Cooperative Mobility Systems and Services for Energy Efficiency

D5.1	**SP5 Use cases & System requirements**

SubProject No.	**SP5**	**SubProject Title**	**ecoTraffic Management and Control**
Workpackage No.	**WP5.2**	**Workpackage Title**	**Use cases & requirements**
Task No.	**T5.2.1** **T5.2.2** **T5.2.3** **T5.2.4** **T5.2.5**	**Task Title**	**EcoAdaptive Balancing and Control** **ecoAdaptive Traveller Support** **ecoMotorway Management** **Functional Components** **Simulation Environment**
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Dissemination level PU/PP/RE/CO		**PU**	
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Abstract	The eCoMove traffic management and control systems will use information from both vehicles and infrastructure to formulate strategies to reduce the total fuel consumption in a network or on a specific corridor. The systems make use of management and control systems that are available in the network (e.g. variable message signs, traffic signals, ramp metering). In addition to that, the systems will generate information (e.g. route or speed advice) that is sent to vehicles and back offices to inform SP3 and SP4 systems of the best ways to minimise fuel consumption.

Control sheet

Version history			
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TERMS AND ABBREVIATIONS

Abbreviation	Definition
CP	Cultural and Political requirement
F	Functional requirement
FVD	Floating Vehicle Data
HGV	Heavy Goods Vehicle
L	Legal requirement
LF	Look and Feel requirement
MPV	Multi Purpose Vehicle
MS	Maintainability and support requirement
OE	Operational and Environmental Requirement
OEM	Original Equipment Manufacturer
P	Performance Requirement
RSU	Road side unit
S	Security requirement
SP	Sub-project
STO	Scientific and Technological Objectives
TBD	To Be Determined
TCC	Traffic Control Centre
TMC	Traffic Management Centre
UH	Usability and Humanity requirement
V2I	Vehicle To Infrastructure
V2V	Vehicle to Vehicle
WP	Work package

1. Introduction

1.1. Purpose of this deliverable and relation to other SPs

This document summarises the work done in WP5.2 – Use cases and requirements for the eCoMove traffic management & control systems.

The eCoMove project aims to reduce fuel consumption and CO_2 emissions by supporting drivers before, during and after their trip to drive in the most eco-friendly way. To this end, cooperative systems and applications are developed that help to reduce inefficiencies in driving. See Figure 1 for an illustration of the eCoMove vision.

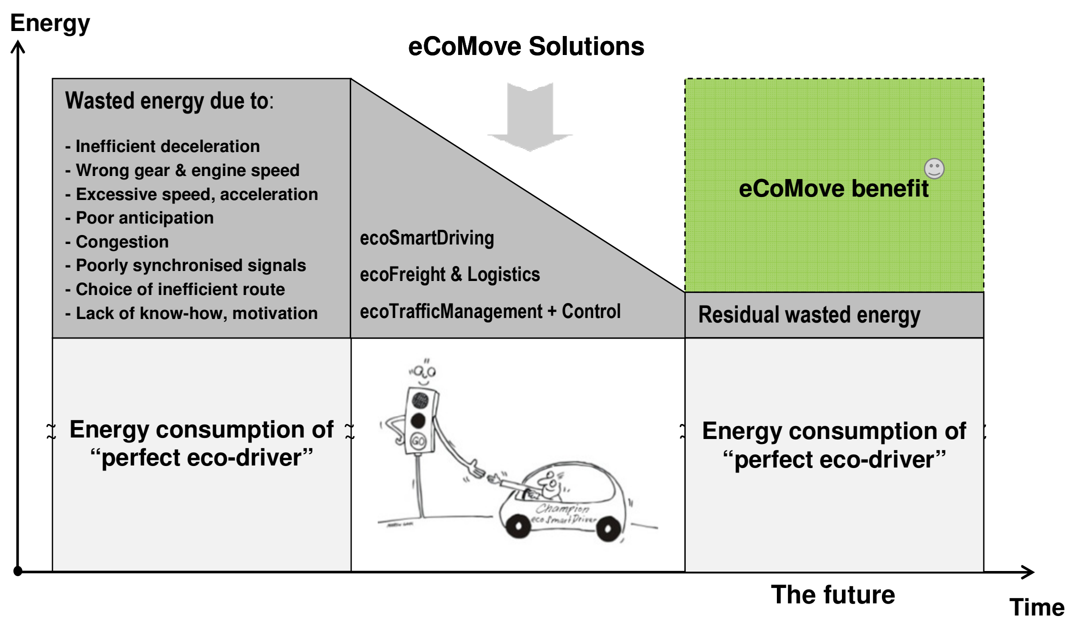


Figure 1: eCoMove aims to remove inefficiencies in driving

The applications will be implemented and tested on several test sites or in a simulation environment. Subsequently, it will be evaluated whether the goal of a 20% reduction in fuel consumption and CO_2 emissions is feasible.

The eCoMove project is split up into six sub projects (see Figure 2). The systems and applications are developed in sub project 3, 4 and 5 and integrated in sub project 2. Sub project 6 focuses on validation and evaluation of the eCoMove systems.

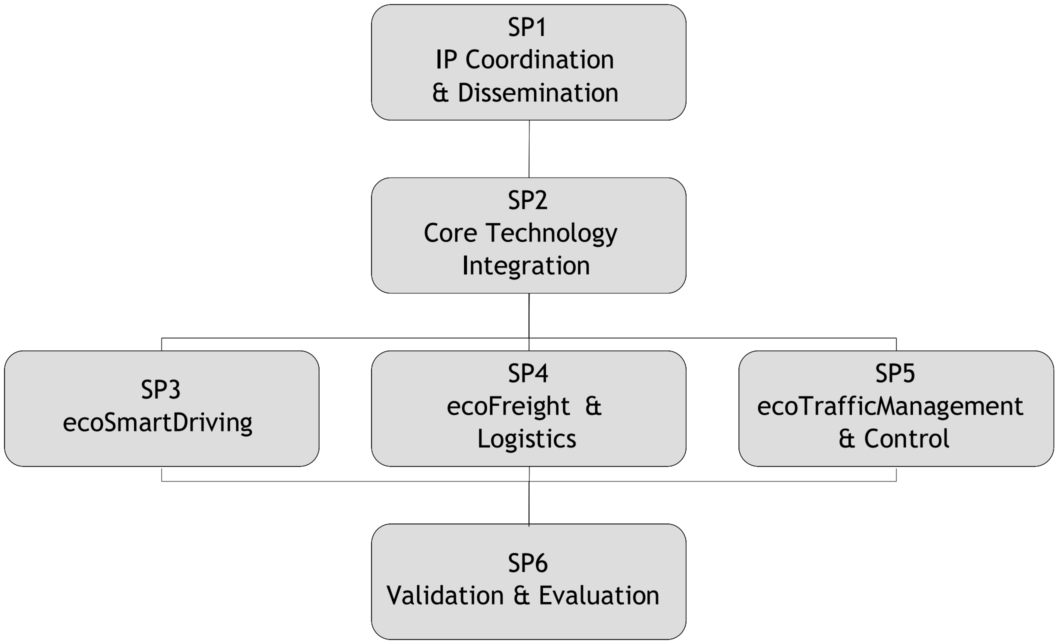


Figure 2: eCoMove sub projects

This deliverable describes the use cases and requirements for SP5, and thus focuses on systems and applications for cooperative traffic management and control. The eCoMove traffic management and control systems will use information from vehicles and the infrastructure to formulate strategies to reduce the total fuel consumption in a network or on a specific corridor. The systems make use of management and control systems available in the network (e.g. variable message signs, traffic signals, ramp metering). In addition to that, the systems will generate data (e.g. route or speed advice) that is sent to vehicles and back offices to inform SP3 and SP4 systems of the best ways to minimise fuel consumption.

This deliverable will, together with the SP3 (ecoSmartDriving) and SP4 (ecoFreight & Logistics) WP2 deliverables, provide input for deliverable D2.1 which provides an overview of the eCoMove system concept and the use cases that are shared by SPs' 3, 4 and 5.

This deliverable will provide the basis for the specification and subsequent implementation and validation of the systems. Each of the SPs will follow the V model in the course of the project (see Figure 3). This document covers the steps User Needs, Use Cases, Functionalities and Requirements.

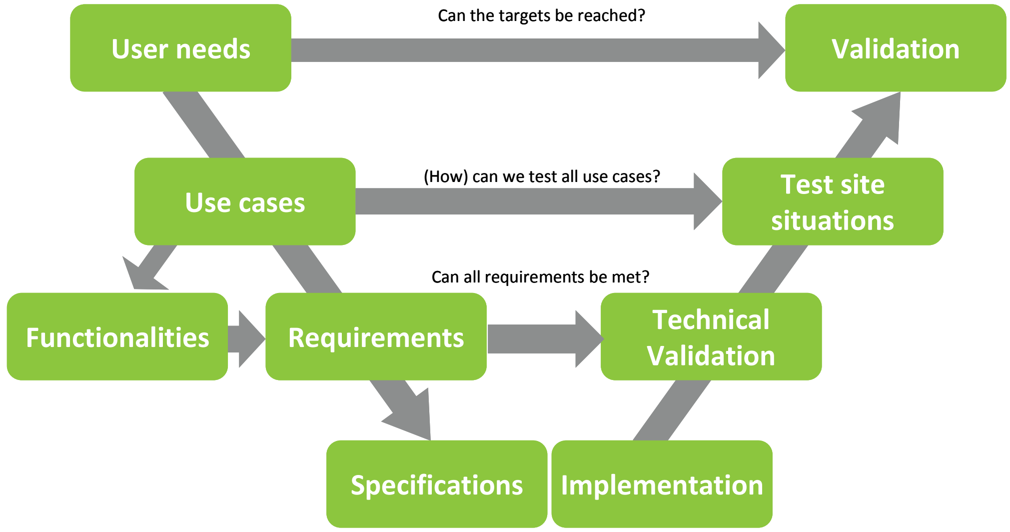


Figure 3: Relation between User Needs, Use Cases and Requirements (V-model)

It should be noted that eCoMove is a Research & Development project. This means that it aims to develop innovative systems and applications. Some of these can be tested on the road within the span of the project; others will be implemented only in a simulation environment as it would not be feasible to equip the required amount of vehicles and road-side units. For this deliverable, it is not relevant in what stage of development the systems/applications are. The use cases and requirements reported here are based on the user needs as expressed by various stakeholders and cover systems/applications; the main selection criterion was whether they address important inefficiencies.

1.2. Reading guide

This introduction is followed by a description of the current situation for ecoTraffic Management & Control in chapter 2. Chapter 3 lists the users and stakeholders for the eCoMove systems and discusses their needs. Chapter 4 gives an overview of the inefficiencies that can be addresses by ecoTraffic Management & Control (and also discusses which inefficiencies and ideas for solutions will not be addressed by eCoMove). Chapter 5 describes the innovations SP5 proposes and limitations that are foreseen. In chapter 6, the ecoTraffic Management & Control systems are presented. Chapter 7 contains the use scenarios identified. Chapter 8 provides the functional requirements of the systems and the requirement regarding the interfaces to the user and the other eCoMove systems. Finally, chapter 9 lists the literature used.

The structure of this document is based on the OCD/SSS and IRS documents of the MIL498-standard and also checked with ISO/IEC 15288.

2. Current situation for eCoTraffic Management & Control

2.1. Background

Poorly executed traffic management and control strategies, together with non-environmentally based driving behaviour, are the main causes of fuel waste in road transport. The main fuel related challenges in the current state of traffic management and control are:

- Unnecessary stops,
- Poorly optimized traffic lights,
- Unstable traffic flows, and
- Congestion.

Until recently a greater emphasize was placed on safety and accessibility objectives in traffic management. However climate changes and European legislation has indicated the need for more environmentally friendly approach to the management of traffic. To address this need there will be a requirement to acknowledge and balance competing and conflicting stakeholder interests, so that a balance may be struck between the needs of the individual and the collective traveller for travel times and fuel reduction objectives.

2.2. Objectives

Four objectives are the basis for the development of new traffic management and control measures which aim to reduce fuel consumption in traffic.

1. Develop a cooperative solution for traffic management that uses real-time vehicle fuel consumption data to balance traffic demand and network capacity at network area and local level (STO-12).
2. Develop a cooperative solution that transmits current and predicted speed profiles along with vehicle-specific route recommendations to vehicles for both efficient vehicle operation and an optimized driving strategy (STO-13).
3. Develop a cooperative suite of measures to optimize vehicle speeds, headway, manoeuvres and flows for smoother, more energy efficient motorway operation (STO-14).
4. Develop a simulation environment for the development cooperative application, the ability to model traffic system components, traffic flows and vehicle movements, and co-operative vehicle-to-infrastructure communication (STO-15).

2.3. Scope

The ecoTraffic Management and Control measures that will be developed within eCoMove are based on the assumption of fixed traffic demand including the time of travel. Therefore topics like demand management, road pricing and multi-modal travelling are out of the scope of this project. Clearly less vehicles means less fuel consumption, but the primary aim of the ecoTraffic Management and Control sub-project is to reduce fuel consumption based on the current traffic situation.
Two approaches have been identified in this sub-project to reduce fuel consumption. One approach aims to improve the operation of traffic systems like traffic lights and

ramp metering installations in a way that is more fuel efficient. The other approach aims to provide vehicles and drivers with roadside information and tailored advices that enable them to improve driving behaviour, and to then provide feedback to show how effective that measure was in that particular situation

2.4. Limitations and constraints in the current situation

Above all traffic safety has to be preserved at all times. Many systems seen as measures to improve accessibility are in fact safety systems, for example traffic lights or variable message signs with incident detection.
Secondly, mobility is acknowledged as a common good. From that perspective measures in favour of fuel savings have to be realistic. That means they have to be acceptable for vehicle drivers, demanded by authorities and aligned with other objectives that are important for stakeholders involved.

2.5. Description of the situation today

Today, there are few traffic management and control measures that explicitly operate based on fuel efficiency criteria. In most cases, systems designed for accessibility reasons like (dynamic) green waves, parking guidance and traffic information have been evaluated on their environmental impact and proved to be also successful in reducing emission and fuel consumption. This is not surprising as in many cases improvements in accessibility (i.e. travel time, throughput, etc.) will also improve environmental conditions. However, when it comes to significant improvements, an approach is needed that explicitly addresses environmental targets such as fuel consumption.

3. Users and Stakeholders for eCoMove

This chapter gives a description of the users (directly interacting with the system) and stakeholders (those that are impacted by the system) of eCoMove that are relevant for the ecoTraffic Management & Control system.

3.1. Users vs. Stakeholders

In eCoMove users are defined as those parties who directly interact with the applications and therefore are within the eCoMove system boundaries. Stakeholders are those actors that are affected by the eCoMove system(s) and do not necessarily reside within the eCoMove system boundaries.

In the figure below the stakeholder diagram shows the different stakeholders that are relevant for the subproject ecoTraffic Management and Control and how they are related to each other and the ecoTraffic Management and Control system

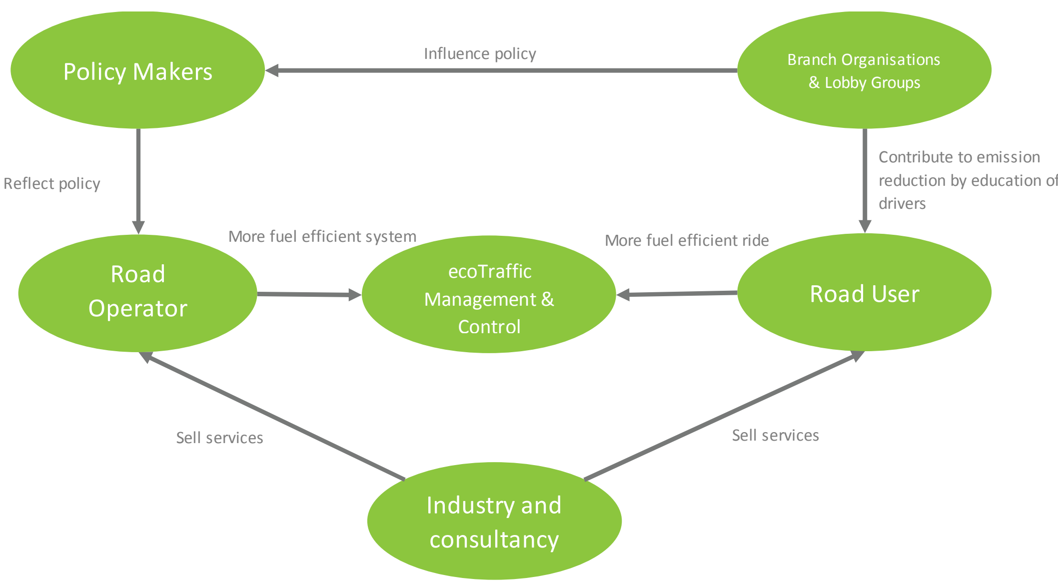


Figure 4: Stakeholder diagram for ecoTraffic Management and Control

3.2. Users for the eCoMove system

The users of the eCoMove-system from the perspective of ecoTraffic Management & Control can be subdivided into two broad categories, namely the road users and the road operators. In the road user category road users can be discerned as those that make direct use of the road infrastructure, such as the driver of a vehicle, and road users that indirectly make use of the available road infrastructure, such as the manager of a fleet.

The following road users can be identified:

- Driver- From the perspective of the eCoMove System the drivers of vehicles are the most important user, as this user is closest to the source of the emission, namely the vehicle. As vehicles of different weights and type have very different emission characteristics it is important to take these differences into account when seeking to improve upon the current system with respect to the amount of CO_2 emitted. At this moment in the project it is too early to tell which types of vehicle groupings will ultimately be discerned, but at this moment it is safe to assume that trucks, busses, and passenger cars will be dealt with differently by the ecoTraffic Management & Control system.

- Public Transport – In order to make public transport more attractive, public transport is often given a higher priority then personal transport when for instance approaching a traffic light. This requirement is also driven by the requirement for public transport to operate to a timetable.
- Emergency Vehicles - Emergency vehicles require special treatment as these vehicles must be given absolute priority by the ecoTraffic Management & Control system.
- Weak traffic participant - Although weak traffic participants (pedestrians and bicyclists) as such are not a significant source of emission they do limit the flexibility with which the ecoTraffic Management & Control system can deal with the prime source of emissions. Any changes the ecoTraffic Management & Control system wishes makes to current traffic management and control practice should be guaranteed not to impinge on the safety of these road user groups
- Fleet managers - Although fleet managers themselves are not directly active on the road they are able to influence the routing and the behaviour of the individual road users and they can serve as an intermediary between traffic operators and the individual road users. In addition they have influence on how the fleet driver behaves on the road network.

