Automotive Requirements for the Infrastructure to Vehicle Information (IVI) Service

CAR 2 CAR Communication Consortium

About the C2C-CC

Enhancing road safety and traffic efficiency by means of Cooperative Intelligent Transport Systems and Services (C-ITS) is the dedicated goal of the CAR 2 CAR Communication Consortium. The industrial driven, non-commercial association was founded in 2002 by vehicle manufacturers affiliated with the idea of cooperative road traffic based on Vehicle-to-Vehicle Communications (V2V) and supported by Vehicle-to-Infrastructure Communications (V2I). The Consortium members represent worldwide major vehicle manufactures, equipment suppliers and research organisations.

Over the years, the CAR 2 CAR Communication Consortium has evolved to be one of the key players in preparing the initial deployment of C-ITS in Europe and the subsequent innovation phases. CAR 2 CAR members focus on wireless V2V communication applications based on ITS-G5 and concentrate all efforts on creating standards to ensure the interoperability of cooperative systems, spanning all vehicle classes across borders and brands. As a key contributor, the CAR 2 CAR Communication Consortium and its members work in close cooperation with the European and international standardisation organisations.

Disclaimer

Document information

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Table 1: Document information

Changes since last release

Release	Date	Changes	Edited by	Approved
1.6.3	2022-12-16	• Phrasing corrections (e.g., replacing “carriageway” in many occurrences) • Integration of preliminary requirements to full requirements • New requirement on laneWidth in RCC	Release Management	Steering Committee
1.6.2	2022-07-22	• Several requirements changed in context of alignment with C-Roads • A list of changed, added or removed requirements can be found in clause 5 of [C2CCC RelOv]	Release Management	Steering Committee
1.6.1	2021-12-17	• Inclusion of the RCC, further detailing of road and zone representation • Introduction of a new clause for preliminary content • Minor improvements	Release Management	Steering Committee
1.6.0	2021-07-23	• Detailing of iviStatus handling • Several improvements of phrasings and figures • Editorial corrections • Renaming of document from: o Automotive Requirements for IVIM to: o Automotive Requirements for the Infrastructure to Vehicle Information (IVI) Service	Release Management	Steering Committee
1.5.3	2021-03-12	No changes	Release Management	Steering Committee
1.5.2	2020-12-16	Initial release	Release Management	Steering Committee

Table 2: Changes since last release

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1 Introduction

Other (informational) **RS_ARI_1**

This document is part of the documentation within the Work Item F0020 'Automotive Requirements for IVIM'. It is the main working document containing identified requirements to the IVIM from an automotive perspective.

It shall serve as an extension to already existing requirements on IVIM in the C-Roads profiles and specifications.

2 Scope

Other (informational) **RS_ARI_2**

The present document provides requirements related to the features of a C-ITS station transmitting IVIM to enable interoperability. The requirements in this document are intended as an addition to existing requirements in [ISO 19321], [TS 103 301] and the C-Roads profile.

In this document only, highway use cases were considered, use cases on other road types or in urban areas may need different profiling. Apart from that, the requirements in this document are independent of the specific use case and shall therefore apply to all highway use cases of the In-Vehicle-Signage Service.

Furthermore, the requirements are focused on the functional level, specifications on the lower communication levels are out of scope of this document. Also, for the functional level, these requirements don't claim to be complete.

The requirements in this document for now only apply to road traffic signs and signages that are physically represented on the road (through analogue or digital displays). For the future consideration of signs, which are not physically present (i.e. only virtual), the requirements will need to be reconsidered and adapted where needed. In addition, all requirements only refer to signs as listed in [ISO 14823], i.e. signs which are mounted on a pole or digital display. This explicitly excludes any kind of road marking.

In some cases, requirements are written in a way which let the implementation open, for example if they refer to very specific implementations which may depend on specific national regulations. Those requirements have to be further detailed by anybody implementing that requirement. Beside these special requirements all other requirements can be further detailed, too.

3 Conventions used

Other (informational) (RS_BSP_152) **RS_ARI_3**

Conventions used in this and other C2C-CC specification documents can be found in [C2CCC ConV].

4 Definitions

Definition (RS_BSP_193) **RS_ARI_9**

'C-ITS time' or *'time base'* means the number of elapsed International Atomic Time (TAI) milliseconds since 2004-01-01 00:00:00.000 Coordinated Universal Time (UTC)+0 as defined in [EN 302 636-4-1]. Timestamps as defined in [TS 102 894-2] follow this time format.

Definition **RS_ARI_10**

The '*station clock'* means a clock representing Cooperative Intelligent Transport Systems (C-ITS) time in a C-ITS station (see RS_RSP_006).

Definition (RS_BSP_429) **RS_ARI_11**

Information provided with a *'confidence level'* of 95 % means that the true value is inside the confidence interval or the confidence area for at least 95 % of the data points in a given statistical base.

Definition (RS_BSP_500) **RS_ARI_12**

A *'confidence interval'* is specified by the estimated value plus/minus the confidence value.

Definition **RS_ARI_13**

An *'instant'* denotes a point on the time axis, often also referred as a 'moment in time' (see also IEC 60050).

Definition **RS_ARI_15**

The *'relevance area'* (or *relevance zone*) is the area on the road for which the signage information is applicable. Each separate signage information is associated a specific relevance zone. The concept of an IVI relevance zone is the equivalent of an eventHistory used for DENMs.

Definition **RS_ARI_16**

The *'awareness area'* (or *detection zone)* is the area where drivers have to be informed about upcoming relevant signage information. The concept of an IVI detection zone is the equivalent of a DENM trace.

Definition **RS_ARI_89**

'Regular driving lanes' refer to all lanes that are an integral part of a highway / motorway segment and which do not assume an implicit, more specific role (such as entry or exit ramps, hard shoulders or emergency lanes).

This corresponds to all lanes of lane numbers 1..13 according to the ETSI numbering scheme for DE_LanePosition [TS 102 894].

5 Parameter settings

Table 3: Parameter settings RS_ARI_22

Parameter	Value	Unit	Description	Min. Value	Max. Value	Source Document
pRepetitionInterval	500	ms	Interval for the IVI repetition service	--	--	--
pIdUniquenessRadius	25	km	Radius around the originating station within which the tuple serviceProviderID-IviIdentificationNumber shall be unique	--	--	--
pIdReuseBlockingTime	24	H	Minimum blocking time before a previously used IviIdentificationNumber may be reused by a service provider			
pRepetitionDuration	5	Min	Duration over which a message shall be repeated	--	--	--
pLongitudinalOffsetSignPosition	3	m	Maximum longitudinal offset to the actual position of the physical sign	--	--	--
pNodeOffset	1	m	Maximum offset between two nodes describing the same geographical position	--	--	--
pMaxNumberofNodesPerZone	100	--	Maximum number of deltaPositions per segment / zone	--	--	--
pMinDetectionZoneLength	800	m	Minimum length of a detection zone for highway use cases	--	--	--
pMaxDetectionZoneLength	2000	m	Maximum length of a detection zone for highway use cases	--	--	--
pLateralNodeOffset	half of the actual lane width of the described road section	--	Intended lateral offset to the centre of the set of all regular driving lanes for the referencePosition	--	--	--

Parameter	Value	Unit	Description	Min. Value	Max. Value	Source Document
pLateralNodeOffsetAbsolute	3	m	Maximum lateral offset to the centre of the set of all regular driving lanes represented by the zone for the deltaPositions in polygonalLine and the referencePosition	--	--	--
pLateralNodeOffsetAbsoluteAD	1	m	Maximum lateral offset to the center of the set of all regular driving lanes represented by the zone for the deltaPositions in polygonalLine and the referencePosition if automated driving shall be supported	--	--	--
pLaneAngleDeviation	5	°	Maximum angle between the connection of the node points and the corresponding tangent to the lane centre	--	--	--
pLaneWidthAccuracy	0,3	m	Accuracy required for a lane's width	--	--	--
pMaxPerpendDistLaneCentre	10	m	Maximum perpendicular distance between the linear connection of two consecutive lane nodes and the actual centre of the lane	--	--	--

6 General understanding of the IVIM

6.1 Purpose of the In-Vehicle Signage use cases

The purpose of the In-Vehicle Signage (IVS) is to enable the receiving vehicle to know at any time and condition all the relevant signage information, based on time and location, but also based on characteristics and type of the vehicle. Receivers can filter sign information based on time, geographical and other relevance criteria (e.g. to only show information relevant ahead to the driver).

6.2 Purpose of the different containers in IVIM

This clause provides a short introduction to the three most relevant containers in IVIM: Management Container, Geographic Location Container and General IVI Container. See also Figure 1 for a simplified representation of the IVIM.

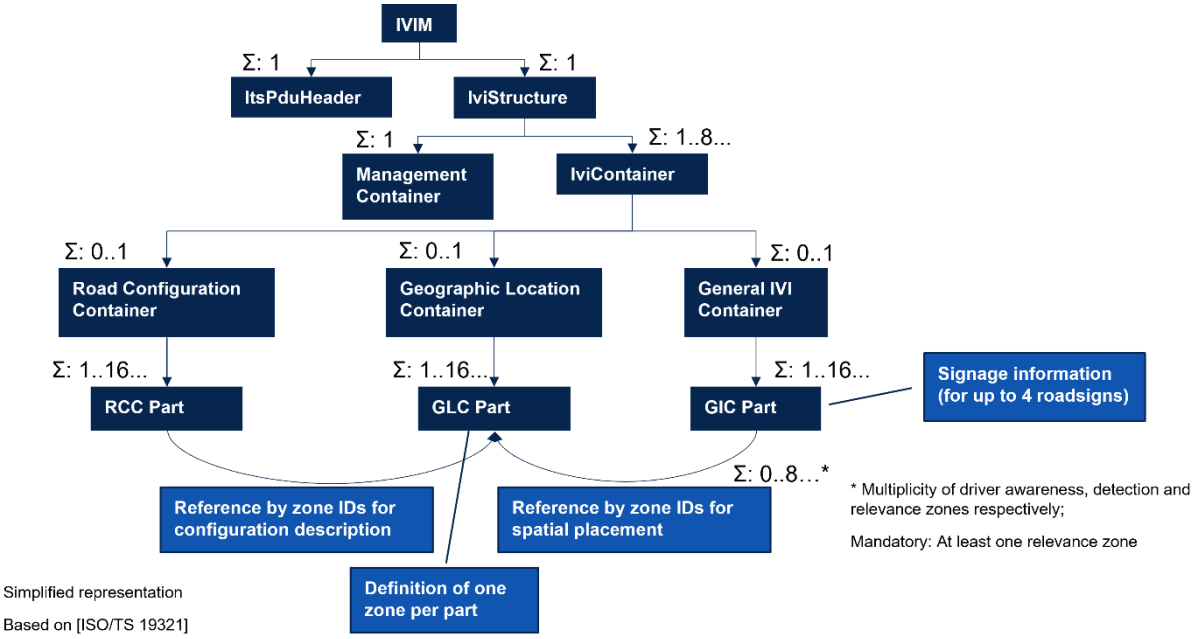


Figure 1: Simplified and shortened representation of IVIM

6.2.1 Management Container

The Management container is mandatory and provides the receiving vehicles with information necessary to handle the entire IVI message, unambiguously identify it (ServiceProviderId, iviIdentificationNumber) as well as to decide on its further processing and determine the status and time validity of its content (e.g. iviStatus, timestamp, validFrom, validTo, etc.)

