THE ICT-EMISSIONS PROJECT

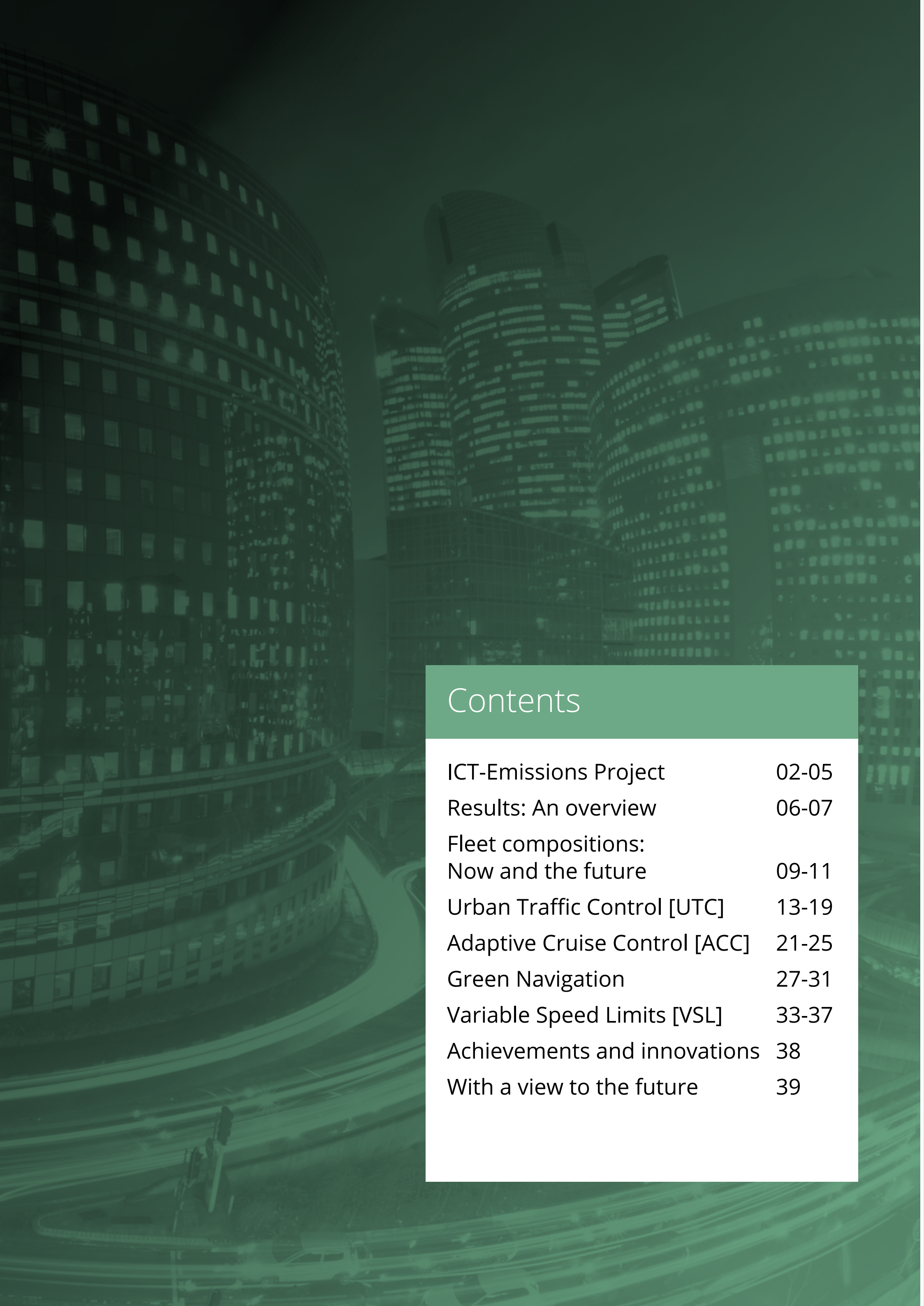
HANDBOOK

THE WISE WAY TO CUT DOWN ON CO_2

THE REAL-LIFE IMPACT OF THE INTELLIGENT TRAFFIC AND IN-VEHICLE SYSTEMS ON CO_2 EMISSIONS AND HOW TO MAKE THE BEST OF THEM

ICT-Emissions

SEVENTH FRAMEWORK PROGRAMME



Contents

Our roads, our cars, our transport systems are important for our way of life, our economy and the progress of our societies in Europe. Very much so! In any given day of the year over 300 million people move along our 5.7 million kilometres of road network producing a sad 875 million ton load of CO_2 emissions annually.

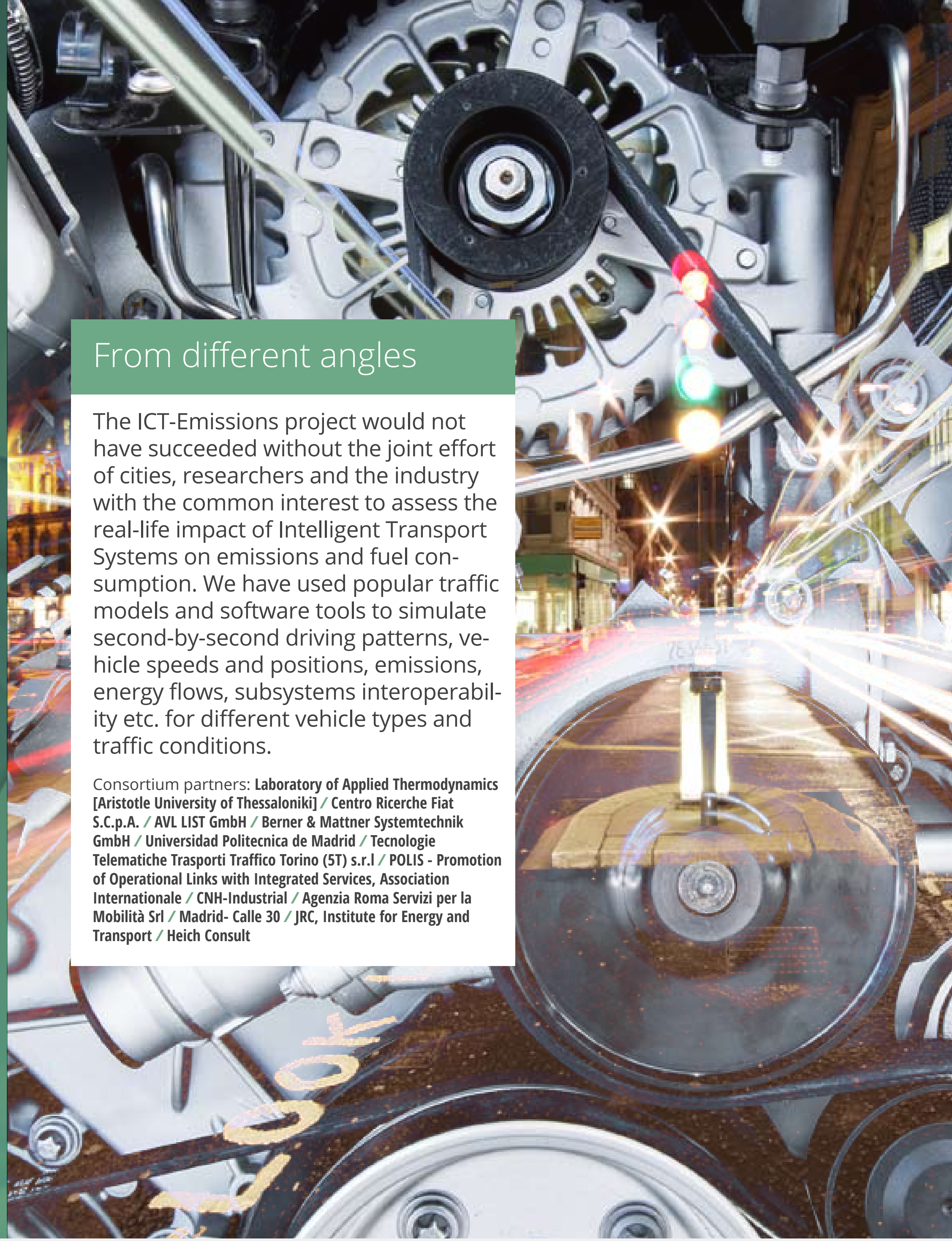
Even more important though is the quality of the air we breathe or the food we grow. The more we speed through new technologies and expand their use, the more we ought to care for their repercussions on our natural environment, the global climate and the sustainability of our resources.

As we opt for a smart, green and integrated transport, we are developing a wide range of measures -most of them impressively innovative- to reduce car emissions and our dependency on fossil fuels. These Information & Communication Technologies (ICT) gear our vehicles, regulate our traffic lights, influence our drivers and enrich our policies.

What are they really worth, how to combine them to maximize their benefits or to evaluate and integrate future ones in our transport systems -this is why this book comes in handy.