In the road operator category the following road operator types can be discerned:

- Traffic Manager – The Traffic Manager's role within the ecoTraffic Management & Control system is to translate the policy objectives of all the stakeholders of the traffic system, starting with the stated policy objectives of the road administration then to road user to derive a workable and balanced set of objectives to fulfil by the ecoTraffic Management & Control system.
- Traffic Engineer – The Traffic Engineer's role within the ecoTraffic Management & Control system is to translate the objectives into control instructions for the different traffic management measures that are available, in a timely and efficient manner.

3.3. Stakeholders

The stakeholders of the eCoMove-system from the perspective of ecoTraffic Management & Control can be subdivided into two broad categories, namely those stakeholders that make use of or are affected by the ecoTraffic Management & Control system directly and those that are dependent on the ecoTraffic Management & Control system to make a living.

The first category is represented by the policy makers of the different domains:

- Traffic
- Environmental

- Transport
- Economical
- Spatial development

And by different lobby groups and branch organisations
- Environmental organisations
- Chambers of commerce
- Car clubs
- Bicycle clubs
- Transport branch organisations
- Traffic safety organisations
- Resident initiatives

The second category is comprised of representatives of Industry & Consultancy, such as:
- Service providers (route guidance)
- Content providers (map data; travel times)
- OEM Roadside
- OEM Vehicle side
- Consultancy

3.4. Important stakeholder needs

The most important stakeholder needs are that the ecoTraffic Management and Control system provides for both a safe, sustainable, reliable, and fast traffic system. This goes for both the users of the traffic system and those affected by it, when roads go through a residential area. To underline the scope of ecoTraffic Management and Control system, the following user needs have been identified for road operators and policy maker.

User needs as expressed by users that represent the road operator:
- Minimize fuel consumption and emissions
- Maximize traffic throughput
- Control variables to change management strategies
- Optimize overall network performance
- Transparent and controllable traffic systems
- Short cycle times for traffic light operation
- Safe traffic
- Clear overview of traffic situation and bottlenecks
- Access restrictions for sensitive areas
- Maximum throughput
- Equal treatment of different road users
- Good connection city network and motorway
- Minimize vehicle delay
- Inform road users about the best travel options
- Traffic data for ex-post evaluations

- Prevent events that impair road capacity
- Routing guidance to available parking places
- Optimal use of available road capacity
- Provide quick and comfortable travel quality for the road user
- Priority for public transport and pedestrians and bikers
- Balance between internal and through traffic

User needs as expressed by users that represent a policy maker:

- Reliable traffic time information and prediction
- Minimize number of traffic accidents
- Minimize fuel consumption and fuel emissions
- Prioritize specific road users (i.e. trucks)
- Prioritize different road types (i.e. motorways)
- Maximize cost-benefit-ratio of infrastructure investments
- Provide mobility to citizens
- Provide accessibility to city region
- Transport as a means for economic growth
- Satisfied civilians and road users

4. Targeted Inefficiencies

At the basis of the eCoMove project are the inefficiencies that cause unnecessary fuel consumption and CO2-emissions. The inefficiencies that are important for the ecoTraffic Management and Control subproject are related to routing, acceleration, deceleration, speed and stops.

The list below show the inefficiencies that are targeted by the subproject ecoTrafficManagement & Control subproject. The numbers and letters refer to the complete overview of the inefficiencies that is included in D2.1. This explains why there are gaps in the numbering.

- INEF07 Inefficient routing
- INEF08a Inefficient acceleration – traffic induced
- INEF08e Inefficient acceleration – signal induced
- INEF09a Inefficient deceleration – traffic induced
- INEF09e Inefficient deceleration – signal induced
- INEF11a Inefficient speed – traffic induced
- INEF11e Inefficient speed – signal induced
- INEF13a Unnecessary stops – traffic induced
- INEF13e Unnecessary stops – signal induced

To determine which of the use cases target each of the inefficiencies identified the reader is referred to section 7.3.

5. eCoMove improvement opportunities

This chapter describes the innovations that will target the inefficiencies identified in the previous chapter and describes the limitations that are foreseen when implementing these innovations.

5.1. Innovations

Many of the innovations that are proposed by the ecoTraffic Management & Control system aim:

1. to increase the awareness each actor in the traffic system has of the effect it has on the other actors in the traffic system, and
2. to take these effects into account when deciding upon an appropriate action.

This necessitates a detection and communication infrastructure that allows actors to build up a more complete and accurate model of the surrounding world. It also requires forecasting models that allow actors to determine the evolution of the world in response to their actions. Together, these form the required ingredients to create an optimisation model. This optimisation model allows the actor to decide upon the most appropriate action that serves the interests of both the actor itself and the other actors in the (cooperative) system. Each of the different applications and use cases identified for the ecoTraffic Management & Control system will have different requirements with respect to the level detail (in both space and time) and the speed of the models used for optimisation. The ideal compromise between accuracy and speed will be determined during the course of the project for each of the identified systems and use cases.

5.2. Limitations foreseen

Many of the applications and use cases identified for the ecoTraffic Management & Control system necessitate a detection and communication infrastructure that allows actors to build up a more complete and accurate model of the surrounding world. Although cooperative systems together with various kinds of (legacy) detection help us to improve the accuracy of this model, it will never be perfect. This challenges us to use various data-enriching techniques to make the most of the data that is available. During the course of the project minimum requirements will be derived for all parts of the system that will have to be met before any improvements with respect to the amount of CO_2 will start to show. These requirements relate amongst others to the necessary penetration rate of equipped vehicles.

6. Use scenarios

The set of eCoMove use cases refers to three different contextual areas that represent different spatial levels of consideration and action in the road network.

The broadest one of these levels is the *network level*. The use cases here describe situations from the road user or operator perspective that achieve the reduction of the vehicles' fuel consumption through network-wide strategic measures that must be harmonized with individual needs. The measures concerned mainly aim to balance urban road networks by dynamically changing network route patterns. Typically, the sub-systems of the use cases are located in TMCs or TCCs and in the vehicles.

On the intermediate level resides the *corridor level*. The use cases here describe situations from the road user or operator point of view that achieve the reduction of the vehicles' fuel consumption through tactical measures along a road section that are communicated with the passing driver. The measures concerned mainly aim (1) to optimize vehicles' speed dynamically and (2) to coordinate traffic control measures along road sections. Typically, the sub-systems of the use cases are located at the road side and in the vehicles.

The spatial most concentrated level is the *local level*. The use cases of this level describe situations from the road user or operator point of view that achieve the reduction of the vehicles' fuel consumption through measures that are limited to a single location like signalized intersections, motorway ramps. The measures concerned mainly aim (1) to optimize traffic control measures due to vehicles' fuel consumption and (2) to optimize the speed of the approaching or passing vehicles dynamically in order to stay in line with the before mentioned control measures. Typically, the sub-systems of the use cases are located at the road side and in the vehicles.

In sections 6.1, 6.2, and 6.3 will elaborate on the use cases for each of the different spatial levels identified (the network, the corridor, and the local level, respectively). In section 6.4 an overview of the different use cases will be given where the different use cases are linked to the earlier identified inefficiencies, links among the different use cases are identified and where the use cases are categorized on the type of cooperation, level of innovation, ease of deployment.

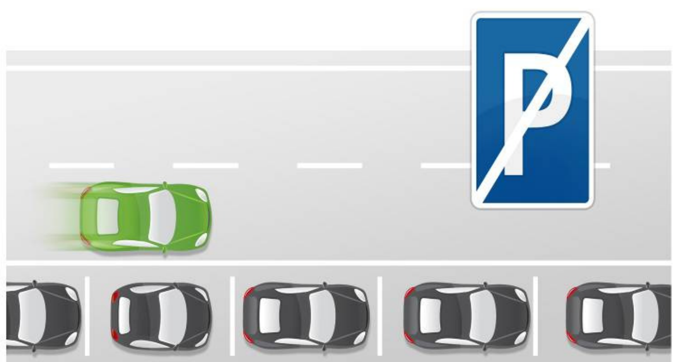
6.1. Manage Network

The set of eCoMove use cases refers to three different contextual areas that represent different spatial levels of consideration and action in the road network.
The broadest one of these levels is the *network level*. The road (and maybe service) operator's perspective at this level is to have enhanced information on the current, future and desired network state available that reflects somehow the overall objective of fuel reduction and CO_2 emission. Furthermore the operator wants sophisticated technical systems to influence route decisions of drivers (by communicating with them) and to control networks capacities in an optimal way.

The road user's view is to get permanent and unobtrusive assistance that helps him to drive with minimal fuel consumption and in line with invisible traffic control strategies while his trip is as safe, comfortable and fast as it was before.

6.1.1. Improve Parking Guidance

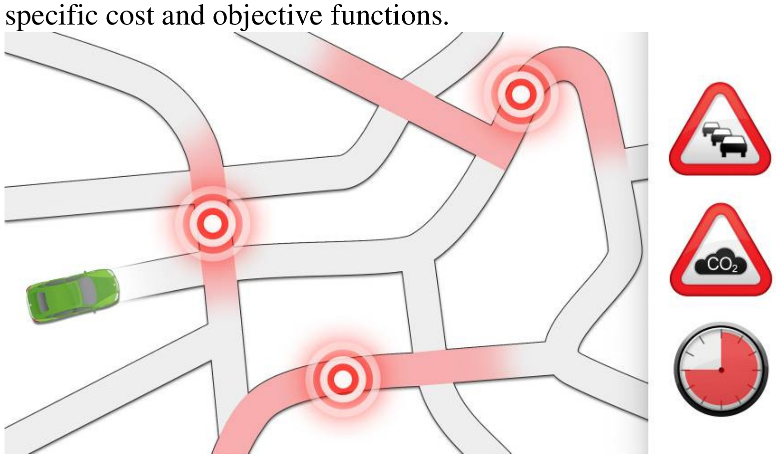
Use Case ID	UC_SP5_1
Lead author(s)	A. Rooke/SP5/TECHNOLUTION L. Broquereau/SP5/ASFA
Contributing partners	TECHNOLUTION, ASFA
Responsible SPs	SP5
Short Description	<u>road user perspective</u> Frequently the location and route to parking facilities is not well known, as is the availability of spaces and alternatives. The result is that the process of finding a place to park is very inefficient for a road user (both private car and truck drivers) as he/she has to drive unnecessary kilometres looking for a parking facility that has space available, and having to wait in stationary queues when entering parking facilities. Road users will directly benefit when they can be guided to an available parking space as efficiently as possible. <u>road operator perspective</u> The road users that are searching for a place to park put an extra strain on the traffic system, indirectly hindering other road users. When the road users are dispersed over and guided to the available parking spaces as efficiently as possible the stress put on the traffic system will be lowered, which will make the traffic system as a whole more efficient and safe.
Goal	To provide real-time information on the location of available parking spaces and dynamic routing to available parking facilities, taking into account network state, events and current levels of pollutants in the atmosphere to reduce unproductive travel kilometres.
Constraints	• User acceptance and compliance. • Quality of data from parking facilities. • System should take into account that trucks are limited in their route choice regarding their loads, size and weight. • Furthermore, there are driving and resting regulations for truck drivers.
Actors	Cars, trucks, roadside units, traffic lights, traffic management centre, car drivers, truck drivers, in-car and in-truck information systems, and other road users.
Driving situation	Traffic networks and parking facilities that are nearly saturated.
Vehicle type & state	Mixed traffic at different levels of saturation.
Inefficiency	INEF07, INEF13A

addressed	• Unnecessary kilometres travelled by road users looking for a parking space • Unnecessary stop-go waves when entering parking facilities • Sub-optimal ratio between driving and resting for truck drivers
Pre-condition	• The road user does not know the location of parking facilities. • The road user does not know the availability of parking space. • The road user wastes time and energy by searching different parking facilities finding space, or queuing at a known parking facility to wait for space.
Post-condition	• The road user will be informed on the parking space availability and the most efficient route towards these parking spaces.
Main flow	Road users invariably need to find parking spaces close to their destination or when regulation forces them to rest. The road operator is made aware of the available parking spaces and the condition of the alternative routes towards these parking spaces. On the basis of this information the road operator can give advice on an individual basis about the most efficient route towards a parking space. The road operator can also provides information to traffic on the most important incoming routes towards for instance a city centre in order to distribute incoming traffic evenly over the available routes and parking facilities. 
Exceptions	Truck delivery logistics and parking space reservation are outside the scope of this use case.
Dependency with other Use Cases	Improve Network Usage, Improve Driver Information
Dependency with application or component	ecoNetwork State, ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoRouting, ecoTruck Parking

6.1.2. Improve Network Usage

Use Case ID	UC_SP5_2
Lead author(s)	P. Mathias/SP5/MAT.TRAFFIC T. Schendzielorz/SP5/TUM

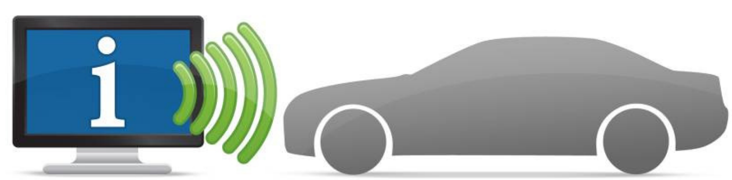
Contributing partners	MAT.TRAFFIC, PEEK, PTV, TNO, TUM
Responsible SPs	SP5
Short Description	road operator perspective To realize optimal traffic control strategies and to deliver strategy compliant data for routing, a dynamic picture of the ideal traffic network states in terms of network route distributions according to the current conditions (traffic demand patterns, capacity limitations, traffic control states) needs to be permanently available. These network states reflect the intended balanced traffic flows in the network. Furthermore, the road operator wants to support routing services in a way that is compliant with his overall system view (reflecting the minimisation of fuel consumption). road user perspective The road user is interested to get route recommendations that are (1) tailored to his specific needs and circumstances and (2) allow him to minimise the overall fuel consumption in the traffic network on his journey. He benefits directly as his travel is influenced by computed route recommendations. These recommendations are based on the desired network states. In addition, the routes should serve the requests of driver on an energy efficient and fast route as best as possible. This leads to an overall balanced network state and with this – on average - to a win-win-situation in terms of travel time and CO_2 reduction for road users and road operators.
Goal	• Determine a macroscopic network traffic state in terms of dynamic source-destination route distributions that reflects minimal fuel consumption for the totality of traffic. • Provide a benchmark for optimal fuel consumption in a road network. • Compute routes which serve the system and the driver requirements (win-win routes). • Provide a data base for other eCoMove components / applications to support their control and management strategies.
Constraints	• Possible trade off between the objective functions • Origin-destination relations need to be known • Insufficient information on the traffic state due to the lack of sensing possibilities • For integration in a simulation model, the model must be able to simulate the local traffic control of eCoMove, features of cooperative systems, and must be able to reroute vehicles dynamically. • For integration on a test sites, data sources have to be accessible online and data from non-eCoMove entities must be comprehensive to guarantee sensible test results.

	• The determined route patterns may not be such that single sub-flows (or vehicles) are discriminated or penalized significantly in order to preserve user acceptance.
Actors	Road operators, vehicles / drivers, traffic light control sub-systems, road sensors, other eCoMove applications.
Driving situation	Free flow networks are of less interest here as the corresponding route patterns are simply conducted by shortest paths. More relevant are driving situations with heavily loaded networks or networks with bottlenecks and congestion phenomena.
Vehicle type & state	All types of vehicles.
Inefficiency addressed	INEF07 • None-optimal distributed route patterns in a road network lead to longer travel-time per vehicle and hence to additional fuel consumption. • Individual (vehicle autonomous) routing tends to create oscillating bottlenecks in case of incidents as a network balancing view is missing here.
Pre-condition	• An optimal distribution of origin-destination-routes with respect to fuel consumption has not been available until now. • Comparable models usually estimate traffic states as they probably are in reality, and not as they should be according to a given strategy.
Post-condition	A database of route patterns for the network is available that can be used by various other applications in order to improve their functionality.
Main flow	When driving in a road network, vehicles share information on their origin and destination to road side systems. By including data on green ratios and cycles times from local traffic controls, traffic state and fuel consumption data from the EnergyMap, and emission data from emission models, an optimal route distribution is computed for all origin-destination relations using specific cost and objective functions.  Following the route assignment and taking into account user and system constraints, vehicles receive route recommendations and

	provide feedback on the adherence of the advice.
Exceptions	• Insufficient data is available to determine a network state. • Insufficient actuation possibilities are present to affect the route choice in a significant manner. • Drivers might not obey the advice given to them.
Dependency with other Use Cases	Improve Parking Guidance, Improve Driver Information, Coordinate Traffic Controllers
Dependency with application or component	ecoNetwork State, ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoRouting, ecoGreen Wave, ecoBalanced Priority, ecoRamp Metering and Merging, ecoSpeed and Headway Management

6.1.3. Improve Driver Information

Use Case ID	UC_SP5_3
Lead author(s)	M. Mann/SP5/PTV F. van Waes/SP5/VIALIS
Contributing partners	PTV, VIALIS
Responsible SPs	SP5
Short Description	road user perspective When travelling from A to B a driver and / or on-board driver assistance system will receive information on the actual and predicted traffic state, route recommendations, speed profile data and traffic light information for efficient vehicle operation and an optimal driving strategy. road operator perspective Infrastructure systems collect information about the historical, actual and predicted traffic states, active traffic strategies and traffic control schemes, and convert this information into a standard protocol. Service providers offer information services tailored to the needs of individual vehicles and driver assistance systems.
Goal	• Provide traffic information to vehicles and drivers. • Provide travel and driving advices to vehicles and drivers. • Reduce fuel consumption by improving traffic operation.
Constraints	• Advices should be in line with the expectations of drivers to ensure acceptance and compliance. • Information must be available and suitable for geographically based referencing. • The validity of dynamic information must be ensured.
Actors	Road operator, drivers, on-broad units, roadside units, traffic management centre, service provider, service centre
Driving situation	Before and during a trip, drivers and vehicles have access to actual and forecasted traffic information representing the whole traffic network. During the trip they receive tailored route and speed recommendations based on network optimisation

	algorithms.
Vehicle type & state	All vehicles
Inefficiency addressed	INEF07, INEF11E Lack of information, plus the inefficiencies addressed by the various other systems expressed in the other use cases.
Pre-condition	Driver and vehicles are lacking information for a good overview of the current and future traffic situation that enables them to find the optimal route, speed, etc. from a fuel use perspective.
Post-condition	Driver and vehicles receive information on actual and forecasted traffic states, activated traffic strategies and traffic light control as well as tailored route and speed recommendations.
Main flow	Infrastructure systems provide drivers and vehicles with general and tailored information before and during the trip. Based on historical data and planned or likely events the prediction horizon could be multiple days ahead. The illustrated state includes the expected effects of active traffic strategies and traffic control schemes to support reaching the desired state (i.e. most fuel efficient from a network viewpoint). Information will be geo-referenced and translated into ordinary link attributes like travel time, densities, speed changes as well as estimates for disturbances of traffic lights, jams, etc. which could include weather influences. 
Exceptions	Information services better allow drivers and fleet operators to plan their trips. Interference with the planning and logistics process before a trip is generated is outside the scope of the information services and therefore not considered.
Dependency with other Use Cases	Improving parking guidance, Improve network usage, Coordinate traffic controllers, Support merging, Improve intersection control, Balance intersection control objectives, Improve ramp control, Improve lane usage, Improve approach velocity, Improve traffic flow stability, Improve driver information
Dependency with application or component	ecoNetwork State, ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoRouting, ecoGreen Wave, ecoBalanced Priority, ecoRamp Metering and Merging, ecoSpeed and Headway Management, ecoTruck Parking, ecoTolling

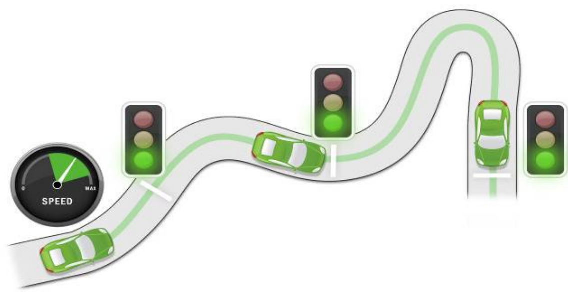
6.2. Manage Corridors

The set of eCoMove use cases refer to three different context areas that represent different spatial levels of consideration and action in the road network.
On the intermediate level resides the *corridor level*. The road operator's perspective at this level is to have sophisticated technical systems in place that dynamically offer speed and lane recommendations to drivers and to run traffic control (esp. traffic lights) procedures that are designed to optimize vehicles' fuel consumption.
The road user's view is to get permanent and unobtrusive assistance that helps him to drive with minimal fuel consumption and in line with invisible traffic control strategies while his trip is as safe, comfortable and fast as it was before.

