IMPROVE RAMP CONTROL AND SUPPORT MERGING WITH ECOMOVE

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ABSTRACT - The goal of the eCoMove-project, supported by European Union, DG INFSO, is to reduce the fuel consumption with 20% by applying cooperative systems. This paper presents two eCoMove measures “Improve Ramp Control” and “Support Merging” to contribute to this goal. Operational tests of these two measures are not foreseen in the eCoMove project. With the presentation Vialis likes to interest stakeholders to join for an operational test.

TECHNICAL PAPER - IMPROVE RAMP CONTROL AND SUPPORT MERGING WITH ECOMOVE

Vehicles enter a motorway mainstream via an on-ramp. This can be a single-lane or dual-lane and single branch or duel 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.

Ramp metering is a successful measure to prevent traffic jams at a nearly saturated highway by managing the rate of vehicles entering the highway with a traffic signal. A ramp meter allows one vehicle to leave the on-ramp at the time which creates a 5-15 second delay between cars. This gap is sufficient to keep the motorway flowing 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, vehicles need to stop as indicated by a traffic light which essentially turns the on-ramp into a buffer. Queuing at metered on-ramp is generally chaotic and leads to many acceleration, deceleration and eventually stop manoeuvres with a negative impact on fuel consumption and presents a safety issue. Besides, the behaviour of ramp control never seems to change even though the traffic conditions on either the mainstream of the on-ramp changes.

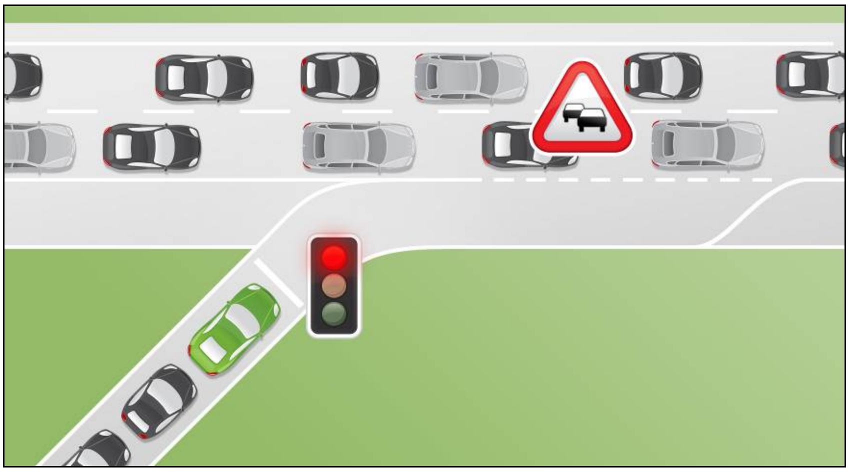


Figure 1. On-ramp with Ramp Metering installation.

The eCoMove project takes care of improving this process with cooperative systems in both roadside systems and vehicles. It shall extend the horizon of the Ramp Controller to better anticipate to changes in the traffic situation and traffic demand, and so reduce fuel waste.

The traffic flow at the highway and the on-ramp are monitored through infrastructure sensors connected with the Ramp Controller to determinate the traffic situation. Due to the cooperative systems vehicles 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 need for ramp metering is determined by the traffic flow on the highway and the control targets from the road operator. If control targets are not met, ramp metering will be switched on.
In near saturation conditions on the mainstream and also based on the on-ramp conditions, the Ramp Controller determines a strategy that best fits the design of the on-ramp and balances the current demands and control targets. This may affect the signal plan, the queuing process as well as the driving behaviour of approaching vehicles.
Improve Ramp Control 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 the ramp meter, and controls in-flow and spillback to the urban network in the optimization process. Green frequencies will vary based on the current conditions, vehicles receive speed recommendations and priority schemes differentiate between light and heavy vehicles.