For good reason

The European Commission aims at "a European transport system that is resource-efficient, climate- and environmentally-friendly, that is safe and seamless for the benefit of all citizens, the economy and society". To this end, a host of ICT measures promising reductions of air pollution and fuel consumption are now available for the policy makers to choose or combine in order to best suit their cities, their fleets and their drivers' configurations. They should be able to evaluate each measure's real performance under various conditions, their interactions and their projected results prior to their costly implementation. This is what the ICT-Emissions provides the science, the methodologies and the tools for.



From different angles

The ICT-Emissions project would not have succeeded without the joint effort of cities, researchers and the industry with the common interest to assess the real-life impact of Intelligent Transport Systems on emissions and fuel consumption. We have used popular traffic models and software tools to simulate second-by-second driving patterns, vehicle speeds and positions, emissions, energy flows, subsystems interoperability etc. for different vehicle types and traffic conditions.

Consortium partners: **Laboratory of Applied Thermodynamics [Aristotle University of Thessaloniki] / Centro Ricerche Fiat S.C.p.A. / AVL LIST GmbH / Berner & Mattner Systemtechnik GmbH / Universidad Politecnica de Madrid / Tecnologie Telematiche Trasporti Traffico Torino (5T) s.r.l / POLIS - Promotion of Operational Links with Integrated Services, Association Internationale / CNH-Industrial / Agenzia Roma Servizi per la Mobilità Srl / Madrid- Calle 30 / JRC, Institute for Energy and Transport / Heich Consult**

At micro and macro scale

Urban traffic is a complex system spanning the full length and diversity of the road networks and commixing driver behaviours, time schedules and vehicle performances: a measure affecting the behaviour of a single vehicle has an impact on the whole network's management and vice versa. Therefore, our methodology combines traffic and emission modelling at micro and macro scales.

Tested and validated

Our simulations of the different ICT measures were tested and validated by real-world experiments in the cities of Turin, Madrid and Rome where floating cars collected data in the streets to feed our models. These data were also used to tune the models to meet the complex urban condition to its best.

Into the future

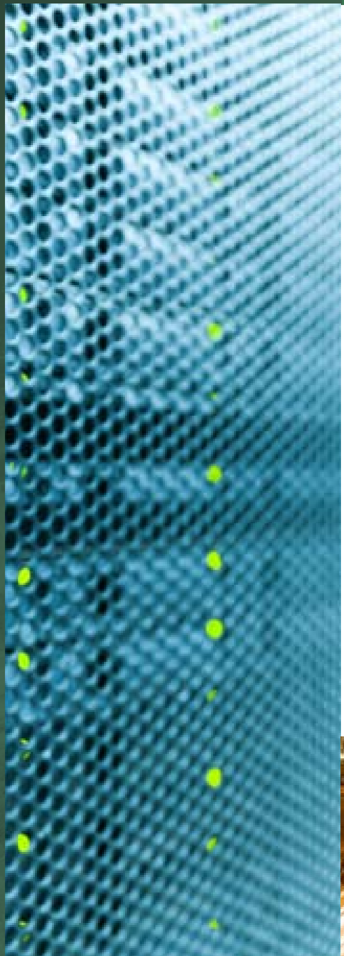
To enable a reliable prognosis of the future developments, the ICT-Emissions Project covers a large number of current and near future technologies such as hybrid, plug-in hybrids and electric vehicles. Moreover, the ICT-Emissions Project provides a standardised assessment methodology to interpret, compare and up-scale different results from related projects and initiatives; the way existing commercial traffic and emission models are defined, interlinked and deployed forms the basis for present and future assessments which truly reflect the real-life conditions in urban areas.

So, if you ask whether to introduce Green Navigation on GPS navigators or how much Adaptive Cruise Control (ACC), Urban Traffic Control Systems or Variable Speed Limits can actually reduce emissions in your city, you shall find this booklet useful.

For detailed information on FP7 Project "ICT-Emissions" please refer to ....

ICT-Emissions Results:

An Overview



The measures under the ICT-Emissions inspection were investigated for different penetration rates and in different traffic conditions (e.g. free flow, congested). The results show sensitivity to these parameters and each case has been modeled for the current and near future fleet composition.

Overall the Intelligent Transport Systems proved their ability to reduce CO_2 emissions by several points depending on local conditions like traffic, infrastructure and fleet composition. This potential will be enhanced in the future with more advanced vehicles and systems.

Vehicle related IT Systems

(Eco-driving, ACC, Green Navigation etc.)

Their effects on a per vehicle basis can be substantial - reductions of CO_2 emissions can exceed 15%. However this CO_2 benefit is constrained by traffic conditions and the penetration rates themselves, as the on-road ITS equipped vehicle fraction increases. The maximum is reached at up to 50% penetration and under non-congested conditions. Benefits range with driving environment, e.g. Adaptive Cruise Control effect maximizes at highway conditions.

Traffic targeted IT Systems

(Variable Speed Limits, Urban Traffic Control etc.)

Under non congested conditions the maximum reduction due to UTC can reach up to 8%. Traffic conditions constrain the effect on total CO_2 emissions, e.g. congestion reduces the benefit. Similarly VSL can have a local effect in the order of 2% CO_2 reduction. Most importantly, the global effect needs to be considered, on top of the local effect.

Now and the future

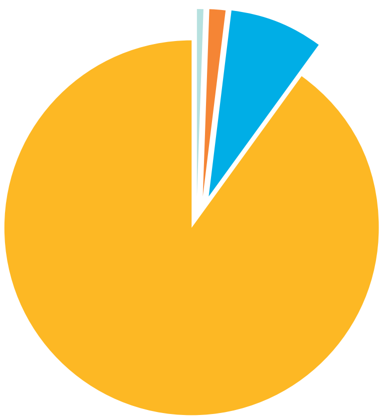
The impact of measures depends on the vehicle fleet structure and its stratification. In ICT-Emissions, we tried to check the sensitivity of the ICT measures tested in different vehicle fleets.

The basic fleet corresponded to a mix of vehicles representing an average European vehicle structure, typical for the 2013-2015 period. In actual implementation of an ICT measure, the exact stratification of vehicles depends on the country and even the city considered. Unique typical vehicle fleets for the Spanish and Italian conditions were constructed due to the corresponding cities tested in this project.

As an example, we show the composition of three different fleets examined in this study, taking Turin, Italy as an example:

- Current fleet: The vehicle fleet reflecting the 2013-2015 time frame.
- Current fleet + Hybrids: Current fleet assuming that 10% of the cars are hybrid ones. This would correspond to a city that has introduced incentives for the wider introduction of hybrid vehicles. In ICT-Emissions, the hybrid vehicles are further split into full hybrids, mild hybrids, plug-in hybrids, and range extenders.
- Future fleet: Expected composition of the vehicle fleet for year 2030. Further to general trends with respect to fuel change and the penetration of advanced technology vehicles, the average conventional vehicle is considered more efficient than in the 'current fleet' case.

Examining alternative fleets in scenarios is important in order to understand the combined impact of the ICT measures and the vehicle technology. Our recommendation when testing the impact of ICT measures is to meticulously design the vehicle fleet considered, using up-to-date information on the vehicle categorisation. Particular emphasis needs to be given to the contribution of advanced technologies, the split between smaller and larger vehicles, the fuel types considered, etc. The detail in the fleet should go hand in hand with the detail in the vehicle models available. However, the main message is that the real-world impact of the measures can only be estimated when a detailed vehicle classification is available.



FLEET COMPOSITION 2013 / 2030

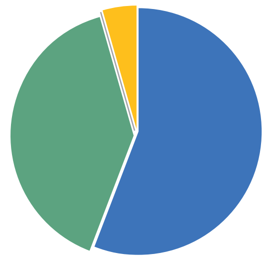
0.31% Buses
1.53% Heavy Duty Trucks
8.13% Light Commercial Vehicles
90.03% Passenger Cars

Key trends observed

Cars hold the lion's share in a city, representing almost 90% of the total vehicle fleet size. In ICT-Emissions we did not take into account power two wheelers (PTWs), despite their abundance in South Europe, because these do not comply with typical traffic modelling patterns, rather they are often known to defy traffic rules and generally not forming traffic light queues. We hence expect the impact of ICT measures on PTWs to be minimal.

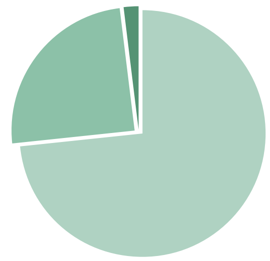
From 2013 to 2030, some major trends are observed for passenger cars. First, the fleet shifts from older vehicle types to Euro 6, which are considered of lower emission levels and superior efficiency. Second, the penetration rate of diesel passenger cars increases reaching more than 50% in 2030. These are expected to change the absolute impact of ICT measures on CO_2 emission reduction. On the other hand, no major changes in vehicle categorization are expected.

Similar trends with regard to the fleets were observed in Madrid and Rome for which unique fleet structures were produced.