6.2.1. Coordinate Traffic Controllers

Use Case ID	UC_SP5_4
Lead author(s)	P.Mathias/SP5/MAT.TRAFFIC J. Vreeswijk/SP5/PEEK
Contributing partners	MAT.TRAFFIC, PEEK, TUM, VIALIS
Responsible SPs	SP5
Short Description	road user perspective Car drivers experience a green wave on a road section. They are stimulated to adjust their speed to stay within the green wave by informing them about the potential fuel savings. road operator perspective Macroscopic (road side sensors) and microscopic (ecoFVD) traffic related data for a defined green wave road section is gathered in the traffic control centre, merged and processed in order to derive detailed traffic state information. New green wave control procedures are used to dynamically define coordinated traffic light control along subsequent urban intersections that target the overall fuel minimisation of the traffic in this road section. The green wave control procedure takes into account the possibility to influence the speed and behaviour of vehicles. Therefore, together with the green wave control parameters also accompanying information (e.g. speed recommendations) is generated that will be provided to the drivers.
Goal	• Minimize fuel consumption and CO_2-emission for a road section of subsequent urban intersections by maintaining acceptable circumstances for all road users. • Use (microscopic) vehicle generated data to get a more detailed picture of the traffic situation (e.g. the concrete shape of vehicle platoons and their evolution in time). • Enable new dynamic green wave control procedures that - besides waiting times and number of stops - explicitly take into account fuel minimising objective functions. • Use short range communication to inform and instruct

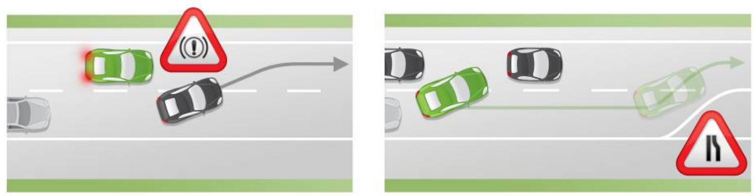
	approaching drivers about green wave coordination speed in order to shape vehicle platoons and to harmonise vehicle speeds with the current green wave strategy.
Constraints	• Road users might not be willing to drive in line with the speed recommendations, especially if the recommended speed is too low. • An ecoGreenWave that is too dynamic might cause significant loss of capacity through unduly frequent switching of local control programs. • If there are no dynamic information signs at the road side, optimal instruction of the drivers can only be achieved with a sufficiently high percentage of equipped vehicles.
Actors	Traffic control centre, road side unit, intersection traffic light controller, vehicles.
Driving situation	• String of traffic light controlled intersections, where the intersection controllers are connected with each other and with a central system. • Mixed traffic at different levels of saturation. • Significant variation in traffic demand patterns over the course of the day or within hours (E.g.: One direction high traffic demand, the other direction low. Later on vice versa).
Vehicle type & state	Mixed traffic at different levels of saturation.
Inefficiency addressed	INEF09E, INEF13E • Generally: Energy waste due to braking & stopping. • More effective traffic light coordination for both driving directions which is made possible through speed recommendations for drivers. • Better identification of actual traffic states (platoons) through V2I-communication. • More dynamic coordination through more detailed traffic information (V2I -communication). • Explicit consideration of special vehicles like trucks (see also use case "Truck priority over queue").
Pre-condition	• Static green waves (without speed recommendations) can often not be formed or do not achieve optimal capacity over both directions as they cannot influence a) the speed of the vehicles while they are driving in the green wave and b) the shape of the platoons. • Objective functions of state-of-the-art green wave control procedures usually try to optimise waiting times and number of stops along the road section, but not explicitly the fuel consumption. • Drivers do not have real information about the coordination speed within the green wave.
Post-condition	• Vehicles undergo less braking and accelerating manoeuvres. • The green waves are much better tuned with respect to both

	driving directions.
Main flow	While approaching a sequence of traffic light, vehicles periodically broadcast information about their position and speed. Together with detector and traffic light data from traffic light controllers a roadside unit processes the information and forwards it to a traffic control centre. The traffic control centre computes green wave control parameters and distributes them to traffic light controllers to enable coordination between controllers. Next, the road side unit computes speed advices based on the current traffic light control and sends the advices to the drivers. When following the speed advice, the vehicle drives smoothly through the green wave section. 
Exceptions	• ecoGreenWaves cannot be implemented in cases where the single intersections are too dynamic in terms of local traffic actuated control (e.g. high prioritisation of public transport, pedestrians, or bicycles). • ecoGreenWaves are difficult to implement if short range communication ranges are too small.
Dependency with other Use Cases	Improve network usage, Improve intersection control, Balance intersection control objectives, Improve approach velocity, Improve driver information
Dependency with application or component	ecoNetwork State, ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoRouting, ecoGreen Wave, ecoBalanced Priority

6.2.2. Support Merging

Use Case ID	UC_SP5_5
Lead author(s)	M. Strating/SP5/VIALIS J. Vreeswijk/SP5/PEEK
Contributing partners	VIALIS, NAVTEQ, PEEK, TNO
Responsible SPs	SP5
Short Description	<u>the road user perspective</u> Changing lanes at on-ramps, weaving sections or lane-drops driving is complex and the workload on drivers significantly increases, for both mergers and non-mergers. Finding the right cruising speed, a safe following distance, a suitable gap to merge in or to let merge somebody merge in, and the right time for

	merging is difficult. Advising mergers and non-mergers about these variables can make merging processes much easier for drivers. road operator perspective Merging points are one of the main causes for congestion. Static road signs have increased driver's awareness at such points, but drivers' lack of anticipation to the prevailing traffic dynamics remain a cause for capacity loss and thus inefficiency. Supporting merging manoeuvres using roadside monitoring systems and road side information will help road operators with their goal to improve traffic performance.
Goal	Increase driver anticipation at merging points and smoothen traffic behaviour to improve traffic performance and reduce fuel waste.
Constraints	• Safety, best represented by following distance (headway), should be guaranteed at all times. • Merge advices should be in line with gap acceptance. • Balancing traffic flows and so prioritizing traffic should be within acceptability thresholds and clear to drivers. • Negative side effects affecting other performance indicators should not exceed the benefits of obtained from better merging.
Actors	Driver, roadside system, in-car information system
Driving situation	When approaching a merging point at an on-ramp, weaving section or lane-drop, drivers will be advised about: the best speed to merge or to allow merging, a safe following distance also allowing gaps for merging vehicles, and the right moment to start merging.
Vehicle type & state	Mixed traffic at different levels of saturation.
Inefficiency addressed	INEF08A, INEF09A, INEF11A, INEF13A • Lack of anticipation at merging points causing too late or too early merging resulting in unnecessary braking or even stopping which might result in congestion. • Disproportional inefficiencies of different traffic flows. The traffic volumes, traffic mix or upstream impact of traffic flows might have very different effects on the network performance. Currently, it is not possible to distinguish between traffic flows based on their priority.
Pre-condition	Vehicle drivers have to make their own assessment of speed, following distance, gap opportunity and merging moment at on-ramps, weaving sections or lane-drops.
Post-condition	Vehicle drivers are advised in their longitudinal and lateral driving behaviour to both merge smoothly themselves and to allow others to merge smoothly. Furthermore, merging traffic flows are balanced in a way that optimizes network performance.
Main flow	By using roadside sensors and collecting ecoFVD an

	infrastructure system monitors traffic flows at merging points on their traffic volumes, density, relative speeds of vehicles and following distances. Using vehicle trajectory data the number of lane changes at merging sections is estimated. First the overall traffic flow performance in terms of flow, speed and density is optimised which results in general speed and headway advices while approaching the merging point. In this process, the importance of the different traffic flows is carefully weighted. Next, near the merging point advices will be adapted to the number of mergers at that time, while the mergers themselves receive individualised recommendations for their speed and merging instant. Right after the merging point drivers will receive an advice that stimulates them to accelerate in order to best use the available road capacity. 
Exceptions	• In case of congestion speed and following distances are restricted and the system loses its effect. • When the differences between two traffic flows are disproportionate the system might not be effective and the use of systems like ramp metering is more appropriate.
Dependency with other Use Cases	Improve network usage, Improve ramp control, Improve lane usage, Improve approach velocity, Increase traffic flow stability, Improve driver information.
Dependency with application or component	ecoNetwork State, ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoRamp Metering and Merging, ecoSpeed and Headway Management

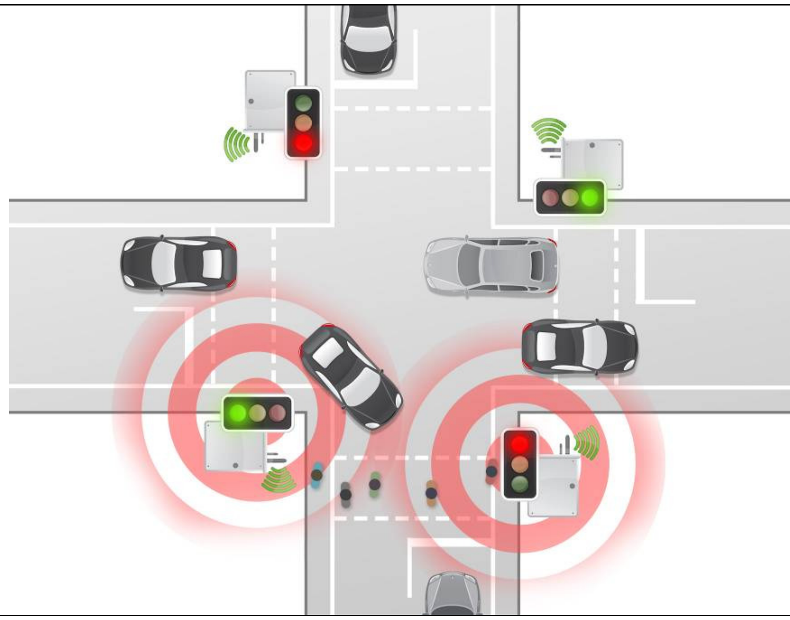
6.3. Manage Local Area

The set of eCoMove use cases refer to three different context areas that represent different spatial levels of consideration and action in the road network.
The spatial most concentrated level is the *local level*. The road (and possibly service) operator's perspective at this level is to have innovative technical systems in place that enhance existing local traffic control systems that are designed to minimize vehicles' fuel consumption, and to dynamically offer speed and lane recommendations to drivers in order to optimize the traffic flows in the vicinity of the local area. The road user's view is to get for certain locations of the road network unobtrusive assistance that helps him to pass with minimal fuel consumption and in line with invisible local traffic control objectives while his trip is as safe, comfortable and fast as it was before.

6.3.1. Improve Intersection Control

Use Case ID	UC_SP5_6
Lead author(s)	R. van Katwijk/SP5/TNO J. Vreeswijk/SP5/PEEK
Contributing partners	TNO, PEEK, TUM
Responsible SPs	SP5
Short Description	road operator perspective Intersection controllers can be made more CO_2 efficient by having them adapt to the actual traffic conditions and having them anticipate on the expected traffic conditions. Using information from the infrastructure and vehicles, the intersection controller can distribute and assign green times more efficiently to accommodate the expected demand. An intersection can furthermore reduce inefficiencies caused by the generally conservatively chosen values for minimum green time, yellow time and clearance time. road user perspective Approaching traffic can be informed about their estimated time of departure from the stop line. Vehicles can be provided with a speed advice or update their approach speed themselves in order to save on fuel. Furthermore, road uses will experience 'better' intersection control.
Goal	Improve the efficiency of an intersection through use of information that can be retrieved from both vehicles and intersections.
Constraints	• Considering CO_2 optimisation, green allocation should be fair and within acceptability boundaries. • Green times should be reasonable given local guidelines and customs. • Time related information should not change too often to prevent negative side-effects.
Actors	On-board units, roadside units upstream and downstream intersections, monitoring stations
Driving situation	Traffic control of mixed traffic at different levels of saturation. Vehicles approaching the controlled intersection receive information related to the timing of the controller.
Vehicle type & state	Mixed traffic at different levels of saturation
Inefficiency addressed	INEF11E, INEF13E • Inefficient allocation of green time as a result of unawareness or disability to process information of approaching traffic. • Lost time due to conservatively chosen clearance times, minimum green times and amber times. • Too high or too low approach velocities which either results in unnecessary stops or waste of green time.

Pre-condition	road operator perspective Intersections are unaware of approaching traffic and are thus unable to determine at which times turning movements can best be served so as to minimize a set criterion (i.e. amount of CO_2 emitted by vehicles on all approaches). Intersections are unaware of the clearance times, minimum green times and amber times that are actually needed. road user perspective Approaching traffic is unaware of the time that it will be able to pass the stop line.
Post-condition	road operator perspective Intersections are aware of approaching traffic as they are informed by upstream traffic signals and by approaching vehicles. This information includes, but is not limited to, information regarding the direction of travel, the estimated arrival time, and the CO_2 emission characteristics of the vehicle. Intersections are able to determine appropriate clearance times, minimum green times and amber times dynamically. The intersection controlled can thus significantly reduce CO_2 emission in a way that is considered reasonable by traffic participants. road user perspective Approaching traffic is given a speed advice or made aware of the most probable time that they will be able to pass the stop line and can thus update their approach speed accordingly in order to save on fuel.
Main flow	Vehicles report to the intersection how they approach the intersection such that the intersection can determine when they enter or exit conflict zones on the intersection, when they pass the stop line, etc. Based on these the controller determines an optimal distribution of green times and tighter, less conservative green, yellow and red times. Information with respect to the estimated time at which vehicles will be able to pass the stop line is sent to the vehicles.

