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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

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Executive summary

Air pollutants from vehicles, such as carbon dioxide (CO_2), carbon monoxide (CO) or nitrogen oxides (NO_x), along with traffic noise, are considered key challenging aspects of urban transport systems. Congested city traffic scenarios such as traffic jams may be critical and have been shown to affect public health. Hence, there is a need to improve monitoring of the local environment, particularly with respect to pollution due to surrounding vehicles. Furthermore, there is a need for continuous ('almost real-time') emissions monitoring due to the dynamic nature of the traffic. In this way, vehicle drivers, passengers and/or VRUs may be better informed of pollution levels and its personal exposure.

The present document studies how C-ITS architecture and any V2X communication technology could be used to enable new type of transport pollution control or management applications.

Introduction

Despite enhancements in vehicle efficiencies, the automotive sector may still be responsible for a very significant portion of pollution caused to the environment. As an example, in Europe, road transport or vehicles account for almost one fifth of Europe's greenhouse gas emissions, and many European cities suffer a concentration of air pollutants that exceed European Union standards. In parallel, various emerging industry trends (e.g. 'pay-as-pollute') require better control and more accurate information about the vehicle emissions to enable the vision of green transport and control negative transport pollution impact to humans.

C-ITS is a technology which allows vehicles to become connected to each other and other parts of transport network to improve decision making. Apart from improving road safety and traffic flow it may reduce environmental transport impact. While the collision and congestion avoidance are already addressed in many existing ITS use cases and requirements, the environmental aspect is less explored, especially in the context of sharing the vehicle emissions information to support various pollution control applications.

1 Scope

The present document provides the overview of how C-ITS architecture and any V2X communication technology could be used to enable new type of transport emissions control and management applications. Based on the identification and analysis of major use cases, the report provides a recommendation for the extension of the existing ETSI ITS standards with new ITS applications reducing the environmental transport impact and improving the transport emissions control.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ISO TS 17378: "Intelligent transport systems. Urban ITS - Air quality management in urban areas" (also published by CEN).

[i.2] ISO TS 19321: "Intelligent transport systems - Cooperative ITS - Dictionary of in-vehicle information (IVI) data structures (also published by CEN)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

ITS Central System: ITS system in the backend

NOTE: For instance: traffic control centre, traffic management centre, or cloud system from road authorities, ITS application suppliers or automotive OEMs.

V2X: vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and/or infrastructure to vehicle (I2V), or vehicle to network (V2N) and/or network to vehicle (N2V) communication

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CAM Cooperative Awareness Message

CMS	Central Management System
CZ	Controlled Zone
DENM	Decentralized Environmental Notification Message
HC	Hydrocarbon
HV	Host Vehicle
IVIM	Infrastructure to Vehicle Information Message
MAPEM	MAP (topology) Extended Message
PM	Particulate Matter
RV	Remote Vehicle
SPATEM	Signal Phase And Timing Extended Message
VMS	Variable Message Sign
VRU	Vulnerable Road User

4 Introduction

4.1 Vehicle emissions crowdsourcing concept

Air pollutants from vehicles, such as carbon dioxide (CO_2), carbon monoxide (CO) or nitrogen oxides (NO_x), along with traffic noise, are considered challenging aspects of existing transport systems. Congested city traffic scenarios such as traffic jams may be critical and may affect public health in at least two different ways:

- Vulnerable Road Users (VRUs) such as pedestrians, cyclists, and motorbike users in city traffic may be exposed to relatively higher risks of emissions due to their physical proximity to vehicle exhausts and lack of air filtering systems, such as cabin air filtering systems that may be included in vehicles.

- Vehicle drivers and/or passengers may be exposed, intermittently or continuously, to relatively higher emissions levels without information about these levels and hence may be exposed to corresponding health risks. Vehicle cabin air filtering systems and/or cabin air recirculation systems may reduce emissions exposure, but may not be available or operational in all vehicles.

Hence, there is the need to improve monitoring of the local environment, particularly with respect to the emissions due to surrounding vehicles. In this way, vehicle drivers, passengers and/or VRUs may be better informed of emissions levels and their exposure.

To address the problem of limited personal emissions exposure information and provide environmental monitoring method which mitigates it, it is proposed to enable vehicle emissions crowdsourcing by which actions may be taken by individual VRUs (or vehicles) in response to the emissions exposure.

