Tomorrow's Elastic Adaptive Mobility

D1.0 TEAM users, stakeholders and use cases

Part C Use cases and enablers for infrastructure-centric applications

Dissemination level	PU
Version	1.5
Due date	30.04.2013
Version date	28.05.2013

www.collaborative-team.eu

This project is co-funded by the European Union – DG Connect

Document information

Authors

Nicolas Gay – Intel

Ingolf Karls – IMC

Sebastian Schwardt – Fraunhofer FOKUS

Kay Massow – Fraunhofer FOKUS

Florian Friederici – Fraunhofer FOKUS

Rafael Grote – Fraunhofer FOKUS

Florian Häusler – Fraunhofer FOKUS

Bernd Schäufele – DCAITI

Frederik Diederichs – Fraunhofer IAO

Matthias Prandtstetter – AIT

Francesco Bellotti – University of Genoa

Nikola Zahariev – NEC

Francesco Alesiani – NEC

Roberto Baldessari – NEC

Fabrizio Gatti – Telecom Italia

Sini Kahilaniemi – Ramboll

Timo Hänninen – Ramboll

Rafael Basso – Volvo

Filip Frumerie – Volvo

Marco Bottero – Swarco Mizar

Samson Tsegay – Swarco Mizar

Sven Kopetzki – Delphi

Sebastian Papierok – Delphi

Luisa Andreone – CRF

Filippo Visintainer – CRF

Laura Gatti – RELAB

Stephane Dreher – Nokia

Mark Foligno – Nokia

Mikko Leimio – Nokia

Robert Shorten – National University of Ireland, Maynooth

Rodrigo Ordóñez – National University of Ireland, Maynooth

Arie Schlote – National University of Ireland, Maynooth

Sebastian Stiller – TU Berlin

Panagiotis Lytrivis – ICCS

Angelos Amditis – ICCS

Nikos Floudas – ICCS

Anastasia Bolovinou – ICCS

Clemens Dannheim – BMW

Jan Löwenau – BMW

Coordinator

Dr. Ilja Radusch

Head of department Automotive Services and Communication Technologies,

Fraunhofer Institute for Open Communication Systems FOKUS

Kaiserin-Augusta-Allee 31, 10589 Berlin

Tel: +49 30 914 26 36 474

Email: ilja.radusch@fokus.fraunhofer.de

Project funding

7th Framework Programme

FP7-ICT-2011-8, objective ICT-2011.6.7.a

Large scale integrating project (IP)

Grant Agreement No. 318621

Revision and history chart

Version	Date	Comment
0.1	06.02.2013	Initial collection of contents
0.2	18.03.2013	Included bullet points from Timo (Section 3.5.)
0.3	19.03.2013	Futher sections added
0.4	20.03.2013	Authors extended, minor corrections, missing sections included
0.5	03.04.2013	Introduction added, more improvements on all sections
0.6	07.04.2013	Many text sections added, almost all application and technology use cases finalized
0.7	10.04.2013	New Sections: Conclusion, Stakeholder sections, more use cases
0.8	13.04.2013	Some restructuring, stakeholder sections improved, lots of minor improvements
0.9	14.04.2013	Missing sections filled (3.5, 3.3.2)
1.0	15.04.2013	Last missing sections filled, some review
1.1	26.04.2013	Formatting, LDM++ changes, minor corrections, more review
1.2	08.05.2013	Changes after review
1.3	13.05.2013	New preamble, longer introduction
1.4	27.05.2013	Latest changes, more clarifiying
1.5	28.05.2013	Finalisation

Table of contents

List of figures

1 Applications and enablers for elastic infrastructures

In this Part C of Deliverable D1.0 the work done dedicated to applications for elasic infrastructure is described. In one section a description of the applications for elastic infrastructure and possible uses cases is given. The second section contains a list of identifed enablers derived from these applications. The concept of enablers is described in Part A TEAM users, stakeholders and applications of Deliverable D1.0.

1.1 Introduction

The FLEX sub-project is dealing with flexible energy efficient and eco-friendly mobility from the infrastructure's side based on interactions among all relevant users (i.e. travellers, vehicles, infrastructures). The key concept in FLEX is "elastic" transport infrastructures tailored to the needs of modern cities and their citizens. Through this elasticity at the infrastructure side the orchestrated use of different modes of transport will be promoted with the primary aim to increase traffic efficiency and minimize pollution which is one of the main problems today.

The work inside FLEX is divided into two main parts, that is a set of enabling technologies to realize a flexible and elastic infrastructure (enablers) and a set of collaborative applications. Enablers include data, aggregated data, algorithms and tools which together with the horizontal technologies and subsystems to be developed at the EMPOWER SP will form the key components used by the applications.

FLEX will have strong interactions with both EMPOWER and DIALOGUE sub-projects. EMPOWER will provide the technological basis and the technological components, such as communication and LDM++, on top of which FLEX applications will be built. DIALOGUE will follow the same collaborative aspect as FLEX but the focus will be on the traveller and driver of this collaborative network while FLEX is focusing on the infrastructure side.

The remainder of this chapter is organized as follows: In the next section the stakeholders of FLEX applications and enablers and their characteristics, preferences and constraints are highlighted. In the following, FLEX applications with their relevant use cases are described in detail, as well as a list of possible enablers are outlined. Finally a summary and some conclusions on the work described are drawn.

1.2 TEAM applications to support elastic infrastructures

In this section the elastic infrastructure applications are described. In the first part, a short overview of the application is provided, whereas in the second part the use cases of the application are highlighted. The use cases are the features of the application. The sum of the application's use cases describes the application entirely. The use cases are described after the short overview.

1.2.1 Collaborative pro-active urban/inter-urban monitoring and ad-hoc control

1.2.1.1 Application Overview

A short overview table of this application is given below.

Application name	Collaborative pro-active urban/inter-urban monitoring and ad-hoc control
Application short name / Identifier	CMC
Application short description	TEAM equipped vehicles monitor urban roads and recognize incidents or special events (road closures, work zones, public large-scale events, …) while driving, provide real-time information to the TMC which validates the reliability of this information and optimizes the traffic efficiency. Such innovative paradigm is based both on the information that comes from the vehicle side as a monitoring sensor and proactive traffic management centre through a V2I communication and information from other data sources (e.g. crowd sourcing, mobile devices tracking, …) and existing legacy monitoring system.
Platforms implementing the application	• Smartphone/Vehicle-API • Backbone (traffic management centre) • Third party (data providers, public authorities) (to be further investigated in next project phases and/or next applications specification iterations)
Application objective	This application will become a B2B base for the TEAM categorized application. Since the info will be gathered from different corners

	thanks to the cars used as sensors and also from existing monitoring systems, this application will provide an helicopter view information and control at a wide area network level, that supports other TEAM application to take advantages to the dynamic nature of the information to be used in a real time to coordinate collaborative traffic control in order to reduce congestion, fuel consumption and consequently emissions level.
Basic functioning	Data coming from xFCD enabled collaborative vehicles and mobile devices are collected and mashed up. Traditional road sensors data are included in this fused data set. Then, algorithms for reliable network status forecast are applied. Specific related control policies are actuated, evaluating the impact of these by implementing a double feedback loop approach.
Application's use cases	• Collaborative data collection • Data set completion • Network observation • Definition of multi-layered policies • Application of collaborative pro-active control • B2B info publication
Required lower layer components	• LDM++ • Communication components • Vehicle data provider • Collaborative vehicles xFCD interface adapter • Traffic status estimation and forecast module • Actuation components (to be defined in the next steps of the project) • Web services for B2B information publication

1.2.1.2 Application use case 1: Collaborative data collection

Overview

Use case name	Collaborative data collection
Use case short name	CDC
Use case identifier	SP3_CMC_CDC
Use case short description	In this use case collaborative vehicles connect to the TMC data gateway adapters by means of specific APIs and manage handshake, then send current travel information. Data are matched to the reference map, accepted/rejected, aggregated/fused, processed through a specific reference model and stored in a dedicated data structure to be shared with other TEAM applications and with the software modules related to CMC use cases.
Precondition	• Collaborative vehicles should be equipped with collaborative on-board units • Proper V2I mobile communication resources should be deployed • The Traffic Management Centre should be enabled to manage and process large amounts of data from an hardware and a database structure point of view
Postcondition	Collaborative xFCD are stored in the TMC database Collaborative xFCD are available for other TEAM applications Collaborative pro-active traffic control is applied
Normal flow	Collaborative vehicles connect and handshake with the TMC adapter/interface xFCD are sent to the TMC xFCD are validated/map matched and aggregated by using

	specific interpretation models xFCD are aggregated by using specific data fusion techniques xFCD are stored in the TMC database
Deployment platforms (vehicle/smartphone/ backbone)	Fully vehicle-integrated Backbone (traffic management centre)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Vehicle	Acts as a source of detailed information about traffic status
TMC	Processes and stores xFCD

Input and Outputs

Input	xFCD
Output	Detailed and (geographically) complete traffic info obtained through xFCD collection and analysis

Required functional components

Components short name	Short explanation
LDM++ with cloud	Support to aggregated xFCD storage function (TMC side of LDM++)
Vehicle data or phone data provider	Required for xFCD provision
Communication components	Required for xFCD provision

(LTE, 802.11p)	
User profile	Not required
Other SP2 component	No
Interaction between SP3 and SP4	Strong interaction because of the data exchange between vehicle and the TMC – potential integration of dedicated features for hybrid vehicles equipped with innovative powertrains (e.g. hybrid or electric powered)

Objectives

This use case is aimed at the collection of xFCD from collaborative vehicles and to the provision of an aggregate form of these that can be used to perform the following use cases and the other relevant TEAM applications and use cases. The objective is therefore to have an aggregate vision of the network status starting from the elaboration of collaborative xFCD.

User benefits

- Integration of legacy monitoring systems with travelling collaborative "sensors" (TEAM collaborative vehicles)
- Improved representation of transportation network status
- Reliable and fast information about anomalies
- Further validation of information collected by legacy systems and other, even innovative (such as MAC addresses tracking, see DSC use case), traffic data collection systems

Basic functioning

The modules required to implement this use case are essentially related to the data collection phase and to the processing of such amount of data. The scalability of the resources has to be taken into account in order to have a flexible system able to adapt to higher data flows coming to the centre. Proper algorithms and protocols (e.g. based on the well known s.i.mo.ne protocol for FCD) for xFCD processing will be defined and developed.

Definition of work

- A specialised (or a number of) web service should be developed to allow vehicles to connect, REST architecture should be evaluated
- A common standard protocol should be implemented (e.g. starting from the s.i.mo.ne protocol)
- Specific algorithms and models has to be designed and developed, in order to exploit the information coming from cooperative vehicles in addition to the traditional FCD (id, position, speed)

Possible Challenges

- Penetration of collaborative vehicles
- Management of large amount of data
- Definition of a common communication protocol
- Standardisation of the defined xFCD communication protocol

Comments, additional features

None

1.2.1.3 Application use case 2: Data set completion

Overview

Use case name	Data set completion
Use case short name	DSC
Use case identifier	SP3_CMC_DSC

Use case short description	Data are collected from existing legacy road sensors such as inductive loops, radars, etc... (already integrated in TMC) and mobile devices by dedicated hardware (e.g. MAC addresses scanners, wireless sensor networks) or software solutions integrated with vertical TEAM technologies (potentially LDM++, by using related APIs), applications and/or related to external federated data providers, in order to enable the innovative paradigm of "floating traveller data".
Precondition	Traffic monitoring systems are installed in the area The Traffic Management Centre is ready to integrate external data in addition to collaborative xFCD LDM++ APIs are available Travellers enable MAC-based functionalities of their mobile devices (example of data completion by innovative sources that could be relevant in TEAM) External data providers (e.g. local authorities, social networks managers) agrees on data provisioning
Postcondition	Collaborative xFCD are integrated with other traffic monitoring systems data Floating traveller data are aggregated and stored in the TMC database External data are integrated in the TMC database xFCD are validated and a reliability/accuracy index is associated to the different sources and parameters
Normal flow	• External legacy systems are interfaced to the TMC by specific front-end processors, built using specific proprietary or possibly open APIs • Specific data processing tasks are carried on, according to the collected data type (e.g. devices matching, travel time calculation, etc.)

	• Data are aggregated and stored in the TMC database (possibly into the centre part of TEAM LDM++) • External data providers connects to the TMC database by using the same APIs • LDM++ data are integrated by using specific LDM++ APIs
Deployment platforms (vehicle/smartphone/backbone)	Backbone (traffic management centre) Third party (e.g. data providers)
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
Legacy traffic monitoring systems	Send road traffic data
Traveller	Sends mobile data through his/her mobile device (e.g. by enabling Wi-Fi or Bluetooth, or logging in into a TEAM mobile application)
TMC	Processes and stores other systems data
External data provider	Provides traffic relevant information to the TMC

Input and Outputs

Input	Legacy traffic monitoring systems data Data from mobile devices Data from external providers LDM++ data

Output	Aggregated traffic information

Required functional components

Components short name	Short explanation
LDM++ with cloud	To integrate xFCD info with context-relevant local information coming from LDM++
Vehicle data or phone data provider	Mobile phones data provider can be included as external data providers to integrate xFCD info
Communication components (LTE, 802.11p)	Existing communication infrastructure could be sufficient to support this use case, mobile capabilities are not strictly required
User profile	Not essential (anonymous data collection methods are preferable, such as MAC address tracking)
Other SP2 component	No
Interaction between SP3 and SP4	None

Objectives

This use case is target at the integration of the xFCD data set with other traffic related information coming from legacy traffic monitoring systems, mobile devices, external data providers and, possibly, LDM++ database. Therefore, the objective of this use case is to give to the following use cases the possibility to exploit a large data set, made up of information that come from independent sources and can be validated through cross-comparison enabling reliable traffic status representation and forecast.

User benefits

- Integration of xFCD with an independent data source that can be used for validation
- Integration of external data in a common TMC omni-comprehensive traffic database

- Integration of the omni-comprehesive traffic database with LDM++ database

Basic functioning

The basic modules required here are again related to data collection and integration. Specific APIs will allow external developers to effectively exchange data with the TEAM TMC.

Definition of work

- A specialised (or a number of) web service should be developed to allow data providers and external systems to connect, REST architecture should be evaluated
- The definition of data exchange format with other traffic data providers should take into consideration DATEX 2 as the preferred solution at a B2B level
- Interfaces to facilitate using and exchange data from elaborated traffic data (using Datex 2 as well), public transport data (using the VDV 452 for static and SIRI for dynamic data), routing data) and traffic data for services (using TPEG UML) shall be provided

Possible Challenges

- Integration of many multiple and innovative data sources
- Availability of LDM++ and subsequent integration
- The consideration made for scalability in UC SP3_CMC_CDC are still valid
- Integration of several standards for data integration (see "Definition of work" section)

Comments, additional features

No additional comments.

1.2.1.4 Application use case 3: Network observation

Overview

Use case name	Network observation
Use case short name	NOS
Use case identifier	SP3_CMC_NOS
Use case short description	All the data collected are mashed up and processed in order to obtain reliable traffic forecasts regarding the status of the network in the short and mid term to define estimated LOS, travel time, saturation ratio and forecasted utilisation of the arcs of the road network
Precondition	Use cases SP3_CMC_CDC and SP3_CMC_DSC are completed
Postcondition	The current and the forecasted network status is estimated in terms of LOS, travel time, saturation ratio, forecasted utilisation, etc. This will enable other TEAM vertical applications to run their own tasks based on the knowledge of current and forecasted traffic status
Normal flow	Information coming from use cases SP3_CMC_CDC and SP3_CMC_DSC are processed The results of this process are stored in a specific database structure Relevant data for other vertical TEAM applications are prepared (mainly selected by applying relevance criteria to be defined later in the project) to be integrated with LDM++
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
TMC	Processes information coming from use cases SP3_CMC_CDC and SP3_CMC_DSC and creates current and the forecasted network status

Input and Outputs

Input	Information coming from use cases SP3_CMC_CDC and SP3_CMC_DSC
Output	Current and forecasted network status

Required functional components

Components short name	Short explanation
LDM++ with cloud	Needed as an integration database between this use case (and, more in general, the CMC application) and other TEAM vertical applications.
Vehicle data or phone data provider	No
Communication components (LTE, 802.11p)	No
User profile	No
Other SP2 component	No (to be further analysed in next phases of the project)
Interaction between SP3 and SP4	Potentially all the TEAM vertical applications can be built on the traffic forecasts carried out in this use case. This will increase the level of integration of all the TEAM applications and the accuracy of the forecasts given by the functionalities implemented in this use case will improve the impact of the TEAM applications.

Objectives

The objective of this use case is to provide a reliable current and forecasted network status estimation in terms of LOS, travel time, saturation ratio, forecasted utilisation, this will be used as a reference to execute pro-active control and for all the other TEAM (both FLEX and DIALOGUE applications).

User benefits

- Complete representation of the current and forecasted network status
- Common and reliable traffic forecasts, built using all the available data, to be used by all the TEAM applications

Basic functioning

The observer module, using the data supplied by the generic detection systems, collates the information from the systems, taking into account the attributes of each piece of information (expiry of data validity period, reliability, precision, nature of information etc.) and makes dynamic traffic state estimations that refer to observed network using run-time information received from the previous use cases (e.g. collaborative xFCD, flows, speeds, densities, travel times etc.).

Definition of work

- Estimation of the current traffic state
- Building of an historical traffic information
- Estimation of statewide averaged Origin-Destination flows
- Calculation of traffic forecasting (e.g. in terms of flows or travel time) in the arcs of the road network

Possible Challenges

- Dynamic reliable traffic forecast

- Processing of such amount of data
- Scalability of resources needed for the forecasts (cloud technologies shall be evaluated)

Comments, additional features

- No additional comments

1.2.1.5 Application use case 4: Definition of multi-layered policies

Overview

Use case name	Definition of multi-layered policies
Use case short name	MLP
Use case identifier	SP3_CMC_MLP
Use case short description	Traffic & mobility control policies/scenarios are defined according to operator settings, performance criteria of the network and spot needs both at strategic and tactical level
Precondition	Use case SP3_CMC_NOS is completed
Postcondition	Multi-layered area-wide policies are defined, to be applied to collaborative traffic control systems
Normal flow	TMC operator rules and constraints are collected Traffic management scenarios are defined Information from use case SP3_CMC_NOS are processed according to the abovementioned definitions Multi-layered traffic control policies are defined
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre)

Expected frequency of use	Low

External actors and components

Actors' short name	Short explanation
TMC operator	Defines rules and constraints
TMC	Defines multi-layered collaborative traffic control policies

Input and Outputs

Input	Information coming from use case SP3_CMC_NOS
Output	Multi-layered collaborative traffic control policies

Required functional components

Components short name	Short explanation
LDM++ with cloud	To be used as the database where to store policies to be used by collaborative traffic control systems (e.g. smart intersection)
Vehicle data or phone data provider	No
Communication components (LTE, 802.11p)	No
User profile	Useful to identify the TMC user/operator (this kind of integration should be evaluated in the next phases of the project, since it is a re-utilisation of a component aimed at a slightly different use)
Other SP2 component	No (shall be further investigated later in the project)

Interaction between SP3 and SP4	N/A

Objectives

The objective of this use case is to define the required policies, to be applied to collaborative traffic control systems. The purpose of these policies is to give commands, both at tactical and strategic level, to collaborative traffic systems on how to maximise the performance of the transportation network and to reduce anomalies and disruptions due e.g. to incidents or unpredictable events.

User benefits

- The TMC operator can define area-wide traffic management constraints
- Automatic creation of multi-layered collaborative traffic control policies
- Cooperation on a large scale among different collaborative traffic control systems that will follow common coordination principles

Basic functioning

In the analysis of the basic functioning of this use case it is possible to recognize two chains which represent the system kernel: one is named Strategic and the other Tactical.

Strategic Chain manages the estimated operations of the Origin/Destination matrix and of traffic volumes assignment on the road system, according to the current and forecasted traffic conditions; these estimations are based on a larger calculation time interval. Tactical Chain manages the operations related to the on-line estimation on the status of the monitored network. Data validation and data fusion are implemented in this chain, which provides also historical data (profiles) and elaborates predictions.

The outcomes of these two processes are a number of multi-layered (strategic and tactical) policies to be applied to collaborative traffic control systems.

Definition of work

- An adequate GUI for the operator should be implemented
- Most (or all) the traffic control systems deployed in the area should be considered
- The work to be done is strictly algorithmic and deals mostly with transportation engineering

Possible Challenges

- Integration of different level of traffic management
- Integration of traffic control systems related to other TEAM applications

Comments, additional features

No additional comments.

1.2.1.6 Application use case 5: Application of collaborative pro-active control

Overview

Use case name	Application of collaborative pro-active control
Use case short name	CPC
Use case identifier	SP3_CMC_CPC
Use case short description	The outcomes of use case SP3_CMC_MLP are translated into a set of actions applied by means of different devices systems for collaborative traffic control (e.g. smart intersection), road-side information and routing, continuously validated by double loop control. In addition to this a dedicate set of warnings/events for the vertical TEAM applications is defined
Precondition	Use case SP3_CMC_MLP is completed
Postcondition	Pro-active traffic control is actuated
Normal flow	• Information from SP3_CMC_MLP are collected

	• Local optimisation is performed • Traffic control is actuated at local (tactical) level
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre) Smartphone/Vehicle-API
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
TMC/RSU	Elaborates local actuation
Vehicle	Reports to the user driving feedbacks to the TMC/RSU

Input and Outputs

Input	Multi-layered policies defined in SP3_CMC_MLP
Output	Traffic control action parameters, specific for each subsystem linked (e.g. area-wide policies for public transport priority management in dependence of private vehicles flows)

Required functional components

Components short name	Short explanation
LDM++ with cloud	To be used as the database where to store policies to be used by collaborative traffic control systems (e.g. smart intersection)
Vehicle data or phone data provider	Used to get feedbacks on traffic control from collaborative vehicles

Communication components (LTE, 802.11p)	Used to get feedbacks on traffic control from collaborative vehicles
User profile	No
Other SP2 component	No (shall be further investigated later in the project)
Interaction between SP3 and SP4	This use case is highly integrated with the "Smart intersections" application, which will extend the traffic control functionalities of this use case with particular reference to public transport and special vehicles priority

Objectives

- Definition of traffic control action parameters, specific for each collaborative traffic control subsystem linked. Pro-active collaborative traffic control can be defined as the paradigm that will be achieved by implementing this use case

User benefits

- Travel time reduction
- Congestion reduction
- Emissions reduction

Basic functioning

This use case is conceived as the implementation of a collaborative pro-active traffic control subsystem in the TEAM environment. According to this model, the characteristics of this subsystem will be:

- Capability to quickly react on traffic forecasts done by the SP3_CMC_NOS use case, taking into account to the policies defined in the SP3_CMC_MLP use case
- Capability to drive traffic demand, in order to reach the global optimisation of the transport network and therefore to increase its capacity

- Capability to collaborate with vehicles giving them information about SPaT and collecting feedbacks about relevant tactical control actions (e.g. forecasted vs. actual time to green)

Definition of work

- Mainly, a collaborative traffic control system will developed, based also on double feedback approach coming from TEAM equipped vehicles
- Further, an algorithm for the prediction of traffic actuated control shall be developed.

