Harmonising European ITS Services

Traffic Management Services
DYNAMIC LANE MANAGEMENT

Deployment Guideline

TMS-DG01 | VERSION 02-02-00 | DECEMBER 2015

The Deployment Guidelines have been developed in EasyWay, EIP and EIP+
Co-financed by the European Union
Trans-European Transport Network (TEN-T)

Support

Further information	dg.its-platform.eu	**Questions/help**	dg.its-platform.eu/user-support

Preface (2016)

After the EasyWay project ended in 2012, the Deployment Guidelines have been updated by the EIP / EIP+ projects. They focussed on updating Best Practice and did neither have the capacity nor the intention for a full revision of the text, since especially the Member State adoption of the guidelines' requirements form a huge asset of European harmonisation. In the light of recent European Delegated Regulations, the EU EIP platform will now consider a full revision of the format and the content of the whole set of Deployment Guidelines.

Preamble (2012)

EasyWay is a cooperation of road authorities and road operators from 27 European countries that have teamed up to unlock the benefits of cooperation and harmonisation in the deployment of Intelligent Transport Systems (ITS) on Europe's major road network. ITS as a technology is a known contributor to sustainable mobility in terms of improved safety, efficiency and reduced environmental impact. Nevertheless, fragmented deployment on a national level will fail to deliver seamless European services and will not contribute to a coherent European Transport network. The European Member States have consequently launched the EasyWay project together with the European Commission as a platform to harmonise their ITS deployments.

This document has been drafted by EasyWay as part of the set of documents containing the 2012 version of the EasyWay Deployment Guidelines (DG 2012). These guidelines have been developed by EasyWay experts and practitioners. They have undergone a thorough review by international domain experts in an intense peer review exercise and they have been validated by the participating Member State Partners of EasyWay in an extensive formal Member State consultation process, which finally led to their adoption as basis for all deployment activities in future EasyWay phases.

EasyWay as a project is not a standardisation body, nor does it have any power to legally constrain the Member State in their national deployment activities. It is therefore crucial to understand that these documents are neither technical standards, nor are they specifications as they would be required for such cases, e.g. as currently developed by the European Commission as their part of the implementation of the ITS Directive 2010/40/EU. But since a certain level of strictness in compliance is required to achieve the intended goal of the EasyWay Deployment Guidelines – harmonisation and interoperability in Europe – the guideline documents are written in a way that clearly defines criteria that deployments have to fulfil in order to claim overall compliance with the guideline.

Although not legally binding in any sense, compliance may be required for the eligibility of deployments in future ITS road projects co-funded by the European Commission. Deviation from compliance requirements may nevertheless be unavoidable in some cases and well justified. It is therefore expected that compliance statements may contain an explanation that justifies deviation in such cases. This is known as the "comply or explain" principle.

Although not standards themselves, the EasyWay DG2012 Deployment Guidelines in some cases do mention – and sometimes require – the use of such standards. This is the case in particular regarding the use of the CEN/TS 16157 series of technical specifications for data exchange ("DATEX II"). Although standardised data exchange interfaces are a powerful tool towards harmonised services in Europe, it must be understood that real world deployments have to fit into existing – and sometimes extensive – infrastructures and investment in these infrastructures must be protected. It is therefore important to note that the use of DATEX II mentioned below as a MUST is referred to implementation of "new" data exchange systems and not the utilisation of the existing ones, unless these latter affect harmonisation of deployments or interoperability of services.

Service at a glance

SERVICE DEFINITION

Dynamic lane management (DLM) service enables a temporally modifiable allocation of lanes by means of traffic guidance panels, permanent light signals, multiple-faced signs, LED road markers, closing and directing installations, etc.

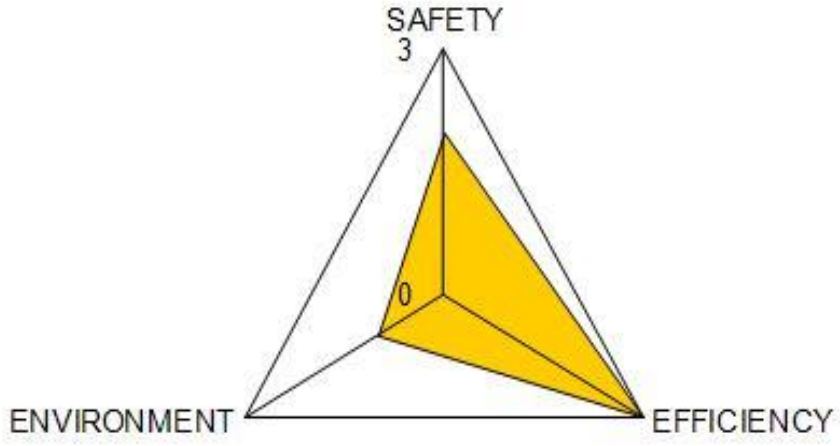
Fundamental applications of this service are: tidal flow systems, lane allocation at intersections, lane allocation at tunnels, hard shoulder running.

SERVICE OBJECTIVE

The overall objective of the dynamic lane management (DLM) service are:

- traffic actuated allocation of traffic flows, therefore higher capacity through better usage of the available cross-section;
- to achieve a temporary closing of lanes in case of accidents, incidents, maintenance work and construction measures (safeguarding of lanes).

SERVICE BENEFIT RADAR



EUROPEAN DIMENSION

Dynamic Lane Management (DLM) is a tool aiming to enhance traffic fluidity on the European network. As such harmonisation of safety requirements and the dissemination of unambiguous and consistent instructions to manage road users' behaviour is a key issue.

On this basis harmonisation of information displayed on VMS should be encouraged and coordinated with ESG4 Mare Nostrum, the group within EasyWay contributing to the creation of a common users' interface all over Europe.

Furthermore, cooperation and interoperability of communication means should be ensured among the Traffic Control Centres operating on neighbouring sections.

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List of abbreviations

CO	Carbon monoxide
CO2	Carbon dioxide
DLM	Dynamic Lane Management
HGV	Heavy Good Vehicles
ICT	Information and Communications Technology
ITS	Intelligent Transport Systems
LoS	Level of Service
NOx	Oxides of nitrogen
OE	Operating Environment
RDS TMC	Radio Data System Traffic Message Chanel
TERN	Trans European Road Network
VMS	Variable Message Sign
FR<#>	Functional requirement <number>
OR<#>	Organisational requirement <number>
TR<#>	Technical requirement <number>
CL&FR<#>	Look and feel requirement <number>
LoSR<#>	Level of service requirement <number>

1 Introduction

1.1 The concept of the EasyWay Deployment Guidelines

1.1.1 Preliminary note

This document is one of a set of documents for the EasyWay project, a project for Europe-wide ITS deployment on main TERN corridors undertaken by national road authorities and operators with associated partners including the automotive industry, telecom operators and public transport stakeholders. It sets clear targets, identifies the set of necessary European ITS services to deploy (Traveller Information, Traffic Management and Freight and Logistic Services) and is an efficient platform that allows the European mobility stakeholders to achieve a coordinated and combined deployment of these pan-European services.

EasyWay started in 2007 and has since established a huge body of knowledge and a consensus for the harmonised deployment of these ITS services. This knowledge has been captured in documents providing guidance on service deployment - the EasyWay Deployment Guidelines.

The first iteration of the Deployment Guidelines mainly captured best practice. This strongly supported service deployment within EasyWay by:

- making EasyWay partners in deployment aware of experiences made in other European deployment programmes.
- helping to avoid making errors others had already made
- reducing risk and facilitating efficient deployment by highlighting important and critical issues to consider

Meanwhile, this best practice has already successfully contributed to ITS deployments across Europe. It is now possible to take the logical next step and actually start recommending those elements of service deployment that have proven their contribution to both the success of the local deployment, as well as the European added value of harmonised deployment for seamless and interoperable services.

1.1.2 Applying Deployment Guidelines – the “comply or explain” principle

The step from descriptive best practice towards clear recommendations is reflected in the document structure used for this generation of the Deployment Guidelines. Apart from introduction and the annexes that cover specific additional material, the Deployment Guidelines consist of two main sections:

Part A – this part covers the recommendations and requirements that are proven to contribute to successful deployment and have been agreed by the EasyWay partners as elements that should be part of all deployments of this particular service within the scope of EasyWay. Thus, the content of this section is prescriptive by nature. EasyWay partners are expected to ensure that their deployments are compliant with the specifications in this section. Wherever concrete circumstances in a project do not allow these recommendations to be followed fully, EasyWay partners are expected to provide a substantial explanation for the need for this deviation. This concept is known as the “comply or explain” principle.

Part B – this part offers an opportunity to provide more valuable but less prescriptive information. Supplementary information may be contained including – but not limited to – regional/national examples of deployment and business model aspects like stakeholder involvement or cost/benefit analysis results.

1.1.3 Use of Language in Part A

It is essential for every prescriptive document to provide specifications in a well-defined and unambiguous language. There are various definitions that clarify the use of particular words (such as those listed below) within their prescriptive texts.

For the purpose of the EasyWay Deployment Guidelines, the well-established provisions of the RFC 2119 (http://www.ietf.org/rfc/rfc2119.txt, see (1)) are used, which is used to specify the basic Internet standards:

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

An overview of the keywords, their meaning and the possible answers in the context of part A provides the following table. In general, the keywords in brackets are possible, but their use is not recommended in order to avoid confusion which may arise as a consequence of different common linguistic usage of the terms in the different EU member states.

Requirement wording	Meaning in RFC 2119	Meaning in EasyWay	Possible checklist answers
MUST (REQUIRED, SHALL)	the definition is an absolute requirement	there may exist insurmountable reasons to not fulfill (e.g. legal regulations…)	**fulfilled: yes** **or** **Fulfilled: no - explanation of insurmountable reasons**
MUST NOT (SHALL NOT)	the definition is an absolute prohibition		
SHOULD (RECOMMENDED)	there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.	The Definition is very close to a "MUST", "MUST NOT" Meaning in EasyWay conform to RFC 2119	**fulfilled: yes** **or** **Fulfilled: no - with explanation**
SHOULD NOT (NOT RECOMMENDED)	there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label		
MAY (OPTIONAL)	The item is truly optional. One deployment may choose to include the item because of particular local circumstances or because it is felt to deliver a special added value	Meaning in EasyWay conform to RFC 2119	**fulfilled: yes - with explanation** **or** **Fulfilled: no**

Table 1: Part A - requirement wording

Note: the capitalisation of these keywords that is frequently used in IT standards is not recommended for EasyWay Deployment Guidelines.

The use of this 'requirements language' allows the direct transfer of the requirements stated in part A to a compliance checklist.

The following paragraph gives an example for a functional requirement:

Functional requirement:

- **FR2:** Data and information collected by both automatically and non-technical sources must be based upon both a consistent geographic reference model and a time validity model, which both **must** be part of data description.

Beneath "Requirement" a new semantic element "Advice" is proposed for part A, which has not the character of a hard requirement but of a "recommendation" and hence must not be listed in the compliance checklist. "Advice" is not immediately related to the three pillars of ITS-service harmonization (Interoperability, Common look & feel, Quality criteria) but to "inner features" of an ITS-service. Nevertheless, such an element delivers a European added value and hence should be addressed by the deployment guidelines.

The notation for using the advice element in the text is as follows:

Organisational advice:

- Clear definitions of organisational aspects are a crucial precondition for the successful implementation of a "Forecast and real-time event information service" and should be documented and accepted of all involved parties/partners in form of a Common partner arrangement/MoU - Memorandum of understanding, which establishes the details of co-operation.

1.2 ITS-Service Profile

1.2.1 ITS-Service Strategy

1.2.1.1 General Service Description

Dynamic lane management (DLM) enables the number of lanes in one direction at a given point of the network to vary. Dynamic Lane Management techniques include the use of traffic guidance panels, permanent light signals, multiple-faced signs or prisms, lane lights, closing and directing installations and so on.

Dynamic lane management can be activated at fixed times or in particular conditions of heavy volumes of traffic, usually by means of variable message signs or other typologies of road signs.

To ensure that there are no broken down vehicles or other objects on the lane or hard shoulder to be allocated, permanent video surveillance using Automatic Incident Detection is recommended, in particular for temporary activated systems (like reverse lane use).