6.2.2 Geographic Location Container

The Geographic Location Container (Glc) describes essential information for receiving vehicles to understand where and how the information provided in the IVI Application Container applies.

It is formed by a part which is common to all the parts of the Application Container plus a sequence of GlcParts that can be specific to the distinct parts of the application container. GlcParts are used to represent detection and relevance zones (following the definitions provided in [C2CCC Glos]).

The GlcParts describe zones generically and don't assign a specific use to them (e.g. as detection or relevance zones). This way zones described in the GLC can be used in different roles by other containers and one zone can act as a detection zone for one information and relevance zone for another.

According to specifications, at least two zones should be contained in each IVI message to provide one detection zone and one relevance zone. Each GlcPart is described, among others, by a zoneId (unambiguously identifying the zone), and a Zone (defining the geographical-shape of the zone)

6.2.3 General IVI Container

The General IVI Container (Gic) provides the signage information to be processed by vehicles. It is a sequence of GicParts, each defining a given piece of signage information. This information refers to Glc information for its spatial relevance. For this, each GicPart contains, among others, detectionZoneID and relevanceZoneId lists indicating respectively the detection and relevance zones that apply to this GicPart. Moreover, each GicPart contains the iviType (e.g. regulatory info or other kind of info), optionally the vehicleCharacteristics (i.e. for which kind of vehicles the info applies) and the specific signage information to communicate (e.g. road sign identifiers roadSignCodes or text messages extraText, etc.).

6.2.4 Road Configuration Container

The Road Configuration Container (RCC) provides information regarding the topology of a certain road section. This information can be used by receivers to get a better understanding of the road (and zone) topology. The RCC also refers to the zones described in the GLC and provides additional information e.g., on the road type and the lane setup (number of lanes, lane types, status ...).

7 Requirement specifications

7.1 IVIM Automotive Requirements

7.1.1 Transmission

Other (informational) **RS_ARI_14**

The following requirements on IVIM apply in addition to the relevant standards ([TS 103 301], [ISO/TS 19321]) and the C-Roads documents [C-ITS Message Profile].

Details:

Tested by:

Requirement **RS_ARI_67**

IVIM shall be repeated with a repetition interval of *pRepetitionInterval*.

Details:

Tested by:

Other (informational) **RS_ARI_38**

Signs which indicate the end of a specific or all regulations / restrictions should not be transmitted explicitly as individual signs in an IviStructure. The meaning of these signs is implicitly given through the ending of the relevance zone of corresponding signs.

If transmitted, all requirements given in this document shall apply.

Note: It is recommended not to transmit the aforementioned signs separately. One reason being that the relevance zone of such signs could stretch along several kilometres.

Details:

Tested by:

Other (informational) **RS_ARI_92**

In case of IVIM delegation (when one service provider's station signs and transmits IVIMs as 'delegate' for another service provider), the transmitting station needs to be fitted with separate certificates containing the required ITS-AID/SSP tuple for the service and the delegating serviceProviderId. Adding multiple such tuples (e.g., for multiple serviceProviderIds) to one certificate is not possible according to clause 6.4.8 of [IEEE 1609.2].

Details:

Tested by:

7.1.2 IviStructure

Requirement **RS_ARI_70**

If the iviStructure corresponds to a physical sign / gantry, it shall provide the legal statement as displayed by the static sign or gantry.

Note 1: This implies that the IviStructure doesn't need to exactly represent what is depicted on the gantry/sign but needs to provide all information required to represent the regulation as indicated by the gantry/sign.

Note 2: In order to support use cases where there is no physical sign, a corresponding suitable requirement may be defined in the future.

Details:

Tested by:

Requirement **RS_ARI_17**

An IviStructure having an iviStatus other than 'cancellation' shall contain at least one instance of GeographicLocationContainer.

Details:

Tested by:

Requirement **RS_ARI_18**

An IviStructure having an iviStatus other than 'cancellation' shall contain at least one instance of GeneralIviContainer.

Details:

Tested by:

Requirement **RS_ARI_19**

The definition of all zones referred to within the IVI Application Containers (e.g. GIV) shall be included in the same iviStructure as the respective Application Container.

Note: This implies that each iviStructure is self-contained.

Note: This implies that an individual Application Container (e.g. one gicPart) may refer to zones that are defined in different GLCs as long as they are all included in the same iviStructure.

Details:

Tested by:

Other (informational) **RS_ARI_90**

Service providers should make an effort to reduce the number of different, individual IVI messages transmitted in parallel as far as possible. Rather the mechanisms provided in the IVIM e.g. to reuse zones defined in GLC for different purposes in the GIVs should be utilized. For a better understanding see the two figures below.

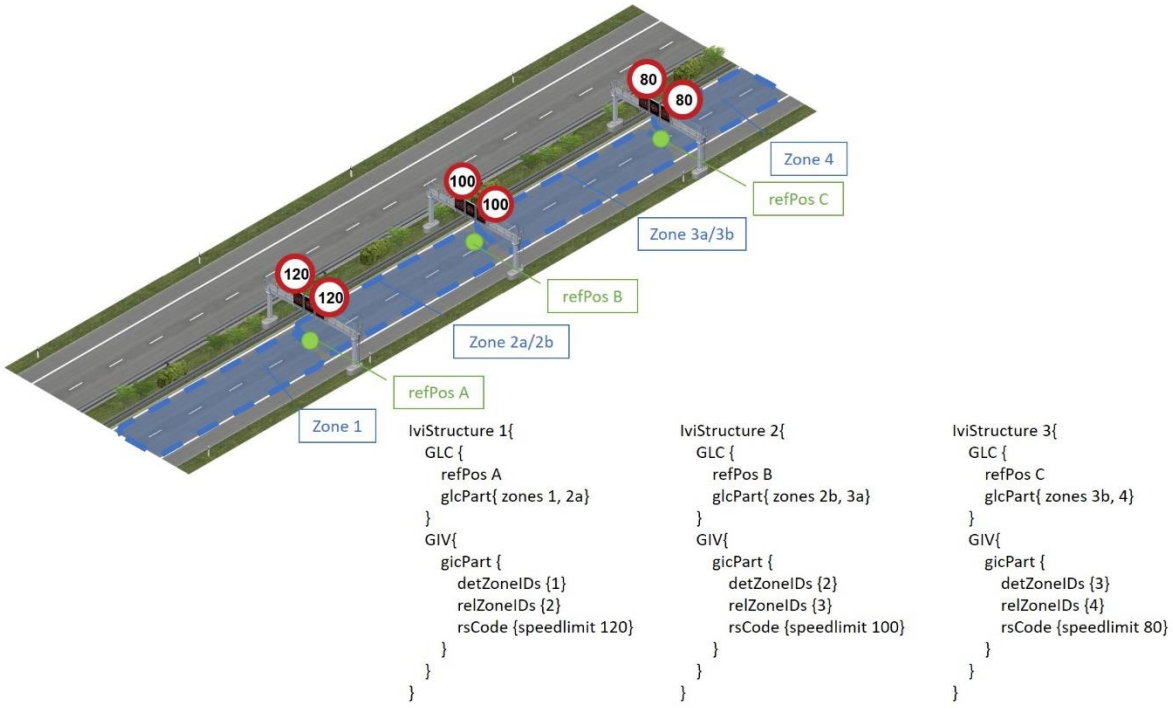
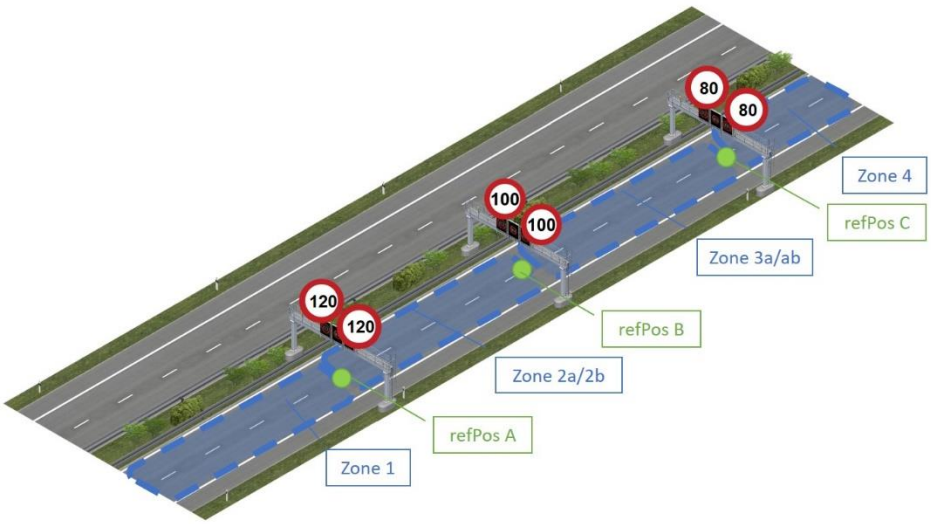


Figure 2: Exemplary implementation for a speed limit cascade with 3 separate IviStructures




```
IviStructure 0{
  GLC {
    refPos A
    glcPart{zones 1, 2a}
  }
  GLC {
    refPos B
    glcPart{zones 2b, 3a}
  }
  GLC {
    refPos C
    glcPart{zones 3a, 4}
  }
  GIV{
    gicPart {
      detZone {1}
      relZone {2a}
      rsCode {speedlimit 120}
    }
    gicPart {
      detZone {2b}
      relZone {3a}
      rsCode {speedlimit 100}
    }
    gicPart {
      detZone {3b}
      relZone {4}
      rsCode {speedlimit 80}
    }
  }
}
```

Figure 3: Exemplary, more efficient implementation for the same speed limit cascade with only one IviStructure

Details:

Tested by:

Requirement **RS_ARI_20**

The IviStructure should not contain any instances of LayoutContainer and TextContainer.

Note: If present, these containers may be ignored by receivers. The containers AutomatedVehicleContainer and RoadSurfaceContainer are currently not considered and may therefore also be ignored by receivers.

Details:

Tested by:

Requirement **RS_ARI_21**

If in vehicle information shall or need to be transmitted in separate IVIMs, the following prioritization shall be applied (number one having the highest priority):

1) Information applying to the same lane should be contained in a single message.
2) Information applying to the same direction of travel should be contained in a single message.
3) Information applying to the same local area should be contained in a single message.

