



C-ITS SERVICE AND USE CASE DEFINITIONS

ROAD WORKS WARNING (RWW) [C-ROADS SUD04]

VERSION 3.1.0

C-Roads Platform

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3.1.0	01.11.2025	Shifted the RWW-WM use case into the new document [C-Roads SUD11] and renamed into ESVN-WM.	Final

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Introduction

The document ‘Service and Use Case Descriptions 01 Intro Document’ [C-Roads SUD01] explains the structure of the service and use case descriptions harmonized in C-Roads. Also, it gives an overview of all harmonized service and use cases and in which document they are described. Each service and its use cases are described in a separate chapter in a separate document. Together, these documents form the integral deliverable of the service and use case descriptions.

All References (in square brackets) refer to the global reference document [WG2 REF], which is part of the whole set of documents of a specific C-Roads release.

4. Road Works Warning (RWW)

4.1 RWW: Introduction

The description of the Roadworks-Warnings service category differs from the others. It is not described by independent use cases but in terms of triggering conditions, operational scenarios, message usage, lifecycle management, components and assembling work zones out of it.

The Road Works Warning service warns drivers of road works, which can be mobile or static, short term or long term. Road works are all types of road operations by the road operator, including operations involving road operator vehicles.

Road works usually affect the road layout and often also the driving regulations. Despite dedicated signage prior to road work zones, such changed conditions often come as a surprise to drivers. This may lead to unsafe situations and sometimes even accidents involving both drivers and workers (i.e., changes in road layout and applicable driving regulations). Moreover, the driver's attention may decrease with regular or longer road works.

Road operator vehicles are not always recognised and are not equipped in the same way as e.g., police vehicles or fire engines. Use cases involving road operator vehicles (e.g., salting, ploughing, securing accident zone, vehicle recovery by road operator) support the safety of the road operators and drivers involved.

More attentive and adapted driving while approaching and passing a work zone or road operator vehicles in operation by providing in-vehicle information and warnings about road works, changes to the road layout and applicable driving regulations.

Expected benefits are:

- The primary expected impact is more attentive driving while approaching and passing a work zone or road operator vehicles in operation, helping to avoid sudden braking or steering/swerving manoeuvres, thereby increasing traffic safety by reducing (the severity of) accidents.
- RWW aims at reducing the number of collisions with road vehicle safety-objects and road operator vehicles near road works. RWW informs the drivers that they are approaching a work zone and simultaneously provides information on the changes of the road layout.
- Better traffic flow in the around road works.
- Less accidents.

4.2 Terminology

A work zone is not only the area where the actual road work is ongoing, but also the area upstream, where pre-warnings and signage indicate the road work and the reduction of speed.

Figure 4:1 schematically depicts the terminology used in the scope of work zones, which includes the 'approach' to the road work and the actual road work area. In the physical domain, physical road signs serve this purpose and in the digital domain respective messages convey this information.

The work area consists of lanes available for traffic and the work site, which is not available for public traffic. This figure also shows components of a work zone. There are two lane closure components and one carriageway crossover component present in this work zone.

A *road configuration* is defined as a specific arrangement of lanes in terms of their number and positioning, their status (open, closing, closed), and their functional characteristics (e.g., lane type, width, or dedicated usage such as for emergency or heavy vehicles).

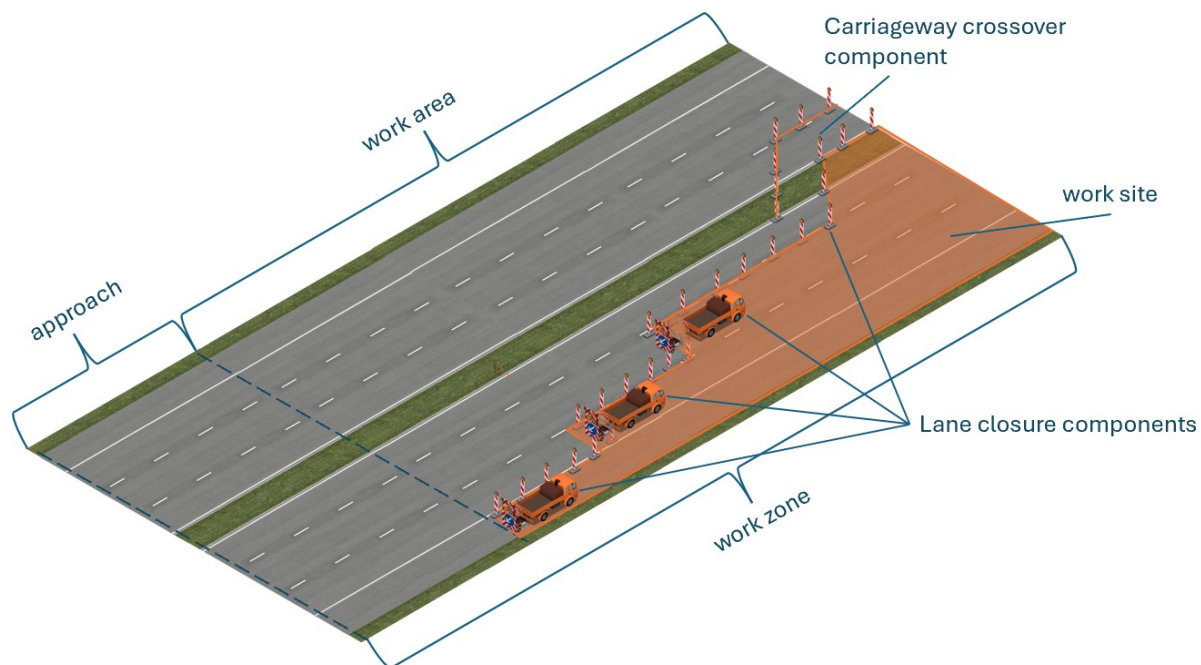


Figure 4:1 Terminology of a work zone

4.3 Scope of this chapter

This chapter is intended to facilitate the communication of information about **mobile** and **static** work zones on directional **multi-lane configurations with the concept of entry and exit**. Other road types, which do not have a legal separation (e.g. physically or visually) between carriageways and no entries and exits, will be covered in a later release based on expected input from urban implementations. The existing use cases cover specific aspects of work zones. These use cases provide message profiles for these specific scenarios. Since road works can be complex, many other scenarios can occur, which are not covered by the use cases. To support the complexity for work zones, a different methodology is described in this chapter.

The development of the RWW service follows these ground rules:

1. Backwards-compatibility: existing implementations from previous C-ROADS releases shall be kept as valid
2. Current capabilities of road operators and vehicle implementations shall be respected, i.e. which messages (DENM, IVIM, MAPEM) can be sent out and processed by vehicles

To ensure these ground rules are followed, the existing use cases RWW-LC (lane closure), RWW-RC (road closure) and RWW-RM (mobile roadworks) are not changed, which means only the functional descriptions have been modified to fit better into the new methodology described in the following sections. The technical requirements (message profile and system profile) will be kept in a backwards compatible way. Although different messages can be used in the context of RWW, the specification respects the current capabilities of road operators (e.g. sending out DENMs only as of this moment) and the receiving vehicles. To support the new methodology, the core components of a work zone are covered by DENM and additional information can be provided via IVIM. Further details on the intended messages usage can be found in chapter 4.6.

Currently, there are different views on work zones between countries, but also between C2C-CC and C-Roads. Most road operators in C-Roads are driven by legislation, which distinguishes between short- and long-term work zones based on the duration of the work, whereas C2C-CC is concerned with differentiation according to the complexity and impact of the work zones from the traffic participant's viewpoint.

These different methodologies lead to the fact that as long as an overarching definition and solution does not exist, the harmonisation between sender and receiver is not fully given, because the details on the work zone are communicated in different ways. Since a uniform solution is the goal, C2C-CC and C-Roads agreed on the following points, which are described in this chapter on road works.

1. The road operator wants to influence the driver's behaviour and therefore shall take the viewpoint of a driver / automated driving system to identify and specify relevant information.
2. Since work zones can vary strongly, it does not make sense to focus on specific configurations. Instead work zones shall be broken down into components (see section 4.8). These components shall be atomic in the sense, that they cover only one specific situation of a work zone and cannot be split up further. By combining these individual components, all kinds of road works and work zones can be covered.
3. For each dangerous situation a dedicated warning shall be issued.

Additional information can also be sent.

4.4 Triggering conditions

To be delivered in a future version of the document.

4.5 Operational scenarios

Road works warning uses different equipment types to communicate information to vehicles: trailer, RSU or road operator and/or contractor vehicles (V_{ro}). The information available to these devices depends on their local sensor systems and connectivity to other information sources. In principle, two major cases exist:

- Stand-alone
 - V2V: the message contains only information available in the vehicle/trailer
 - Message disseminated via vehicle/trailer directly
 - I2V: the message contains only information available in the TCC
 - Message disseminated via RSU or C-ITS-S
- Augmented
 - V2V: the message is enhanced with additional information received from TCC
 - message still disseminated by vehicle/trailer
 - I2V: the message is enhanced with additional information received from vehicle/trailer
 - message still disseminated via RSU or C-ITS-S

Since the receiver is not aware of the current operational scenario, the road operator shall specify a basic set of information (see Figure 4:2), which is provided in all cases so that in-vehicle applications can rely on it. Additional information might also be provided but is not guaranteed.

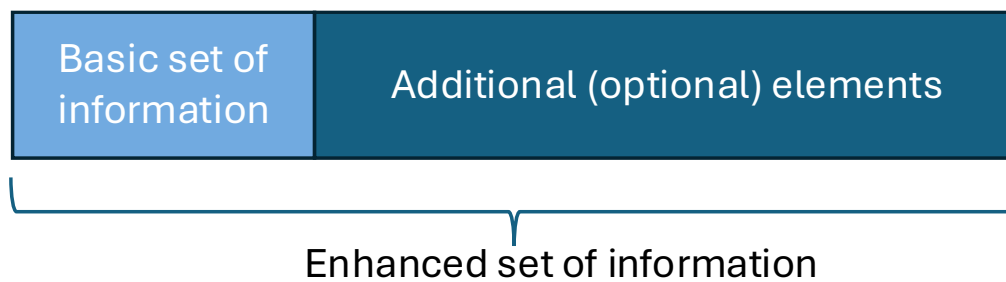


Figure 4:2 operational scenarios

4.6 Message usage

The development of RWW requires a migration path to sustain the existing implementations. As described in chapter 4.2, the existing use cases are integrated into the new methodology. This implies that the message usage and profiles of the previous use cases are maintained unchanged regarding mandatory message components. In the following sections a migration is reflected in the requirements, which enable the road operators to work towards the full solution but keep the existing implementation.

4.6.1 Main Requirements

ID	<i>SUD_Req_0061 (1)</i>
Requirement	<p>If a work zone contains lane or road closures, individual DENM warnings for these components shall be sent.</p> <p>Note: These components and their resulting DENM based warnings represent the RWW use cases present in previous C-ROADS releases and thus constitute a backwards-compatible migration path. No other components or messages are mandatory in this current profile when encoding a work zone</p>

ID	<i>SUD_Req_0062 (1)</i>
Requirement	The DENM profiles in chapters 4.8.3 and 4.8.4 shall be used respectively for lane closures and road closures.

ID	<i>SUD_Req_0063 (1)</i>
Requirement	<p>If a work zone contains no lane or road closure resulting in the dissemination of a DENM warning or if no detailed information about the work zone is available in general, a generic DENM warning using the profile in chapter 5.3 shall be disseminated.</p> <p>Note: Every work zone is expected to generate at least one DENM warning. In order to be backwards compatible, this is either the lane or road closure DENM or, in their absence, a generic DENM.</p>

ID	SUD_Opt_0065 (1)
Option	<p>To fully describe a work zone, all warning, signage and topology information messages associated to the different components and phases of a work zone should be disseminated.</p> <p>Note: While only warning DENMs for the lane or road closure components are mandatory due to backwards compatibility, road operators are encouraged to disseminate all available information for the different components and phases and their resulting warning, signage and topology information messages as indicated in chapter 5.2.C-ROADS reserves the right to make further warning as well as signage and topology information dissemination mandatory in future releases.</p>

4.6.2 Intended methodology

The fully established methodology should cover all components and also accompany the DENM with IVIM and/or MAPEM to convey additional information (e.g. signage and topology information). With respect to the messages to be sent, the following aspects are considered for the announcement of road works:

1. A generic danger warning (DENM) of the start of the work zone
2. Additional more detailed warnings (DENMs) for the components of the work zone that trigger a dedicated DENM
3. Signage information (via IVIM)
4. Topology information (via IVIM or MAPEM).

C-ROADS reserves the right to make IVIM (3+4) dissemination mandatory in future releases, when IVIM adoption is wide-spread, as this is essential information for roadworks.

4.6.3 Default generic RWW warning

This generic profile for RWW is based on the DENM general elements and Road works Warning (RWW) profiles of the DEN Basic Service (DEN Basic FLS) specified in sections 4.2.1.1 and 4.2.1.3 of [C-Roads MP]. The profile in this document specifies additional requirements for RWW. The requirements of the base profiles are not repeated unless further profiling is required, or it is necessary for clarity.

The intention of the generic warning DENM is a general warning to the driver that there is road works coming up, if the first component of the work zone (most upstream component) does not trigger a DENM. Additional DENMs might be transmitted in case the work zone has components that trigger a dedicated warning. For the information on which message type shall be used for the respective component, please see section "Technical assessment on messages to be used" provided for each of the components. These dedicated DENM warnings are based on the generic DENM profile that is described in this section. If there are deviating requirements or further profiling is necessary for the specific component, it is specified in the message profile requirements section of the component specific interoperability requirements. Thus, for the component specific warning DENMs, the message profile requirements that are specified in the component always overrule the generic DENM profile.

4.6.3.1 Generic DENM Requirements

ID	<i>SUD_Req_0066 (1)</i>
Requirement	In case detailed information about a work zone is not available or not reliable or the life cycle of a work zone is not monitored, the generic warning DENM shall be sent instead of individual component DENM warnings.

ID	<i>SUD_Req_0010 (1)</i>
Requirement	<p>The generic warning shall always be sent, except if the first component of the work zone (most upstream component) triggers a DENM, e.g. a lane closure. In that case, no generic warning shall be sent.</p> <p>Note: This ensures, that there will not be multiple DENMs referring to the same roadworks with the same reference position (i.e. eventPosition).</p> <p>Example: In case the first component of the work zone is a lane closure, a DENM for the single lane closure component will be sent with an eventPosition set to the most upstream point of the work area. An additional generic DENM with the same eventPosition would not be of any benefit.</p>

ID	<i>SUD_Req_0011 (1)</i>
Requirement	<p>When an event is identified as ended, a respective cancellation DENM should be issued.</p> <p>Note: Due to backwards compatibility, this is only a recommendation and not a requirement. The use of cancellation is advised and planned to become mandatory in future releases.</p>

DE/DF	<i>DENM.denm.management.eventPosition</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0012 (1)</i>
Requirement	<p>The eventPosition shall be set to the location where the first physical blockage of a work zone occurs. If the data is not available on site, the road operator shall provide that location using plan data.</p> <p>Note: This requirement can be overruled by more specific, component-based requirements. The first physical blockage is not supposed to be a pre-warning sign situated on the hard shoulder</p>

DE/DF	<i>DENM.denm.management.validityDuration</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Rec_0013 (1)</i>
Recommendation	validityDuration should be at most 10800 seconds.