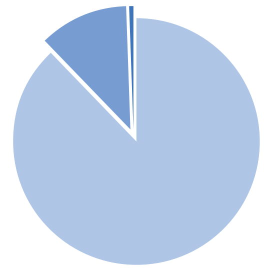
CARS FLEET COMPOSITION 2013

56.00% Gasoline
39.69% Diesel
0.03% Hybrid
4.28% Others



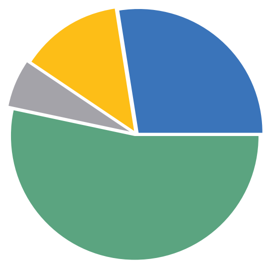
CAR DIESEL TECHNOLOGIES 2013

<= Euro 4
Euro 5
Euro 6



CAR GASOLINE TECHNOLOGIES 2013

<= Euro 4
Euro 5
Euro 6



CARS FLEET COMPOSITION 2013

56.00% Gasoline
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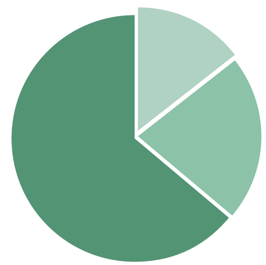
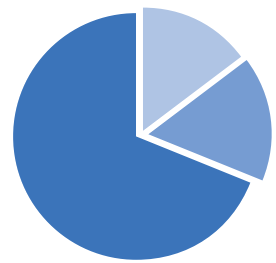


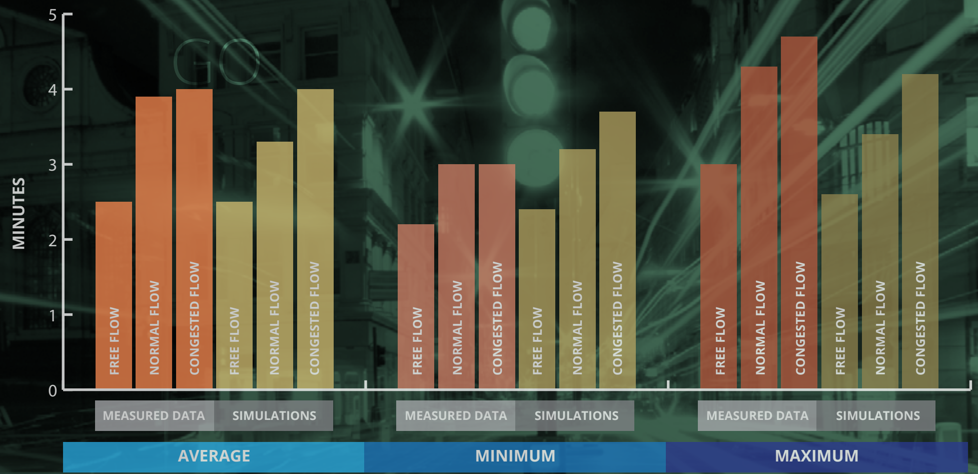
CAR DIESEL TECHNOLOGIES 2030

<= Euro 4
Euro 5
Euro 6

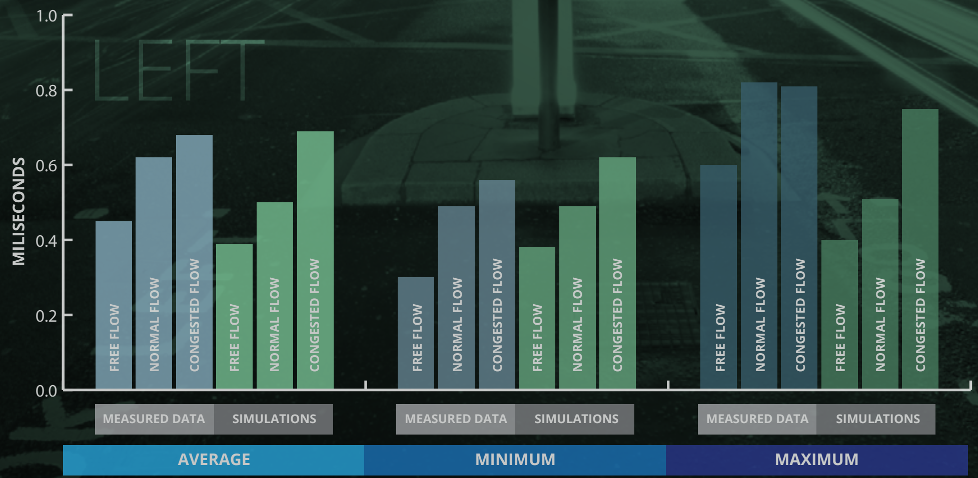


CAR GASOLINE TECHNOLOGIES 2030

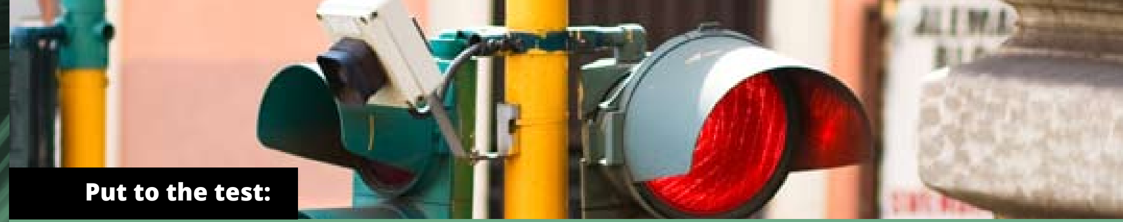
<= Euro 4
Euro 5
Euro 6



Travel time: comparison between measured data and simulations



Positive acceleration: comparison between measured data and simulations



Put to the test:

Urban Traffic Control *[UTC]*

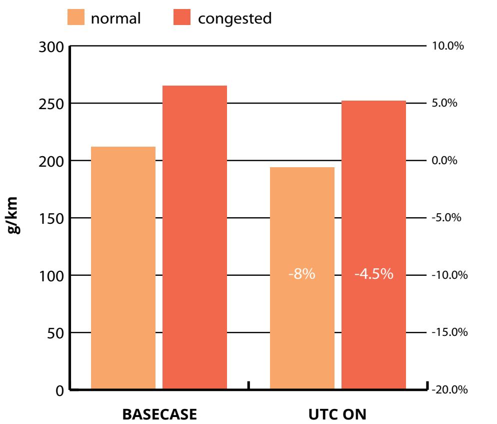
-8%
Normal
-4,5%
Congested

ICT-Emissions studied the impact of traffic-adaptive Urban Traffic Control [UTC] on CO_2 emissions at an urban level. Such UTC systems are able to measure and forecast queue lengths and adjust green-light phases to optimise efficiency, (this is not based on a fixed timing plan).

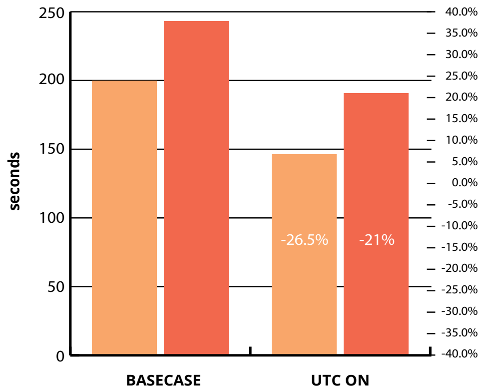
UTC was implemented in Rome and Turin, utilizing simulations at both micro and macro levels. UTC was implemented in stretches of urban arteries of 1.6 km in Turin (Corso Lecce) and 6.3 km in Rome (Via Appia). The AIMSUN model was used in Turin and VISSIM in Rome. Both models were first calibrated so that traffic parameters like travelling time, mean stop time, mean acceleration, etc. matched measurements conducted using floating cars at various times of the day, to reflect different congestion levels. Real-world experiments were conducted with the UTC system on and off, with the assistance of the traffic control centres in both cities (5T – Turin and Agenzia Roma Servizi per la Mobilità S.r.l. – Rome)

Results presented refer to the micro-level only. At the macro level (city-wide level) impacts are much smaller because of the limited area that the measure was tested. Scaling up effects of UTC measures is therefore a delicate procedure.

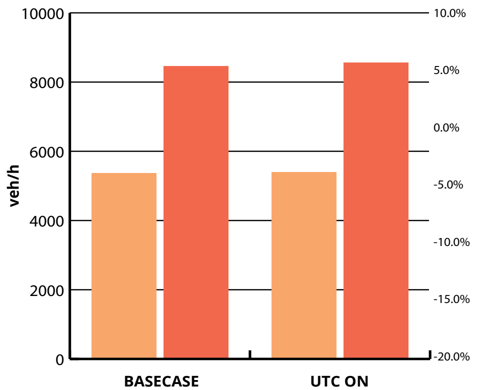
When implementing traffic-adaptive UTC, travel time drops, the percentage of stops decreases and even the capacity of the network increases slightly. Effects of the UTC On scenarios compared in the basecase are shown in the following figures in the case of Turin.



Impact of UTC on average CO_2 emission levels per unit of distance travelled. The values refer to the average vehicle (including passenger cars, light commercial vehicles, buses, and trucks).



Drop In the travelling time [s] with the UTC system on.

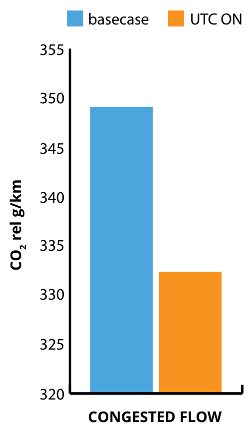


Slight increase in the road capacity with the UTC system on.