Details:

Tested by:

Requirement **RS_ARI_25**

If there are multiple physical signs showing the same information applicable to the same road segment (e.g. one in a distance, one directly at the location of danger), only one IviStructure and GicPart shall be transmitted for all signs.

Details:

Tested by:

Requirement **RS_ARI_52**

At every point in time every combination of RsCode and relevanceZoneIds contained in an IviStructure shall be unique for that IviStructure.

Note: This means, that the combination of RsCode and relevance zone shall not be duplicated in in more than one IviStructure at any given point in time. This also excludes a situation as shown in Figure 4.

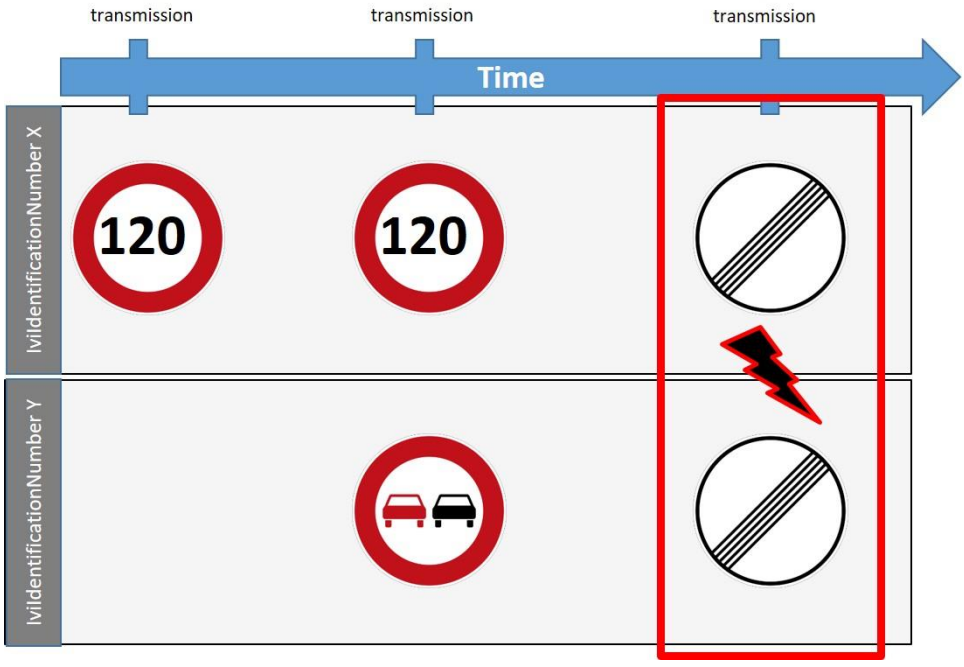


Figure 4: No duplicate information in separate IviStructures, example

Details:

Tested by:

Requirement **RS_ARI_53**

All in-vehicle information to be conveyed via IVIM should be transmitted in as few separate IviStructures as possible.

Details:

Tested by:

Requirement **RS_ARI_60**

An IviStructure shall contain the RCC to provide information about the total number of lanes where a vehicle can possibly drive in a given direction, including all lanes which the referenced zones represent (i.e. at least all lanes available for regular driving and all lanes for which signage information is provided in that zone).

An exception to this requirement applies, if the road operator has not even information on the total number of lanes available for regular driving. In this case, the RCC and applicableLanes in GicParts shall be omitted in the IviStructure.

If this exception is applied, only signs applying to the entire single or unidirectional carriageway shall be transmitted in an IviStructure.

Note: It is recommended to provide information on all lanes of the carriageway (if available, e.g. also hard shoulder).

Details:

Tested by:

7.1.3 ManagementContainer

Requirement **RS_ARI_58**

The tuple of ServiceProviderID and IviIdentificationNumber shall be unique at every given point in time within a radius of at least *pIdUniquenessRadius* around the transmitting C-ITS station.

Details:

Tested by:

Other (informational) **RS_ARI_94**

Inference of combined requirements RS_ARI_55, RS_ARI_58, RS_ARI_65 for the management of iviIdentificationNumbers:

- RS_ARI_58 asserts the uniqueness of an iviIdentificationNumber within a certain radius at any point in time;
- RS_ARI_65 asserts that iviStructures are repeated as long as the validity period indicated through 'validTo' has not passed and
- RS_ARI_55 asserts that cancellations are repeated for a certain time period.

This means that adherence to all aforementioned requirements in combination asserts that iviIdentificationNumbers are truly locally unique for the receiving vehicle at any given point in time for valid iviStructures. For cancelled iviStructures, the cancellation repetition together with the message's timestamp acts as a buffer before the iviIdentificationNumber may be reused for a new iviStructure.

Details:

Tested by:

Requirement **RS_ARI_56**

The timestamp shall be present and set to the time of information generation by the service provider (as defined in [TS 103 301]).

Note: This also holds, if the iviStatus is already set to 'update'. When a new content change occurs, timeStamp shall be set to the point in time of the generation of the new information.

Details:

Tested by:

Requirement **RS_ARI_62**

The component validFrom shall be present in an IviStructure if the contained information is not yet applicable at the point in time when the message is transmitted.

Details:

Tested by:

Requirement **RS_ARI_63**

The component validFrom shall be omitted in an IviStructure if the contained information is applicable at the point in time when the message is transmitted.

Details:

Tested by:

Requirement **RS_ARI_71**

The component validTo may only be used to indicate the end of the validity period of the information contained in the IviStructure if it is ensured that validTo coincides with or is later than the actual end of the validity period.

Note: This means, that validTo shall not be earlier than the actual end of the validity period of the information. This prevents, that vehicles travelling in the relevance zone wrongly cancel the information to the driver when validTo times out only because an update of the validTo is not received.

Note: Example of a scenario that could benefit from using validTo: Speed limit for purposes of noise reduction over night, e.g. 10 p.m. to 6 a.m. In this scenario the validity period is deterministic and the end can be conveyed via validTo, thus lifting the need for a separate cancellation message.

Note: An example of a scenario where a different usage than specified here can lead to critical situations is when the component validTo is set to a time only some minutes in the future and is updated every time before timing out. In such cases vehicles, that have passed the gantry and are already out of the RSU coverage, but yet in the relevance zone, would disable the received IVI road signs upon reaching the validTo time, even if the RSU has updated the validTo and still transmits the road signs.

Details:

Tested by:

Requirement **RS_ARI_37**

If in vehicle information shall or need to be transmitted in separate IVIMs following RS_ARI_21 due to message size restrictions, the data element connectedIviStructures shall be present and used to connect at least all messages applying to the same traffic direction.

Details:

Tested by:

Other (informational) **RS_ARI_64**

For better understanding of the following requirements, Figure 5 provides a state machine for the usage of iviStatus including references to the relevant documents and requirements for the respective state transitions.

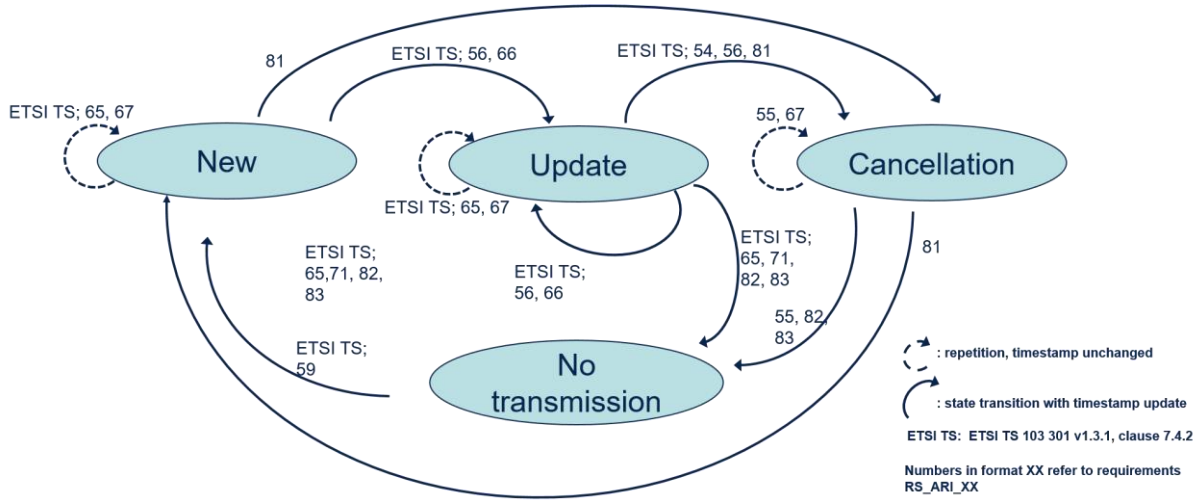


Figure 5: State machine for iviStatus

Details:

Tested by:

Requirement **RS_ARI_65**

An IviStructure with status ‘new’ or ‘update’ shall be repeated as long as all information contained remains unchanged or the time value represented by validTo hasn’t yet passed in time.

Details:

Tested by:

Requirement **RS_ARI_66**

Whenever any signage information changes (meaning any change in the GIVs, TCs or AVCs present in an IviStructure), the IviStructure shall be transmitted with iviStatus ‘update’.

Note: For any changes in the geographic information see requirement RS_ARI_81.

Details:

Tested by:

Requirement **RS_ARI_81**

Whenever any geographic information changes (meaning any change in the GLCs, MLCs or RCCs present in an IviStructure), the IviStructure shall be transmitted with iviStatus ‘cancellation’ and a new IviStructure with iviStatus ‘new’ containing the updated geographic information shall be transmitted.

Note: For any changes in the signage information see requirement RS_ARI_66.

Details:

Tested by:

Requirement **RS_ARI_54**

Whenever all the information given in an IviStructure is not valid any more (i.e. the gantry is switched off and the information isn't shown any more), the IviStructure shall be transmitted with iviStatus 'cancellation'.

Details:

Tested by:

Requirement **RS_ARI_55**

An IviStructure with status 'cancellation' shall be repeated for *pRepetitionDuration* starting from the point in time of the first transmission of the cancellation IVIM.

Details:

Tested by:

Requirement **RS_ARI_57**

An IviStructure with status 'cancellation' shall consist of the ManagementContainer only.

Details:

Tested by:

Requirement **RS_ARI_82**

If the gantry is dark (i.e. if no signage information is available in the R-ITS-S) for longer than *pRepetitionDuration*, no IviStructure shall be transmitted.

Details:

Tested by:

Other (informational) **RS_ARI_83**

In case of any failure or error in the R-ITS-S, no IviStructure shall be transmitted.

Details:

Tested by:

7.1.4 Geographic Location Container

Requirement **RS_ARI_30**

The referencePosition in GLC shall be centred laterally among the regular driving lanes. Longitudinally it shall be located somewhere along the longitudinal extension of the zones defined in the same GLC (i.e., between the start and end of the zones defined in the same GLC).