DE/DF	<i>DENM.denm.management.stationType</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0014 (1)</i>
Requirement	<p>The stationType shall be set according to the type of C-ITS station disseminating the generic DENM warning, using one of the following values available in [ETSI TS 102 894-2]:</p> <ul style="list-style-type: none"> ○ 9 (trailer) ○ 10 (specialVehicle) ○ 15 (roadSideUnit)

DE/DF	<i>DENM.denm.situation.eventType</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0016 (1)</i>
Requirement	The eventType shall be set to causeCode roadworks3, subCauseCode 0 (unavailable).

DE/DF	<i>DENM.denm.situation.eventZone</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Rec_0017 (1)</i>
Recommendation	<p>eventZone should not be used for the generic RWW DENM.</p> <p>Note: For other components, the requirement might be different.</p> <p>Note: Currently a new option for specifying the length of the event along the road in meters is developed in standardization in ETSI for DENM/CDD. The current datatype of the DE eventEnd in the SituationContainer is restricted to 8189 m, which is not sufficient for work zones. As soon as the new option is available, it will be integrated into the message profiles for RWW.</p>

DE/DF	<i>DENM.denm.alacarte.roadWorks.closedLanes</i>
O/M/C/F	<i>Forbidden</i>
ID	<i>SUD_Req_0018 (1)</i>
Requirement	<p>This DF shall not be used for the generic DENM warning.</p> <p>Note: For other components, the requirement might be different.</p>

DE/DF	<i>DENM.denm.alacarte.roadWorks.trafficFlowRule</i>
O/M/C/F	<i>Forbidden</i>
ID	<i>SUD_Req_0019 (1)</i>
Requirement	This DF shall not be used for the generic DENM warning. Note: For other components, the requirement might be different.

4.6.4 Generic IVIM Profile for RWW

4.6.4.1 Methodology

This generic profile for RWW is based on the In-Vehicle Signage (IVS) and the HD Topology (HDT) profiles of the Infrastructure to Vehicle Information (IVI) Service (IVI FLS) specified in [C-Roads MP]. This profile specifies additional requirements for RWW. The requirements of the base profile are not repeated unless necessary for clarity. The herein described methodology shall be applied in case of IVIMs used in RWW.

The relevant elements within the IVIM profile for RWW are:

- GLC – Geographic Location Container, containing geographical zones to be used by other containers
- GIC – General IVI Container, containing information about traffic signs and their applicability to certain vehicle classes
- RCC – Road Configuration Container, containing status and topological information for all driving lanes

For the sake of harmonised approach to define the geographical zones within the GLC (i.e., instances of GlcPart), the road works zone shall be longitudinally divided into N segments, where the first segment (Segment #0) will be the detectionZone of the first information (e.g., a traffic sign), and the following segments are demarcated by:

- the position of a traffic sign (see segments 1,2,3,4,6,8,9,12,13 and 14 in Figure 4:3) and/or,
- the start/end of a different road topology, if not coinciding with any of the points identified above (see segments 5, 7, 10 and 11 in Figure 4:3) and,
- the end of the road works zone, if not coinciding with any of the points identified above.

The identified segments shall be defined as the geographical zones (instances of GlcPart) in the IVIM. The resulting IVIM for RWW contains, as a minimum N geographical zones (instances of GlcPart), described in one or more GLC(s) that can be used for different purposes, such as:

- the description of detection and relevance zones for signage information in the GIC, so that signs can be displayed at the correct locations, and
- the description of topology information in the RCC, so that signs can be displayed within the road context (e.g. the actual number of lanes), and changes and deviations from normal road topology are known to the vehicle and can be used by Automated Driving System functions, specifically, for the lateral vehicle motion control.

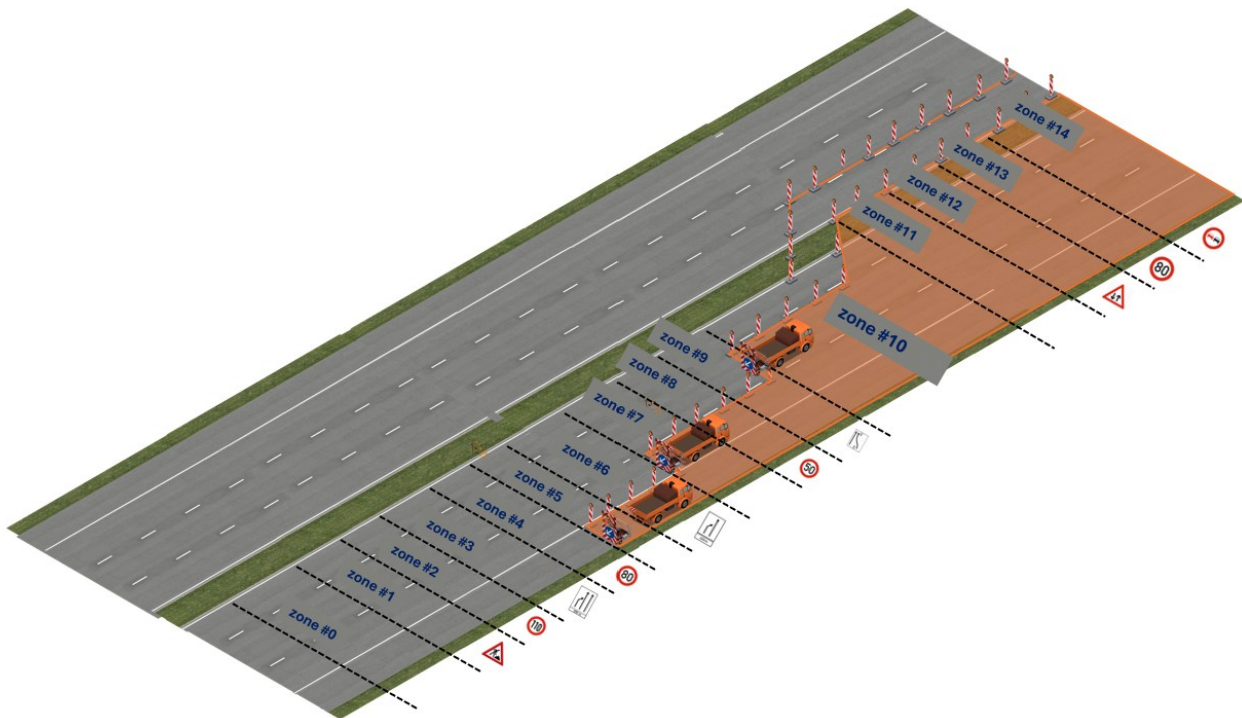


Figure 4:3 Segments of a work zone

The default option for GLCs is to describe the N geographical zones (instances of `GlcPart`) of a road works zone, by placing a polygonal line at the transversal middle of the set of regular driving lanes (excluding the hard shoulder). If necessary, the polygonal line may be placed at the transversal middle of the individual lane, when the trajectory of single lanes deviates from the normal course.

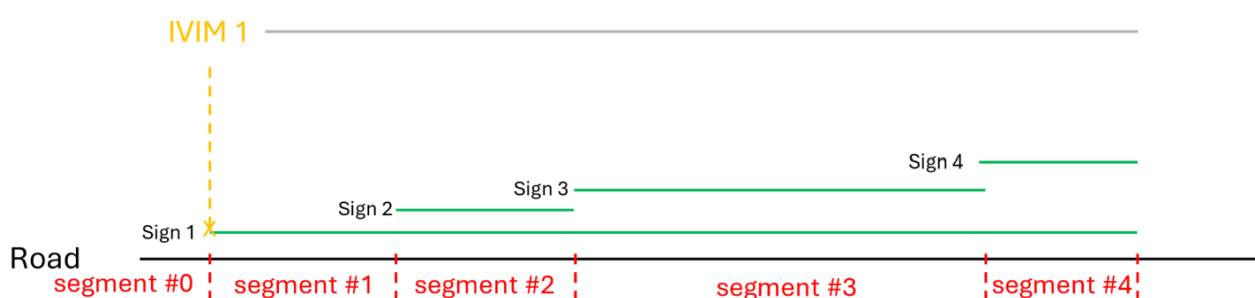
Following the approach of dividing the work zone into segments described above, it might occur that not all information can be encoded into one IVIM due to the MTU (Maximum Transmission Unit) limit of the message is reached. The relevant limitation here is the MTU size of ITS-G5. In this case, the work zone has to be split up and encoded into as many IVIMs as required to disseminate the complete information of the work zone. This might lead to additional segments that have to be defined. Figure 4:4 shows an example for this situation. For simplicity, the example only shows signs and omits possible topology changes. The top part of the example shows a work zone that is divided into 5 segments, where all required information is encoded into one IVIM. The bottom part of the example shows the case that one IVIM is not sufficient to encode all necessary information. The first IVIM can only encode segments 0, 1 and 2 for signs 1 and 2, covering segments 3 (for signs 1 and 3) would exceed the MTU of the message. The second IVIM can only cover part of the original segments 3 for the relevance zone of signs 1 and 3, and an additional `detectionZone`. Therefore, the original demarcation points of segments 3 has to be changed to cover the part of the relevance zone of signs 1 and 3 that can be accommodated by the second IVIM. This would result in an additional segment between signs 3 and 4, due to MTU limitation of the message. Then, the third IVIM then covers segments 4 (new) and 5 to describe the remaining relevance zones for signs 1 and 3 and the relevance zone for sign 4, together with the additional `detectionZone`. Note that the additional segment introduced in the bottom example is not the result of a position of a road sign or a topology change as described in the above approach. It is the result of the MTU limitation of the message i.e. the description of zones does not fit into one IVIM.

The bottom example has one other implication. According to requirement MP_Req_0092 (1) defined in [C-Roads MP], an IVIM shall be self-contained, so the definition of all geographical zones referred to within the IVIM shall be included in the same IVIM. This requirement implies that signs 1 has to be encoded in all three

IVIMs, and sign 3 has as to be encoded in second and third IVIMs, as it is not possible to assign a relevance zone to a sign, where the relevance zone is defined in a different IVIM.

It also worth noting that, in the provided example, although there is only one additional segment between the top and bottom of the cases (i.e., 5 segments for the top and 6 segments for the bottom), there would be additional 3 geographical zones (instances of GlcPart) in total for the bottom case compare to the top one (i.e., total of 5 instances of GlcPart for top case and 8 instances of GlcPart for bottom case), due to the fact that each IVIM will have an additional geographical zone (instances of GlcPart) for the detectionZone of the first sign within each IVIM (i.e. segment #6 for IVIM 2 and segment #7 for IVIM 3).

Single IVIM



Multiple IVIMs

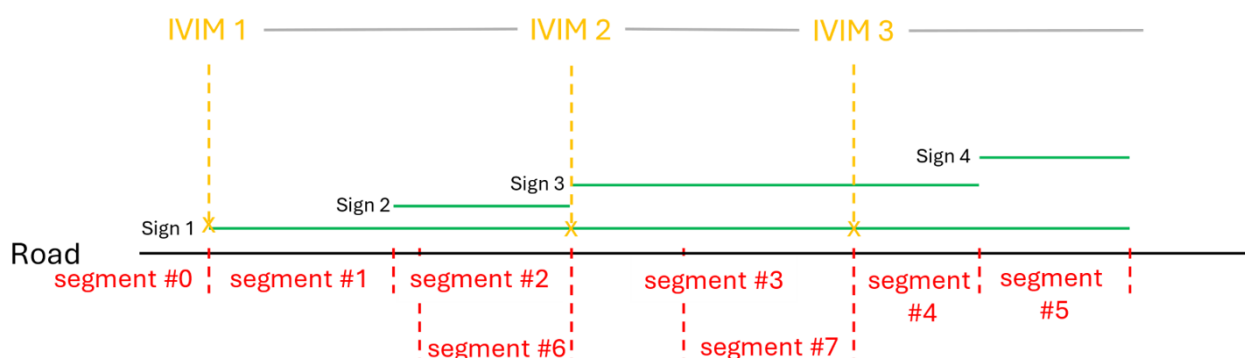


Figure 4:4 Segmentation of work zone in case multiple IVIMs are required

4.6.4.2 Component independent IVIM requirements

DE/DF	<i>IviStructure.mandatory.connectedIviStructures</i>
O/M/C/F	<i>Conditional</i>
ID	<i>SUD_Req_0001 (1)</i>
Requirement	<p>If known that there are multiple IVIMs covering the same workzone in the same driving direction, connectedIviStructures shall be used to connect individual, self-contained IVIMs belonging to the same work zone.</p> <p>An additional IVIM is required under the following circumstances:</p> <ol style="list-style-type: none"> 1. The possibilities of DE/DF utilisation are exhausted, i.e., the maximum amount of a specific message component is reached, necessitating a split into multiple IVIMs. 2. The Maximum Transmission Unit (MTU) size limitation restricts the inclusion of all required information in a single IVIM. 3. Different life cycles of the information requiring independent updates of the information 4. Limitation of data sources do not allow for a full view <p>Note: Usually, the MTU size is the trigger for an additional IVIM.</p>

DE/DF	<i>IviStructure.mandatory.connectedDenms</i>
O/M/C/F	<i>Recommendation</i>
ID	<i>SUD_Req_0002 (1)</i>
Recommendation	<p>connectedDenms shall be used to link DENMs that are sent out for the same work zone (in case the work zone consists of one or more components that trigger a DENM).</p>

DE/DF	<i>IviStructure.optional.glc</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Inf_0003 (1)</i>
Information	<p>The combined GLC(s) of all IVIMs describe(s) the course of the affected carriageway starting from the position of the first sign at the start of the work zone and describing all parts/segments of the work zone as individual zones in the IVIM(s).</p>
ID	<i>SUD_Req_0004 (1)</i>
Requirement	<p>The IVIM shall contain additional instances of GlcPart if necessary (because of road configuration changes of one or more lanes) to describe deviating lanes or exits and entries to the motorway, connected DENMs should be used.</p>

DE/DF	<i>IviStructure.optional.glc.parts</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0005 (1)</i>
Requirement	In all IVIM related to RWW, the GLCs shall define N parts, where N is the number of segments that can be covered by one IVIM according to the definition in section 5.4.1. Note: This requirement refers to the definition of a single IVIM. In case defining all N segments in one or more GLCs in an IVIM would result in exceeding MTU of a single message, multiple IVIMs have to be defined as described in section 5.4.1.

DE/DF	<i>IviStructure.optional.glc.applicableLanes</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0006 (1)</i>
Requirement	This DE shall be used to identify the lanes inside the work zone for which the signage information is applicable. Most signs are applicable to all lanes that are open to traffic, but since some lanes may be closed, the applicable lanes must be indicated explicitly.

DE/DF	<i>IviStructure.optional.glc.laneStatus</i>
O/M/C/F	<i>Forbidden</i>
ID	<i>SUD_Req_0007 (1)</i>
Requirement	The DE laneStatus shall not be used, since lane information is covered by the mandatory RCC.