This algorithm shall be able also to cover adaptive control, like influences by busses, heavy trucks and other specialized vehicles, able to influence the traffic control for prioritisation requests

Possible Challenges

- Development of collaborative pro-active traffic control algorithms
- Implementation of cooperative functionalities (SPaT – Signal Phases and Timing messages exchange among the infrastructure and)
- Integration of "Smart intersections" application

Comments, additional features

No additional comments

1.2.1.7 Application use case 6: B2B info publication

Overview

Use case name	B2B info publication
Use case short name	B2B
Use case identifier	SP3_CMC_B2B
Use case short	Specialised web-services are published to share raw data and

description	processed information with the potential data consumers (mainly other TEAM vertical applications, external data/service providers, public authorities, …)
Precondition	According to the type of data to be published, other use cases of CMC should be completed and related data stored in the TMC database
Postcondition	Raw data and processed information are available to the potential data consumers
Normal flow	• Data has to be stored in specific data sets for information exchange • Specialised web services expose methods to be called by trusted data consumers to get data • Data are transferred
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre),
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
TMC	Exposes web services
Other TEAM application	Consumes data
External data consumer	Consumes data

Input and Outputs

Input	Data coming from previous use cases
Output	Raw data and processed traffic-related information

Required functional components

Components short name	Short explanation
LDM++ with cloud	Tentative use of LDM++ integration by using specific APIs
Vehicle data or phone data provider	No
Communication components (LTE, 802.11p)	No
User profile	Needed for all the security aspects related to trusted data consumers identification
Other SP2 component	No (shall be further investigated later in the project)
Interaction between SP3 and SP4	Strong interactions, because of the B2B data provider character of this use case (in this use case the link between this B2B horizontal application and other TEAM vertical applications will be realised)

Objectives

The objective of this use case is to provide access to raw traffic data, stored in the TMC database, and to processed traffic information data, to all other TEAM application and to trusted external consumers. The added value of this information is the reliability that can be obtained by integrating several data sources and through the complex operations carried out by previous use cases.

User benefits

- Distributed availability of dense and reliable traffic information

- Optimisation of TEAM resources, building a common database for traffic-related information, to be used by all vertical applications
- Possibility to share TEAM ecosystem data with external consumers such as public authorities, data centres, etc.

Basic functioning

This use case can be defined as the Presentation Layer, the top level of the application. It displays information related to the application/services activity in the platform. It communicates with other tiers and with external stakeholders/applications by outputting results to the browser/client tier and all other tiers in the network. The integration of RESTful interfaces could give to this use case significant benefits in terms of organisation of complex data sets and relationships into simpler resources.

Definition of work

- Identity management system
- RESTful dedicated web-services

Possible Challenges

- Management of trusted data consumers identities
- Integration of standard protocols such as DATEX 2, TPEG, …
- Development of newly developed RESTful interfaces

Comments, additional features

No additional comments

1.2.2 Collaborative co-modal route planning

1.2.2.1 Application Overview

A short overview table of this application is given below.

Application name	Collaborative co-modal route planning
Application short name / Identifier	COPLAN
Application short description	The TEAM multi-modal planner, in addition to providing multimodal information, has an omni-comprehensive system view integrated into global network optimization (coming from the "Collaborative pro-active urban/inter-urban monitoring and ad-hoc control" application) and user-centric route planning methods and is able to connect to advanced services like the "Co-modal coaching with support from virtual/avatar users". This application has a high environmental impact, thanks to the inclusion of the more eco-efficient modes (increase in the usage of public transportation), and routes, and through more optimized usage of the whole transportation system.
Platforms implementing the application	Smartphone/Vehicle-API Backbone (traffic management centre)
Application objectives	COPLAN will provide • Collaborative multi-modal route planning as a service for deployed collaborative applications by fusing and aggregating information coming from multiple FLEX and DIALOGUE applications. These include heterogeneous data from e.g. the Collaborative pro-active urban/inter-urban Monitoring and Ad-Hoc Control application such as environmental sensor and traffic-related data, or even information from 3rd parties relevant to real time or/and to predicted/forecasted/planned road incidents, etc. as well as serious gaming aspects from applications such as "co-modal coaching"; The stakeholders/sources from which information can be collected

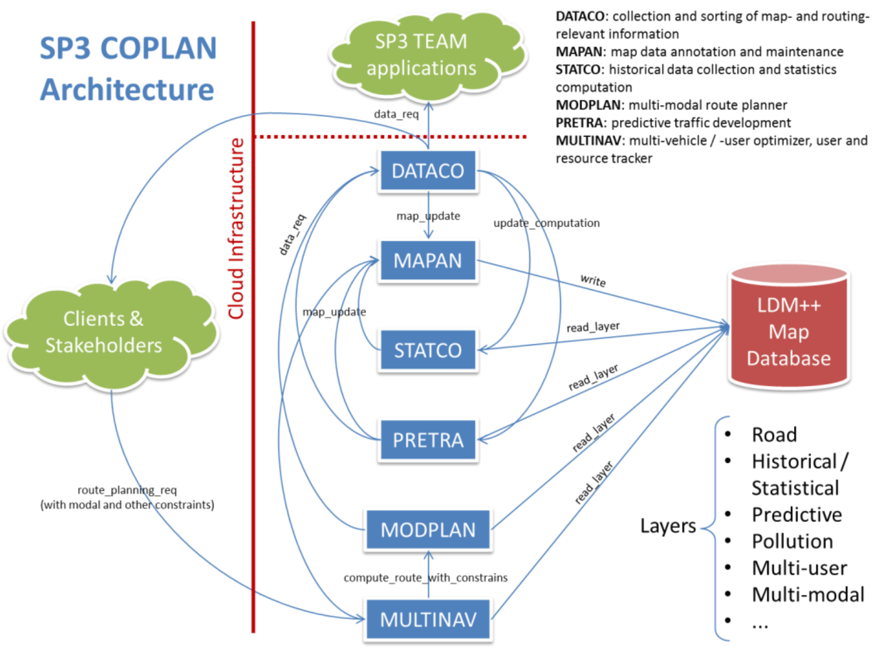
	can be: 1. Public Safety Answering Points (PSAP), police or fire brigade: providing information about an emergency incident that took place on the road, or at a specific location, 2. Municipality services, road operators etc.: e.g. providing information regarding planned civil works that will be performed on a part of the road at specific dates, thus rendering specific roads or lanes inaccessible. 3. Historical traffic related data (e.g. any kind of info gathered from TEAM users). Based on this information, the application will provide end-users with alternative routes and transportation modes based on user-centric info (e.g. origin and destination, Departure time, User preferences (travel time, cost, environmental criteria, number of changes, transportation type, etc.)) ● Statistical information for specific geo-locations upon request, for instance by generating dynamic statistics (e.g. moving average) of a given road intersection or location, or even along a computed route. Statistical information can be derived from processing historical traffic related data, gathered from TEAM users or other stakeholders/sources as described above. In this way, in-vehicle routing algorithms can decide to avoid specific locations (i.e. dangerous crossings, problematic traffic areas, etc.) ● Real-time evaluation and computation of predictive traffic development based on information regarding real-time events as well as on information provided by TEAM users regarding their preferences and decisions (origin, destination, travel time, selected co-modal route); COPLAN uses this predictive information on computed routes to determine whether the current route should be considered or alternatives must be computed. The basic assumption is that the vehicle needs time

	to arrive up to the event, which is changing over time and therefore alters the time-of-arrival continuously. In this context, depending on the interest expressed (e.g. based on origin-destination) and taking into account any kind of available info (3rd parties, historical data), the TEAM system may come up with an additional, more appealing, co-modal route, e.g. a new bus line from A->B or a car-sharing option, and communicate it to the interested TEAM stakeholders/users. • Evaluation of location-specific multi-vehicle routing data to provide feedback information for truly collaborative navigation, i.e. global optimization of a fleet of vehicles collaborating to compute individual routes in a coordinated way, for instance providing additional routing constraints • Optionally, in case a TEAM user selects its own car option and requests a parking space at destination, the system should investigate the possibility to offer a parking upon arrival so as to reduce the travel time, cost, traffic at destination area and environmental impact and the passengers' stress level
Basic functioning	COPLAN receives requests either to evaluate or compute multi-modal routes. It combines information coming from a number of sources, including other FLEX and DIALOGUE applications, in order to provide accurate predictions regarding time-of-arrival and other predictive information and makes suggestions for specific co-modal routes based on specific optimisation criteria. COPLAN complies with metrics-annotated requests of the sort being proposed by SP4 Collaborative Application Framework, so that the application can prioritize requests according to currently available information / resources and can generate adequate constraints for the optimization engine.
Application's use cases [+ DRAFT DESCRIPTIONS]	1. Heterogeneous data and service requests collection, aggregation and compilation 2. COPLAN issues requests to different TEAM services and applications to collect diverse data on traffic state for all

	supported routing modes available in the region. COPLAN uses a layered processing scheme to aggregate data at different granularity levels, i.e. assessing traffic state at different geographic scales. After analysing and bringing heterogeneous data to a common format, COPLAN employs a scoring system for particular locations, paths and regions, according to the supported routing modes. This scheme enables a simpler multi-modal route optimization in a later stage. Annotations are dynamic and contribute to the creation of statistical data (see UC 4) 3. Map data annotation 4. COPLAN annotates maps (e.g. using concepts introduced in LDM++) to enable faster multi-modal route optimization. Map data annotation should be a centralized operation, in order to avoid map inconsistencies. This use-case also involves the actual management of the multiple layers being kept in the LDM++ database. 5. Multi-modal route planning 6. A user request (e.g. complying with SP4 Collaborative Application Framework message protocol) triggers the calculation of a route. The message contains information related to user preferences such as the optimisation criteria e.g. travel time, cost, environmental criteria, number of changes, desired traffic modes (perhaps even with a given priority), etc. COPLAN considers requests made by other traffic actors to optimize traffic even further. 7. Statistical / historical geo-location specific data collection 8. COPLAN collects data in an event- or time-triggered fashion building e.g. a running average of significant traffic data. This information is delivered to other TEAM applications or used to compute routes considering the history of particular locations, roads or regions. Thus, COPLAN will avoid or inform the user of particularly dangerous or problematic locations, roads and

	areas. The computation of co-modal routes should include links / elements from serious gaming applications. 9. Real-time evaluation and computation of predictive traffic development 10. COPLAN can recognize dynamic events from the periodically collected data / historical data (this functionality can also be part of other applications or be in itself an application). Dynamic events may have a geometrical form (point, line, area) and a dynamic evolution (change over time, stored as snapshots at specific time intervals). Such events can be bottlenecks, slow moving traffic, etc. This information can be used to compute predictive behaviour to be involved in the route computation (i.e. the multi-objective, multi-variable optimization algorithm). 11. Multi-vehicle routing data evaluation, computation and large-scale coordination for collaborative navigation 12. COPLAN considers multiple routing requests and previous calculated routes (e.g. based on user preferences and selected tentative travel plans that have been sent to the application) to deliver new routes. Thus avoiding sending too much traffic over the same routes. This UC introduces additional constrains in the optimization algorithm.
Required lower layer components	COPLAN is made up of the following modules (we take each use case specified above as a module performing an specific function): • DATACO: collection of map- and routing-relevant information • MAPAN: map data annotation and maintenance • STATCO: historical data collection and statistics computation • MODPLAN: multi-modal route planner • PRETRA: predictive traffic development analyzer • MULTINAV: multi-vehicle / -user optimizer, user and resource tracker

	The following diagram establishes relations among the different modules:



1.2.2.2 Application use case 1: Heterogeneous data and service requests collection, aggregation and compilation

Overview

Use case name	Heterogeneous data and service requests collection, aggregation and compilation
Use case short name	DATACO
Use case identifier	SP3_COPLAN_DATACO
Use case short description	COPLAN issues requests to different TEAM services and applications to collect diverse data on traffic state for all supported routing modes available in the region. COPLAN uses a layered processing scheme to aggregate data at different granularity levels, i.e. assessing traffic state at different geographic scales. After analysing and bringing heterogeneous data to a common format,

	COPLAN employs a scoring system for particular locations, paths and regions, according to the supported routing modes. This scheme enables a simpler multi-modal route optimization in a later stage. Annotations are dynamic and contribute to the creation of statistical data (see use-case 4, STATCO). DATACO also considers the classification of data as well as its redirection to the corresponding modules (STATCO, PRETRA, etc.), triggering a recalculation of dynamic information on the corresponding layer of the LDM++ based map.
Precondition	SP3_CMC (collaborative monitoring application) delivers data, answering to specific requests. An inference engine is in place at CMC to allow complex requests and perform data pre-processing and filtering. Applications use a standardized messaging system as proposed within the SP4 Collaborative Application Framework to exchange data.
Postcondition	COPLAN issues request to different applications demanding heterogeneous data. COPLAN triggers the update of dynamic information performed by other modules (STATCO, PRETRA, etc.) COPAN collects and processes data in preparation for map annotation.
Normal flow	1. COPLAN issues messages to individual SP3/SP4 applications (COPLAN might talk to individual users when more information is needed to perform a given type of optimization, as originally requested by the requesting SP4 application). These messages are annotated with metrics, for instance regarding latency requirements. 2. SP3/SP4 applications respond according to the requested metrics, providing (or not) the requested information. 3. COPLAN processes the requested data as needed and prepares it for map annotation. The module DATACO performs also filtering and classification of information. 4. DATACO issues update requests to other modules (STATCO, PRETRA, MAPAN, etc.) in order to trigger specific processing of

	the just collected data.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre / cloud), Third party (e.g. public transport operator)
Expected frequency of use	high

External actors and components

Actors' short name	Short explanation
SP3_CMC	This SP3 application is responsible for heterogeneous data collection.
SP4_CONAV	COPLAN might need additional input from particular traffic actors running this application or other running navigation applications related to route planning.

Input and Outputs

Input	Data from other SP3/SP4 apps (e.g. SP3_MCM, SP4_CONAV)
Output	Processed data compatible to LDM++ data format

Required functional components

Components short name	Short explanation
LDM++ with cloud	Need to know in what format data is to be transformed to, in order to be compatible with the LDM++ map annotation scheme.
Vehicle data or phone data provider	SP4_CONAV running on different platforms (vehicle, smartphone, etc.) will provide collaborative route planning requests and additional data might be required from COPLAN (this can be by-passed if the CONAV request

	already has all necessary information → requirements to the TEAM-specific messaging format)
Communication components (LTE, 802.11p)	NA
User profile	NA
Other SP2 component	NA
Interaction between SP3 and SP4	Message exchange, messaging protocol Sensor data format

Objectives

Gather data relevant to COPLAN for collaborative route planning, predictive traffic development / evolution, historical / statistical map annotation and other, and annotate it with a location-specific scoring scheme.

User benefits

Concentrate all external data requests from COPLAN into a single, for this specific end specialized module.

Basic functioning

A separate module or thread within the COPLAN application (e.g. the DATACO module) will gather and process information "in parallel" to requests being made to COPLAN. Other modules (or threads) will use the processed information to fulfil requirements of other use-cases in COPLAN. DATACO can also receive specific data requests, for instance via MODPLAN, which DATACO must broadcast to other application or services.

Definition of work

- TEAM-specific, cross-application, messaging and data exchange protocol (message format, inter-application communication protocol) for application interoperability must be defined and implemented. A proposal for a TEAM-specific Collaborative Messaging protocol is being prepared in SP4.

- TEAM-specific / ITS sensor data format with support for streaming data sources.
- Inference engine to perform complex queries, eventually supporting data pre-processing, filtering, aggregation and sensor data fusion.
- Data processing engine to bring all collected data to an LDM++ compatible data format.
- Facility to instantiate remote/local data streaming modules/entities in SP3 / SP4 applications themselves or locally that periodically send/retrieve information for DATACO. The communication / data exchange protocol makes sure that if DATACO does not acknowledge the reception after a number of retries, the instantiated module/entity is killed and resources are freed up.

Possible Challenges

Compliance with real-time requirements of SP4 applications.

Comments, additional features

SP3_MCM will provide input to DATACO module following a common format for information request and delivery.

1.2.2.3 Application use case 2: Map data annotation

Overview

Use case name	Map data annotation
Use case short name	MAPAN
Use case identifier	SP3_COPLAN_MAPAN
Use case short description	COPLAN annotates maps to enable faster multi-modal route optimization. To this end, MAPAN employs the data collected, aggregated and compiled by DATACO and STATCO and issues

	write requests to the LDM++ map database in a centralized way.
Precondition	COPLAN gets data from other SP3/SP4 applications and processes it in an LDM++ compatible format.
Postcondition	COPLAN provides routing information with annotated LDM++ maps which are periodically / asynchronously refreshed. MAPAN updates LDM++ layers depending on the information provided by DATACO, STATCO, PRETRA, etc.
Normal flow	1. MAPAN receives map update requests from other COPLAN modules (which work fully asynchronous). 2. MAPAN refreshes the corresponding LDM++ layer in the map database using a double-buffering scheme to avoid accessing maps being currently updated, hence offering 100% service availability to other applications and modules that might concurrently issue a read request to the map database.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre / cloud), Third party (e.g. public transport operator)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
None	MAPAN module is internal to COPLAN

Input and Outputs

Input	LDM++ data from DATACO, STATCO, PRETRA, etc.
Output	Annotated LDM++ layers.

Required functional components

Components short name	Short explanation
LDM++ with cloud	MAPAN will maintain LDM++ based maps
Vehicle data or phone data provider	NA
Communication components (LTE, 802.11p)	NA
User profile	NA
Other SP2 component	NA
Interaction between SP3 and SP4	NA

Objectives

- Maintain annotated LDM++ maps for COPLAN
- Assure 100% availability upon requests

User benefits

Improved map database manageability due to centralized write operations.

Basic functioning

MAPAN works as a separate module or thread within the COPLAN application. It receives update requests from DATACO, STATCO and other modules or applications, getting LDM++ formatted data, in order to update LDM++ based maps.

Definition of work

1. Determine type and range of database operations related to map annotation, possibly including high-level database management operations based on requirements of modules making up COPLAN.
2. Implement operations in specific communication messages in order to streamline individual access operations.
3. Test operations under different conditions including simultaneous requests from different modules and intensive workloads (e.g. a large number of vehicles / traffic participants accessing the service and concurrently modifying the LDM++ database).

Possible Challenges

Ability to provide simultaneous access operations under very large workloads. Solution: provide a database architecture and overall TEAM architecture delivering linear scalability.

Comments, additional features

None

1.2.2.4 Application use case 3: Multi-modal route planning

Overview

Use case name	Multi-modal route planning
Use case short name	MODPLAN
Use case identifier	SP3_COPLAN_MODPLAN
Use case short description	A client request (e.g. complying with SP4 Collaborative Application Framework message protocol) triggers the calculation of a route. The message contains information as to what traffic modes may be used with a given user-assigned priority.
Precondition	• Existence of LDM++ annotated maps provided by MAPAN • Multiple / individual requests from SP4_CONAV for large-scale,

	multi-vehicle, multi-modal route planning
Postcondition	MODPLAN provides the actual multi-modal, multi-vehicle/actor route planning for external applications (SP4, SP3).
Normal flow	1. A route planning request is accepted. 2. The optimization engine employs navigation profiles (e.g. "in a hurry", "Sunday drive", "Emergency", etc. → ties to serious gaming) and additional information (e.g. prioritized, desired/available multi-modal options: car, bus, train, underground, bicycle, walk, etc.) to establish priority lists which help in the optimization process. 3. The information collected in point 2 is combined with map information (as provided by STATCO, DATACO, PRETRA, MULTINAV, etc.). If additional information is required, MODPLAN issues requests to the corresponding module, which will collect the data and eventually trigger a map update through MAPAN. 4. MODPLAN generates a potential route and eventually iterates between point 3 and 4, when any of the other modules issues a map update request.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre, SP3 cloud infrastructure), Third party (e.g. public transport operator)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
NA	NA

Input and Outputs

Input	• LDM++ maps • Route planning requests with constraints (prioritized traffic modes, prioritized routes depending on number of routed actors, traffic density, etc.)
Output	• Routes for individual SP4 applications, for instance CONAV. • Event-triggered route update requests (considering also that the actor might be unreachable). • List of messages / warnings along the way as extracted from the LDM++ map

Required functional components

Components short name	Short explanation
LDM++ with cloud	MODPLAN must have access to LDM++ annotated maps in order to compute new routes.
Vehicle data or phone data provider	NA
Communication components (LTE, 802.11p)	NA
User profile	NA
Other SP2 component	NA
Interaction between SP3 and SP4	NA

Objectives

To provide large-scale, multi-modal route planning considering multiple constraints to requesting services and applications.

User benefits

- MODPLAN provides optimized large-scale routing services considering a large number of constraints including multiple traffic modes (car, bus, train, underground, walk, bike, etc.), statistical / historical information, predictive traffic development, weather, environmental conditions, energy consumption, total cost, vehicles being already routed, current traffic conditions along the way, etc.
- The service is provided in a per-user basis, allowing dynamic changes and re-computing the route as long as the user has not reached its desired destination.
- The service provides event-triggered routing updates to the user, tracking events along the computed route.

Basic functioning

As described in the normal flow. MODPLAN should be, as all other modules in COPLAN, a separate module.

Definition of work

1. Define user profiles including parameters that comprise such a profile

2. Elaborate on the optimization and route planning algorithms to include parameters from other modules (STATCO, DATCO,. PRETRA, MULTINAV, etc.) as well user profile parameters

3. Develop a linearly scalable optimization and route planning engine that involves the algorithms develop in point 2. Provide mechanism to map the engine on distributed facilities or with the ability to communicate and interact with remote applications performing the same task, i.e. a MODPLAN module running on another system.

4. Test the optimization and route planning engine against different workloads and conditions.

Possible Challenges

Ability to provide global optimization when several instances of MODPLAN are running in different locations and facilities. Solution: provide layered communication facilities to allow internetworking between remote applications. Include mechanisms to deliver distributed optimization.

Comments, additional features

None

1.2.2.5 Application use case 4: Statistical / historical geo-location specific data collection

Overview

Use case name	Statistical / historical geo-location specific data collection
Use case short name	STATCO
Use case identifier	SP3_COPLAN_STATCO
Use case short description	COPLAN collects data in an event- or time-triggered fashion building e.g. a running average of significant traffic data. This information is delivered to other TEAM applications or is used to compute routes considering the history of particular locations, roads or regions. Thus, COPLAN will avoid or inform the user of particularly dangerous or problematic locations, roads and areas. The computation of co-modal routes should include links / elements from serious gaming applications.
Precondition	Existence of traffic-relevant data (events) associated with particular locations, roads, landmarks, etc. Specific events can be derived through data aggregation and sensor data fusion, e.g. average vehicle speed in a given street segment / point at a certain time of the day, other events are more straightforward, e.g. number of accidents at a given road crossing or along a road segment.
Postcondition	STATCO generates LDM++ annotated maps (through MAPAN) with historical / statistical data that is used to avoid or reduce traffic through certain locations, road segments, crossings, etc., to warn or

	to inform the user of potential risks, or to trigger safety actions in other applications.
Normal flow	• STATCO filters data coming from DATACO or triggers specific requests to DATACO. • Data is aggregated to specific geographic features with specific geo-locations (crossing/point, road, landmark, road segments, area, etc.). The reason behind this is that specific events might be annotated with slightly different geo-locations. Also a given event can contribute to several different categories. • This information which is associated with specific events and geo-locations and geographic features is examined in connection to previous entries in a LDM++ map with annotated historical / statistical data. • STATCO then calculates a running average (if relevant), or the pertinent / relevant / required statistical feature or magnitude. STATCO issues an annotation request to MAPAN in order to update the historical / statistical LDM++ layer.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre, TEAM cloud infrastructure), Third party (e.g. public transport operator)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
None	

Input and Outputs

Input	Specific events associated with geo-locations
Output	Annotations to the historical/statistical LDM++ layer, which is used by MODPLAN to calculate new routes considering associated statistical data

Required functional components

Components short name	Short explanation
LDM++ with cloud	Indirectly. STATCO provides data to MAPAN module to annotate LDM++ maps with historical / statistical data on specific locations, landmarks, roads, etc.
Vehicle data or phone data provider	NA
Communication components (LTE, 802.11p)	NA
User profile	NA
Other SP2 component	NA
Interaction between SP3 and SP4	NA

Objectives

- To provide statistical / historical data associated with potential risks (e.g. in areas such as safety, comfort, etc.) for the computation of routes

User benefits

- The user will get a route which avoids or tries to reduce traffic through historically/statistically dangerous locations, road segments, crossings, etc.