Note: In cases of complex traffic measures comprising multiple signs/gantries in close vicinity, this allows for using only one (or few) GLC(s) to represent all required zones. In case of more simple traffic measures, it is desirable to provide a reference position for each sign/gantry, located at the position of the respective sign/gantry, as shown in Figure 6.

Note: This implies that not every relevanceZone needs to start with a referencePosition.

Note: This requirement is useful to receivers since they may use the referencePosition as a first means for a relevance check (e.g., matching their own path with the referencePosition) it thus is intended to ensure more future-proof specifications. Hence, the referencePosition shall be located within the area described in the IviStructure.

Note: If zones describe only individual lanes and not the entire width of a road section, the referencePosition shall still be laterally centred on the regular driving lanes. This supports vehicles in the correct matching of the iviStructure's content and its own path. The lateral offset in the first deltaPosition of each zone then explains the zone's position relative to the centre of the regular driving lanes.

Note: By introducing this requirement the computational complexity in each vehicle can be reduced (simplification of understanding the location of the information). The generating system only needs one additional calculation (if at all).

Note: At the time of the definition of the GLC, the ‘role’ of a zone (detection, relevance, or awareness) is not known, hence the referencePosition can be placed alongside/within any zone independently of its role in the iviStructure.

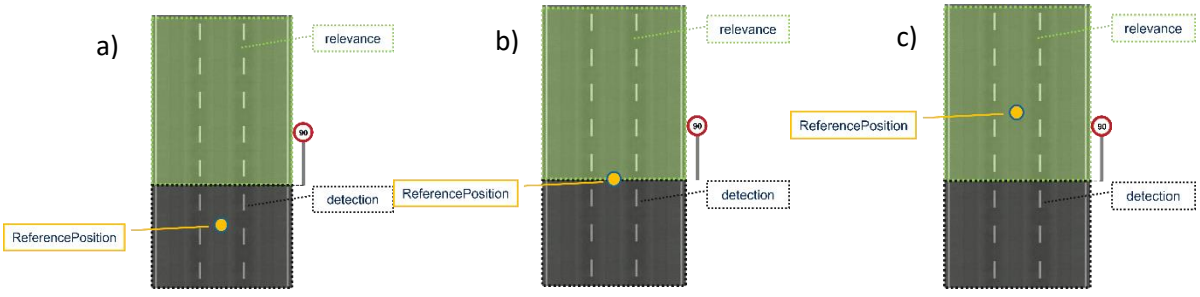


Figure 6: Examples of correct placements of the reference position in zones that cover all regular driving lanes.

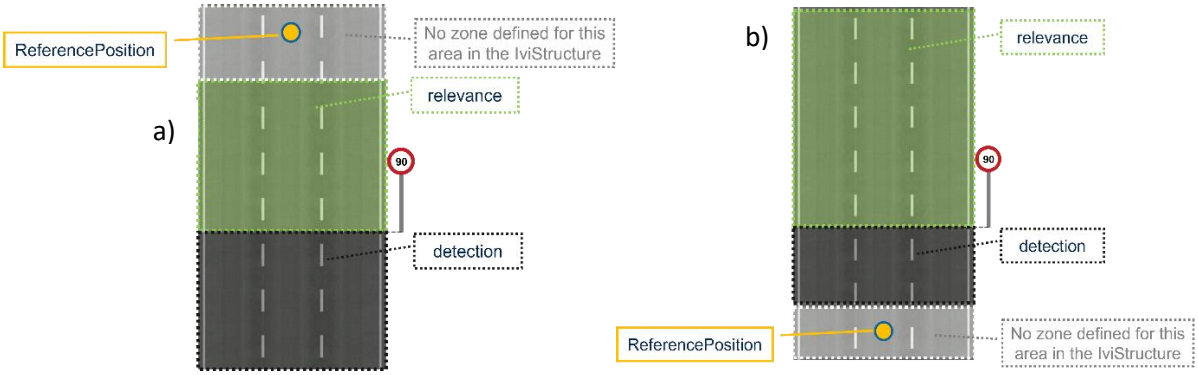


Figure 7: Examples of faulty placements of the reference position in case of zones covering all regular driving lanes. The reference position is located in an area where there is no zone definition available in the iviStructure.

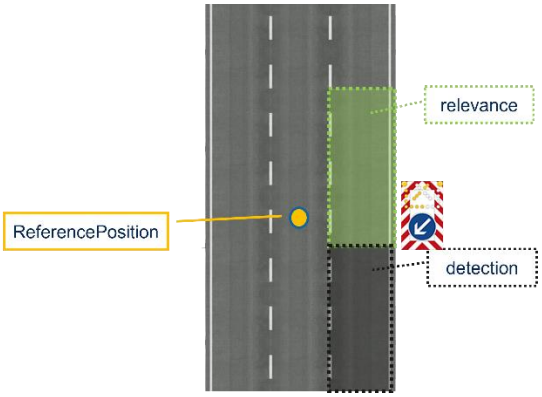


Figure 8: Example of a correct placement of the reference position for zones that cover only a subset of lanes. Even if the centre of all regular driving lanes is not part of the zone, the reference position shall still be laterally located there.

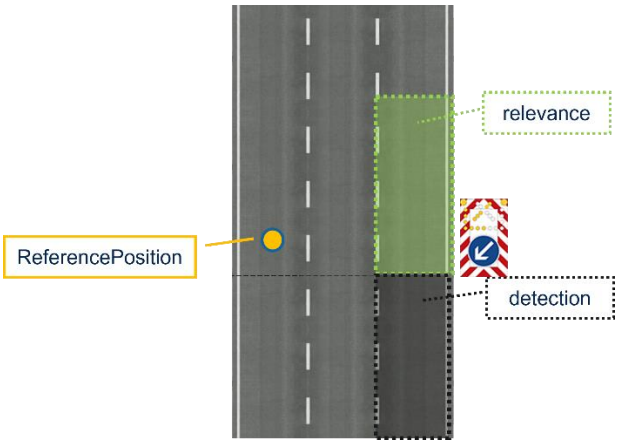


Figure 9: Example of a faulty placement of the reference position for zones that cover only a subset of lanes. The reference position is not centred among the regular driving lanes.

Details:

Tested by:

Requirement **RS_ARI_29**

The accuracy of the referencePosition in GLC shall be within a maximum lateral offset to the true centre of the regular driving lanes. The maximum lateral offset should be less than *pLateralNodeOffset*. The maximum lateral offset shall be below *pLateralNodeOffsetAbsolute*.

Details:

Tested by:

Requirement **RS_ARI_93**

For geographically static signage information, the referencePositionTime, referencePositionHeading or referencePositionSpeed shall not be included in the GLCs of the iviStructure.

Details:

Tested by:

Requirement **RS_ARI_95**

The definition of all zones referred to within the Application Containers (e.g. GIV) should be included in as few GLCs as possible. An additional GLC should only be included in an iviStructure if zones that are required for the iviStructure can't be defined within the value range constraints of DF_DeltaPositions with the referencePosition given in the first GLC(s).

Note: The objective is to optimize the message, both in size and interpretation effort. Thus, the idea is to define as many zones as possible in a single GLC, and also to define the geographical dimensions of a zone only once.

Note: The intention of this requirement is to reduce the amount of data and also evaluation complexity on receiver side. Having multiple GLCs each containing only single/few glcParts is to be avoided.

Note: E.g., in the design of the GLCs and zones for an iviStructure this requirement can be fulfilled by placing the referencePosition approximately at the longitudinal centre of a traffic measure comprising multiple gantries. Thus, a maximum of zones can be defined with only a single GLC (and a single referencePosition).

Note: In the scenario shown in Figure 10, the 'upper' referencePosition is placed such that the first note of the 'upper' zone is just so covered by the value range of DE_deltaPosition (~1.11 km). But the distance between this referencePosition and the beginning of the zone on the lowest end of the figure is greater than what can be covered by DF_deltaPosition. Hence, an additional GLC is provided.

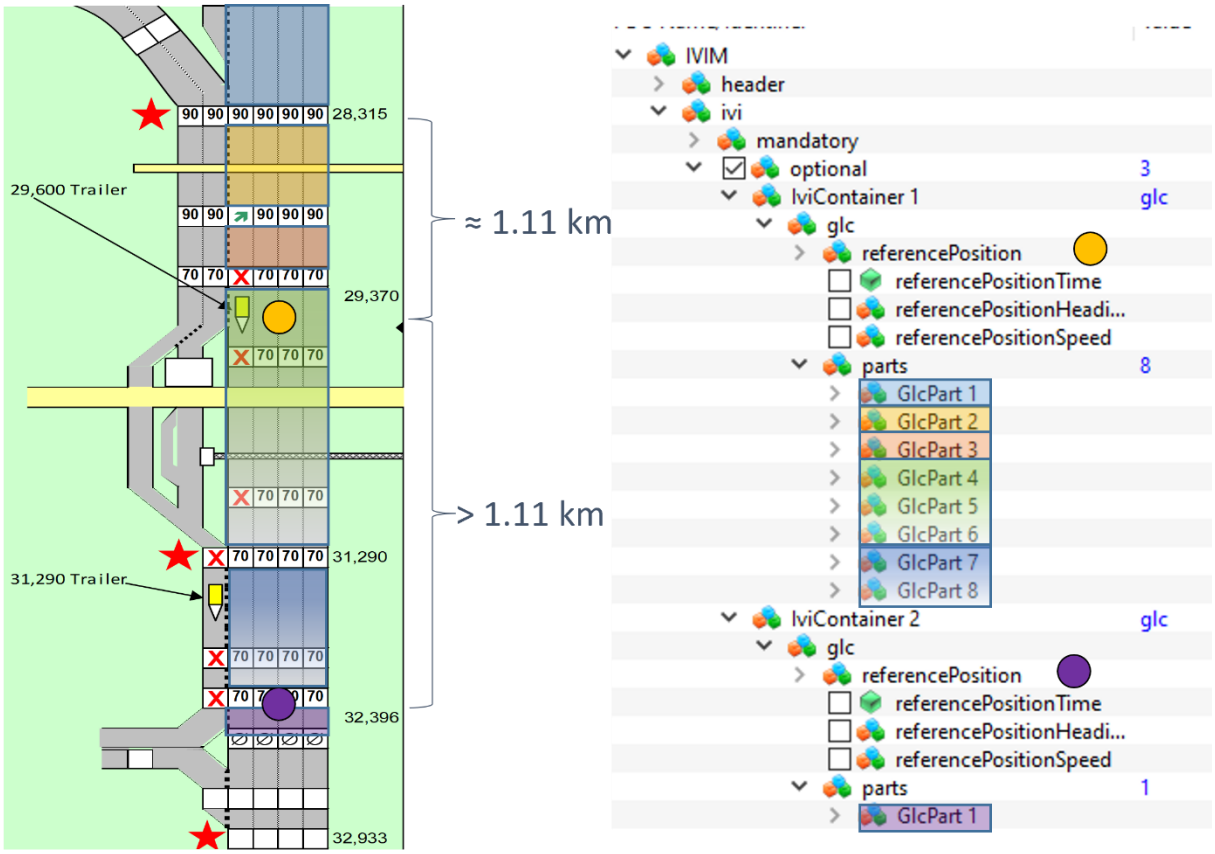


Figure 10: Example of a case where an additional GLC is needed.