When Ramp Metering is activated, green frequencies are calculated based on the flow characteristics on the highway. From the calculated green frequencies, a signal plan will be derived. This signal plan is optimized by using the emission prediction components developed in eCoMove. The optimized signal plan is then sent to the Ramp Controller (which controls the ramp metering traffic light). From the signal plan, a uniform ideal approach speed is calculated and sent to equipped vehicles.

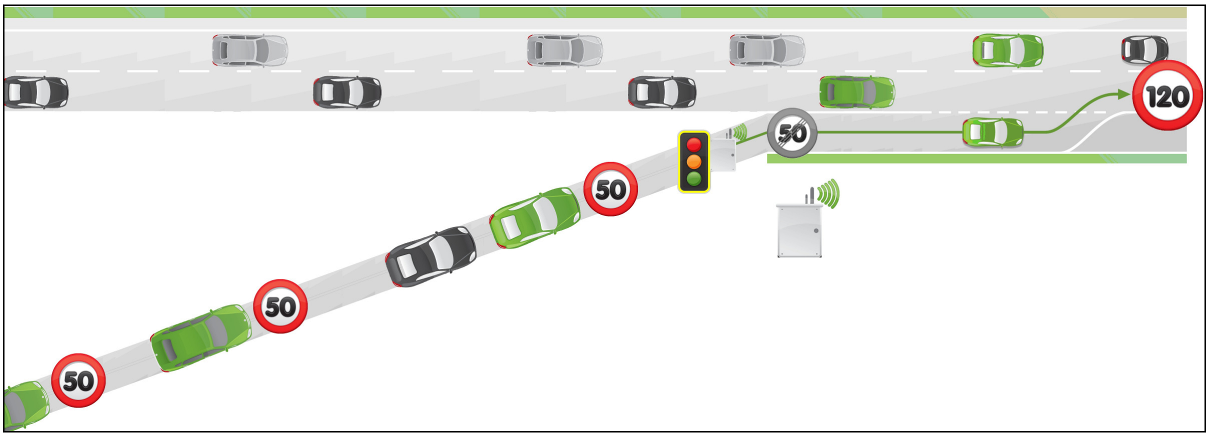


Figure 2. On-ramp with a cooperative Ramp Metering installation. The green cars are also cooperative.

The technical feasibility of Improve Ramp Control shall be verified. This verification shall be executed with the microscopic VISSIM-model. VISSIM shows how road circulation is affected by traffic measures as Improve Ramp Control. VISSIM proves to be an indispensable tool for optimizing traffic circulation, but the effect of traffic measures on air quality and fuel consumption remained underexposed.

The environmental simulation model EnViVer shall fulfil this gap. EnViVer consists of two components: the software application that establishes the connection with VISSIM and the on-line vehicle emission database from TNO. This database contains more than 12,000 measurements to determine emissions patterns of several vehicles under different driving circumstances for all vehicle categories (personal cars as well as trucks). The generated output gives insight into the emissions of Oxides of Nitrogen (NOx), Carbon dioxide (CO_2) and PM_{10} (particulates) for a traffic situation (road network and traffic volumes). The emission of Carbon dioxide is equivalent to the fuel consumption.
Table 1 and figure 3 shows the effect from an optimized intersection with a reduction of 4 percent. This is without the use of cooperative systems.

Basic situation				**Optimized situation**		
CO_2	**NOx**	**PM10**		CO_2	**NOx**	**PM10**
653.10 kg	2164 g	108.2 g		628 kg	2120 g	105.1 g
477 g/km	1.581 g/km	0,07902 g/km		482.7 g/km	1.63 g/km	0,0808 g/km

Table 1. EnViVer output from a basic situation at an intersection compared with the output from an optimized situation. Figure 3 shows the graphical EnViVer output.