1.2.1.2 What is the Vision?

Use of the Dynamic lane management (DLM) is differentiated according to the following fundamental applications:

Tidal flow system

A tidal flow system is defined as the dynamic management of lanes for one direction on road sections. This allows operators to temporally (daytime, event-based) react to different capacity requirements in different directions of route sections. These sections are delimited by means of transition areas at the beginning and at the end of the section. In the case of tidal flow systems, suitable control measures have to ensure that the lanes are released in one direction only and that “driving in the wrong direction” is excluded. The reversible allocation of an additional lane to one direction during peak hours reduces the traffic density per lane at equal inflow of traffic and therefore traffic flow is improved while the frequency and extent of incidents are reduced at the same time.

Lane allocation at the intersection

Intersections can be involved in lane signalization as long as the cross-section and the directional allocation of the respective lanes are kept in the intersection area. An additional lane allocation on the approach to signal-controlled intersections increases the exiting traffic and reduces congestion at unchanged green periods.

The target of dynamic lane management at access points to motorways is the variable management of lanes on the main carriageway and the access ramp. On the main carriageway the right lane is closed for through traffic while at the same time the lane is provided as an additional access lane of the ramp. Thus temporally increasing capacity demands of entering/exiting traffic with low loads on the main carriageway are taken into account.

Lane allocation before and in the tunnel

The possibilities and application areas for dynamic lane management at entry links to and inside tunnels should guarantee safe and smooth traffic use of the tunnels as far as possible, both in the normal case and in case of incidents, construction and maintenance works. With this aim the traffic is guided on to the counter flow lane, the so-called counter-flow operation, and guided together with the traffic in the contra-flow tube lane in case of closures in the tunnel or total closure of a tunnel tube.

Hard shoulder running

Temporary hard shoulder running provides a significant capacity increase of the crossroad section. In order to exploit the benefits of the higher capacity of hard shoulder usage, and to minimize the safety loss due to the removal of the hard shoulder, certain preconditions have to be fulfilled before the release (technical equipment, proof of economic efficiency, provision of emergency stops, infrastructure conditions).

Lane clearance ahead of road-works sites

Variable message signs (VMS) or dynamic prisms are used here to protect work teams on the roads/motorways. This use of VMS or dynamic prisms for dynamic lane management (DLM) helps to keep traffic flowing smoothly because drivers know what is happening some hundred metres ahead of the road works site and have enough time to change lane without the need to brake. Furthermore, this procedure represents an additional element of safety for road workers.

Lane clearance due to incidents

For this typology of dynamic lane management (DLM) existing VMS are used to guide traffic from the lane impacted to neighbouring lanes in advance of the incident location and thus to assist police on the road/motorway. Agreements should be concluded with Police, Traffic Officers or rescue staff (according to the system applied in each country) in order to activate VMS and to agree in advance the content of the messages on the VMS.

1.2.1.3 What is the Mission?

The overall objectives of Dynamic Lane Management (DLM) services are:

- to optimize the capacity of existing roads by using dynamic devices that affect vehicle flow by assigning the number of lanes that are open or the types of vehicles which are authorized,
- to achieve a temporary clearance of lanes in case of accidents, incidents, maintenance work or construction measures (safeguarding of lanes),
- to allocate lanes on black spot areas (bridges or tunnels) or at locations with poor safety records.

In most cases, Dynamic Lane Management provides road managers with a temporary increase of road sections (working sites and incidents are exceptions). DLM is meant to be implemented on sections or network areas concerned with highly varying traffic loads and capacity issues.

The tidal flow system is appropriate on sections without any kind of built lane separation. Otherwise cross-over sections have to be deployed according to the network geometry, e.g. before tunnel sections.

DLM is concerned with the misuse or unclear instructions given to road users through VMS or fixed signs. Therefore, road operators should be concerned with information display with the intent to inform users in the least ambiguous way (VMS, fixed signs or traffic lights). Road operators should also focus on safety precautions before activating the DLM services.

From a global perspective, DLM measures have the positive effect of limiting congestion in a specific spot.

According to the different implementations of DLM, specific objectives are:

Tidal flow system: The objective of tidal flow systems is to react to capacity demands on route sections for different directions (real-time or scheduled events).

Lane allocation at exits: The objective of DLM service at exits of motorways is to variably assign the lanes of the main carriageway and the access ramp in connection with traffic demands of the two sections.

Lane allocation before and in the tunnel: The objective of dynamic lane management before and in tunnels is to ensure safe and smooth use of tunnels as far as possible for both normal conditions as well as in the case of incidents.

Hard shoulder running: The objective of temporary hard shoulder running is to significantly improve the capacity of the road section. When it is done with variable speed limits, the overall safety situation should be improved.

Lane clearing ahead of working sites: The objective is to use existing and/or mobile VMS to protect work teams on the road/motorway.

Lane clearing due to incidents: The objective is to use VMS to assist police, road operators and rescue teams on the road/motorway.

Important note: Hard shoulder running is a specific application case of dynamic lane management. A dedicated guideline describes this application, consequently the present DLM Guideline doesn't present any information, requirements or recommendations dealing with this specific application. They are described in the Hard shoulder running deployment guidelines (see TMS DG04).

1.2.1.4 EasyWay harmonization focus

A main focus of this EasyWay deployment guideline lies in providing the dynamic lane management service on Variable Message Signs (VMS) which are operated along the route by road operators in a harmonized European way.

A second main focus is to ensure coherent information dissemination with other supports when the service is activated. This means that the Internet and navigation on-trip information services must be able to display the same on-trip information used with VMS support.

1.2.1.5 Distinctiveness from other ITS-services

Relevant information for this service is:

- Traffic conditions status on the network

Relevant complementary information, not included within this Deployment Guidelines and to be covered by other DGs, is:

- Pre-trip and on-trip information services which may be used to inform users pre-trip or on-trip about the current operational status of the dynamic lane management service (see TIS DG01-DG02),
- Recommendations for VMS use (see VMS DG01-DG02),
- Hard shoulder running is a special application case of dynamic lane management. A dedicated DG describes this application (see TMS DG04),
- Information provision should be coherent with traffic management plans (TMP, see TMS-DG07) initiated by road authorities or traffic management centres, with Incident Management information (TMS DG05-08) and Overtaking Ban information (TMS DG06).

1.2.2 Contribution to EasyWay Objectives

1.2.2.1 Service radar

The graph below provides a quantification of the added value of "Dynamic Lane Management" services regarding the three main objectives of EasyWay which are: safety, efficiency and environment. The applied scales for the service radars are based on an expert view and not on specific scientific analysis.

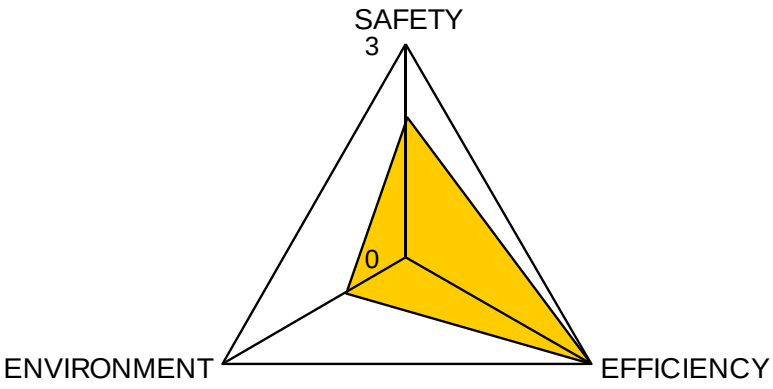

Figure 1: Service radar "Dynamic Lane Management"

1.2.2.2 Safety

In most cases, Dynamic lane management (DLM) enables the temporary, demand-responsive capacity increase of sections (working sites and incidents are exceptions). Since a better distribution of traffic in the road section is possible by raising the number of lanes, the following behaviour can be better adjusted and the danger of accidents can be reduced. The impact analysis of comparable systems confirms the positive effect on the traffic safety.

Moreover, some DLM measures are clearly safety-oriented: lane allocation before and in tunnels, lane allocation due to incidents / accidents and lane clearing ahead of working sites.

1.2.2.3 Environmental impact

Systems for dynamic lane management (DLM) have positive effects on the traffic flow and reduce traffic-related congestion and accidents (followed by further congestion). By means of traffic smoothing, noise and pollutant emissions are reduced.

1.2.2.4 Network efficiency

A demand-oriented increase of the capacity on route sections and at junctions clearly results in an improvement of the traffic flow in the whole network area concerned. In particular, it has been proved that the number of accidents and their frequency decrease where the dynamic management of lanes is planned and activated properly. From the point of view of users, this also contributes to a more regular traffic flow (due to a better use of road capacities) and to a reduction of travel time losses.

1.2.3 Current status of deployment

Systems for dynamic lane management (DLM) consist - in dependence of the impact area - in a combination of constructional changes (mostly marking, partially lane-separating components) as well as operational and organizational tasks and responsibilities. In general, they are part of a complex traffic control measure.

Depending on the organization and functional area a check of the carriageway is done by video cameras and could be done in the future by automatic scan function before the release of a lane. Detected incidents are transmitted to the operator. After the operator has determined that the lane is clear of obstructions the lane is opened to traffic. For visualization, matrix signs are applied as well as variable routing signs (in LED or prism technology). The measure can be supported by light signal heads (red light) and road markers in the carriageway (such as dynamic road marking) as well as by automatic barriers. The use of the latter needs careful consideration before implementation as they can be activated only after having carried out a monitoring action by means of cameras and the carriageway is cleared by means of patrols.

This is relevant for traffic operation of change in direction. In other cases, traffic detectors are enough.

There are already some experiences for the deployment of this service in Europe. Several evaluations have been conducted for such deployment and experimentation. The main results and effects of the DLM evaluations conducted in Europe are presented in section B.

These experimentations allow us to determine the main advantages or disadvantages of this traffic management service implementation from a user point of view as well as from the road traffic manager perspectives.

1.2.4 European Dimension

The European road network is characterized in many areas – and not only in the surrounding areas of big cities and metropolitan areas – by high traffic loads with, in part, highly varying main directions. The application of dynamic lane management (DLM) on road sections, at intersections and in the surrounding areas of road tunnels provides trans-national application fields to improve capacity until a corresponding road extension.

What becomes necessary on a European-wide level when activating dynamic lane management (DLM) is to harmonise safety requirements and to spread unambiguous instructions for users on how to behave when facing dynamic lane management (DLM) events on the basis of agreed protocols.

For instance, instructions are given differently all over Europe and the harmonisation of the messages displayed on the variable message signs is of great important in order to contribute to users' safety. Messages displayed on the VMS should be as far as possible language independent. The use of easily understood symbols and abbreviations should be encouraged. The work group of the European Study ESG4 "Mare Nostrum", for instance, is contributing within EasyWay to the creation of a common users' interface all over Europe. This common interface, once developed, would be very useful for the purposes of the harmonization of instructions.

Furthermore, interoperability should be granted among the traffic control centres of different operators, when they are called to collaborate together. The word interoperability in this case means mainly capability to cooperate and, in particular, to agree upon specific issues like uniformity of communication towards the users. The difference between a cross-border and a national level is the responsibility for traffic management which, while within a national borders, is sometimes assigned to a single body (e.g. in Italy is Ministry of Interiors with the cooperation of Motorway Operators), whilst at a cross-border or cross-regional level must be carefully defined in order to guarantee an appropriate level of traffic safety and a clear scenario of responsibilities.

2 Part A: Harmonization Requirements

2.1 Service Definition

"Dynamic lane management (DLM) service enables a temporally modifiable allocation of lanes by means of traffic guidance panels, permanent light signals, multiple-faced signs, LED road markers, closing and directing installations, etc.

Fundamental applications of this service are: tidal flow systems, lane allocation at intersections, lane allocation at tunnels, hard shoulder running."

Dynamic lane management (DLM) provides a way of optimizing the capacity of existing roads by using dynamic devices that affect vehicle flow by assigning the number of lanes that are open or the types of vehicles which are authorized.

The service is mainly applicable along the network characterised by:

- flow-related problems (daily or seasonal) and/or
- safety problems

The additional following main parameters are generally taken into consideration for the deployment of this service:

- the traffic flow
- the period
- the presence of particular critical events.