Details:

Tested by:

Other (informational) **RS_ARI_91**

If the signage intention of the service provider is to inform vehicles on multiple stretches of road (diverging, converging), then all those stretches shall be represented by corresponding zones in GLC, referenced in GIC as either detection or relevance zone depending on the situation.

Note: This applies in addition to adequate RSU position and geonetworking settings ensuring reception on such stretches of road where the infrastructure wants the vehicle to consider the information.

Note: The decision if, when and how to make use of certain information is still up to the OEM.

Example: If the signage intention of the service provider is to inform vehicles already 2 km ahead, no matter which road / entry ramp they are travelling on, also all concerned entry ramps should by represented by corresponding zones, see the figure below for a better understanding.

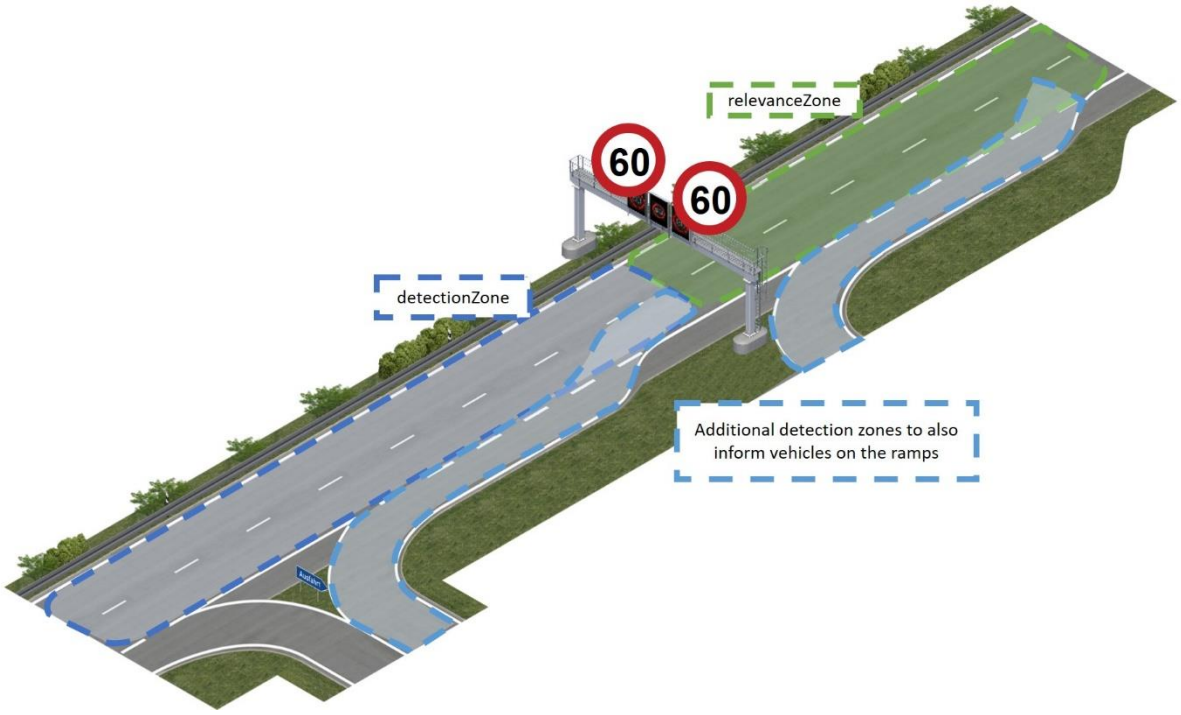


Figure 11: Example, the service provider wants to inform all concerned vehicles about the low speed limit and therefore also provides detection zones on the ramps

Details:

Tested by:

7.1.4.1 Geographic Location Container Part

Requirement **RS_ARI_31**

The zoneId in GlcPart shall be unique throughout the entire IviStructure (i.e. this also applies, if multiple GLCs are used within one IviStructure).

Note: Uniqueness is only required for the triple serviceProviderID + iviIdentificationNumber + zoneID. Hence, for signage information spread over multiple messages, zoneIDs may be reused.

Details:

Tested by:

Other (informational) (RS_ARSM_31) **RS_ARI_45**

To describe a zone, the component segment shall be used with the polygonal line centred laterally among the set of all regular driving lanes of that zone.

Note: With the information on the total number of lanes (RS_ARI_60) and the zone width (if provided), the receiver then can create the box describing the zone.

Note: The concept of zones describing only a subset of all available regular driving lanes will be introduced in a future version of the standard [ISO TS 19321].

Details:

Tested by:

Requirement **RS_ARI_72**

The number of deltaPositions per segment shall be limited to *pMaxNumberofNodesPerZone*.

Details:

Tested by:

Requirement **RS_ARI_40**

In all instances of IVI.IviStructure.optional.glc.parts.zone.segment.line in an IviStructure, only either the component deltaPositions or the component deltaPositionsWithAltitude shall be used.

Details:

Tested by:

Requirement **RS_ARI_61**

The first deltaPosition contained in PolygonalLine shall refer to the reference position given in the corresponding GLC.

Note: See RS_ARI_76 for a better understanding.

Details:

Tested by:

Requirement **RS_ARI_75**

The referencePosition shall not be part of the zone itself. This means that the first deltaPosition in a zone shall describe the first node of the respective zone. If a zone shall begin at the referencePosition, the first deltaPosition shall be set to (0, 0). See RS_ARI_74 and RS_ARI_76 for further information.

Note: This requirement is in compliance with [ISO/TS 19321], where a note explains that the referencePosition of the GLC is not part of the polygonal line (confirmed in the document version of 2020).

Note: Not including the reference position to the zones by default becomes even more important when zones are not directly attached to the referencePosition (e.g. when considering ramps).

Details:

Tested by:

Other (informational) **RS_ARI_76**

The graphic below shows the problematic implications when including the referencePosition in the zone description. For individual zones per lane the inclusion of the reference position would 'distort' the zone causing possible problems for interpretation on vehicle side, therefore the first deltaPosition is considered to be the very first node of the zone.

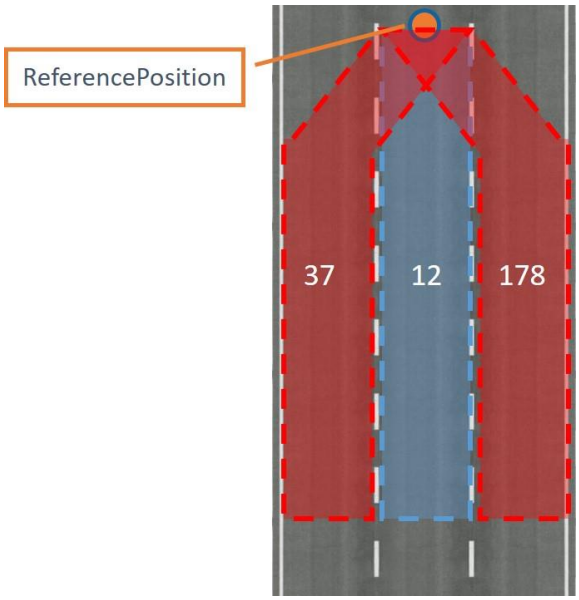


Figure 12: 'Distortion' of zones when including the referencePosition

Details:

Tested by:

Other (informational) **RS_ARI_74**

Requirements RS_ARI_29, RS_ARI_30, RS_ARI_61 and RS_ARI_75 specify polygonal lines in a very generic way in order for them to be applicable to all possible scenarios and settings. The graphic below shows the implications of these requirements on the affected data elements in IVIM.

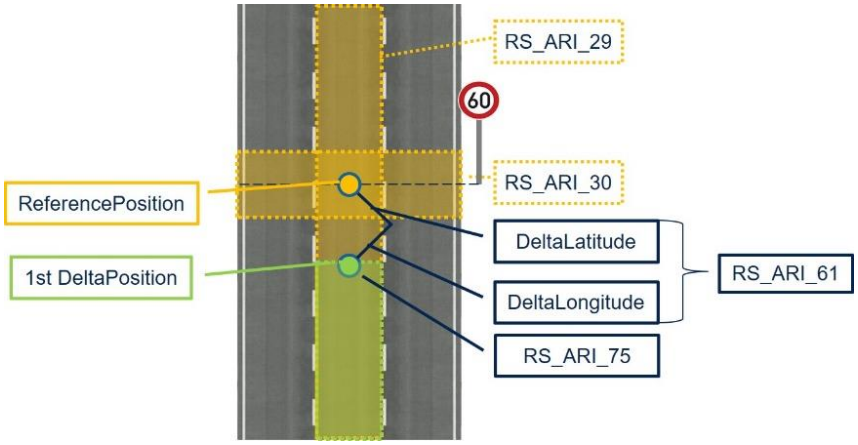


Figure 13: Placement of the referencePosition and definition of the first deltaPosition

Details:

Tested by:

Requirement **RS_ARI_42**

The delta positions in PolygonalLine shall be sorted starting from the zone's extremity that is closest to the reference position to the extremity that is farthest from the reference position, along the course of the road.

Note: In case of identical distance of both extremities to the reference position, the designer may choose the most suitable extremity to start with.

Note: That way, zones are always sorted in direction of traffic or against the direction of traffic. See RS_ARI_77 for a better understanding.

Details:

Tested by:

Other (informational) **RS_ARI_77**

Requirement RS_ARI_42 is phrased in a very generic way. This is necessary for cases where the referencePosition isn't located at the borders between the zones but actually in the middle of a zone (see RS_ARI_30 for the placement of the referencePosition).

Details:

Tested by:

Requirement (RS_ARSM_32) **RS_ARI_46**

The absolute lateral offset of node points to the centre of the set of all regular driving lanes represented by the zone shall be less than *pLateralNodeOffsetAbsolute*.

Details:

Tested by:

Requirement (RS_ARSM_94) **RS_ARI_47**

Let $\vec{a}$ be the vector representing the linear connection of two delta positions, and $\vec{p}$ be the vector representing the shortest distance of vector $\vec{a}$ to the center of the set of all regular driving lanes represented by the zone (that is, $\vec{p}$ is perpendicular to the tangent of the center line of the set of all regular driving lanes represented by the zone at the foot of the dropped perpendicular).