DE/DF	<i>lviStructure.optional.gic.roadSignCodes</i>		
O/M/C/F	<i>Mandatory</i>		
ID	<i>SUD_Inf_0008 (1)</i>		
Information	Specification of the traffic sign (including additional (sub)signs attached to it) using [ISO 14823-1] GDD codes, e.g.:		
	Warning that there is a segment where work is in progress	11	348
	Notice that motor vehicles with more than the specified width are forbidden to pass through the designated segment of the road	12	499
	Notice that the maximum speed for motor vehicles is regulated	12	557
	Notice of closure of a traffic lane, two lanes to one (right lane ends)	13	651
	Notice of closure of a traffic lane, three lanes to two (right lane ends).	13	652
	Notice of lane convergence, four lanes to three (right lane ends).	13	653
	Notice of closure of a traffic lane, two lanes to one (left lane ends).	13	654
	Notice of closure of a traffic lane, three lanes to two (left lane ends).	13	655
	Notice of closure of a traffic lane, four lanes to three (left lane ends).	13	656
	Notice that two adjacent traffic lanes are separated. The right-hand lane moves to the right but remains within the same carriageway with width restriction on right hand lane.	13	657
	Notice that two traffic lanes move to the right: one crosses over to the other carriageway. The advised speed where the lanes divert is specified.	13	658
	Two lanes move to the left.	13	672
	One lane shifts to the right opposing carriageway.	13	673
	One lane shifts to the left opposing carriageway.	13	674
	Two lanes shift to the left opposing carriageway.	13	675
	Two lanes shift to the right opposing carriageway.	13	676
	The traffic lane shifts to the right.	13	677
	The traffic lane shifts to the left.	13	678
	Notice that traffic partially deviated to opposite carriageway ahead	13	679
	<ul style="list-style-type: none"> • Note: This list is not intended to restrict or exhaustively define all possible road sign codes that may be used within the scope of a Road Works Warning (RWW). • Additional values may be applied as appropriate, provided they remain within the bounds of the specification. 		

DE/DF	<i>IviStructure.optional.rcc</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0009 (1)</i>
Requirement	The IVIM shall include a distinct instance of RccPart for each unique road configuration. The IVIM shall include a distinct RCC part for each unique road configuration within the road works zone.
ID	<i>SUD_Req_0067 (1)</i>
Requirement	In case a single IVIM cannot cover all different road configurations of the work zone, additional IVIMs shall be provided to cover this (see section 4.6.4.1).
ID	<i>SUD_Req_0068 (1)</i>
Requirement	<p>The RCC shall be based either on:</p> <ul style="list-style-type: none"> the In-Vehicle Signage (IVS) profile specified in [C-Roads MP], when signage information is provided (see first purpose below), or on the HD Topology (HDT) profile specified in [C-Roads MP] when topology information is provided (see second purpose below). <p><i>Note: The RCC(s) can be used by the receiving C-ITS-Station for the following purposes:</i></p> <ul style="list-style-type: none"> The provision of road configuration information, so that traffic signs can be displayed within the road context (e.g. the actual number of lanes) The provision of topology information, so that changes and deviations from normal topology are known to the vehicle and can be used by Automated Driving System functions, specifically for the lateral vehicle motion control

4.7 Lifecycle management: Setup, remodelling and dismantling of a work zone

4.7.1 Phases

Motorway networks are usually built for heavy amounts of traffic. In order not to restrict mobility, motorway sections are usually not closed entirely. The setup of the work zone and the work itself are carried out under rolling traffic. For this reason, a high degree of care is needed in planning and implementation. The better the traffic is warned and can adapt to the new situation, the safer and smoother the traffic flow.

When considering the lifecycle of a work zone, one must distinguish between four phases: (1) setup phase, (2) work phase, (3) remodelling phase and (4) dismantling phase (see Figure 4:5). Each of these phases has specific features that must be considered. In this paragraph the phases 1, 3 and 4 are addressed. In the next paragraphs the components that built up phase 2 (the work phase) are described.

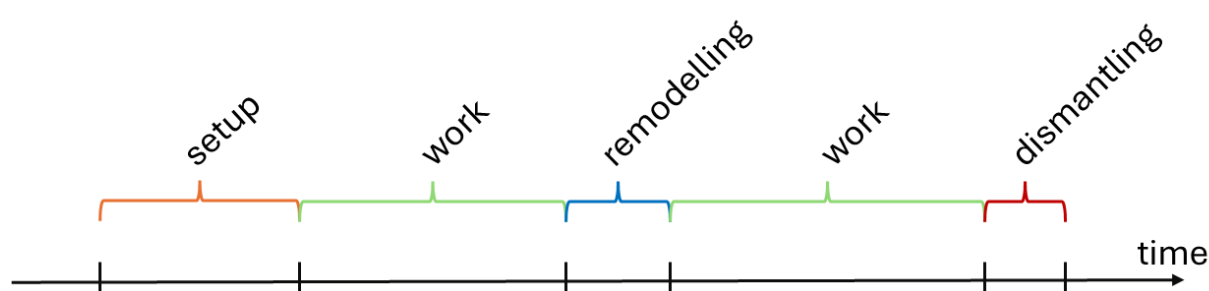


Figure 4:5 Schematic of the lifecycle of a work zone

During the setup phase, the planned topology of a work zone has not been reached yet. Thus, it is not always possible to send accurate and up-to-date topology information of the current work zone to the vehicles, as the topology changes continuously. In this case, since it is difficult to always synchronise the situation in the work zone with the content of the message, a general warning message indicating the danger of ongoing road works would be suitable.

Road operator and/or contractor vehicles are usually operating at this time, securing the work zone and thus already in front of the later-to-be-changed traffic routing. These vehicles know their position exactly and can issue suitable warnings. For safety reasons, the aim is to keep the information they disseminate as up to date as possible.

Another issue is road markings. Original lane markings may no longer be correct, and new markings might not be updated or may change during the work zone setup. This is crucial for autonomous and semi-autonomous driving, as lane markings are used for vehicle orientation. If lane markings continue but the lane is closed, vehicle misbehaviour can occur.

A general warning (e.g., via a DENM) can be sent immediately at the beginning of the setup. However, further topology information can only be disseminated after all changes are made. In addition, signage messages that refer to traffic regulations also need to be aligned with the signage that is present at the work zone. Multi-step speed reductions before approaching the work zone are especially relevant here. This must therefore take place in the first step by means of physical signage and subsequently also represented by the digital message (e.g. IVIM). This means that messages for signage and topology information (e.g., IVIM or MAPEM for topology) can only be sent after the setup phase ends, while a general warning message (e.g., DENM) can be sent right away to warn the traffic.

During the work phase, information about the components of the work zone shall be sent as specified in the following sections. Messages in the work phase should be as up to date as possible, as outdated messages will mislead the receiver and thereby create additional dangers. The basic rule for message dissemination is that the message must always reflect the current situation on the road. As premature sending of information that is not yet valid is even worse, the most that can be issued here is a general warning that indicates the hazardous situation (setup or dismantling of a work zone). Additional relevant information (for new or omitted components) must be included as soon as they become valid.

Road works are often conducted in segments and therefore require remodelling of the work zone after the work on one segment is done. During the remodelling phase, road workers restructure the work zone, block open lanes and open closed lanes. This work can be done by a road operator or a contractor. A warning message during this period will usually not contain detailed and up-to-date information about the actual and dynamic situation on the road. Therefore, a general warning about the ongoing remodelling is adequate. For the OEMs, it is important to receive correct information. Therefore, disseminating a general warning with less but correct information is better than detailed not up to date information. A remodelling phase can occur multiple times during the life cycle of a road work. So Figure 4:5 depicts a simplified version of a work zone's lifecycle. There can be other constellations like setup phase, work phase, remodelling phase, work phase, remodelling phase, work phase, dismantling phase.

In the dismantling phase, the same requirements apply as for the setup. The topology of the work zone changes until the final lane conditions are reached. During this time, a warning message indicating the danger of ongoing road works should be sent to vehicles until the final condition is reached and all lanes are cleared. The messages for lane markings, possibly narrowed lane and closure of the hard shoulder apply the same way as during setup phase.

4.7.2 Message profile and usage for setup, remodelling and dismantling phases of a work zone

As described above, only a warning DENM can be sent during the setup, remodelling and dismantling phases of a work zone. Therefore, the warning DENM is profiled for these phases.

4.7.2.1 Warning DENM Requirements

This warning DENM requirements are based on the generic DENM requirement provided in section 4.6.3. Requirements of the generic DENM profiles are not repeated unless further profiling is required, or it is necessary for clarity.

ID	SUD_Req_0060 (1)
Requirement	During the setup, remodelling and dismantling phases road workers might have to work on the road near the traffic. Thus, a HLN-APR DENM with the subCauseCode set to road-worker(6) shall be sent in addition to the warning message that is described below.

DE/DF	<i>DENM.denm.situation.eventType</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0023 (1)</i>
Requirement	<p>The eventType shall be set as follows:</p> <ul style="list-style-type: none"> ○ Setup phase: causeCode roadworksroad works3, subCauseCode 7 (setupPhase) ○ Remodelling phase: causeCode roadworksroad works3, subCauseCode 8 (remodellingPhase) ○ Dismantling phase: causeCode roadworksroad works3, subCauseCode 9 (dismantlingPhase) <p>Legacy note: Current vehicle implementations do not support the subCauseCodes 7-9. To reach these vehicles, subCauseCode 0 (unavailable) can be used instead.</p>

DE/DF	<i>DENM.denm.alacarte.roadWorks.closedLanes</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Rec_0024 (1)</i>
Recommendation	<p>This DF should not be used for the DENM during setup phase, remodelling and dismantling phase.</p> <p>Note: For the working phase, the requirement might be different.</p>

DE/DF	<i>DENM.denm.alacarte.roadWorks.trafficFlowRule</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Rec_0025 (1)</i>
Recommendation	<p>This DF should not be used for the DENM during setup phase, remodelling and dismantling phase.</p> <p>Note: For the working phase, the requirement might be different. See also SUD_Rec_0024.</p>

4.8 Components

4.8.1 Introduction

In this chapter, work zones are broken down into components. Components are atomic in the sense that they cover only one specific situation of a work zone and cannot be split up further in a meaningful manner for C-ITS notification purpose. By combining these individual components, all kinds of road works and work zones can be covered, at least in theory. The following paragraphs will introduce all components identified so far in the C-ROADS process, provide examples and a technical assessment on the C-ITS message sets to be used to convey the respective relevant information to vehicles.

C-Roads used the following process to identify the work zone components and specify the information, which is relevant.

1. Based on inputs from different member states, a collection of work zone components was created. Each component is briefly described with its main characteristics.
2. For each of the components, the following questions needed to be answered:
 - a. Does this component require a dedicated warning?
 - b. Is additional information for this component necessary? (Depending on the required additional information, different messages can be used)
3. Create the message profile(s) for each component
4. Formulate a mechanism to combine the atomic components and how to construct the messages appropriately.

The following chapters will introduce all components identified so far in the C-ROADS process, provide examples and a technical assessment on the C-ITS message sets to be used to convey the respective relevant information to vehicles.

Each component is described functionally using a template similar to the known one from use case descriptions. The explanation of the template can be found in the previous chapter 1.3 of this document.

The interoperability requirements are split into message profile requirements, which are component specific, while the cross-component requirements are provided in chapter 4.8.2.

Note that all components are written from the perspective of one carriageway. If the carriageway in the opposite direction is affected by the road works (e.g. by a carriageway crossover), respective messages shall be sent for the opposite carriageway (using the components described in this document).

Incursions (vehicle entered a work site) are out of scope of this document. They may be covered by a future HLN use case.

4.8.2 Component independent interoperability requirements

4.8.2.1 Security and data protection requirements

Security requirements and specifications of certificates are described in the [C-ITS Security Requirements and Specifications] document.

An overall introduction to the common European trust model is described in [C-ITS Security and Governance] which is referring to the relevant ETSI standards for certificates and PKI management as the underlying technical basis.

This use case is based on the causeCode roadworks3 and therefore requires appropriate DENM permission (SSP) in the certificate to be used (AT):

CauseCodeType / Container	SSP position	
	Octet position	Bit position
roadworks3	1	2

The here listed SSP shall be granted only for C-ITS stations used by road operators or any service provider (e.g. contractor) on their behalf.

4.8.2.2 Communication technology requirements: ITS-G5

For ITS-G5 based implementations of use cases where roadside stations are used, the requirements of [C-Roads RSP] shall apply.

For ITS-G5 based implementations of use cases where mobile stations are allowed and used, the requirements of [C-Roads MSP] shall apply.

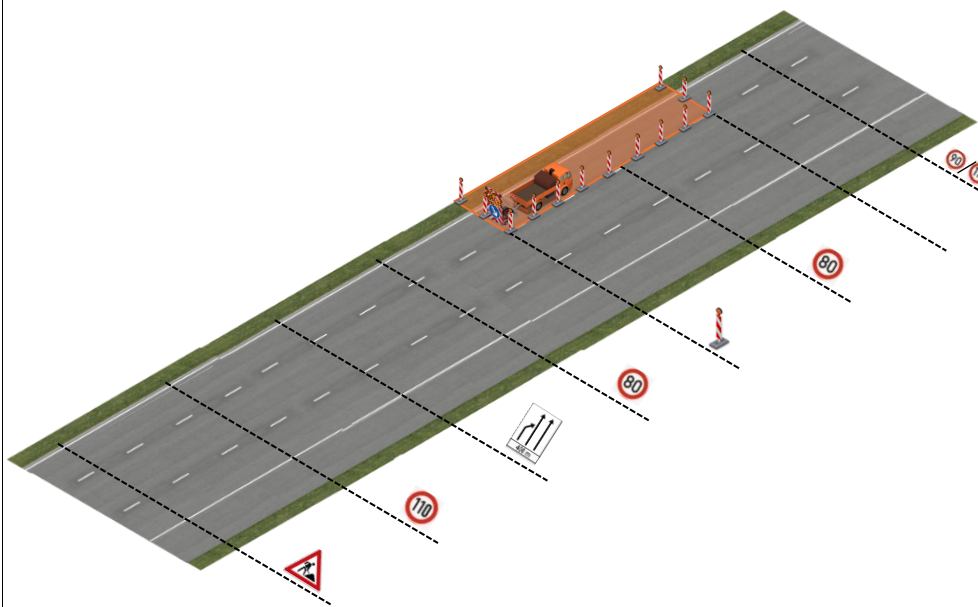
4.8.2.3 Communication technology requirements: IP based

For IP based implementations of use cases that use shared backend communication, the requirements of [C-ITS IP Based Interface Profile] shall apply.

4.8.3 Single lane closure

4.8.3.1 Component Introduction

Type of road network	Highway, motorway
Type of vehicle (receiver)	All
Component introduction	
Summary	<p>Due to the presence of a static/temporary road works site or an area where mobile road works are planned, a whole lane is closed. This component does not cover alternate modes or road closures. This component is the simplest kind of road works, where just one lane is closed. In case multiple lanes are closed, this component should be used multiple times.</p> <p>This component also covers mobile road works as a moving lane closure.</p>
Background	Vehicles unintentionally entering work sites or colliding with the protection equipment of the work site due to a lack of timely awareness put road workers and the public at risk. The risk is even higher with mobile work sites that are “lighter” in terms of protection and signalling, because they are moving. Providing advanced warnings and information would reduce such risks, as drivers can adapt their driving behaviour accordingly.
Objective	<ul style="list-style-type: none"> • The objective is to inform drivers early enough about lane closures due to road works on the road ahead to give them the opportunity to adapt their speed and change lanes in time. • In case of mobile road works, the location of the lane closure is moving, so the objective is to raise the awareness of the drivers of the mobile work zone. • Note: It is not the objective to inform the drivers about a road closure. Therefore, alternative route information will not be provided for this component. It is also not the objective to signal to the users that they are likely to have to stop, as in the case of a road closure.
Desired behaviour	<ul style="list-style-type: none"> • Increased vigilance. • Speed adaption. • Change of lanes (if needed).
Expected benefits	<ul style="list-style-type: none"> • Reduced risk and number of accidents and dangerous situations for drivers and workers. • In case of mobile road works, the severity and number of accidents will be reduced • Improved traffic management due to reduced traffic incidents on the road.