	
Exceptions	• In highly oversaturated traffic conditions intersection control loses its effectiveness. • In case of low penetration of vehicles sending FVD the controllers' operates sub-optimal due to missing data.
Dependency with other Use Cases	Coordinate traffic controllers, Balance intersection control objectives, Improve approach velocity, Improve lane usage, Improve driver information
Dependency with application or component	ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoRouting, ecoGreen Wave, ecoBalanced Priority

6.3.2. Balance Intersection Control Objectives

Use Case ID	UC_SP5_7
Lead author(s)	R. van Katwijk/SP5/TNO J. Vreeswijk/SP5/PEEK
Contributing partners	TNO**,** PEEK
Responsible SPs	SP5
Short Description	Traffic participants can have many different expectations with respect to what can be considered acceptable and desirable. The traffic operator has to find an appropriate balance between all these local expectations and at the same time take into account that the intersection is part of network. This use case presents the different ways through which the traffic operator can prioritize certain target groups and constrain the intersection controller to find a balance between the different interests. 1. Prioritizing certain vehicle categories that either a. leave a large CO_2 footprint when having to accelerate after a stop (i.e. passenger cars versus heavy goods vehicles)

	b. are more environmentally friendly (i.e. electric cars versus large MPV's) 2. Prioritizing vehicles that are part of a flow of vehicles on a prioritized traffic corridor (i.e. a green wave) 3. Dynamically selecting between a flexible and a fixed signal group. A flexible sequence allows for more efficient signal group control as it allows giving green to the direction that needs it most, without the necessity to complete the cycle. A fixed sequence allows a traffic participant to recognize the sequence more easily, preventing unsafe behaviour. 4. Allowing higher maximum waiting times for traffic participants, even above the normal threshold, to give sufficient green to the various directions to prevent gridlock and keep flows moving when they are in motion.
Goal	Provide a more CO_2 efficient traffic intersection controller that is considered acceptable given the prevailing traffic conditions.
Constraints	The overall benefits may not come at unacceptable costs for some individuals. The safety of the intersection must not deteriorate.
Actors	Road operator, vehicle, roadside unit, traffic controller
Driving situation	Traffic control of mixed traffic at different levels of saturation. Based on vehicle properties and vehicle clustering the traffic controller initiates priority schemes to balance traffic on their environmental load. Vehicles approaching the controlled intersection will experience 'ad-hoc' control in combination with improved or disturbed throughput as a result of priorities balancing.
Vehicle type & state	Mixed traffic at different levels of saturation.
Inefficiency addressed	INEF08E, INEF13E • Many constraints for intersection control that hinder the flexibility and freedom to meet demand and balance between local and network goals. • All traffic demand is generally treated equally without explicitly considering traffic composition and vehicle properties leading to unnecessary stops and waiting time.
Pre-condition	A traffic signal plan that does not reflect the interests of all concerned actors.
Post-condition	A traffic signal plan that reflects the interests of all concerned actors.
Main flow	Vehicles report to the intersection controller about their approach of the intersection such that the intersection can build a detailed representation of demand. Starting from a basic intersection control plan (see use cases Improve intersection control), the controller now integrates priority schemes for specific vehicles and platoons and allows flexible sequences for traffic light control to find a best balance between changing demands. As

	suggested by other use cases, vehicles approaching the controlled intersection will be informed with speed and time related information.
Exceptions	• In highly oversaturated traffic conditions intersection control loses its effectiveness. • In case of low penetration of vehicles sending FVD the controllers' operates sub-optimal due to missing data.
Dependency with other Use Cases	Improve network usage, Coordinate traffic controllers, Improve intersection control, Improve approach velocity, Improve driver information
Dependency with application or component	ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoRouting, ecoGreen Wave, ecoBalanced Priority

6.3.3. Improve Ramp Control

Use Case ID	UC_SP5_8
Lead author(s)	M. Strating/SP5/VIALIS J. Vreeswijk/SP5/PEEK
Contributing partners	VIALIS, PEEK, TNO
Responsible SPs	SP5
Short Description	road user perspective Queuing at ramp metering installation is generally chaotic and frustrating. The desired speed before and after the ramp meter is often too high which results in unnecessary acceleration, deceleration and eventually stops, which is inefficient and presents a safety issue. In addition, the behaviour of ramp control does not appear sensitive to changes even though the traffic conditions on either the mainstream or the on-ramp changes. road operator perspective Ramp metering installations generally operate solely on macroscopic indicators, making them too simplistic to deal with changing traffic conditions and traffic demands. They can be improved by including multiple control variables, both macroscopic (i.e. traffic flow) and microscopic (i.e. vehicle), by applying different strategies for different designs of on-ramps, by informing vehicles about the best driving strategy before and after the ramp meter, and by controlling in-flow and spillback to the urban network in the optimisation process.
Goal	Widen the scope and extend the horizon of ramp control to better anticipate to changes in the traffic situation and traffic demand, and so reduce fuel waste.
Constraints	• Synchronisation with urban control measures to prevent that the urban traffic operation is negatively affected by the ramp control.

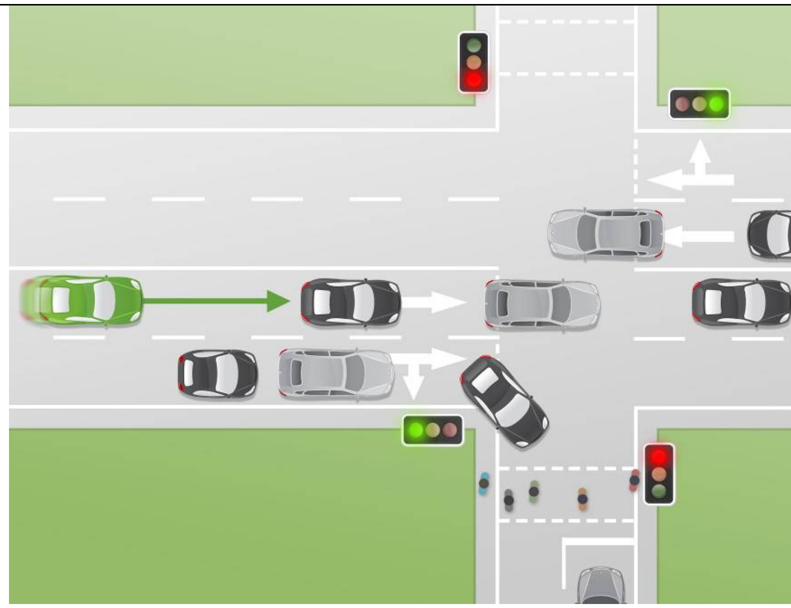
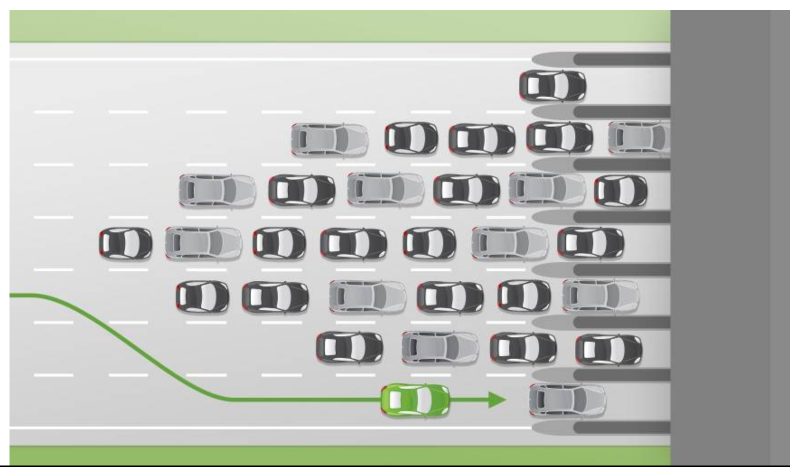
	• In case the mainstream is far from saturated or oversaturated the ramp control strategy should be terminated. • Driving behaviour recommendations should be in line with the actual traffic situation, easy to follow, and not change too often.
Actors	On-board units, roadside units, ramp controllers, drivers, road operators, traffic management centre, upstream intersection controllers
Driving situation	Vehicles enter a motorway mainstream via an on-ramp. This can be a single-lane or dual-lane and single branch or dual branch on-ramp. If the flow of the mainstream plus the flow on the on-ramp exceed the motorway capacity downstream of the on-ramp the in-flow of the on-ramp is controlled by means of a ramp metering installation. Vehicles need to stop as indicated by a traffic light which essentially turns the on-ramp into a buffer. During their approach to the ramp metering installation, vehicles will receive advices with the aim to optimize the approach speed, queuing process, and balancing between different lanes and branches.
Vehicle type & state	Mixed onramp traffic at various levels of saturation
Inefficiency addressed	INEF08E, INEF11E, INEF13E • Chaotic queuing behaviour on metered on-ramps resulting in many acceleration, deceleration and stops. • Insufficient length or width of on-ramps to serve as buffer space which eventually affect the performance of the urban road network. • Road users' unawareness which driving strategy to adopt while approaching a ramp meter.
Pre-condition	Isolated ramp meter control using simple singular indicators and strategy objectives, without balancing, coordination and information strategies. Chaotic and frustrating traffic situation as a result of unawareness at the driver side resulting in many stop-go manoeuvres.
Post-condition	Using multiple indicators, multi-objective ramp meter control including balancing, coordination and information strategies that reduce fuel waste. Wider scope and extend horizon for both the controller and the driver as a result of interaction with other actors.
Main flow	Vehicle report to the ramp controller about their approach of the ramp metering installation such that the ramp controller can build a detailed representation of the traffic demand on the on-ramp. The conditions on the mainstream (i.e. motorway) and upstream urban controlled intersections are monitored through infrastructure sensors and other roadside units. Near saturation on the mainstream and based on the mainstream, onramp and upstream conditions, the ramp controller determines a strategy that best fits the design of the on-ramp and balances the current

	demands and overall objectives. This may affect the control scheme, the queuing process as well as the driving behaviour of approaching vehicles. The latter is strongly related to information provisioning to drivers as discussed in other use cases. 
Exceptions	In free-flow conditions or oversaturated conditions the ramp metering installation is not operational.
Dependency with other Use Cases	Support merging, Balance intersection control objectives, Improve lane usage, Improve approach velocity, Increase traffic flow stability, Improve driver information
Dependency with application or component	ecoNetwork State, ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoBalanced Priority, ecoRamp Metering and Merging, ecoSpeed and Headway Management

6.3.4. Improve Lane Usage

Use Case ID	UC_SP5_9
Lead author(s)	J. Lüßmann/SP5/TUM T. Schendzielorz/SP5/TUM
Contributing partners	TUM, PTV, PEEK, VIALIS, NAVTEQ, ASFA
Responsible SPs	SP5
Short Description	road user perspective Vehicles receive advice which lane is best to take when approaching an uncontrolled or controlled intersection, an on-ramp meter or a toll gate where they have several lanes to choose. The goal is to reduce the number of stops and waiting time by helping the driver to chose the lane so he/she can pass the intersection, ramp or toll gate without stopping or waiting too long. road operator perspective The traffic operator distributes the vehicles to the lanes of the intersection, ramp or toll gate to adjust the saturation flow on all available lanes. The goal is to utilize the capacity of all lanes and

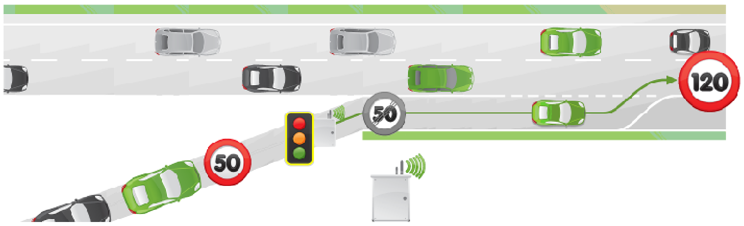
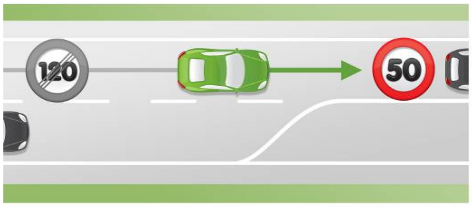
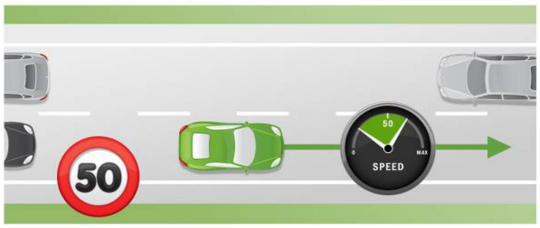
	therefore of the whole intersection, ramp or toll gate and smooth the traffic flow. It also allows the traffic operator to minimize platoon dispersion.
Goal	Make best use of available road capacity at intersections, on-ramps and toll gates and so reduce congestion, unnecessary waiting time, number of stops, and so smoother traffic flows.
Constraints	• Advice should be in line with the expectation of the driver to guarantee acceptance and compliance. • Traffic safety must be preserved.
Actors	Vehicles, roadside units and traffic lights, toll gates, ramp meters traffic management centre, drivers and other road users.
Driving situation	A vehicle approaches a traffic light, ramp metering installation, toll gate or other infrastructure constraint. The driver has to decide which lane he or she wishes to take.
Vehicle type & state	Mixed traffic at high levels of saturation.
Inefficiency addressed	INEF07, INEF08E, INEF09e, INEF13e Inefficient lane choice, unnecessary braking and acceleration, excessive stops and unstable traffic flows.
Pre-condition	Drivers choose a lane at an intersection, ramp or toll gate. This decision is based on subjective impressions, such as spillback length and takes no capacity aspects or energy efficient parameters into account.
Post-condition	The drivers are advised to take the lane that allows them to pass an intersection, ramp meter or toll gate in the most energy efficient manner.
Main flow	Vehicles broadcast information about their position, speed, heading, etc. while they approach an (controlled) intersection, ramp metering installation or toll gate. Based on the actual queues, the control scheme and the approaching vehicles, the best distribution of vehicles over the available lanes is calculated. Next, individual vehicles are allocated to specific lanes and vehicle drivers are informed whether they should continue on the same lane or not. In the figure below this use case is illustrated for a vehicle that approaches an intersection. The green vehicle is directed to the best lane for it to follow, given its destination, the queue length and the expected speed of outflow for each lane

	 In the figure below this use case is illustrated for a vehicle that approaches a toll plaza. The green vehicle is directed to the best lane for it to follow, given its method of payment, destination, the queue length and the expected speed of outflow for each lane (which depends amongst others on the method of payment) 
Exceptions	• On single-lane approaches the system does not work. • Non-equipped vehicles cannot be addressed.
Dependency with other Use Cases	Support merging, Improve intersection control, Improve ramp control, Improve approach velocity, Improve driver information
Dependency with application or component	ecoVehicle Trajectory Prediction, ecoRouting, ecoGreen Wave, ecoBalanced Priority, ecoRamp Metering and Merging, ecoTolling

6.3.5. Improve Approach Velocity

Use Case ID	UC_SP5_10

Lead author(s)	J. Vreeswijk/SP5/PEEK M. Mann /SP5/PTV R. van Katwijk/SP5/TNO
Contributing partners	ASFA, MAT, NAVTEQ, PEEK, PTV, TNO, TUM, VIALIS
Responsible SPs	SP5
Short Description	road user perspective Road users that are approaching a disruption in traffic flow will receive advice on optimal driving speed and timing to anticipate on the downstream traffic conditions and mitigate the disruption in the most energy-efficient way. The source of a disruption in traffic flow can either have a fixed location (i.e., a controlled intersection, a toll plaza or a change in speed limit) or be moving (i.e., in case of a shock wave) road operator perspective Traffic control systems can be informed about approaching traffic so that the trajectories of individual vehicles can be predicted. This allows the traffic control systems to deal with traffic demand as efficiently as possible. The road user can be made aware of the downstream conditions and advised about the best way to approach the discontinuity.
Goal	Minimize the number of stops, unnecessary acceleration and deceleration, resulting in continuous stop-go traffic in order to minimize fuel consumption.
Constraints	• Advised speeds should be clear and logical for the driver as well as realistic to guarantee acceptance. • Vehicle speed is subject to the speed of the preceding vehicle. In case of platoon shaping this means that other vehicles are restricted by the vehicles before them. • Vehicle speed is subject to the (dynamic) speed limits in place at road sections. Transition from one speed to another should be as energy-efficient as possible. • Sufficient input of current traffic measurements is necessary for trajectory predictions for representative inflow estimations. • Normal traffic rules remain valid.
Actors	Traffic light controller, ramp metering installation, toll gate, road side unit, vehicles, traffic control centre.
Driving situation	*Green wave* A vehicle approaching a traffic light receives a speed advice or speed bandwidth. Maintaining this speed allows the vehicle to pass the traffic light without stopping. When multiple vehicles are involved, speed advices are given in such a way that platoons are being shaped. In case of multiple intersections the vehicle receives a speed profile. *Ramp metering* A vehicle approaching a ramp metering installation receives a

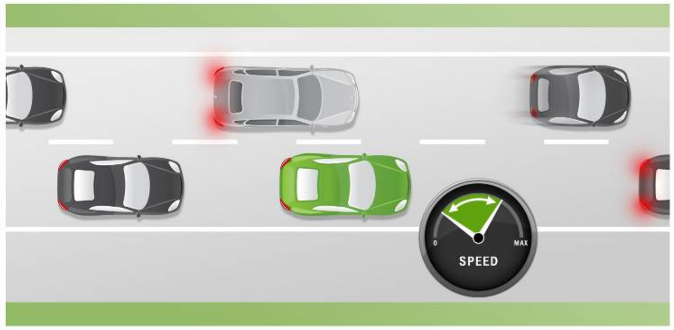
	speed or acceleration advice. Following the advice minimizes the number of stop-go movements while queuing.  *Toll gate* A vehicle approaching a toll gate first receives a deceleration advice for the most efficient transition from high speed to low speed conditions, followed by a speed advice that enables the vehicle to pass the toll gate smoothly. *Merging* A vehicle approaching a merging point, for example at a on-ramp or a lane-drop, receives a speed advice that best corresponds to the local traffic conditions and allows smooth merging to prevent traffic flow disturbance. Speed advises can be given to both the merging traffic (that aims for a gap in the traffic flow with which to merge) and the traffic with which is merged (that can create gaps to facilitate merging).  *Traffic jam* A vehicle approaching a traffic jam on a motorway receives a deceleration and speed advice that corresponds with the road capacity at the bottleneck or current dynamic speed limit and allows the vehicle to pass the congested area smoothly. *Dynamic speed zone* A vehicle approaching a motorway stretch where a dynamic speed limit measure is activated receives a deceleration advice for the most efficient transition from high speed to the speed limit conditions, followed by a speed alert that corresponds to the current speed limit applied on the section. 