The crowdsourcing approach would use C-ITS V2X communications technologies to leverage accurate measurement techniques for the design of more effective mechanisms to combat emissions and reduce its negative impact on the users of the transport system. Vehicle emissions crowdsourcing could be defined as the process by which vehicles periodically share the information (e.g. by using ETSI ITS Cooperative Awareness Messages or similar) about its currently generated emissions levels using V2X based communication. In particular, the coordinated utilization of multiple vehicle emission measurements by means of V2X within a geographic area would allow obtaining reliable estimations of air pollutant concentration at locations where no direct measurement is available.

The overview of the vehicle emissions crowdsourcing approach is presented in Figure 1.

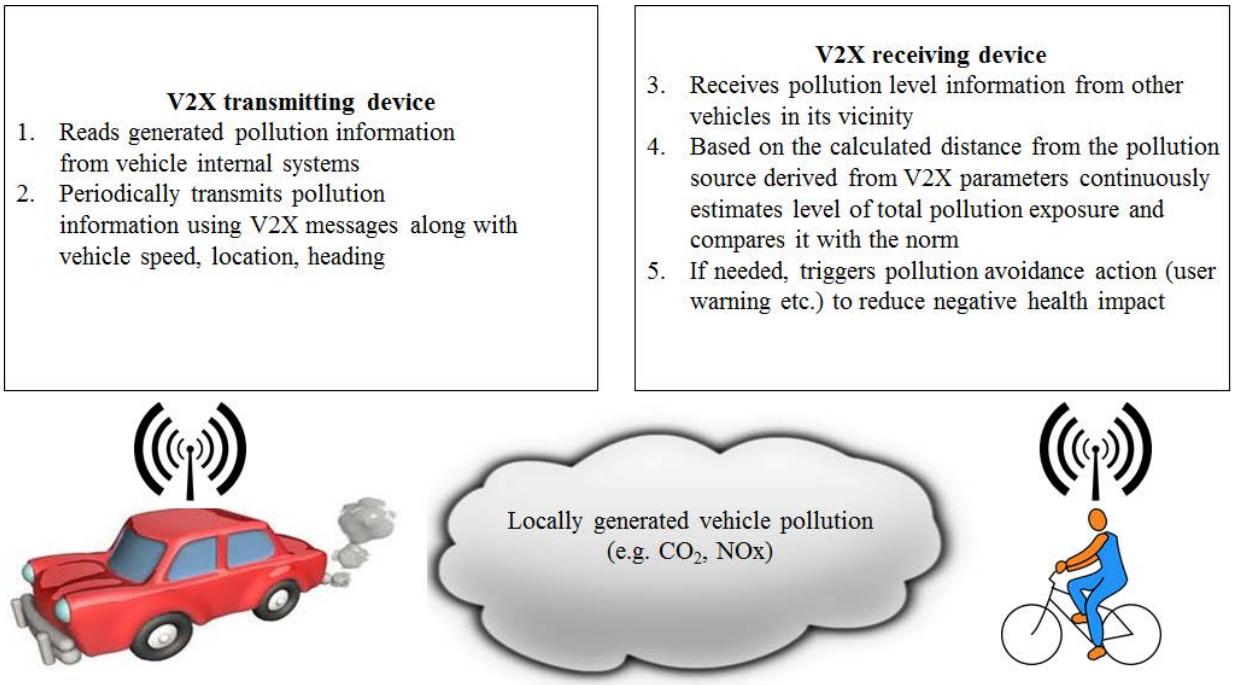

Figure 1: Simplified diagram of the V2X based emissions crowdsourcing approach

Considering technical and non-technical vehicle implementation aspects, the air pollutants of interest for this crowdsourcing approach would be the following:

- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Nitrogen oxides (NOx)
- Hydrocarbons (HC)
- Particulate matter (PM)

From the use case perspective, utilization of these emissions measurements and estimations could be an enabler for a new domain of Green ITS applications used by the C-ITS ecosystem (VRU devices, V2X enabled vehicles, roadside infrastructure, etc.) in order to control and minimize the level of emissions exposure to the human(s). As an example, these new applications may include:

- Warning through the VRU device (e.g. smartwatch, smartphone or personal navigation device) about the level of negative health impact (e.g. low/medium/high comparing to the norm) to allow the VRU to change its route or location if possible (V2P, Use case category: Vulnerable road use).
- Automated windows closure of a vehicle exposed to outside emissions, switching on the vehicle cabin air recirculation system, or similar preventive measure to reduce the emissions exposure (V2V, Use case category: Convenience).
- Emissions based speed control applications in urban roads (V2I, Use case category: Convenience, Vulnerable road use).
- V2I enabled traffic lights displaying the current emissions level for passing pedestrians or prioritizing VRU traffic when the exposure level is high (V2I, Use case category: Vulnerable road use).