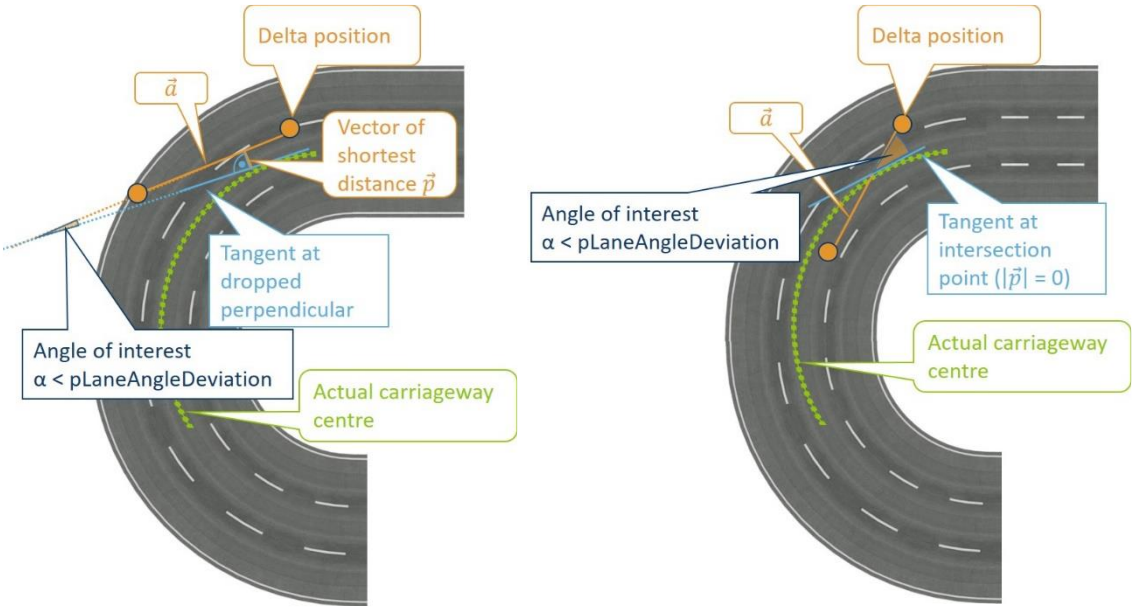
Then for $|\vec{p}| > 0$ it shall always hold that

$$\cos^{-1}\left(1 - \frac{\vec{a}*\vec{p}}{|\vec{a}|*|\vec{p}|}\right) \leq pLaneAngleDeviation.$$

For $|\vec{p}| = 0$ (i.e. $\vec{a}$ crosses the centre of the set of all regular driving lanes represented by the zone) the angle α between $\vec{a}$ and the tangent to the centre of the set of all regular driving lanes represented by the zone at the intersection point with the lane centre shall be less than *pLaneAngleDeviation*.

Note: In less formal wording this means that the angle between the linear connection of two node points and the corresponding tangent to the centre of the set of all regular driving lanes represented by the zone shall not be greater than *pLaneAngleDeviation.*

Note: See drawings below for a better understanding (exemplary for a polygonalLine describing the centre of the set of all regular driving lanes represented by the zone):



Details:

Tested by:

Requirement (RS_ARSM_34) **RS_ARI_48**

The perpendicular distance between the linear connection of two delta positions and the centre of the set of all regular driving lanes represented by the zone shall be less than *pMaxPerpendDistLaneCentre*.

Details:

Tested by:

Requirement **RS_ARI_50**

If the zone represents only a single lane, the component IVI.IviStructure.optional.glc.parts.zone.segment.laneWidth shall provide the zone width with an accuracy of *pLaneWidthAccuracy*.

Details:

Tested by:

7.1.5 MAP Location Container

Requirement **RS_ARI_37**

The MAP Location Container shall not be used for highway use cases.

Note: This container may be used at intersections where a MAPEM is transmitted anyway, for such use cases this needs to be profiled explicitly.

Details:

Tested by:

7.1.6 General IVI Container Part

Requirement **RS_ARI_23**

The set of zones referenced within the data element *detectionZoneIds* shall be defined in such a way that there is always a concatenation of zones that leads up to a corresponding set of relevance zones. In detail, this means that the first point of each individual zone in the set of zones shall geographically coincide with either:

a) any point in a corresponding set of physically consecutive relevance zones with a maximum offset of *pNodeOffset* OR with

b) any point in a set of physically consecutive detection zones which leads up to a corresponding set of physically consecutive relevance zones with a maximum offset of *pNodeOffset*.

Note: The basic case being that the first point of a set of physically consecutive detection zones coincides with the first point of the corresponding set of relevance zones (i.e. the physically consecutive detection zones lead up to the start of the relevance zone)

Note: In some cases, entry ramps on highways may merge into the highway in the middle of a relevance or detection zone, in these cases, the corresponding detection zone on the ramp may lead up to a suitable entry point of the relevance or detection zone.

Note: For a better understanding see the graphics below.

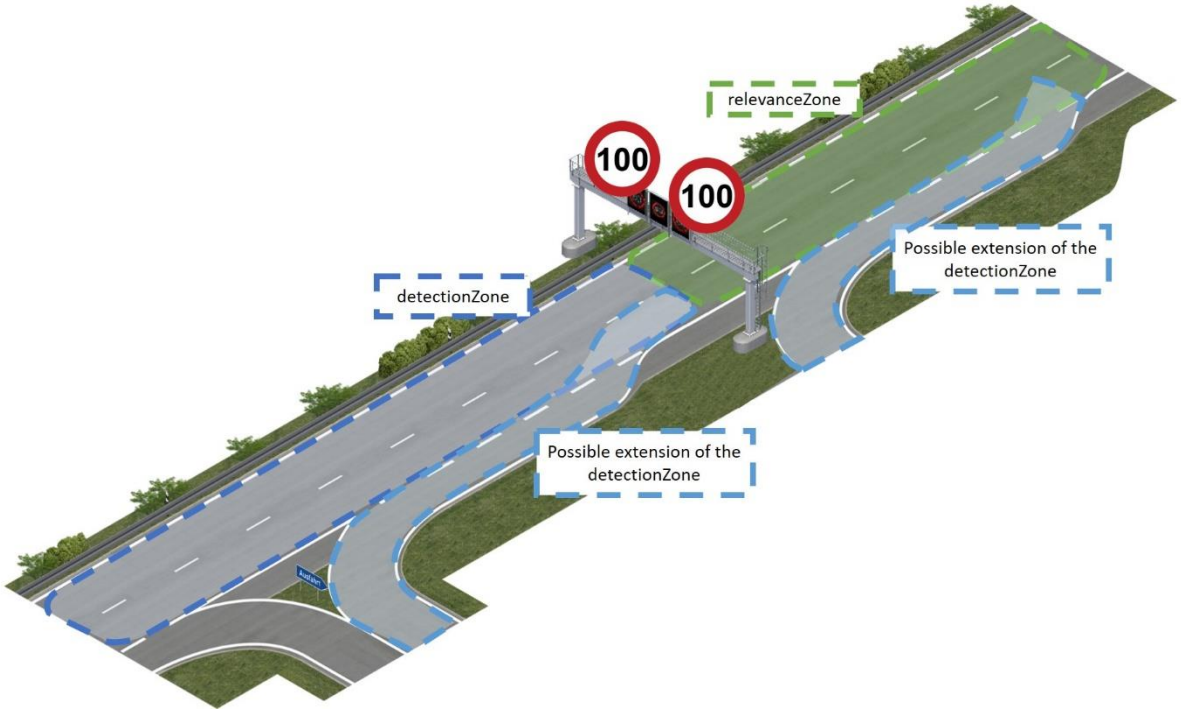


Figure 14: Example, detectionZones leading up to the beginning of the relevanceZone or to another suitable entry point to the relevanceZone

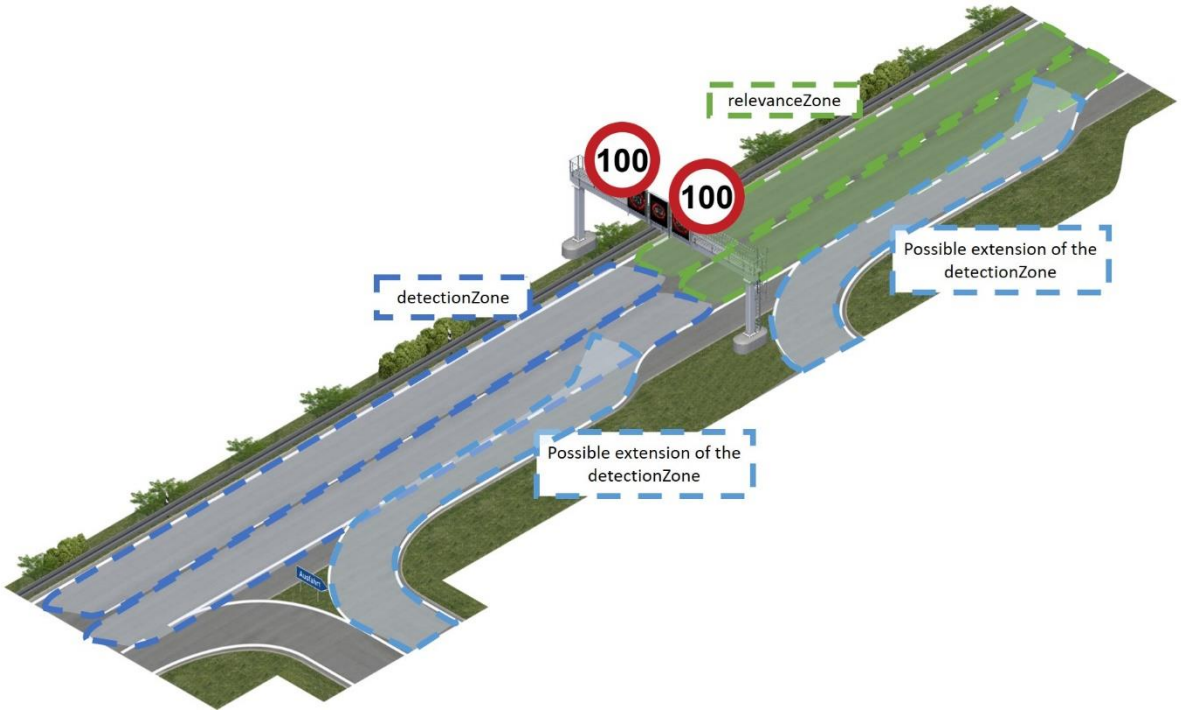


Figure 15: Example, detectionZone on the first ramp leading up to a suitable entry point to another detectionZone

Details:

Tested by:

Requirement **RS_ARI_51**

Each set of physically consecutive zones referenced by the data element detectionZoneIds in a GicPart shall have an accumulated length of at least *pMinDetectionZoneLength*.