Vehicle type & state	All vehicles.
Inefficiency addressed	INEF09A, INEF09E, INEF11E, INEF13E • Fuel waste due to excessive speed, unnecessary braking and stopping, and continuous stop-go traffic. • Inefficient traffic control operation caused by insufficient information about approaching road users or by inefficient (dispersed) arrivals.
Pre-condition	A vehicle approaches a traffic signal, traffic event or road section with normal speed and needs to stop or slow down strongly. In dense traffic the vehicle is in a queue and only after multiple stops in stop-go traffic the vehicle is able to continue.
Post-condition	A vehicle approaches a traffic signal, traffic event or road section with normal speed, gently anticipates to the traffic conditions by smooth deceleration and continues by adjusted speed. The number of stops significantly reduces and stop-go traffic is prevented.
Main flow	The Infrastructure system detects vehicles based on their information broadcast and determines the best speed for the vehicles to pass the traffic signal, traffic event or road section taking into account current regulations and current traffic situations. The Infrastructure system transmits the speed advice, alerts or speed profile to the vehicle based on location information of the vehicle. On-board unit informs the driver.
Exceptions	• In case the system cannot prevent a stop, vehicle drivers are informed about the best acceleration profile to speed up. • In case the speed advice is higher than the speed of a preceding vehicle, no speed advice is sent to the vehicle.
Dependency with other Use Cases	Coordinate traffic controllers, Support merging, Improve intersection control, Improve ramp control, Improve lane usage, Increase traffic flow stability, Improve driver information
Dependency with application or component	ecoTraffic Strategies, ecoGreen Wave, covalence Priority, ecoRamp Metering and Merging, ecoSpeed and Headway Management, ecoTolling

6.3.6. Increase Traffic Flow Stability

Use Case ID	UC_SP5_11
Lead author(s)	F. Petit/SP5/ASFA R. van Katwijk/SP5/TNO
Contributing partners	ASFA, TNO, PEEK
Responsible SPs	SP5
Short Description	road user perspective Traffic is dense but not yet congested. The speed of the road-user is constrained by the speeds of the vehicles in front of him. Road users get a tailored speed or headway advice that allows them to adopt a smoother, more comfortable and fuel efficient car

	following behaviour. road operator perspective Traffic is dense but not yet congested. Small disturbances in traffic flow can potentially lead to bigger disturbances such as a shock wave and the accompanying drop in capacity. To increase the stability of the traffic flow the road operator can give specific speed or headway advice such that small disturbances will be dampened and not grow in magnitude as they propagate upstream.
Goal	• Avoid frequent heavy braking and acceleration from vehicles driving too close to each other, and thus reduce fuel consumption. • Prevention of shock waves by ensuring that disturbances in traffic flow do not grow in magnitude as they propagate upstream. • Indirectly, improve road safety and comfort.
Constraints	• Advices should be in line with the expectation of the driver to guarantee acceptance and compliance. • Sufficient number of equipped vehicles.
Actors	Road users, on-board units, motorway network, road operator, traffic management centre, road side units
Driving situation	In a dense but not yet congested traffic people drive at different speeds, resulting in frequent braking followed by accelerations. The system recommends a speed to each road user that allows them to adopt a smoother, more comfortable and fuel efficient car following behaviour and that at the same times prevents disturbances in traffic to grow as they propagate upstream.
Vehicle type & state	Mixed traffic at high levels of saturation.
Inefficiency addressed	INEF08A, INEF09E, INEF11A, INEF13A • Instable traffic flows, shock waves and congestion. • Energy waste due to braking and acceleration.
Pre-condition	Road users continuously accelerate and decelerate in order to maintain certain headway. Small disturbances grow in magnitude as they propagate upstream eventually causing a shock wave.
Post-condition	Road users adopt a smooth speed profile. Small disturbances are dampened and shrink in magnitude as they propagate upstream. Shock waves are prevented.
Main flow	Infrastructure systems gather information about speeds and headways of vehicles in the traffic flow. Based on this information the stability of the traffic flow is judged. Advice on speed and headway is given to drivers in order to improve the stability of the traffic flow and smooth out the speed profiles of the vehicles.

	
Exceptions	In case an insufficient number of vehicles are equipped the system is not effective.
Dependency with other Use Cases	Support merging, Improve ramp control, Improve approach velocity, Improve driver information
Dependency with application or component	ecoEmission Estimation and Prediction, ecoTraffic Strategies, ecoVehicle Trajectory Prediction, ecoRamp Metering and Merging, ecoSpeed and Headway Management

6.4. Overview of the ecoTraffic Management & Control use cases

In this section an overview of the different use cases will be given. An overview is given of the inefficiencies that are targeted by each use case. Furthermore, the links between the different use cases are summarized. Finally, the use cases are categorized based on the type of cooperation employed, the expected benefit, the level of innovation, and ease of deployment.

The next table (Table 1) summarizes for each of the use cases of the ecoTraffic Management & Control subproject the inefficiencies that it targets.

Table 1: Inefficiencies versus use cases

		Use cases										
		Improve parking guidance	Improve network usage	Improve driver information	Coordinate traffic controllers	Support merging	Improve intersection control	Balance intersection control objectives	Improve ramp control	Improve lane usage	Improve approach velocity	Increase traffic flow stability
Inefficiencies	INEF07 Inefficient routing	X	X	X						X		
	INEF08a Inefficient acceleration – traffic induced					X					X	X
	INEF08e Inefficient acceleration – signal induced				X		X	X	X		X	
	INEF09a Inefficient deceleration – traffic induced					X					X	X
	INEF09e Inefficient deceleration – signal induced				X		X	X	X		X	
	INEF11a Inefficient speed – traffic induced			X		X					X	X
	INEF11e Inefficient speed – signal induced			X			X	X	X		X	
	INEF13a Unnecessary stops – traffic induced					X				X	X	X
	INEF13e Unnecessary stops – signal induced				X		X	X	X	X	X	

The following table shows the relations between the different use cases. Although each use case can be independently implemented, in most cases there is an added advantage if they are implemented together. For instance, the CO_2 emitted at an intersection can be significantly reduced if the use cases ‘improve intersection control’, ‘improve lane usage’, and ‘improve approach velocity’ are developed jointly.

Table 2: Use cases versus use cases

Level	Name	Improve parking guidance	Improve network usage	Improve driver information	Coordinate traffic controllers	Support merging	Improve intersection control	Balance intersection control objectives	Improve ramp control	Improve lane usage	Improve approach velocity	Increase traffic flow stability
Network	Improve parking guidance	O	X	X								
	Improve network usage		O	X	X							
	Improve driver information	X	X	O	X	X	X	X	X	X	X	X
Corridor	Coordinate traffic controllers		X	X	O		X	X		X	X	
	Support merging		X	X		O			X	X	X	X
Local	Improve intersection control			X	X		O	X		X	X	
	Balance intersection control objectives		X	X	X		X	O			X	
	Improve ramp control			X		X		X	O	X	X	X
	Improve lane usage			X	X	X	X		X	O	X	
	Improve approach velocity			X	X	X	X		X	X	O	X
	Improve traffic flow stability			X		X			X		X	O

In the table below the use cases from sub project ecoTraffic Management & Control are categorized based on the type of cooperation envisaged (Table 3).

Table 3: Categorisation of use cases on the types of cooperation

		Type(s) of cooperation			
		Independent but cooperative approach beneficial	Cooperative (V2I & I2V)	Cooperative (I2I)	Cooperative (V2V)
Use cases	Improve parking guidance	X	X		
	Improve network usage	X	X		
	Improve driver information		X		
	Coordinate traffic controllers	X	X	X	
	Support merging		X	X	X
	Improve intersection control	X	X		
	Balance intersection control objectives	X			
	Improve ramp control	X	X	X	
	Improve lane usage		X		
	Improve approach velocity		X		
	Increase traffic flow stability		X		X

The table below (Table 4) provides an indication of the expected benefits, the level of innovation and the deployment effort for each use case. Note that these are preliminary indications as it is difficult to judge these beforehand. An expected benefit of more than 15% reduction of CO_2 is considered a high benefit. An expected benefit of less than 15%, but more than 5% is considered a medium benefit. The level of innovation indicated is based on the uniqueness of concept, and the existence of other implementations (that might not focus on CO_2). The deployment effort indicated is based on the number of interfaces, the amount of data required, and the complexity of algorithms foreseen.

Table 4: Categorisation of use cases

Level	Name	Expected benefit	Level of innovation	Deployment effort
Network	Improve parking guidance	Medium	Medium	Low
	Improve network usage	High	Medium	Medium
	Improve driver information	High	Medium	High
Corridor	Coordinate traffic controllers	High	Medium	Low
	Support merging	Medium	Medium	High
Local	Improve intersection control	High	Medium	Medium
	Balance intersection control objectives	Medium	High	Low
	Improve ramp control	Medium	Medium	Medium
	Improve lane usage	Medium	Medium	High
	Improve approach velocity	High	High	Medium
	Improve traffic flow stability	Medium	Medium	High

7. The ecoTraffic Management & Control subsystem

This section describes the ecoTraffic Management and Control subsystem. The ecoTraffic Management and Control subsystem can be subdivided over two levels:

- **The system level:** a set of interacting or interdependent applications, components and databases forming an integrated whole. A sub-system is only partly integrated at the roadside or vehicle. For example: routing of traffic in combination with traffic light control or traffic light control in combination with individual travel information. Systems in SP5: ecoAdaptive Balancing and Control, ecoAdaptive Traveller Support and ecoMotorway Management

- **The application and component level:**
    - **Application**: an entity that performs an *action* <u>with</u> direct interaction with a system user. It is a functional entity that is perceived from a user as the implementation of one or more use cases. For example a traffic light that switches to green, a roadside system that is activated, or a speed or route advice that is sent to a vehicle. Applications in SP5: ecoRoute Advice, ecoGreen Wave, ecoBalanced Priority, ecoRamp Metering and Merging, ecoSpeed and Headway Management, ecoTruck Parking and ecoTolling.
    - **Component:** an entity that performs an *activity* <u>without</u> direct interaction with a system user. These are information sources for applications and content providers of databases. For example: estimation and prediction of traffic state and emissions. Components in SP5: ecoNetwork State, ecoEmission, ecoVehicle Trajectory Prediction and ecoTraffic Strategies.

Section 7.1 describes the systems that are identified within the ecoTraffic Management & Control subproject. Subsequently, in section 7.2, the applications and components that form the basis of these systems are described. Section 7.3 shows how the use cases and the applications and components are related. Finally, section 7.4, provides a functional analysis of the different systems and the interfaces between them.

It is important to note that the descriptions presented in this chapter only provide a first outline of the applications and components. Their actual appearance is subject to a number of research questions that will be answered in the next phase of the project.

7.1. Description of systems

The ecoTraffic Management & Control subproject discerns the following (sub)systems. Between brackets the applications and components related to the system are presented.

- ecoAdaptive Balancing & Control (ecoRoute Advice, ecoGreen Wave, ecoBalanced Priority, ecoNetwork State, ecoEmission Estimation and Prediction, eco Traffic Strategies)

- ecoMotorway Management (ecoRamp Metering and Merging, ecoSpeed and Headway Management, ecoTruck Parking, ecoTolling, ecoNetwork State, ecoEmission Estimation and Prediction, ecoTraffic Strategies)

- ecoAdaptive Traveller Support (ecoRoute Advice, ecoSpeed and Headway Management, ecoNetwork State)

These (sub)systems are described in the next three sections.

7.1.1. System: ecoAdaptive Balancing and Control (ecoABC)

The objective of ecoABC is to balance traffic demand and network capacity at network (strategic, i.e. wide area routing) and local (tactical, i.e. speed advice) levels thereby combining vehicle generated data (like positions, speed and real-time fuel consumption) and road-side sensor data. The types of measures can be subdivided into microscopic and macroscopic as they refer to individual road users (e.g. lane choice and balanced priority) or to traffic streams (e.g. traffic strategies and green wave), respectively. The application areas therefore combine components for route guidance and traffic control. It addresses the paradigm of travel time versus CO_2, with consideration of traffic safety, comfort, reliability and other pollutions (i.e. noise NO_x and $PM_{10/20}$).

Traffic data is gathered from traffic lights, infrastructure sensor and vehicles to model the current and future traffic state (ecoNetwork State) with emphasis on emission (ecoEmission Estimation and Prediction). Given these states the best possible distribution of traffic over the network is calculated (ecoRouteAdvice) and control targets for the complementary measures on the lower level of ecoABC are defined (ecoTraffic Strategies). Control models will improve as they include vehicle drivers within their optimisation. For example, drivers will be informed when and where they are within a green wave, which speed profile to maintain or to stay within the green band (ecoGreen Wave, ecoBalanced Priority), and which route is best for their next trip segment (ecoRouteAdvice).

7.1.2. System: ecoMotorway Management (ecoMM)

The objective of ecoMM is to reduce fuel consumption and CO_2 emissions by enabling smooth traffic control on strategic road systems. The system combines applications for motorway management measures, for ramp metering and merging, speed and headway management, truck parking and toll gates. ecoMM coordinates the different measures based on traffic state and emission monitoring, while explicitly preserving safety constraints and providing the road operator with detailed information on the motorway traffic performance.

The desired common state on motorways is free flowing at relatively high speeds. When road capacity becomes insufficient, congestion will result with vehicles continually stopping and starting which is a significant cause of CO_2 production. All the measures are expected to reduce stop-go traffic and lead to lower fuel-consumption and associated emissions. They will also result in a general calming of the traffic flow and a higher efficiency of fuel consumption, and improved road safety.

7.1.3. System: ecoAdaptive Traveller Support (ecoATS)

The objective of ecoATS is to improve traveller information to enable the development of new or to improve existing applications that support the driver in his/her driving task. This includes information not only about existing incidents but also on traffic management strategies which would include route recommendations from local authorities, traffic state information and prediction in terms of current and future travel times, speed limits and information on traffic light controls. The information can be provided either on a local, non personalised level using car to car communication or on a global level allowing individual tailoring of information. This application therefore offers an information service for route guidance, driving advice or driver assistance. The two main stakeholder groups are the road user with their individual objectives and the road operator with collective objectives. The road operator has an interest in distributing more and accurate traffic related information in order to directly influence driving behaviour. The complexity of ecoATS is to connect to and collect traffic management and control information and distribute it in a standardised and way (e.g. tailored and in time) using the appropriate communication channel to the driver.

7.2. Description of applications and components

The ecoTraffic Management & Control subproject discerns the following applications. Between brackets the system related to the applications and components are presented.

- ecoRoute Advice (ecoABC, ecoATS)
- ecoGreen Wave (ecoABC)
- ecoBalanced Priority (ecoABC)
- ecoRamp Metering and Merging (ecoMM)
- ecoSpeed and Headway Management (ecoMM, ecoATS)
- ecoTruck Parking (ecoMM)
- ecoTolling (ecoMM)

Furthermore, the following components are discerned by the ecoTraffic Management & Control subproject:

- ecoNetwork State (ecoABC, ecoMM, ecoATS)
- ecoEmission Estimation and Prediction (ecoABC, ecoMM)
- ecoTraffic Strategies (ecoABC, ecoMM)

These applications and components are described in the following sections.

7.2.1. Application: ecoRoute Advice

The ecoRouting application is divided into three sub applications. The **ecoRouting macro** guides vehicles through a network in the most fuel efficient way. It also includes a re-routing in a small scale (e.g. one block), if this is necessary due to changing traffic conditions. Therefore, it takes into account the current, future and desired traffic state and the route pattern. As an infrastructure-based application, the focus is to optimise fuel consumption in the whole network, by assigning the vehicles to different routes considering the optimal origin-destination route. Besides this, it also can guide the single vehicles most fuel efficient journey through the network. This should reduce the number of saturated intersections and minimizing the chance of bottlenecks in the network.

The **ecoRouting micro** is routing vehicles locally. It distributes the vehicles the most fuel efficient way on the available lanes. This should utilize the capacity of all lanes and therefore of the whole intersection, ramp or tollgate and smooth the traffic flow. It also allows the traffic operator to minimize platoon dispersion on a green wave. To do so, the distribution of traffic on the different lanes in the approach of an intersection, the current and predicted state of the local traffic light control and the local current and local predicted traffic state need to be taken into account.

Thirdly, **ecoParking Guidance** supports road users with finding parking spaces close to their destination. The road operator is made aware of the available parking spaces and the condition of the alternative routes towards these parking spaces. On the basis of this information the road operator can give advice on an individual basis about the most efficient route towards a parking space. The road operator can also provide information to traffic on the most important incoming routes towards for instance a city centre in order to distribute incoming traffic evenly over the available routes and parking facilities.

7.2.2. Application: ecoGreen Wave

Traditionally green waves are created by establishing a fixed timing relationship between successive intersections such that vehicles, travelling at a predetermined speed, can pass through the green indications at successive signals. This explicit timing relation however limits the flexibility of the system. Ideally green waves emerge and dissolve on demand with elastic coordination speed in reaction to current or expected traffic conditions.

Unlike existing control procedures, the ecoGreen Wave will not only synchronize subsequent signalized intersections but also seeks to influence the spatial-temporal structure of the traffic flows as it forms platoon shapes depending on traffic volume and vehicle characteristics. Moreover, these control measures shall be accompanied by direct driver assistance (e.g. speed advice). The cooperative features of the procedure are crucial for maximal reduction of fuel consumption. By using cooperative technologies ecoGreen Wave will have more information about the spatial-temporal state of moving platoons and their composition (vehicle types) and, as a consequence, it will even incorporate this platoon data in the control mechanisms. The behaviour of an ecoGreen Wave system therefore depends on the traffic volumes, the smoothness of the traffic flows and the ways in which platoons can be formed, assisted by co-operative technology.

7.2.3. Application: ecoBalanced Priority

The balanced priority application controls signalised intersections by balancing the needs of the approaching vehicles in a way that minimizes fuel consumption without affecting safety. The approach is based on detailed knowledge about the demands and characteristics of individual vehicles approaching an intersection that are transmitted by means of short-range communication. The algorithm optimises the traffic signal programs for multiple criteria: reliability of public transport travel times, total CO_2 emission of all modes and streams, total time lost for private transport. The strategy is based on the utilisation of remaining capacity in order to balance the demands of road users and road operators with difference interests. Examples of functionalities are the priority to specific vehicle categories like those who leave a large CO_2 footprint when stopped or public transport, in addition priority to vehicle part of a traffic flow or platoon on a prioritized traffic corridor. Other functionalities aim to improve the operation of traffic light in nearly saturated traffic conditions, in particular by increasing the flexibility of the controller. In such operation mode, available green time goes to the directions that need it most to prevent the intersection and eventually a larger area to become gridlocked. Measures include introducing variability in the signal group sequence, allow higher maximum waiting times, and dynamic determination of the minimum values for green times, yellow times and clearance time. Within ecoAdaptive Balancing and Control there is strong relation with the application ecoGreen Wave and ecoRouteAdvice.

7.2.4. Application: ecoRamp Metering and Merging

Ramp metering is a successful measure to prevent traffic jams on a nearly saturated highway by managing the rate of vehicles entering the highway with a traffic signal. A ramp meter allows one vehicle to enter the motorway at a time which creates a 5-15 second delay between cars. This gap is sufficient to keep the motorway flow downstream of the on-ramp below capacity, to control the number and severity of disturbance to the mainstream and to enable merging from the on-ramp to the mainstream. However, queuing at ramp metering installation is generally chaotic and leads to many acceleration and deceleration manoeuvres with a negative impact on fuel consumption.

The goal of ecoRamp Metering and Merging is to widen the scope and extend the horizon of ramp control to better anticipate to changes in the traffic situation and traffic demand, and so reduce fuel waste. It takes into consideration multiple control variables, both macroscopic (i.e. traffic flow) and microscopic (i.e. vehicle), applies different strategies for different designs of on-ramps, informs vehicles about the best driving strategy before and after the ramp meter, and controls in-flow and spillback to the urban network in the optimisation process. Green frequencies will vary based on the current conditions, vehicles receive speed and lane recommendations and priority schemes differentiate between light and heavy vehicles.