Dynamic lane management can be deployed on motorways, 3 or 4 lane roads, corridors, peri-urban motorways, critical spots. In most cases (if not in the standard case) DLM is a part of a traffic control system and needs to be coordinated with other systems (i.e. speed limit, incident warning, hard shoulder running, HGV overtaking ban).

2.2 Functional Requirements

2.2.1 Functional architecture

The following table and diagram show the typical functional and information architecture of the Dynamic lane management service.

Functional requirement:

- **FR1**: Dynamic lane management service implementation **should** be carried out the following functional decomposition into sub-functions:
  - Carry out an advisability study
  - Prepare the Dynamic lane management implementation
  - Collect and analyse data transmitted from monitoring systems
  - Monitoring
  - Decide the relevant Dynamic lane management implementation strategy to apply
  - Traffic guidance to road users
  - Track the decision for assessment use
  - Evaluate and assess, measure the impacts in order to provide recommendation and improvement (if possible)

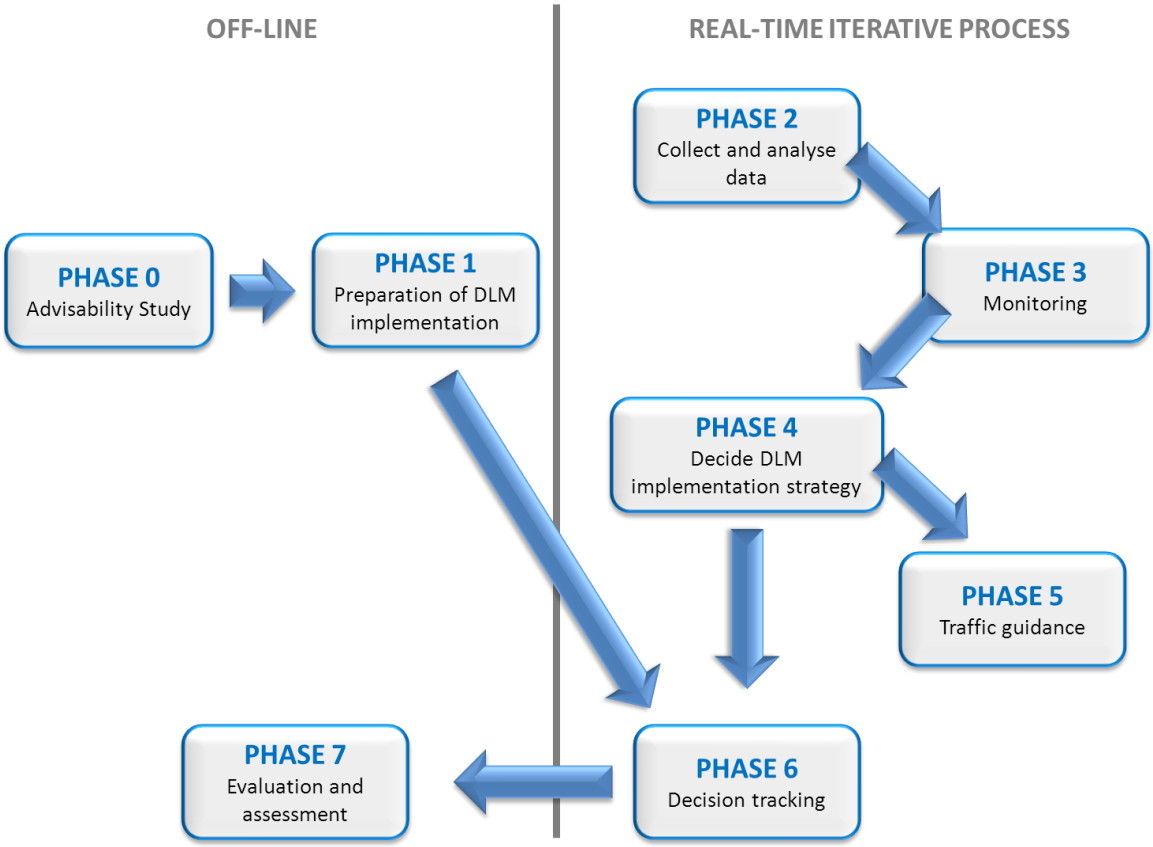

Figure 2: Iterative process of Dynamic Lane Management development

2.2.2 Functional decomposition[1] and interfaces

Sub-function "Prepare implementation"

Functional requirements:

- **FR2**: A analysis of traffic flows and current and required infrastructure **may** be carried out before implementing the service to define whether it is needed or not, if it will bring benefits to traffic efficiency and if it is feasible
- **FR3**: Physical layout – the following items shall be taken into account:
  - acceleration and deceleration ramps **should** be long enough to let vehicles have the time to check the carriageway before entering it, without causing queues
  - enough lay-bys **should** be available to allow vehicles to stop in case of emergency when lanes are allocated (especially for hard shoulder running)

Sub-function "Data collection and analysis"

This sub-function includes traffic monitoring and road clearance control. The devices and methodologies for traffic data collection are not covered by this deployment guideline. They depend amongst others on the particular used data collection system and are left to the operator to select.

Functional requirements:

[1]The ITS service is "distributed" over more than one administration (cross-border, cross-regional) for operation, i.e. different road operators and other parties are involved, providing "logical sub-functions". Between the distributed functions interoperability must be guaranteed by properly specified interfaces.

- **FR4:** Monitoring: infrastructure and control equipment **may** be used to monitor the traffic conditions and regulate traffic flows. Monitoring data collection system (also CCTV) **may** be able to detect real time vehicle flow and speed.
- **FR5:** Road clearance monitoring: before applying any dynamic lane management (DLM), it **must** be verified that no car is stopped on the dynamic lane or in lay-bys from where no signs are visible (done by video-cameras and/or police or alternative technologies where appropriate).
- **FR6**: The clearing process **should** take place by controlling lane availability. This can be done for the whole section or in stages. To start the clearing process, particularly with lane safeguarding, a yellow/white lane divert arrow (with or without flashing lights) **should** be used as transition signal, before lane closure signs (red crosses) are used in advance of the incident site.
- **FR7**: Site investigation: local control devices **must** be connected to a traffic control centre. Operators in the traffic control centre **must** have access to an interface to remotely monitor traffic detectors and activate all VMS on the carriageway, managed by the centre itself.
- **FR8:** Safety procedures: they **must** exist in order to apply all safety measures (before and during the DLM process). Safeguarding measures in the form of dynamic road markings, closing and guidance facilities can then be launched.
- **FR9**: Before the final release it **must** be checked whether the lane concerned is available to corresponding traffic by means of video monitoring, police, traffic officers or alternative technologies where appropriate.

Sub-function "Traffic guidance to users"

Functional requirements:

- **FR10**: Traffic guidance to road users: suitable information means such as variable message signs, permanent light signs, multiple-faced signs or prisms, lane lights **must** be used when implementing a dynamic lane management (DLM) system to keep users informed about the availability of lanes.
- **FR11**: Public Information Campaign involving the media **may** be organized to explain users the benefits of DLM management, including concrete examples and how to behave when the service is activated. This would help to gain acceptance of the service

2.3 Organisational Requirements

The implementation of Dynamic Lane Management comprises different applications:

- Tidal flow system
- Lane allocation at junctions
- Lane allocation before and in tunnels
- Hard shoulder running
- Lane clearing ahead of working sites
- Lane clearing due to incidents.

Independently of the initial objectives, the expected benefits of the service mainly rely on the implementers' involvement and the end users' acceptance.

DLM usually involves a range of partners such as road authorities, road operators, the police, the fire brigade, ambulance services, recovery services and the media. Performance of the DLM process relies on an overall cooperation. This cooperation should be initiated some time before the operation of the DLM service to ensure service continuity and quality display of the DLM service.

Organisational Architecture

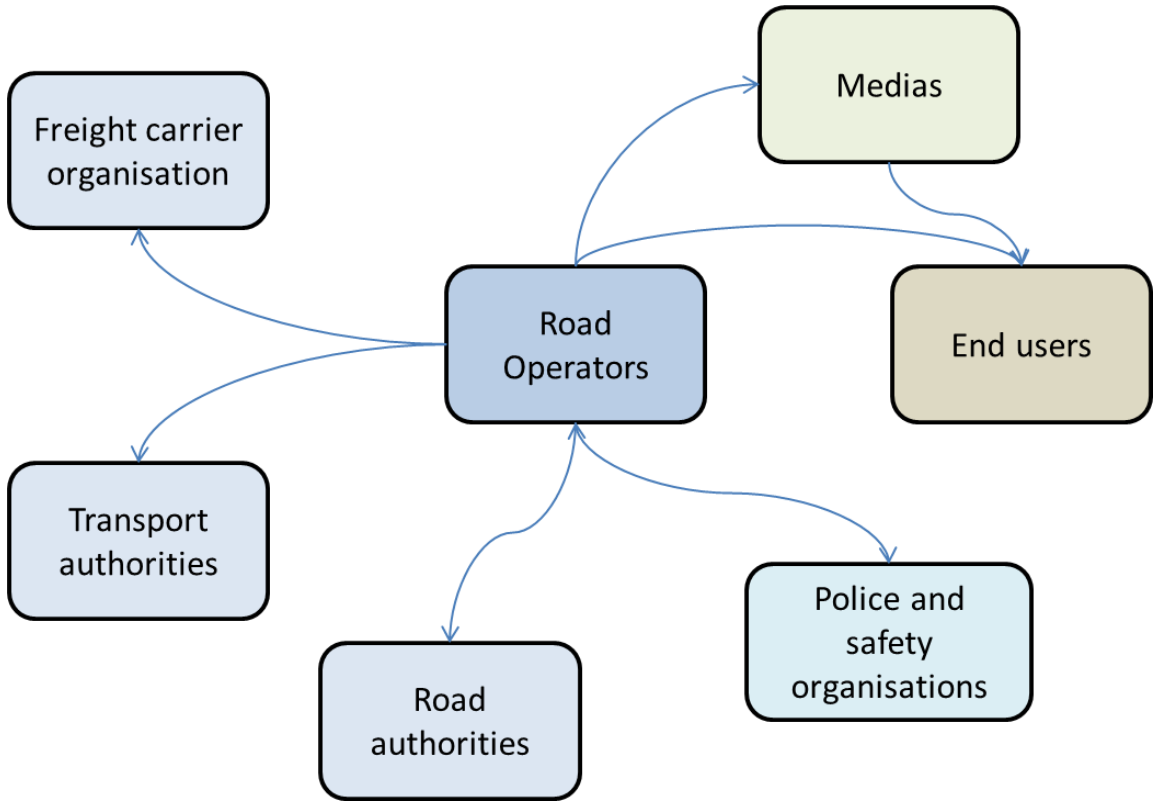

Figure 3: Organisational architecture

Organisational requirements:

- **OR1:** The organisational and operational structure of the service, as well as the role of each organisation/body and its tasks, **must** be defined.
- **OR2:** Appropriate procedures **must** be defined for the activation and deactivation of the dynamic management of lanes. These measures should be integrated to the traffic control system.

2.4 Technical Requirements

2.4.1 ICT Infrastructure requirements

The deployment of the dynamic lane management (DLM) requires a minimum infrastructure.

Technical requirements:

- **TR1:** Variable message signs for the closure or release of lanes **must** be installed.
- **TR2:** Vehicle detectors **must** be installed (double inductive loops, infrared, microwave, video or radar sensors) along the main carriageway, providing information on current traffic conditions; in some cases, they are needed to decide whether to activate the DLM process
- **TR3**: Video surveillance (including CCTV) **must** be implemented for tidal flow, DLM in tunnels and, when possible, for hard shoulder release.
- **TR4:** A control centre with operation and visualization, control software, reporting and report archiving system **must** be available

Technical advice:

- Grid-bound data connection for video surveillance and control, combination of analogue (e.g. video data per coaxial) and digital data communication (e.g. connection to a local control station via fibre optics) may be possible
- Communication facilities between sensors, variable message signs and control systems in local control stations, sub-centres and higher traffic control centres may be possible
- Surrounding data collection technology: if surrounding data collection is implemented the most important collectors are sensors for rain, snow, ice-smoothing and visibility. The integration of this information in the traffic control system is of advantage.
- Moveable turning bars, retractable beacons or cones should be implemented for closing and directing installations horizontally, if needed. The installations can be activated and deployed by remote control after checking all VMSs are functioning properly.
- Local control stations may be equipped with data input/output devices, connection to energy and data supply

2.4.2 Standards and Agreements: Existing and Required

Technical requirement:

The most relevant standards in Europe concerning technologies and systems examined by this guideline are EN 12966-1/2/3:2005. Road vertical signs - Variable message traffic signs. These include:

- Road vertical signs - Variable message traffic signs - Part 1: Product standard
- Road vertical signs - Variable message traffic signs - Part 2: Initial type testing
- Road vertical signs - Variable message traffic signs - Part 3: Factory production control

2.4.2.1 DATEX II profiles

Interoperable interfaces between systems are essential for the delivery of many EasyWay objectives like continuity of services and cross-border traffic management cooperation. Hence, EasyWay has itself decided to actively contribute to the establishment of the required standardisation effort by launching a dedicated working group ESG5 and liaising with the relevant European standardisation body, namely with CEN TC278 WG8 (“Road Traffic Data”). The result of this cooperation is the “DATEX II” specification for interoperable machine-to-machine communication of ITS services, available as European Standard CEN/TS 16157. This specification is used throughout EasyWay for interoperable access to dynamic traffic and travel data.