- The user will also be informed of potential risks if the route unavoidably passes through dangerous locations.
- Applications requesting a routing service with this feature active will be able to trigger appropriate safety actions.

Basic functioning

As described in the normal flow above. STATCO should also be implemented as a separate module, unit or thread that works in parallel to other modules in COPLAN.

Definition of work

- Need to determine what type of specific events are to be recorded. Could we make this list upgradeable / extensible? Should associate events with a given "risk level" in order to better weight risks during the optimization phase (route planning).
- Need to develop a data aggregation/sensor fusion engine for specific geographic features at different scales (same as by DATACO → enabler).
- Statistics engine: what kind of statistical data is to be computed, e.g. running average, mean, normal deviation, etc. i.e. how should the statistical distribution be characterized? What kind of information has relevance for route planning?

Possible Challenges

Data might not be enough (or too widespread) to clearly determine a statistical pattern or distribution

Comments, additional features

None

1.2.2.6 Application use case 5: Real-time evaluation and computation of predictive traffic development

Overview

Use case name	Real-time evaluation and computation of predictive traffic development
Use case short name	PRETRA
Use case identifier	SP3_COPLAN_PRETRA
Use case short description	COPLAN can recognize dynamic events from the periodically collected data. Dynamic events have a form (e.g. point, line, area) and a dynamic evolution, i.e. change over time, stored as snapshots at specific time intervals. Such events can be bottlenecks, slow moving traffic, etc. This information can be used to compute predictive behaviour to be involved in the route computation, i.e. the multi-objective, multi-variable optimization algorithm) or be forwarded to the requesting client.
Precondition	Existence of reliable multi-modal traffic sensors or data (streaming) sources.
Postcondition	The system can detect and track the current development / evolution of traffic and generate predictions as to what the future development / evolution of specific events will be (traffic jams, slowly moving traffic, density changes, etc.) in a number of time- and geo-scales. This information can be considered during route computation or be forwarded to the user or other applications for e.g. strategy changes.
Normal flow	1. PRETRA maintains several layers in the LDM++ map database dealing with historical traffic conditions. Each layer comprises a given geographic scale and contains geometric objects and diverse annotations that encode spatially distributed traffic events, for instance a traffic jam on a given road, 2. PRETRA access the current traffic condition map (layer "road")

	and based on already identified objects, it looks for the same object with (slight) geometrical changes. PRETRA also detects new conditions (i.e. objects). 3. Upon object identification, it stores a snapshot of the current traffic condition map. 4. PRETRA then analyses a number of map snapshots to determine short and long term evolutions of the identified objects. PRETRA also looks for clues to these objects in other information sources, by issuing data requests with specific goals, e.g. event originating a traffic jam, or by analysing collected data in the LDM++ map database. These clues and their associated quality might alter predictions. 5. PRETRA then provides predictions in different time-scales (e.g. several layers each corresponding to a given time scale). These predictions constitute constraints that COPLAN's other modules, particularly MODPLAN, employ in their computations. 6. PRETRA might also provide periodic updates to clients requesting its services, which might for instance trigger a new route planning on an already existing route.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre, TEAM cloud infrastructure), Third party (e.g. public transport operator)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
None	PRETRA is internal to COPLAN

Input and Outputs

Input	• Current traffic conditions map • Annotated events affecting traffic (in a general sense, traffic is here multi-modal)
Output	Maps (layers) for different time scales with short and long term predictions of spatially distributed events (i.e. traffic objects) which pose routing constraints to other route planning modules in COPLAN.

Required functional components

Components short name	Short explanation
LDM++ with cloud	Integral part of COPLAN
Vehicle data or phone data provider	NA
Communication components (LTE, 802.11p)	NA
User profile	NA
Other SP2 component	NA
Interaction between SP3 and SP4	NA

Objectives

PRETRA will provide short and long-term multi-modal traffic evolution predictions at different geographic and temporal scales, which pose additional constraints to other route planning modules in COPLAN.

User benefits

Improving traffic routing and time-of-arrival prediction by considering short- and long-term spatially distributed events affecting multi-modal traffic.

Basic functioning

As other modules in COPLAN, PRETRA constitutes an independent module. Its basic functioning is described in the normal flow above.

Definition of work

- List of traffic-affecting/-related objects that should be identified by PRETRA
- Algorithms to identify these objects
- Traffic / object prediction engine

Possible Challenges

Ability to provide traffic predictions requiring specific real-time / latency constraints. Solution: provide a hierarchical system architecture that is able to deal with events in different time and spatial scales. Enable interapplication messaging protocols supporting prioritized requests in order to speed up message forwarding, but particularly enforcing real-time operations, i.e. specific latency requests.

Comments, additional features

None

1.2.2.7 Application use case 6: Multi-vehicle routing data evaluation, computation and large-scale coordination for collaborative navigation

Overview

Use case name	Multi-vehicle routing data evaluation, computation and large-scale

	coordination for collaborative navigation
Use case short name	MULTINAV
Use case identifier	SP3_COPLAN_MULTINAV
Use case short description	COPLAN considers multiple routing requests and previous calculated routes to deliver new routes, thus avoiding sending too much traffic over the same routes. MULTINAV will keep track of existing actors and their routes. It will assign and re-assign route priorities and issue requests for route re-computation in case of conflicting situations, and thus introduce additional constrains in the optimization algorithm.
Precondition	The main condition is the existence of a number of clients requesting use of COPLAN on the same geographical zone. If the number of clients is high enough, multi-vehicle optimization is required to avoid increasing the impact of routed traffic over already loaded routes and to avoid routing too many TEAM actors over the same roads, which might potentially cause interference / disturbances among users of the same service.
Postcondition	COPLAN takes into account already routed traffic as well as concurrent routing requests to compute new routes or eventually re-compute old ones. In this way a better traffic load balancing both in terms of geographical and temporal scale is achieved.
Normal flow	1. Multiple requests for route planning are accepted, these can be fully asynchronous, so that new requests must be fitted to and may possible alter already calculated routes. All requests are queued and assigned a given priority, which depends on a number of factors like e.g. navigation profile, request age, etc. Existing routes –which have been already assigned to specific traffic actors- might change their priority, for instance if a safety relevant actor (e.g. ambulance) makes a request. Otherwise existing routes have a higher priority than those assigned to newcomers. 2. MULTINAV keeps track of all routed actors, their actual position

	and heading. When a new routing request is accepted, MULTINAV issues a routing request to MODPLAN, thereby adding further constraints given by existing routes. To this end, MULTINAV maintains an LDM++ layer in the map database with current actors, their current characteristics (position, heading, velocity, etc.), and their assigned routes. If an actor is detected to deviate from the current route, a route re-computation is issued to MODPLAN. 3. "Living routes" are distributed among participants and these receive updates as soon as traffic conditions change and thus alternative routes must be generated 4. Traffic actors using the service provide feedback in the form of actor position, velocity, direction, etc. to MULTINAV through the user-level applications (SP4) and these in turn through the supporting sub-services in COPLAN. As the actors move around, new updates to the existing routes on the LDM++ map are generated, thus freeing up map resources. MULTINAV takes care of issuing update requests to maps due to the dynamic nature of already in-place routes.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre), Third party (e.g. public transport operator)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
None	MULTINAV is an internal module to COPLAN

Input and Outputs

Input	Routing request from external TEAM actors. This is the main entry point for clients and stakeholders requests, since MULTINAV keeps track of multiple traffic participants being routed. MODPLAN is only the route planning engine, which only computes a new route under a number of constraints (from the MODPLAN's perspective these constraints are static, map updates trigger a route re-computation).
Output	Multi-user / vehicle, multi-modal routing LDM++ based maps.

Required functional components

Components short name	Short explanation
LDM++ with cloud	Read operations to LDM++ map database
Vehicle data or phone data provider	NA
Communication components (LTE, 802.11p)	NA
User profile	Eventually
Other SP2 component	NA
Interaction between SP3 and SP4	NA

Objectives

MULTINAV tracks multi-modal TEAM actors and generates multi-route constraints for MODPLAN. MULTINAV builds up the main entry point to external TEAM requests (SP4 applications). It prioritizes requests depending on a number of factors and thus simplifies the multi-vehicle optimization problem to a single-vehicle optimization problem with additional routing constraints.

User benefits

- Improve mobility by avoiding jams and general traffic slow down of already routed vehicles (e.g. assuming a large number of vehicles and traffic actors employing the TEAM infrastructure).

Basic functioning

MULTINAV should be implemented as a separate module. MULTINAV will work as follows:

1. Multiple requests for route planning are accepted, these can be fully asynchronous, so that new requests must be fitted to and may possible alter already calculated routes. All requests are queued and assigned a given priority, which depends on a number of factors like e.g. navigation profile, request age, etc. Existing routes –which have been already assigned to specific traffic actors- might change their priority, for instance if a safety relevant actor (e.g. ambulance) makes a request. Otherwise existing routes have a higher priority than those assigned to newcomers.
2. MULTINAV keeps track of all routed actors, their actual position and heading. When a new routing request is accepted, MULTINAV issues a routing request to MODPLAN, thereby adding further constraints given by existing routes. To this end, MULTINAV maintains an LDM++ layer in the map database with current actors, their current characteristics (position, heading, velocity, etc.), and their assigned routes. If an actor is detected to deviate from the current route, a route re-computation is issued to MODPLAN.
3. "Living routes" are distributed among participants and these receive updates as soon as traffic conditions change and thus alternative routes must be generated.
4. Traffic actors using the service provide feedback in the form of actor position, velocity, direction, etc. to MULTINAV through the user-level applications (SP4) and these in turn through the supporting sub-services in COPLAN. As the actors move around, new updates to the existing routes on the LDM++ map are generated, thus freeing up map resources. MULTINAV takes care of issuing update requests to maps due to the dynamic nature of already in-place routes.

Definition of work

1. Define prioritization mechanisms and classification, so that requests can be univocally queued. Define rules to avoid inconsistencies and conflict definition.

2. Define and develop mechanisms to provide real-time feedback from actors that have requested the route planning service. This feedback will update in real-time the LDM++ database, keeping track of individual traffic actors and will enable the creation of "living routes".

3. Define and provide mechanisms to seamlessly deliver route updates to current traffic actors.

4. Implement a monolithic, scalable software module.

5. Perform tests including workload scalability.

Possible Challenges

Ability to provide further optimization by a large number of traffic participants. Solution: define "knock-out" rules beyond which no more constraints can be included.

Comments, additional features

None

1.2.3 Co-modal coaching with support from virtual/avatar users

1.2.3.1 Application Overview

A short overview table of this application is given below.

Application name	Co-modal coaching with support from virtual/avatar users
Application short name / Identifier	CCA
Application short description	This is a co-modal app with post trip cost/benefit analysis functionalities, made through a comparison of the behaviours of the real user and the "virtual" avatar user. The proposed idea does not aim on vague pre-trip forecasts but reliable and exact post-trip information about realized trip alternatives a user would have had for the same origin-destination pair including monitoring and displaying their true costs, travel times and CO_2 emissions based on real-time knowledge about occurred traffic jams or delays in public

	transport, private transport etc.
Platforms implementing the application	Smartphone/Vehicle-API Backbone (traffic management centre)
Application objective	The idea in here is to understand the users' mobility patterns and provide co-modal real-time route recommendations, that integrate environmental footprint costs on post planned journey, offering travellers the opportunity to choose the most environmental friendly alternative of mode for their journey by making.
Basic functioning	A comparison will be made through real time monitoring the individual route of a user and the encountered trip alternatives of an avatar travelling by optimal transport modes from the same origin to the same destination at mostly the same time. Such cost-benefit analysis can create good understanding on a user in taking decisions about a real mobility options on his next trips. The integration of this app with collaborative and social aspects of TEAM will further increase its end-user impact.
Application's use cases	O/D recognition User/Avatar preferences setting Avatar trip simulation On-trip Avatar coaching Post-trip Avatar coaching
Required lower layer components	Components related to application "Collaborative pro-active monitoring and ad-hoc control" to get all the traffic information needed to perform the coaching function Vehicle HMI (for in-vehicle coaching) – this components belongs to DIALOGUE enablers Smartphone HMI (for public transport on-trip and post-trip travellers coaching)

1.2.3.2 Application use case 1: O/D recognition

Overview

Use case name	O/D Recognition
Use case short name	ODR
Use case identifier	SP3_CCA_ODR
Use case short description	ODR attempt to provide to the use the most probable destination and route; this implies that the user has provided his trip history and that the application computes the possible mode of transport for each destination; The information is also used in other applications or use cases to predict the user behaviour.
Precondition	The user provides the trip history and his/her activity schedule. This is obtained using a dedicated application and information from social media and more, particularly Twitter.
Postcondition	The application has now the possible destinations and routes of the user
Normal flow	• The user inputs his data • Information from Twitter regarding the mobility behaviour of the user is accumulated • The user trip is recorded • The system computes a trip profile for the user • At the next trip the system provides possible destination, activity type and route to the user • The user can select among the possible routes/destination
Deployment platforms	Smartphone

(vehicle/smartphone/ backbone)	Vehicle API Backbone
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Traveller / Device	The traveller interfaces the system via an HMI and provides information to the platform.
Backbone/TMC	Identifies origin and destination of the trip of the travellers, self-learns preferred origins and destinations
Other Components	Other components belonging to other co-modal TEAM applications will use the information provided by in this use case

Input and Outputs

Input	• Trip history of the traveller • User's Tweets • Traveller preferences
Output	• Most probable destinations • Most probable routes • Most probable routes

Required functional components

Components short name	Short explanation
LDM++ with cloud	No (further analyses will be carried out during the next

	phases of the project)
Vehicle data or phone data provider	• Data from the vehicle • Data from Twitter • External Probe data provider can be an additional source of information
Communication components (LTE, 802.11p)	Use to exchange data with the mobile device that is the interface with the traveller
User profile	Needed to identify the kind of user and preferred destinations
Other SP2 component	No
Interaction between SP3 and SP4	SP4: This feature may be common to SP4 application

Objectives

- Provide to the traveller and other components the most probable destination and origin of travel
- Provide to the traveller and other components the most probable route of the traveller

User benefits

Provide to user suggestion on actual interested destination a given number of the times (to be defined later in the project)

Basic functioning

The algorithm to be developed in this use case is able to identify the behaviour of the traveller and therefore to learn the preferred destinations e.g. depending on the time of the day and on the day-type (holiday/working day)

Definition of work

The software module takes some time to identify the possible destination of the traveller

- When the boundary conditions of each identified trip are repeated, the preferred O/D is proposed to the traveller
- If the proposed O/D is wrong, the module accepts a new itinerary (possibly interfacing with COPLAN or CONAV applications)

Possible Challenges

- User not sharing information
- Privacy of user data

Comments, additional features

No additional comments

1.2.3.3 Application use case 2: User/Avatar preferences setting

Overview

Use case name	User/Avatar preferences setting
Use case short name	UPS
Use case identifier	SP3_CCA_UPS
Use case short description	The user sets his preferences in terms of special needs, preferred transport means, etc. giving also a weighting factor to the reference parameters used for the calculation of the ideal path (CO_2 emissions, travel time, fuel consumption).
Precondition	The user installed the avatar application The user has registered/logged into the application

Postcondition	The user and Avatar preferences are defined
Normal flow	The user logs in into the application The user sets preferences Preferences are stored by the application
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone/Vehicle-API Backbone (traffic management centre, trip planner server)
Expected frequency of use	Low

External actors and components

Actors' short name	Short explanation
Traveller	Sets preferences
TMC	Stores preferences

Input and Outputs

Input	Preferences regarding the relevance of CO2 emissions, travel time, fuel consumption parameters
Output	User profile

Required functional components

Components short name	Short explanation
LDM++ with cloud	No
Vehicle data or phone data provider	No

Communication components (LTE, 802.11p)	Communication between the mobile device (or the vehicle) and the TMC
User profile	Extremely relevant for the execution of this use case (set of weight for different parameters)
Other SP2 component	No
Interaction between SP3 and SP4	Interaction regarding the in-vehicle coaching of the driver, which could be based on vehicle API and on the on-board HMI

Objectives

The objective of this use case is to define the preferences of the user in a standardised way, in order to understand his perception of the benefit in terms of CO2 emissions, fuel consumption, and travel time. This could enable the categorisation of users according to the relevance given to each of these parameters.

User benefits

- Clear definition of the parameters involved in the analysis
- Enabling easy traveller profiling

Basic functioning

This use case should be based on a simple graphical interface, maybe web (or mobile application) based, to give to the traveller the possibility to easy set coaching parameters. Special needs such as motion disabilities and/or visual impairment could be taken into account.

Definition of work

- A web portal and/or a web application should be implemented
- The same portal/application will be used for the functionalities inked to other use cases

- Back-office data management will require secure identity management

Possible Challenges

- User privacy
- Definition of a reliable relationship between different optimisation parameters in order to reach a satisfactory global optimisation

Comments, additional features

- No additional comments.

1.2.3.4 Application use case 3: Avatar trip simulation

Overview

Use case name	Avatar trip simulation
Use case short name	ATS
Use case identifier	SP3_CCA_ATS
Use case short description	According to the network information coming from the TEAM application Collaborative pro-active urban/inter-urban monitoring and ad-hoc control, the trip of the Avatar is simulated – the simulation is updated during trip with current network conditions
Precondition	The traveller has registered/logged in into the application The traveller shared its O/D information The traveller has set preferences
Postcondition	The optimal path is simulated and updated according to traveller preferences and dynamic events (e.g. congestion, incidents, …)
Normal flow	• O/D are collected

	• relevant current traffic conditions info are collected • co-modal trip simulation is performed • relevant current traffic conditions info are updated every given number of seconds • co-modal trip simulation is updated
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
TMC	Get user preferences, get dynamic traffic info, get public transport info, simulates the Avatar trip

Input and Outputs

Input	User preferences, dynamic traffic data
Output	Ideal trip

Required functional components

Components short name	Short explanation
LDM++ with cloud	LDM++ as a local dynamic content provider to collect relevant current traffic conditions info
Vehicle data or phone data	No

provider	
Communication components (LTE, 802.11p)	No
User profile	Used to correctly simulate the trip, according to the preferences set in the SP3_CCA_UPS use case and associate to each TEAM user
Other SP2 component	Not at this stage
Interaction between SP3 and SP4	The simulation of the trip could include travelling by private vehicle so some SP4 apps are could be relevant for what concerns this part of the co-modal trip

Objectives

The objective of this use case is to simulate the ideal co-modal trip of the Avatar under current traffic conditions and to update it when necessary, according to dynamic information (e.g. about congestion) coming from "Collaborative pro-active monitoring and ad-hoc control" application.

User benefits

Creation of an ideal co-modal trip to be compared with the one followed by the user. In this way the user will have an optimum trip that takes into account his preferences and real-time traffic conditions, since the simulation is periodically refreshed by using as inputs information coming from the CMC application.

Basic functioning

This use case should be based on a concept very similar to traffic micro-simulation. The Avatar will start the trip at the same time of the traveller and follow the best route to reach the destination by considering the current public transport offer and traffic conditions, in addition to user preferences, since each user could give a different significance to the reference parameters (e.g. sometimes a short travel time is more important than low fuel consumptions).

Definition of work

- Core component of this use case is the simulator
- Data exchange interfaces with the TMC and PT operators will be needed
- Implementation of standard communication protocols such as DATEX 2 and SIRI/Transmodel should be evaluated

Possible Challenges

- Execution of accurate co-modal simulation
- Real-time update of such simulation
- Inclusion of data related to different transport providers

Comments, additional features

No additional comments.

1.2.3.5 Application use case 4: On-trip avatar coaching

Overview

Use case name	On-trip Avatar coaching
Use case short name	OAC
Use case identifier	SP3_CCA_OAC
Use case short description	On specific waypoints, the application interacts with the user notifying deviations from the ideal path, due to traffic accidents that happened in the mean time, forecasted congestion and/or wrong user decisions
Precondition	• The ideal co-modal trip is known • The current position/mean of transport of the traveller is known

Postcondition	The traveller receives directions to optimise its trip
Normal flow	• Optimal path is get from use case SP3_CCA_ATS • The ideal current position/mean of transport of the traveller is analysed If different than the optimal, specific directions are sent to the traveller
Deployment platforms (vehicle/smartphone/backbone)	Smartphone/Vehicle-API Backbone (traffic management centre)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
TMC	Elaborates paths, sends directions
Vehicle HMI/Smartphone app	Reports instructions to the traveller

Input and Outputs

Input	Traveller path, Avatar ideal co-modal path
Output	Real-time directions

Required functional components

Components short name	Short explanation

LDM++ with cloud	No
Vehicle data or phone data provider	Needed to monitor traveller position during the trip
Communication components (LTE, 802.11p)	Yes, to ensure the adequate communication infrastructure to coach the driver
User profile	Yes, coming from other use cases of the application
Other SP2 component	No
Interaction between SP3 and SP4	Interaction in case of in-vehicle coaching

Objectives

This use case is aimed at coaching the traveller during its co-modal journey by comparing its co-modal choices and its behaviour in travelling in the transportation network with the reference Avatar, which is following the ideal path from the same origins and destinations. Therefore the objective is to continuously monitor the position of the driver and if needed send instruction on how to optimise the travel.

User benefits

- Reduction of CO2 emissions
- Reduction of fuel consumption
- Reduction of (co-modal) travel times
- Optimisation of the whole transportation network

Basic functioning

This use case is based on a comparison that will be made through real time monitoring the individual route of a user and the encountered trip alternatives of an avatar travelling by other transport modes from the same origin to the same destination at the same time. Such cost-benefitratios on the trips made and alternatives used by the traveller in comparison with that of the results achieved virtually can create good understanding on a user in taking decisions about a real mobility options on his next trips

Definition of work

- Need to implement a solid end-user communication interface
- Need to design a specific architecture for real-time update of the ideal path and to give directions in a time fashion
- Interface with SP4 and in-vehicle aspect has to be taken in strong consideration

Possible Challenges

- User acceptance of the guidance
- Dynamic navigation
- Safety aspects – coaching while driving (regarding SP4 aspect of the application)

Comments, additional features

No additional comments.

1.2.3.6 Application use case 5: Post-trip avatar coaching

Overview

Use case name	Post-trip Avatar coaching
Use case short name	PAC
Use case identifier	SP3_CCA_PAC
Use case short description	Reports about the last period (day, week, …) or trip are generated in terms of possible savings in CO_2 emissions, travel time, fuel

	consumption with specific travelling advices
Precondition	Real traveller trip has ended Avatar trip has ended
Postcondition	Evaluation of the potential benefits given by following the Avatar path
Normal flow	• Real traveller trip is analysed • Avatar trip is analysed • A comparison of the two solutions is made and reported to the traveller
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone only Backbone (traffic management centre)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
TMC	Performs analysis of the two trips
Smartphone app/web portal	Reports a summary of the actual trip and of potential benefits of following the Avatar trip

Input and Outputs

Input	Actual traveller trip info, Avatar trip info
Output	A "balance sheet" describing the two trip, differences and potential benefits

Required functional components

Components short name	Short explanation
LDM++ with cloud	No
Vehicle data or phone data provider	No
Communication components (LTE, 802.11p)	To communicate with the mobile app, to send the results of the trip analysis
User profile	Needed for user identification and historical data collection, statistics generation, …
Other SP2 component	No
Interaction between SP3 and SP4	This use case will include also coaching about the in-private-vehicle part of the trip (only in terms of followed path)

Objectives

This use case is aimed at summarising the info gathered and computed by previous use case into a unique report, to give to the traveller a global understanding of its impact in terms of CO2 emissions and fuel consumption and in travel time spent in congestion and/or in inefficient transportation modes. Therefore the objective is again to create good understanding on a user in taking decisions about a real mobility options on his next trips.