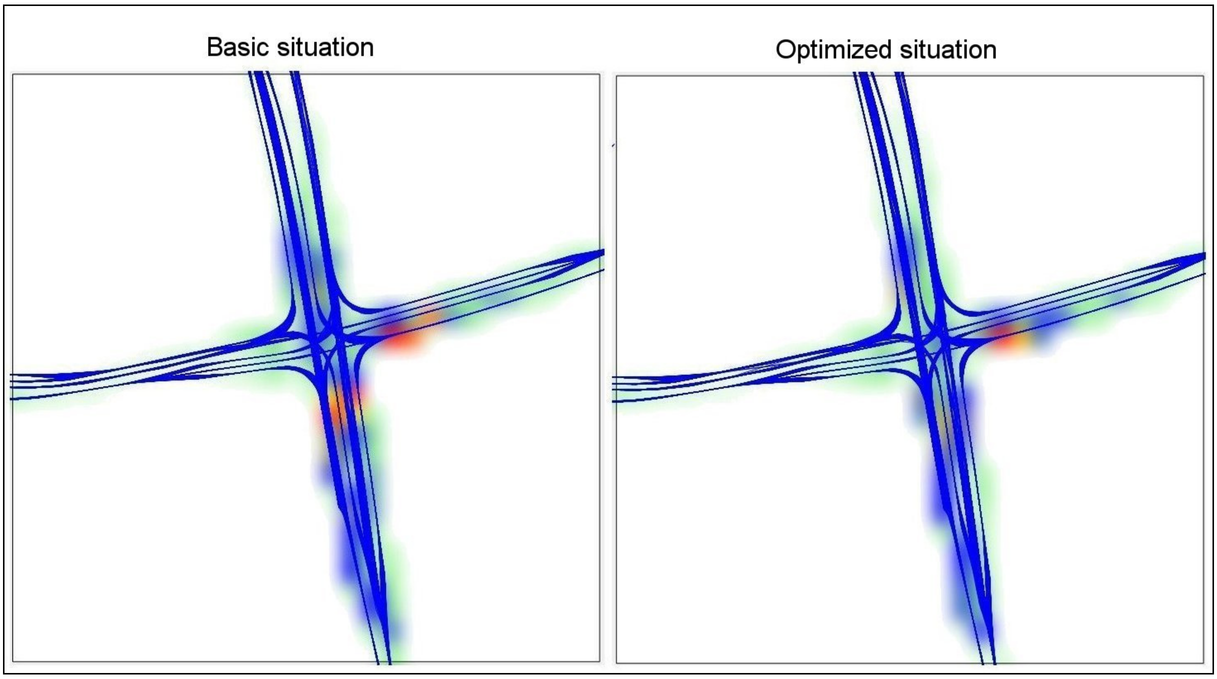


Figure 3. The EnViVer graphical output shows the CO2 emission in the basic and the optimized situation. Red indicates CO2 hot spots.

Other situations show a CO_2 emission reduction between 2 and 10 percent. Based on this experience a contribution of 5 percent in the CO_2 emission reduction from intersections is taken into account. Due to the cooperative systems the same contribution of 5 percent is assumed. This explains the number of 10 percent in the following requirements for verification: “Improve Ramp Control shall guide the cooperative cars on the ramp with a speed advice to save fuel with 10%, to reduce the number of stops with 10% and the number of acceleration with 10%.”

One simulation run shall be done during rush-hour without Improve Ramp Control. The VISSIM output data is the input data for EnViVer. The same procedure shall be executed for the second run with Improve Ramp Control. The verification shall be concluded by comparing the EnViVer outputs from both runs like presented in table 1 and figure 3.

An operational test of Improve Ramp Control is not planned in the eCoMove project. Therefore Vialis is looking for a location to execute an operational test of this measure.

SUPPORT MERGING

When changing lanes, driving at weaving sections or at 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 somebody merge in, is difficult. The same is true for the exact timing of the merging action. Advising mergers and non-mergers about these variables can make merging processes much easier for drivers.

From the 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.