Merging at on-ramps, or at a weaving section or lane-drop, driving is complex and the workload on drivers significantly increases, for both mergers and non-mergers. Finding the right cruising speed, a safe following distance, a suitable gap to merge in or to let somebody merge in, and the right time for merging is difficult. Advising mergers and non-mergers about these variables can make merging processes much easier for drivers.

By using roadside sensors and collecting ecoFVD, ecoRamp Metering and Merging monitors traffic flows. Using vehicle trajectory data the number of lane changes at merging sections is estimated. First the overall traffic flow performance in terms of flow, speed and density is optimised which results in general speed and headway advices while approaching the merging point. In this process, the importance of the different traffic flows is carefully weighted. Next, near the merging point advices will be adapted to the number of mergers at that time, while the mergers themselves receive individualised recommendations for their speed and merging instant. Right after the merging point drivers will receive an advice that stimulates them to accelerate in order to best use the available road capacity.

7.2.5. Application: ecoSpeed and Headway Management

In a dense but not yet congested traffic people drive at different speeds and headways, resulting in frequent braking, possibly stops and followed by accelerations. Speed and Headway Management gathers information about speeds and headways of vehicles in the traffic flow. Based on this information the stability of the traffic flow is judged. Globally it monitors traffic flows and traffic density and more specifically vehicle speed, vehicle headway, and speed and headway variation. In particular in unstable conditions the system recommends speeds and headways for certain road sections or road users individually, which allows drivers to adapt to smoother, more comfortable and fuel efficient driving behaviour. The aim is to prevent disturbances in traffic that could lead to congestion as they propagate upstream. Its application is essential near bottlenecks, dynamic speed sections, on-ramps, etc. where anticipation to upcoming traffic conditions is generally poor.

7.2.6. Application: ecoTruck Parking

The objective of the ecoTruck Parking application is to reduce fuel consumption and CO_2 emissions wasted by truck drivers when searching for a place to rest on motorway corridors. Truck parks along motorways improve goods security but most of the time drivers are not informed of the availability of places or are not planning and anticipating their stops which leads to unproductive kilometres driven. Some truck drivers do not stop and rest in an efficient way because they do not stop at the right available space or because they spend too much time to find an available place. From a more global point of view, there is a growing deficit of suitable truck parking areas along major European transport corridors, while in the meantime the volume of HGV traffic increases. Intelligent Truck Parking applications may have notable benefits for energy efficiency by: achieving the optimum use of existing capacities, optimising parking spaces and managing their occupancy more efficiently. The application will inform in real-time truck drivers about availability of parking slots along their route.

7.2.7. Application: ecoTolling

Passing tolling stations requires each vehicle to decelerate, choose a lane, stop and accelerate again. To improve fuel efficiency, the purpose of ecoTolling is to deploy dedicated toll lanes that allow passing at a nominal speed which compromises between stop-and-go behaviour and fuel efficiency. The aim is threefold: improvement of travel time, to decrease CO_2 emissions, and to decrease toll congestion through a better distribution of traffic over the different toll gates. To achieve these goals vehicle drivers will be informed about which lane and speed to choose, while electronic toll tag detection takes care of registration aspects.

Special attention will be paid to driver behaviour, inefficient lane usage, wrong driving, no electronic toll tag detection – in such situations, the system operates in degraded mode, i.e. normal toll collection with stop-and-go – through indicator analysis. ecoTolling will be available for all vehicles equipped with electronic toll tag. Upstream, the driver is led to slow down with signalling approach reminding the nominal speed expected is 30km/h. When approaching the toll barrier, specific dynamic signs will display information for non-stop-and-go lane choice.
Both corridor entrance and exit barriers will be equipped with toll tag detection on the one hand to open the barrier at toll tag detection, on the other to monitor the exit barrier opening when driving at 30 km/h nominal speed.

7.2.8. Component: ecoNetwork State

Based on various static network attributes, dynamic capacity related information, road side sensor data and - above all - vehicle generated data (positions, speed, routes), the *current*, *future* and *desired* traffic state for the road network is estimated by this ecoNetwork State component. The estimation of current and future states is being carried out for urban as well as motorway networks by taking into account user optimal objective functions. In the case of the desired traffic states, the optimisation follows a system optimum strategy that reflects the system operator's view by minimising the overall fuel consumption/CO_2emission.

The results are provided in form of travel/waiting times, average speed and volumes per link (in the case of current and future states). The result of the desired states is expressed through travel times and source-destination route distributions. The fuel-efficient route distribution reflects ideal traffic states from the system operator's point of view with respect to fuel consumption.

7.2.9. Component: ecoEmission Estimation and Prediction

The ecoEmission Estimation and Prediction components are the components that will compute the CO_2 emissions for the different ecoTraffic Management & Control applications for both real world traffic and traffic simulations.

The ecoEmissionMicro component will compute the CO_2 emissions for the ecoTraffic Management & Control applications based on individual vehicle and driving characteristics. Commonly, average speed models are used to calculate vehicle emissions. However, it is impossible to take into account the vehicle dynamics in those models, while these influence the emissions significantly. Therefore it is impossible to use those average speed models to calculate the effects of measures aiming to smoothen the traffic dynamics. By using emission models that use the speed of each individual vehicle as an input, the traffic flow dynamics can be taken into account and the CO_2 emissions/reductions can be calculated.

The ecoEmissionMacro component will compute the CO_2 emissions based on macroscopic parameters such as the number of vehicles, the dynamics of the flow, average speed, traffic situation (i.e. at a (controlled) on-ramp, an intersection, a motorway, etc.). At this moment, it is not possible to calculate reliable emissions based on macroscopic traffic parameters. To realize this, a new set of macro emission models will be made. This will be done by simulating traffic and emissions with a micro model, derive macro parameters for macro models and then fit new models on the parameters of the macro model and the emissions calculated with the micro model.

7.2.10. Component: ecoVehicle Trajectory Prediction

The short-term prediction of vehicle trajectories x(t) is important for energy efficient driving, as there is the potential to reduce fuel consumption and emissions by optimizing the vehicles' speed v(t) on a temporally very detailed level (e.g. by gear shifting, smoothing deceleration / acceleration). In urban road networks, traffic lights and resulting traffic phenomena (queues and platooning of vehicles) have a big impact on vehicle trajectories. Consequently, a link will be established between the x(t) prediction and the traffic light related applications like ecoGreen Wave, ecoBalanced Priority, but also other applications like ecoRouting in case lane choice is involved. On the one hand, detailed information about the traffic light setting (green begin / end) is needed for the accurate prediction of x(t). This is challenging if there is traffic adaptive traffic light actuation, on the other hand, the optimal signal setting is – at least partly – dependent of the trajectories of the vehicles approaching controlled intersections.

7.2.11. Component: ecoTraffic Strategies

The traffic strategies component serves as the link between regional-strategic operations and local eco traffic control measures. It establishes a traffic strategy tailored to the eCoMove objectives and provides sector or local traffic control targets. Fuel-efficiency serves as the main criterion for balancing the road network load while maintaining network efficiency and meeting users' demand. Control targets for the eco traffic control measures are uniform in order to provide various applications on this level, like traffic light control, route guidance and speed recommendations, with harmonized strategies which they can align with their control measures. A vital element for ecoTraffic Strategies is the interface between the strategy level and the various control applications. Examples of uniform control targets are: increase throughput, hold traffic, etc.

7.3. Relation between the use cases and the applications and components

The table below links the use cases that have been identified to each of the applications and components that have been discerned within the ecoTraffic Management & Control system. Each of the rows denotes one of the identified use cases, while each of the columns of the table denotes an application. An 'X' denotes a relation between a use case and an application and ultimately the existence of interfaces. An 'O' indicates an overlap between a use case and an application. Note that an overlap may only concern elements of a use case and not necessarily the complete functionality.

Table 5 Applications and components versus use cases

		Use cases										
		Improve parking guidance	Improve network usage	Improve driver information	Coordinate traffic controllers	Support merging	Improve intersection control	Balance intersection control objectives	Improve ramp control	Improve lane usage	Improve approach velocity	Increase traffic flow stability
Applications and Components	ecoNetwork State	X	X	X	X	X			X			
	ecoEmission Estimation and Prediction	X	X	X	X	X	X	X	X			X
	ecoTraffic Strategies	X	X	X	X	X	X	X	X		X	X
	ecoVehicle Trajectory Prediction		X	X	X	X	X	X	X	X	X	X
	ecoRouting	X	X	X	X		X	X		X		
	ecoGreen Wave		X	X	X		X	X		X	X	
	ecoBalanced Priority		X	X	X		X	X	X	X	X	
	ecoRamp Metering and Merging		X	X		X			X	X	X	X
	ecoSpeed and Headway Management		X	X		X			X		X	X
	ecoTruck Parking	X		X								
	ecoTolling			X						X	X	

7.4. Functional analysis and interfaces with other subsystems

In essence all ecoTraffic Management and Control measures operate in the same way. A functional analysis of a typical ecoTraffic Management and Control (SP5) application is shown in the figure below.

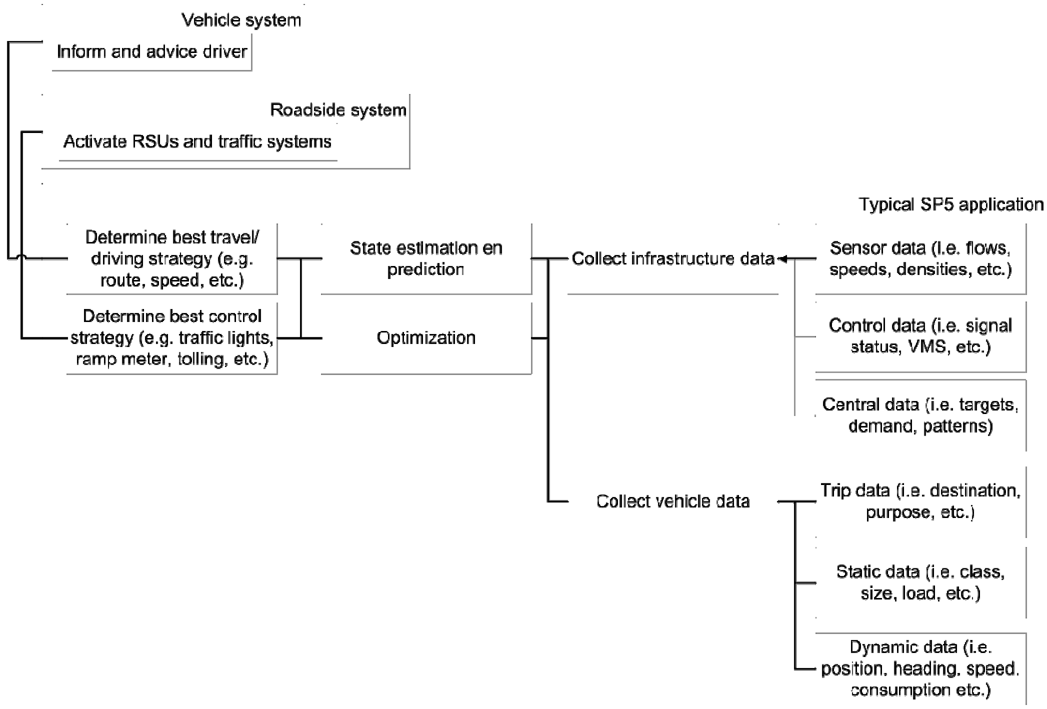


Figure 5: functional analysis ecoTraffic Management and Control

The basis for all applications is data collection from both the infrastructure and vehicle sides. For example, traffic light signal data and floating vehicle data. Based on the available data, an estimation and prediction process starts to determine the current and near future traffic state and fuel consumption levels. Given these insights, an optimisation process follows with the aim to prevent fuel waste and reach more fuel efficient condition by activating the right measures. Possible measures include different control strategies for traffic systems which are activated either directly or indirectly through roadside units, and better travel and driving strategies which are communicated to vehicles and drivers by means of information provisioning and dedicated advices.

The data exchange between vehicles and roadside systems minimally includes ecoFloating Vehicle Data (ecoFVD) according to the standard for Cooperative Awareness Messages (CAMs) only extended with destination, route and relevant (to be decided) fuel data.

The data exchange between roadside systems and vehicle minimally includes traffic state prediction, traffic signal states, network optimal routes and local advices for lane choice, speed choice, etc.

8. Requirements

This chapter summarizes the functional and non-functional requirements for the ecoTraffic Management and Control applications and components that are listed in chapter 7. A requirement is a singular documented need of what the components should be or do. The requirements are meant here as inputs into the subsequent design stages of the sub-project. The use cases, user needs and the stakeholder needs of the ecoTraffic Management and Control application provide the basic input for creating these requirement specifications. For a complete overview of requirements of all eCoMove sub-systems and interfaces between the sub-systems the reader is referred to eCoMove deliverable D2.1. A more detailed description of the ecoTraffic Management and Control requirements can be found in the Annex.

The core objective of the eCoMove Project and its sub-project, ecoTraffic Management & Control (SP5), is achieved by developing a co-operative system that addresses the user and stakeholder needs. However in order to successfully realize this co-operative system, defining use cases (see chapter 6), identifying the desired functionality (see section 7.4) and documenting the requirements (this chapter) of what the system is expected to do becomes an inevitable process. The overall requirements for the eCoMove system are listed in the deliverable D2.1. In this chapter we will summarize the requirement specification for the ecoTraffic Management & Control applications and its components (as listed in chapter 7).

The requirement specification is basically a complete description of the behaviour of a system to be developed and it describes what the system is to accomplish rather than how it is to be accomplished. The requirement specification for an application or component basically consists of the following types:

- a **Functional requirement**: this requirement describes the core functionality of the application/ component
- an **Interface Requirement**: this specifies the interaction of the application/ component with other application/component, users, hardware, software, and communications
- a **Non-Functional Requirement**: these are requirements which impose constraints on the design or implementation of the system (such as performance requirements, security, usability & humanity, legal requirements etc).

The identified requirement specification provides a basis for architecture development and defining the system specification in the next phase of this project.
In the following section (8.1) a brief description is provided on how to read the requirements table. The remainder of this chapter provides the collected requirements specification for all applications and components.

8.1. How to read the requirements table

The requirements for ecoMove are collected in a requirements template as shown below.

Table 6: Requirements Template

«Requirement_No»	*«Req_Type»*	*«Description»*
		«Rationale»

In the table above, the first column consist of a requirement number of the format

SP5 - **X** - **YYYYz**

SP5 – stands for ecoTraffic Management & Control subproject

X – the number for the application/ component as listed in the previous chapter

0 - General SP5 requrimentes
1 - ecoRoute Advice
2 - ecoGreen Wave
3 - ecoBalanced Priority
4 - ecoRamp Metering and Merging
5 - ecoSpeed and Headway Management
6 - ecoTruck Parking
7 - ecoTolling
8 - ecoNetwork State
10 - ecoEmission Estimation and Prediction
11 - ecoTraffic Strategies
S - Simulation Environment

YYYY– is the actual number of the requirement (e.g. 0001)

In case several requirements are closely related then they have the same sequential number indexed by a trailing alphabet (e.g. YYYYz - 0001a)

The second column in *Table 6* consists of the type of the requirement. It could be a functional requirement or a non-functional requirement (all the other types except the functional ones listed in the *Table 7* below are identified as non-functional requirement).

Table 7 Requirements type

Type	Abbreviation
Cultural & Political	CP
Functional	F
Legal	L
Maintainability & Support	MS
Performance	P
Usability & Humanity	UH
Look & Feel	LF
Operational & Environmental	OE
Security	S

The third column of the first row of *Table 6* consists of the actual description containing the intention of the requirement and third column, second row consists of rationale for that requirement.