User benefits

- Immediate awareness of potential benefits of following the Avatar trip
- Reduction of CO2 emissions, fuel consumption, (co-modal) travel times
- Optimisation of the whole transportation network

Basic functioning

The proposed idea does not aim on vague pre-trip forecasts but reliable and exact post-trip information about realized trip alternatives a user would have had for the same origin-destination pair including monitoring and displaying their true costs, travel times and CO_2 emissions based on real-time knowledge about occurred traffic jams or delays in public/private transport

Definition of work

- Need to develop a user-friendly mobile app or an equivalent tool for reporting trip data and easily compare trip alternatives
- This use case is based on a cooperatively monitored data from varied sensors, vehicle etc. It is end user centric as it has a direct impact at influencing the behaviour of end user that eventually brings about emission reduction, fuel consumption, etc.

Possible Challenges

- Acceptance of Avatar guidance
- Creation of a good understanding of the optimal trip
- Social sharing of data (cooperation with social gaming application)

Comments, additional features

No additional comments.

1.2.4 Collaborative smart intersections for intelligent priority

1.2.4.1 Application Overview

A short overview table of this application is given below.

Application name	Collaborative smart intersections for intelligent priority
Application short name / Identifier	Smart Intersections / CSI

Application short description	This is an integrated application for intersections. One of the main objectives is to optimize public transport, giving priority to buses. Priority techniques can generate improvements in service regularity, which usually means alignment with nominal time-tables and headways. A regular service guarantees a good level of transport capacity (expressed in terms of "passengers per hour"): the major goal of transport management. Moreover it makes service planning easier, reduces the time lost by passengers at bus or tram stops, increases user satisfaction and reduces driver stress. The priorities can also be considered based on the vehicle type (e.g. truck, bus, tram, car, motorcycle, pedestrians, cyclists etc.) and on other factors (truck with dangerous goods, ambulance, disabled person wanting to cross the street, etc.). This application also includes communication and synchronization of multiple traffic lights in a region to optimize traffic flow. The vehicles will send their intended destination to the current intersection and that one will communicate with the next ones to help regulate the traffic flow, based on the number of vehicles that will follow in each direction. The vehicles will receive a speed recommendation in order to get to the next traffic light in green. Additionally, the application includes start and stop functionality based on information that comes from smart and pro-active RSUs (i.e. how long do they have to turn off the engine, when to turn on the engine, duration of the red light phase, when the lights will be green, position in a queue etc.)
Platforms implementing the application	Smartphone/Vehicle-API, Fully vehicle-integrated, Backbone (traffic management centre), Road side
Application objective	The goal of this application is to have fully collaborative intersections that can dynamically optimize the traffic flow by giving priorities to certain vehicles, but at the same time taking into

	account the current traffic conditions.
Basic functioning	The intersections broadcast time and phase information for all traffic lights. The vehicles send relevant information about themselves to the intersection. The intersection then can prioritize and change time and phase for different traffic lights accordingly and then communicate the new information to the vehicles. The in-vehicle HMI coaches the driver to cross the intersection in green or to brake eco-friendly with smart start-stop.
Application's use cases	Intersection broadcast information Vehicle sends information Intersection adapts to priority and flow Green Light Optimal Speed Advisor Smart start-stop and braking recommendation
Required lower layer components	LDM++ Communication components Prioritization algorithms Vehicle data provider GLOSA component In-vehicle HMI

1.2.4.2 Application use case 1: Intersection broadcast information

Overview

Use case name	Intersection broadcast information

Use case short name	IBI
Use case identifier	SP3_SCI_IBI
Use case short description	Intersection periodically or on demand broadcasts information about its topology, signal phase and timing and which services are available (i.e. prioritization)
Precondition	Topology is encoded and provided to the intersection controller or to central equipment. Prediction is prepared by historic or logic information. System is configured for authentication of allowed vehicles prioritisation. The intersection can collect information about phase and time for all traffic lights
Postcondition	The vehicles nearby get information about the intersection, traffic lights and pre-emption
Normal flow	• Intersection broadcasts periodically • Intersection reply on request for information
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre), Roadside
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Intersection	The intersection with traffic lights equipped with a TEAM ITS roadside station

Input and Outputs

Input	• Intersection topology
	  • Lanes and directions
	  • Traffic lights
	• Signal phase and time for traffic lights
	• Additional services available
	  • Prioritization

Output	Output used for debugging, quality assurance will be the logging of the prioritisation relevant data. Output generated and distributed to the vehicles is the content of the Topology and Signal Phase and Timing data as it will be defined in the SPaT and MAP messages specified out of this project for ISO TC 204 WG18.

Required functional components

Components short name	Short explanation
LDM++ with cloud	Intersection topology
Vehicle data or phone data provider	N/A
Communication components (LTE, 802.11p)	Communication with the vehicles nearby
User profile	N/A
Other SP2 component	N/A
Interaction between SP3 and SP4	N/A

Objectives

This use case compiles all relevant information from the intersection and communicates that to the vehicles nearby.

User benefits

The main benefits of this use case, together with the complete application are to improve traffic flow and reduce emissions. The specific benefits are that the vehicles nearby receive information about the intersection and traffic lights.

Basic functioning

The intersection collects all relevant information and sends to vehicles nearby.

The information to be sent is listed in the field "Input" in this document. This data is derived from different sources in the intersection controller and traffic lights, as well as from the traffic management central, when appropriate.

Definition of work

- A component that can aggregate all relevant data about the intersection and traffic lights
- An integrated algorithm that is able to predict signalling information out of historical data and actual events
- Traffic applications able to priories public transport vehicles on demand
- A protocol to communicate this information to the vehicles

Possible Challenges

- Possible extensions of protocols currently under standardization
- Get an acceptable prediction of signalling in cases of traffic actuated control and in cases of self-influenced real-time adaptations.

Comments, additional features

None

1.2.4.3 Application use case 2: Vehicle sends information

Overview

Use case name	Vehicle sends information
Use case short name	VI
Use case identifier	SP3_CSI_VI
Use case short description	When the vehicle approaches the traffic light, it sends information about its type, weight, number of passengers, schedule, route, etc.
Precondition	The vehicle is able to collect relevant information
Postcondition	The intersection receives information about the nearby vehicles
Normal flow	1. Vehicle approaches a traffic light 2. Vehicle sends information about itself to the traffic light
Deployment platforms (vehicle/smartphone/ backbone)	Fully vehicle-integrated, Backbone (traffic management centre), Roadside
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station

Intersection	The intersection with traffic lights equipped with a TEAM ITS roadside station

Input and Outputs

Input	• Vehicle type
	  • truck, bus (long and short distance), tram, car, motorcycle, cyclist, ambulance, etc.
	• Authentication
	  • For PT pre-emption, for emergency prioritization, etc.
	  • Schedule
	  • Public transport vehicle schedule (i.e. the bus is ahead or behind schedule)
	  • Deliveries/trucks (number of stops, impact of priorities on the trucks)
	• Load information
	  • Number of passengers in the vehicle (car, bus, etc.)
	  • Weight and type of load (dangerous goods)
	  • Position, speed and intended destination
	  • C-ACC vehicles driving together (platoon)
	• Serious games points

Output	Information to be communicated to the intersection

Required functional components

Components short name	Short explanation
LDM++ with cloud	Necessary to know if the vehicle is approaching a traffic light.

Vehicle data or phone data provider	All relevant data about the vehicle and load
Communication components (LTE, 802.11p)	Communication with the infrastructure
User profile	Serious gaming could have an effect in the prioritization Authentication profile for the vehicle with information what levels of prioritisation is allowed to request. Authentication profile for the roadside unit to get information about requesting station for prioritisation.
Other SP2 component	System for authentication of vehicles to get access to the prioritisation. This authentication might be relevant for other applications also and should be a separate application in SP2. This authentication must be integrated into the lower communication level and only provide access for the application level. Lane positioning
Interaction between SP3 and SP4	N/A

Objectives

This use case compiles all relevant information from the vehicle and communicates that to the traffic light for prioritization.

User benefits

The main benefits of this use case, together with the complete application are to improve traffic flow and reduce emissions. An additional benefit includes the improvement of service quality for buses and public transport vehicles, as they can be given priority at intersections and consequently be able to follow their schedule more effectively. The innovation compared to existing radio based systems is the expected better availability for the future, standardised interchangeable systems that enables the operation of busses in regions not usually operating. E.g. use of busses from other operator in cases of special events.

Basic functioning

The vehicle collects all relevant information and sends to the traffic light for prioritization.

The information to be sent is listed in the field "Input" in this document. This data is derived from different sources, including sensors in the vehicle.

Definition of work

- A component that can aggregate all relevant data about the vehicle
- A protocol to communicate this information to the traffic lights

Possible Challenges

- Possible extensions of protocols currently under standardization

Comments, additional features

None

1.2.4.4 Application use case 3: Intersection adapts to priority and flow

Overview

Use case name	Intersection adapts to priority
Use case short name	IP
Use case identifier	SP3_CSI_IP
Use case short	When the intersection receives information about the vehicles nearby, it uses a parameterized algorithm to decide the priorities. It

description	could prioritize certain vehicle types (i.e. heavy vehicles, public transport, emergency), traffic flow (i.e. congestions in one of the road segments) or other criteria (i.e. regional optimization of several intersections).
Precondition	The intersection is able to receive information and control all traffic lights. The intersection receives information about the nearby vehicles
Postcondition	The intersection decides on priorities and communicates the new values for signal phase and time of all traffic lights.
Normal flow	1. Intersection evaluates priority of vehicles nearby 2. Intersection evaluates traffic flow conditions 3. Intersection calculates new signal phase and time for all traffic lights 4. Intersection communicates SPaT values via broadcast
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre), Roadside
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Intersection	The intersection with traffic lights equipped with a TEAM ITS roadside station

Input and Outputs

Input	• Nearby vehicles information • Vehicle types (truck, bus (long and short distance), tram, car, motorcycle, pedestrians, cyclists • Truck with dangerous goods, ambulance, disabled person wanting to cross the street • Public transport vehicle schedules (i.e. the bus is ahead or behind schedule) • Number of passengers in vehicles (car, bus, etc.) • Weight and type of load of vehicles • Deliveries/trucks (number of stops, impact of priorities on the trucks) • Pedestrians waiting time (especially when close to the bus/tram stops) • C-ACC vehicles driving together • Position, speed and intended destination of vehicles • Serious games points • Traffic information • Density/congestion of traffic in each direction • Nearby intersections status and information • Central traffic management system parameters for optimization • Prioritization and optimization parameters • From the city/traffic planner
Output	New signal phase and time for all traffic lights at the intersection

Required functional components

Components short name	Short explanation
LDM++ with cloud	Map of vehicles approaching the intersection
Vehicle data or phone data provider	N/A
Communication components (LTE, 802.11p)	Communication with the vehicles Communication with the other intersections in the same region
User profile	N/A
Other SP2 component	N/A
Interaction between SP3 and SP4	N/A

Objectives

This use case takes into account all relevant information received from nearby vehicles, nearby traffic lights and traffic management system to optimize traffic flow and prioritize public transport or other special vehicles.

User benefits

The main benefits of this use case, together with the complete application are to improve traffic flow and reduce emissions.

Basic functioning

The intersection controller collects all relevant information for optimizing signal phase and time of all traffic lights at the intersection and prioritizing public transport or other special vehicles.

The information to be sent is listed in the field "Input" in this document. This data is derived from different sources, including vehicles communication and traffic management centre.

Definition of work

- A component that can aggregate all relevant data
- A parameterized algorithm to optimize signal phase and time for all traffic lights at the intersection
- An algorithm to predict regularly influenced traffic signalling
- A protocol to communicate this information to the vehicles

Possible Challenges

- Algorithm complexity
- Detection of the necessary data
- Possible extensions of protocols currently under standardization

Comments, additional features

None

1.2.4.5 Application use case 4: Green light optimal speed advisor

Overview

Use case name	Green Light Optimal Speed Advisor
Use case short name	GLOSA
Use case identifier	SP3_SCI_GLOSA
Use case short description	The vehicle receives information from the traffic lights and the driver is coached to pass the intersection when the traffic light is green. According to ETSI day 1 application and standards.

Precondition	The vehicle receives signal phase and time, and topology information from the intersection
Postcondition	The vehicle optimized speed to reduce fuel consumption and CO_2 emission.
Normal flow	The vehicle receives information about signal time and phase from the traffic light Based on position and speed, a speed range for crossing in green is calculated The speed range is shown to the driver, or is input in the C-ACC. The vehicle crosses the intersection in green
Deployment platforms (vehicle/smartphone/ backbone)	Fully vehicle-integrated
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Intersection	The intersection with traffic lights equipped with a TEAM ITS roadside station

Input and Outputs

Input	• Signal time and phase from the traffic light • Position and distance to the traffic light • Maximum speed allowed on the lane

	• Number and speed of cars ahead • Distance to end of waiting cars • Time to release lane when traffic light switches to green • Vehicle speed
Output	Recommended speed range

Required functional components

Components short name	Short explanation
LDM++ with cloud	Information about position and distance to the traffic light
Vehicle data or phone data provider	Speed of the vehicle
Communication components (LTE, 802.11p)	Communication with the intersection
User profile	N/A
Other SP2 component	Lane positioning
Interaction between SP3 and SP4	HMI might use components developed in SP4 C-ACC application from SP4

Objectives

This use case calculates the optimal speed range for crossing the intersection when the traffic light is green.

User benefits

The main benefits of this use case, together with the complete application are to improve traffic flow and reduce emissions.

Basic functioning

The vehicle collects all relevant information for calculating the optimal speed range to cross the intersection when the traffic light is green.

The information to be sent is listed in the field "Input" in this document. This data is derived from different sources.

The driver receives information about the ideal speed range and is coached to drive within that range. Alternatively, the optimal speed range is input in the C-ACC which controls automatically the speed of the vehicle for crossing in green.

Definition of work

- A protocol to receive information from the traffic light
- A component to calculate the optimal speed range
- An HMI component to coach the driver
- An interface with the C-ACC application

Possible Challenges

- Possible extensions of protocols currently under standardization

Comments, additional features

None

1.2.4.6 Application use case 5: Smart start-stop and braking recommendation

Overview

Use case name	Smart start-stop and braking recommendation

Use case short name	SSSBR
Use case identifier	SP3_SCI_SSSBR
Use case short description	The vehicle receives information from the traffic lights and finds out that it will not be possible to cross the intersection when the traffic light is green. The driver is coached to brake in an eco-friendly way and a smart start-stop function is optimized based on signal phase and time of the traffic light.
Precondition	The vehicle receives signal phase and time, and topology information from the intersection
Postcondition	The vehicle optimized speed, braking and start-stop function to reduce fuel consumption and CO_2 emission.
Normal flow	The vehicle receives information about signal time and phase from the traffic light Based on position and speed, it discovers that it cannot pass in green The driver is coached to brake eco-friendly, or the braking pattern is input in the C-ACC. The start-stop function is optimized with SPaT information from the traffic light
Deployment platforms (vehicle/smartphone/ backbone)	Fully vehicle-integrated
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station

Intersection	The intersection with traffic lights equipped with a TEAM ITS roadside station

Input and Outputs

Input	• Signal time and phase from the traffic light • Position and distance to the traffic light • Maximum speed allowed on the lane • Number and speed of cars ahead • Distance to end of cars that also has to stop at red • Vehicle speed
Output	• Recommended braking pattern • Input to the smart start-stop function

Required functional components

Components short name	Short explanation
LDM++ with cloud	Information about position and distance to the traffic light
Vehicle data or phone data provider	Speed of the vehicle, braking capacity, start-stop function
Communication components (LTE, 802.11p)	Communication with the intersection
User profile	N/A
Other SP2 component	Lane level positioning
Interaction between SP3 and SP4	HMI might use components developed in SP4 C-ACC application from SP4

Objectives

This use case calculates the optimal braking pattern when the vehicle cannot cross the intersection when the traffic light is green. It also optimizes the start-stop function based on information from the traffic light.

User benefits

The main benefits of this use case, together with the complete application are to improve traffic flow and reduce emissions.

Basic functioning

The vehicle collects all relevant information for calculating the optimal speed range to cross the intersection when the traffic light is green.

The information to be sent is listed in the field “Input” in this document. This data is derived from different sources.

The vehicle finds out that it cannot cross the intersection in green.

The driver receives braking information to decelerate the vehicle in an eco-friendly way. Alternatively, the optimal braking pattern is input in the C-ACC which controls automatically the speed of the vehicle for stopping the vehicle.

When the vehicle is stopped at the traffic light, it optimizes the engine start-stop function based on signal phase and time information from the traffic lights.

Definition of work

- A protocol to receive information from the traffic light
- A component to calculate the optimal braking pattern
- An HMI component to coach the driver
- An interface with the C-ACC application
- An interface with the start-stop function

Possible Challenges

- Possible extensions of protocols currently under standardization
- Detection of necessary input data
- Interface with start-stop function
- Braking coaching HMI

Comments, additional features

None

1.2.5 Collaborative public transport optimization

1.2.5.1 Application Overview

A short overview table of this application is given below.

Application name	Collaborative public transport optimization
Application short name / Identifier	CPTO
Application short description	This application is closely related to the concept of "elastic transport infrastructures" which intend to serve the needs of modern cities. A public transport operator taking into account the origin and destination information from the travellers together with information about the current traffic situation or even information regarding aspects such as the number of passengers that will take the bus at every stop or the estimated time that a bus will spend in a stop, dynamically adapts the timetables and the routes in order to achieve a specific goal. For example, the optimization of the overall network efficiency which in turn will lead to CO_2 emissions

	reduction.
Platforms implementing the application	• Third party (e.g. public transport operator) • Smartphone/Vehicle
Application objective	The goal of this application is to highlight the flexibility of the transport infrastructure serving dynamically the demand of the cities and the citizens (adapted to their needs). This application will focus mainly on buses but can be extended to other means of transport such as trams, trains, metros taking into account the specific constraints of these transport means. Actually the main restriction in the latter case is that these means have fixed infrastructure (i.e. rails) but the timetables and the stops could be adapted dynamically based on the demand. It would be desirable TEAM to be capable of proposing changes to the schedules (even routes) of the public transportation means (buses, etc.) in order to flexibly serve the demand (based on historical data, user information, etc.), although it should be considered that the reliability of such suggestions implies wide adoption of the TEAM apps.
Basic functioning	The main assumption that we make in this application is that the majority - ideally all - users/travellers are using a smartphone which is running the TEAM framework and have installed this specific application and that they are using it to communicate their position (start point) and their intended destination (end point) to this framework and possibly “declare” the selected bus line(s) and the departure time in order to provide the TEAM system with valuable information towards both the short and the long term bus scheduling optimization. Taking into account this information together with information about the traffic (current situation on the road) or even information regarding aspects such as the number of passengers that will take the bus at every stop or the estimated time that a bus will spend in a stop, the public transport operator dynamically adapts the

	timetables and the routes in order to achieve a specific goal. In our case an example of such goal could be the optimization of the overall network efficiency which in turn will lead to CO2 emissions reduction. Another example could be to avoid sending out buses travelling around without actual demand at a certain point in time minimizing the cost for the operator (as well as the environmental impact), or to make speed recommendations to further increase the efficiency of the network. This is an interactive application and the dynamic rescheduling can be done within an interactive window of at least 5 sec to 5 min based on real time traffic data, available historical/statistical data and the dynamic requests of the travellers (current demand). Of course the interactive time window may be greater and varies depending on the incident and the actual infrastructure restrictions (e.g. speed of vehicles/buses, time to withdraw a train from a lane etc.). Real time information from the public transport operator (or the bus itself) will be also communicated to the travellers to keep them informed about the current location of the bus of interest, the time they have to wait at the stop for the bus, their current position when they are on the move, info on the forthcoming stations, the estimated time to their destination, considerable delays on the route of interest, suggestions on alternative routes, etc. In future it might be possible also to adapt the route in order to dynamically create new stations/stops when there is a high demand.
Application's use cases	1. Accident or traffic based route adaptation 2. Event-based route adaptation 3. Adding and/or skipping bus stops 4. Headway adaptation 5. Input data from the traveller

	6. En-route information to the traveller 7. Pre-trip information to the traveller
Required lower layer components	• LDM++ with cloud • Vehicle data or phone data provider • Communication components (LTE, 802.11p) • HMI components for bus drivers and travellers

1.2.5.2 Application use case 1: Accident or traffic based route adaptation

Overview

Use case name	Accident or traffic based route adaptation
Use case short name	ATBRA
Use case identifier	SP3_CPTO_ATBRA
Use case short description	Dynamically adapt (in real-time) the route of the bus if an accident has happened and the road is blocked or there is a traffic congestion at a specific road segment.
Precondition	• The current bus location and the bus line information should be available. • Traffic management information should be available to the application. • The bus should be equipped with the TEAM system to inform the driver in time for the current road situation and suggest alternative routes. • The public transport operator should allow modification of routes under specific circumstances.
Postcondition	The bus avoided an accident or a congestion area allowing passengers to get to their destination efficiently by following an

	alternative route.
Normal flow	1. The traffic management system indicates a blocked road problem. 2. The application should locate the buses that are heading to the blocked road. 3. The application should calculate the best alternative route for the bus to be on track and inform the bus driver. 4. The bus driver or/and other system should inform the passengers on the change. 5. The bus driver should follow the alternative route.
Deployment platforms (vehicle/smartphone/ backbone)	• Third party (public transport operator) • Smartphone/Vehicle
Expected frequency of use	Low

External actors and components

Actors' short name	Short explanation
Public transport operator	Provide relevant public transport data such as current bus location, stop locations, bus routes etc. and dynamically re-route a bus
Traffic management centre	Provide information related to traffic density and accidents
Travellers	Data prosumers (both producing and consuming information)
Network providers	Mobile network, internet

Input and Outputs

Input	• Bus timetables/schedules/routes

	• Stop locations and lines of correspondence • Buses current locations (dynamic information) • Traffic information on every road within the bus lines network (incl. detected accidents)
Output	• Suggested route to avoid a blocked route for every involved bus.

Required functional components

Components short name	Short explanation
LDM++ with cloud	Should contain fixed information on bus routes and bus stop locations and dynamic information on every running bus location.
Vehicle data or phone data provider	Vehicle data could be necessary for collaborative positioning and better accuracy on bus current location.
Communication components (LTE, 802.11p)	Communication is needed between the bus and the automotive cloud for the application to run.
User profile	The bus ID can be sent to the application.
Other SP2 component	Security module: The communication among the public transport operator and the travellers should be secure and respect privacy aspects.
Interaction between SP3 and SP4	Interaction with *Collaborative pro-active monitoring and ad-hoc control* application. HMI components for presenting information both to the bus drivers and the passengers.

Objectives

This application should provide the bus driver with useful information on possible "obstacles" (i.e. traffic jams or accidents) in the road ahead obstructing their routes. The application should calculate the benefits for following an alternative route and suggest in time the driver to follow this.