Details:

Tested by:

Requirement **RS_ARI_79**

Each set of physically consecutive zones referenced by the data element detectionZoneIds in a GicPart shall have an accumulated length of at most *pMaxDetectionZoneLength*.

Details:

Tested by:

Requirement **RS_ARI_80**

The set of zones referenced by the data element detectionZoneIds in GicPart shall be completely contained in the destination area defined in the GeoNet header.

Details:

Tested by:

Requirement **RS_ARI_26**

An instance of driverAwarenessZoneIds shall be present in all GicParts which refer to a physical sign that is located before the start of the relevance zone.

Details:

Tested by:

Requirement **RS_ARI_27**

The driver awareness zone in a GicPart (i.e. the combination of all zones referred to in the instance of *driverAwarenessZoneIds*) shall represent the complete area between the location of the physical sign and the start of the relevance zone, if the sign's applicability doesn't start at the position of the sign but in a certain distance.

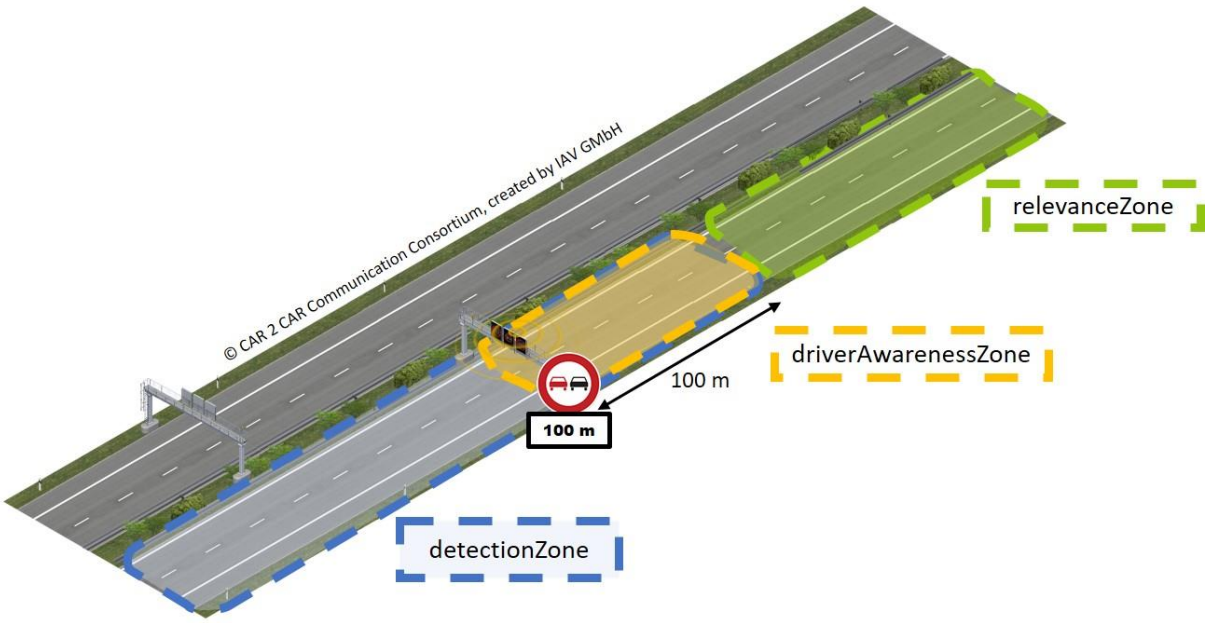


Figure 16: Example: overtaking ban applicable in a distance - e.g., due to a situation on the road

Details:

Tested by:

Requirement **RS_ARI_24**

If defined, a driver awareness zone shall be part of the detection zone (i.e., geographically contained within the detection zone).

Details:

Tested by:

Requirement **RS_ARI_35**

In every instance of GicPart the data element *relevanceZoneIds* shall be present and refer to a nonempty set of zones described in a GLC.

Details:

Tested by:

Requirement **RS_ARI_43**

For each set of physically consecutive zones (along the path of the road segment) referenced in *relevanceZoneIds* in an instance of GicPart, there shall be a corresponding set of physically consecutive zones referenced in *detectionZoneIds*, which fulfils requirement RS_ARI_23 .

Details:

Tested by:

Requirement **RS_ARI_33**

The relevanceZone in a GicPart (i.e., the combination of all zones referred to in the instance of *relevanceZoneIds*) shall represent the complete road segment where the traffic rules according to the sign described in GicPart are applicable.

Note: If the relevanceZone ends and no further signs are transmitted via IVIMs, this means, that from the last point of the relevanceZone downstream, the previous roadsign transmitted via IVIM doesn't apply any more. Figure 17 shows an example of a correct implementation, Figure 18 shows a possible receiver interpretation in case of a faulty implementation in the same situation.

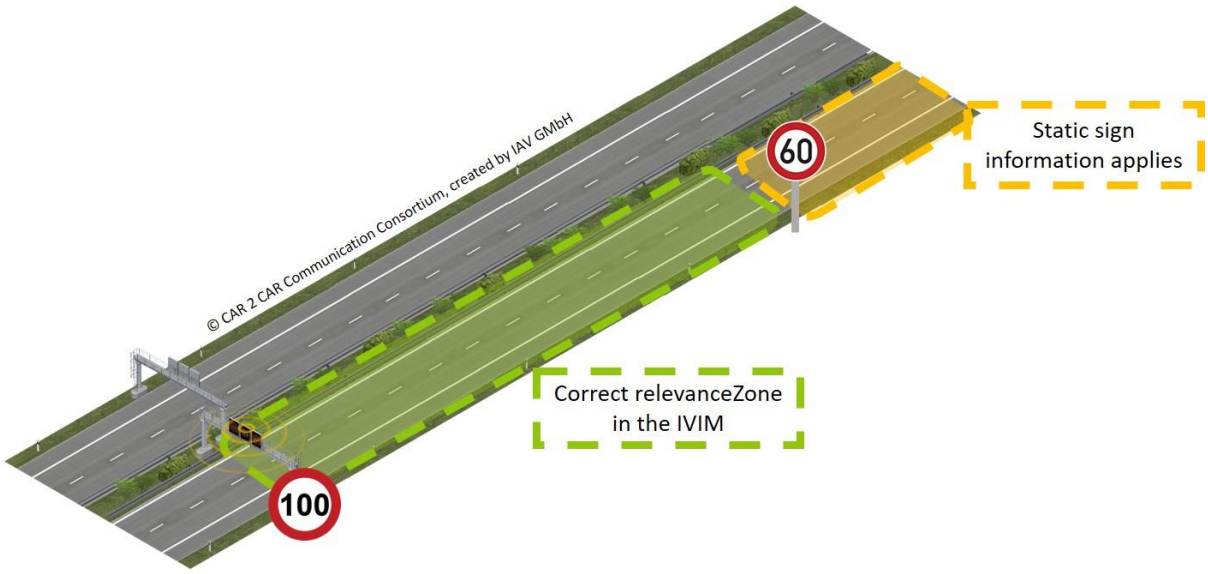


Figure 17: Example of a correct implementation of relevanceZone

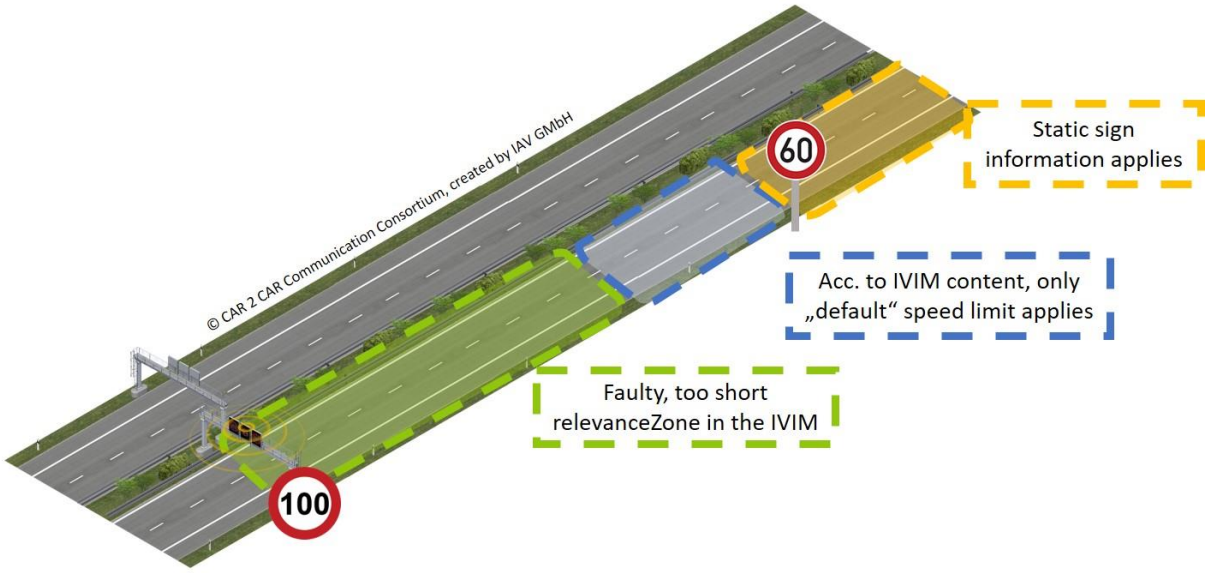


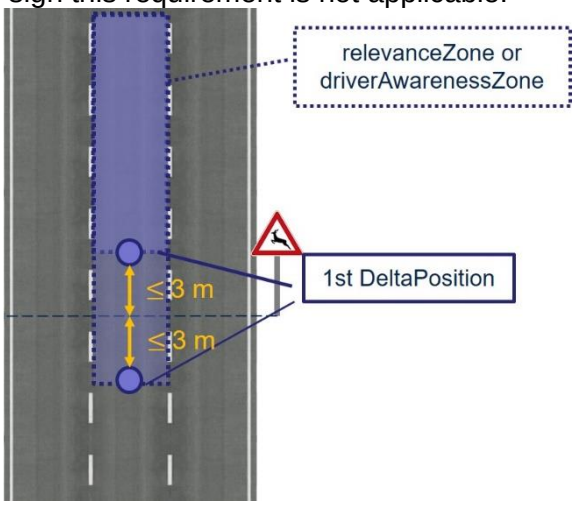
Figure 18: Possible receiver interpretation in case of a faulty implementation

Details:

Tested by:

Requirement **RS_ARI_28**

The longitudinal position w.r.t. the carriageway of the first node of the set of zones referenced by *relevanceZoneIds* (or by *driverAwarenessZoneIds*, if used), shall coincide with the longitudinal position of the physical sign (if applicable), with a maximum offset of *pLongitudinalOffsetSignPosition* if the traffic rule according to the sign is applicable starting from the position of the sign.
Note: In this case 'if applicable' means, if there is a physical sign present. In case of virtual signage without physical sign this requirement is not applicable.