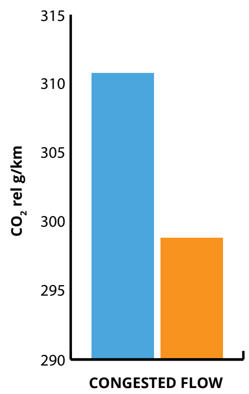
The structure of the fleet is important when UTC is considered because the effect of traffic conditions on emissions depends on vehicle technology. This was examined in the case of Rome, performing scenarios with the current and the 2030 fleet. The future fleet exhibits overall lower CO_2 emissions in g/km (average of the actual vehicle mix in Via Appia) due to the more efficient technologies used. However, the relative improvement with UTC ON seems to drop from 5% to 4.5%. This is because vehicles become overall more efficient, are equipped with start and stop systems and hence the impact of stop time on average CO_2 emissions is overall lower.

Hybrid and electrified vehicles may also show a different performance when modifying traffic conditions. This is because their technology offers the potential to optimize between different driving modes and to take advantage of the possibility to use either the electric motor or the internal combustion engine. The relative improvement of CO_2 emissions seems to maximize for full hybrid vehicles, even beyond the relative improvement for vehicles with the possibility for external charging, when the latter are used within their electric range.

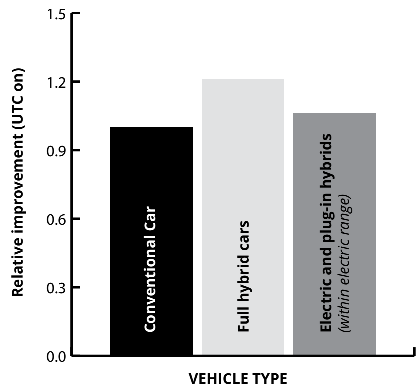
Relative improvement of CO_2 emissions with UTC system on for different vehicle types, relative to conventional vehicles. The improvement for conventional cars has been arbitrary assigned the value of one.



Current fleet

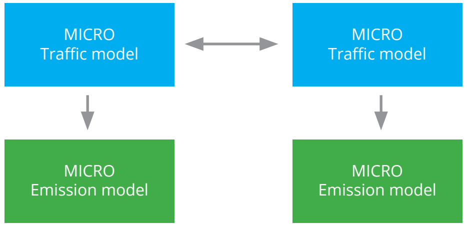


Future fleet



Modelling scale

Urban Traffic Control was simulated both at macro and micro level in the case of Rome but only at micro level in the case of Turin.



UTC: modelling framework

In Turin, the software used was AIMSUN, which includes the possibility of simulating UTC measure with adaptive control interface UTOPIA. In Rome, micro model assignment was carried out by using PTV-VISSIM, while macro traffic model is developed in Transcad.

Turin

The tested section is a corridor of 1,6 km in Turin with two traffic intensity levels, in the morning rush hour (8-9 h) representing congested conditions and at lunch hour (12-13 h) representing normal traffic conditions.

Traffic model - AIMSUN

Direction 1: corridor in corso Lecce from Corso Regina to Via Lera

Direction 2: corridor in corso Lecce from Via Lera to corso Regina

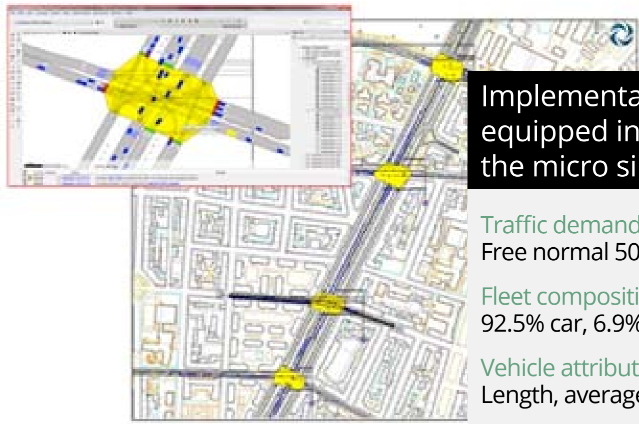
Turin's UTC test site

Modelling process description

We performed a 6-day campaign of car measurements at the normal and congested conditions at two traffic system states (UTC OFF and UTC ON), operated by 5T. We built four AIMSUN scenarios (at macro and micro level); we inserted the average demand of the campaign days, and we extracted the micro simulation area from the macro scenario. We built and run four scenarios, with combinations of UTC OFF and UTC ON at normal and congested traffic using the GIPPS extended car following model, estimated on the basis of FIAT eco:Drive data of normal users.

DATA COLLECTION	BUILT SCENARIO	RUN CALIBRATION SCENARIO	DATA ANALYSIS CONCLUSION
CAMPAIGN 6 DAYS OF MEASURES TRAFFIC NORMAL CONGESTED STATE UTC ON, OFF	TRAFFIC MODEL AIMSUN 4 SCENARIO EMISSION MODEL CRUISE COPERT	ON THE CORRIDOR BY FLOW, TRAVEL TIME and OTHER PERFORMANCE INDEX	COLLECT AND COMPARE THE DATA GIVE THE CONCLUSION

Turin's UTC process followed



The scenario built

Implementation of 5 equipped intersections on the micro simulation model

Traffic demand
Free normal 5000 veh. congested 7500 veh

Fleet composition
92.5% car, 6.9% LDV 0.2% HDV 0.4% BUS

Vehicle attributes
Length, average accelaration

User reaction time
0.5s 30%, 0.75s 45%, 1s 20%, 1.25s 5%
+0.25s HDV, BUS

Scenarios

We considered two traffic conditions, at normal and congested driving, involving a demand respectively of 5000 and 7500 vehicles per hour respectively.

Scenario ID	Variables for each scenario			
	Traffic conditions	Penetration level	Number of replication	Fleet composition
112_01	Normal	n/a	10	Turin 2013
113_01	Congested	n/a	10	Turin 2013

UTC: Turin case study. Scenarios considered at micro level

Rome

Rome test case is an important road itinerary (Via Appia) long 6,3 km and located in south-eastern side of the urban area as illustrated below. The itinerary is ruled by 23 traffic lights coordinated by an UTC system that represents the main topic of the analysis. The test case was split in three different scenarios: in particular one refer to the base case condition (UTC off) while the other two simulate the effects of ICT measures as better illustrated below;

- in the first one, the environmental analyses have been carried out on the whole study area, simulating the effects of UTC-off condition only along Via Appia (Scenario ID = 102);
- in the second one, the same analyses have been carried out on the whole study area, simulating the effects of UTC-off condition on all the 22 different urban axes under UTC scheme, with a total length of 80 km (Scenario ID = 103).