Component description	
<p>Situation</p>	<ul style="list-style-type: none"> • Road works with warning beacons/temporary traffic signs/illuminated light arrows on a road with separate carriageways or on a dual carriageway. • This component is usually used in one of the following situations: <ul style="list-style-type: none"> ○ Lane closure by sign gantries (lane control system) as part of road works. ○ Lane closure by warning trailer equipped with RSU (short term road works). ○ Mobile road works (e.g. mowing, road markings, fixing restraint systems, phyto-sanitary treatments, sweeping/road cleaning, etc.) ○ Carriageway crossover on the opposite carriageway requires a lane closure on the carriageway in focus as part of road works. <p>The diagram below is an example of a single lane closure. The signs and speed limits are shown as examples only and must be adapted to real situations.</p>  <p><i>Figure 4:6 Example of a single lane closure</i></p>

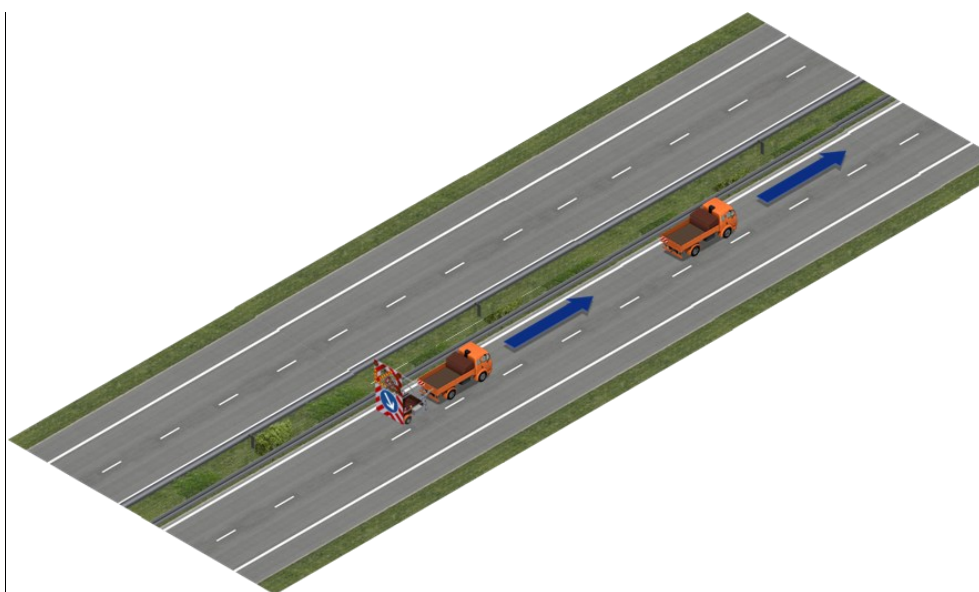


Figure 4:7 Example of a single lane closure

Triggering conditions	<p>Once the topology and signage change is confirmed, it should be reflected in the disseminated messages as soon as possible.</p> <p>The component shall not be sent during setup, remodelling and dismantling phases.</p>
Logic of transmission	I2V, V _{RO} 2V ¹
Actors and relations	<ul style="list-style-type: none"> • Road operator: Is the origin of the information of the message. It can be the TCC, and/or a road operator vehicle. • Drivers: The drivers approaching the work zone are the end-user of this service (receives the information/message). • Service provider: The distributor of the information. Can be the road operator or a third party service provider.
Component scenario	<p>There are various implementation scenarios (I2V: TCC/RSU sending the messages; V2V: trailer or V_{RO} sending the messages) that differ in the type of station sending the message and the information available. Independently of the implementation scenario, a basic set of information will be provided. Additional information might be present, depending on the capabilities of the sending station and possibly manual input. Combined scenarios exist, where the vehicle stations and infrastructure stations exchange information, leading to augmented messages coming from either side (vehicle station or infrastructure station). This is especially relevant for mobile road works, where the location information of the mobile lane closure constantly changes.</p> <p>Possible implementation scenarios are described here:</p>

¹ V_{RO}2V: Road Operator Vehicle to Vehicle

	<p><u>I2V:</u></p> <ul style="list-style-type: none"> • The road operator programs road works in its Traffic Management System (TMS). <ul style="list-style-type: none"> ○ The information contains all the elements that could be used to precisely describe the work site ○ start/end position of the work site; in case of mobile road works the start and end of the area, where the mobile road works will be conducted (this zone will not be used entirely the whole time. The actual work zone will be safeguarded) ○ duration ○ Additional information could be added, such as the speed limit of each affected segment. ○ Some data could be provided to the TCC by the trailers or road operator (vehicle) of the road work. • The message is then disseminated to the drivers. • The drivers receive the information and processes it. <p><u>V_{RO}2V:</u></p> <ul style="list-style-type: none"> • A trailer or road operator vehicle with specific equipment is used for lane closure <ul style="list-style-type: none"> ○ If a connection to the TCC exists, additional information can be integrated into the messages • The message is then disseminated to the drivers • The drivers receive the information and process it.
Intended Presentation/Alert principle	<ul style="list-style-type: none"> • When drivers arrive near the work zone site, they receive information that allows them to adjust their speed and position on the road to prevent dangerous situations. The information needs to be presented on the HMI early enough and should be moderately intrusive (at the manufacturer's decision). • The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Functional constraints / dependencies	<ul style="list-style-type: none"> • It is not always possible to assure that information generated and disseminated via different messages/information networks can be linked by the receiver to the same road works event due to e.g. lack of connectivity between the disseminating ITS stations. • Currently, the validation process of transmitted information (quality) against the physical layout of a RWW site is usually not done. • How the information is presented to the drivers is not part of the service description. It is left to the provider of the in-vehicle information system with HMI how information is presented. Information might e.g., be translated to the preferred language of the driver.

<p>Link to other C-Roads use cases and components</p>	<p>C-Roads Use Cases</p> <ul style="list-style-type: none"> • IVS-TS: warning about several aspects of the lane closure can be provided using traffic signs • HLN-APR: In case road workers are on the road without proper protection • ESVN-ERVI: There can be a road operator vehicle in the road works zone. • IVS- FT: a VMS can be in or close to the work zone providing information related to the road work. <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> • Narrow lanes • Carriageway crossover • Single Lane Closure: This component can be applied multiple times consecutively in case multiple lanes are closed stepwise. • Road Closed in direction of travel: The lane closure can lead to a road closure in case the last lane is closed • Entry inside RW • Exit inside RW • Work site entry and exit
<p>Interoperability requirements</p>	
<p>Communication technology requirements: IP based</p>	<p>For IP based implementations the requirements [C-ITS IP Based Interface Profile] shall apply.</p> <p>For use cases based on DENM messages the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = RWW – LC • messageType = DENM <p>Geographic area (Quadtree) for DENM message:</p> <p>The event is characterized by its eventPosition, detectionZonesToEventPosition, detectionZonesToSpecifiedEventPoint and eventZone. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = IVS-TS • messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>

Test and validation requirements	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C-Roads_TVC] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>
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4.8.3.2 Technical assessment on messages to be used

4.8.3.2.1 Messages overview

From the driver’s perspective relevant information:

- Announcement of a lane closure
- Information about which lane is closed
- Information about the exact position, where the lane is closed

This work zone component uses DENM and IVIM to convey all necessary information. Since a lane closure is a dangerous situation, a DENM is required to warn about the danger. The DENM is used to convey most of the relevant and necessary information whereas the IVIM is used to convey additional information (including all signage used in the scenario). The following sections provide the specific message requirements for this component.

4.8.3.2.2 Single lane closure component warning DENM Requirements

This warning DENM requirements are based on the generic DENM requirements provided in section 4.6.3.1. Requirements of the generic DENM profiles are not repeated unless further profiling is required, or it is necessary for clarity.

DE/DF	<i>DENM.denm.management.awarenessDistance</i>
O/M/C/F	<i>Forbidden</i>
ID	<i>SUD_Req_0027 (1)</i>
Requirement	<p>The awarenessDistance shall not be used for the single lane closure component.</p> <p>Note: For other components, the requirement might be different.</p>

DE/DF	<i>DENM.denm.situation.eventType</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0029 (1)</i>
Requirement	<p>The eventType shall be set to causeCode roadworks3, subCauseCode 4 (shortTermStationaryRoadworks) or causeCode roadworks3, subCauseCode 3 (slowMovingRoadMaintenance) in case of mobile roadworks.</p> <p>Note: The current naming of the sCC 4 for lane closure is not appropriate. A renaming is currently proposed at ETSI.</p>

DE/DF	<i>DENM.denm.situation.eventZone</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Opt_0030 (1)</i>
Option	<p>The DF eventZone may be provided.</p> <p>Note: Currently an approach for specifying the length of the event along the road in meters is developed. The current datatype of the DE eventEnd in the SituationContainer is restricted to 8.189 m, which is not sufficient for work zones. As soon as the new approach is available, it will be integrated into the message profiles for RWW.</p>

DE/DF	<i>DENM.denm.situation.linkedDenms</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Rec_0031 (1)</i>
Recommendation	If multiple DENMs are sent out for the same work zone, linkedDenms should be used to link the component specific DENMs.

DE/DF	<i>DENM.denm.location.detectionZonesToEventPosition</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0073 (1)</i>
Requirement	In case of V2V implementation using trailers, a trace (i.e. an instance of detectionZonesToEventPosition) leading to the current position of the trailer, which indicates the start of the lane closure, shall be provided.

DE/DF	<i>DENM.denm.alacarte.roadWorks.recommendedPath</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Rec_0032 (1)</i>
Recommendation	This DF should be used to indicate a recommended path to be followed.

DE/DF	DENM.denm.alacarte.roadWorks.trafficFlowRule
O/M/C/F	Optional
ID	SUD_Opt_0033 (1)
Option	<p>This DF may be used for the single lane closure component using one of the values passToLeftOrRight (0), passToRight (2), passToLeft (3).</p> <p>Note: For other components, the requirement might be different.</p> <p>Note: The trafficFlowRule value accurately reflects the permitted traffic behavior and needs to be consistent with the physical road topology and traffic layout at the location to which it applies.</p>

4.8.3.2.3 Single lane closure component IVIM Requirements

4.8.3.2.3.1 Requirements for single lane closure component

The IVIM requirements for this component are based on the component independent IVIM requirements (see 4.6.4.2), which are not repeated unless further profiling is required, or it is necessary for clarity.

4.8.3.2.3.2 Example IVIM for single lane closure component

The following example shows how the IVIM is assembled for the lane closure component based on the road works example shown in Figure 4:8.

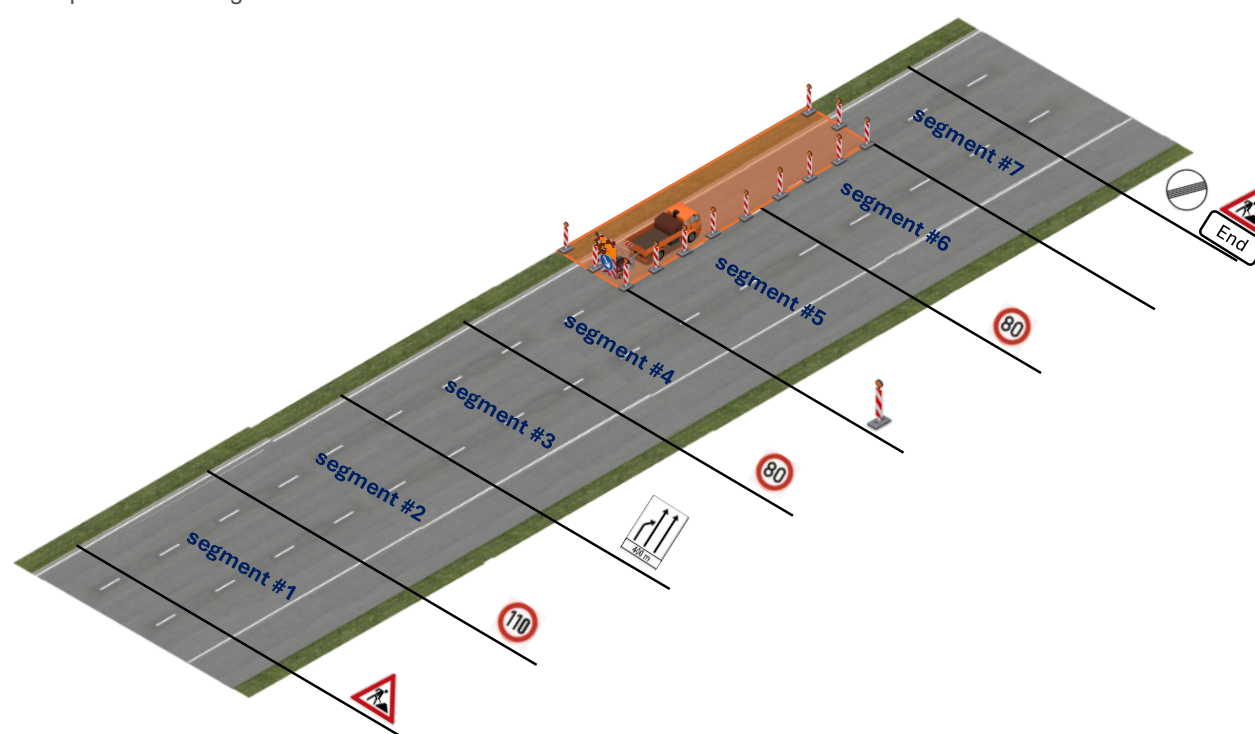


Figure 4:8 Example IVIM for lane closure component

For this example, the number of segments (N) in the roadwork zone is 8, demarcated by 8 points (6 positions of traffic signs and 2 positions of road topology change i.e., start and end of the lane closure that is not coincide with any traffic signs). Since the end of the road works zone and all traffic restrictions coincides with the position of the last traffic sign, no additional demarcation point is considered for the end of the road works zone.

In the GIC, each GIC Part pertains to one physical sign in the road works zone and, and described by:

- detectionZonelds:
 - for the RWW warning sign, by the zoneld (GLC Part) that describes the segment #0,
 - for 110km/h sign, by the zoneld (GLC Part) that describes the segment #1, if the segment #1 $\geq 800\text{m}$, if not, the zonelds (GLC Parts) that describe the segments #0 and #1,
 - and so on...
- relevanceZonelds:
 - for the RWW warning sign, by the zonelds (GLC Parts) that describe segments #1 to #7,
 - for 110km/h sign, by the zonelds (GLC Parts) that describe segments #1 and #2,
 - and so on...
- applicableLanes:
 - all driving lanes for relevance zones that are described by segments #1,2,3,4 and 7, and
 - lane 2 and 3 for relevance zones that are described by segments #5 and #6.
- roadSignCodes:
 - for the RWW warning sign it is 11 348,
 - for 110km/h sign it is 12 557,
 - and so on...

The RCC for this component, which is based on the In-Vehicle Signage (IVS) profile, specifies three parts:

- The first RCC part pertains to the part of the road works zone where no lane closure is present (described by segments #1,2,3,4 and 7). This RCC part indicates the lane with Status “open”.
- The second RCC part pertains to the part of the road works zone where the lane is closing, and the traffic needs to merge. This RCC part indicates the lane that is closing with Status “mergeR” or “mergeL” (as applicable). Dependent on national regulation for road works, e.g. if cones are used before an obstacle (trailer, barrier, etc) is physically blocking the road, the merging zone might differ (described by either segment #4 or #5).
- The third RCC part pertains to the part of the road works zone where a lane closure is present (described by segment #6 or segments #5 and #6). This RCC part indicates the closed lane with Status “closed”.