User benefits

The user acceptance for the public transport operator services will increase if their buses are not stacked in traffic and have a time schedule of high reliability. The user preference on reliable transport operator will increase the commuters using public transport with benefits such as lower traffic, lower gas emission, profitable public operator etc.

Basic functioning

Every bus of the public operator fleet should be equipped with positioning and communication modules and transmit dynamically and continuously their location. Real time traffic management information should also be available. Passengers should be constantly informed through their smartphones.

Definition of work

- Dynamic information on bus location and traffic flow should be included in the LDM++ data in real time.
- An algorithm that can quickly recognise the road blocking situations and the buses on this way should be implemented.
- An algorithm that takes into consideration road blocking situations and proposes alternative routes is needed.

Possible Challenges

- Traffic management information on blocking road may arrive late.
- The message for alternative route suggestion may arrive late.
- A road being blocked could lead to a domino effect of nearby roads blocking as well, so as the alternative route suggestion could fail.

- Low connectivity between the bus and the LDM++ can generate problems.
- Travellers miss their intended stop since it is located in the congestion/accident area.

Comments, additional features

None

1.2.5.3 Application use case 2: Event-based route adaptation

Overview

Use case name	Event-based route adaptation
Use case short name	EBRA
Use case identifier	SP3_CPTO_EBRA
Use case short description	Dynamic adaptation of routes and timetables at a region (e.g. a stadium, a museum etc.) where an event (e.g. conference, concert etc.) is taking place and there is a high demand on the opening and closing hours of the event.
Precondition	• The public transport operator should allow modification of routes under specific circumstances • The public transport operator is aware of the event and its programme either from the organisers or from the travellers (based on the demand) or from past experience (e.g. football games take place every Sunday) • The public transport operator should be able to coordinate its fleet to reach efficiently the intended event location taking into account traffic information • Support from the TMC in coordinating also drivers trying to reach the event location from different roads

Postcondition	All the attendees of this event reach their destination efficiently (avoiding congestions) in time, possibly from different directions. Traffic is uniformly distributed to or out of the event location with the support of the traffic management centre.
Normal flow	1. Public transport operator is informed about the event and its program. 2. The application should dynamically detect available buses and allocate them for transporting guests to the event location. 3. The application should calculate the best alternative routes and frequencies for the buses to head to or out of the event. 4. The bus driver or/and other system should inform the passengers on the way they will reach the event location.
Deployment platforms (vehicle/smartphone/ backbone)	Third party (public transport operator) Smartphone/Vehicle
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
Public transport operator	Provide the means to reach or depart the event place in time and in an efficient way
Traffic management centre	Provide information related to current traffic situation in the road segments converging to the event location
Travellers	Data prosumers (both producing and consuming information)
Network providers	Mobile network, internet

Input and Outputs

Input	• Bus timetables/schedules/routes • Number of travellers who are going to attend the event and their origin position • Traffic information on the road segments close to the event location
Output	Suggested route to reach the event location or depart from it

Required functional components

Components short name	Short explanation
LDM++ with cloud	Dynamically store and share the adapted public transport schedules to reach/depart the event location
Vehicle data or phone data provider	Needed to estimate the current location of public transport means and the origin positions of the travellers that intend to attend the event
Communication components (LTE, 802.11p)	Communication is needed between the public transport means and the automotive cloud for the application to run. Also the input data from the travellers are communicated through their smartphone.
User profile	Not necessary
Other SP2 component	Security module: The communication among the public transport operator and the travellers should be secure and respect privacy aspects.
Interaction between SP3 and SP4	Interaction with *Collaborative pro-active monitoring and ad-hoc control* application. HMI components for presenting information both to the bus drivers and the passengers.

Objectives

This application should efficiently direct travellers to a specific event location and help them also to depart from this place. This application should have access to real-time traffic conditions in the transportation network around the event location as well as information about other transport means supporting the public to reach or depart from the event.

User benefits

This application will increase the use of public transport means to reach and depart from a stadium, conference place etc. to avoid congestions by using private cars especially in the opening and closing hours of the event. The overall efficiency of the network will be increased leading in turn to a decrease in the CO_2 emissions.

Basic functioning

The public transport means should be equipped with positioning and communication modules and transmit dynamically and continuously their location. Real time traffic management information should also be available. Passengers should be able to indicate their origin position and their intention to attend this specific event and should be constantly informed through their smartphones.

Definition of work

- Dynamic information on public transport means location and traffic flow should be included in the LDM++ data in real time.
- An algorithm that can quickly coordinate the public transport means and redirect traffic to reach/depart efficiently from the event location should be implemented.

Possible Challenges

- There is a shortage in available buses or other transportation means in a specific point in time due to the normal scheduled routes.
- Underestimation or overestimation of the demand might degrade the performance of the whole network and risk the successful operation of the event.

- The coordination of public transport means in order to maintain also the smooth operation of the rest of the network together with the independent drivers reaching/departing from the event place and the nearby roads.
- Low connectivity between the bus and the LDM++ can generate problems.

Comments, additional features

None

1.2.5.4 Application use case 3: Adding and/or skipping bus stops

Overview

Use case name	Adding and/or skipping bus stops
Use case short name	ASBS
Use case identifier	SP3_CPTO_ASBS
Use case short description	Dynamically add or skip bus stops based on the demand.
Precondition	• The public transport operator should allow adding and/or skipping bus stops under certain circumstances • The majority of the travellers (ideally all of them) should have a smartphone to interact with the public transport operator
Postcondition	The bus route will not be static anymore and will be dynamically adapted to the needs of the travellers avoiding meaningless bus stops (nobody stepping in or out of the bus) and adding bus stops where necessary.
Normal flow	1. The bus starts from the departure point 2. In the first stop nobody has indicated that he wants to leave the bus

	3. Moreover nobody from the travellers waiting at the stop has indicated (using the TEAM smartphone) that she/he is expecting this specific bus 4. The bus drives through this stop
Deployment platforms (vehicle/smartphone/ backbone)	Third party (public transport operator) Smartphone/Vehicle
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Public transport operator	Provide relevant public transport data such as current bus location, stop locations, bus routes etc.
Travellers	Data prosumers (both producing and consuming information)
Network providers	Mobile network, internet

Input and Outputs

Input	• Bus timetables/schedules/routes • Stop locations and lines of correspondence • Buses current locations (dynamic information) • Desired location that a traveller wants to enter or leave a bus
Output	A list of suggested stops after adding/skipping some of the initial ones

Required functional components

Components short name	Short explanation
LDM++ with cloud	Should contain fixed information on bus routes and bus stop locations, dynamic information on every running bus location and the updated list of stops.
Vehicle data or phone data provider	Vehicle data to know the current position of the vehicle and phone data to know the intention of the travellers
Communication components (LTE, 802.11p)	Establish communication between the buses, the transport operator and the travellers
User profile	Not relevant
Other SP2 component	Security module: The communication among the public transport operator and the travellers should be secure and respect privacy aspects.
Interaction between SP3 and SP4	HMI components for presenting information both to the bus drivers and the passengers.

Objectives

The main objective is to keep the route of the bus fixed while adding and/or skipping stops based on the demand. This way the demand of travellers will be served in a more effective way and the bus will avoid meaningless stops (or add needed ones) which gradually in the long term will lead in a re-design of the stops.

User benefits

This use case will mainly increase the use of the transport system both in the short and in the long term. gradually the transportation system will be updated constantly to the needs of the citizens.

Basic functioning

The travellers will insert in the TEAM application running in their smartphone intended enter and exit locations. The system running in the public transport operator server should calculate the new list of stops and provide this information to the bus drivers and the travellers. A proper way for providing this information should be examined.

Definition of work

- Dynamic information on public transport means location and traffic flow should be included in the LDM++ data in real time.
- An algorithm that can quickly aggregate the input data from the travellers and optimize the list of bus stops and inform accordingly bus drivers and travellers should be implemented.

Possible Challenges

- The algorithm aggregating information from the travellers is delayed so some stops are neglected while actually there is a need for their existence.
- The coordination among the different buses, their routes and especially common stops might pose threats to the smooth operation of the transport network
- Dynamically adding bus stops might not be feasible because there are some preconditions for the creation of a new bus stop that is quite difficult to meet at the lifetime of the project (e.g. safety reasons, free space for the stops etc.)

Comments, additional features

None

1.2.5.5 Application use case 4: Headway adaptation

Overview

Use case name	Headway adaptation
Use case short name	HDA
Use case identifier	SP3_CPTO_HDA

Use case short description	Dynamically adapt the distance between the buses performing the same routes. There is a problem with frequently run bus routes in the congested areas: If the first bus is getting slightly late compared to its schedule, more people will arrive into the bus stops on the route, the bus stays in each bus stop longer, it is getting more and more crowded, and more and more late. The second bus (running e.g. 5 minutes after the first one based on the schedule) needs to pick up less and less passengers and finally it reaches or even passes the first bus.
Precondition	• The public transport operator should provide real-time collaboration among the different buses performing the same route • Information on the current traffic situation by the traffic management centre • The majority of the travellers (ideally all of them) should have a smartphone to interact with the public transport operator
Postcondition	More efficient transport network without buses chaining one behind the other without properly serving the public
Normal flow	1. A bus "A" leaves its departure point 5 minutes delayed 2. A second bus "B" should not leave the departure point right behind bus "B" but should wait for an indication from the transport operator 3. Based also on the demand, the distance between the two buses is constantly monitored and adjusted by the transport operator. 4. The travellers are informed by their smartphones
Deployment platforms (vehicle/smartphone/ backbone)	Third party (public transport operator) Smartphone/Vehicle
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Public transport operator	Coordination between different buses following the same route
Traffic management centre	Provide information related to current traffic situation in the road segments converging to the event location
Travellers	Data prosumers (both producing and consuming information)
Network providers	Mobile network, internet

Input and Outputs

Input	• Bus timetables/schedules/routes • Stop locations and lines of correspondence • Buses current locations (dynamic information) • Desired location that a traveller wants to enter or leave a bus
Output	Recommendation to the bus drivers on speeds and time slots that they have to leave from the bus stops. Information disseminated also to the travellers.

Required functional components

Components short name	Short explanation
LDM++ with cloud	Should contain information on bus routes and bus stop locations, dynamic information on every running bus location and the updated speed and timing recommendations to the bus drivers.
Vehicle data or phone data	Vehicle data to define the positioning of each bus. Phone

provider	data to know the intention of the travellers
Communication components (LTE, 802.11p)	Establish communication among the different actors
User profile	Not relevant
Other SP2 component	Security module: The communication among the public transport operator and the travellers should be secure and respect privacy aspects.
Interaction between SP3 and SP4	Strong integration with *Collaborative pro-active monitoring and ad-hoc control* application. Proper HMI components for providing suggestions to the collaborating drivers and informing the travellers.

Objectives

The main objective of this application is to avoid the frustration of both bus drivers and travellers when consecutive buses following the same route are close together resulting in packed passengers in the first bus while the second bus is driving almost empty.

User benefits

The mobility and the quality of service provided to the travellers will increase. Also bus drivers will be more relaxed while driving. This will increase also the efficiency of the transport network in cases of congested areas.

Basic functioning

The system running in the public transport operator server should be aware of their fleet positions and the traffic situation (from the TMC) and adapt the headway between consecutive buses serving the same line by providing speed and timing (i.e. specific time to leave a specific bus stop) recommendations to the involved drivers. A proper way for providing this information to the drivers should be examined. Moreover, the travellers should be also informed about this situation by their smartphones.

Definition of work

- Dynamic information on public transport means location and traffic flow should be included in the LDM++ data in real time.
- An algorithm that can quickly calculate the best headway between the buses based on the current traffic situation and the demand should be implemented.

Possible Challenges

- The coordination among the different buses and the adapted headway might result to further delays in dense traffic conditions.
- Dynamically adjusting the headways might be a non-trivial mathematical problem

Comments, additional features

None

1.2.5.6 Application use case 5: Input data from the traveller

Overview

Use case name	Input data from the traveller
Use case short name	IDT
Use case identifier	SP3_CPTO_IDT
Use case short description	The traveller has to insert origin & destination information from his/her smartphone including also the desired time of departure or arrival
Precondition	• The travellers should have a smartphone running the TEAM framework which is connected to the transport operator through the LDM++ cloud

	• There should be an appropriate interface for inserting relevant information
Postcondition	The travellers could provide data in a more efficient way to the transport operator
Normal flow	1. The traveller wants to go from a specific location to another one 2. He/she uses the application interface of his/her smartphone to insert origin and destination locations indicating also desired arrival or departure time 3. The public transport operator receives relevant information
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Traveller	Send needed data to the operator
Public transport operator	Receives and further processes data provided by the travellers
Network providers	Mobile network, internet

Input and Outputs

Input	Data that is needed to implement the use case
Output	Data which is generated through the use case

Required functional components

Components short name	Short explanation
LDM++ with cloud	No
Vehicle data or phone data provider	Origin and destination data inserted in the smartphone
Communication components (LTE, 802.11p)	Establish communication among the different actors
User profile	Not relevant
Other SP2 component	Security module: The communication among the public transport operator and the travellers should be secure and respect privacy aspects.
Interaction between SP3 and SP4	• The interface will be provided by SP4 based on the specific needs of this application • The same or a quite similar GUI should be available to almost all applications

Objectives

The objective of this use case is to highlight one critical component which will serve as an input device to the TEAM system and support all the other use cases related to this application (and almost all other applications).

User benefits

The traveller can communicate his/her intended trip to the TEAM compliant public transport operator and benefit from using this application to minimise waiting times, delays etc.

Basic functioning

Users uses his/her smartphone with a proper GUI for inserting needed data.

Definition of work

Development of a GUI for inserting origin and destination data together with information related to desired arriving or departing time.

Possible Challenges

Not foreseen

Comments, additional features

None

1.2.5.7 Application use case 6: En-route information to the traveller

Overview

Use case name	En-route information to the traveller
Use case short name	ERIT
Use case identifier	SP3_CPTO_ERIT
Use case short description	Real time information on: current location of other bus of interest, next close bus station, time schedule, connection capabilities at next stops and possible obstructions on current bus path. An amount of information can be provided by default and more details can be given on demand.
Precondition	• The bus operator should offer the current location of their fleet together with bus line indication and other information. • Traffic management information should be available to the application. • The traveller smartphone should be equipped with the

	information.
Postcondition	The traveller should get the requested information while on board a bus.
Normal flow	• A traveller is on a bus and requests from the application one of the following: • Estimated time to the next or other requested stop of the current bus. • Bus lines that serving the next or other requested stop and times of arrival together with information on other bus routes if requested. • Request to reach a certain bus line or location with the application to suggest a bus stop to descend, including walking time to their destination or/and waiting time to an intermediate stop. • The planned route of the user is obstructed by an unknown reason (accident, traffic) the application should inform the traveller and provide the best alternative route. • The application should provide in time the requested information or inform otherwise the user.
Deployment platforms (vehicle/smartphone/backbone)	Third party (public transport operator) Smartphone
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Public transport operator	Relevant data such as bus locations, stop locations, bus routes etc.

Traffic management centre	Traffic management centre data
Travellers	Data consumers
Network providers	Mobile network, internet

Input and Outputs

Input	• Buses fixed route information • Bus stop locations and lines of correspondence • Buses current locations (dynamic information) • Traffic flow on nearby roads
Output	• Estimated time to reach every bus stop per running bus • Suggested routes to reach a certain location (close to a bus stop)

Required functional components

Components short name	Short explanation
LDM++ with cloud	Should contain fixed information on bus routes and bus stop locations and dynamic information on every running bus location.
Vehicle data or phone data provider	Current user location is needed to associate them with the travelling bus on which they are on-board.
Communication components (LTE, 802.11p)	Communication is needed between the user and the automotive cloud for the application to run.
User profile	Not necessary
Other SP2 component	Security module: The communication among the public transport operator and the travellers should be secure and respect privacy aspects.

Interaction between SP3 and SP4	HMI components for presenting information to the travellers through their smartphones

Objectives

This application should provide the on-board traveller with useful information on their desired route and location per request, should provide additional information if requested (traveller decides to change planned route) or should provide information/suggestion in case some unexpected event obstructs the travellers initial planning.

User benefits

The user acceptance for the public transport operator services will be increased after limiting the waiting time at stops and by providing, in time information on problems (e.g. traffic jams, accidents) to the travellers. The user preference on reliable transport operator will increase the commuters using public transport with benefits such as lower traffic, lower gas emission, profitable public operator etc.

Basic functioning

Every bus of the public operator fleet should be equipped with positioning and communication modules and transmit dynamically and continuously their location. Real time traffic management information should be also available.

Definition of work

- Dynamic information on bus location and traffic flow should be included in the LDM++ data in real time.
- An algorithm that associates current user location with the bus on which he/she is on-board should be implemented.
- An algorithm that takes into consideration bus location and traffic flow and estimates the time to stop per running bus.

- A bus route planning algorithm that provides suggested route for a requested location that lies close to a bus stop.
- In case of that a bus traffic problem arises, all users that follow a suggested route will be informed through their smartphones for the problem and the application will calculate the best alternative bus route.

Possible Challenges

- Dynamic information e.g. every bus location, traffic flow information can arrive late or be unreliable, leading to false assumptions.
- Low connectivity between the traveller and the LDM++ can generate problems.

Comments, additional features

None

1.2.5.8 Application use case 7: Pre-trip information to the traveller

Overview

Use case name	Pre-trip information to the traveller
Use case short name	PTIT
Use case identifier	SP3_CPTO_PTIT
Use case short description	Pre-trip information on: current location of the buses of interest, next close bus station, time schedule, connection capabilities. An amount of information can be provided by default and more details can be given on demand.
Precondition	• The bus operator should offer the current location of their fleet together with bus line indication and other information. • Traffic management information should be available to the

	application. • The traveller smartphone should be equipped with the information.
Postcondition	• The traveller should get the requested information before the trip.

Normal flow	• A traveller is in his/her office or home and requests from the application one of the following:
	  • Estimated time of the next buses at the requested origin location
	  • Estimated time of the scheduled trip duration
	  • Request to reach a certain bus line or location with the application to suggest a bus stop to descend, including walking time to their destination or/and waiting time to an intermediate stop.
	• The planned route of the user is obstructed by an unknown reason (accident, traffic) the application should inform the traveller and provide the best alternative route.
	• The application should provide in time the requested information or inform otherwise the user.

Deployment platforms (vehicle/smartphone/ backbone)	Third party (public transport operator) Smartphone
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Public transport	Relevant data such as bus locations, stop locations, bus routes etc.

operator	
Traffic management centre	Traffic management centre data
Travellers	Data consumers
Network providers	Mobile network, internet

Input and Outputs

Input	• Buses fixed route information • Bus stop locations and lines of correspondence • Buses current locations (dynamic information) • Traffic flow on nearby roads
Output	• Estimated time to reach every bus stop per running bus • Suggested routes to reach a certain location (close to a bus stop)

Required functional components

Components short name	Short explanation
LDM++ with cloud	Should contain fixed information on bus routes and bus stop locations and dynamic information on every running bus location.
Vehicle data or phone data provider	Origin and destination locations are needed to associate them with the travelling buses they are going to board.
Communication components (LTE, 802.11p)	Communication is needed between the user and the automotive cloud for the application to run.
User profile	Not necessary
Other SP2 component	Security module: The communication among the public transport operator and the travellers should be secure and

	respect privacy aspects.
Interaction between SP3 and SP4	HMI components for presenting information to the travellers through their smartphones

Objectives

This application should provide a pre-trip planner to the traveller with useful information on their desired route and location per request, should provide additional information if requested (traveller decides to change planned route) or should provide information/suggestion in case some unexpected event (e.g. a strike) which obstructs the travellers initial planning.

User benefits

The user acceptance for the public transport operator services will be increase after limited waiting time, a-priori information on problems etc. The user preference on reliable transport operator will increase the commuters using public transport with benefits such as lower traffic, lower gas emission, profitable public operator etc.

Basic functioning

Every bus of the public operator fleet should be equipped with positioning and communication modules and transmit dynamically and continuously their location. In case there is a change in the planned trip the traveller is informed in advance and his trip is re-scheduled.

Definition of work

- Dynamic information on bus location and traffic flow should be included in the LDM++ data.
- An algorithm that associates the desired origin and destination locations with the buses on which the traveller should board should be implemented.
- In case a bus traffic problem arises, all users that follow a suggested route will be informed through their smartphones for the problem and the application will calculate the best alternative bus route in advance.

Possible Challenges

Not foreseen

Comments, additional features

None

1.2.6 Collaborative dynamic corridors

1.2.6.1 Application Overview

A short overview table of this application is given below.

Application name	Collaborative Dynamic Corridors
Application short name / Identifier	Dynamic Corridors / DC
Application short description	This is an application of the concept of transport corridors with an ITS perspective. The application could be understood as a set of digital services the infrastructure provider (or someone contracted by the provider) offers to users of the road infrastructure. It will be the digital infrastructure of the smart highway. Some of these services might be free i.e. they are paid through the tax bill, others might be premium services paid by road users on demand. The main objective is to establish corridors for heavy vehicles, being trucks or buses, in a dynamic way. Certain lanes could be reserved for certain vehicles during a certain period. For example, a bus lane could be assigned in the city centre only for buses during the period of peak in traffic, in order to prioritize public transportation schedule. Another example is to have lanes dedicated to distribution vehicles during the early morning to

	deliver goods in an efficient way. As a last example, inter-urban roads could have dynamic dedicated lanes only for heavy trucks. The collaborative aspect of this application is the possibility of dynamically start or finish a dedicated lane depending on the traffic conditions and priorities. Additionally, drivers could be motivated by serious games to improve their behaviour and increasing their priority in accessing those lanes. Another way to create a more dynamic traffic environment is to have dynamic vehicles that can adapt to local regulations. An example could be low noise zones where vehicles can choose different strategies to fulfil the regulation that allow them to enter the area; a hybrid vehicle can turn into full electric mode while a diesel truck can prevent heavy accelerations or high number of revolutions. Access control is an important feature and should be monitored in real-time. The vehicles could have lane position to determine if they are using the lanes inappropriately and also could require access remotely and be granted via in-vehicle HMI. For this application, there is the possibility of connecting with the SP4 "Cooperative Driving" application with the merging feature, which can help the drivers of heavy vehicles to access the corridor lanes. The assistance should be given both to the heavy vehicle driver and to the nearby car drivers in order to merge in an eco-friendly and safe way.
Platforms implementing the application	Smartphone/Vehicle-API, Fully vehicle-integrated, Backbone (traffic management centre), Third party (e.g. public transport operator)
Application objective	The goal of this application is to have fully collaborative dynamic transport corridors focused on heavy vehicles to optimize the utilization of lanes, assist the drivers to access and leave those lanes and enable monitoring and control of usage.
Basic functioning	The central system has a map of dedicated lanes currently available

	and areas with special local regulations. The vehicles approaching the lanes or areas receive a notification of availability and acceptance criteria. The vehicle requests permission to enter and receives a response. If access is granted, the merge assistance coaches the driver to join the lane. Data is logged for compliance analysis and planning.
Application's use cases	1. Dynamic Dedicated Lanes for Corridors 2. Dynamic Vehicle Adaption to Local Regulations 3. Serious games for eco driving 4. Intelligent Access Control 5. Lane merge assistance 6. Data logging
Required lower layer components	• LDM++ • Communication components • Lane level positioning • Prioritization algorithms • Vehicle data provider • Vehicle controlling and adaptation component • Data logging • Serious gaming component • Merge assistant • In-vehicle HMI

1.2.6.2 Application use case 1: Dynamic dedicated lanes for corridors

Overview

Use case name	Dynamic Dedicated Lanes for Corridors
Use case short name	DDLC
Use case identifier	SP3_DC_DDLC
Use case short description	Dynamic dedicated lanes are lanes that are able to adapt to the current traffic situation. The lanes could be dedicated to buses, commercial city distribution, or inter-urban truck transports. It may for example be a need for dedicated bus lanes during rush hours, but for the remaining period the traffic situation could benefit from having all lanes accessible for all kind of traffic.
Precondition	There are several lanes on the road and one can be assigned to a special purpose.
Postcondition	The vehicles nearby get information about the available dedicated lanes
Normal flow	Vehicle approaches a location with dynamic dedicated lanes Vehicle gets information about the availability of the lanes
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone/Vehicle-API, Fully vehicle-integrated, Backbone (traffic management centre)
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station

Infrastructure	The traffic infrastructure equipped with a TEAM ITS roadside station
Driver	Driver of the vehicle

Input and Outputs

Input	• Road topology
	  • Lanes and directions
	  • Intersections
	  • Access and exit lanes
	• Availability of the corridor lanes
	• Criteria for acceptance
	• Itinerary
	• Additional services available
	• Prioritization

Output	Information to the driver about availability of lane

Required functional components

Components short name	Short explanation
LDM++ with cloud	Road topology
Vehicle data or phone data provider	Vehicle characteristics
Communication components (LTE, 802.11p)	Communication with the traffic infrastructure
User profile	N/A
Other SP2 component	Lane level positioning

Interaction between SP3 and SP4	Not specifically for this use case

Objectives

Dynamic dedicated lanes aim to improve the utilization of the road capacity. There may for example be a need for dedicated bus lanes during rush hours, but for the remaining period the traffic situation could benefit from having all lanes accessible for all kind of traffic. This application also includes dedicated lane for trucks.