EasyWay provides DATEX II profiles to support core service deployment in the domains of Traffic Management, Traffic Information and Freight & Logistics services. These profiles describe a subset of the DATEX II data model,

tailored to the needs of the particular core service. If these deployments have a special requirement to support particular downstream standards used in subsequent stages of the service delivery chain, it may become important to tailor these profiles further and to use only the cross-section between the TIS/TMS/FLS-DGs profile and a DATEX profile tailored for interoperability to the particular downstream standard.

As an example, a TIS profile may allow for multiple location referencing methods, but if dissemination of the information via RDS-TMC is envisaged by a particular deployment, compliance with the ALERT-C standard is essential since this standard only supports the use of ISO 14819-3 location codes. Hence, it might be preferable to tailor the EasyWay TIS profile further to use only ALERT-C location codes to ensure that the service provider can use the data provided.

The use of DATEX II mentioned below as a MUST is referred to implementation of "new" data exchange systems and not the utilisation of the existing ones, unless these latter affect harmonisation of deployments or interoperability of services.

Technical Requirements:

- **TR5**: In the case that road operators have to exchange data requiring interoperability between two or more different organisations, they **must** enable their system to use DATEX II.
- **TR6:** Service operators intending to display DLM measures **must** be able to integrate the DATEX II publications provided by road operators.
- **TR7:** The mapping of information related to dynamic lane management (DLM) into the DATEX II level A data model is comparably easy. DATEX II has a dedicated class for this type of information called RoadOrCarriagewayOrLaneManagement. This class is a specialisation of the SituationRecord class, hence the information regarding dynamic lane management (DLM) **should** be published via a SituationPublication.

The following UML diagram displays the main model elements. Some optional attributes in the ancestor class of RoadOrCarriagewayOrLaneManagement have been deselected, since they did not appear to be useful in the context of a dynamic lane management (DLM) service:

- in class SituationRecord the attribute severity
- in class NetworkManagement the attributes complianceOption and placesAtWhichApplicable.

In the same manner, not all of the optional components attached to the ancestor classes of RoadOrCarriagewayOrLaneManagement are needed and have been addressed:

- for SituationRecord, only Impact and Validity have been included, with attributes numberOfLanesRestrcited, residualRoadWidth and traffcConstrictionType deselected for Impact and Validity being reduced to status, start and optional end time
- The restriction of measures for particular types of vehicles (VehicleCharacteristics) has been deselected for NetworkManagement, since it also does not apply for dynamic lane management (DLM).

Location referencing has been restricted to linear locations. The SupplementaryPositionalDescription feature is needed for dynamic lane management (DLM), but the footpath attribute in the AffectedCarriageWayAndLanes seems obsolete and has been deselected as well. The resulting set of classes and features is depicted on the following figure.

The resulting schema can be found in the annex. The schema is slender (892 lines) compared to the full DATEX II schema (4707 lines).

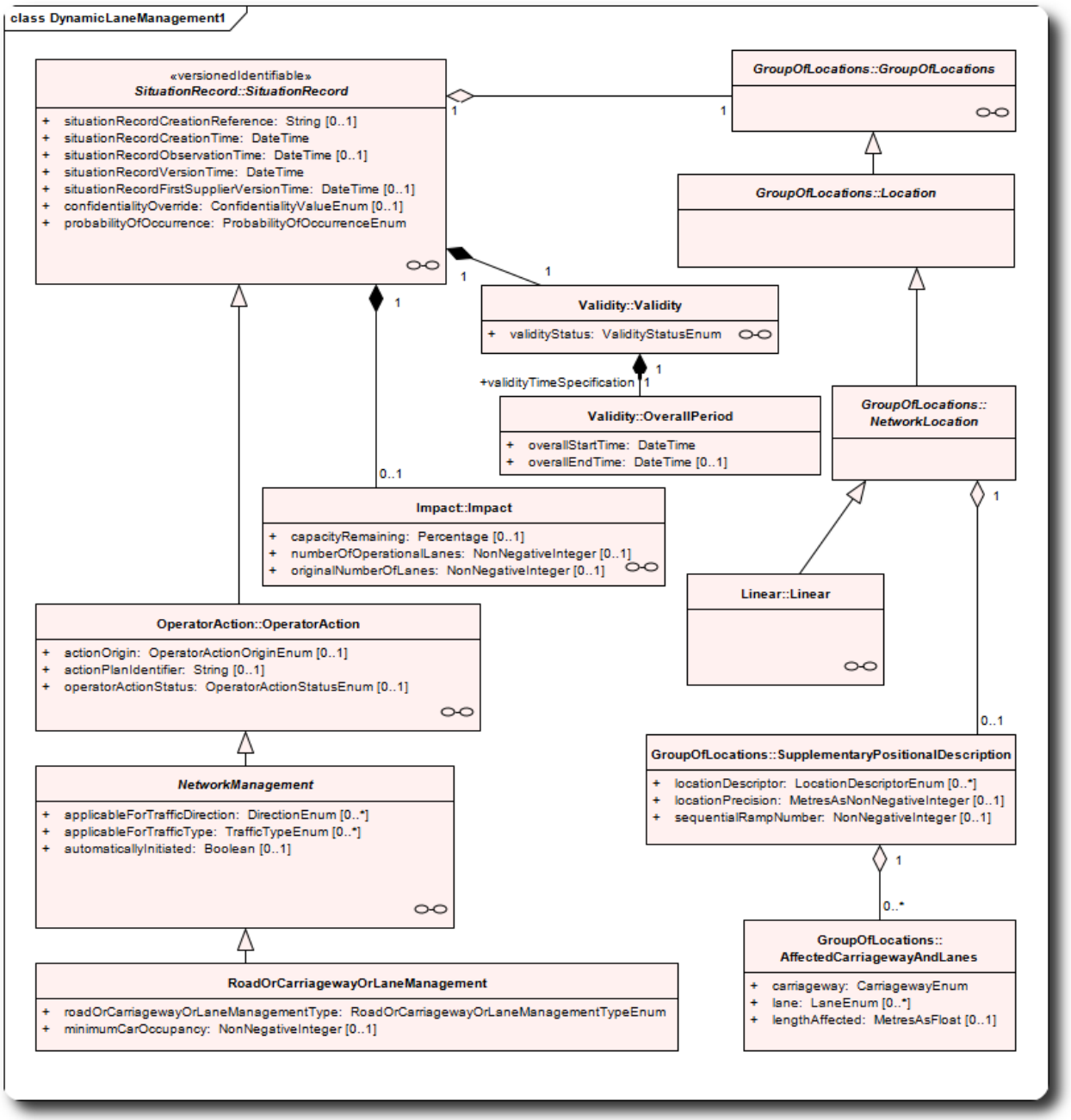

Figure 2: Main UML class diagram

2.5 Common Look & Feel

The dynamic management of lanes is displayed to users by means of Variable Message Signs. When dealing with cross-border or cross-regional dynamic lane management (DLM) systems, Variable Message Signs display should be as harmonised as possible so as to be more comprehensible to users. The display is usually located overhead (VMS mounted on traffic sign gantries) or laterally in single cases (VMS mounted on masts) besides the carriageway.

The compliance rate and the acceptance of systems with dynamic lane management (DLM) by the car drivers may vary heavily dependent on the comprehensibility of the operated switching. It should therefore be checked and improved, if needed, by a comprehensive quality control.

End-user acceptance of the system can be improved by deploying Variable Message Signs which provide users with detailed information of how to behave on the section affected by dynamic lane management (DLM). Such information, given to the users progressively, can make them feel safer: in the case of hard shoulder allocation, for instance, users should be informed in advanced that the system is active, how they can profit from an added lane opened (or in the case of HGV how they are obliged to keep to the inside lane), how they have to reduce speed, how long an additional lane is sustained and when the system reduces lane availability again. The more the system is comprehensible for users, the more it is accepted by them.

All measures can then be considered to be successful when users easily understand them and traffic flow is kept under control.

2.5.1 General requirement

In the process of harmonisation, Dynamic Lane Management is part of a traffic control system and the requirements listed below are some general requirements to be fulfilled when Dynamic Lane Management is activated. It has to be considered that DLM deals with a lot of different situations and in some cases exceptions must be possible.

Common look & feel requirements:

- **CL&FR1:** The display of signs/pictograms on VMS or other end-user devices **should** be in accordance with prevailing national road codes and in line with the requirements of the EW-DG VMS-DG01-VMS Message Design Principles:
  - MS which ratified the 1968 Convention MUST respect the 1968 Convention and SHOULD consider the Consolidated Resolution on Road Signs and Signals (R.E.2);
  - MS which did not ratify the 1968 Convention SHOULD follow the 1968 Convention and also consider the R.E.2.

  It is up to the deploying road operator to ensure that real signs are well and widely understood by the road users.
- **CL&FR2**: Normally every VMS **must** display a sign (speed limit, green arrow, yellow/white deflection arrow, “end of restriction” or red cross) over each lane. An exception to this is the use of red crosses over “hard shoulder running lanes” or special “rush hour lanes” that are not in use; in that case there is no need to display any sign on VMS.
- **CL&FR3**: A yellow/white deflection arrow **must** be displayed before the closure of the lane (red cross) in the case where there are enough VMS in series before.

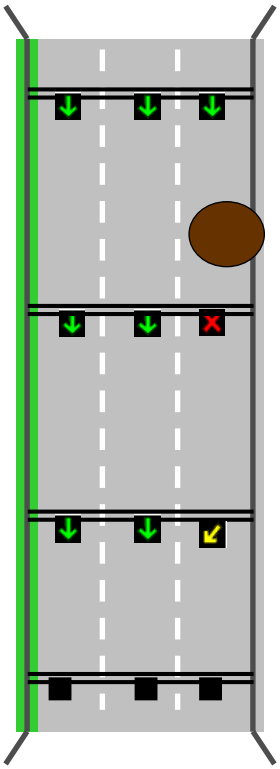

Figure 3: DLM signage for instance in case of accident

- **CL&FR4**: A yellow/white deflection arrow **must not** point towards a lane that appears closed on the next signal gantry.
- **CL&FR5**: The road operator **must** close only one lane at a time. More than one lane can be closed at a time only if there aren't enough signal gantries to move traffic across a lane at a time.