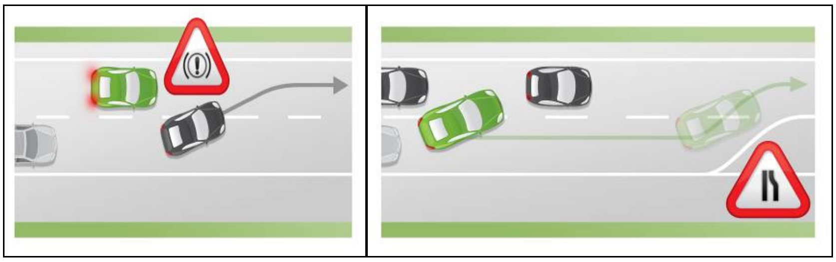
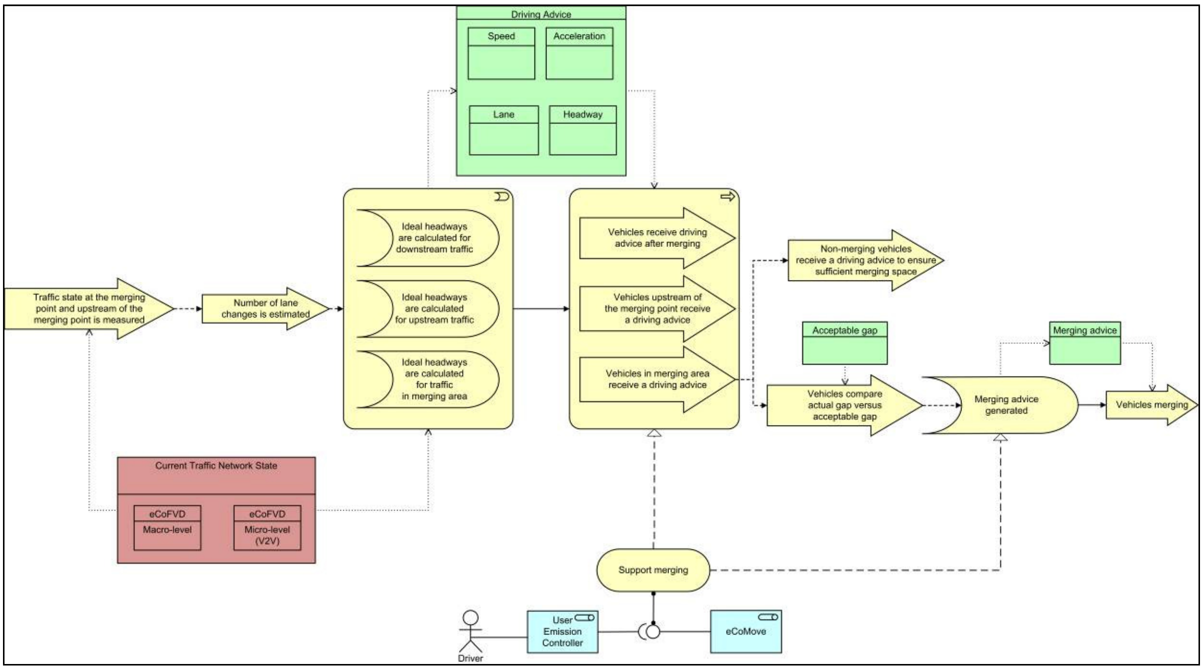


Figure 4. Merging (left) compared with cooperative merging (right).

The eCoMove project takes care of increasing driver anticipation at merging points to improve traffic performance and reduce fuel waste with cooperative systems in the cars. When approaching a merging point, 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.

As infrastructure provider, Vialis is looking for automotive partners to implement Support Merging in their cars and to execute an operational test. Vialis has described the sequence of happenings in the Business Layer Diagram (figure 5) as a process flow and has made a system design for the implementation of Support Merging in the Application Layer Diagram (figure 6). The foreseen physical implementation is presented in the Technology Layer Diagram (figure 7).

Business Layer Diagram



Figuur 5. The Business Layer Diagram for Support Merging.