8.2. Functional requirements

SP5-1-0001	F	**Description**: Vehicles and drivers are guided to available parking spaces in the most energy efficient way
		Rationale: Information on availability and routes is not available
SP5-2-0002	F	**Description**: The system is based on a representation of a road network which minimally consist of origins, destinations, links and nodes.
		Rationale: The same structure as for digital maps and simulation models is benig used
SP5-2-0003	F	**Description**: The traffic demand on a particular road/route should be calucated based on the available origin-destination relations?
		Rationale: Calcutions on OD-relations are a good compromise between macro and micro approahces
SP5-2-0004	F	**Description**: Traffic demand is derived from ecoFVD and completed with historic data and infrastructure sensor data
		Rationale: Multiple data sources are needed for the most reliable estimation
SP5-2-0005	F	**Description**: Provide dynamic network route destribution that reflect minimal total fuel consumption.
		Rationale: As a basis for routing services that support minimisation of overall fuel consumtion.
SP5-2-0006	F	**Description**: Use vehicle generated data (CAM + routes) to determine o-d-matrices and route patterns
		Rationale: In order to narrow the gap of data completion and gain reliable results.
SP5-2-0007	F	**Description**:

		Use vehicle curent fuel consumption data to improve the estimation of link specific fuel consumption
		Rationale: To have more specific data available on fuel consumption other than traffic volumes
SP5-2-0008	F	**Description**: Use traffic control states and data from road side sensors to estimate the ideal route distribution
		Rationale: To improve and enrich the data base (the more information available the better the results)
SP5-2-0009	F	**Description**: Take into account capacity restrictions (incidents, accidents, road work, etc.)
		Rationale: To make the results more realistic
SP5-4-0010	F	**Description**: The scope of the system should cover multiple controlled intersection in line.
		Rationale: A green wave covers multiple controlled intersections in line
SP5-4-0011	F	**Description**: Vehicles are able to pass a sequences of controllers without abrupt changes in their speed profile
		Rationale: A green wave allows vehicles to pass multiple controlled intersections at ones
SP5-4-0012	F	**Description**: Demand fluctuations are reflected in the control strategy
		Rationale: Green waves resolve when the demand from a conflicting direction increases
SP5-4-0013	F	**Description**: Vehicles that are driving in the road section of the green wave shall be provided permanently with speed recommendations.
		Rationale: To hold platoons together and bring them in line with the coordination timing of the intersections.
SP5-4-0014	F	**Description**:

Identify the moving regions that should be the ideal position

		for vehicle platoons.
		Rationale: To make the coordination of intersection traffic light control more efficient and flexible.
SP5-4-0015	F	**Description**: Determine and update dynamically coordination speeds for green waves according to traffic demands.
		Rationale: To make the coordination of intersection traffic light control more efficient and flexible.
SP5-4-0016	F	**Description**: Use vehicle generated data (CAM) to estimate accurate traffic states for the road section of the green wave.
		Rationale: For a more accurate tuning of coordination speed and strategies, and priorisation of directions.
SP5-4-0017	F	**Description**: The procedure can take into account additional strategic data from central systems.
		Rationale: To influence priorisation of routes or directions from a central traffic management instance.
SP5-5-0018	F	**Description**: Traffic flow conditions change so that there is sufficient space for merging vehicles to change lanes
		Rationale: Lower speeds and bigger headways better allow merging
SP5-5-0019	F	**Description**: Merging traffic flows are treated disequally based on their importance to the network traffic conditions
		Rationale: Two flows might have very different impacts on upstream conditions
SP5-5-0020	F	**Description**: Acceleration and deceleration movements are minimized. Stop movements are to be prevented.
		Rationale: They cause fuel consumption and are likely to lead to congestion
SP5-6-0021	F	**Description**: Traffic light control is based on ecoFVD and local sensor data

		Rationale: The traffic light control (optimisation) should consider ecoFVD and local sensor data
SP5-6-0022	F	**Description**: Progressive control settings are enabled in exceptional traffic conditions
		Rationale: In oversaturated conditions normal traffic light control is not effective
SP5-7-0023	F	**Description**: Individual vehicles, platoons and traffic flows are weighed differently based on their importance to control objectives
		Rationale: Priority green should go to the direction with the biggest impact on fuel consumption
SP5-8-0024	F	**Description**: Flow control weighs multiple macroscopic and microscopic performance indicators and multiple optimization criteria
		Rationale: Multiple perspectives should be combined for effective and balanced control
SP5-9-0025	F	**Description**: Preven unnecessary queueing and traffic jams from happening
		Rationale: Often road capacity is locally available but it is not used
SP5-0-0026	F	**Description**: Modeling of driver behavier for eCoMove equipped and non vehicles
		Rationale: Parametrise vehicle and driver models within the microscopic simulation for eCoMove equipped and non vehicles
SP5-0-0027	F	**Description**: The micro simulation models should be capable of modelling traffic movements, its inefficiencies and the eCoMove applications and components in a realistic way
		Rationale: Microscopic simulation models have a few weak points when it comes to the kind of modelling needed in eCoMove. For instance, microsimulation models do not properly reflect driving behaviour in free flow situations (too constant); also, route choice, accel

SP5-0-0028	F	**Description**: The macro simulation models should be capable of modelling traffic movements, its inefficiencies and the eCoMove applications and components in a realistic way
		Rationale: Macroscopic simulation models can be applied to model some of the inefficiencies and some of the applications eCoMove focuses on, but not all (as macroscopic models provide output on the level of traffic flows, not individual vehicles). The models need to
SP5-0-0029	F	**Description**: The simulation environment support developers in testing their applications and components.
		Rationale: Preliminary testing and evaluation is needed.
SP5-0-0030	F	**Description**: The simulation environment support roads operators in deteriming the effects of traffic management and control strategies
		Rationale: Road operators want to know the effects of measures before they are implemented in a easy way.
SP5-0-0031	F	**Description**: The simulation environment is available, transparant and easy to operate
		Rationale: Non-experts should be able to use the simulation environment.
SP5-0-0032	F	**Description**: The simulation environment is re-usable
		Rationale: Application should be possible for any location and any road type.
SP5-0-0033	F	**Description**: The simulation environment is able to run in real-time to support real-time applications
		Rationale: Some application or traffic systems only allow real-time interfaces.
SP5-0-0034	F	**Description**: The simulation environment is adjustible to the test and evaluation needs

		Rationale: Algorithms and parameters should be accessible and changeable

8.3. Interface requirements

SP5-0-0035	OE	**Description**: The eCoMove platform minimally should be CVIS compliant
		Rationale: Legacy of CVIS and other projects should be re-used to guarantee interoperability and minimize development efforts.
SP5-0-0036	OE	**Description**: Vehicle systems should be capable of transmitting vehicle information to infrastructure following the CAM standard
		Rationale: Vehicle information is needed by most of the infrastructure functionalities
SP5-0-0037	OE	**Description**: The vehicles and fleet operators or navigation service providers provide destination and route information (TBD) to the infrastructure system.
		Rationale: The infrastructure system should consider information about current traffic demand coming from vehicles and fleet operators or navigation service providers to determine: current traffic state and prediction and vehicles approaching traffic lights
SP5-0-0038	OE	**Description**: Infrastructure systems should be capable of transmitting infrastructure information to vehicle
		Rationale: Infrastructure information (e.g. status of traffic light control) is needed by the vehicle in order to provide corresponding advice to the driver
SP5-0-0039	OE	**Description**: Vehicle systems should be capable of processing infrastructure information as well as tailored advices and display them to the driver
		Rationale: Both generic information and individual advices should be able to reach the driver

SP5-1-0040	OE	**Description**: The occupancy of parking and resting areas must be provided and up to date to the road operator
		Rationale: Information about occupancy of parking and resting areas is used for optimised route advice to drivers
SP5-1-0041	OE	**Description**: The current and near future accessibility of parking and resting areas in terms of travel time and fuel cost must be known by the road operator
		Rationale: Information about the expected fuel consumption to reach the parking space must be known
SP5-1-0042	OE	**Description**: Dimensional restrictions of vehicle must be provided to the road operator
		Rationale: Information about dimensional restrictions of a vehicle is used for optimised route advice to drivers
SP5-1-0043	OE	**Description**: Dimensional restrictions of parking places and resting areas must be provided to the road operator
		Rationale: Information about dimensional restrictions of parking places and resting areas is used for optimised route advice to drivers
SP5-3-0044	OE	**Description**: The infrastructure system provides traffic and signal states to the vehicles
		Rationale: Information from infrastructure system is needed by the vehicle in order to improve vehcle applications
SP5-3-0045	OE	**Description**: The infrastructure (traffic operator) provides forecast information to the vehicles and other service provider
		Rationale: Forecast information is needed by the vehicle or other service providers for realistic short term and long term plannings
SP5-3-0046	OE	**Description**: The infrastructure (traffic operator) should provide tailored information to the vehicles

		Rationale: A vehicle should only receive relevant information for ist trip
SP5-3-0047	OE	**Description**: ecoTraffic state can be converted to ecoMessages (TBD)
		Rationale: To distribute traffic state information to the driver and fleet operators or navigation service providers a suitable (standardised) format will be used to describe the information
SP5-3-0048	OE	**Description**: ecoTraffic forecast can be converted to ecoMessages (TBD)
		Rationale: To distribute traffic state prediction to the driver and fleet operators or navigation service providers a suitable (standardised) format will be used to describe the information
SP5-3-0049	OE	**Description**: ecoStrategies can be converted to ecoMessages (TBD)
		Rationale: To distribute traffic control strategies to the driver and fleet operators or navigation service providers a suitable (standardised) format will be used to describe the information
SP5-3-0050	OE	**Description**: traffic light control information can be convertes to ecoMessages (TBD)
		Rationale: To distribute traffic light control information to the driver a suitable (standardised) format will be used to describe the information
SP5-3-0051	OE	**Description**: traffic control information (e.g. speed limit) can be converted into ecoMessages (TBD)
		Rationale: To distribute traffic control information to the driver a suitable (standardised) format will be used to describe the information
SP5-3-0052	OE	**Description**: The infrastructure system provides ecoMessages (TBD) to the vehicles and fleet operators or navigation service providers.
		Rationale:

		Vehicles and fleet operators or navigation service providers should consider current information as: traffic state and prediction, route advice, speed limits and remaining green times, coming from the infrastructure system for trip or route planning, navi
SP5-3-0053	OE	**Description**: The vehicle and fleet operators or navigation service providers can request tailored information (ecoMessages TBD) from the infrastructure system
		Rationale: The infrastructure system should only provide relevant (TBD) information to the vehicles and fleet operators or navigation service providers in order to reduce the amount of information to be exchanged
SP5-3-0054	OE	**Description**: The location reference of the information provided by the infrastructure system is map independend, unambiguous and accurate regarding the position
		Rationale: Map or position related information should not require the same map on sender and receiver side.
SP5-0-0055	OE	**Description**: Information should be exchanged between vehicles/drivers and infrastructure like this is done in reallity
		Rationale: Modeling of communication between vehicles and infrastructure-side application and components within the microscopic simulation
SP5-0-0056	OE	**Description**: Exchange of information is feasible between simulation environment and applications and components
		Rationale: Between the vehicles in the simulation and the linked up infrastructure and applications (and components) the necessary informations has to be exchanged
SP5-0-0057	OE	**Description**: Direct link-up or reproduce the applications (and components) and infrastructure units to the microscopic simulation
		Rationale: For testing and calibration of the application and components they have to be conected to the simulation.It is also necessary to link up the traffic light controllers to the

		microscopic simulation
SP5-0-0058	OE	**Description**: Link up to an emission model
		Rationale: For the estimation of fuel consumption effects

8.4. Non-functional requirements

SP5-0-0059	P	**Description**: The application should be able to receive the ecoFVD messages from all vehicles within a TBD distance from the application unit
		Rationale: Sufficient communication range and bandwidth capacity is needed
SP5-0-0060	P	**Description**: Recommendations from infrastructure systems should not affect traffic safety
		Rationale: Major constraint for road operators
SP5-0-0061	P	**Description**: A sufficient number of vehicles broadcasting ecoFVD should be present to ensure significant effects
		Rationale: Without sufficient penetration the system has no use
SP5-3-0062	P	**Description**: In-car information and road-side information must be synchronised in real-time
		Rationale: Different information on both an in-car display and i.e. a matrix sign is not tolerated
SP5-3-0063	P	**Description**: ecoMessages are map independendly referenced (TBD)
		Rationale: The positioning information of an ecoMessage is unambiguous and accurate
SP5-6-0064	P	**Description**: The precision of travel time estimation increases with the use of information on traffic light control schemes
		Rationale: Delays at traffic light can be included in the estimation of

		arrival time
SP5-7-0065	P	**Description**: Overall benefits do not come at unacceptable cost for some individuals
		Rationale: Control scheme shouldn't lead to frustration and irritation
SP5-7-0066	P	**Description**: Flow control has a positive affect on the downstream traffic conditions (highway traffic)
		Rationale: Congestion downstream of a on-ramp is prevented or solved
SP5-8-0067	P	**Description**: Flow control does not negatively affect upstream traffic conditions disproportionally
		Rationale: Queues on the on-ramp should not block urban intersections
SP5-9-0068	P	**Description**: Vehicles join the queue in which the disturbance of an infrastructure constraint has the least impact
		Rationale: Selection of the queue that resolves quickest is not easy
SP5-9-0069	P	**Description**: Saturation flow at intersection constraint is close to the maximum possible
		Rationale: A high number of vehicles passing an intersection contraint when possible (e.g. on green) is vital for its performance
SP5-10-0070	P	**Description**: Vehicle speed profiles follow a smooth pattern while passing a discontinuity in traffic flow
		Rationale: Hard acceleration and decceleration and especially stops need to be prevented
SP5-11-0071	P	**Description**: Small disturbance in traffic are absorbed through anticipatory vehicle interaction
		Rationale: Dynamic changes in speed and headway increase the stability of traffic and prevent congestion
SP5-10-0072	L	**Description**: Normal traffic rules like the legal speed limit remain valid

		Rationale: Exceeding the legal speed limit should remain not allowed
SP5-0-0073	LF	**Description**: Advices from infrastructure system should be conform the acceptance of drivers
		Rationale: Advice from infrastructure should improve acceptance by drivers
SP5-5-0074	LF	**Description**: Merge timing should be in line with the driver's acceptance of gaps between vehicles
		Rationale: Gaps between vehicles may seem to small for merging for some people
SP5-7-0075	LF	**Description**: Intersection control appears at it is operating in ad-hoc mode
		Rationale: New traffic ligth control schemes behave differently than people are use to
SP5-10-0076	LF	**Description**: Speed related information is in line with the speed related conditions in the environment of the vehicle
		Rationale: Following the speed advice should be practically possible