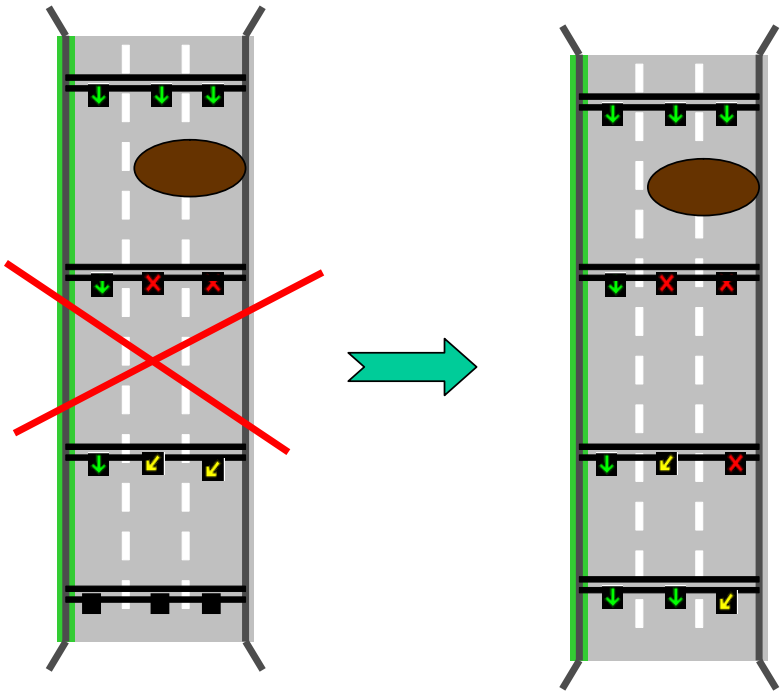

Figure 4: DLM signage in case of accident

- **CL&FR6**: At the end of the DLM zone, normal allocation of lanes **must** be indicated on VMS display either by a green arrow or by an “end of restriction” sign.
- **CL&FR7**: When there is a wish to display both a speed limit and a green arrow over the lanes, an additional VMS **should** be used.
- **CL&FR8**: The distance between 2 VMS series **should** not be too long (suggestion: < 1000m).

2.5.2 Tidal flow system requirement

Common look & feel requirement:

- **CL&FR9:** On the dedicated tidal lane at least one section of the lane **must** be cancelled to traffic prior to DLM implementation: one on both directions.

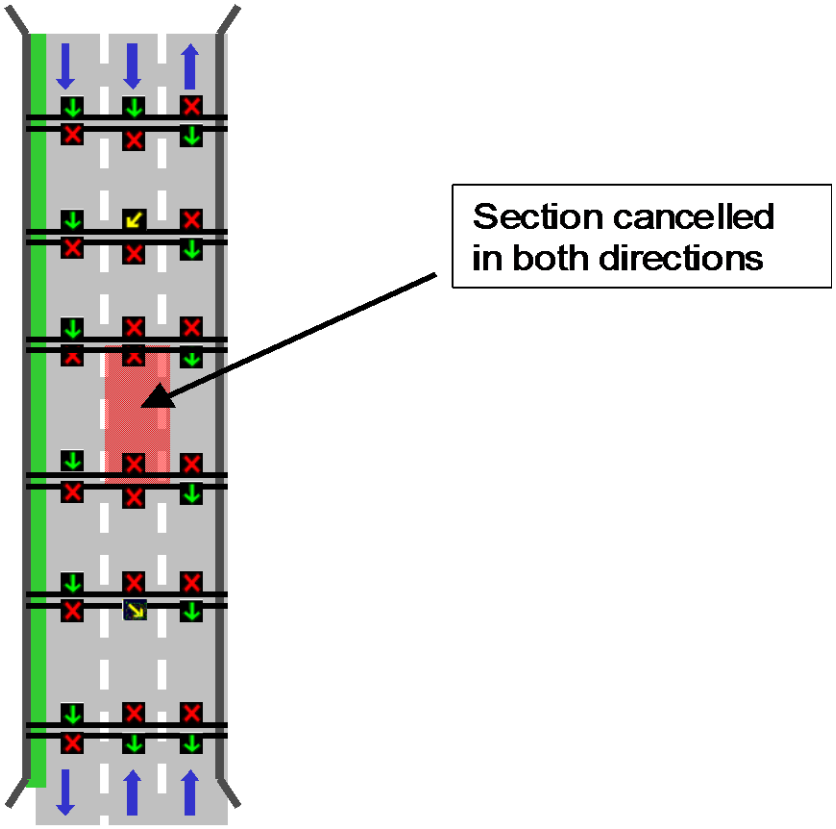

Figure 5: Tidal flow system

2.5.3 Lane allocation before and in the tunnel

Common look & feel requirements:

- **CL&FR10**: VMS series **must** be installed so as to ensure maximum service visibility.

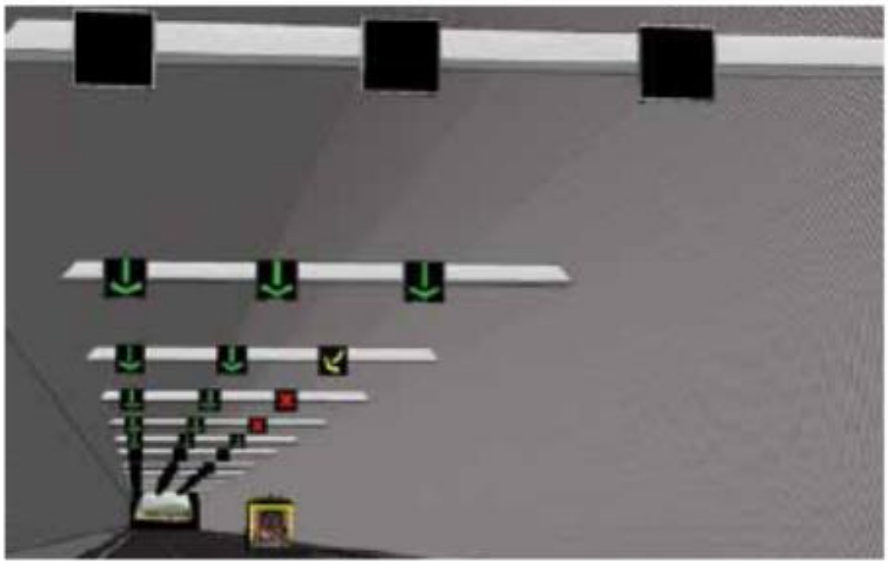

Figure 6: DLM in tunnel

- **CL&FR11**: If lane availability within tunnels is reduced due to planned works or incidents, DLM **should** be activated before the tunnel entrance.
- **CL&FR12**: Lane allocation **should** remain constant within the tunnel.

2.5.4 Lane clearing ahead of working sites

Common look & feel requirement:

- **CL&FR13**: DLM service **must** be activated in accordance with the local signalisation pattern.

2.6 Level of Service Definition

2.6.1 Preliminary remark

The scope of EasyWay is to provide Core European Services to the European road users. These services are harmonized in content and functionality, but also in their availability: The road users shall be able to expect certain services to be available in a specific road environment. In order to provide a basis for the harmonization process EasyWay needs a tool to define such environments in an agreed manner. This tool is the Operating Environments – a set of pre-defined road environments combining physical layout of the road and network typology with traffic characteristics.

In essence, EasyWay has agreed on a set of 18 pre-defined Operating Environments (OE) where each OE is a combination of three criteria:

- Physical characteristics – Motorways, other 3/4 lane roads or 2-lane roads
- Network typology – Corridor, Network, Link or Critical spot
- Traffic characteristics – Traffic flow and road safety situations (with optional additions)

For more information and details, visit https://dg.its-platform.eu.

2.6.2 Level of Service Criteria

LEVELS OF SERVICE: DYNAMIC LANE MANAGEMENT			
Core Criteria	**A**	**B**	**C**
Display of traffic information (support)	Dynamic information on lane allocation (arrows on VMS)	Dynamic information on lane allocation + possibility of speed limit	Dynamic information on lane allocation + possibility of speed limit + extra information (overtaking ban, etc.)
Monitoring	Manual via traffic officers and/or police	Semi-automatic via traffic officers and/or police cameras	Automatic via cameras, loops, sensors
Safeguarding	Physical	Physical and through cameras	Physical + cameras + automatic detection
Activation and deactivation	Manual	Manual and remote-controlled	Manual and based on decision support systems
Operational availability	Service periodically ensured during critical periods	Extended availability, when required	Service 24/7 ensured, when needed (in case of major events)

Table 2: Level of Service

Notes:

Attention must be paid to Level C of “Display of traffic information (support)” because it could create information overflow if not well organised.

Each level shows a technical advancement, but a higher level is not necessarily better than a lower level.

2.6.3 Level of Service Criteria related to Operating Environment

- **LoSR1**: In the case that pre-deployment surveys/evaluations provide the necessary evidence to proceed with the deployment of the ITS-service "Dynamic Lane Management", the minimum and optimum LoS **should** respect the following Level of Service to Operating Environment mapping table.

DYNAMIC LANE MANAGEMENT Criteria for the Levels of Service [reference TMS - DG01]			EasyWay OPERATING ENVIRONMENT																
			C1	T1	T2	T3	T4	R1	R2	R3	R4	R5	R6	R7	R8	S1	S2	N1	N2	P1
Display of traffic information (support)	C	Information about the dynamic allocation of lanes and users' guidance (arrows on VMS) with possibility of speed limits and other pictograms (overtaking ban, etc.)	O			O	O									O	O			
	B	Information about the dynamic allocation of lanes and users' guidance (arrows on VMS) with possibility of speed limits												O	O			O	O	O
	A	Just information about the dynamic allocation of lanes and users' guidance (arrows on VMS)	M			M	M							M	M	M	M	M	M	M
	/	*Service unavailable*		NA	NA			NA	NA	NA	NA	NA	NA							
Monitoring	C	Automatic via cameras, loops, sensors	O													O	O			O
	B	Semi-automatic via traffic officers and/or police and cameras				O	O							O	O			O	O	
	A	Manual via traffic officers and/or police	M			M	M							M	M	M	M	M	M	M
	/	*Service unavailable*		NA	NA			NA	NA	NA	NA	NA	NA							
Safeguarding	C	Physical + cameras + automatic detection														O	O			
	B	Physical and through cameras	O			O	O							O	O			O	O	O
	A	Physical	M			M	M							M	M	M	M	M	M	M
	/	*Service unavailable*		NA	NA			NA	NA	NA	NA	NA	NA							
Activation and deactivation	C	Manual and based on decision support systems	O			O	O									O	O			
	B	Manual and remotecontrolled	M			M	M							O	O	M	M	OM	OM	OM
	A	Manual on-site												M	M					
	/	*Service unavailable*		NA	NA			NA	NA	NA	NA	NA	NA							
Operational availability	C	Service 24/7 ensured, when needed (in case of major events)	O																	
	B	Extended availability, when required				O	O							O	O	O	O	O	O	O
	A	Service periodically ensured during critical periods	M			M	M							M	M	M	M	M	M	M
	/	*Service unavailable*		NA	NA			NA	NA	NA	NA	NA	NA							

Recommendations for LoS per OE:					
	M	Minimum LoS recommended		O	Optimum LoS recommended
	OM	Minimum = Optimum		NA	Not relevant

Table 3: Levels of Service related to Operating Environment

OE	Explanation
C1	critical spots, local flow-related traffic impact and/or potential safety concerns
T1	motorway (link), no flow-related traffic impact and no major safety concerns
T2	motorway (link), no flow-related traffic impact, potential safety concerns
T3	motorway (link), seasonal or daily flow-related traffic impact, no major safety concerns
T4	motorway (link), seasonal or daily flow-related traffic impact, potential safety concerns
R1	two-lane road (link), no flow-related traffic impact, no major safety concerns
R2	two-lane road (link), no flow-related traffic impact, potential safety concerns
R3	two-lane road (link), seasonal or daily flow-related traffic impact, no major safety concerns
R4	two-lane road (link), seasonal or daily flow-related traffic impact, potential safety concerns
R5	three-/four-lane road (link), no flow related traffic impact, no major safety concerns
R6	three-/four-lane road (link), no flow related traffic impact, potential safety concerns
R7	three-/four-lane road (link), seasonal or daily flow related traffic impact, no major safety concerns
R8	three-/four-lane road (link), seasonal or daily flow related traffic impact, potential safety concerns
S1	motorway corridor or network, at most seasonal flow-related impact, possibly safety concerns
S2	motorway corridor or network, daily flow-related traffic impact, possibly safety concerns
N1	road corridor or network, at most seasonal flow-related traffic impact, possibly safety concerns
N2	road corridor or network, daily flow-related traffic impact, possibly safety concerns
P1	peri-urban motorway or road interfacing urban environment, possibly safety concerns

OE type	Number	Flow-related traffic impact				Potential safety concerns	
		NO	SEASONAL	DAILY		NO	YES
Critical spots							
C	1		X	X	and/or		X
Motorway links							
T	1	X			and	X	
	2	X			and		X
	3		X	X	and	X	
	4		X	X	and		X
Road links							
R	1	X			and	X	
	2	X			and		X
2	3		X	X	and	X	
lanes	4		X	X	and		X
R	5	X			and	X	
	6	X			and		X
3 or 4	7		X	X	and	X	
lanes	8		X	X	and		X
Motorway corridor or network							
S	1		X		and		(X)
	2			X	and		(X)
Road corridor or network							
N	1		X		and		(X)
	2			X	and		(X)
Peri-urban motorway or road							
P	1				and		(X)

Table 4: Legend - EasyWay Operating Environments for Core European ITS Services

3 Part B: Supplementary Information

The EasyWay Deployment Guidelines contain two main elements:

- *Part A elaborates on the content of the ITS service addressed, describing the entire deployment framework including Requirements and Levels of Services.*
- *Part B is an appendix of informative content. Its objective is to illustrate part A with examples and feedback from deployments in the field.*

Part B is a lively chapter – in contrast to Part A, which by nature should be stable for a certain time – and subject to continuous development and update. The focus of Part B lies on national practices and experiences which, as cross-fertilisation material, can benefit any road operator in Europe and which are documented in Chapter "3.1 Best Practice" consisting of two main sections:

Examples of deployment 2010 - 2012

This section consists of contributions delivered by those EasyWay-Partners that have actively participated in the development and editing of the EW Deployment Guidelines 2012. Against this background, the examples - in detail listed in Chapter "3.1.1 Examples of deployments 2010 - 2012" – reflect the state of the art at the end of the year 2012. As such they delivered the basis for the discussion of the EW-deployment guideline development process and the setup of Part A "Harmonization requirements" at this point in time. But this means also that no direct relation or compliance to the harmonization requirements of Part A (as they are listed in the Compliance checklists in Annex A) can be assumed for these examples. Nevertheless, the given examples provide a concrete documentation of the state of the art at that time and in most cases, they can still be considered as current best practice.