The Business Layer Diagram in figure 5 shows the main subsequent processing steps of "Support Merging" in yellow.
The traffic state at the merging location is derived from the current traffic network state.
Using vehicle trajectory data, the number of lane changes at merging sections is estimated.
At any stretch of road where merging is required, ideal headways are calculated for both approaching and merging traffic, as well as for traffic leaving the merging area. In all cases, vehicles get a driving advice in terms of lane, speed and acceleration.
The driving advice and merging advice information is received by both cars and trucks. It is processed by the eCoMove service "ecoDriving Support" that decides to which degree it will follow those advices.
The eCoMove service "ecoEmission Prediction" is not used in this case because the communication is mainly between cars. Data exchange with the remote emission prediction service would be too slow, so this is not expected to improve the merging process.

Application Layer Diagram

The Application Layer Diagram in figure 6 shows the four blue main components and the four yellow functions of "Support Merging", together with their green input and output data objects, and the associated services.
The main components to implement are "Merging Calculator", "Driving Advice Calculator", "Headway Calculator" and "Traffic Data Processor".
The component "Traffic data processor" gets the current traffic state by collecting floating car data, especially current V2V-data. It retrieves the current flow status from this data to monitor traffic flows at merging points on their traffic volumes, density, relative speeds of vehicles and following distances.

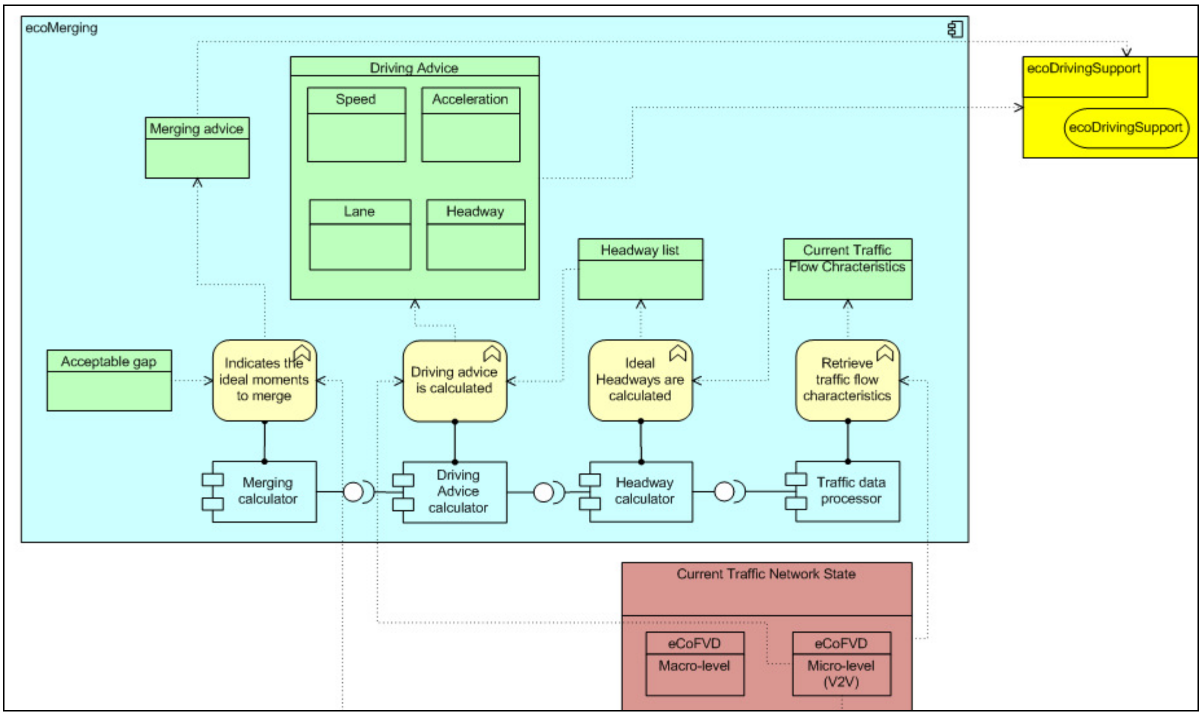


Figure 6. The Application Layer Diagram for Support Merging.