Location of Via Appia within the urban area

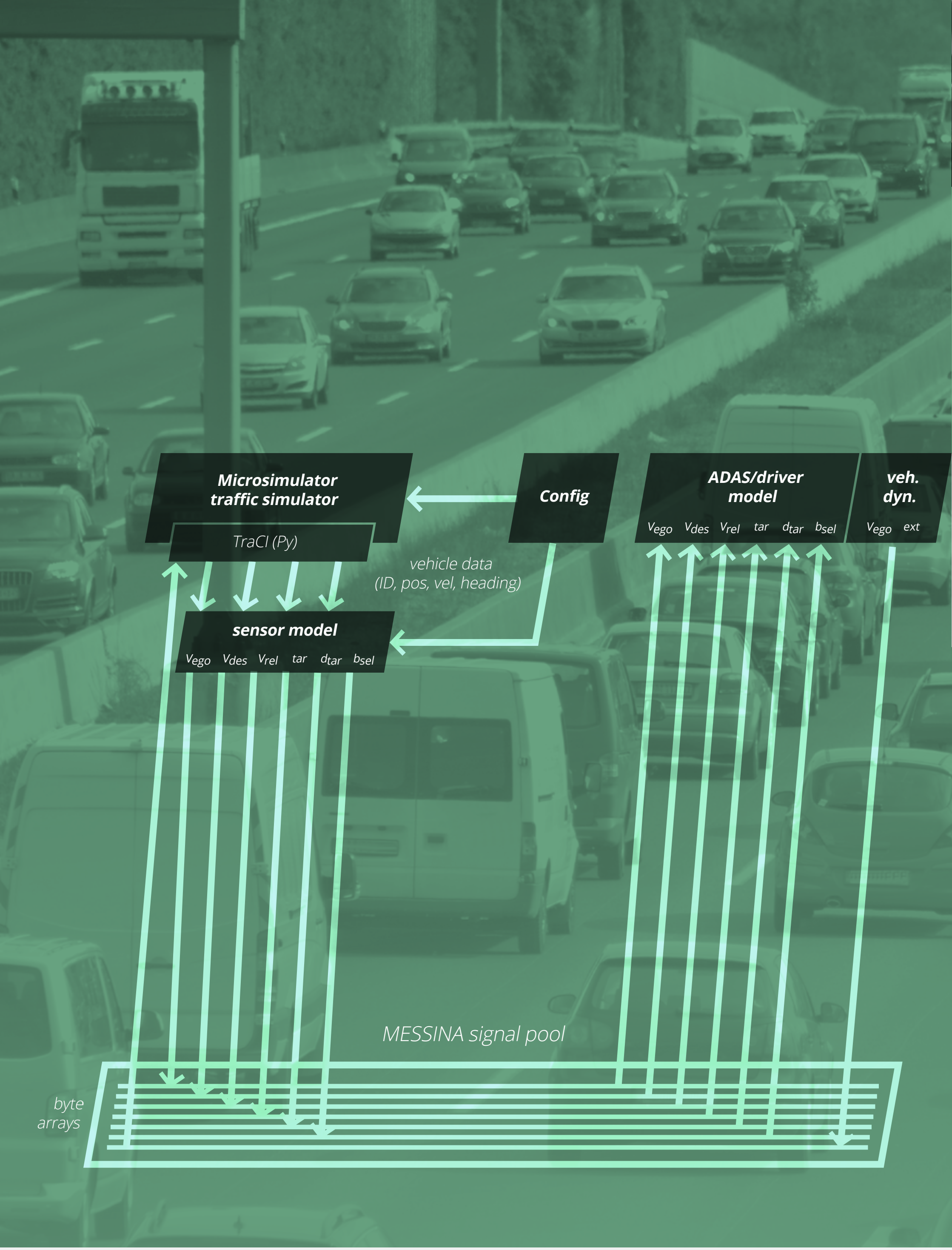
Modelling process description

The UTC effects were simulated both on micro and macro scale in order to develop a comprehensive methodology to assess the impact of ITS measures on road transport CO_2 emissions by taking into account the real-world driving and traffic behaviour in urban agglomerations.

The micro model has been built using VISSIM software that allows to represent in detail the “mobility process” of vehicles on the road since VISSIM uses the psycho-physical driver behaviour model where stochastic distributions of speed and spacing thresholds replicate individual driver behaviour characteristics. With this software it is possible to model accurately all the elements of the road network such as traffic lights controls, priority rules, reduced road sections, on street parking, on street bus stops, lateral distances between different classes of vehicles, etc.

The parameters required to run the models were obtained by an accurate calibration process, an iterative process that consists of continuous adjustments to be done to the model’s parameters and the following comparison of the modelled data with the observed data, being it traffic or travel times or other significant parameter, until this comparison shows a satisfactory representation of the observed data by the micro model.

For experimental data we used measured (monitored) traffic flows, as well as information from instrumented floating vehicles in an experiment conducted on the particular road with the UTC system ON and OFF.



Put to the test:

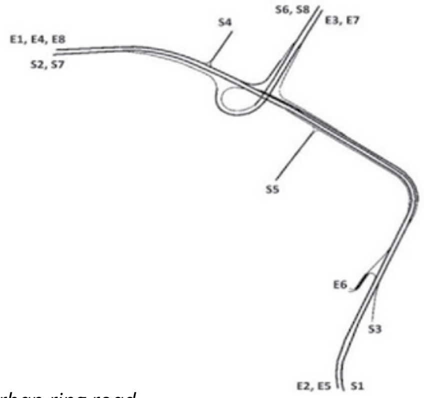
Adaptive Cruise Control *[ACC]*

-7,4
Urban Highway
-2,0
City Network

Adaptive Cruise Control (ACC) is an Advanced Driver Assistance System (ADAS) which controls the velocity of a vehicle by measuring the distance to the vehicle in front. If it is larger than a safe distance specified by the driver, the vehicle is automatically accelerated; as it gets closer and closer to the safe distance the vehicle is decelerated.

For modelling the impact of ACC, we produced a new interface within ICT-Emissions. The baseline is the speed profile produced by the micro-model and then a specific vehicle-control model corrects this to simulate the impact of ACC. In ICT-Emissions, the vehicle control model has been developed on the MESSINA software platform, maintained by B&M and proper plugin interfaces for its operation have been developed for the Aimsun and SUMO microscopic traffic models.
The Vehicle control model interacts with the MICRO Traffic model on-line when a simulation is executed and computes the speed profiles of the vehicles in the simulation in real-time subject to their environment. The emissions are computed from the speed profiles by the MICRO Emission model after the simulation has finished.
In each simulation step information about the velocities of the vehicles in the traffic simulation as well as about the distances to the preceding vehicles is transmitted to the ACC model in MESSINA. The latter computes from this data the velocities of the vehicles for the next simulation step. Hence, there is a continuous exchange of information between the traffic simulator and the vehicle simulator in MESSINA.

The impact of ACC was examined in two scenarios, one referring to an urban ring road (urban highway) and one referring to typical urban conditions. Both examples were located in the wider Munich area (Schwabing). The urban results were repeated at the traffic conditions of Turin (Corse Lecce)

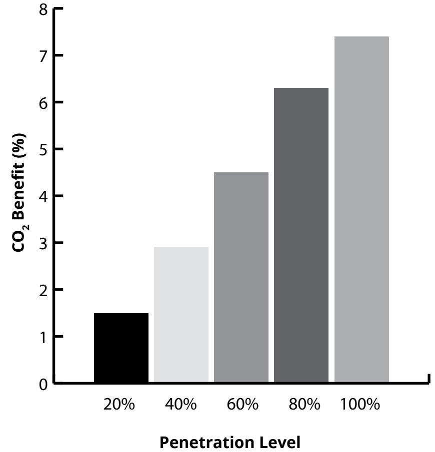


Urban ring road

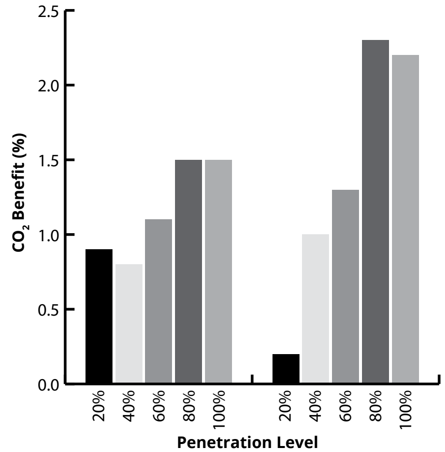
City quarter

ACC Implementation sites at an urban highway and an urban network in Schwabing, Munich, Germany. Top: Urban highway (ring road), Bottom: City network.

The impact of ACC depends on the share of on road vehicles equipped with ACC, as an ACC equipped vehicle also affects its surrounding traffic. The following figure shows the expected ACC benefit as a function of the ACC penetration level on the fleet vehicles for normal driving conditions



Urban-Highway - Munich



City Network

Results show that ACC can be effective on a city highway where the rate of acceleration largely determines CO_2 emissions. However, results from both Munich and Turin show that at urban traffic conditions, ACC is much less effective. This is due to the fact that the vehicles in the city scenario often have to stop at the crossroads and re-accelerate again. This disturbs the traffic flow and makes the ACC less effective.

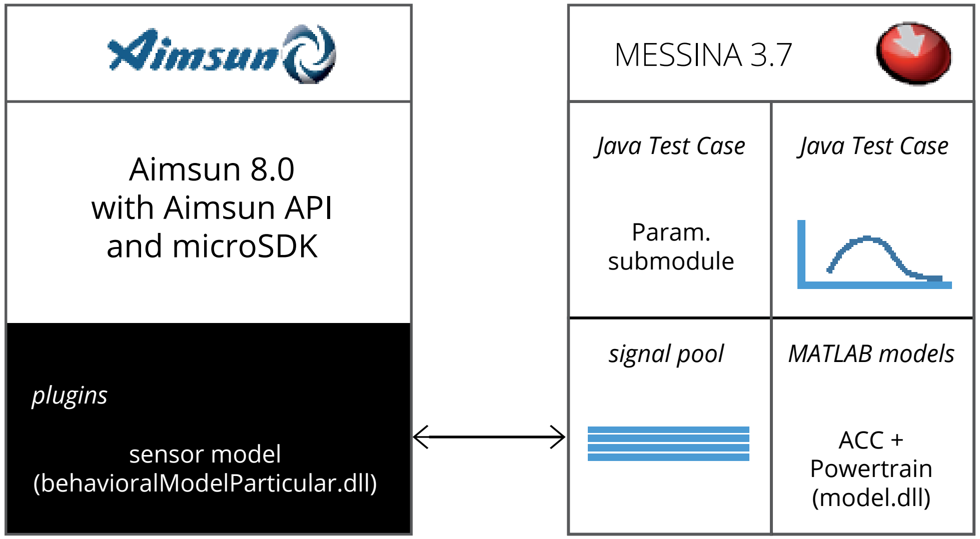
Methodology

For the integration of the ADAS/ Driver Simulator in the ICT-Emissions integrated simulation platform, an interface to the microscopic traffic simulator Aimsun was implemented and then further implemented in the Turin case.

The figure below shows the realization of the general architecture in the tools Aimsun and MESSINA. The data exchange between Aimsun and the signal pool of MESSINA (simulated bus system) is performed via a TCP/ IP connection.