EIP/EIP+ user and application survey 2013 - 2015

In trying to keep Part B up-to-date, the EasyWay follow up project EIP (European ITS Platform) – launched in 2013 – started two phases of activities to contribute to Part B by collecting user as well as application experiences (both technical and organisational) of national deployments that applied or at least considered the EW-DG 2012:

- *In the time period from the beginning of 2013 to the end of 2014, the EIP work programme provided essential post-processing steps to improve the usability of the DGs in ITS deployments and further to reflect the initial experiences and feedback gained with the guidelines since their release at the end of the year 2012.*
- *In 2015, the EIP+ work programme contained a follow-up activity with the goal to monitor and collect feedback on the application of the DGs in the five European ITS Deployment Corridor projects and to consolidate reporting of the results, lessons learned and best practices concerning the DG practicability and the compliance with the DG requirements on a European scale.*

The results of those two activities are based on responses on questionnaires which were circulated to national ITS deployment experts and European ITS corridor projects and finally are reflected in Chapter "3.1.2 EIP/EIP+ user and application survey 2013 - 2015".

3.1 Best Practice

3.1.1 Examples of deployment 2010 - 2012

3.1.1.1 Example Italy (Autostrade per l'Italia)

- Spot of deployment: Motorway A14 Bologna – Bari – Taranto (known as “Adriatica”) between Km 8+400(Intersection Casalecchio A1-A14) and Bologna S.Lazzaro (Km 22+231)
- Type of deployment: Service implemented
- Operating environment: Three-lane existent motorway sections
- Main evaluation results: no
- Road operator contact: Autostrade per l’Italia – Francesco Trallori, francesco.trallori@autostrade.it

General Context:

The dynamic lane is a part of the activities that have been performed for the Single Convention Motorways License between Autostrade per l’Italia and ANAS (Italian Public Road Authority), that in this specific case provided for the modernization and expansion of the Motorway A14 Bologna - Bari - Taranto.

The route of the A14 describes a straight north - south along the Adriatic coast and connects Milan to Bologna and Taranto, then it represents one of the main national highway connections between South and North.

In the first stretch between the Km 8+400(Intersection Casalecchio A1-A14) and Bologna S.Lazzaro (Km 22+231), starting from an existing two lanes plus emergency (2L+1E) and because of the existence of a sub-urban ring belt all along the motorway section, it has been impossible to enlarge the carriageway (2L+1E) to three lanes plus emergency lane (3L+1E) and as a consequences the project has focused on the opening of the emergency lane to the traffic by mean of transforming it in a dynamic lane and obtaining a configuration 2L+1L/E Dynamic.

This stretch has been opened to traffic on January, 15 2008.

The project is going on and the next stretch foreseen for the year 2013 on the same motorway A14 will be comprised between Bologna S. Lazzaro (Km 22+231) and Km 29+000. In this case the final aim and configuration refers to 3L+1L/E Dynamic, which represents a wider carriageway respect to the previous and already working section.

Beyond the Km 29+000 and Km 56+600 (Ravenna) it is possible to expand to a configuration 4L+1E because of the inexistence of a sub urban road all along the motorway and there will be no dynamic.

Geographical Context:

The intervention of expansion to IV lane of A14 is located entirely in the territory of the Emilia Romagna region. The entire motorway section is divided into two provinces, respectively Bologna (equal to 92.6% of total development) and Ravenna (equal to 7.4%)

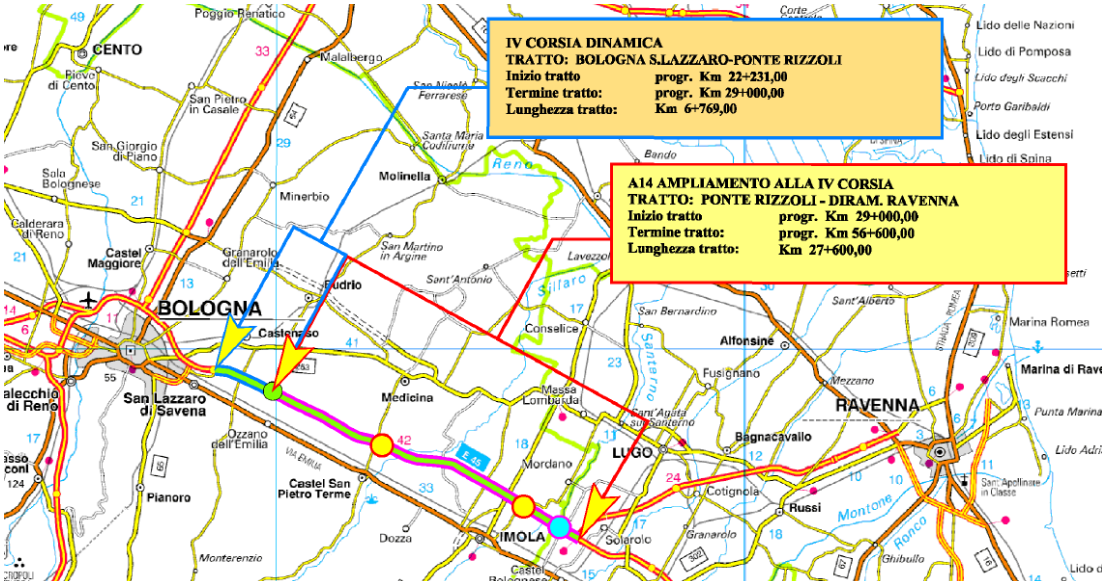

Figure 7: Example Italy

Traffic flow Context:

Moving from Rimini to Bologna, the road section between Ravenna and Bologna San Lazzaro of the Motorway A14 Bologna - Taranto presents current levels of traffic ranging from about 88.500 vehicles per day to about 92.500 with an incidence of heavy vehicles in traffic of about 25%, which is higher than the national network average that is 23%.

The current 3 lanes in each direction of travel are able to give to the system a transport capacity sufficient to provide more adequate answer to the request of mobility expressed by the territory, that has a significant component of short distances traffic due to the proximity of the capital and the current level of congestion characterizing the SS9 Via Emilia.

The relationship between travel demand and the flow capacity of the supply system has, despite of high traffic volumes, conditions of service still acceptable.

Technical Context (refers to the future IV dynamic lane):

The chosen reference architecture is consistent with the analysis of the preliminary project, it is in line with experience in similar achievements and provides multi-level systems.
Starting from the lowest level, which is from the road, we have:

The first level is composed by peripheral devices connected to the relevant units or local units, using copper connections, coaxial cable or ad-hoc optical fiber depending on the specific needs.

The second level is composed by "concentrator" devices or multifunctional MFO ("MultiFuctional Outstation") nodes, grouped (in terms of communications and functions)in sets of devices linked to the centre: so a hierarchical network is realized. These nodes of "concentration" will result in fibre optic infrastructure nodes realized by adopting technologies that enable transmission transport up to 1 GB/ps.

The third level is composed by front-ends or centres for the individual subsystems;

The fourth level is composed by the integrated system supervision centre that allows management of the various subsystems.

The various peripheral devices (Local Units) are grouped together and placed in appropriate local (shelters). The criterion for groupings and then locating the shelter is the portal LCS, so there will be a shelter at each LCS panel. The following table summarizes the quantity of devices necessary to distinguish the different types of each subsystem:

ITS sub system	Quantity
AID (Automatic Incident Detection)	46
CCTV	24
RT Sensors (count of vehicles above ground)	84
RT Sensors Loop (count of vehicles under ground)	4
VMS text (traffic information)	8
VMS pictograms	89
Gantry for VMS (one direction)	15
TOTALE	270

Table 5: Quantity of devices

The following figure provides a schematic diagram for the workstation type physical architecture, where all devices are located for the different subsystems. The working hypothesis is that each station is available for the access to the backbone via Ethernet switch-hubs.
Units of local management of traffic sensors UL_RT, of VMS and LCS (UL_PMV), codec for video surveillance system and AID system analyser are located inside the shelter. The diagram shows the types of connections assumed.

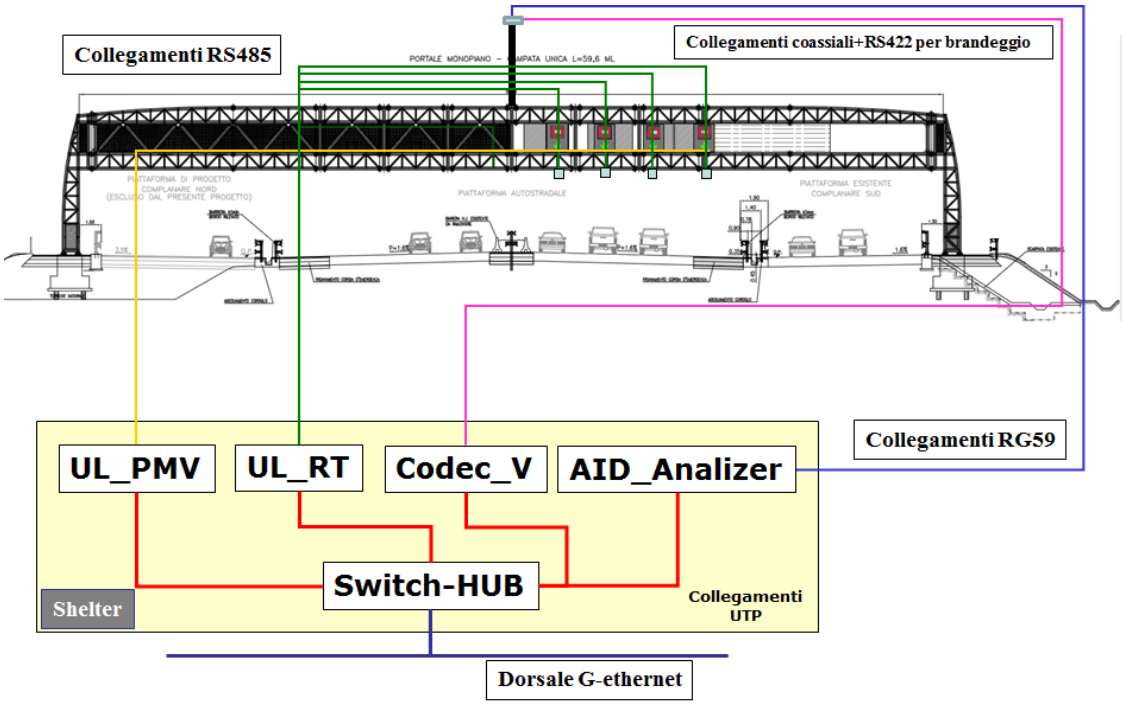

Figure 8: Type of connections

The ULCT (Control Local Unit) software will be able to communicate with sensors and control centre, to perform sensors and network diagnosis and to process the following data:
a) Count of vehicles
b) Distance between vehicles
c) Speed of vehicles

d) Vehicle Classification
e) Vehicle length
f) Employment%
g) Traffic slowed
h) Traffic stop

Count of vehicles: Where "above ground" sensors are used, the error of vehicle count, for a section, for each lane or for each direction of travel must not exceed + / - 3%.