In addition to air pollutant emissions, other emission sources like noise can be of interest to assess and control.

4.2 CMS based air quality management

The present document also describes use-cases that are derived from the strategies and technologies described in ISO TS 17378 [i.1].

These use-cases show how to apply the new communication means provided by C-ITS to pure Central Management System based pollution/air quality management.

5 Use cases

5.1 CMS based air quality management

The clauses below present use-cases derived from the strategies and technologies described in ISO TS 17378 [i.1]. Four use cases have been identified:

- Vehicle emissions-based speed control (clause 5.2)
- Access Restriction based on vehicle type or vehicle emission type (clause 5.3)
- Access restriction based on environmental measurements (clause 5.4)
- Warning on environmental dangers (clause 5.5)

These use-cases show how to apply the new communication means provided by C-ITS to pure Central Management System (CMS) based pollution/air quality management.

5.2 Vehicle emissions-based speed control

The use case is shown in Figure 2.

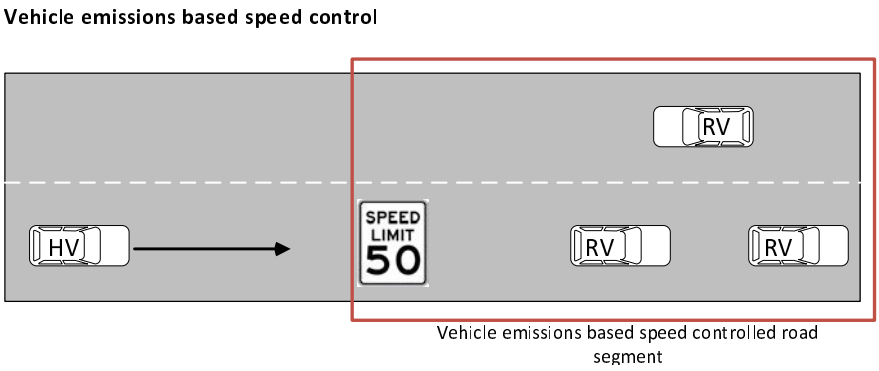

Figure 2: Use-case vehicle emissions based speed control

Use Case Name	Vehicle Emissions Based Speed Control
User Story	Control speed limit based on gathering generated emissions data from polluting vehicles in the vehicle emissions based speed controlled road segment. See notes 1 and 2.
Category	Convenience
Road Environment	Urban | Rural | Highway
Short Description	CMS periodically receives a vehicle generated emissions data sent from polluting vehicle(s) and reduces the speed limit if the local pollution level is too high in the vehicle emissions based speed controlled road segment. This could be also a speed limit specific to a vehicle class (Trucks, SUVs, …).
Actors	• Host Vehicle (HV) - its behaviour may be impacted by the use case • Optional: Remote Vehicle(s) RVs • CMS • VMS showing Speed limit
Vehicle Roles	• HV and RV(s) represent the polluting vehicles periodically sending its emissions data. • HV represents the vehicle receiving, via variable speed limit road signs, the information about the recommended speed for road segment ahead and need to adjust its speed.
Road & Roadside Infrastructure Roles	• Road segments are defined by their lane designations and geometry. • Recommended speed limits are associated with road & lane segments. • Recommended speed limit is updated and displayed on VMS. • Recommended speed limit is disseminated to Vehicles.
CMS Roles	Based on the periodically received emissions data from the polluting vehicles and other information sources the CMS recommends and controls the variable road sign speed limit.
Goal	• By controlling local speed limit in the vehicle emissions based speed controlled road segment reduces the vehicles generated pollution below the acceptable level according to local regulations. • Notify HV of the optimal speed to enable environmental friendly driving.
Needs	• Polluting HV and RV(s) need to periodically share its emissions data. Legacy vehicles will not send emission classes due to the lack of C-ITS. Non-polluting vehicles should transmit "exhaust free" and Electric powered cars will emit particulate matter and noise. • HV needs to know the recommended speed to minimize pollution in the vehicle emissions based speed controlled road segment.
Constraints/Presumptions	HV on the road segment is notified and abide by the recommended speed.
Geographic Scope	Global
Pre-Conditions	• The vehicle emissions based speed controlled road segment is determined from: o Local pollution level o Lane designations and geometry. • The lane or road segments posted speed limit is known. • HV is moving forward approaching the vehicle emissions based speed controlled road segment.
Event Flow	CMS periodically polls the polluting vehicle emissions data and other available data (e.g. fixed air quality measurement stations). If the CMS detects that local pollution level is too high in the vehicle emissions based speed controlled road segment: • CMS recommends new speed limit and updates the variable road sign Road sign alerts HV of the new speed limit. If the CMS detects that local pollution level is no longer too high in the vehicle emissions based speed controlled road segment: • CMS recommends new speed limit and updates the VMS and informs HV of the new speed limit.
Post-Conditions	• New speed limit is displayed on the VMS in the vehicle emissions based speed controlled road segment. • HV is aware of the new speed limit.
Service-Level Key Performance Indicators	• Generated emissions data timeliness, reliability and accuracy • Positioning Accuracy of vehicle

