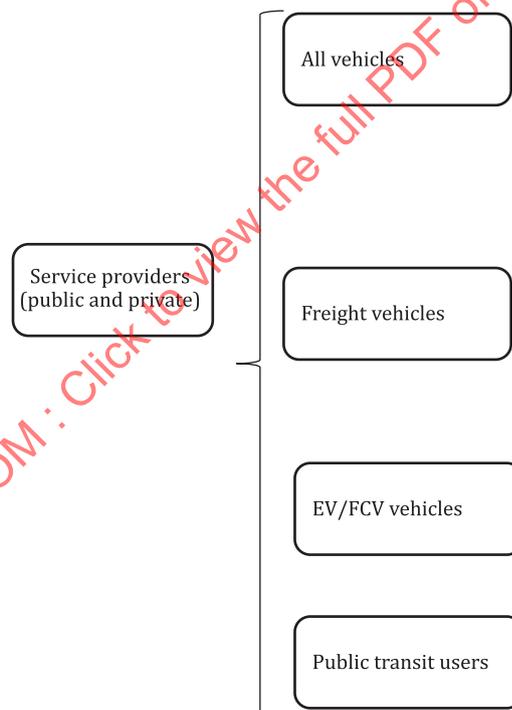

Figure 9 — The role of service providers

For all vehicles, disaster information provisioning systems for safer and timely evacuation activities, traffic signal (SPaT-MAP), the signal phase and timing and road topology messages information provision for safer and efficient traffic flow in the urban area, urban/suburban/expressways mobility modes specific safety information provisioning and traffic monitoring, dynamic map management including probe data collection, data aggregation, managing digital twin in the cloud and provisioning safety in formation provisioning to the vehicles, EFC from services such as parking, event admission, car sharing, vehicle remote maintenance applications such as over the air soft updating, intelligent parking such as automatic ballet parking supporting systems, car sharing management including booking, fee collection, battery monitoring and maintenance, dynamic map utilizing service applications for automated driving bus, shuttle, freight vehicles for efficient and safe operation can be effective.

For freight vehicles, freight vehicle management applications supporting efficient and safe transport fleet operation can be effective.

For electric vehicles (EV)/ fuel cell vehicles (FCV), EV charging applications such as booking, monitoring, fee collection and security, fuel cell vehicle charging applications like EV can be effective.

For public transit users, public transit information provisioning to users in a timely and dynamic real time basis, taxi fleet management applications such as booking, matching between user and driver, safety information provisioning, tourist information/advice provisioning service applications to inbound users, bicycle/motor cyclist's ITS service applications such as vulnerable road user safety information provisioning services can be effective.

The examples used to examine the role of the service providers are as follows:

a) Disaster information provisioning systems for safer and more timely evacuation activities: the service provider offers information needed to the vehicle in the case of emergency and instructions for the vehicle to evacuate from the disaster area.

   An example can be found at Reference [5].

b) Traffic signal (SPaT-MAP), the signal phase and timing and road topology messages information provision for safer and efficient traffic flow in the smart city ITS area: the service provider offers traffic signal timing information to the vehicles to help maintain the vehicle emission level low and assist a safe driving behaviour for the driver.

   An example can be found at Reference [11].

c) Urban/suburban/expressways mobility mode-specific safety information provisioning and traffic monitoring: the service provider offers mobility-specific safety information to each vehicle and monitors vehicle behaviour to keep the city centre safe.

d) Dynamic map management including probe data collection, data aggregation, managing digital twin in the cloud and provisioning safety information provisioning to the vehicles: the service provider collects vehicle probe data, updates the dynamic map at the centre and monitors traffic on the digitally-structured infrastructure platform (also called the "digital twin" or the "twin of real traffic") so that the service provider can provide each vehicle specific safety information in a timely manner.

   An example can be found at Reference [12].

e) EFC from services such as parking, event admission and car sharing: the service provider monitors the vehicle entering the parking facility, event facility, or a car sharing facility (can be road or kerb side) and collects fee from users of those services.

   An example can be found at Reference [13].

f) Vehicle remote maintenance applications such as over-the-air software updating: the service provider provides remote maintenance service to the vehicle users by performing software updates when the vehicle is idle.

   An example can be found at Reference [14].

g) Intelligent parking such as automatic valet parking supporting systems: the service provider provides automated valet parking services by monitoring and controlling each vehicle parked inside or nearby an area of the parking facility. Verifying user rights and payment processes are included in the service.

   An example can be found at Reference [15].

h) Car sharing management including booking, fee collection, battery monitoring and maintenance: the service provider provides service information required for car sharing application to the car or