Distance between two vehicles: The subsystem must detect the distance between vehicles in the control area of each sensor. Where above ground sensors are used, the error on the distance from the vehicle ahead, calculated for each class of vehicle, must not exceed + / - 5%.

Speed of vehicles: The subsystem must detect the speed of vehicles in the control area of each sensor. Where above ground sensors are used, the error on the rate, calculated for each class of vehicle, must not exceed + / - 5%.
Vehicle Classification: The processing software will be able to classify both the vehicle passing on each lane and those passing in each direction according to the following table:

Speed Class

I	From 0 to 30 Km/h
II	From 30 to 50 Km/h
III	From 50 to 70 Km/h
IV	From 70 to 90 Km/h
V	From 90 to 110 Km/h
VI	Over 110 Km/h

Length Class

I	From 0 to 2,5 m
II	From 2,5 to 5 m
III	From 5 to 7,5 m
IV	From 7,5 to 10 m
V	From 10 to 12,5m
VI	From 12,5 to 15m
VII	From 15 to 17,5 m
VIII	Over 17,5 m

The error in assigning a vehicle to a class must not exceed 5%. The classification error will be calculated on a sample of 50 vehicles with the following formula:

$$E_{att} = \frac{|Real\ vehicles\ of\ the\ class - Vehicles\ assigned\ to\ the\ class|}{Real\ vehicles\ of\ the\ class} * 100$$

Slow Traffic: This condition is defined as an alarm if in a lane the traffic is moving with average speed below a predetermined threshold via software between 10 and 40 km/h for a defined minimum time via software between 10 and 180 seconds.

Stopped traffic: This condition is defined as an alarm when a lane traffic is stationary or is moving with average speed below a predetermined threshold via software from 0 to 10 km/ h for a defined minimum time via software between 10 and 180 seconds.

Infrastructure Density Context:

Referring to the existing 2L+1E/L Dynamic between the Km 8+400(Intersection Casalecchio A1-A14) and Bologna S.Lazzaro (Km 22+231) the density of gantries supporting all the ITS sub-system is 22 in one direction and the same quantity viceversa, reaching a total of 44.

According to the length of 13.600 mt, we have a gantry every 618 mt, which allow the driver to be constantly updated about the functionality of the dynamic lane.

The capillarity of the ITS systems is high enough to have a full monitoring of the motorway section and capable to deliver the necessary information to TCC operator in charge of managing promptly the opening or the closing of the lane.

In the following pictures (the first one is taken from the software platform “Autotraf “) we have represented the inner section of the existing 2L+1 E/L and two operational gantries.

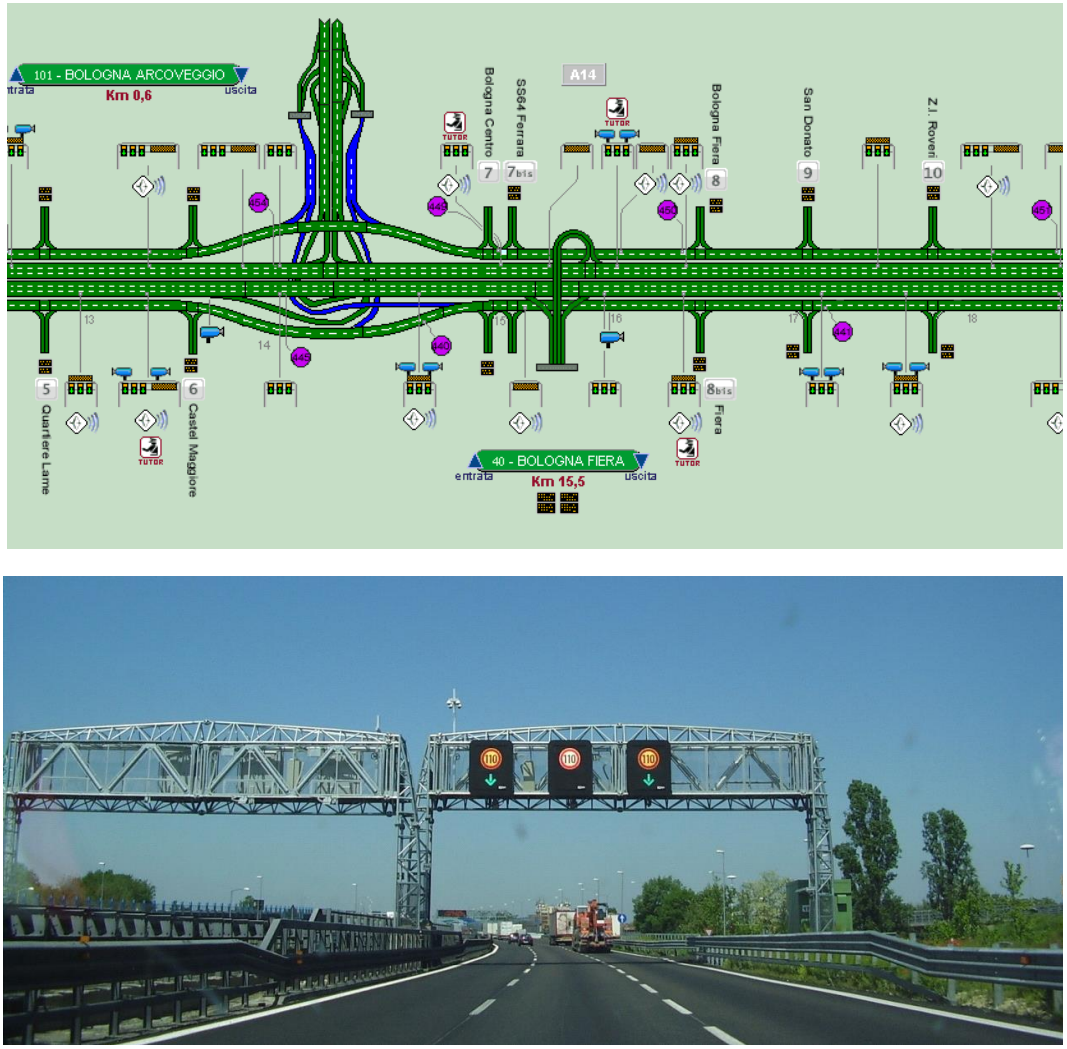

Figure 9: Gantries

3.1.1.2 Example the Netherlands (Tidal flow lanes corridor A1)

GENERAL INFORMATION

Name of service	Tidal flow lanes in median of motorway A1
Web link	www.rijkswaterstaat.nl
Contact	Rudi Kraaijeveld (rudi.kraaijeveld@rws.nl)
Applicable deployment guideline	TMS-DG01 (dynamic lane management)

GEOGRAPHICAL ASPECTS

Country	the Netherlands
Region	Amsterdam area
Location Muiderberg (A1/A6)	Motorway A1 between junction 2 (Diemen) and Motorways interchange
Network concerned	Motorways A1, A6, A9
Length of section	8.5 km
Number of entrances/exits	4

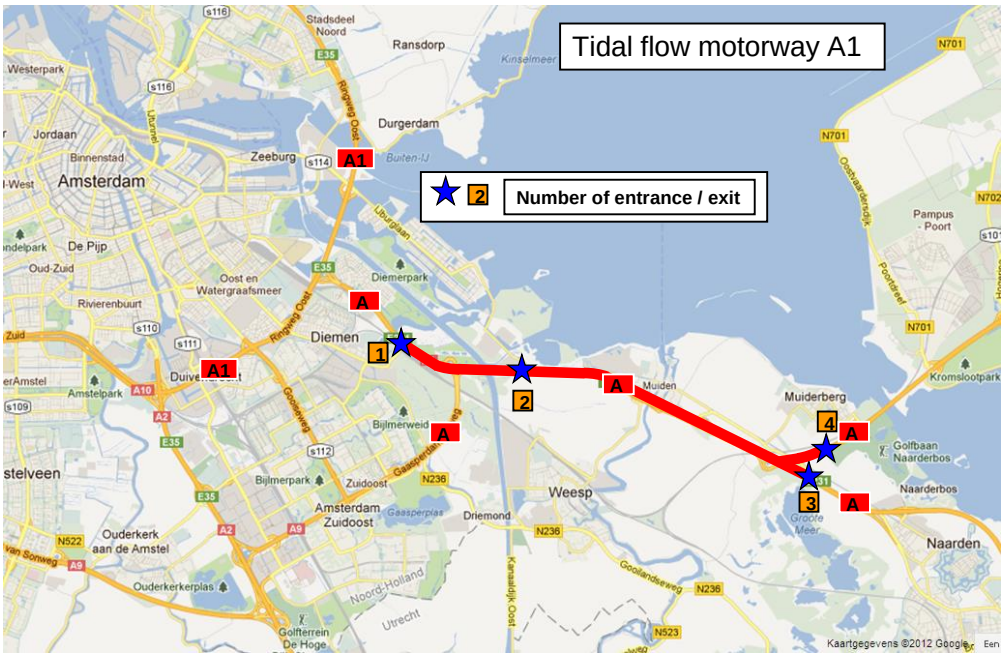

Figure 10: Example The Netherlands

entrance / exit	Motorway section	location	Traffic allocation	
			From	To
Entrance 1	A1	km 7.1	A10 ring road Amsterdam	A1 Amersfoort only (no exit 4)
Exit 1		km 7.1	A1 Amersfoort	A10 ring road Amsterdam

			A6 Almere	
Entrance 2		km 9.9	A1 Amsterdam A9 Haarlem	A1 Amersfoort only (no exit 4)
Exit 2		km 9.9	A1 Amersfoort A6 Almere	A9 Haarlem A10 ring road Amsterdam
Entrance 3		km 15.6	A1 Amersfoort	A9 Haarlem A10 ring road Amsterdam
Exit 3		km 15.6	A1 Amsterdam A9 Haarlem	A1 Amersfoort
Entrance 4 (no exit)	A6	km 41.9	A6 Almere	A1 Amsterdam A9 Haarlem

Table 6: Motorway sections

SERVICE DESCRIPTION

Problems addressed

☒ Reduction of congestion

☒ Optimizing network performance

☒ Utilization of existing road envelope (bridge)

ITS service description

The service deploys an integrated traffic management system with dynamic lane allocation with VMS, dynamic route signing and real time travel time information. Activation of the service by means of decision support system with triggers from network status. Intensified Incident management on the Amsterdam road network Initial response time of incidents is 15 minutes at the highest.

The ITS systems are connected to the regional traffic control centre (TCC in Velsen-Zuid). It includes vehicle detection (loops), CCTV surveillance, lane allocation by means of the existing motorway traffic management system (MTM) and traffic information services generated from a special server (CDMS) and communicated with road users by means of dynamic information panels (DRIPs).

IMPLEMENTATION ASPECTS

Date of implementation

September 1994 (1 lane)

April 2011 (extension to 2 lanes)

Duration of project

17 months (Dec 2009 - Apr 2011)

Type of contract

Design and build

Lessons learned

Early set up of control scenarios for traffic management in early stage of project.

Planning of test procedures technical systems critical (FAT, ISAT).

ILLUSTRATIONS

Figure 11: Birds view of current situation with 2 tidal flow lanes.

Figure 12: Typical cross section of tidal flow lanes in motorway A1

Figure 13: Entrance no. 3 with dynamic route sign (median side). Tidal flow lanes open.