Details:

Tested by:

Requirement **RS_ARI_44**

The data element *direction* shall be present in every instance of GicPart in an IviStructure.

Details:

Tested by:

Requirement **RS_ARI_86**

The component applicableLanes in a GicPart shall be present if the corresponding RsCode(s) apply only to a subset of all lanes represented by the set of relevance zones to which the GicPart applies.

If the component is absent, this means that the RSCode(s) apply at least to all lanes represented by the set of relevance zones.

Note: This corresponds to the C-Roads requirement on usage of the component 'applicableLanes'.

Details:

Tested by:

Requirement **RS_ARI_68**

The component iviType shall be set in accordance with the service categories as defined in [ISO/TS 14823]. The following mapping shall be used:

iviType	Service category
0 (immediateDangerWarningMessages)	11 (Warning), 31 (ambient road condition), 32 (road condition)
1 (regulatoryMessages)	12 (regulatory)
2 (trafficRelatedInformationMessages)	13 (guide)
3 (pollutionMessages)	n/a
4 (noTrafficRelatedInformationMessages)	21 (public facilities)

Details:

Tested by:

Requirement **RS_ARI_73**

RSCodes that apply to multiple lanes shall occur only once in an IviStructure (i.e., in only one single GicPart) with indication of the concerned lanes in the component applicableLanes as specified in RS_ARI_86.

Note: This implies that it is not allowed to repeat the same road sign in separate GicParts, each of them associated to only one applicableLane. It serves the purpose of data minimization.

Details:

Tested by:

7.1.7 Road Configuration Container Part

Requirement **RS_ARI_87**

On highways and motorways, the lanes present in the RCC shall be assigned one of the laneTypes ‘traffic (0)’, ‘acceleration (3)’, ‘deceleration (4)’ or ‘emergency (18)’ in accordance with the laneType definitions in [ISO/TS 19321].

Details:

Tested by:

Requirement **RS_ARI_88**

In the RCC, the laneType shall be set to ‘traffic’ for all lanes available for regular driving.
Details:

Tested by:

Requirement **RS_ARI_96**

The component IVI.IviStructure.optional.rcc.laneConfiguration.laneWidth shall be present if the information is known. If present, it shall provide the width of the lane with an accuracy of *pLanetWidthAccuracy*.
Note: Provision of an accurate lane width helps receiving vehicles to better match themselves to a specific lane. This is especially helpful for lane-specific signage.
Details:

Tested by:

7.2 Open questions and subjects

7.2.1 Usage of zoneHeading

According to current C-Roads specifications, the usage of zoneHeading in GlcPart is mandatory (see [C-ITS Message Profile]).

The profile defines it as ‘Effective direction of applicability of the sign at the Reference Position, indicating the traffic direction’. C2C-CC’s understanding is, that this information shall be given through ‘direction’ in GIC.

Furthermore, it is not clear, how this value will be determined and how it is defined – will it be the heading between the ‘first’ two nodes of the zone? What is the intended added value of this information? E.g., we are not sure if the enabling of a differentiation between the zones on a highway and the zones on a ramp would work in all situations (see figure below).

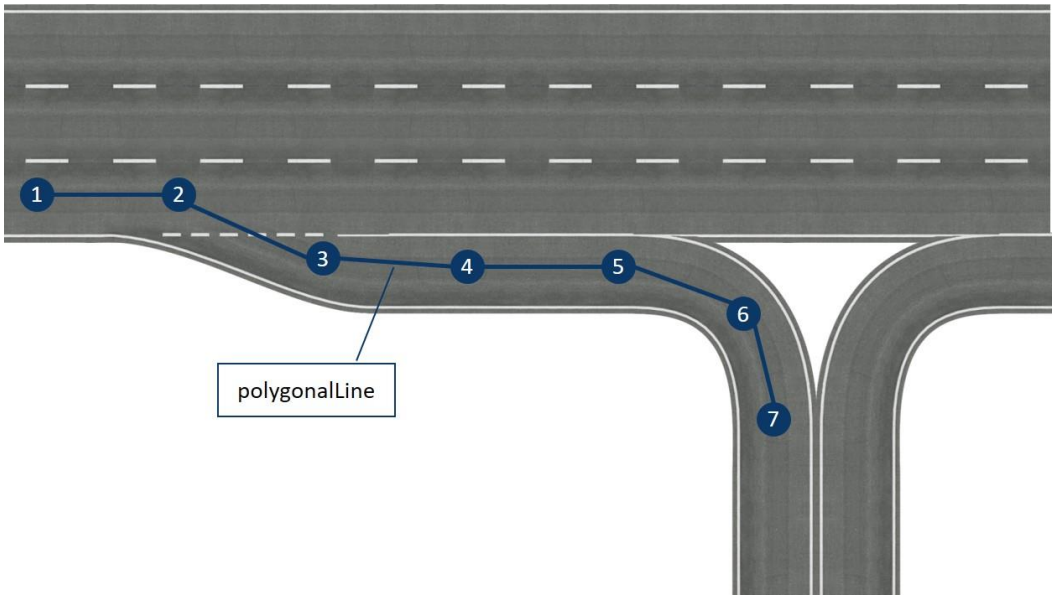


Figure 19: Motorway exit ramp; heading of the first two nodes wouldn't differ from the heading of zones on the motorway (representation simplified to ease understanding)

Some clarification in the specifications is needed for us to understand how to make use of the data element.

8 Annex

This annex contains a table for IVIM showing which data elements are mandatory according to the standard (CEN/ISO), this document and the C-Roads profile in Release 1.7.

Legend:

- The number of '+' in the column 'Layer' and the shading of the row represents the layer / level of the corresponding data element within the message.
- '-': This data element is not mentioned in the respective document.
- 'O': This data element is optional.
- 'M': This data element is mandatory.
- 'O/M': This data element is mandatory only under certain conditions which are defined in the respective document.
- 'C': This data element is an option within a 'Choice'.
- 'NU': (C-Roads specific) This data element is not used in C-Roads.
- 'F': The respective document forbids the usage of this data element.
- 'O/F': This data element is forbidden under certain conditions which are defined in the respective document.
- 'O/F/M': This data element is mandatory only under certain conditions and forbidden und other conditions which are defined in the respective document.
- (p): The corresponding requirement for this data element is for now only preliminary

8.1 IVIM mandatory and optional data elements

Layer	Data element / data field in and IviStructure	ISO 19321	C2C-CC (this document)	C-Roads (Release 1.7)	Combined
+	managementContainer	M	-	M	M
++	serviceProviderId	M	M	M	M
++	iviIdentificationNumber	M	M	M	M
++	timeStamp	O	M	M	M
++	validFrom	O	O/F/M	O	O/F/M
++	validTo	O	O/F	M	O/F

Layer	Data element / data field in and IviStructure	ISO 19321	C2C-CC (this document)	C-Roads (Release 1.7)	Combined
++	connectedIviStructures	O	O/M	NU	O/M
++	iviStatus	M	M	M	M
++	connectedDenms	O	-	-	O
+	iviContainers (sequence of IviContainer)	O	O/M	M	M
++	geographicLocationContainer	C	O/M	M	O/M
+++	referencePosition	M	M	M	M
++++	latitude	M	-	-	M
++++	longitude	M	-	-	M
++++	positionConfidenceEllipse	M	-	-	M
++++	altitude	M	-	-	M
+++	referencePositionTime	O	F	NU	F
+++	referencePositionHeading	O	F	NU	F
+++	referencePositionSpeed	O	F	NU	F
+++	parts (sequence of GlcParts)	M	M	M	M
++++	zoneId	M	M	M	M
++++	laneNumber	O	-	O/M	O/M
++++	zoneExtension	O	-	NU	
++++	zoneHeading	O	-	M	M
++++	zone	O	M	M	M
+++++	segment	C	M(p)	M	M
++++++	line	M	M	M	M
+++++++	deltaPosition	C	C	M	M

Layer	Data element / data field in and IviStructure	ISO 19321	C2C-CC (this document)	C-Roads (Release 1.7)	Combined
+++++++	deltaPositionsWithAltitude	C	C	?	?
+++++++	absolutePositions	C	F	F	F
+++++++	absolutePositionsWithAltitude	C	F	F	F
++++++	laneWidth	O	O/M	O/M	O/M
+++++	area	C	-	F	F
++++++	…				
+++++	computedSegment	C	-	F	F
++++++	…				
++	generalIviContainer (sequence of GicParts)	C	O/M	C/M	O/M
+++	detectionZoneIds	O	M	M	M
+++	Its-Rrid	O	-	NU	
+++	relevanceZoneIds	O	M	M	M
+++	direction	O	M	M	M
+++	driverAwarenessZoneIds	O	O/M	NU	O/M
+++	minimumAwarenessTime	O	-	NU	
+++	applicableLanes	O	O/M(p)	O/M	O/M
+++	iviType	M	M	M	M
+++	iviPurpose	O	-	NU	
+++	laneStatus	O	-	O	O
+++	vehicleCharacteristics	O	-	O	O
++++	…				
+++	driverCharacteristics	O	-	NU	

Layer	Data element / data field in and IviStructure	ISO 19321	C2C-CC (this document)	C-Roads (Release 1.7)	Combined
+++	layoutId	O	-	NU	
+++	preStoredlayoutId	O	-	NU	
+++	roadSignCodes (sequence of RSCode	M	M	M	M
++++	layoutComponentId	O	-	O	O
++++	code	M	-	M	M
+++++	viennaConvention	C	-	F	F
++++++	…				
+++++	iso14823	C	-	M	M
++++++	…				
+++++	itisCodes	C	-	F	F
++++++	…				
+++++	anyCatalogue	C	-	F	F
++++++	…				
+++	extraText (sequence of Text)	O	-	O	O
++++	layoutComponentId	O	-	M* (due to error in previous ISO version)	O*
++++	language	M	-	-	M
++++	textContent	M	-	-	M
++	roadConfigurationContainer (sequence of rccParts)	C	M	NU	M/NU
+++	relevanceZoneIds	M	M	M	M
+++	roadType	M	M	M	M

Layer	Data element / data field in and IviStructure	ISO 19321	C2C-CC (this document)	C-Roads (Release 1.7)	Combined
+++	laneConfiguration (sequence of laneInformation)	M	M	M	
++++	laneNumber	M	M	M	M
++++	direction	M	M	M	M
++++	validity	O	-	-	O
++++	laneType	M	M	M	M
++++	laneTypeQualifier	O	-	-	O
++++	laneStatus	M	M	M	M
++++	laneWidth	O	O	-	-
++++	…				
++	textContainer	C	F	NU	
+++	…				
++	layoutContainer	C	F	NU	
+++	…				
++	automatedVehicleContainer	C	-	NU	
+++	…				
++	mapLocationContainer	C	F	NU	
+++	…				
++	roadSurfaceContainer	C	-	NU	
+++	…				