User benefits

It is assumed that the traffic flow can be improved by assigning lanes to specific types of vehicles dynamically. There can be lanes exclusively for buses or trucks, or certain vehicles could also use them with certain criteria, such as emergency vehicles, taxis etc. Instead of having static dedicated lanes, they can adapt to the traffic flow, as for example congestions.

Basic functioning

The driver should receive a notification about the availability of dedicated lanes that fit the vehicle and driver profile.

Definition of work

- A decision and planning tool to assign lanes
- Algorithms for allocating dynamic lanes automatically and for suggesting to the operator
- A component that can aggregate information about dynamic lanes
- A protocol to communicate this information to the vehicles
- An HMI component to show the information to the driver
- In-vehicle to assist drivers to join the dedicated lanes
- Variable Message Signs to inform the other drivers about the dedicated lanes

Possible Challenges

- Possible extensions of protocols currently under standardization
- Algorithm for allocation of dynamic lanes
- Communication with the vehicles by road infrastructure or cloud

Comments, additional features

None

1.2.6.3 Application use case 2: Dynamic vehicle adaption to local regulations

Overview

Use case name	Dynamic Vehicle Adaption to Local Regulations
Use case short name	DVALR
Use case identifier	SP3_DC_DVALR
Use case short description	Vehicles adapt to local regulations regarding noise, emissions, safety, and speed, by changing their way of operation. A hybrid truck could for example switch to full electric mode to fulfil a low noise regulation, while a diesel truck achieves the same thing by prohibiting the ability to perform heavy accelerations or run on high revolutions.
Precondition	It is possible to get information about special regulations for certain areas.
Postcondition	The vehicles adapts to the local regulation (noise, emission, safety, speed)
Normal flow	Vehicle gets information about local regulations. The information must be available in advance so that the vehicle has time to adapt

	to the regulation or the driver could be informed that the regulation could not be fulfilled. The driver shall then have time to stop or find another road. If necessary, vehicle takes actions in order to adapt to the regulation. If actions have been taken, it could be necessary to inform the driver. This is basically the case when the driver could experience the driving behaviour as strange if no information is given. Vehicle enters the area with a noise level below the regulated max level.
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone/Vehicle-API, Fully vehicle-integrated, Backbone (traffic management centre)
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Infrastructure	The traffic infrastructure equipped with a TEAM ITS roadside station
Driver	Driver of the vehicle

Input and Outputs

Input	• Current local regulation (noise, emission, safety, speed) • Vehicle characteristics • Itinerary
Output	Information to the driver about adaption (or not) to the regulations

Required functional components

Components short name	Short explanation
LDM++ with cloud	Road topology
Vehicle data or phone data provider	Vehicle characteristics
Communication components (LTE, 802.11p)	Communication with the traffic infrastructure
User profile	N/A
Other SP2 component	N/A
Interaction between SP3 and SP4	Not specifically for this use case

Objectives

There is an enormous amount of parameters for traffic environments, resulting in a vast range of different types of environments, all with their own requirements and challenges:

- For a motorway high capacity is priority one.
- Streets in a residential area shall be quiet, clean, and safe.
- Crowded indoor shopping areas require zero emissions and extreme safety, but a too silent vehicle may be a risk here.

These are just a few examples, and it's important to notice that local conditions could change from one part of a street to another, e.g. when passing a school.

The toolbox available to shape the traffic and adapt it to local conditions is pretty much empty today, apart from the obvious speed-limit signs. In addition to that there are things like environmental zones, signs to ban special vehicle types (like trucks), or warning signs for things like playing children. But they all have their limitations. The geographic definitions of environmental zones are not very precise, and they tend to ban certain type of vehicles instead of actual high emissions from individual vehicles, the same things goes for sign that bans certain vehicle types.

Sign like “Playing children” is of course good but it’s not clear in what way the traffic should adapt to the information.

With adaptive vehicles it will be possible to create more specific local regulation, for individual streets or streets segments, and still not exclude certain type of vehicles.

Example of new regulations would be to specify permitted levels regarding noise, emissions, and (un)safety, in addition to speed regulations.

This kind of regulations, that state the purpose of the regulation – a clean, quiet, or safe environment – leaves it open to the vehicles to decide on how to fulfil the regulation; a hybrid vehicle could fulfil the noise regulation by switching to full electric mode, and a diesel vehicle could do it by prohibiting the ability to perform heavy accelerations or run on high revolutions.

Dynamic vehicles will reduce the need for vehicles dedicated to specific traffic environments. It will also make it possible for authorities to introduce new kinds or more precise regulations as it can be done without excluding whole categories of vehicles.

User benefits

The vehicle will be able to reduce the level of noise, reduce emissions, limit speed or enter a safe mode when needed. If the regulation is mandatory (and not just a recommendation) it will increase the vehicle operation area, as it will give the vehicle access low noise areas where it would be banned without this functionality.

It will make it possible for authorities to introduce more strict regulation without the risk of banning whole categories of vehicles.

Basic functioning

The vehicle control system must be able to know about local regulations. This information should be available in advance so that the vehicle is able to perform the needed adaptation, and also to give the driver a chance to take another road if the vehicle will not be able to adapt to the regulation.

Definition of work

- A component that can aggregate information about local regulations for different areas
- A protocol to communicate this information to the vehicles
- A component that aggregates the vehicle characteristics related to regulation adaption
- Vehicle control system to actuate in the vehicle to change its characteristics related to regulations (speed, noise, emissions, safety)
- Measurement components to read vehicle information in real-time
- An in-vehicle HMI component to show the information to the driver

Possible Challenges

- Possible extensions of protocols currently under standardization
- Measurement in real-time
- Vehicle controlling
- Communication with the vehicles by road infrastructure or cloud

Comments, additional features

None

1.2.6.4 Application use case 3: Serious games for eco driving

Overview

Use case name	Serious games for eco driving
Use case short name	SGED
Use case identifier	SP3_DC_SGED
Use case short description	Gaming is a way to encourage good driving behaviour. A driver could win or lose "points" depending on the way of driving. Example of parameters that could be taken into account is: right

	speed, keeping distance, low fuel consumption etc.
Precondition	It is possible to get real-time information about the driver performance and compliance to regulations
Postcondition	The driver receives a grade based on his/her style of driving and gaming points by behaving in an eco-friendly way.
Normal flow	Based on driver behaviour, the system attributes a grade to the driver
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone/Vehicle-API, Fully vehicle-integrated, Backbone (traffic management centre)
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Infrastructure	The traffic infrastructure equipped with a TEAM ITS roadside station
Driver	Driver of the vehicle

Input and Outputs

Input	• Vehicle characteristics • Itinerary • Road topology and information (speed limits, etc.) • Real-time vehicle measurements (speed, acceleration, braking, etc.)
Output	Information to the driver about how to drive (coaching)

Required functional components

Components short name	Short explanation
LDM++ with cloud	Road topology and information (speed, etc.)
Vehicle data or phone data provider	Vehicle characteristics and real-time measurements (speed, acceleration, braking, etc.)
Communication components (LTE, 802.11p)	Communication with the traffic infrastructure
User profile	Driver profile
Other SP2 component	Lane level positioning
Interaction between SP3 and SP4	Not specifically for this use case

Objectives

The main objective of this use case is to grade the driver based on his driving behaviour and compensate that behaviour (positively or negatively) with access to dedicated lanes and areas.

User benefits

The user will be benefited by being allowed to access special road infrastructure (lanes and regions) based on a good behaviour.

The driver will be motivated to behave well in traffic in order to get a positive compensation.

Basic functioning

Based on a set of criteria, the driver will be graded based on his/her behaviour and this grading system will be used to grant access to special road infrastructure.

Definition of work

- A gaming component
- Measurement components to read vehicle information in real-time
- An In-vehicle HMI component to coach the driver

Possible Challenges

Establishing what is a good behaviour for different types of vehicles

Comments, additional features

None

1.2.6.5 Application use case 4: Intelligent access control

Overview

Use case name	Intelligent Access Control
Use case short name	IAC
Use case identifier	SP3_DC_IAC
Use case short description	Intelligent access control makes it possible for authorities to easily and effectively control the access for individual vehicles to certain areas or corridors. Vehicles should identify themselves and give information about size and weight. It should be possible for authorities and stakeholders to monitor for compliance to rules and regulations.
Precondition	The vehicle can communicate its own static and dynamic characteristics. The central system has a set of criteria for access control.

Postcondition	The vehicles nearby get information about if they are allowed to access a dedicated lane or a regulated area
Normal flow	• Vehicle approaches a location with dynamic dedicated lanes or with special regulations (noise, emission, safety, speed) • Vehicle gets information about the availability of the lanes or restricted area • Based on a set of criteria, such as vehicle characteristics and serious games, the system decides if the vehicle is granted access • The driver is informed if he/she has been granted access
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone/Vehicle-API, Fully vehicle-integrated, Backbone (traffic management centre)
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Infrastructure	The traffic infrastructure equipped with a TEAM ITS roadside station
Driver	Driver of the vehicle

Input and Outputs

Input	• Road topology
	  • Dedicated lanes
	  • Regulated regions

	• Criteria for acceptance • Vehicle characteristics • Driver points • Itinerary
Output	Information to the driver about access (granted or denied)

Required functional components

Components short name	Short explanation
LDM++ with cloud	Road topology
Vehicle data or phone data provider	Vehicle characteristics and real-time measurements (speed, acceleration, braking, etc.)
Communication components (LTE, 802.11p)	Communication with the traffic infrastructure
User profile	Driver profile
Other SP2 component	Lane level positioning
Interaction between SP3 and SP4	Not specifically for this use case

Objectives

Intelligent control makes it possible to control the usage of a corridor or part of corridors, either by just monitoring the usage or by prohibit the access to certain vehicles that don't fulfil the requirements or in some other way has disqualified themselves for usage of the corridor.

User benefits

By dynamically controlling the access to certain kinds of infrastructure, such as dedicated lanes or specially regulated areas, it should be possible to reduce emissions in the overall traffic and increase the efficiency especially of trucks and buses.

Basic functioning

When a vehicle is about to enter a corridor or regulated area, it asks for permission to enter. It could be a check for compliance to rules and regulations. The driver could also be asked to accept special rules and conditions before access is granted, this could for example be the permission to let the traffic management monitor the vehicle.

Definition of work

- A set of criteria for access control
- Algorithms for checking access for certain vehicles
- A protocol to communicate between infrastructure and vehicle
- An in-vehicle HMI component to inform the driver about his/her access rights

Possible Challenges

- Possible extensions of protocols currently under standardization
- Algorithm for access control

Comments, additional features

None

1.2.6.6 Application use case 5: Lane merge assistance

Overview

Use case name	Lane merge assistance
Use case short name	LMA
Use case identifier	SP3_DC_LMA
Use case short description	Assist drivers when there is a need to merge. Example of scenarios include when a heavy vehicles wishes to merge and the car drivers receive advice to give space, but also when cars need to merge and there are heavy vehicles on the lane. Another scenario can be when the vehicle is in the access ramp and is going to merge in the lane.
Precondition	Lane level positioning and a map with nearby vehicles
Postcondition	The vehicles get assistance and perform a successful merge.
Normal flow	The vehicle approaches a dedicated lane and is granted access The vehicles in the lane receive advice that there is another vehicle wishing to merge The vehicle that wishes to merge receives advice to perform the merging
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone/Vehicle-API, Fully vehicle-integrated
Expected frequency of use	Medium

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Driver	Driver of the ego-vehicle
Other drivers/vehicles	The other vehicles/drivers on the lane

Input and Outputs

Input	• Road topology
	  • Dedicated lanes
	  • Access ramps
	• Vehicles already on the lane
	• Vehicle characteristics (weight, braking capacity, etc.)
	• Real-time information (speed, position, etc.)
	• Itinerary

Output	Driver coaching to merge

Required functional components

Components short name	Short explanation
LDM++ with cloud	Road topology
Vehicle data or phone data provider	Vehicle characteristics and real-time measurements (speed, acceleration, braking, etc.)
Communication components (LTE, 802.11p)	Communication with the traffic infrastructure
User profile	N/A
Other SP2 component	Lane level positioning
Interaction between SP3 and SP4	This use case is also a part of SP4 Collaborative Driving application

Objectives

Support drivers when there is a need to merge. It can remove stress and pressure for all the drivers involved, and it could also improve traffic flow.

User benefits

- Easier and more effective merging of heavy vehicles to dynamic corridors.

Basic functioning

When a vehicle is about to enter a corridor, the driver is coached to perform a safe and effective merging in the lane. The drivers of the surrounding vehicles also receive assistance to allow the heavy vehicle to merge.

Definition of work

- A merge assistance component
- An in-vehicle HMI component to coach the drivers

Possible Challenges

- Vehicle characteristics that influence the merging process (i.e. weight, braking capacity, acceleration capacity, etc.).

Comments, additional features

None

1.2.6.7 Application use case 6: Data logging

Overview

Use case name	Data logging
Use case short name	DL

Use case identifier	SP3_DC_DL
Use case short description	Data should be logged for the authorities to evaluate the usage of the corridors and be able to improve the traffic. It should also be possible to identify violations and make impact assessment. For example, it should be possible to visualize if there is too much traffic of heavy vehicles in a bridge.
Precondition	It is possible for the vehicle to upload data to a central system
Postcondition	The usage of dedicated lanes and restricted areas are logged for planning activities, performance and compliance analysis
Normal flow	All vehicles that get access to a dedicated lane or restricted area are monitored for performance analysis
Deployment platforms (vehicle/smartphone/ backbone)	Smartphone/Vehicle-API, Fully vehicle-integrated, Backbone (traffic management centre)
Expected frequency of use	High

External actors and components

Actors' short name	Short explanation
Vehicle	The vehicle equipped with a TEAM ITS vehicle station
Infrastructure	The traffic infrastructure equipped with a TEAM ITS roadside station

Input and Outputs

Input	• Vehicle characteristics (weight, braking capacity, etc.) • Real-time information (speed, position, etc.) • Itinerary

Output	Logged data

Required functional components

Components short name	Short explanation
LDM++ with cloud	N/A
Vehicle data or phone data provider	Vehicle characteristics and real-time measurements (speed, acceleration, braking, etc.)
Communication components (LTE, 802.11p)	Communication with the traffic infrastructure
User profile	N/A
Other SP2 component	Lane level positioning
Interaction between SP3 and SP4	Not specifically for this use case

Objectives

By logging data authorities can evaluate the usage of the corridors and be able to improve the traffic or infrastructure by learning from statistics from the corridor usage. Data will be logged when the vehicle is in the corridor or restricted area and includes information about position, speed and vehicle characteristics such as weight, load, type of vehicle, engine and fuel information etc.

User benefits

- Better planning of dynamic corridors resulting in improved traffic flow and reduced emissions.

Basic functioning

The system should log all the time data from the vehicles.

Definition of work

- A component that aggregates the vehicle characteristics
- Measurement components to read vehicle information in real-time
- A data logging component

Possible Challenges

- Data volume

Comments, additional features

None

1.2.7 Community gaming (cities, infrastructure)

The application has been merged with the gaming application from SP4. A description of this application is given in Part D, Section 1.2.4.

1.3 FLEX enablers

The current chapter describes the purpose of enablers. It closes with a list of categorized enablers derived from FLEX applications. For a detailed description of the concept of enables, please refer to Part A of Deliverable D1.0.

Enablers are used to designate three groups of entities: 1) data or aggregated data, 2) algorithms used by the applications and 3) tools.

1. **Enablers related to data or aggregated data** support application development. Such kind of data is e.g. the status of the traffic light, dynamic and static parking information, public transport time tables, routes and fares, fuel consumption information, real time traffic situation, road side aggregated data about the road status, FCD and XFCD from the field (incl. sensor data), traffic LOS and events, control strategy rules, indication of components operation (i.e. active, inactive components, reliability values) and so on.

2. **Enablers related to algorithms** are for instance: algorithms/metrics to evaluate different behavioural options from a system-centric perspective, logic/algorithms for mobility behaviour orchestration, conflict resolution algorithms, co-modal routing algorithms (in cooperation with DIALOGUE), social network monitoring, optimal control of users' incentives, driver, stakeholder and context modelling for cooperative driving, macro-level game theory-derived dynamic routing strategies providing incentives to drivers that contribute to the common benefit, micro-level game theory-derived collaboration strategies for vehicle/infrastructure traffic control strategy providing incentives that redefine win-win situations for both parties, highway traffic control strategies based on cloud computing, cloud-based data analysis of driver/traveller movements, trip cost comparison mechanisms, etc.
   Moreover, strategies for adaptive traffic management and control to achieve the optimization of the network operation at both network level and local level (e.g. intersection level for start and stop application) belong to this group. Some examples are: intersection rules that manage cooperative signalling, interaction manager which gives appropriate instructions to approaching vehicles based on their current position and the duration of traffic light phases (e.g. turn on/off engine), algorithms for calculating traffic light phase parameters (duration of traffic light phases in real time, vehicle position in a queue etc.).
3. **Enablers related to tools** include: a tool to evaluate different behavioural options from a system-centric perspective, a gateway for integrating data/information from different relevant infrastructural data providers (i.e. a data adaptor which processes data from data providers and formats it in a way, that it could be handled by TEAM), a tool to handle all stakeholder needs such that they can be further processed, the simulation as a tool for applications (not for evaluation purposes but to serve applications directly), a social driving platform, with sub-modules such as geo-tagging, geo-messaging, car-transport semantics, support for proximity, community building and analysis and ad-hoc gaming support.

1.3.1 Enabling use cases

Enabling use cases were found during FLEX application discussion. The following list of use cases are associated to enabling components of a particular application (COPLAN), which are expected to serve multiple applications. An extensive list of enablers covering all applications will be provided in an upcoming document.

1.3.1.1 SP3_COPLAN_DATACO: Heterogeneous data and service requests collection, aggregation and compilation

Use case name	Heterogeneous data and service requests collection, aggregation and compilation
Use case short name	DATACO
Use case identifier	SP3_COPLAN_DATACO
Use case short description	COPLAN issues requests to different TEAM services and applications to collect diverse data on traffic state for all supported routing modes available in the region. COPLAN uses a layered processing scheme to aggregate data at different granularity levels, i.e. assessing traffic state at different geographic scales. After analysing and bringing heterogeneous data to a common format, COPLAN employs a scoring system for particular locations, paths and regions, according to the supported routing modes. This scheme enables a simpler multi-modal route optimization in a later stage. Annotations are dynamic and contribute to the creation of statistical data (see use-case 4, STATCO). DATACO also considers the classification of data as well as its redirection to the corresponding modules (STATCO, PRETRA, etc.), triggering a recalculation of dynamic information on the corresponding layer of the LDM++ based map.
Precondition	SP3_CMC (collaborative monitoring application) delivers data, answering to specific requests. An inference engine is in place at CMC to allow complex requests and perform data pre-processing and filtering. Applications use a standardized messaging system as proposed within the SP4 Collaborative Application Framework to exchange data.
Postcondition	COPLAN issues request to different applications demanding heterogeneous data. COPLAN triggers the update of dynamic information performed by other modules (STATCO, PRETRA, etc.) COPAN collects and processes data in preparation for map annotation.
Normal flow	1. COPLAN issues messages to individual SP3/SP4 applications (COPLAN might talk to individual users when more information is needed to perform a given type of optimization, as originally requested by the

	requesting SP4 application). These messages are annotated with metrics, for instance regarding latency requirements. 2. SP3/SP4 applications respond according to the requested metrics, providing (or not) the requested information. 3. COPLAN processes the requested data as needed and prepares it for map annotation. The module DATACO performs also filtering and classification of information. 4. DATACO issues update requests to other modules (STATCO, PRETRA, MAPAN, etc.) in order to trigger specific processing of the just collected data.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre / cloud), Third party (e.g. public transport operator)
Expected frequency of use	high

1.3.1.2 SP3_COPLAN_MAPAN: Map data annotation

Use case name	Map data annotation
Use case short name	MAPAN
Use case identifier	SP3_COPLAN_MAPAN
Use case short description	COPLAN annotates maps to enable faster multi-modal route optimization. To this end, MAPAN employs the data collected, aggregated and compiled by DATACO and STATCO and issues write requests to the LDM++ map database in a centralized way.
Precondition	COPLAN gets data from other SP3/SP4 applications and processes it in an LDM++ compatible format.
Postcondition	COPLAN provides routing information with annotated LDM++ maps which are periodically / asynchronously refreshed. MAPAN updates LDM++

	layers depending on the information provided by DATACO, STATCO, PRETRA, etc.
Normal flow	MAPAN receives map update requests from other COPLAN modules (which work fully asynchronous). MAPAN refreshes the corresponding LDM++ layer in the map database using a double-buffering scheme to avoid accessing maps being currently updated, hence offering 100% service availability to other applications and modules that might concurrently issue a read request to the map database.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre / cloud), Third party (e.g. public transport operator)
Expected frequency of use	High

1.3.1.3 SP3_COPLAN_MODPLAN: Multi-modal route planning

Use case name	Multi-modal route planning
Use case short name	MODPLAN
Use case identifier	SP3_COPLAN_MODPLAN
Use case short description	A client request (e.g. complying with SP4 Collaborative Application Framework message protocol) triggers the calculation of a route. The message contains information as to what traffic modes may be used with a given user-assigned priority.
Precondition	• Existence of LDM++ annotated maps provided by MAPAN • Multiple / individual requests from SP4_CONAV for large-scale, multi-vehicle, multi-modal route planning
Postcondition	MODPLAN provides the actual multi-modal, multi-vehicle/actor route planning for external applications (SP4, SP3).