A parameterization submodule is used to set input parameters in the ACC simulations, such as the traffic density in the scenario or the penetration level for ACC vehicles and vehicle types.

The acceleration behaviour of the vehicles without ACC in the simulations is determined by human drivers. It is assumed that there are equal shares of aggressive, normal, and timid drivers. The parameters of the Gipps model, which is used as a human driver model, are set accordingly. The ACC vehicles are randomly distributed over all vehicles in the scenario. Hence, to balance out statistical effects, multiple simulation runs are performed at each penetration level. Thirty repetitions per condition were performed in our case.



Realization of the architecture of the ADAS/Driver simulation framework with Aimsun and MESSINA.

For this framework to operate, the following conditions need to be met:

- The vehicle simulator has to be able to establish a TCP/IP connection to the micro-traffic simulator for inter-process communication and data exchange.
- All components in the system must be able to process data from multiple vehicles in a single simulation step to enable the bidirectional communication between the traffic model and the ADAS driver simulator.
- The programming interface (API) of the micro traffic model must provide methods to access data which is required by the sensor model.
- For each vehicle in the simulation the sensor model must be able to detect a target vehicle, which the vehicle should follow. The sensor model has to compute the distance between a vehicle and its target vehicle and the difference in velocity.
- The bus system must be able to transmit data from multiple vehicles over a wire.
- The ADAS driver simulator model must implement a switch which allows the selection of either an ADAS model or a human driver model for the acceleration behaviour of a given vehicle in the simulation.
- The ADAS driver simulator computes an acceleration value based on the distance and the difference in velocity between a vehicle and its target vehicle as well as a defined safe distance which the vehicle should guard with respect to its preceding vehicle.
- The powertrain model embedded in the ADAS driver simulator must take into account the running resistance of a vehicle in motion and the constraints of a real-world engine on the acceleration behaviour of a vehicle.
- The powertrain model must include different parameterizations for different vehicle classes (e.g., small passenger cars, limousines, vans etc.)
- The parameterization submodule has to offer the possibility for a user to define relevant parameters in the micro-traffic simulation and in the driver simulator. Relevant parameters in the micro-traffic simulation are the traffic scenario (road network) and the traffic density. Relevant parameters in the driver simulator are the shares of different driver types (calm, aggressive etc.), the penetration level of ACC vehicles and the type of vehicle in the powertrain model.

Put to the test:

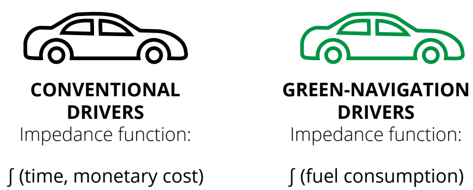
Green Navigation

-6,5%
CO_2 savings

With ‘green’ enhanced navigation systems on-board the vehicle, routing recommendations provided take into account the network traffic conditions and inform the driver on the optimum route to use in order to reduce fuel consumption and, hence, CO_2 emissions.

Green navigation implies routing recommendations based on calculation of environmental impact and real-time traffic situation. This means, in practice, people follow the route which minimises their emissions. The modelling of Green Navigation can only be made at the macro level as we basically need to solve a new optimization problem where the objective function, in this case the traffic impedance function, is not time but fuel consumption. In the ICT-Emissions project, the new impedance function was derived by converting the default fuel consumption function of COPERT (g/km) to an expression as a function of time (g/s).

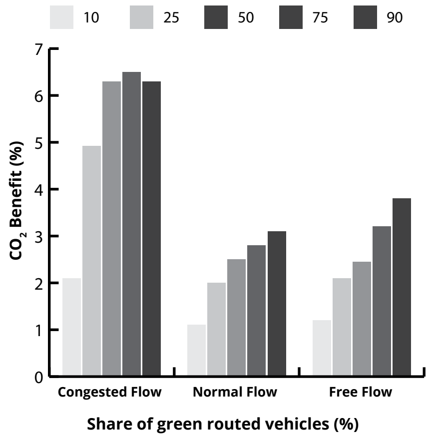
The impact of green navigation depends on the share of vehicles (drivers) in actual traffic for which enhanced routing information is available. Also, relative impacts may depend on the traffic level, i.e. free, normal, or congested. We demonstrate here the impact of Green Navigation in the case of Madrid, using the VISUM modelling framework with the impedance function derived from COPERT as outlined above.



Modelling Green Navigation outline

Results

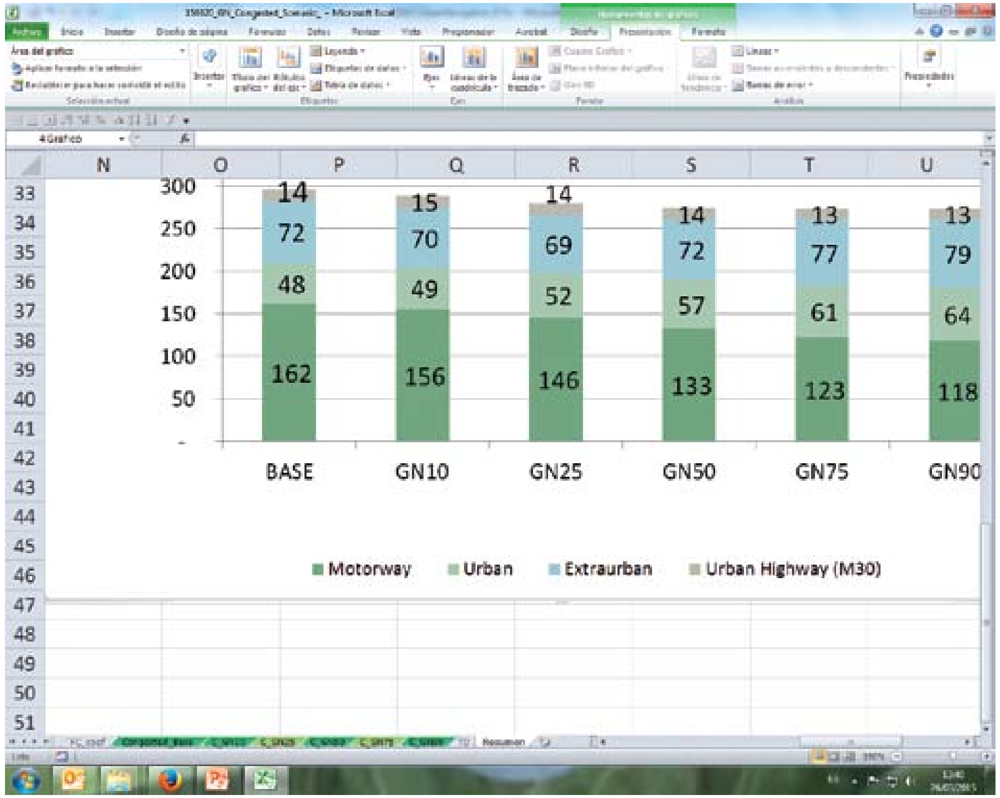
The results with the implementation of the Green Navigation function are shown in the following figure, as a function of the share of green routed vehicles. Benefits at a congested network are substantially larger than normal and free-flow. Small differences between normal and congested are rather negligible.



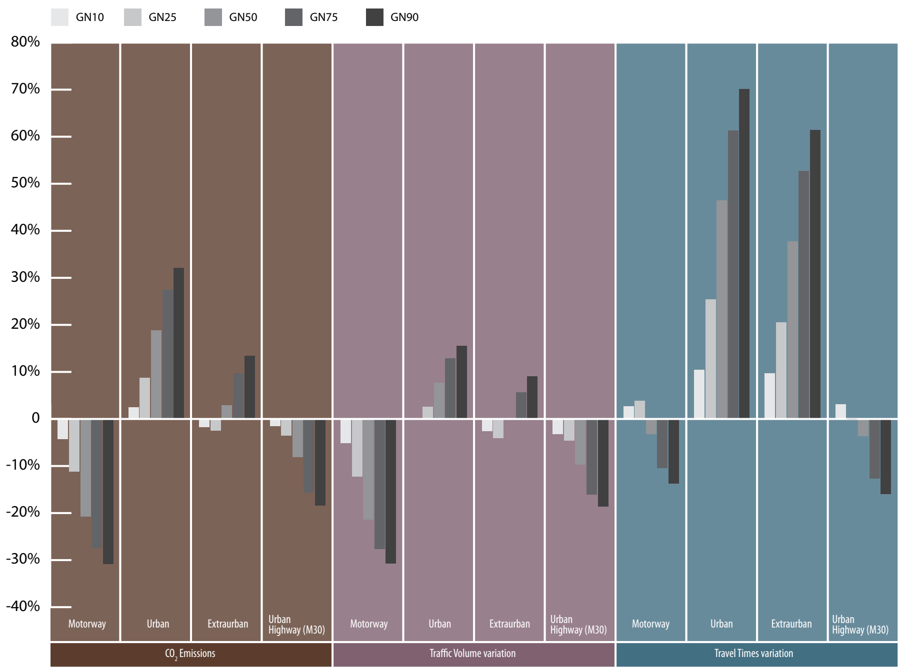
The important message from this figure is that green navigation benefits for a congested network do not change above a certain penetration level, i.e. maximum benefits have been already reached at a 50% penetration. This is because there is no further optimization possible in a congested network, above a certain level.