Annex

Requirement No:	SP5-1-0001	**Requirement Type**	F	**Usecase No:**	UC_SP5_1
Description	Vehicles and drivers are guided to available parking spaces in the most energy efficient way				
Rationale	Information on availability and routes is not available				
Originator	J.V.				
Fit Criterion	Vehicle or drivers reaches an available parking space				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0002	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	The system is based on a representation of a road network which minimally consist of origins, destinations, links and nodes.				
Rationale	The same structure as for digital maps and simulation models is benig used				
Originator	J.V.				
Fit Criterion	Map, model and simulation data can be exchanged				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0003	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	The traffic demand on a particular road/route should be calucated based on the available origin-destination relations?				
Rationale	Calcutions on OD-relations are a good compromise between macro and micro approahces				
Originator	J.V.				
Fit Criterion	An OD-matrix is available				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0004	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	Traffic demand is derived from ecoFVD and completed with historic data and infrastructure sensor data				
Rationale	Multiple data sources are needed for the most reliable estimation				
Originator	J.V.				
Fit Criterion	Reliable short and long term predictions are feasible				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0005	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	Provide dynamic network route destribution that reflect minimal total fuel consumption.				
Rationale	As a basis for routing services that support minimisation of overall fuel consumtion.				
Originator	P.M.				
Fit Criterion	Theoretical reasoning that shows that the used objective function serves for the minimisation of fule consumption				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0006	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	Use vehicle generated data (CAM + routes) to determine o-d-matrices and route patterns				
Rationale	In order to narrow the gap of data completion and gain reliable results.				
Originator	P.M.				
Fit Criterion	Direct comparision in a simulation environment.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0007	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	Use vehicle curent fuel consumption data to improve the estimation of link specific fuel consumption				
Rationale	To have more specific data available on fuel consumption other than traffic volumes				
Originator	P.M.				
Fit Criterion	The referred data is available as input for the procedure (simulation environment and test side)				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0008	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	Use traffic control states and data from road side sensors to estimate the ideal route distribution				
Rationale	To improve and enrich the data base (the more information available the better the results)				
Originator	P.M.				
Fit Criterion	The referred data is available as input for the procedure (simulation environment and test side). Show in the simualtion envoironment that the results are of less quality if the data concerned is not available.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-2-0009	**Requirement Type**	F	**Usecase No:**	UC_SP5_2
Description	Take into account capacity restrictions (incidents, accidents, road work, etc.)				
Rationale	To make the results more realistic				
Originator	P.M.				
Fit Criterion	The referred data is available as input for the procedure (simulation environment). Show in the simualtion envoironment that the results are of less quality if the data concerned is not available.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0010	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	The scope of the system should cover multiple controlled intersection in line.				
Rationale	A green wave covers multiple controlled intersections in line				
Originator	J.V.				
Fit Criterion	Systems affects the green timing of multiple intersections in line				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0011	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	Vehicles are able to pass a sequences of controllers without abrupt changes in their speed profile				
Rationale	A green wave allows vehicles to pass multiple controlled intersections at ones				
Originator	J.V.				
Fit Criterion	Vehicles pass a sequence of controlled intersections on green without needing to stop				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0012	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	Demand fluctuations are reflected in the control strategy				
Rationale	Green waves resolve when the demand from a conflicting direction increases				
Originator	J.V.				
Fit Criterion	In varying demand green waves appear and disappear				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0013	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	Vehicles that are driving in the road section of the green wave shall be provided permanently with speed recommendations.				
Rationale	To hold platoons together and bring them in line with the coordination timing of the intersections.				
Originator	P.M.				
Fit Criterion	The vehicles permanently receive speed data.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0014	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	Identify the moving regions that should be the ideal position for vehicle platoons.				
Rationale	To make the coordination of intersection traffic light control more efficient and flexible.				
Originator	P.M.				
Fit Criterion	Visualisation of the regions on a presentation of the road section.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0015	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	Determine and update dynamically coordination speeds for green waves according to traffic demands.				
Rationale	To make the coordination of intersection traffic light control more efficient and flexible.				
Originator	P.M.				
Fit Criterion	Theoretical reasoning that shows and proves the optimisation strategy. Demonstration of changing coordination speed during changing situations.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0016	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	Use vehicle generated data (CAM) to estimate accurate traffic states for the road section of the green wave.				
Rationale	For a more accurate tuning of coordination speed and strategies, and priorisation of directions.				
Originator	P.M.				
Fit Criterion	The referred data is available as input for the procedure.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-4-0017	**Requirement Type**	F	**Usecase No:**	UC_SP5_4
Description	The procedure can take into account additional strategic data from central systems.				
Rationale	To influence priorisation of routes or directions from a central traffic management instance.				
Originator	P.M.				
Fit Criterion	The procedure shows different behaviour that is in line with the transmitted strategic rules.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-5-0018	**Requirement Type**	F	**Usecase No:**	UC_SP5_5
Description	Traffic flow conditions change so that there is sufficient space for merging vehicles to change lanes				
Rationale	Lower speeds and bigger headways better allow merging				
Originator	J.V.				
Fit Criterion	Speed decreases and headway increase				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-5-0019	**Requirement Type**	F	**Usecase No:**	UC_SP5_5
Description	Merging traffic flows are treated disequally based on their importance to the network traffic conditions				
Rationale	Two flows might have very different impacts on upstream conditions				
Originator	J.V.				
Fit Criterion	One traffic flow has to decrease speed and headways more strongly than the other				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-5-0020	Requirement Type	F	Usecase No:	UC_SP5_5
Description	Acceleration and deceleration movements are minimized. Stop movements are to be prevented.				
Rationale	They cause fuel consumption and are likely to lead to congestion				
Originator	M.S.				
Fit Criterion	Number of stops decreases				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-6-0021	Requirement Type	F	Usecase No:	UC_SP5_6
Description	Traffic light control is based on ecoFVD and local sensor data				
Rationale	The traffic light control (optimisation) should consider ecoFVD and local sensor data				
Originator	J.V.				
Fit Criterion	ecoFVD and local sensor data is used as input for traffic light control				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-6-0022	Requirement Type	F	Usecase No:	UC_SP5_6
Description	Progressive control settings are enabled in exceptional traffic conditions				
Rationale	In oversaturated conditions normal traffic light control is not effective				
Originator	J.V.				
Fit Criterion	Total travel time loss increases				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-7-0023	Requirement Type	F	Usecase No:	UC_SP5_7
Description	Individual vehicles, platoons and traffic flows are weighed differently based on their importance to control objectives				
Rationale	Priority green should go to the direction with the biggest impact on fuel consumption				
Originator	J.V.				
Fit Criterion	Overall fuel consumption decreases				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-8-0024	**Requirement Type**	F	**Usecase No:**	UC_SP5_8
Description	Flow control weighs multiple macroscopic and microscopic performance indicators and multiple optimization criteria				
Rationale	Multiple perspectives should be combined for effective and balanced control				
Originator	J.V.				
Fit Criterion	The applied strategies changes based on varying traffic flow and vehicle properties				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-9-0025	**Requirement Type**	F	**Usecase No:**	UC_SP5_9
Description	Preven unnecessary queueing and traffic jams from happening				
Rationale	Often road capacity is locally available but it is not used				
Originator	M.S.				
Fit Criterion	Throughput increases				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0026	**Requirement Type**	F	**Usecase No:**	Simulation
Description	Modeling of driver behavier for eCoMove equipped and non vehicles				
Rationale	Parametrise vehicle and driver models within the microscopic simulation for eCoMove equipped and non vehicles				
Originator	J.L.				
Fit Criterion	Getting desired speed and acceleration from a driving simulator				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0027	**Requirement Type**	F	**Usecase No:**	Simulation
Description	The micro simulation models should be capable of modelling traffic movements, its inefficiencies and the eCoMove applications and components in a realistic way				
Rationale	Microscopic simulation models have a few weak points when it comes to the kind of modelling needed in eCoMove. For instance, microsimulation models do not properly reflect driving behaviour in free flow situations (too constant); also, route choice, accel				
Originator	I.W.				
Fit Criterion	The simulation models should be validated against a real world data set, provided such a data set is available				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0028	**Requirement Type**	F	**Usecase No:**	Simulation
Description	The macro simulation models should be capable of modelling traffic movements, its inefficiencies and the eCoMove applications and components in a realistic way				
Rationale	Macroscopic simulation models can be applied to model some of the inefficiencies and some of the applications eCoMove focuses on, but not all (as macroscopic models provide output on the level of traffic flows, not individual vehicles). The models need to				
Originator	I.W.				
Fit Criterion	The simulation models should be validated against a real world data set, provided such a data set is available				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0029	**Requirement Type**	F	**Usecase No:**	Simulation
Description	The simulation environment support developers in testing their applications and components.				
Rationale	Preliminary testing and evaluation is needed.				
Originator	J.V.				
Fit Criterion	Guidelines are available how to use the simulation environment the development phase				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0030	Requirement Type	F	Usecase No:	Simulation
Description	The simulation environment support roads operators in deteriming the effects of traffic management and control strategies				
Rationale	Road operators want to know the effects of measures before they are implemented in a easy way.				
Originator	J.V.				
Fit Criterion	Guidelines are available how to use the simulation environment for the effect evaluations				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-0-0031	Requirement Type	F	Usecase No:	Simulation
Description	The simulation environment is available, transparant and easy to operate				
Rationale	Non-experts should be able to use the simulation environment.				
Originator	J.V.				
Fit Criterion	Everybody in the project is able to use the simulation environment				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-0-0032	Requirement Type	F	Usecase No:	Simulation
Description	The simulation environment is re-usable				
Rationale	Application should be possible for any location and any road type.				
Originator	J.V.				
Fit Criterion	The simulation environment is used for multiple networks and road types				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-0-0033	Requirement Type	F	Usecase No:	Simulation
Description	The simulation environment is able to run in real-time to support real-time applications				
Rationale	Some application or traffic systems only allow real-time interfaces.				
Originator	J.V.				
Fit Criterion	The simulation environment runs in real-time				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-0-0034	Requirement Type	F	Usecase No:	Simulation
Description	The simulation environment is adjustible to the test and evaluation needs				
Rationale	Algorithms and parameters should be accessible and changeable				
Originator	J.V.				
Fit Criterion	Internals of the simulation environment can be changed				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-0-0035	Requirement Type	OE	Usecase No:	General SP5
Description	The eCoMove platform minimally should be CVIS compliant				
Rationale	Legacy of CVIS and other projects should be re-used to guarantee interoperability and minimize development efforts.				
Originator	J.V.				
Fit Criterion	eCoMove platform is interoperable with CVIS platform				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-0-0036	Requirement Type	OE	Usecase No:	General SP5
Description	Vehicle systems should be capable of transmitting vehicle information to infrastructure following the CAM standard				
Rationale	Vehicle information is needed by most of the infrastructure functionalities				
Originator	J.V.				
Fit Criterion	Infrastructure systems should be able to receive and interpret vehicle information				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-0-0037	**Requirement Type**	OE	**Usecase No:**	General SP5
Description	The vehicles and fleet operators or navigation service providers provide destination and route information (TBD) to the infrastructure system.				
Rationale	The infrastructure system should consider information about current traffic demand coming from vehicles and fleet operators or navigation service providers to determine: current traffic state and prediction and vehicles approaching traffic lights				
Originator	J.V.				
Fit Criterion	Infrastructure systems receive and interpret vehicle route and destination information				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0038	**Requirement Type**	OE	**Usecase No:**	General SP5
Description	Infrastructure systems should be capable of transmitting infrastructure information to vehicle				
Rationale	Infrastructure information (e.g. status of traffic light control) is needed by the vehicle in order to provide corresponding advice to the driver				
Originator	J.V.				
Fit Criterion	Vehicle systems should be able to receive and interpret infrastructure information				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0039	**Requirement Type**	OE	**Usecase No:**	General SP5
Description	Vehicle systems should be capable of processing infrastructure information as well as tailored advices and display them to the driver				
Rationale	Both generic information and individual advices should be able to reach the driver				
Originator	J.V.				
Fit Criterion	Infrastructure messages are displayed on an in-vehicle display				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-1-0040	**Requirement Type**	OE	**Usecase No:**	UC_SP5_1
Description	The occupancy of parking and resting areas must be provided and up to date to the road operator				
Rationale	Information about occupancy of parking and resting areas is used for optimised route advice to drivers				
Originator	J.V.				
Fit Criterion	The occupancy information must be available to the application				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-1-0041	**Requirement Type**	OE	**Usecase No:**	UC_SP5_1
Description	The current and near future accessibility of parking and resting areas in terms of travel time and fuel cost must be known by the road operator				
Rationale	Information about the expected fuel consumption to reach the parking space must be known				
Originator	J.V.				
Fit Criterion	Travel time and fuel cost can be calculated by the road operator				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-1-0042	**Requirement Type**	OE	**Usecase No:**	UC_SP5_1
Description	Dimensional restrictions of vehicle must be provided to the road operator				
Rationale	Information about dimensional restrictions of a vehicle is used for optimised route advice to drivers				
Originator	J.V.				
Fit Criterion	The information about dimensional restrictions of a vehicle can be interpreted by the road operator				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-1-0043	Requirement Type	OE	Usecase No:	UC_SP5_1
Description	Dimensional restrictions of parking places and resting areas must be provided to the road operator				
Rationale	Information about dimensional restrictions of parking places and resting areas is used for optimised route advice to drivers				
Originator	J.V.				
Fit Criterion	The information about dimensional restrictions of parking places and resting areas can be interpreted by the road operator				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-3-0044	Requirement Type	OE	Usecase No:	UC_SP5_3
Description	The infrastructure system provides traffic and signal states to the vehicles				
Rationale	Information from infrastructure system is needed by the vehicle in order to improve vehcle applications				
Originator	J.V.				
Fit Criterion	Vehicle systems should be able to receive and interpret information coming from infrastructure system				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-3-0045	Requirement Type	OE	Usecase No:	UC_SP5_3
Description	The infrastructure (traffic operator) provides forecast information to the vehicles and other service provider				
Rationale	Forecast information is needed by the vehicle or other service providers for realistic short term and long term plannings				
Originator	J.V.				
Fit Criterion	vehicles and service providers should be able to receive and inteerpret forecast information coming from the infrastructure / road operator				
Implementation Priority	1		Conflicts	None	

Requirement No:	SP5-3-0046	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	The infrastructure (traffic operator) should provide tailored information to the vehicles				
Rationale	A vehicle should only receive relevant information for ist trip				
Originator	J.V.				
Fit Criterion	Tailored information can be received and interpreted by the vehicle				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0047	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	ecoTraffic state can be converted to ecoMessages (TBD)				
Rationale	To distribute traffic state information to the driver and fleet operators or navigation service providers a suitable (standardised) format will be used to describe the information				
Originator	M.M				
Fit Criterion	The content of an ecoMessage is identical to the content provided by ecoTraffic state				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0048	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	ecoTraffic forecast can be converted to ecoMessages (TBD)				
Rationale	To distribute traffic state prediction to the driver and fleet operators or navigation service providers a suitable (standardised) format will be used to describe the information				
Originator	M.M				
Fit Criterion	The content of an ecoMessage is identical to the content provided by ecoTraffic state prediction				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0049	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	ecoStrategies can be converted to ecoMessages (TBD)				
Rationale	To distribute traffic control strategies to the driver and fleet operators or navigation service providers a suitable (standardised) format will be used to describe the information				
Originator	M.M				
Fit Criterion	The content of an ecoMessage is identical to the content provided by ecoStrategies				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0050	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	traffic light control information can be convertes to ecoMessages (TBD)				
Rationale	To distribute traffic light control information to the driver a suitable (standardised) format will be used to describe the information				
Originator	M.M				
Fit Criterion	The content of an ecoMessage is identical to the content provided by the traffic light controller				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0051	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	traffic control information (e.g. speed limit) can be converted into ecoMessages (TBD)				
Rationale	To distribute traffic control information to the driver a suitable (standardised) format will be used to describe the information				
Originator	M.M				
Fit Criterion	The content of an ecoMessage is identical to the content provided by the traffic controller				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0052	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	The infrastructure system provides ecoMessages (TBD) to the vehicles and fleet operators or navigation service providers.				
Rationale	Vehicles and fleet operators or navigation service providers should consider current information as: traffic state and prediction, route advice, speed limits and remaining green times, coming from the infrastructure system for trip or route planning, navi				
Originator	M.M				
Fit Criterion	Vehicles receive ecoMessages (TBD) from infrastructure systems				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0053	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	The vehicle and fleet operators or navigation service providers can request tailored information (ecoMessages TBD) from the infrastructure system				
Rationale	The infrastructure system should only provide relevant (TBD) information to the vehicles and fleet operators or navigation service providers in order to reduce the amount of information to be exchanged				
Originator	M.M				
Fit Criterion	Infrastructure systems provide tailored information on request				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0054	**Requirement Type**	OE	**Usecase No:**	UC_SP5_3
Description	The location reference of the information provided by the infrastructure system is map independend, unambiguous and accurate regarding the position				
Rationale	Map or position related information should not require the same map on sender and receiver side.				
Originator	M.M				
Fit Criterion	Location referencing of data is possible with any map				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0055	**Requirement Type**	OE	**Usecase No:**	Simulation
Description	Information should be exchanged between vehicles/drivers and infrastructure like this is done in reallity				
Rationale	Modeling of communication between vehicles and infrastructure-side application and components within the microscopic simulation				
Originator	J.L.				
Fit Criterion	Development and calibration of a comunication model that is linked up with the microscopic simulation				
Implementation Priority	1	**Conflicts**	None		

Requirement No:	SP5-0-0056	**Requirement Type**	OE	**Usecase No:**	Simulation
Description	Exchange of information is feasible between simulation environment and applications and components				
Rationale	Between the vehicles in the simulation and the linked up infrastructure and applications (and components) the necessary informations has to be exchanged				
Originator	J.L.				
Fit Criterion	From vehicle to infrastructure the following information has to be exchanged in the microscopic simulation: Speed, accelaration , position (longitudinal and lane), time and distance headway, vehicle class (including fuel consumption classes), route, desti				
Implementation Priority	1	**Conflicts**	None		

Requirement No:	SP5-0-0057	**Requirement Type**	OE	**Usecase No:**	Simulation
Description	Direct link-up or reproduce the applications (and components) and infrastructure units to the microscopic simulation				
Rationale	For testing and calibration of the application and components they have to be conected to the simulation.It is also necessary to link up the traffic light controllers to the microscopic simulation				
Originator	J.L.				
Fit Criterion	Real-life implementation can be duplicated in simulation				
Implementation Priority	1	**Conflicts**	None		

Requirement No:	SP5-0-0058	**Requirement Type**	OE	**Usecase No:**	Simulation
Description	Link up to an emission model				
Rationale	For the estimation of fuel consumption effects				
Originator	J.L.				
Fit Criterion	Fuel consumption effects can be estimated				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0059	**Requirement Type**	P	**Usecase No:**	General SP5
Description	The application should be able to receive the ecoFVD messages from all vehicles within a TBD distance from the application unit				
Rationale	Sufficient communication range and bandwidth capacity is needed				
Originator	J.V.				
Fit Criterion	Infrastructure systems receive ecoFVD from all vehicles in TBD range				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0060	**Requirement Type**	P	**Usecase No:**	General SP5
Description	Recommendations from infrastructure systems should not affect traffic safety				
Rationale	Major constraint for road operators				
Originator	J.V.				
Fit Criterion	Safety indicators do not deteriorate				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0061	**Requirement Type**	P	**Usecase No:**	General SP5
Description	A sufficient number of vehicles broadcasting ecoFVD should be present to ensure significant effects				
Rationale	Without sufficient penetration the system has no use				
Originator	J.V.				
Fit Criterion	System effect as a function of penetration rate. To be derived from simulation.				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0062	**Requirement Type**	P	**Usecase No:**	UC_SP5_3
Description	In-car information and road-side information must be synchronised in real-time				
Rationale	Different information on both an in-car display and i.e. a matrix sign is not tolerated				
Originator	M.S.				
Fit Criterion	In-car and roadside display show the same information content				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-3-0063	**Requirement Type**	P	**Usecase No:**	UC_SP5_3
Description	ecoMessages are map independendly referenced (TBD)				
Rationale	The positioning information of an ecoMessage is unambiguous and accurate				
Originator	M.M				
Fit Criterion	The receiver can geo-reference the positioning information in ist local system				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-6-0064	**Requirement Type**	P	**Usecase No:**	UC_SP5_6
Description	The precision of travel time estimation increases with the use of information on traffic light control schemes				
Rationale	Delays at traffic light can be included in the estimation of arrival time				
Originator	J.V.				
Fit Criterion	Accuracy of travel time information increases				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-7-0065	**Requirement Type**	P	**Usecase No:**	UC_SP5_7
Description	Overall benefits do not come at unacceptable cost for some individuals				
Rationale	Control scheme shouldn't lead to frustration and irritation				
Originator	J.V.				
Fit Criterion	Overall benefits / Individual cost ratio is below a threshold (TBD)				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-7-0066	**Requirement Type**	P	**Usecase No:**	UC_SP5_8
Description	Flow control has a positive affect on the downstream traffic conditions (highway traffic)				
Rationale	Congestion downstream of a on-ramp is prevented or solved				
Originator	M.S.				
Fit Criterion	Throughput of the motorway remain above threshold (TBD)				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-8-0067	**Requirement Type**	P	**Usecase No:**	UC_SP5_8
Description	Flow control does not negatively affect upstream traffic conditions disproportionally				
Rationale	Queues on the on-ramp should not block urban intersections				
Originator	J.V.				
Fit Criterion	Delays upstream of the metering point should not increase with more than threshold (TBD)				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-9-0068	**Requirement Type**	P	**Usecase No:**	UC_SP5_9
Description	Vehicles join the queue in which the disturbance of an infrastructure constraint has the least impact				
Rationale	Selection of the queue that resolves quickest is not easy				
Originator	J.V.				
Fit Criterion	Less waiting time at queueing points, higher throughput				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-9-0069	**Requirement Type**	P	**Usecase No:**	UC_SP5_9
Description	Saturation flow at intersection constraint is close to the maximum possible				
Rationale	A high number of vehicles passing an intersection contraint when possible (e.g. on green) is vital for its performance				
Originator	J.V.				
Fit Criterion	Saturation flow is close to theoretical capacity				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-10-0070	**Requirement Type**	P	**Usecase No:**	UC_SP5_10
Description	Vehicle speed profiles follow a smooth pattern while passing a discontinuity in traffic flow				
Rationale	Hard acceleration and decceleration and especially stops need to be prevented				
Originator	J.V.				
Fit Criterion	Speed variation is below threshold (TBD)				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-11-0071	**Requirement Type**	P	**Usecase No:**	UC_SP5_11
Description	Small disturbance in traffic are absorbed through anticipatory vehicle interaction				
Rationale	Dynamic changes in speed and headway increase the stability of traffic and prevent congestion				
Originator	J.V.				
Fit Criterion	A small disturbance that normally leads to congestion now does not lead to congestion				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-10-0072	**Requirement Type**	L	**Usecase No:**	UC_SP5_10
Description	Normal traffic rules like the legal speed limit remain valid				
Rationale	Exceeding the legal speed limit should remain not allowed				
Originator	J.V.				
Fit Criterion	No recommendations that stimulate the driver to exceed the speed limit				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-0-0073	**Requirement Type**	LF	**Usecase No:**	General SP5
Description	Advices from infrastructure system should be conform the acceptance of drivers				
Rationale	Advice from infrastructure should improve acceptance by drivers				
Originator	J.V.				
Fit Criterion	Drivers follow the advice				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-5-0074	**Requirement Type**	LF	**Usecase No:**	UC_SP5_5
Description	Merge timing should be in line with the driver's acceptance of gaps between vehicles				
Rationale	Gaps between vehicles may seem to small for merging for some people				
Originator	J.V.				
Fit Criterion	Vehicle headways should be (TBD) before a 'merge now' is recommended				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-7-0075	**Requirement Type**	LF	**Usecase No:**	UC_SP5_7
Description	Intersection control appears at it is operating in ad-hoc mode				
Rationale	New traffic ligth control schemes behave differently than people are use to				
Originator	J.V.				
Fit Criterion	Control scheme behaves differently than a traditional one, but performance better				
Implementation Priority	1		**Conflicts**	None	

Requirement No:	SP5-10-0076	**Requirement Type**	LF	**Usecase No:**	UC_SP5_10
Description	Speed related information is in line with the speed related conditions in the environment of the vehicle				
Rationale	Following the speed advice should be practically possible				
Originator	J.V.				
Fit Criterion	Speed information corresponds with environmental conditions within (TBD) boundary				
Implementation Priority	1		**Conflicts**	None	