Information Requirements	• Polluting vehicles generated emissions data (e.g. Carbon dioxide CO2, Carbon monoxide CO, Nitrogen oxides NOx, Hydrocarbons HC, Particulate matter PM). Non-polluting vehicles should transmit "exhaust free" and Electric powered cars will emit particulate matter and noise. • Vehicles location • Lane designations and geometry • Recommended speed limit associated with lane or road segments and vehicle class.
Means of information transport	VMS showing current speed limit C-ITS message (see clause 6)
NOTE 1: Electric powered cars will still emit particulate matter and noise, so these vehicles could send "exhaust free" and their noise classification. Independent speed control for non-polluting vehicles may be possible (e.g. by using dedicated lanes) but it is implementation specific and out of scope for the purpose of the present document. NOTE 2: The way to measure and/or calculate the emissions of a vehicle are out of scope of the present document. A possibility would be to use the existing data from the vehicles type certification (e.g. emission class, drive type, noise classification).	

5.3 Access restriction based on vehicle type or vehicle emission type

The use case is shown in Figure 3.

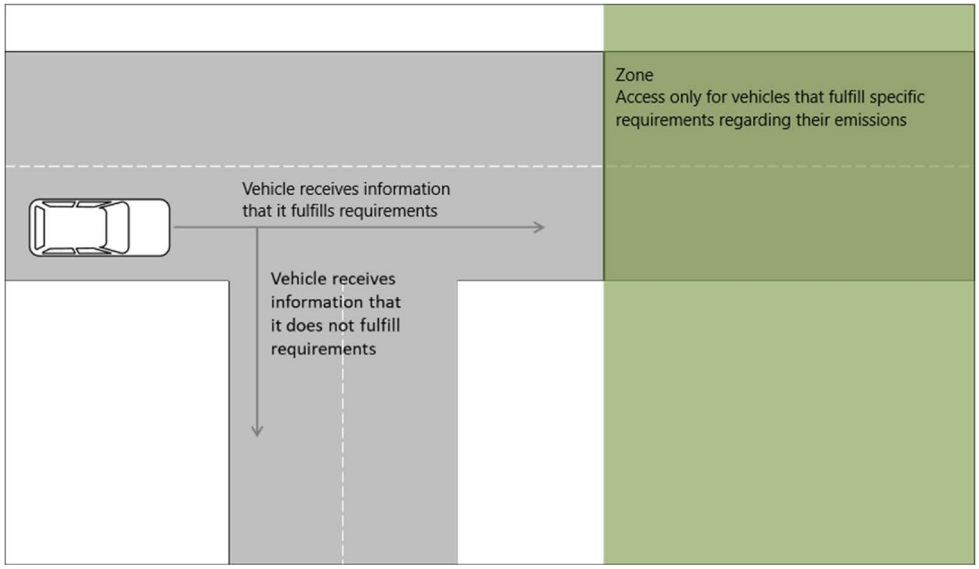

Figure 3: Illustration use-case access restriction based on vehicle type or vehicle emission type