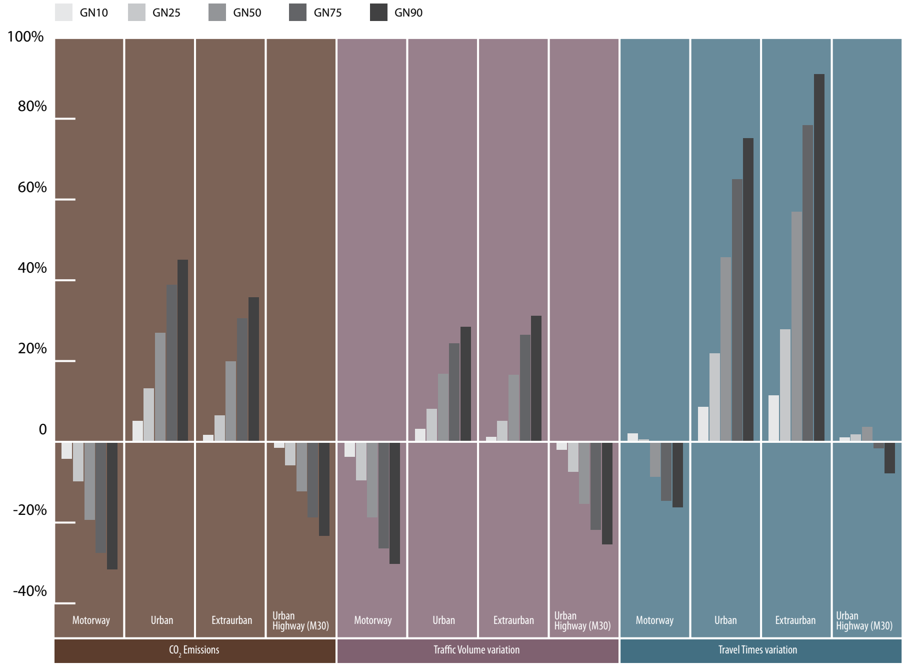
The following figures show how results differ per road type. Green navigation entails significant changes on how traffic is routed in the city. It appears that in the interest of fuel consumption, vehicles opt for shorter (and busier) routes with a big toll in terms of travelling time. At 50% green navigation routing, the total activity from the urban highways drops by 20%, while the urban network traffic increases by almost 10%.

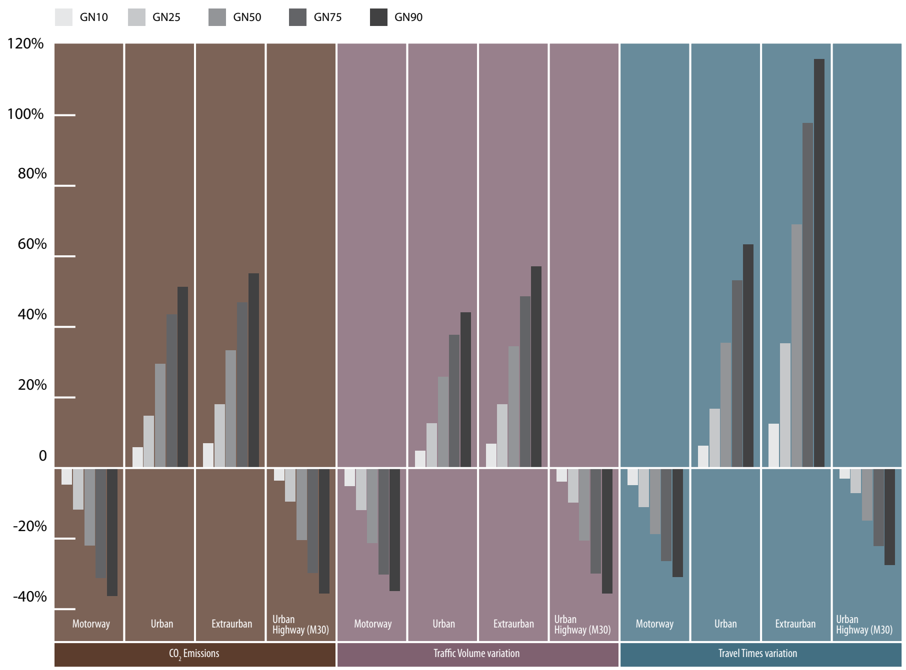
In reality, it is not certain whether the average driver will accept a 40% increase in travelling time to save 6.5% of the total fuel consumption. Hence, despite modelling results show a significant benefit, it is difficult to imagine how this can be reached in practice.

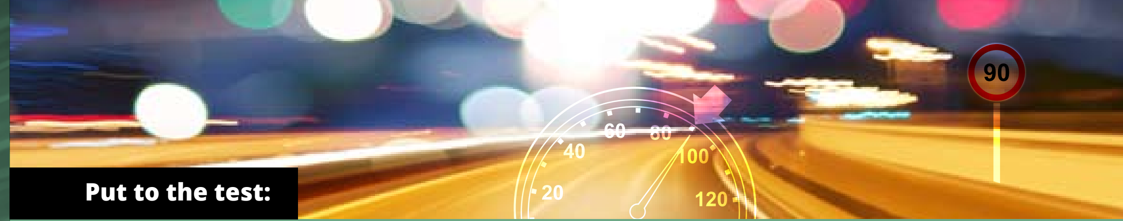


Methodology
T.....









Put to the test:

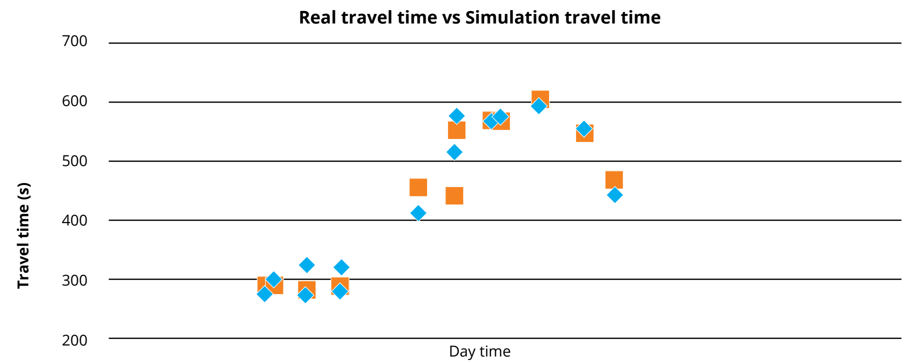
Variable speed limits [VSL]

-1,5% CO_2 savings

Variable Speed Limits (VSL) can be defined simply as speed limit management systems which are time dependant and utilize traffic detectors to determine the appropriate speed.

The results show both absolute and relative CO_2 emissions savings around 1.5%, which are in line with the floating cars measurements. We can observe a significant drop in the stop time percentage, which gives us an idea of more homogeneous traffic flow due to the impact of variable speed limits.

The simulation data [▪] were validated with real time measurements [◆]:

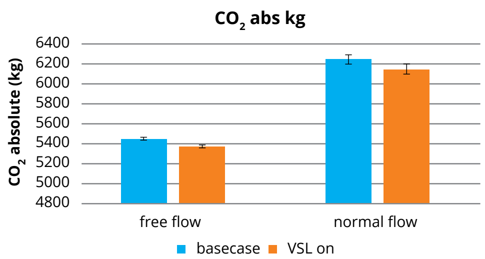


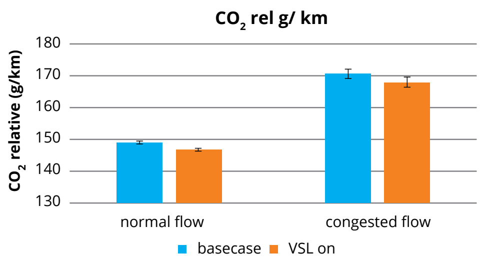
Test on the Madrid ring motorway
The west section of Madrid is a 3 lanes motorway (southbound) with traffic intensity in the afternoon peak hours rounding 3,300 veh/h., (upstream) and with a length of 6.6 km. Most of the section is limited to 90 km/h, except the last 100 m., limited to 70 km/h. (tunnel entrance). The congestion is usually caused by the bottleneck situated in the M500 junction, as around 2,800 vehicles merge in the M30 in peak hour.

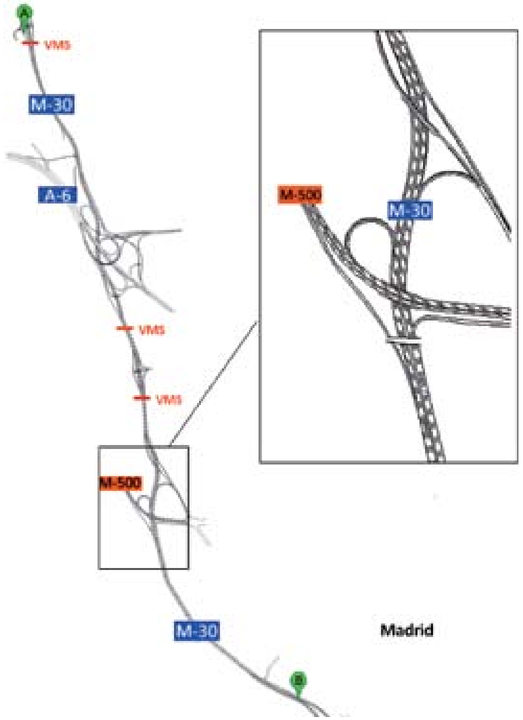
The VSL system is activated at specific points only when there is a certain reduction in speed. The scenarios, therefore, considered are at normal and congested traffic conditions (10 replications each - free flow conditions were excluded).