4.8.4 Road closed in direction of travel

4.8.4.1 Component Introduction

Type of road network	Highway, motorway
Type of vehicle (receiver)	All
Component introduction	
Summary	Due to the presence of a static/temporary road works site, a road is closed. In a road closure, lanes are closed one by one (using the lane closure component) with the road closure component occurring where the last lane is closed.
Background	When drivers encounter a road closure without being informed about the situation, they may become anxious and make dangerous manoeuvres or use an inappropriate lane (e.g., hard shoulder). Providing advance information about road closures can prevent such situations and improve safety and comfort. There is an added value in this component if the information is accurately linked with re-routing information.
Objective	The objective is to inform drivers early enough about road closures due to road works to give them the opportunity to adapt their speed and change lanes in time. Allow drivers to recognize the closure of a road so they can choose an alternate route.
Desired behaviour	<ul style="list-style-type: none"> • Increased vigilance. • Speed adaption. • Appropriate route change.
Expected benefits	<ul style="list-style-type: none"> • Increased road safety (avoid dangerous behaviour, e.g., U-turns). • Improved traffic management. • Improved comfort for drivers.
Component description	
Situation	<ul style="list-style-type: none"> • On a dual carriageway: one direction is closed. • On a two-way carriageway: the whole road is closed. • In both cases: a deviation is indicated near the closure. This component occurs when the final lane is closed. <p>The diagram below is an example of road (the main carriageway) closure just after an exit ramp.</p>

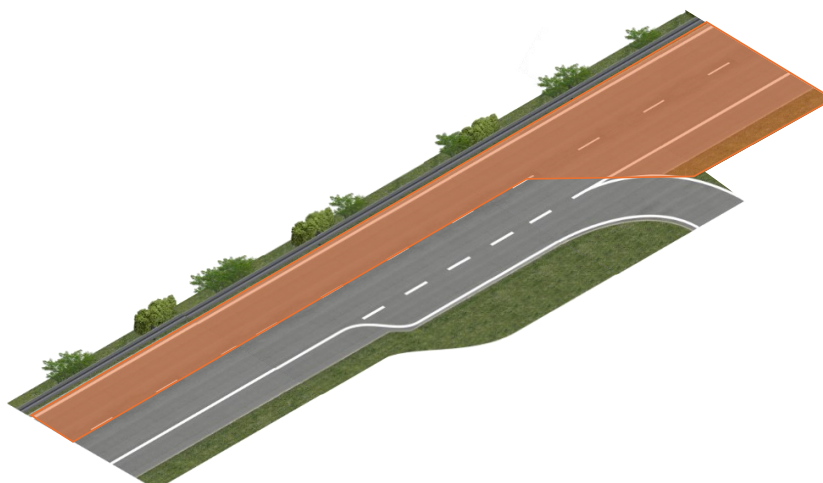


Figure 4:9 example of road (the *main* carriageway) closure just after an exit ramp.

Logic of transmission	I2V
Actors and relations	<ul style="list-style-type: none"> • Road operator: The road operator is the sender of the message and can be in contact with other road operators in order to implement a smart deviation route. • Drivers: The driver is the end-user of the service, who receives the information and adapts the driving behaviour, accordingly. • Service Provider: The distributor of the information. Can be the road operator.
Component scenario	<ul style="list-style-type: none"> • The road operator programs static and planned road works in its TMC. • This information contains all the elements that can be used to precisely describe the work site (start/end position of the closure, duration) and potential alternative routes (may be different by type of driver or destination). • The message is then disseminated to drivers approaching the road closure, so that they can adapt their route. • The information is received in the vehicle and presented to the driver.
Intended Presentation/Alert principle	<ul style="list-style-type: none"> • Minor alert in the case of an early warning; a more intrusive alarm in case of a warning shortly before the road closure. • The presentation of alternate routes should be considered. • The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Functional constraints / dependencies	<ul style="list-style-type: none"> • Access to information about the event including event lifecycle information. • How the information is presented to the drivers is not part of the service description. The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.

<p>Link to other C-Roads use cases and components</p>	<p>C-Roads Use Cases</p> <ul style="list-style-type: none"> • RWW: There can be mobile roadwork vehicles in or close to the work zone. • ESVN-ERVI: There can be a road operator vehicle in the road works zone. • IVS-FT: a VMS can be in or close to the work zone providing information related to the road work. • IVS-TS: a respective traffic sign is usually set up upstream of the road closure <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> • Narrow lanes • Single Lane Closure: This component can be applied multiple times consecutively in case multiple lanes are closed stepwise. • Exit inside RW • Work site entry and exit
<p>Interoperability requirements</p>	
<p>Communication technology requirements: IP based</p>	<p>For IP based implementations of use cases shared using backend communication, the requirements of [C-ITS IP Based Interface Profile] shall apply.</p> <p>For use cases based on DENM messages the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = RWW – RC • messageType = DENM <p>Geographic area (Quadtree) for DENM message:</p> <p>The event is characterized by its eventPosition, detectionZonesToEventPosition, detectionZonesToSpecifiedEventPoint, eventZone and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = IVS-TS • messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>
<p>Test and validation requirements</p>	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C Roads_TVC] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>

4.8.4.2 Technical assessment on messages to be used

4.8.4.2.1 Messages overview

From the driver's perspective relevant information:

- Announcement of the closure of carriageway
- Information about where the closure is
- Information about the exact position, where the road is closed

Since the road closure is a dangerous situation, a dedicated DENM is necessary. In addition, an IVIM and/or MAPEM is needed to convey the road topology information associated with this component. This component is usually at the end of a list of lane closures. The road closure needs to be announced early on, so the drivers can prepare and move towards the exit safely.

In the event of a road closure, if a road with multiple lanes is closed, lanes are closed in stages consecutively, until all lanes are closed. For each lane closure a separate DENM must be sent out as defined in the chapters above. If the last lane is being closed and the traffic is deviated, a different DENM has to be sent out. The following chapters elaborate the usage of the messages specifically for the closure of the last lane and therefore the carriageway.

4.8.4.2.2 Road closed in direction of travel component warning DENM Requirements

DE/DF	<i>DENM.denm.management.awarenessDistance</i>
O/M/C/F	<i>Forbidden</i>
ID	<i>SUD_Req_0036 (1)</i>
Requirement	The DE awarenessDistance shall not be used for the road closure component. Note: For other components, the requirement might be different.

DE/DF	<i>DENM.denm.situation.eventType</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0037 (1)</i>
Requirement	The eventType shall be set to causeCode roadworks3, subCauseCode 1 (majorRoadworks). Note: A renaming of the sCC to "roadClosure" is currently in discussion and will be proposed to ETSI.

DE/DF	<i>DENM.denm.situation.eventZone</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Opt_0038 (1)</i>
Option	<p>eventZone may be provided for the closed part of the road.</p> <p>Note: Currently an approach for specifying the length of the event along the road in meters is developed. The current datatype of the DE eventEnd in the SituationContainer is restricted to 8.189 km, which is not sufficient for work zones. As soon as the new approach is available, it will be integrated into the message profiles for RWW.</p>

DE/DF	<i>DENM.denm.situation.linkedDenms</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Rec_0039 (1)</i>
Recommendation	If multiple DENMs are sent out for the same work zone, linkedDenms should be used to link the component specific DENMs.

DE/DF	<i>DENM.denm.alacarte.roadWorks.closedLanes</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Rec_0040 (1)</i>
Recommendation	<p>This DF should be used with all lanes set to closed for the road closure component. NOTE: For other components, the requirement might be different.</p> <p>NOTE: The lanes are counted from inside border of the road excluding the hard shoulder.</p>

DE/DF	<i>DENM.denm.alacarte.roadWorks.trafficFlowRule</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Opt_0041 (1)</i>
Option	<p>This DF may be used for the road closure component using one of the values passToRight (2), passToLeft (3).</p> <p>Note: For other components, the requirement might be different.</p> <p>Note: The trafficFlowRule value accurately reflects the permitted traffic behavior and needs to be consistent with the physical road topology and traffic layout at the location to which it applies.</p>

4.8.4.2.3 Road closed in direction of travel component IVIM Requirements

The IVIM requirements for this component are based on the component independent IVIM requirements (see 4.6.4.2), which are not repeated unless further profiling is required, or it is necessary for clarity.

The identification of the segments is as described in section 4.6.4.1 as well as the example for the single lane closure component (see chapter 4.8.3). The methodology for the specification of the RCC parts is also shown

in the example for the single lane closure component. For the road closure component, with the difference, that the last instance of RccPart indicates all available lanes with status "closed".

4.8.5 Carriageway crossover

4.8.5.1 Component Introduction

Type of road network	All roads with physical separation
Type of vehicle (receiver) (sender for PVD)	All vehicles (as receiver)
Component introduction	
Summary	Due to the presence of a static/temporary road works site, one or more lanes of the two carriageways is/are closed to traffic and vehicles of one or more lanes are redirected from the original to the opposite carriageway, where possibly a reduction of the number of available lanes or their width is applied.
Background	In the presence of the road works site, the lane configuration is modified so the driver needs to change his usual behaviour due to a (from the driver's viewpoint unexpected) modification with a potential risk of causing an accident.
Objective	The objective is the safe passage of the carriageway crossover by allowing the driver to anticipate the carriageway crossover due to the road work site and adapt its behaviour, i.e., properly change speed and move to the dedicated lane on the opposite carriageway.
Desired behaviour	<ul style="list-style-type: none"> • Increased vigilance. • Speed adaption.
Expected benefits	<ul style="list-style-type: none"> • Reduction of the risk of accidents (for drivers and road agents) • better traffic flow
Component description	
Situation	Some or all lanes of the carriageway are closed to traffic, and traffic partially or totally redirected in the opposite carriageway. For the opposite carriageway, a lane closure or at least narrow lanes occur, which need to be communicated as described in the components "lane closure" and "narrow lanes". The respective messages shall be send for the opposite carriageway. Type of barriers: Permanent barriers; beacons (only with heavy speed reduction)

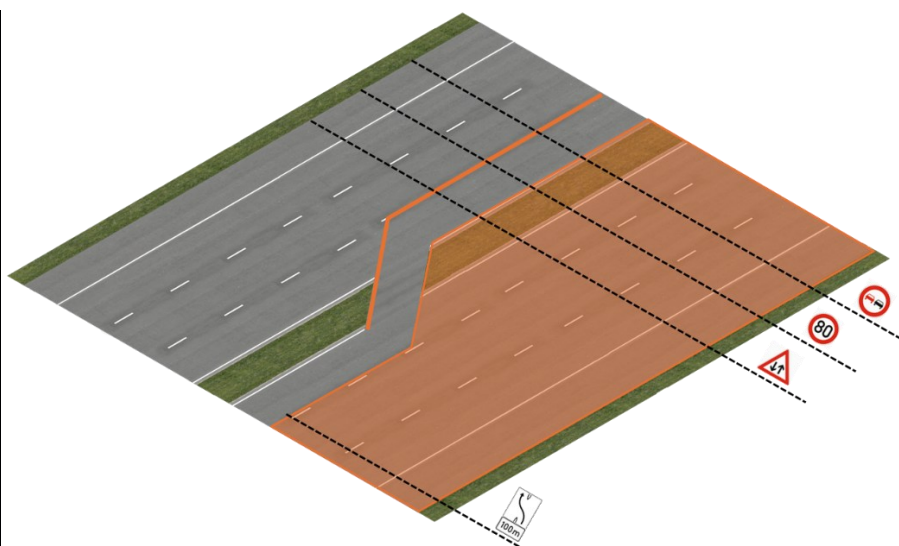


Figure 4:10 Example *Carriageway crossover*

Logic of transmission	I2V logic broadcast
Actors and relations	<ul style="list-style-type: none"> • Road operator: The road operator can be the sender of the messages. • Service provider: The distributor of the information. Can be the road operator or a third party service provider. • Drivers: The driver is the end-user of the service. He receives the information and adapts its behaviour.
Component scenario	<p>I2V only:</p> <ul style="list-style-type: none"> • The road operator programs static and planned road works in its Traffic Management System (TMS). • This information contains all the elements that can be used to precisely describe the work site (start/end position of the carriageway crossover, duration) and the modified road configuration • The work zone is set up. • The message(s) is(are) then sent to the drivers approaching the carriageway crossover, so that users can adapt their behaviour. • The information is received in the vehicle and presented to the driver.
Intended Presentation/Alert principle	<ul style="list-style-type: none"> • An alert inside the vehicle is shown, with indication of the carriageway crossover (the respective traffic sign) and the details of the modified road configuration at that specific point. • The HMI display sequence is at the vehicle manufacturer's and/or service providers own responsibility.
Functional constraints / dependencies	<ul style="list-style-type: none"> • It must be assured that information generated via different messages/information networks can be linked by the receiver to the same road works event. • The validation process of transmitted information (quality) against the physical layout of a RWW site needs to be taken care of.

	<ul style="list-style-type: none"> How the information is presented to the drivers is not part of the service description. It is left to the provider of the in-vehicle information system with HMI how information is presented. Information might e.g., be translated to the preferred language of the driver.
Link to other C-Roads use cases and components	<p>C-Roads Use Cases</p> <ul style="list-style-type: none"> IVS – FT: a VMS can be used to inform the drivers about the presence of the Exit, or the exclusive use of the lane to Exit. IVS – TS: a respective traffic sign is usually set up upstream of the crossover <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> Narrow lanes Exit inside RW: in case of a crossover, the affected lane can pass an exit, which cannot be reached from the deviated lane Work site entry and exit
Interoperability requirements	
Security and data protection requirements	<i>NOTE: These will be available in a future release of the TF2 document.</i>
Communication technology requirements: IP based	<p>For IP based implementations of use cases shared using backend communication, the requirements of C-Roads, C-ITS IP Based Interface Profile [C-ITS IP Based Interface Profile] shall apply.</p> <p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> serviceType = IVS-TS messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>
Test and validation requirements	<p><i>The document “C-ITS Cross-Border Testing and Validation Concept” [C Roads_TV] contains the generic applicable framework and process for interoperability testing.</i></p> <p><i>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</i></p>

4.8.5.2 Technical assessment on messages to be used

4.8.5.2.1 Messages overview

From the driver's perspective relevant information:

- Announcement of the carriageway crossover
- Topology information on the carriageway crossover

From the driver's perspective the lane is just taking turns. So, if the driver behaves normally and follows the lane markings, no specific danger exists. Therefore, no dedicated DENM for the lane closure is needed. Note that this crossover lane component is part of a wider RW zone, and therefore, there will be DENM(s) indicating the danger of this work zone already prior to this component. Instead, an IVIM or MAPEM is needed to convey the road topology information. As there is and will be signage to inform the drivers of the deviation of carriageway/carriageway crossover, the IVIM covering the whole work zone is needed to convey the signage information anyhow and can also cover road topology information.

4.8.5.2.2 Carriage crossover component warning DENM Requirements

As stated above, in this work zone component no DENM is needed. However, if a change in standard occurs, which provides a separate CC/sCC combination for carriageway crossover, a separate DENM can be sent.

4.8.5.2.3 Carriage crossover component IVIM Requirements

The IVIM requirements for this component are based on the component independent IVIM requirements (see 4.6.4.2), which are not repeated unless further profiling is required, or it is necessary for clarity.