Use Case Name	Restriction based on environmental zones
User Story	Specific vehicle access restrictions in controlled road segments and zones based on the type of vehicle or vehicle emission type.
Category	Safety | Convenience
Road Environment	Urban | Rural | Highway
Short Description	A road segment or zone is defined in the CMS and annotated with the banned vehicle types or enumerated list of allowed emission standards (e.g. EURO Norm classes). This geo-fence information is periodically disseminated via surrounding RSUs or other communication equipment.
Actors	• Vehicles • Roadside unit (acting as gateway) • CMS • Fixed or Variable Road Signs showing restriction
Vehicle Roles	• Vehicles (e.g. passenger cars, trucks, etc.) receiving the information about the controlled zone or road segment • If affected by the restrictions, the vehicle warns the driver upon entering the controlled zone or road segment or avoids this by route recalculation
Road & Roadside Infrastructure Roles	• Road segments and zones are defined by their geometry. • Restrictions are displayed on a fixed (static) or variable road signs.
Other Actors' Roles	A CMS manages the defined zones and road segments. CMS triggers and controls dissemination (e.g. using assigned RSUs).
Goal	According to local air pollution regulations, zones and road segments are defined, where specific vehicles (e.g. passenger cars, trucks, etc.) are restricted. The procedure prohibits the entry or transit in the defined zones or road segments for defined vehicles and therefore reduces the pollution.
Needs	• The central management system provides the information about the defined zones and road segments. • The vehicle needs the information about restricted zones.
Constraints/Presumptions	The vehicles need to be notified before they enter the defined zones and road segments. Therefore careful planning of the dissemination area is needed.
Geographic Scope	Global
Pre-Conditions	• The restriction is determined from: o Local air pollution regulations • The vehicle is approaching the defined zones or road segments.
Event Flow	• The CMS disseminates the information about the restricted road segments and zones (see clause 6 for details). • The roadside unit receives the information and sends it out to the vehicles.
Post-Conditions	• The vehicle is aware of the restriction zones/road segments and is not allowed to enter the zone. • The vehicle warns the driver on controlled zone or adjusts its route, if possible.
Service-Level Key Performance Indicators	• Accuracy of restriction zones or road segments information • Vehicle positioning accuracy • Information delivery in time (before entering zone) • Positioning Accuracy of vehicle
Information Requirements	• Vehicle location and planed route • Controlled zones/road segments • (Optional: Alternative routes)
Means of information transport	VMS showing access restriction C-ITS message (see clause 6)

5.4 Access restriction based on environmental measurements

The use case is shown in Figure 4.

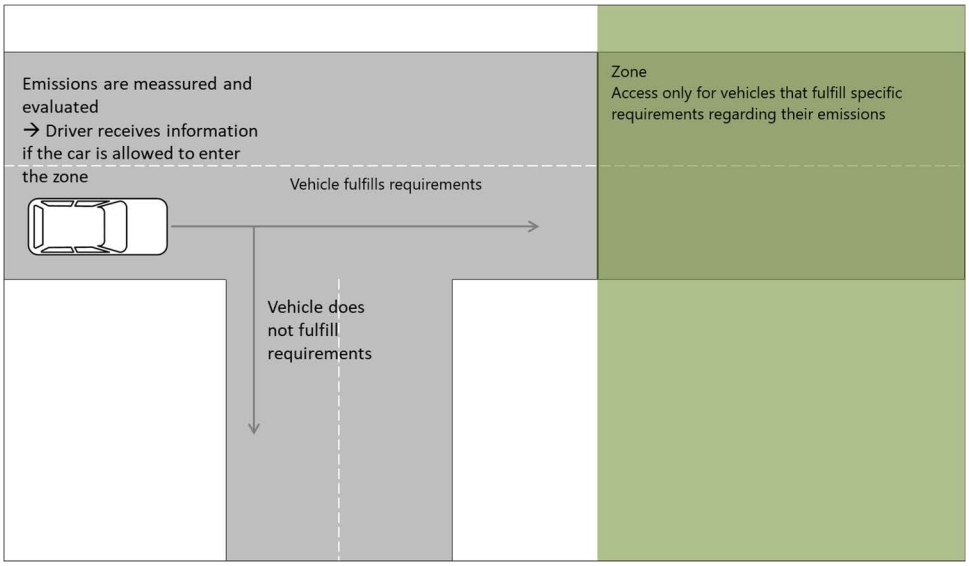

Figure 4: Illustration use-case access restriction based on vehicle emission types