The component “Headway calculator” determines every vehicle’s ideal headway before, during and after merging. Using vehicle trajectory data, the number of lane changes at merging sections is estimated. In this process, the importance of the different traffic flows is carefully weighted. 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. The data output is a list with the headways.
From these headways, driving advice in terms of headway, lane, speed and acceleration is calculated by the component “Driving advice calculator”. The driving advice information is processed by the eCoMove service “ecoDriving Support”.
For the vehicles that actually have to merge, the ideal merging instant is calculated by the component “Merging calculator”. The actual gaps are retrieved from V2V data. Advices will be adapted to the number of mergers at that time. When an acceptable gap is detected, a sign is given to merge to the service “ecoDriving Support”. The value of the acceptable gap can be different at every location (due to general driving style, road geometry). Right after the merging point drivers will receive an advice that stimulates them accelerate in order to best use the available road capacity.

<u>Technology Layer Diagram</u>

The Technology Layer Diagram in figure 7 shows the three subsystems in a cooperative system. The Traffic Management Centre is mentioned “Central ITS Station”. The roadside system is called “Roadside ITS Station”. The vehicle is indicated as “Vehicle ITS Station”. The corresponding green blocks show the components to be implemented. The four components of Support Merging are at the vehicle side. There are no interfaces with the other subsystems.

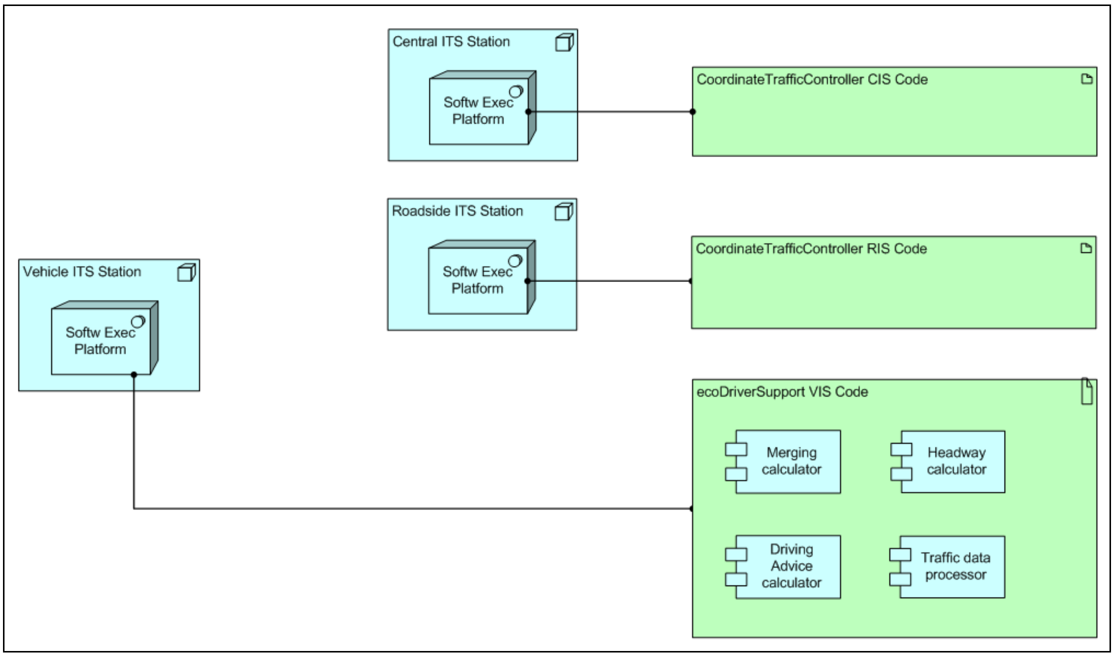


Figure 7. The Technology Layer Diagram for Support Merging.

For the verification of Support Merging the following requirements are defined: “Support Merging should be capable of reducing fuel usage and the number of stops of all traffic surrounding the relevant merging location in rush-hour conditions with 10%.

CONCLUSIONS

One year eCoMove has delivered the specification of several measures. Improve Ramp Control and Support Merging are presented as a potential measure to contribute to the eCoMove objectives. Only a field operational test is not yet planned.