The identification of the segments is as described in section 4.6.4.1 as well as the example for the single lane closure component (see chapter 4.8.3).

DE/DF	<i>lviStructure.optional.rcc</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0043 (1)</i>
Requirement	The IVIM shall contain at least one instance of RCC based on the HD Topology profile.

DE/DF	<i>lviStructure.optional.glc.parts</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0044 (1)</i>
Requirement	The GLC parts shall specify the various segments of the lane starting from the position (middle of the lane) where the lane(s) starts to deviate from its/their normal course. Every change in topology (width, type of delimitation, lane markings ...) or accuracy of information about the topology or signage shall result in a new segment. Descriptions of road works segments leading to the deviating lane(s) may be described either as a set of lanes or as single lanes.

4.8.6 Exit inside RW

4.8.6.1 Component Introduction

Type of road network	Any interurban road that includes the concept of "exit," such as freeways and highways, where the exit is only accessible from one direction of traffic flow (dual-carriageway roads)
Type of vehicle (receiver) (sender for PVD)	All
Component introduction	
Summary	<p>The Road Works Warning – Exit inside a RW component informs the driver about the presence of an open exit inside a road works.</p> <p>This exit may be the only action that can be taken by the driver in that particular lane. There is always the possibility of driving through the work zone without exiting, whether it is in the same lane with the exit or another lane.</p>
Background	<p>When drivers inside a work zone intend to use an exit, they may become anxious if it is unclear whether or not that exit is reachable.</p> <p>When drivers expect to use a specific exit, they may become anxious if the exit cannot be reached from the lane they are in.</p>
Objective	<p>One objective is to inform drivers early enough about the presence of an Exit inside of road works ahead to give them the opportunity to adapt their speed and change lanes in time.</p> <p>Another objective is the safe passage to the exit by allowing the driver to anticipate the presence of the exit inside the work zone and adapt its behaviour, i.e., properly change speed and move to the dedicated lane, following the topology information.</p>
Desired behaviour	<p>Increased vigilance</p> <p>Speed adaption.</p> <p>Change of lanes (if needed).</p>
Expected benefits	<p>Reduced risk and number of accidents and dangerous situations for drivers and workers.</p> <p>Improved traffic management due to reduced traffic incidents on the road.</p>
Component description	
Situation	<p>Some of lanes of the carriageway are closed to traffic, and traffic may be partially or totally redirected.</p> <p>Inside the road works is an Exit.</p>

The topology is changed due to the work zone using cones, trailers, mobile barriers.

Scenario 1:

The exit can be reached inside the road works with or without switching lane(s), but the driver has the ability to drive through the work zone without having to exit.

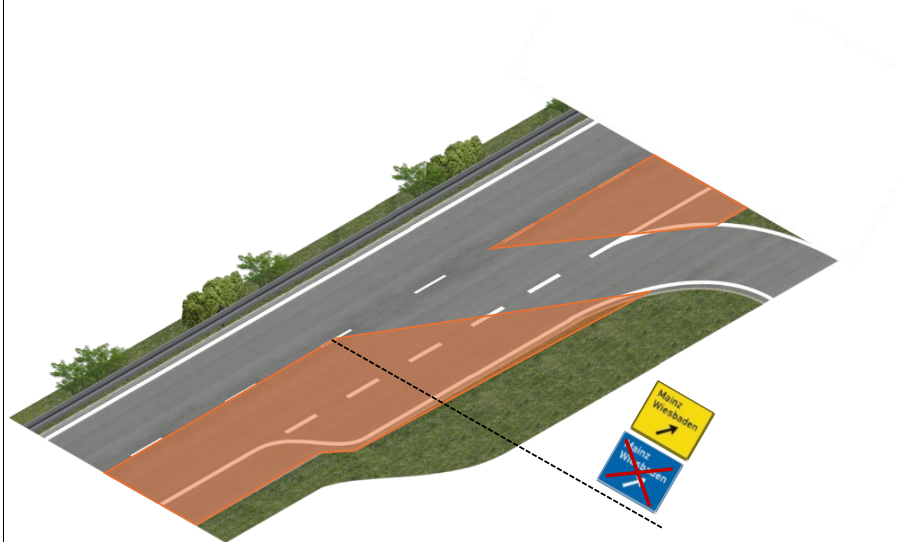


Figure 4:11 Example Scenario 1

Scenario 2:

The exit can be reached inside the road works with or without switching lane(s), but the driver must be in the exit lane in advance of the separation.

To drive through the road works the driver has to choose another lane in advance of the separation.

All navigation information needs to be provided in advance of the separation.

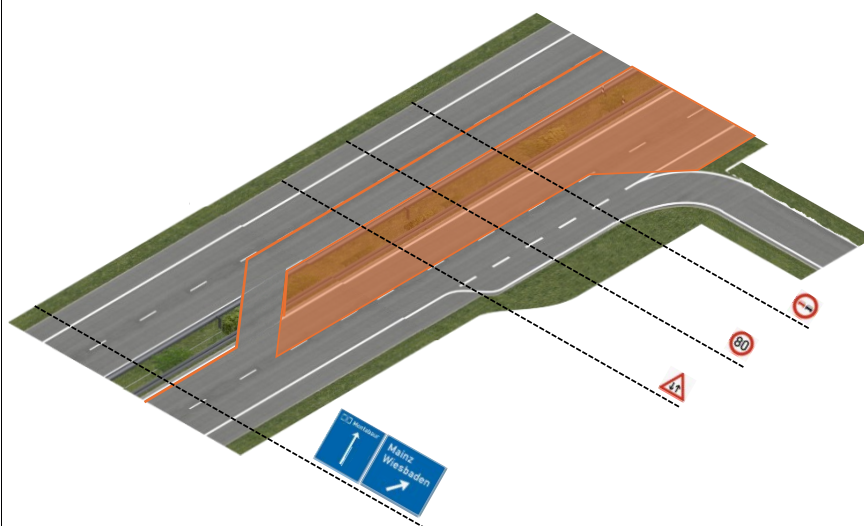


Figure 4:12 Example Scenario 2

Logic of transmission	I2V logic broadcast
Actors and relations	<ul style="list-style-type: none"> • Road operator: Is the origin of the information of the message. It can be the TCC, or a road operator vehicle if there is no connection to the central station ("stand-alone mode"). • Drivers: The drivers approaching the area are the end-user of this service (receives the information/message). • Service provider: The distributor of the information. Can be the road works planner of the road operator, a management system or the RSU on the trailer (in case of the "stand-alone mode").
Component scenario	<ul style="list-style-type: none"> • The road operator programs static and planned road works. • This information contains all the elements that can be used to precisely describe the work site (start/end position of the closure, duration) and potential alternative routes (may be different by type of driver or destination). • The message is then disseminated to approaching drivers so that they can adapt their route.
Intended Presentation/Alert principle	<ul style="list-style-type: none"> • Minor alert in the case of an early warning; a more intrusive alarm in case of a warning shortly before the Exit. • The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Functional constraints / dependencies	<ul style="list-style-type: none"> • Access to information about the event including event lifecycle information. • How the information is presented to the drivers is not part of the service description. The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.

Link to other C-Roads use cases and components	<p>C-Roads Use Cases</p> <ul style="list-style-type: none"> • RWW: There can be operating agents in the zone near the exit (or in the exit lane) • ESVN-ERVI: There can be a road operator vehicle in the road works near the exit (or in the exit lane) • IVS-FT: a VMS can be used to inform the drivers about the presence of the Exit, or the exclusive use of the lane to Exit. • IVS-TS: an Exit inside a road works is also indicated with traffic signs <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> • Narrow lanes • Carriageway crossover • Lane Closure • Entry inside RW (we can have both Entry/Exit inside a RW)
Interoperability requirements	
Security and data protection requirements	Note: These will be available in a future release of the TF2 document.
Communication technology requirements: IP based	<p>For IP based implementations of use cases shared using backend communication, the requirements of C-Roads, C-ITS IP Based Interface Profile [C-ITS IP Based Interface Profile] shall apply.</p> <p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = IVS-TS • messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>
Test and validation requirements	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C Roads_TV] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>

4.8.6.2 Technical assessment on messages to be used

4.8.6.2.1 Messages overview

From the driver's perspective relevant information:

- Announcement of the exit
- Topology information on how to reach the exit

In this work zone component, technically, there is no new event from the driver's perspective. Therefore, no dedicated DENM for exit inside road works is needed. Instead, an IVIM or MAPEM is needed to convey the road topology information. As there is and will be signage to inform the drivers of the exit inside road works, the IVIM covering the whole work zone is needed to convey the signage information anyhow and can also cover road topology information.

4.8.6.2.2 Exit inside RW component warning DENM Requirements

As stated above, in this work zone component no DENM is needed.

4.8.6.2.3 Exit inside RW component IVIM Requirements

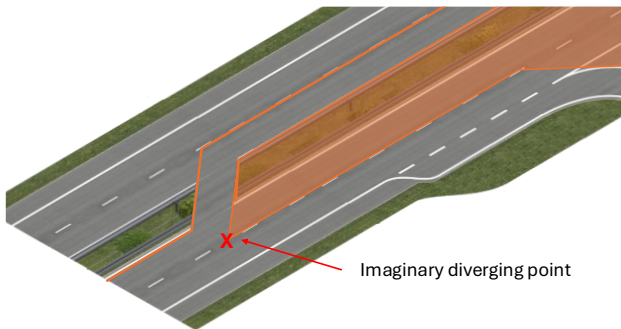
This profile is based on the generic IVIM Profile for RWW.

The identification of the segments is as described in section 4.6.4.1as well as the example for the single lane closure component (see chapter 4.8.3).

DE/DF	<i>IviStructure.optional.rcc</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0045 (1)</i>
Requirement	The IVIM shall contain as many instances of RCC and RccPart based on the HD Topology profile as different road configurations of the exit lane and remaining lane(s) exist throughout their topology. Topology changes can be changes in delimitation, lane width or lane markings as well as changes in the accuracy of the information provided

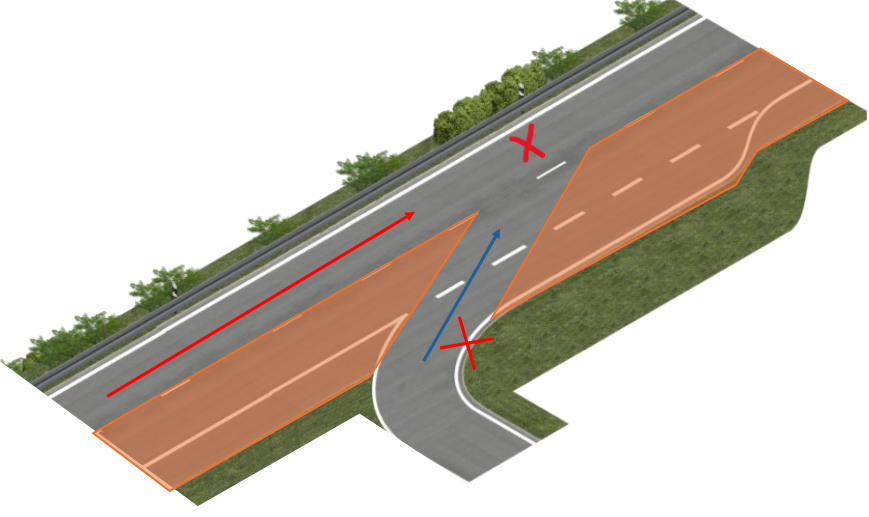
DE/DF	<i>IviStructure.optional.giv.detectionZoneIds</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0046 (1)</i>
Requirement	The IVIM shall contain a GlcPart with a lane-specific detection zone leading to the start of the exit lane.

DE/DF	<i>IviStructure.optional.giv.relevanceZoneIds</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0071 (1)</i>
Requirement	At least one relevance zone shall start at the start position of the exit lane.
ID	<i>SUD_Req_0047 (1)</i>
Requirement	The IVIM shall contain a GlcPart with a relevance zone covering the extension of the exit lane.

DE/DF	<i>IviStructure.optional.glc.parts</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0048 (1)</i>
Requirement	<p>The IVIM for the exit inside RW component shall contain a GLC that describes:</p> <ul style="list-style-type: none"> ○ A zone leading to the start of the exiting lane at the imaginary diverging point (if not provided by other GLCs). ○ The exiting lane starting at the imaginary diverging point on the (middle of the) outer-most open lane of the regular carriageway, divided in at least as many instances of GlcPart as different road configurations exist throughout its topology. The exit lane starts, where you cannot shift lanes anymore. ○ The remaining lane(s) starting at the imaginary diverging point, divided in at least as many instances of GlcPart as different road configurations exist throughout its topology. ○ All zones pertaining to traffic signs. ○ A <i>road configuration</i> is defined as a specific arrangement of lanes in terms of: their number and positioning, their status (open, closing, closed), and their functional characteristics (e.g., lane type, width, or dedicated usage such as for emergency or heavy vehicles).  <p style="text-align: center;">Figure 4:13 Example</p>

4.8.7 Entry inside RW

4.8.7.1 Component Introduction

Type of road network	Any interurban road that includes the concept of "entry," such as freeways and highways, not necessarily with separate carriageway (dual-carriageway roads)
Type of vehicle (receiver) (sender for PVD)	All
Component introduction	
Summary	The Road Works Warning – Entry inside a RW component informs the drivers joining the carriageway through the entry that they are entering a work zone. The traffic stream that enters the road shall receive information about the RW ahead.
Background	The traffic on the carriageway is already inside the work zone. The joining traffic is entering a work zone and needs to be informed about it.
Objective	The joining traffic needs to be warned about the work zone so the vehicles can navigate safely through the work zone
Desired behaviour	The driver is vigilant and prepared for changed topology and additional signs as well as potentially dirty roads and secondary lane markings.
Expected benefits	Less accidents and congestion inside the work zone
Component description	
Situation	<p>The on-ramp can end in a shortened or no acceleration lane. Additionally, the traffic can end not on the outer most lane but on another lane.</p>  <p>Figure 4:14 Example</p>

	The topology is changed using cones, trailers, mobile barriers etc.
Logic of transmission	I2V
Actors and relations	<ul style="list-style-type: none"> • Road operator: Is the origin of the information of the message. It can be the TCC, or a road operator vehicle if there is no connection to the central station (“stand-alone mode”). • Drivers: The drivers approaching the area are the end-user of this service (receives the information/message). • Service provider: The distributor of the information. Can be the road works planner of the road operator, a management system or the RSU on the trailer (in case of the “stand-alone mode”).
Component scenario	<ul style="list-style-type: none"> • The road operator programs static and planned road works. • This information contains all the elements that can be used to precisely describe the work site (position of the entry) • The message is then disseminated to approaching drivers so that they can adapt their behaviour.
Intended Presentation/Alert principle	<ul style="list-style-type: none"> • The user is presented with the information on the situation when he enters the road. • The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Functional constraints / dependencies	How the information is presented to the drivers is not part of the service description. The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Link to other C-Roads use cases and components	<p>C-Roads Use Cases</p> <ul style="list-style-type: none"> • RWW: There can be mobile roadwork vehicles in or close to the work zone. • ESVN-ERVI: There can be a road operator vehicle in the road works zone. • IVS-FT: a VMS can be in or close to the work zone providing information related to the road work. • IVS-TS: a respective traffic sign is usually set up upstream of the road works entry. <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> • Narrow lanes • Single Lane Closure: some lanes can be closed when the vehicles leave the ingress lane
Interoperability requirements	
Security and data protection requirements	<i>NOTE: These will be available in a future release of the TF2 document.</i>

Communication technology requirements: IP based	<p>For IP based implementations of use cases shared using backend communication, the requirements of C-Roads, C-ITS IP Based Interface Profile [C-ITS IP Based Interface Profile] shall apply.</p> <p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = IVS-TS • messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>
Test and validation requirements	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C Roads_TVC] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>

4.8.7.2 Technical assessment on messages to be used

4.8.7.2.1 Messages overview

From the perspective of driver(s) already on the highway, relevant information:

- Topology information about the location of the entry

The traffic already on the highway (see red arrow in the example above) is already informed about the work zone. Merging traffic from the entry is therefore no reason for a warning. The topology information was already communicated within the IVIM/MAPEM.