Use Case Name	Access restriction based on environmental measurement
User Story	Specific vehicle restrictions in controlled road segments and zones based on environmental measurements.
Category	Safety | Convenience
Road Environment	Urban | Rural | Highway
Short Description	The pollution value is measured constantly in a defined zone. When a specified limit is reached, the central management system will be informed and sends out a restriction message for vehicles in defined zones.
Actors	• Environmental measurements (detectors) • Vehicles • Roadside unit (acting as gateway and aggregator) • CMS • VMS showing access restriction
Vehicle Roles	• Vehicles receiving the information about vehicle restriction zones. • If affected by the restrictions, the vehicle warns the driver when approaching the controlled zone or road segment or avoids this by route recalculation.
Road & Roadside Infrastructure Roles	• CMS manages the defined zones and road segments. • CMS disseminates. • The road side units distribute the IVIM to vehicles approaching the defined zones.
Other Actors' Roles	Environmental detectors measure the value of the pollution and inform the CMS when a defined limit is reached. CMS triggers and controls dissemination (e.g. using assigned RSUs).
Goal	According to local regulations, zones and road segments are defined, which restrict vehicles (e.g. passenger cars, trucks, etc.). The procedure prohibits the entry or transit in the defined zones or road segments for defined vehicles and therefore reduces the pollution.
Needs	• The central management system needs the information about the emission value of the detectors. • The vehicle needs the information about restricted zones.
Constraints/Presumptions	The vehicles need to be notified before they enter the defined zones and road segments.
Geographic Scope	Global
Pre-Conditions	• The restriction based environmental measurements are determined from: o Local regulations. • The vehicle is approaching the defined zones or road segments.
Event Flow	• The central management system receives information that a defined emission value is reached from the environmental detectors. • The central management system sends out an IVIM with a restriction for the affected zones. • The roadside units distribute the information to the vehicles.

Post-Conditions	• The vehicle is aware of the restriction zones/road segments and is not allowed to enter the zone. • The vehicle warns the driver on controlled zone or adjusts it route, if possible.
Service-Level Key Performance Indicators	• Accuracy of restriction zones or road segments information • Vehicle positioning accuracy • Information delivery in time (before entering zone) • Positioning Accuracy of vehicle
Information Requirements	• Vehicle location and planed route • Controlled zones/road segments • Detected emission value • (Optional: Alternative routes)
Means of information transport	VMS showing access restriction C-ITS message (see clause 6)

5.5 Warning on environmental dangers

Use Case Name	Warning on environmental dangers due to harmful or toxic air-pollution
User Story	Warn vehicles located in a specific area (e.g. tunnel, parking garage) on dangerous air-quality situations.
Category	Safety, Health
Road Environment	Urban | Rural | Highway
Short Description	In case of fire or other sources of high air-pollution (e.g. in a tunnel) a message warning relevant vehicles of this danger is disseminated. The vehicles can thus seal the interior and shutdown air-flow.
Actors	• Vehicles • Roadside unit • Triggering authority • Traffic Light signal
Vehicle Roles	• Vehicles receiving information • If traffic light blocks road, the vehicle stops or changes its route if possible • If affected, the vehicles reconfigure the in-vehicle air flow system and warn the driver
Road & Roadside Infrastructure Roles	• Traffic light signal before area • Disseminates a dedicated Warning message
Other Actors' Roles	A triggering authority (e.g. tunnel supervision unit) monitors a specific area (for fires and other potential air-pollutants). The authority decides to start or stop dissemination of warning and controls a traffic light.
Goal	Avoid fatalities or danger to personal health.
Needs	• The triggering authority monitors air-quality and supervises area. • The vehicle needs location information inside the supervised area (e.g. the tunnel).
Constraints/Presumptions	-
Geographic Scope	Global
Pre-Conditions	• A vehicle is approaching or is inside the supervised area.
Event Flow	• The triggering authority detects fire or any other source of dangerous air pollution. • The triggering authority decides to dissemination a warning message. • The triggering authority can decide to block the road segment switching the traffic light located at start of road segment. • The roadside units distribute the information to the vehicles. • The vehicles receive danger information and trigger health maintaining procedures (e.g. sealing interior by closing air-vents).
Post-Conditions	• Vehicles outside the danger area are blocked entering the zone. • Vehicles inside the danger area are instructed seal interior.
Service-Level Key Performance Indicators	• Vehicle positioning accuracy • Information delivery in time • Positioning Accuracy of vehicle
Information Requirements	• Vehicle location (direction of driving) • Detected emissions (potential dangers)

Means of information transport	Traffic light blocking/allowing access to area C-ITS message (see clause 6)

6 Gap Analysis

6.1 CAM

For the use cases described in clause 5.2 and clause 5.4, emission information should be added to the CAM message.