Normal flow	1. A route planning request is accepted. 2. The optimization engine employs navigation profiles (e.g. "in a hurry", "Sunday drive", "Emergency", etc. → ties to serious gaming) and additional information (e.g. prioritized, desired/available multi-modal options: car, bus, train, underground, bicycle, walk, etc.) to establish priority lists which help in the optimization process. 3. The information collected in point 2 is combined with map information (as provided by STATCO, DATACO, PRETRA, MULTINAV, etc.). If additional information is required, MODPLAN issues requests to the corresponding module, which will collect the data and eventually trigger a map update through MAPAN. 4. MODPLAN generates a potential route and eventually iterates between point 3 and 4, when any of the other modules issues a map update request.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre, SP3 cloud infrastructure), Third party (e.g. public transport operator)
Expected frequency of use	High

1.3.1.4 SP3_COPLAN_STATCO: Statistical / historical geo-location specific data collection

Use case name	Statistical / historical geo-location specific data collection
Use case short name	STATCO
Use case identifier	SP3_COPLAN_STATCO
Use case short description	COPLAN collects data in an event- or time-triggered fashion building e.g. a running average of significant traffic data. This information is delivered to other TEAM applications or is used to compute routes considering the history of particular locations, roads or regions. Thus, COPLAN will avoid or inform the user of particularly dangerous or problematic locations, roads

	and areas. The computation of co-modal routes should include links / elements from serious gaming applications.
Precondition	Existence of traffic-relevant data (events) associated with particular locations, roads, landmarks, etc. Specific events can be derived through data aggregation and sensor data fusion, e.g. average vehicle speed in a given street segment / point at a certain time of the day, other events are more straightforward, e.g. number of accidents at a given road crossing or along a road segment.
Postcondition	STATCO generates LDM++ annotated maps (through MAPAN) with historical / statistical data that is used to avoid or reduce traffic through certain locations, road segments, crossings, etc., to warn or to inform the user of potential risks, or to trigger safety actions in other applications.
Normal flow	1. STATCO filters data coming from DATACO or triggers specific requests to DATACO. 2. Data is aggregated to specific geographic features with specific geo-locations (crossing/point, road, landmark, road segments, area, etc.). The reason behind this is that specific events might be annotated with slightly different geo-locations. Also a given event can contribute to several different categories. 3. This information which is associated with specific events and geo-locations and geographic features is examined in connection to previous entries in a LDM++ map with annotated historical / statistical data. 4. STATCO then calculates a running average (if relevant), or the pertinent / relevant / required statistical feature or magnitude. 5. STATCO issues an annotation request to MAPAN in order to update the historical / statistical LDM++ layer.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre, TEAM cloud infrastructure), Third party (e.g. public transport operator)
Expected frequency of	High

use	

1.3.1.5 SP3_COPLAN_PRETRA: Real-time evaluation and computation of predictive traffic development

Use case name	Real-time evaluation and computation of predictive traffic development
Use case short name	PRETRA
Use case identifier	SP3_COPLAN_PRETRA
Use case short description	COPLAN can recognize dynamic events from the periodically collected data. Dynamic events have a form (e.g. point, line, area) and a dynamic evolution, i.e. change over time, stored as snapshots at specific time intervals. Such events can be bottlenecks, slow moving traffic, etc. This information can be used to compute predictive behaviour to be involved in the route computation, i.e. the multi-objective, multi-variable optimization algorithm) or be forwarded to the requesting client.
Precondition	Existence of reliable multi-modal traffic sensors or data (streaming) sources.
Postcondition	The system can detect and track the current development / evolution of traffic and generate predictions as to what the future development / evolution of specific events will be (traffic jams, slowly moving traffic, density changes, etc.) in a number of time- and geo-scales. This information can be considered during route computation or be forwarded to the user or other applications for e.g. strategy changes.
Normal flow	1. PRETRA maintains several layers in the LDM++ map database dealing with historical traffic conditions. Each layer comprises a given geographic scale and contains geometric objects and diverse annotations that encode spatially distributed traffic events, for instance a traffic jam on a given road, 2. PRETRA access the current traffic condition map (layer "road") and based on already identified objects, it looks for the same object with (slight) geometrical changes. PRETRA also detects new conditions (i.e.

	objects). 3. Upon object identification, it stores a snapshot of the current traffic condition map. 4. PRETRA then analyses a number of map snapshots to determine short and long term evolutions of the identified objects. PRETRA also looks for clues to these objects in other information sources, by issuing data requests with specific goals, e.g. event originating a traffic jam, or by analysing collected data in the LDM++ map database. These clues and their associated quality might alter predictions. 5. PRETRA then provides predictions in different time-scales (e.g. several layers each corresponding to a given time scale). These predictions constitute constraints that COPLAN's other modules, particularly MODPLAN, employ in their computations. 6. PRETRA might also provide periodic updates to clients requesting its services, which might for instance trigger a new route planning on an already existing route.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre, TEAM cloud infrastructure), Third party (e.g. public transport operator)
Expected frequency of use	High

1.3.1.6 SP3_COPLAN_MULTINAV: Multi-vehicle routing data evaluation, computation and large-scale coordination for collaborative navigation

Use case name	Multi-vehicle routing data evaluation, computation and large-scale coordination for collaborative navigation
Use case short name	MULTINAV
Use case identifier	SP3_COPLAN_MULTINAV
Use case short	COPLAN considers multiple routing requests and previous calculated

description	routes to deliver new routes, thus avoiding sending too much traffic over the same routes. MULTINAV will keep track of existing actors and their routes. It will assign and re-assign route priorities and issue requests for route re-computation in case of conflicting situations, and thus introduce additional constrains in the optimization algorithm.
Precondition	The main condition is the existence of a number of clients requesting use of COPLAN on the same geographical zone. If the number of clients is high enough, multi-vehicle optimization is required to avoid increasing the impact of routed traffic over already loaded routes and to avoid routing too many TEAM actors over the same roads, which might potentially cause interference / disturbances among users of the same service.
Postcondition	COPLAN takes into account already routed traffic as well as concurrent routing requests to compute new routes or eventually re-compute old ones. In this way a better traffic load balancing both in terms of geographical and temporal scale is achieved.
Normal flow	1. Multiple requests for route planning are accepted, these can be fully asynchronous, so that new requests must be fitted to and may possible alter already calculated routes. All requests are queued and assigned a given priority, which depends on a number of factors like e.g. navigation profile, request age, etc. Existing routes – which have been already assigned to specific traffic actors – might change their priority, for instance if a safety relevant actor (e.g. ambulance) makes a request. Otherwise existing routes have a higher priority than those assigned to newcomers. 2. MULTINAV keeps track of all routed actors, their actual position and heading. When a new routing request is accepted, MULTINAV issues a routing request to MODPLAN, thereby adding further constraints given by existing routes. To this end, MULTINAV maintains an LDM++ layer in the map database with current actors, their current characteristics (position, heading, velocity, etc.), and their assigned routes. If an actor is detected to deviate from the current route, a route re-computation is issued to MODPLAN. 3. "Living routes" are distributed among participants and these receive

	updates as soon as traffic conditions change and thus alternative routes must be generated. 4. Traffic actors using the service provide feedback in the form of actor position, velocity, direction, etc. to MULTINAV through the user-level applications (SP4) and these in turn through the supporting sub-services in COPLAN. As the actors move around, new updates to the existing routes on the LDM++ map are generated, thus freeing up map resources. MULTINAV takes care of issuing update requests to maps due to the dynamic nature of already in-place routes.
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre), Third party (e.g. public transport operator)
Expected frequency of use	High

1.3.1.7 SP3_CONAV_EDB: Edit network information in real time (for balanced routing and other applications)

Use case name	Edit network information (for balanced routing and other application)
Use case short name	EDB
Use case identifier	SP3_CONAV_EBD
Use case short description	Traffic managers will need to edit network objectives. The information in such a way that balanced routing is possible. This is only one of several applications which require such an interface to traffic managers or others who wish to control or influence traffic by this instrument.
Precondition	• Information about actual traffic and network state. • Network connection (not necessarily C2X).

Post-condition	• Route recommendation for balancing the network could be calculated.
Normal flow	1. A traffic manager has information about recent traffic load. Based on that, he edits relevant information. 2. Using the LDM++ this information is forwarded to the end user (driver), where it is used to achieve a balanced network. 3. In a closed control loop, the infrastructure could measure the updated traffic states and could thus in consequence update the information entered as weights or similar (step one above),
Deployment platforms (vehicle/smartphone/ backbone)	Backbone (traffic management centre)
Expected frequency of use	Often

1.3.2 Enabler list from SP3 applications

Here we illustrate potential enablers, which may be part of applications (status so far). But these enablers could be externalized to serve not only one but multiple applications.

1.3.2.1 SP3_MCM: Collaborative Pro-Active Urban / Interurban Monitoring and Ad-Hoc Control

Application "Collaborative Pro-Active Urban / Interurban Monitoring and Ad-Hoc Control" (MCM)	
Data Enablers	**LDM++ database**: to be integrated with specific additional tables/databases for supporting collaborative traffic monitoring and control functionalities
	PT info: • Public transport timetables and routes: A module in which the timetables and routes are stored, updated and from which they can be retrieved

	• Data on the public transport vehicle fleet (location, availability, load)
	Traveller info (to be provided by CCA and COPLAN). Data on traveller demand and time constraints. Relevant information from the travellers such as starting position and intended destination along with their departure, and their (Avatar related) preferences
	Vehicles info (to be provided by DIALOGUE Apps/Enablers). Information (based on the xFCD paradigm) about the status of the vehicle itself and environmental conditions.
	Transport infrastructure data: Raw data (coming from legacy road sensors and specific systems) and processed information about the current and forecasted status of the network (accidents, expected congestion, …), traffic control parameters (e.g. SPaT) and demand driving multi-layered policies.
Algorithm Enablers	**xFCD map matching**. Self-explanatory. A common standard protocol should be implemented (e.g. starting from the s.i.mo.ne protocol)
	xFCD aggregation/validation/fusion. Self-explanatory.
	Traffic forecast. Self-explanatory.
	Multi-layered policies agent. This algorithm is in charge to consider all the available information and the constraints given by the operator to create ad-hoc multi-layered traffic control policies and generate events to be used as an input from vertical applications such as COPLAN and CCA (e.g. expected congestion, re-routing, …).
	Traffic control optimization. This algorithm is aimed at the definition of the local optimal control to be applied at the intersection level, taking into account all the need of vertical applications (e.g. Smart Intersection-PT priority, Green Corridors, …) including DIALOGUE Apps and UCs (e.g. collaborative start & stop).
Tools Enablers	**Gateways** for integrating other enablers
	B2B information service. To be used to deliver traffic info to internal and external actors (mainly vertical FLEX and DIALOGUE applications).
	Virtual road-side unit. Tool to run traffic control optimization algorithms and potentially multi-layered policies from the cloud.
	Traffic operator GUI. Potentially web desktop based (SaaS).
	Traffic simulator for testing/benchmarking (TSS Aimsun, VSimRTI)

1.3.2.2 SP3_CPTO: Collaborative Public Transport Optimization

Application "Collaborative Public Transport Optimization" (CPTO)	
Data Enablers	**Public transport timetables and routes**: A module in which the timetables and routes are stored, updated and from which they can be retrieved
	Data on the public transport vehicle fleet (location, availability, load)
	Real-time traffic data (incl. accidents): This module retrieves traffic information and possible accidents in specific road segments (this will be provided by the CMC application)
	Data on traveller demand and time constraints: A module aggregating all the relevant information from the travellers into a time based data base, that is; a module collecting all users' starting position (start point) and intended destination (end point) along with their departure time (and possibly their expected time to reach their destination), and their tentative preferences regarding the means of transport they will take and the route they will follow.
	Positioning information: A module that can specify the travellers' location so as to provide information to the travellers about their current position when they are on the move (expected from EMPOWER).
Algorithm Enablers	**Routing optimization algorithms** (accident-based, traffic-based, event-based): The goal of this algorithm is to optimize the overall public transport network efficiency, minimization of CO_2 emissions (by proposing alternative solutions to a number of travellers and/or by providing speed recommendations to the bus drivers)
	Scheduling optimization algorithms: Cancellation of bus trips with no actual demand at a certain point in time, adaptation of routes in order to dynamically create new stations/stops when there is a high demand, headway adaptation etc.
	Prediction algorithm for traveller demand: This algorithm calculates the demand per time frame, per transport medium (e.g. bus, train, taxi), per route segment etc. in terms of number of passengers.
	Optimization algorithm for journey of individual traveller: A module which based

	on the updated schedules, the traveller O/D and current position provides in real-time information to the traveller such as: • the current location of the bus of interest, • the time they have to wait at the stop for the bus, • info on the forthcoming stations, • the estimated time to their destination, • considerable delays on the route of interest, • suggestions on alternative routes,
Tools Enablers	**Gateway** for integrating info from different public transport operators (needed from most FLEX applications)
	Traveller/Bus driver data exchange module: A module that serves the information/data exchange between the traveller and bus driver devices and the central application platform; that is an application layer communication module that uses the underlying communication interface/module of the end-device (expected from EMPOWER)
	Communication module: A module that establishes connectivity with an available communication network in order to perform the data exchange between the traveller/bus driver device and the central application platform (expected from EMPOWER)
	A **GUI** for presenting relevant information both to the bus driver and the travellers (expected from DIALOGUE)
	Simulator for testing (VSimRTI simulator will be examined)
	Social driving platform (expected from Serious Gaming and Community Building application)

1.3.2.3 SP3_CCA: Co-modal Coaching with support from Virtual / Avatar users

Application "Co-modal Coaching with support from Virtual / Avatar users" (CCA)

Data Enablers	**LDM++ database**: to be integrated with specific additional tables/databases for supporting collaborative traffic monitoring and control functionalities
	PT info: Public transport timetables and routes: A module in which the timetables and routes are stored, updated and from which they can be retrieved Data on the public transport vehicle fleet (location, availability, load)
	Traveller info (to be provided by CCA and COPLAN). Data on traveller demand and time constraints. Relevant information from the travellers such as starting position and intended destination along with their departure, and their (Avatar related) preferences
	Vehicles info (to be provided by DIALOGUE Apps/Enablers). Information (based on the xFCD paradigm) about the status of the vehicle itself and environmental conditions.
	Transport infrastructure data: Raw data (coming from legacy road sensors and specific systems) and processed information about the current and forecasted status of the network (accidents, expected congestion, …), traffic control parameters (e.g. SPaT) and demand driving multi-layered policies.
	User profiles: Self-explanatory. To be defined together with other B2C vertical applications.
Algorithm Enablers	**Ideal path algorithm**: Co-modal algorithm for the dynamic identification of the ideal co-modal trip to be followed (differently from the consolidated approach in transportation engineering, not necessarily the shortest one in terms of distance/time).
Tools Enablers	**Gateways** for integrating Enablers "LDM++ database" and "user profiles".
	Traveller GUI. To set preferences, parameters and receive (pre-trip and post trip) coaching instructions. Could be based on screen mirroring to be used on multiple devices at the same time (e.g. smartphone + in-car multimedia system display when the traveller is driving a car).
	Traveller trip monitor. Self-explanatory.
	Avatar trip simulator to run the ideal path algorithm and then generate the ideal trip followed by the Avatar. The concept is rather different than tradition micro-simulators used for Decision Support and evaluations, therefore a specific study is needed.
	Social driving app interface. Self-explanatory.

1.3.2.4 SP4_SGCB: Serious Gaming and Community Building

Application "Serious Gaming and Community Building" (SGCB)	
Data Enablers	**Map data aggregation module**: A mapping system able to aggregate and manage highly dynamic information layers in the cloud (also including geo-tagging and geo-messaging by drivers and passengers)
	Safe/green driving behaviour models: Models of vehicles that can assess how well (safe/green) that specific vehicle is being driven
	Multimodal transport ontology as basis for the communication and collaboration
Algorithm Enablers	**User profiling and assessment module** able to quantitatively assess in real-time the driver performance, with respect to some particular targets, such as green and safe driving
	Driver coaching module able to give the driver formative feedback in real-time about his performance
	Module to recognize accidents
	Module to recognize traffic jams
	Module to filter collaborative map information provision to the driver
Tools Enablers	**Collaboration management system**
	User/friendship management system (for which state of the art open source solutions may be integrated and adapted, such as elgg)
	Credibility management system (for which the ITS 2.0 solution by the Telecom Italia TEAM partner could be a proper starting point)
	Appealing **Human-Machine Interaction** consistent with the other GaLA applications.
	Data distribution module: Module which transmits the vehicle data to a hub and the hub distributes them to the relevant applications (in order to optimize wireless bandwidth consumption)

	CAN-smartphone gateway
	CAN reader

1.3.2.5 SP3_COPLAN: Collaborative Co-Modal Route Planning

Application "Collaborative Co-Modal Route Planning" (COPLAN)	
Data Enablers	**Heterogeneous data and service requests collection, aggregation and compilation (DATACO)**: COPLAN issues requests to different TEAM services and applications to collect diverse data on traffic state for all supported routing modes available in the region. COPLAN uses a layered processing scheme to aggregate data at different granularity levels, i.e. assessing traffic state at different geographic scales. After analysing and bringing heterogeneous data to a common format, COPLAN employs a scoring system for particular locations, paths and regions, according to the supported routing modes. This scheme enables a simpler multi-modal route optimization in a later stage. Annotations are dynamic and contribute to the creation of statistical data (see use-case 4, STATCO). DATACO also considers the classification of data as well as its redirection to the corresponding modules (STATCO, PRETRA, etc.), triggering a recalculation of dynamic information on the corresponding layer of the LDM++ based map.
	LDM++ Database (data format, layer and database addressing, etc.)
	Map data annotation (MAPAN): COPLAN annotates maps to enable faster multi-modal route optimization. To this end, MAPAN employs the data collected, aggregated and compiled by DATACO and STATCO and issues write requests to the LDM++ map database in a centralized way.
	Statistical / historical geo-location specific data collection (STATCO): COPLAN collects data in an event- or time-triggered fashion building e.g. a running average of significant traffic data. This information is delivered to other TEAM applications or is used to compute routes considering the history of particular locations, roads or regions. Thus, COPLAN will avoid or inform the user of particularly dangerous or problematic locations, roads and areas. The computation of co-modal routes should include links / elements from serious gaming applications.

Algorithm Enablers	**Multi-modal route planning (MODPLAN)**: A client request (e.g. complying with SP4 Collaborative Application Framework message protocol) triggers the calculation of a route. The message contains information as to what traffic modes may be used with a given user-assigned priority.
	Real-time evaluation and computation of predictive traffic development (PRETRA): COPLAN can recognize dynamic events from the periodically collected data. Dynamic events have a form (e.g. point, line, area) and a dynamic evolution, i.e. change over time, stored as snapshots at specific time intervals. Such events can be bottlenecks, slow moving traffic, etc. This information can be used to compute predictive behaviour to be involved in the route computation, i.e. the multi-objective, multi-variable optimization algorithm) or be forwarded to the requesting client.
	Multi-vehicle routing data evaluation, computation and large-scale coordination for collaborative navigation (MULTINAV): COPLAN considers multiple routing requests and previous calculated routes to deliver new routes, thus avoiding sending too much traffic over the same routes. MULTINAV will keep track of existing actors and their routes. It will assign and re-assign route priorities and issue requests for route re-computation in case of conflicting situations, and thus introduce additional constrains in the optimization algorithm.
Tools Enablers	Not foreseen at the moment

1.3.2.6 SP3_CSI: Collaborative Smart Intersections

Application "Collaborative Smart Intersections" (CSI)	
Data Enablers	**Traffic flow:** A component that aggregates information about the traffic conditions in a certain region (i.e. congestions)
	Nearby vehicles: A component that aggregates position and relevant information about the nearby vehicles (relative to the intersection)
	Navigation, itinerary and schedule: A component that can supply information about the vehicle itinerary and schedule (bus stops or deliveries)

	Vehicle characteristics: A component that aggregates all relevant static and dynamic vehicle characteristics (type, current speed, size, weight, load, passengers, etc.)
	Intersection information: A component that contains information about coming phase and time for all traffic lights in an intersection
Algorithm Enablers	**Prioritization algorithms**: Algorithms that can analyse priority of vehicles according to a set of criteria
	Serious gaming: A component that can grade drivers based on their behaviour
	Traffic analysis tool: For controlling several intersections in a region in order to optimize the traffic flow
	GLOSA: A component to calculate the optimal speed to cross an intersection when the traffic light is green. This component also includes a braking pattern recommendation, in case the vehicle cannot make to green.
Tools Enablers	**Driver coaching HMI**: An HMI component to coach the driver in different situations (GLOSA, braking recommendation, etc.)
	Vehicle controlling: A component that can control several aspects of the vehicle (i.e. start-stop, etc.)

1.3.2.7 SP3_DC: Collaborative Dynamic Corridors

Application "Collaborative Dynamic Corridors" (DC)	
Data Enablers	**Traffic flow:** A component that aggregates information about the traffic conditions in a certain region (i.e. congestions)
	Nearby vehicles: A component that aggregates position and relevant information about the nearby vehicles (relative to a traffic infrastructure or another vehicle)
	Data logging: A cloud component to log the trips of vehicles
	Navigation, itinerary and schedule: A component that can supply information about the vehicle itinerary and schedule (bus stops or deliveries)

	Local regulations: A component that have a set of special regulations for selected areas (noise, emission, speed, safety)
	Vehicle characteristics: A component that aggregates all relevant static and dynamic vehicle characteristics (type, current speed, size, weight, load, passengers, etc.)
Algorithm Enablers	**Prioritization algorithms**: Algorithms that can analyse priority of vehicles according to a set of criteria (can be used for dedicated lanes, regulated areas etc.)
	Serious gaming: A component that can grade drivers based on their behaviour
	Traffic analysis tool: For planning and assignment of dedicated lanes and especially regulated areas
Tools Enablers	**Access control**: A component to verify and grant or deny access to a certain transport infrastructure. In this context a lane or an especially regulated area, but it could be extended to bridges, tunnels etc.
	Driver coaching HMI: An HMI component to coach the driver in different situations (Merging, access control, etc.)
	Vehicle controlling: A component that can control several aspects of the vehicle (electricity/diesel, maximum revolutions, maximum speed, etc.)

1.4 Summary

FLEX sub-project aims at flexible energy efficient and eco-friendly mobility from the infrastructure's side based on interactions between all relevant users (i.e. travellers, vehicles, infrastructures). The key concept in FLEX is "elastic" transport infrastructures, that is infrastructures, such as parking places, road lanes and public transport, will start to be flexible and change based on citizens' or cities' demand.

At the beginning of this chapter the FLEX applications and their relevant use cases were described in detail based on a common template agreed by the consortium. A lot of information about the required components, the inputs/outputs and possible challenges of the applications and their use cases were highlighted.

Finally, a first draft list of enablers and enabling use cases were provided. This list will be enhanced and fixed in the specifications' phase, based on the outcome of the discussions not only internal to FLEX but with EMPOWER & DIALOGUE."