From the perspective of driver(s) entering the highway within the work zone, relevant information:

- Warning about the work zone
- Topology information

The entering traffic (see blue arrow in the example above) needs to be warned via a DENM about the work zone and the changed topology via IVIM or MAPEM. Since the situation from the driver’s viewpoint is different to a lane closure, a generic warning is required.

4.8.7.2.2 Entry inside RW component warning DENM Requirements

ID	<i>SUD_Req_0069 (1)</i>
Requirement	In case no other component DENM already covers the entry, a new generic warning DENM with eventPosition on merging point of the entry lane and detectionZone only on the entry lane and roads leading to the entry shall be disseminated.

ID	<i>SUD_Opt_0070 (1)</i>
Option	In case another DENM component already covers the entry, an instance of detectionZonesToSpecifiedEventPoint may be added to that DENM, creating an additional detection zone covering the entry lane leading into the roadworks event zone

DE/DF	<i>DENM.denm.situation.eventZone</i>
O/M/C/F	<i>Optional</i>
ID	<i>SUD_Req_0051 (1)</i>
Requirement	In case an eventZone already covers the entry and it is intended to use detectionZonesToSpecifiedEventPoint, then one event point of the eventZone shall be located at the location, where the entry lane merges with the outer most driving lane.

4.8.7.2.3 Entry inside RW component IVIM Requirements

The IVIM requirements for this component are based on the component independent IVIM requirements (see 4.6.4.2), which are not repeated unless further profiling is required, or it is necessary for clarity.

The identification of the segments is as described in section 4.6.4.1as well as the example for the single lane closure component (see chapter 4.8.3).

DE/DF	<i>IviStructure.optional.rcc</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0052 (1)</i>
Requirement	The IVIM shall contain at least one instance of RCC based on the HD Topology profile, which specifies as many RCC parts as different road configurations of the entering lane exists throughout its topology, e.g. changes in delimitation, lane width or lane markings and also changes in the accuracy of the information provided. Each part shall only describe one individual segment of the entering lane.

DE/DF	<i>IviStructure.optional.giv.relevanceZoneIds</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0071 (1)</i>
Requirement	At least one relevance zone shall start at the end position of the entering lane.
ID	<i>SUD_Req_0053 (1)</i>
Requirement	The relevance zone for one RCC part shall be identified as one GLC part corresponding to the road configuration described in that part.

DE/DF	<i>IviStructure.optional.glc.parts</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0072 (1)</i>
Requirement	<ul style="list-style-type: none"> The IVIM for the entry inside RW component shall contain a GlcPart that starts at the end position of the entering lane, i.e. the first deltaPosition is located at the end of the entering lane. Note: A corresponding GlcPart starting at the end of the entering lane is implied by the presence of a relevanceZone in the GIC (REQ 71). No separate enforcement is necessary.
ID	<i>SUD_Req_0054 (1)</i>
Requirement	<ul style="list-style-type: none"> The IVIM for the entry inside RW component shall contain a GLC that describes the entering lane ending at the middle of the right-most open lane of the regular carriageway, divided in at least as many different GLC parts as different road configurations are given throughout its topology.

4.8.8 Closed exit

4.8.8.1 Component Introduction

Type of road network	All
Type of vehicle (receiver)	All
Component introduction	
Summary	The Road Works Warning – Closed Exit component informs the driver about a temporary exit closure due to road works. The component describes a simple form of road closure where the exit lane is closed.
Background	When drivers inside a work zone intend to use an exit, they may become anxious if it is unclear whether or not that exit is reachable. Providing advance information about the closure and an alternative exit will provide the driver with the information they need to safely navigate the changed road environment. There is an added value in this component if the information is accurately linked with re-routing information.
Objective	Give drivers advanced notification of a closed exit and provide them the information they need to plan an alternative route, avoiding higher risk manoeuvres.
Desired behaviour	Appropriate route change.
Expected benefits	<ul style="list-style-type: none"> Increased road safety (avoid dangerous behaviour, e.g., harsh braking, speeding, U-turns). Improved traffic flow.
Component description	
Situation	The exit lane is temporarily closed e.g. by trailer, cones, steel barrier.

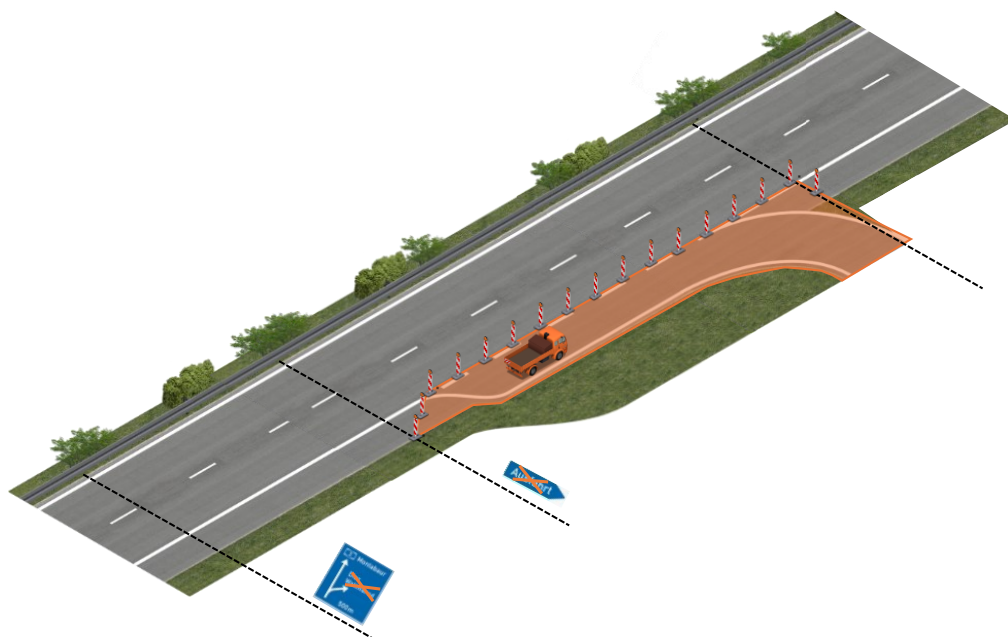


Figure 4:15 Example temporarily closed exit lane

Logic of transmission	I2V.
Actors and relations	<ul style="list-style-type: none"> • Road operator: The road operator is the sender of the message, and can be in contact with other road operators in order to implement a smart deviation route. • Drivers: The drivers are the end-users of the service (receiver of the road closure information). • Service Provider: Can be the road operator.
Component scenario	<ul style="list-style-type: none"> • The road operator programs static and planned road works. • This information contains all the elements that can be used to precisely describe the work site (start/end position of the closure, duration) and potential alternative routes (may be different by type of driver or destination). • The message is then disseminated to drivers approaching the exit closure, so that they can adapt their route. Driver information may include alternate exits before and after the closed exit.
Intended Presentation/Alert principle	<ul style="list-style-type: none"> • Minor alert prior to the exit and shortly before the exit closure. • The presentation of alternate routes should be considered. • The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Functional constraints / dependencies	<ul style="list-style-type: none"> • Access to information about the event including event lifecycle information. • Provision of alternate routing information dependent on knowledge of destination.

	<ul style="list-style-type: none"> How the information is presented to the drivers is not part of the service description. The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Link to other C-Roads use cases and components	<p>C-Roads Use Cases</p> <ul style="list-style-type: none"> RWW: There can be mobile roadwork vehicles in or close to the work zone. ESVN-ERVI: There can be a road operator vehicle in the road works zone. IVS-FT: a VMS can be in or close to the work zone providing information related to the road work. IVS-TS: a respective traffic sign is usually set up upstream of the closed exit. <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> Narrow lanes Carriageway crossover Single Lane Closure: This component can be applied multiple times consecutively in case multiple lanes are closed stepwise.
Interoperability requirements	
Security and data protection requirements	<i>NOTE: These will be available in a future release of the TF2 document.</i>
Communication technology requirements: IP based	<p>For IP based implementations of use cases shared using backend communication, the requirements of C-Roads, C-ITS IP Based Interface Profile [C-ITS IP Based Interface Profile] shall apply.</p> <p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> serviceType = IVS-TS messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>
Test and validation requirements	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C Roads_TVC] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>

4.8.8.2 Technical assessment on messages to be used

4.8.8.2.1 Messages overview

From the perspective of the entering driver relevant information:

- Warning about the work zone
- Topology information

In this work zone component technically, there is no new event from the driver's perspective. Therefore, no DENM for closed exit is needed. Instead, a IVIM or MAPEM is needed to convey the road topology information. As there is and will be signage to inform the drivers of the closed exit, the IVIM covering the whole work zone is needed to convey the signage information. Additionally, the IVIM shall also cover the road topology information.

4.8.8.2.2 Closed exit component warning DENM Requirements

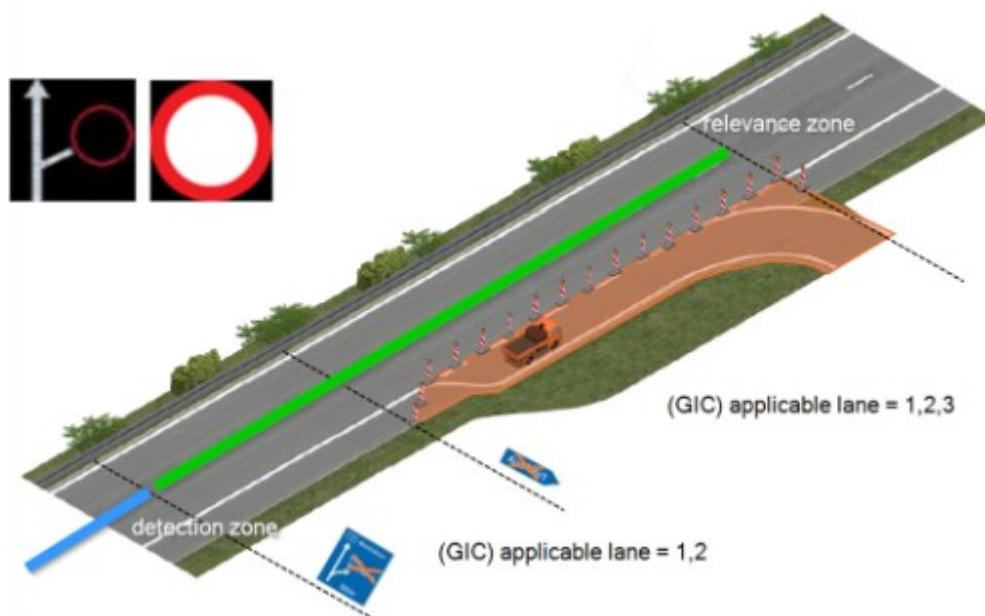
As stated above, in this work zone component no DENM is needed.

4.8.8.2.3 Closed exit component IVIM Requirements

The IVIM requirements for this component are based on the component independent IVIM requirements (see 4.6.4.2), which are not repeated unless further profiling is required, or it is necessary for clarity.

The identification of the segments is as described in section 4.6.4.1 as well as the example for the single lane closure component (see chapter 4.8.3).

DE/DF	<i>IviStructure.optional.giv.relevanceZoneIds</i>
O/M/C/F	<i>Mandatory</i>
ID	<i>SUD_Req_0057 (1)</i>
Requirement	The IVIM shall contain a GlcPart with a relevance zone starting at the location of the sign indicating the close of the exit and ending right after the exit.

DE/DF	<i>lviStructure.optional.gic.roadSignCodes</i>										
O/M/C/F	<i>Mandatory</i>										
ID	<i>SUD_Req_0058 (1)</i>										
Requirement	<p>The roadSignCodes shall be encoded in one of two ways:</p> <ol style="list-style-type: none"> Composite sign: <p>Using as main sign:</p> <table border="1"> <tr> <td>Notice of diagrammatic sign of the traffic restrictions/warning at the next exit</td><td>13</td><td>692</td></tr> <tr> <td>Notice of diagrammatic sign of the traffic conditions at exit after the next one</td><td>13</td><td>694</td></tr> </table> <p>Using as sub-sign:</p> <table border="1"> <tr> <td>Notice that all vehicles are forbidden to pass through the designated section of the road</td><td>12</td><td>415</td></tr> </table> <div data-bbox="371 909 1361 1523" data-label="Image">  </div> <p>Figure 4:16 Example Composite sign</p>		Notice of diagrammatic sign of the traffic restrictions/warning at the next exit	13	692	Notice of diagrammatic sign of the traffic conditions at exit after the next one	13	694	Notice that all vehicles are forbidden to pass through the designated section of the road	12	415
Notice of diagrammatic sign of the traffic restrictions/warning at the next exit	13	692									
Notice of diagrammatic sign of the traffic conditions at exit after the next one	13	694									
Notice that all vehicles are forbidden to pass through the designated section of the road	12	415									