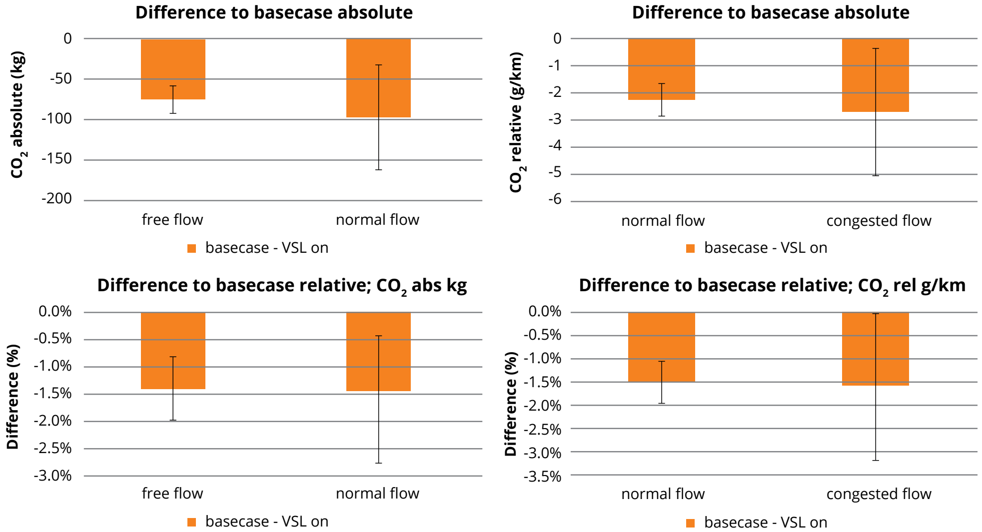
The analysis of variables related to emissions, traffic and vehicle dynamics shows variations corresponding to the base case scenarios:

Scenario *traffic conditions*	Absolute results			Variation with respect to the base case		
	CO_2 abs kg	CO_2 rel g/km	percent stop time	CO_2 abs kg	CO_2 rel g/km	Percent stop time
	kg	g/km	%	%	%	
normal	5369.4	146.70	0.85	-1.4%	-1.5%	-19.6%
congested	6143.6	167.88	3.56	-1.6%	-1.6%	-6.4%









Variable Speed Limits: Madrid case study, Absolute values and Difference basecase.

Modelling scale

Variable speed limits have been modelled at micro level with PTV VISSIM, while the emissions at this level have been calculated with AVL Cruise. Following the micro-to-macro interface procedure described in D6.2, PTV VISUM simulates the traffic at macro level and COPERT the emissions.

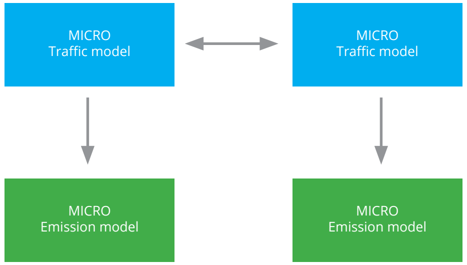
Modelling process description

VISSIM software includes the possibility of simulating VSL by adapting the Vehicle Actuating Programming or using the COM Interface. In this particular case the system has been implemented by means of programming the VSL algorithm in Visual Basic. Using this Interface, Visual Basic controls the parameters of VISSIM simulation.

In the case study of Madrid the VSL system consists of a Variable Message Sign situated between A6 and M500 junction, approximately situated half way of the section under study. This VMS (Panel 22241) display a recommended speed limit of 40, 50, 60, 70 or 80 km/h, depending on the control algorithm.
The real traffic speed is obtained from existing induction loops. The speed data is smoothed to avoid instantaneous speed fluctuations.

The algorithm is based on the smoothed speed on the measuring point PM22121, with the following conditions:

- Smoothed speed at or above 85 km/h.: recommended speed is not reported.
- Smoothed speed between 84 and 50 km/h.: it is posted a recommended speed by subtracting 5 km/h. to the smoothed real speed and then rounding down to the nearest ten.



VSL: modelling scaleResults.

To extend the versatility of the system and its adaptation to complex situations, another condition must be fulfilled:
The difference between smoothed velocities in two measurement points is strictly higher than a given configurable value "DV".

Panel	Measur. points		Speed range		Difference between smoothed speeds
			Vmax	Vmin	
22241	22121	22211	85	40	8

Difference between smoothed speeds value of VSL algorithm.

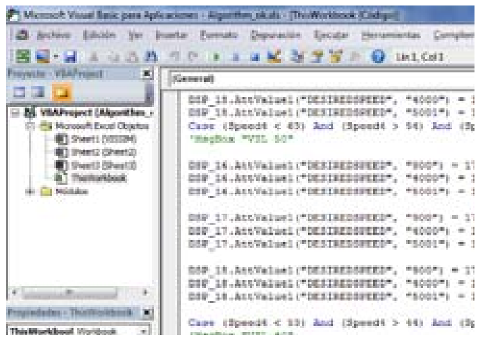
Location of Variable Message Sign and measuring points in the studied section of the M30 Urban Motorway.

Implementation process and calibration of new desired speed decision

The base case model has been calibrated (see Deliverable 6.2) using traffic and floating car data from the evening of Wednesday March 13th 2013, while the VSL system was not activated. Therefore, it is necessary to calibrate the model for other day in which the system is activated. The day selected has been Wednesday 17th of April 2013.

It is important to remind that the posted speed is recommended and, consequently, the effects on the driver behaviour are not as much evident as they would be if the variable speed limits where mandatory.

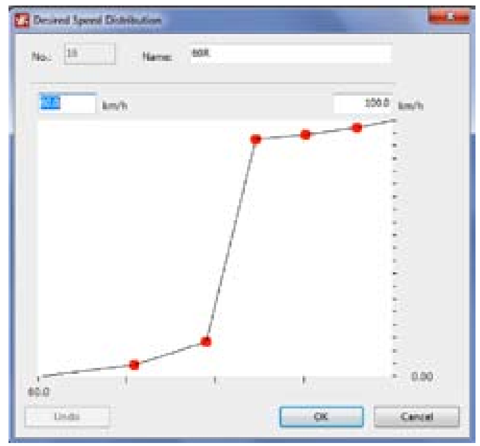
The algorithm has been implemented in VISSIM using Visual Basic and the COM Interface, which allows to control externally some of the parameters of the model.



Algorithm implementation in Visual Basic through VISSIM COM Interface

The analysis of the speed profiles from floating cars does not show concluding results, so the procedure to obtain the new desired speed distributions is the following:

1. Using the calibrated basecase model, traffic inputs are changed according to the real data from 17th April. The other parameters are kept constant.
2. Routing decisions are adapted to fit traffic data collected from induction loops
3. Definition of new desired speed distribution affected by recommended speed limits.
4. Programming of Visual Basic code to control VISSIM and simulate the variable speed limits.
5. Adjustment of desired speed distribution to fit travel times data recorded by floating vehicles.



With this procedure, it has been possible to obtain a new desired speed distribution for each possible posted recommended speed limit while achieving good results with regard to travel times

More on ICT-emissions: achievements and innovations

The Methodology
The main achievement is the overall consistency of the modeling approach across micro- and macro modelling both for traffic- and emission modelling. In addition, the existing commercial models have been modified and calibrated to reflect the real-life conditions in urban areas.
Some highlights are:
New Gibbs function for eco-driving simulation, development of micro-level vehicle simulators, interfaces between micro-traffic simulators and vehicle simulators, extension of ADAS simulator to micro traffic simulators and extension of COPERT applicability

for more information
www.ict-emissions.eu

With a view to the future

The work undertaken, the results obtained and the know-how of the interdisciplinary project team allow a rather clear view of the developments to come:

> ICT-Emissions methodology and toolset will expand beyond CO_2 and passenger cars to air pollutants and commercial vehicles.

> ICT-Emissions know-how and team of experts can participate in any Smart Cities Solution and assist in deploying effective ICT measures for any particular application.

> ICT-Emissions methodology can serve as a test bench for the assessment and certification of eco-innovations.

> ICT-Emissions can contribute to International Collaborations of the EU with a wealth of experiments, test data, case studies and validated methods and tools.

> ICT-Emissions is one major step toward an urgently necessary Standarised Assessment Methodology (SAM) -a system for the interpretation, comparison and up-scaling of different approaches for a Smart, Green and Integrated Transport.

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ICT-Emissions

SEVENTH FRAMEWORK PROGRAMME