To keep backward compatibility the following proposal uses the ASN.1 extension feature.

The BasicContainer has the '…' extension point specified, which is used to add an optional Emission container. The fields are imported from relevant ISO standards (like already used in the IVIM).

NOTE: An important aspect to consider when applying the proposal in the present document for the update of the CAM specification is the fact that, by adding this vehicle specific data to the CAM, the "privacy footprint" of an ITS station will be also impacted. So care needs to be taken to find the balance between fuzziness and usefulness.

```
IMPORTS
DieselEmissionValues, ExhaustEmissionValues, EngineCharacteristics, EnvironmentalCharacteristics
FROM EfcDsrcApplication {iso (1) standard(0) 14906 application(0) version6(6)}

EuVehicleCategoryCode, Iso3833VehicleType
FROM ElectronicRegistrationIdentificationVehicleDataModule {iso(1) standard(0) iso24534 (24534)
vehicleData (1) version1 (1)}

BasicContainer ::= SEQUENCE {
  stationType        StationType,
  referencePosition  ReferencePosition,
  ...,
  [[ -- Extension for Pollution management
    emissions       EmissionContainer OPTIONAL ]]
}

EmissionContainer ::= SEQUENCE {
  euVehicleCategoryCode    EuVehicleCategoryCode OPTIONAL,
  iso3833VehicleType       Iso3833VehicleType,
  euroAndCo2value          EnvironmentalCharacteristics OPTIONAL,
  engineCharacteristics    EngineCharacteristics,
  exhaustEmissionValues    ExhaustEmissionValues OPTIONAL,
  dieselEmissionValues     DieselEmissionValues OPTIONAL,
  ...
}
```

6.2 DENM

For the use case described in clause 5.5, a new event Cause code should be added.

For this warning message a new CauseCode and SubCauseCode should be added to the Common Data dictionary.

```
CauseCodeType ::= INTEGER {
  reserved                             (0),
  trafficCondition                     (1),
  accident                             (2),
  roadworks                            (3),
  impassability                        (5),
  adverseWeatherCondition-Adhesion     (6),
  aquaplannning                        (7),
  hazardousLocation-SurfaceCondition (9),
  hazardousLocation-ObstacleOnTheRoad(10),
  hazardousLocation-AnimalOnTheRoad  (11),
  humanPresenceOnTheRoad               (12),
  wrongWayDriving                      (14),
  rescueAndRecoveryWorkInProgress      (15),
  adverseWeatherCondition-ExtremeWeatherCondition   (17),
  adverseWeatherCondition-Visibility    (18),
  adverseWeatherCondition-Precipitation (19),
```

```
  slowVehicle                          (26),
  dangerousEndOfQueue                  (27),
  vehicleBreakdown                     (91),
  postCrash                            (92),
  humanProblem                         (93),
  stationaryVehicle                    (94),
  emergencyVehicleApproaching          (95),
  hazardousLocation-DangerousCurve     (96),
  collisionRisk                        (97),
  signalViolation                      (98),
  dangerousSituation,                  (99),
  dangerousEmissions                   (100),
} (0..255)

DangerousEmissionsSubCauseCode ::= INTEGER {
  unavailable                          (0),
  flueGas                              (1),
  carbonMonoxide                       (2),
  carbonDioxide                        (3),
  nitrogen                             (4),
  toxicGas                             (5)
} (0..255)
```

6.3 IVIM

For the use cases described in clauses 5.2, 5.3 and 5.4, the IVIM could be used as instrument to transport restriction information to the vehicles. The definitions already include the definition of road segments, and the needed other elements to notify limitations or limits.

The containers defined in ISO TS 19321 [i.2] already include all necessary data elements. Therefore no change or addition are necessary.

6.4 SPATEM/MAPEM

For the use case defined in clause 5.5, no changes or additions are necessary.

Annex A:
Change History

Date	Version	Information about changes
December 2016	0.0.1	Initial version
October 2019	0.0.6	Prepare Final Draft. Change of Rapporteur
November 2019	0.0.7	Added preliminary CZ dictionary from ISO TS 17380
January 2020	0.0.8	Added comments during Drafting Session
May 2020	0.0.9	Prepare Draft for Approval

History

Document history		
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