2. Using 12 415 for the specified relevance zone

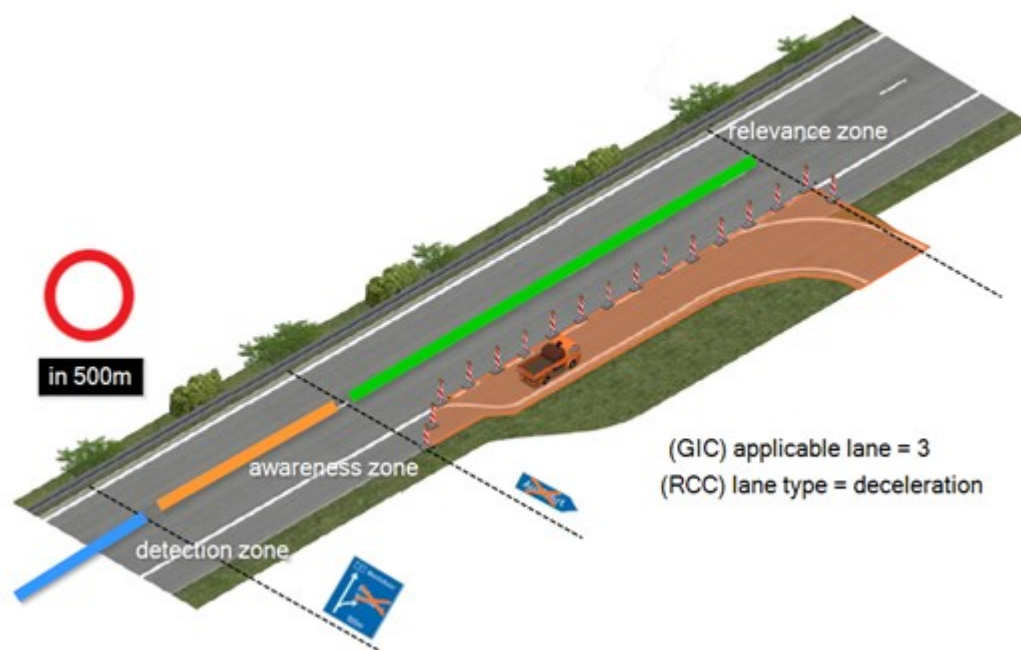
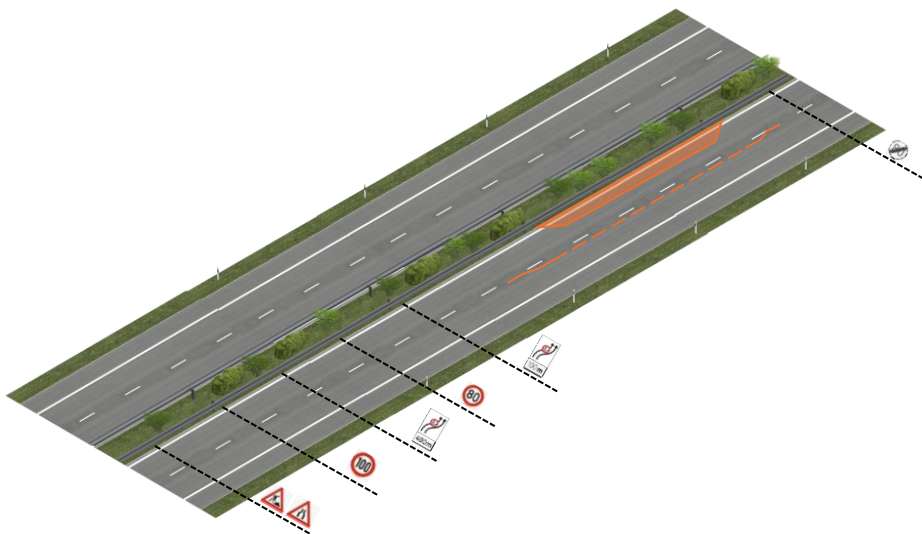


Figure 4:17 Using 12 415 for the specified relevance zone

4.8.9 Narrow lanes

4.8.9.1 Component Introduction

Type of road network	All
Type of vehicle (receiver) (sender for PVD)	All
Component introduction	
Summary	The component Narrow lanes describe a narrowing of at least one lane of the carriageway and thus a modification of at least one lane within the original lane or beyond its own lane.
Background	Used to save space on one or multiple lanes for road works to retain as many lanes as possible and minimise traffic disruptions.
Objective	Provide drivers advanced notification of narrowed lanes due to road works so the drivers can switch to an appropriate lane and navigate safely through the work zone.
Desired behaviour	<ul style="list-style-type: none"> Increased vigilance. Speed adaption.

	Possible rerouting of large vehicles
Expected benefits	<ul style="list-style-type: none"> Reducing the risk and number of accidents and dangerous situations for drivers and workers. Informing the drivers about a risk of discomfort on the road (slowing down, manoeuvring). Provision for transit of large vehicles
Component description	
Situation	<p>A road works site is present on the road, with a consequent of at least one narrow lane on the road.</p> <p>For this purpose, the actual lane marking is replaced by a temporary lane marking. The temporary lane marking can consist of different forms and be of different types of marking. Additionally, the lanes are limited by cones or mobile barriers.</p> <p>The incoming drivers on the impacted road are informed in time that a narrowing of at least one lane is present and adapt their speed and behaviour to follow the modified road configuration (e.g. change driving lane).</p>  <p><i>Figure 4:18 Example Narrow lanes</i></p>
Logic of transmission	I2V
Actors and relations	<ul style="list-style-type: none"> Road operator: Is the origin of the information of the message. It can be the TCC, or a road operator vehicle if there is no connection to the central station ("stand-alone mode"). Drivers: The drivers approaching the area are the end-user of this service (receives the information/message). Service provider: The distributor of the information. Can be the road works planner of the road operator, a management system or the RSU on the trailer (in case of the "stand-alone mode").
Component scenario	<ul style="list-style-type: none"> The road operator programs static and planned road works.

	<ul style="list-style-type: none"> • This information contains all the elements that can be used to precisely describe the work site (start/end position of the closure, duration) and potential alternative routes for large vehicles. • The message is then disseminated to approaching drivers so that they can adapt their driving behaviour and route.
Intended Presentation/Alert principle	<ul style="list-style-type: none"> • When drivers arrive near the work zone site, they receive information that allows them to adjust their behaviour. • Drivers of large vehicles are notified of a potential rerouting. • The information needs to be presented on the HMI early enough and should be moderately intrusive (at the manufacturer's decision). • The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Functional constraints / dependencies	<ul style="list-style-type: none"> • Access to information about the event including event lifecycle information. • How the information is presented to the drivers is not part of the service description. The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.
Link to other C-Roads use cases and components	<p>C-Roads Use Cases</p> <ul style="list-style-type: none"> • RWW: There can be mobile roadwork vehicles in or close to the work zone. • ESVN-ERVI: There can be a road operator vehicle in the road works zone. • IVS-FT: a VMS can be in or close to the work zone providing information related to the road work • IVS-TS: a respective traffic sign is usually set up upstream of the narrowed lanes. <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> • Carriageway crossover • Single Lane Closure: This component can be applied multiple times consecutively in case multiple lanes are closed stepwise. • Road Closed in direction of travel: The lane closure can lead to a road closure in case the last lane is closed • Entry inside RW • Exit inside RW • Work site entry and exit
Interoperability requirements	
Security and data protection requirements	<i>NOTE: These will be available in a future release of the TF2 document.</i>
Communication technology requirements: IP based	For IP based implementations of use cases shared using backend communication, the requirements of C-Roads, C-ITS IP Based Interface Profile [C-ITS IP Based Interface Profile] shall apply.

	<p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = IVS-TS • messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication men-tioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>
Test and validation requirements	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C Roads_TV] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>

4.8.9.2 Technical assessment on messages to be used

4.8.9.2.1 Messages overview

From the perspective of the entering driver relevant information:

- Warning about the work zone
- Topology information

In this work zone component technically, there is no new event from the driver’s perspective. Therefore, no DENM for narrow lanes is needed. Instead, a IVIM or MAPEM is needed to convey the road topology information. As there is and will be signage to inform the drivers of the lane narrowing, the IVIM covering the whole work zone is needed to convey the signage information. Additionally, the IVIM shall also cover the road topology information.

4.8.9.2.2 Narrow lanes component warning DENM Requirements

As stated above, in this work zone component no DENM is needed.

4.8.9.2.3 Narrow lanes component IVIM Requirements

The IVIM requirements for this component are based on the component independent IVIM requirements (see 4.6.4.2), which are not repeated unless further profiling is required, or it is necessary for clarity. Since there are no specific IVIM requirements for this component other than those specified for the component independent IVIM, no requirement is provided for this component.

The identification of the segments is as described in section 4.6.4.1 as well as the example for the single lane closure component (see chapter 4.8.3).

4.8.10 Work site entry and exit

4.8.10.1 Component Introduction

Type of road network	dual-carriageway roads
Type of vehicle (receiver) (sender for PVD)	All
Component introduction	
Summary	Informing vehicles inside a work zone about work site entry and exit, which are used by the construction vehicles to enter and exit the work site of a work zone.
Background	Work site entries and exits pose a threat to the traffic since the construction vehicles can carry dirt on the road and cause accidents when the slow vehicles leave the work zone or when the construction vehicles slow down to enter the work zone.
Objective	Avoid accidents
Desired behaviour	Attentive driving
Expected benefits	Reduction of the risk of accidents (for drivers and road agents)
Component description	
Situation	Work zones may provide dedicated work site entries and exits for construction vehicles. These vehicles need to slow down before entering the work site. When leaving the work site, they will most likely be slower than the traffic on the road.
Logic of transmission	I2V
Actors and relations	<ul style="list-style-type: none"> • Road operator: The road operator can be the sender of the messages. • Service provider: Alternatively, the service provider, which is doing the road work, can be the sender of the messages. • Drivers: The driver is the end-user of the service, who receives the information and adapts the driving behaviour, accordingly.
Component scenario	
Intended Presentation/Alert principle	The driver can be warned about an upcoming work site entry or exit ahead.
Functional constraints / dependencies	How the information is presented to the drivers is not part of the service description. The HMI presentation sequence is at the vehicle manufacturer's and/or service provider's own responsibility.

Link to other C-Roads use cases and components	<p>C-Roads Use Cases:</p> <ul style="list-style-type: none"> • RWW: There can be mobile roadwork vehicles in or close to the work zone. • ESVN-ERVI: There can be a road operator vehicle in the road works zone. • IVS-FT: a VMS can be in or close to the work zone providing information related to the road work • IVS-TS: a respective traffic sign is usually set up upstream of work site entry and exit. <p>RWW Components: (It depends on the topology of the RW and the road)</p> <ul style="list-style-type: none"> • Narrow lanes • Lane Closure
Interoperability requirements	
Security and data protection requirements	<i>NOTE: These will be available in a future release of the TF2 document.</i>
Communication technology requirements: IP based	<p>For IP based implementations of use cases shared using backend communication, the requirements of [C-ITS IP Based Interface Profile] shall apply.</p> <p>For use cases based on IVIM the AMQP filtering tables specified in chapter 3.3 of [C-ITS IP Based Interface Profile] shall apply:</p> <ul style="list-style-type: none"> • serviceType = IVS-TS • messageType = IVIM <p>Geographic area (Quadtree) for IVIM:</p> <p>The event is characterised by its referencePosition, detectionZone(s), relevanceZone(s) and DestinationArea. These fields draw a geographic area and C-ITS actors shall publish in a set of tiles corresponding to the maximum set of tiles containing all the geographic indication mentioned.</p> <p>Please be aware that the exact details of specification are defined in chapter 3.3 of [C-ITS IP Based Interface Profile].</p>
Test and validation requirements	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C Roads_TV] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>

4.8.10.2 *Technical assessment on messages to be used*

4.8.10.2.1 *Messages overview*

From the perspective of the entering driver relevant information:

- Information about the position of the work site entry/exit
- Warn about the possibility of suddenly breaking vehicles (entry) or entering vehicles from the work site

For this component, there might be the situation of vehicles slowing down, if a road works vehicle enters or exits a work site. However, since this danger is always not present, no DENM shall be sent specific to this component. As there is and will be signage to inform the drivers of the work site entry and exit, the IVIM covering the whole work zone is needed to convey the signage information. Additionally, the IVIM or MAPEN shall also cover the road topology information.

4.8.10.2.2 *Work site entry and exit warning DENM requirements*

As stated above, in this work zone component no DENM is needed.

4.8.10.2.3 *Work site entry and exit IVIM requirements*

The IVIM requirements for this component are based on the component independent IVIM requirements (see 4.6.4.2), which are not repeated unless further profiling is required, or it is necessary for clarity.

The identification of the segments is as described in section 4.6.4.1 as well as the example for the single lane closure component (see chapter 4.8.3).

4.9 Assembling a work zone composed of multiple components

To depict a work zone and cover all its aspects in C-ITS messages, it may be necessary to combine multiple components. As every component defines an element or cut out of a work zone, it is important to be able to combine the components in every possible order. Therefore, it is essential to precisely define segments of the work zone to be able to convey all the necessary information to drivers.

Step 1: identify the components

Step 2: check if a generic warning DENM is necessary. If yes, prepare the generic DENM.

Step 3: check which components require a dedicated DENM warning

Step 4: prepare the DENMs

Step 5: define the zones of the IVIM

- a) Since the work zone situation doesn't begin where the road works are conducted, the beginning of the work zone shall be the position of the first road works warning sign which indicates the start zone ('approach' to the road work according to the definition of terminology in chapter 4.2). The zone for the approach to the work zone shall include warning signs and speed reduction signs and ends with the first component of the work zone in the work area.
- b) Define relevance zones to be able to provide signage and topology information within one IVIM. One relevance zone shall cover the part of the work zone until either the next relevance zone begins, or the maximum validity of the road sign is reached. Therefore, relevance zones shall begin with each new road sign, with every topology change (with or without new road sign), and when the validity of a road sign is reached.
- c) Note: Section 4.6.4 describes the situation that additional segments must be specify in order to split up the work zone into multiple IVIMs in case covering the information of the complete work zone exceeds the MTU of a single IVIM.

Step 6: prepare the IVIM(s). If additional IVIMs are necessary due to a large geographical extent that cannot be covered by one IVIM these shall be linked (via connectedIviStructures).

Step7: Link the IVIM with the DENMs (via connectedDenms).

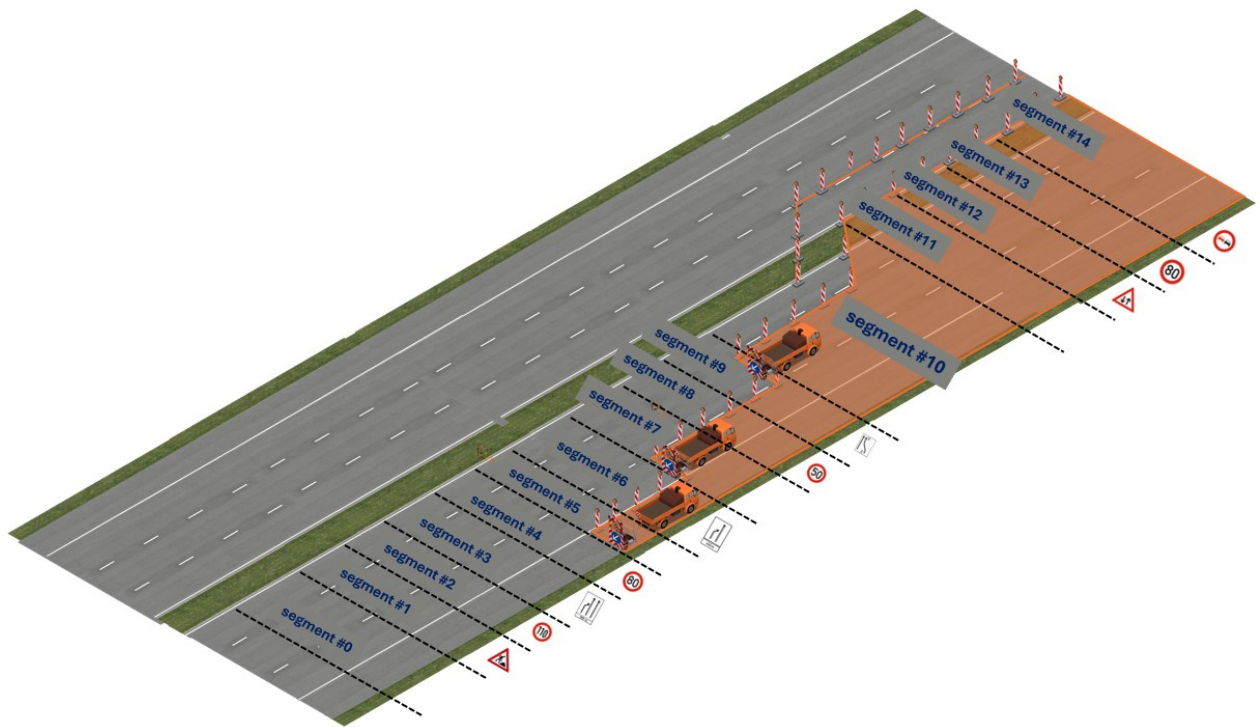


Figure 4:19 Example of a segmented work zone