Figure 14: Entrance no. 3 with dynamic route sign

Figure 15: Entrance number no. 3 with closed beam (median side). Tidal flow closed

3.1.1.3 Example the Netherlands (Lane control at work zones on motorways)

GENERAL INFORMATION

Name of service	Lane closure at work zones on motorways.
Web link	www.rijkswaterstaat.nl
Contact	Bob Hamel (bob.hamel@rws.nl)
Applicable deployment guideline	TMS-DG01 (dynamic lane management)

GEOGRAPHICAL ASPECTS

Country	the Netherlands
Region	All regions
Location	All locations with section control systems.
Network concerned	Controlled motorway network
Length of section	Depending from work zone length

Figure 16: Work zone

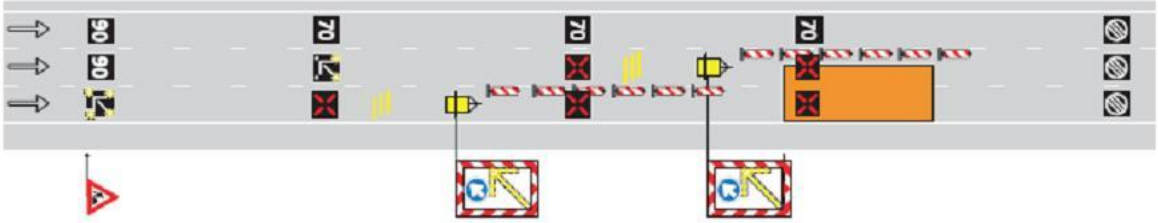

Figure 17: Work zone schematic

SERVICE DESCRIPTION

Problems addressed	Creating safety work zones at road works.
ITS service description	The service deploys a lane assignment system by means of lane closures and speed reduction in order to provide traffic passing through road work zones in a safe way.

IMPLEMENTATION ASPECTS

In work zones on motorways, where a section control system is available and where lane closures are activated, overhead signals are used for lane assignment and variable speed regimes.

In cases of a lane closure from the left or right lane of the carriageway of motorways, the traffic signals are used to guide traffic over the remaining lanes, and this applies regardless of the traffic demand and the duration of the work.

For a unique and effective deployment of a section control system during road works, the following general principles for stationary lane closures are applied:

- The first gantry shows a skewed arrow with flashers and a speed limit of 90 km / h over the remaining lanes in use.
- The second gantry shows a red cross and a speed limit of 90 or 70 km / h.
  50 m after the gantry with the first red cross so called ‘andreas’ strips are placed (at the insertion and removal of these strips is the weighted action with car crash absorber always after the red cross).
- If an open separation (led beacons or cones) is used, the intermediate gantries show one or more red X signs and a repeating speed limit of 70 or 90 km/h.
- If a closed separation (recurring vehicle barrier) is used, the red X sign is not applied on the intermediate gantries. Only a speed limit of 90 or 70 km / h above the lanes are in use.
- The final gantry downstream the working zone shows an ‘end all restrictions' sign.

3.1.2 EIP/EIP+ user and application survey 2013 - 2015

3.1.2.1 Results "Concept and Practicability" questionnaire

Answers were received from one Member State participating to the project URSA MAJOR. Main results from these answers regarding new implementations of the Dynamic Lane Management service related deployments and practicability of the DG requirements can be summarized in the following way:

- *DG requirements were easy to apply*
- *Additional effort or costs for applying the requirements were low or medium*
- *Acceptance of the requirements was high*

In particular, two responses have been received from Italy and all of them find that the functional and organisational requirements are easy to apply with a low/medium cost and with a high acceptance. Opinions become stricter when it comes to technical requirements especially regarding DATEX II profiles that is found hard to apply with a high cost and low acceptance.

Respondents to the questionnaire believe that requirements for tidal flow and lane allocation or clearing under the Common Look & Feel area are easy to apply and generally with low costs and high acceptance.

The overall conclusion is that categories regarding functional, organisational and common look & feel requirements are generally easy to apply with low/medium costs and a high acceptance but when DATEX II is taken into evaluation the fulfilment gets more challenging because some road operators are still operating DATEX I and slowly updating ahead. On the other hand, this situation comes into play when you need to exchange information with others.

3.1.2.2 Results "Compliance checklists" questionnaire

Results from the Compliance checklists questionnaire of categories Functional, Technical and Common Look & Feel requirements can be summarized in the following way:

- All "must" requirements were fulfilled. There was just one deviation reported that regards TR5 and TR6 (DATEX II) where Autostrade del Brennero affirmed that although they are equipped with DATEX II they have difficulties to exchange data with other partners, because few Italian road operators run it.
- All “should” and “may” requirements were fulfilled in all categories (Functional, Technical, Common Look & Feel) and there were no deviations reported.

Results from the Compliance check lists of Operating environments can be summarized in the following way:

- The opinions regarding operating environments are complex. A common EU criterion for safety concern, in terms of vehicles/day per carriageway, seems to be a better approach instead of being able to use an independent threshold that do not allow a confrontation among Member States.
- Another important issue is the evaluation of single or multiple lanes road together with the distinction between motorway or non-motorway, in this case the considerations received indicate that we should not combine class of roads or single lane roads with multiple lane roads in order to have a more specific evaluation and also to avoid confusion. The reason appears obvious to respondents because different kinds of road mean a wider evaluation in terms of thresholds.
- The distinction or separation between urban, peripheral urban and extra urban network or area seems to be a very critical point. The answers show that it is very hard to distinguish where one network ends and where the other begins. Yet, the subject who is able to give a proper answer, could not be found among motorway operators because they manage motorways that have a small relation with urban areas. The management of those networks is run by different Authorities depending on which Member State we are taking into consideration.

- The OE classes and attributes are considered enough to make a full evaluation although a respondent points out that an attribute based classification could give a more specific and better way to determine what we are talking about, leaving no field to interpretation.

3.1.2.3 New best practice examples of deployment 2013-2015

None.

Annex A: Compliance Checklist

3.2 Compliance checklist "**must**"

#	Requirement	Fulfilled?		If no – quote of insurmountable reasons
		Yes	No	
Functional requirements				
FR5	Road clearance monitoring, before applying any dynamic lane management (DLM), it **must** be verified that no car stopped on the dynamic lane or in the lay-bys from where no signs are visible (done by video-cameras and/or police or alternative technologies where appropriate).			
FR7	Site investigation: local control devices **must** be connected to a traffic control centre. Operators in the traffic control centre **must** have access to an interface to remotely monitor traffic detectors and activate all VMS on the carriageway, managed by the centre itself.			
FR8	Safety procedures: they **must** exist in order to apply all safety measures (before and during the DLM process). Safeguarding measures in the form of dynamic road markings, closing and guidance facilities can then be launched.			
FR9	Before the final release it **must** be checked whether the lane concerned is available for the corresponding traffic by means of video monitoring, police, traffic officers or alternative technologies where appropriate.			
FR10	Traffic guidance to road users: suitable information means such as variable message, permanent light signs, multiple-faced signs or prisms, lane lights **must** be used when implementing a dynamic lane management (DLM) system to keep users informed about the availability of lanes.			
Organisational requirements				
OR1	The organisational and operational structure of the service as well as the role of each organisation/body and its tasks **must** be defined.			
OR2	Appropriate procedures **must** be defined for the activation and deactivation of the			

	dynamic management of lanes. These measures should be integrated to the traffic control system.			
Technical requirements				
TR1	Variable message signs for the closure or release of lanes **must** be installed			
TR2	Vehicles detectors **must** be installed (double inductive loops, infrared, microwave, video or radar sensors) along the main carriageway, providing information on the current traffic conditions; in some cases, they are needed to decide whether to activate the DLM process			
TR3	Video surveillance (including CCTV) **must** be implemented for tidal flow, DLM in tunnels and when possible for hard shoulder release.			
TR4	A control centre with operation and visualization, control software, reporting and report archiving system **must** be available			
TR5	In the case road operators have to exchange data requiring interoperability between two or more different organisations, they **must** enable their system to use DATEX II.			
TR6	Services operators intending to display DLM measures **must** be able to integrate the DATEX II publications provided by road operators.			
Common look & feel requirements				
CL&FR2	Normally every VMS **must** display a sign (speed limit, green arrow, yellow/white deflection arrow, “end of restriction” or red cross) over each lane. An exception to this is the use of red crosses over “hard shoulder running lanes” or special “rush hour lanes” that are not in use; in that case there is no need to display any sign on VMS.			
CL&FR3	A yellow/white deflection arrow **must** be displayed before the closure of the lane (red cross) in the case where there are enough VMS in series before.			

CL&FR4	A yellow/white deflection arrow **must not** point towards a lane that appears closed on the next signal gantry.			
CL&FR5	The road operator **must** close only one lane at a time. More than one lane can be closed at a time only if there aren't enough signal gantries to move traffic across a lane at a time.			
CL&FR6	At the end of the DLM zone, normal allocation of lanes **must** be indicated on VMS display either by a green arrow or by an "end of restriction" sign.			
CL&FR9	On the dedicated tidal lane at least one section of the lane **must** be cancelled to traffic prior to DLM implementation: one on both directions.			
CL&FR10	VMS series **must** be installed so as to ensure maximum service visibility.			
CL&FR13	DLM service **must** be activated in accordance with the local signalisation pattern.			
Level of Service requirements				
None				

3.3 Compliance checklist "**should**"

#	Requirement	Fulfilled?		If no – explanation of deviation
		Yes	No	
Functional requirements				
FR1	Dynamic lane management service implementation **should** be carried out following the functional decomposition and sub functions: • Carry out an advisability study • Prepare the Dynamic lane management implementation • Collect and analyse data transmitted from monitoring systems • Monitoring • Decide the relevant Dynamic lane management implementation strategy to apply • Traffic guidance to road users • Track the decision for assessment use Evaluate and assess, measure the impacts in order to provide recommendation and improvement (if possible)			
FR3	Physical layout – the following items shall be taken into account: • acceleration and deceleration ramps **should** be long enough to let vehicles have the time to check the carriageway before entering it, without causing queues enough lay-bys **should** be available to allow vehicles to stop in case of emergency when lanes are allocated (especially for hard shoulder running)			
FR6	The clearing process **should** take place by controlling lane availability. This can be done for the whole section or in stages. To start the clearing process, particularly with lane safeguarding, a yellow/white lane divert arrow (with our without flashing lights) **should** be used as transition signal, before lane closure signs (red crosses) are used in advance of the incident site.			

Technical requirements				
TR7	The mapping of information related to dynamic lane management (DLM) into the DATEX II level A data model is comparably easy. DATEX II has a dedicated class for this type of information called RoadOrCarriagewayOrLaneManagement. This class is a specialisation of the SituationRecord class, hence the information regarding dynamic lane management (DLM) **should** be published via a SituationPublication.			
Common look & feel requirements				
CL&FR1	The display of signs/pictograms on VMS or other end-user devices **should** be in accordance with prevailing national road codes and in line with the requirements of the EW-DG VMS-DG01-VMS Message Design Principles: • MS which ratified the 1968 Convention MUST respect the 1968 Convention and SHOULD consider the Consolidated Resolution on Road Signs and Signals (R.E.2); • MS which did not ratify the 1968 Convention SHOULD follow the 1968 Convention and also consider the R.E.2.			
CL&FR7	When there is a wish to display both a speed limit and a green arrow over the lanes, an additional VMS **should** be used.			
CL&FR8	The distance between 2 VMS series **should** not be too long (suggestion: < 1000m).			
CL&FR11	If lane availability within tunnels is reduced due to planned works or incidents, DLM **should** be activated before the tunnel entrance.			
CL&FR12	Lane allocation **should** remain constant within the tunnel.			
Level of service Requirements				
LoSR1	In the case that pre-deployment surveys/evaluations provide the necessary evidence to proceed with the deployment of the ITS-service “DYNAMIC LANE MANAGEMENT”, the minimum and			

	optimum LoS **should** respect the following Level of Service to Operating Environment mapping table.			

3.4 Compliance checklist "**may**"

#	Requirement	Fulfilled?		If yes –remarks
		Yes	No	
Functional requirements				
FR2	An analysis of traffic flows and current and needed infrastructure **may** be carried out before implementing the service to define whether it is needed or not, if it will bring benefits to traffic efficiency and if it is feasible			
FR4	Monitoring: infrastructure and control equipment **may** be used to monitor the traffic conditions and regulate traffic flows. Monitoring data collection system **may** be able to detect in real time vehicle flow and speed.			
FR11	Public Information Campaign involving the media **may** be organized to explain users the benefits of DLM management, including concrete examples and how to behave when the service is activated. This would help them gaining acceptance of the service.			

4 Annex B: Bibliography

1) S. Bradner, (Network Working Group). Key words for use in RFCs to Indicate Requirement Levels. *The Internet Engineering Task Force (IETF).* [Online] March 1997. http://www.ietf.org/rfc/rfc2119.txt.