List of abbreviations and acronyms

Abbreviation	Meaning
(eco)CAM/DENM	Special form of CAM/DENM message for ecological information exchange
11p	See 802.11p
2G	2nd generation mobile communication standard, GSM
3G	3rd generation mobile communication standard, UMTS
3GPP	3rd Generation Partnership Project, unites telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TTA, TTC)
4G	4rd generation mobile communication standard, LTE
802.11p	See IEEE 802.11p
ACC	Adaptive cruise control
ADAS	Advanced driving assistance system
AIDE European project	European project, Adaptive Integrated Driver-vehicle InterfacE, http://www.aide-eu.org
AKTIV	German research iniative, Adaptive and Cooperative Technologies for the Intelligent Traffic, http://www.aktiv-online.org/english/projects.html
API	Application programming interface
Application	Group of eventually distributed functions which cause a system to perform useful tasks which are recognizable to the end user, see Part A, Section 1.2.2
ASTM E2213-03	Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems — 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications
Automotive cloud	Distributed storage and computing systems dedicated to automotive systems
B2B	Business to business
Basic technologies	Fundamental technologies required by applications, refers in TEAM context to technologies developed by EMPOWER, see Part A, Section 1.2.1

Abbreviation	Meaning
C-ITS	Collaborative intelligent transport systems
C2C	Car to Car
C2I	Car to Infrastructure
C2X	Car to Car / Car to Infrastructure
CA (certificate authority)	Certificate authority, certificate issueing entity
CA (communication agent)	Communication agent, see Part B, Section 1.3.4.5.
CACC	Collaborative adaptive cruise control, see Part D, Section 1.2.1
CALM	Communications access for land mobiles, http://www.isotc204wg16.org/concept
CAN bus	Controller Area Network bus, vehicle network
CCA	Co-modal coaching with support from avatar
CCTV	Closed Circuit Television
CDM	Collaborative driving and merging
Chromaroma	London based public transport online game, http://www.chromaroma.com/
citylog	CITYLOG European project, http://www.city-log.eu/
CLM	Cooperative Localization Message, see Part B, Section 1.3.1
Cloud	Distributed storage and computing systems
CMC	Collaborative pro-active inter-urban monitoring and ad-hoc control
CO2	Carbon dioxide
CODIA	Impact assessment study for cooperative systems, http://www.cvisproject.org/en/links/codia.htm
COMeSafety (2)	European support action, http://www.comesafety.org.
CONAV	Collaborative eco-friendly navigation
COPLAN	Collaborative co-modal route planning
CoVeL	Cooperative Vehicle Localization for Efficient Urban Mobility, http://www.covel-project.eu/
CPTO	Collaborative public transport optimization
CSE	Community services enablers, set of functions allowing to receive, validate and publish a series of contents, generated by a community of users, about mobility issues/conditions
CSI	Collaborative smart intersections for intelligent priority

Abbreviation	Meaning
CVIS	European research project, Cooperative vehicle.infrastructure systems, www.cvisproject.org
Datex 2 / Datex II	DATEX II TS 16157 1-3, Standard for communicating and exchanging traffic information, http://www.datex2.eu/
DC	Collaborative dynamic corridors
DIALOGUE	Sub-project of TEAM, SP4.
DRIVE C2X	European research project, http://www.drive-c2x.eu
DSRC	Dedicated short range communication
EASY-C	German project EASY-C, http://www.easy-c.de/index_en.html
EC	European Commission
eCall	Emergency Call, European initiative intended to bring rapid assistance to motorists involved in a collision anywhere in the European Union. The eCall initiative aims to deploy a device installed in all vehicles that will automatically dial 112
ECDSA	Elliptic Curve Digital Signature Algorithm
Eco Assistant	Driver assistant system for ecological driving.
Eco Pro	BMW assistant system for ecological driving, http://www.bmw.com/com/de/insights/technology/efficientdynamics/phase_1/measures_ecopro.html
eco:Drive	FIAT assistant system for ecological driving, http://www2.fiat.co.uk/ecodrive/
eco:Ville	Online community for FIAT customers using the eco:Drive product, see eco:Drive.
EcoGuide	Ford assistant system for ecological driving.
ecoHMI working group	working group in eCoMove project
eCoMove	European research project, www.ecomove-project.eu/.
EDAS	EGNOS Data Access Service
EFP	Collaborative eco-friendly parking
EGNOS	European Geostationary Navigation Overlay Service
ELGG	Open source social networking engine, http://elgg.org/
EMPOWER	Sub-project SP2 of TEAM
Enabler	Used for data or aggregated data, tools and algorithms to be used by the applications, see Part A, Section 1.2.3

Abbreviation	Meaning
eNodeB	E-UTRAN Node B, hardware part in UMTS networks
ESoP	European Statement of Principleson human machine interface, http://euroalert.net/en/news.aspx?idn=7680
ETIS ITS G5	Set of protocols and parameters for European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band
ETSI	European Telecommunications Standards Institute
ETSI ITS	European Telecommunications Standards Institute Intelligent Transport System
ETSI TS 102 636	Family of documents defining GeoNetworking
European CEN	European Committee for Standardization
EVALUATION	Sub-project SP5 of TEAM
FCD	Floating car data; data and information collected by probe vehicles, typically speed and position
FDD	Frequency Division Duplex, variant of LTE technology
FLEX	Sub-project SP3 of TEAM
FOT	Field Operational Test
G5	Set of protocols and parameters for European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band
GaLA	Games and Learning Alliance, http://www.galanoe.eu/
Galileo	GNSS built by EU and European Space Agency, similar to US-american GPS
Geo-casting	Delivery of information to a group of destinations in a network identified by their geographical locations
GeoNet	GeoNet European Project, http://www.geonet-project.eu/
GeoNetworking	Networking including georouting
GMSA	GSM Association of mobile operators and related companies devoted to supporting the standardising, deployment and promotion of the GSM mobile telephone system
GNBTPAPI	GeoNetworking/BTP API, a software component developed in DRIVE C2X project
GNSS	Global navigation satellite system
GPS	Global Positioning System, a GNSS developed by US Department of

Abbreviation	Meaning
	Defense
GSM	Global System for Mobile Communications, ETSI 2nd generation mobile communication standard
HARDIE Guidelines	Harmonisation of ATT Roadside and Driver Information in Europe Design Guidelines Handbook, DRIVE II Project V2008, Deliverable No. 20
HCI	Human computer interaction
HMI	Human machine interface
HPSA+	High speed packet access, extension to HPSA
HSDPA	High speed downlink access, extension to UMTS, part of HPSA protocol family
HSPA	High speed packet access, extension to UMTS communication technology
HSUPA	High-Speed Uplink Packet Access, extension to UMTS, part of HPSA protocol family
HTML5	Hyper Text Markup Language 5. Markup language for structuring and presenting content for the World Wide Web and a core technology of the Internet
HW	Hardware
I-GEAR	European research project, Incentives and Gaming Environments for Automobile Routing
I2I	Infrastructure to infrastructure communication
I2V	Infrastructure to vehicle communication
ICE	Internal combustion engine
IEEE	Institute of Electrical and Electronics Engineers
IEEE 1609	Higher layer standard based on the IEEE 802.11p
IEEE 802.11p	Approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE)
IMS	IP Multimedia subsystem
IMT-2000	International Mobile Telecommunications-2000. 3G technology comply with IMT-2000.
IMT-Advanced	International Mobile Telecommunications-2000. 4G technology comply with IMT-2000.
INTIME	European research project, Intelligent and efficient travel

Abbreviation	Meaning
	management for European cities, http://www.in-time-project.eu
INVENT	German research initiative, Intelligent traffic and userfriendly technology, http://www.invent-online.de/
IP	Internet protocol
ISO	International Organization for Standardization
ISO TC 204	ISO Technical committee, is responsible for the overall system aspects and infrastructure aspects of intelligent transport systems, http://www.iso.org/iso/iso_technical_committee?commid=54706
iTRETRIS	European research project, Integrated Wireless and Traffic Platform for Real-Time Road Traffic Management Solutions, www.ict-itetris.eu/.
ITS	Intelligent Transportation Systems.
ITS 2.0	Product by Telecom Italia.
ITS G5A	Operation of ITS-G5 in European ITS frequency bands dedicated to ITS for safety related applications in the frequency range 5,875 GHz to 5,905 GHz
ITS station	According ETSI EN 302 665, there are four ITS stations: Personal ITS stations, Vehicle ITS stations, Roadside ITS station, and Central ITS station
ITS-g5	Set of protocols and parameters for European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band.
ITSA	Intelligent Transportation Society of America
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union Radiocommunication Sector
Ko-PER	German research project Ko-PER, http://ko-fas.de/deutsch/ko-per---kooperative-perzeption.html.
LDM	Local dynamic map
LDM++	TEAM concept based on the LDM
Local Dynamic Map	Concept developed in the SAFESPOT project. It is a data store located within an ITS station containing information which is relevant to the safe and successful operation of ITS applications.
LOS	Level of service
LSTI	LTE/SAE Trial Initiative alliance founded as a global collaboration

Abbreviation	Meaning
	between vendors and operators with the goal of verifying and promoting the new standard. Scope to ensure the global introduction of the technology as quickly as possible
LTE	Long-term evolution, marketed as 4G LTE. Standard for wireless communication of high-speed data for mobile phones and data terminals.
LTE/SAE Trial Initiative	See LSTI
M453	European Commission Mandate M/453. It invites the statdardisation bodies CEN, CENELEC and ETSI to prepare a coherent set of standards specifications and guidelines to support European Community wide implementation and deployment of Cooperative ITS
MAC	Media access control
MANET	Mobile ad-hoc network
MM-wave	Millimeter wave: Extremely high frequency is the highest radio frequency band, a form of electromagnetic radiation. Upcoming Wi-Fi standard IEEE 802.11ad will run on the 60 GHz band
MNO	Mobile-Network Operators
Mobilitätsdatenmarktplatz	Oline portal to exchange mobility data, http://www.mdm-portal.de
MTC	Machine-type communication
NFC	Near field communication
O/D	Origin/Destination
OBD	On-board diagnostics
OBD2	OBD2 or OBD-II is an improvement over OBD (OBD-I) in capacity and standadisation
OBU	On-board unit
OEM	Original Equipment Manufacturer
OS	Operating System
P2P	Pedestrian to Pedestrian
PC	Personal Computer
PHY	Physical layer according to OSI model
Physical Storage Format	Layout format describing how map data is stored on a physical device
PKI	Public key infrastructure

Abbreviation	Meaning
POI	Point of Interest
PRE-DRIVE C2X	European research project, Preparation for Driving implementation and Evaluation of C-2-X communication technology
PSAP	Public Safety Answering Points
PSF	Physical Storage Format
PSOBU	Public Safety OBU, a vehicle with capabilities of providing services normally offered by RSU
QoS	Quality of Service
RAN	Radio Access Network
RED-like algorithm	Refers to Random early detection algorithm.
REST architecture	Representational State Transfer (REST) architecture, a style of software architecture for distributed systems such as the World Wide Web
RESTful	Applications or services conforming to the REST constraints
RFID	Radio-Frequency Identification
roadside unit	Equivalent to ITS Roadside station.
RSU	Road-Side-Unit, equivalent to ITS Roadside station
RSUO	RSU Operators
S.I.MO.NE	s.i.mo.ne floating car, http://simone.5t.torino.it/
S.I.MO.NE protocol for FCD	s.i.mo.ne floating car data exchange protocol, http://simone.5t.torino.it/
SaaS	Software as a Service
SAFESPOT	EU SAFESPOT project, http://www.safespot-eu.org/
Serious gaming	game designed for a primary purpose other than pure entertainment, main purpose is to train or educate users
SG	Serious Gaming
SG-CB	Serious Gaming and Community Building
SG-CB	Serious gaming and community building
SHF	Stakeholder Forum
Short Range Communication	Generic term for three incompativle different short-range communication standards in Europe, USA and Japan
simTD	German project sichere intelligente mobilität - Testfeld Deutschland, http://www.simtd.de

Abbreviation	Meaning
SIRI	Service Interface for Real Time Information, model for real time public transport data exchange, http://www.kizoom.com/standards/siri/
SP	TEAM sub-project
SP2/SP3/SP4/SP5	TEAM sub-projects EMPOWER/FLEX/DIALOGUE/EVALUATION
SPaT	Signal phases and timing of traffic lights
SPITS	Strategic Platform for Intelligent Traffic Systems, http://www.cvisproject.org/en/news/spits_the_strategic_platform_for_intelligent_traffic_systems.htm
Stakeholder Forum	TEAM initative to exchange with stakeholders of the TEAM project and TEAM technologies.
Sunset	Sunset EU Project, http://sunset-project.eu/
SW	Software
TD-LTE	Synonym for TDD LTE variant
TDD	Time Division Duplex, variant of LTE technology
TEAM	Tomorrows Elasic Adaptive Mobility project, https://www.collaborative-team.eu/
TECH Group	Basic technology group, group of partners within TEAM with special knowledge or interest regarding a basic technology
TMC	Traffic Management Centre
TMC	Traffic Message Channel, technology for delivering traffic and travel information to motor vehicle drivers
TMS	Traffic Management Systems
TPEG UML	Transport Protocol Experts Group Unified Modeling Language, standardized modeling language to describe conceptual content
TSS Aimsun	Transport Simulation Systems Aimsun, integrated transport modelling software
TwinLin	TwinLin project of Hamilton Institute, Fraunhofer Fokus and TU Berlin, http://www.hamilton.ie/twinlin/
UC	Use case
UMTS	Universal Mobile Telecommunications System, 3rd generation mobile cellular system for networks based on the GSM standard, developed and maintained by the 3GPP
US DoT	Department of Defense of the United States of America

Abbreviation	Meaning
USB	Universal Serial Bus, data exchange standard for wired connections
V2I	Vehicle to Infrastructure
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle to Vehicle / Vehicle to Infrastructure
V2X-Vehicle-Network-Bridge	Enabler providing access to vehicle sensors and functions, see Part D, Section 1.3.1
VANET	Vehicular Ad Hoc Network
VDV 452	Verband deutscher Verkehrsunternehmen (association of German traffic companies) Schrift 452, document describing an interface for route network and schedule exchange for public transport
Vehicle-API	API to access sensors and functions of a vehicle
VII	Vehicle Infrastructure Integration, initiative fostering research and applications development for a series of technologies directly linking road vehicles to their physical surroundings in order to improve road safety
Voice over LTE	voice communication delivery over LTE networks
VSimRTI	V2X Simulation Runtime Infrastructure, comprehensive framework for the assessment of new solutions for Cooperative Intelligent Transportation Systems, http://www.dcaiti.tu-berlin.de/research/simulation/
WAVE	Wireless Access in Vehicular Environments, IEEE 1609 family of standards on top of IEEE 802.11p
Waze	Free social GPS application featuring turn-by-turn navigation, http://waze.com/
WCDMA	Wideband Code Division Multiple Access, UMTS air interface standard
WG HMI	TEAM working group for human machine interface
WHO	World Health Organization
Wi-Fi	Wireless LAN technology based on IEEE 802.11 standard
WiMAX2	IEEE 802.16m-2011, also known as Mobile WiMAX Release 2, standard for Wireless Metropolitan Area Networks
WP	TEAM work package
WPxy	TEAM work package x.y

Abbreviation	Meaning
xFCD	Extended Floating Car Data

References

[CM1] Connecting Cars: The Technology Roadmap – GSMA report available on: http://www.gsma.com/connectedliving/gsma-connecting-cars-the-technology-roadmap

[CM2] Rémi THOMAS, "LSTI - A Success Story about Boosting an Industry Eco-System in Telecommunications" available on: http://www.ngmn.org/events/ngmnevents/eventssingle1/article/huge-success-of-joint-gsma-ngmn-conference-stream-at-mobile-world-congress-2011-524.html?tx_ttnews%5BbackPid%5D=63&cHash=7874c2d3ea

[CM3] http://www.etsi.org/technologies-clusters/technologies/intelligent-transport

[CM4] http://en.wikipedia.org/wiki/IEEE_802.11p

[CM5] http://www.etsi.org/deliver/etsi_ts/102600_102699/1026360601/01.01.01_60/ts_1026360601v010101p.pdf

[CM6] http://www.etsi.org/WebSite/document/Technologies/16_Design_Principles_of_CALM.pdf

[CM7] http://its-standards.info/ITS_Venice_Session6_Fischer_v02.pdf

[CM8] http://www.ieee802.org/802_tutorials/06-November/IEEE%20802%20CALM%20Tutorial%20Part%202_v2.pdf

[CM9] http://vii.path.berkeley.edu/1609_wave/

[CM10] http://www.pre-drive-c2x.eu/

[CM11] http://www.safespot-eu.org/

[CM12] http://www.cvisproject.org/

[CM13] http://www.simtd.de

[CM14] http://www.teliasonera.com

[CM15] http://3gpplte-longtermevolution.blogspot.de/2010/06/3gpp-standardization-body.html

[CM16] http://www.itu.int/en/ITU-R/pages/default.aspx

[CM17] http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=4152738

[CM18] http://en.wikipedia.org/wiki/CALM_M5

[CM19] http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51398

[CM20] http://en.wikipedia.org/wiki/IEEE_802.16

[CM21] http://www.comesafety.org/

[CM22] http://www.3gpp.org/

[CM23] http://ec.europa.eu/information_society/activities/esafety/ecall/index_en.htm

[CP1] R. H. Ordóñez-Hurtado, *Preliminary Overview of Cooperative Positioning Research for TEAM Project*, National University of Ireland Maynooth, Ireland, Technical Report, 36 p., March 2013.

[CP2] R. H. Ordóñez-Hurtado, *Overview of Cooperative Positioning in Vehicular Ad-hoc Networks for TEAM Project*, National University of Ireland Maynooth, Ireland, Technical Report, 11 p., March 2013.

[CS1] http://www.ocit.org/english.htm

[CS2] The protocol has been developed by the Transport Protocol Expert Group, http://www.tisa.org/technologies/tpeg/

[CS3] http://www.ndw.nu/pagina/en/16/about_ndw

[CS4] http://www.mdm-portal.de/

[CS5] J. Dean and S. Ghemawat, "MapReduce: Simplified Data Processing on Large clusters", in Proc. Sith Symposium on Operating System Design and Implementation, San Francisco, Ca, December, 2004.

[CS6] N. Smith, K. Wevers and S. Dreher, The Local Dynamic Map, a data-store for cooperative applications, Navigation News, Royal Institute of Navigation, March/April 2010

[CS7] http://www.safespot-eu.org

[CS8] http://www.cvisproject.org/

[PS1] 7th Framework programme, ICT for Cooperative Systems (2009): "PRE-DRIVE C2X - Security Architecture Deliverable D1.3," Final Deliverable, 2009-02-09.

[PS2] ETSI (2010): ETSI TR 102 893 V1.1.1 Intelligent Transport Systems (ITS); Security; Threat, Vulnerability and Risk Analysis (TVRA). Sophia Antipolis Cedex – France, March 2010

[PS3] Kurihara, T. M. (2006): IEEE 1609.2-2006 Trial Use Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages, New York, USA

[PS4] ETSI (2010): ETSI TS 102 731 V1.1.1 Intelligent Transport Systems (ITS); Security; Security Services and Architecture. Sophia Antipolis Cedex – France, September 2010

[PS5] TS 33.401, 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; 3GPP System Architecture Evolution (SAE): Security architecture

[SG1] M. Prensky, "Digital game-based learning", ACM Computers in Entertainment, vol. 1, no. 1, 2003.

[SG2] M. Zyda. "From visual simulation to virtual reality to games". IEEE Computer, September 2005.

[SG3] F. Bellotti, R. Berta and A. De Gloria, "Designing Effective Serious Games: Opportunities and Challenges for Research", Special Issue: Creative Learning with Serious Games, Int.l Journal of Emerging Technologies in Learning (IJET), Special Issue: Creative Learning with Serious Games Vol. 5, 2010, pp. 22-35

[SG4] Gee, J.P. What video games have to teach us about learning and literacy. Palgrave MacMillan: New York. 2007

[SG5] Van Eck R., Digital Game-Based Learning: It's Not Just the Digital Natives Who Are Restless, EDUCAUSE Review, vol. 41, no. 2, 2006

[SG6] Iacovides, I., Exploring the link between player involvement and learning within digital games. In Proceedings of the 23rd British HCI Group Annual Conference on People and Computers: Celebrating People and Technology, Cambridge, UK, September , 2009

[SG7] www.games4change.org

[SG8] Swarz, J., Ousley, A., Magro, A., Rienzo, M., Burns, D., Lindsey, A.M., Wilburn, B., Bolcar, S., , "CancerSpace: A Simulation-Based Game for Improving Cancer-Screening Rates," Computer Graphics and Applications, IEEE , vol.30, no.1, pp.90-94, Jan.-Feb. 2010

[SG9] Alankus, G. M. May, A. Lazar, C. Kelleher. Towards Customizable Games for Stroke Rehabilitation. Proceedings of CHI 2010, Atlanta, GA, USA, 2010

[SG10] L. Gamberini, N. Corradi, L. Zamboni, M. Perotti, C. Cadenazzi, S. Mandressi, G. Jacucci, G. Tusa, A. Spagnolli, C. Björkskog, M. Salo, P. Aman, Saving is fun: designing a persuasive game for power conservation, Advances in Computer Entertainment Technology 2011: 16

[SG11] http://www.chromaroma.com/

[SG12] S. Deterding, M. Sicart, L. Nacke, K. O'Hara, and D. Dixon, "Gamification. using game-design elements in non-gaming contexts", in Proc. CHI Extended Abstracts, 2011

[SG13] G. Zichermann, C. Cunningham, "Gamification by Design: : Implementing Game Mechanics in Web and Mobile Apps", O'Reilly Media, 2011

[SG14] Y. Liu, T. Alexandrova, and T. Nakajima. 2011. Gamifying intelligent environments. In Proceedings of the 2011 international ACM workshop on Ubiquitous meta user interfaces (Ubi-MUI '11). ACM, New York, NY, USA

[SG15] http://www.fiat.com/ecodrive/

[SG16] http://media.ford.com/article_display.cfm?article_id=29300

[SG17] http://www.bmw.com/com/en/newvehicles/7series/sedan/2012/showroom/efficiency/eco-pro-mode.html

[SG18] http://automobiles.honda.com/insight-hybrid/fuel-efficiency.aspx

[SG19] http://arstechnica.com/gadgets/2011/11/is-the-chevy-volt-the-answer-to-urban-speeding/

[SG20] C. Shi, H. J. Lee, J. Kurczak, A. Lee, Routine Driving Infotainment App: Gamification and Performance Driving, 4th Int.l Conference on Automotive User Interfaces and Interactive Vehicular Applications (Automotive UI ,12), October 17-19, 1012 Portsmouth, NH, USA

[SG21] Nokia Maps APIs. http://api.maps.nokia.com/en/index.html

[SG22] Bose, R., Brakensiek, J., and Park, K.Y. Terminal Mode - Transforming Mobile Devices into Automotive Application Platforms. Proc. AutomotiveUI 2010, pp. 148-155.

[SG23] Meschtscherjakov, A., Wilfinger, D., Scherndl, T., and Tscheligi, M. Acceptance of Future Persuasive In-Car Interfaces Towards a More Economic Driving Behaviour. Proc. AutomotiveUI'09: 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 2009. pp. 81–88,

[SG24] Inbar, O., Tractinsky, N. Driving the Scoreboard: Motivating Eco-Driving Through In-Car Gaming. Workshop on Gamification and HCI, as part of CHI2011.

[SG25] Koenig, V ; Boehm, F ; McCall, R Pervasive Gaming as a Potential Solution to Traffic Congestion: New Challenges Regarding Ethics, Privacy and Trust, UL-CONFERENCE-2012-436

[SG26] Nunes, A.A.; Galvao, T.; Falcao e Cunha, J.; Pitt, J.V.; , "Using Social Networks for Exchanging Valuable Real Time Public Transport Information among Travellers," Commerce and Enterprise Computing (CEC), 2011 IEEE 13th Conference on , vol., no., pp.365-370, 5-7 Sept. 2011

[SG27] http://sunset-project.eu

[SG28] http://www.mydrivesolutions.com/blog/driver-behaviour-profiling

[SG29] http://www.blackboxtelematics.co.uk/driverbehaviour.html

[SG30] http://m2m.telekomaustria.com/our-offer/solutions/eco-driving-solution/

[SG31] http://world.waze.com/

[SG32] S. Deterding, S. Bjoerk, D. Dixon, L. E. Nacke, "Designing Gamification: Creating Gameful and Playful Experiences", CHI 2013 Workshop http://gamification-research.org/chi2013/

[SG33] http://elgg.org/