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InDiD

Infrastructure Digitale de Demain

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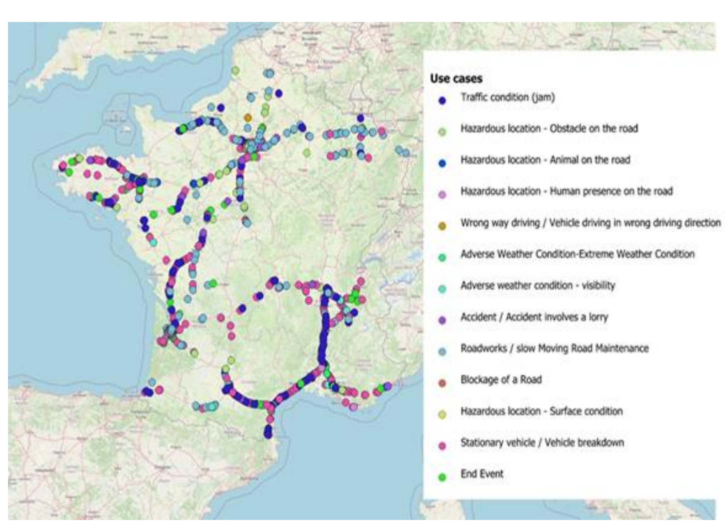
June 2024

The following Newsletter aims to present the most significant evaluation results of the InDiD project. Impact studies come after a significant period of specification, development and validation of InDiD use cases. The purpose of the C-ITS system is to increase the safety of the user. Before the user experience, we need to evaluate it from a functional point of view. We can then evaluate how this new technology is received by users, but also by the road managers who use it daily.
The contribution of new technology in an area as important as transport will have an economic impact. Indeed, connected infrastructure has a cost for road managers. We evaluated their return on investment. Anticipating events will have a significant impact on road safety. Smoother driving will have an effect on traffic and emissions. This newsletter will provide some answers about the impact of C-ITS on the vehicles of tomorrow.

Results of the technical evaluation of Coopits

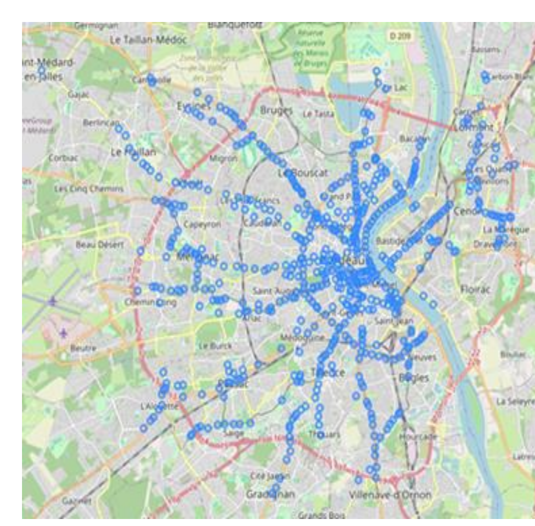
The functional evaluation of Coopits was conducted after 8 months of data collection. The study made it possible to ensure the proper functioning of the application. In order to enable the system to ensure the best quality of data and a real sobriety of data while maintaining a high quality of service, the technical evaluation focused on the level of repetition of the messages, their distribution areas and their period of validity.
Data exchanged during the experiment were analyzed to determine if the operation corresponds to what is necessary for the use case to work properly. Useless messages and false information should be avoided, and the network should not be overloaded unnecessarily. Indicators such as the distribution of services on the territory, i.e. the positions of the different messages (CAM, DENM, IVIM, SPATEM, MAPEM) received or sent by the smartphone, represented in the following figures.

Positioning Messages (CAM)



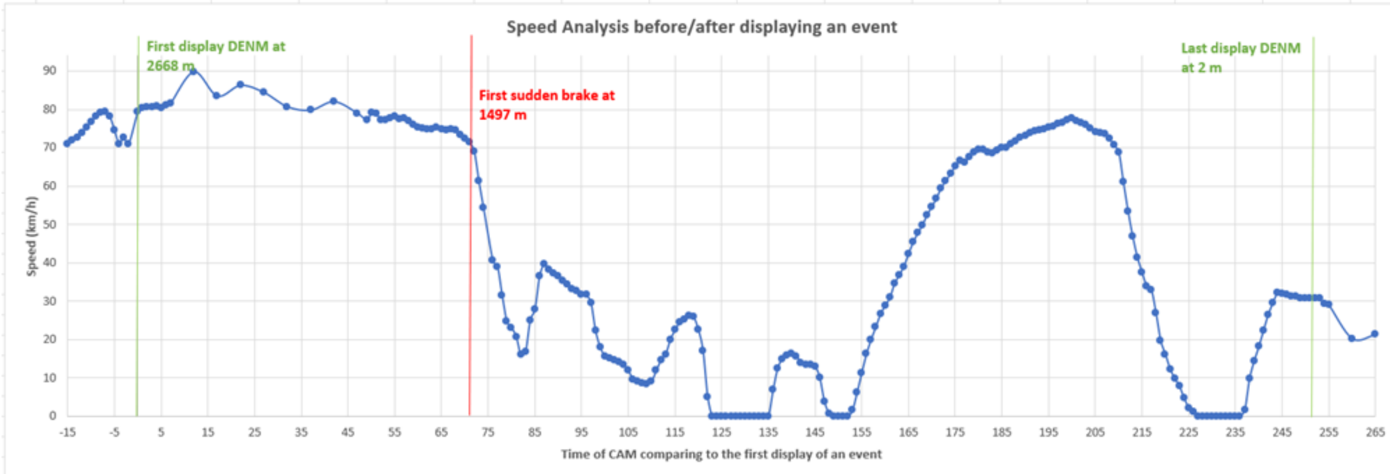
Event Messages (DENM) by Use Case

Road Sign Messages (IVI)



Messages for Traffic Light Status (SPATEM) over 585 intersections

We observed a good distribution of messages through the territory through different road managers' networks. The functional evaluation focused on several elements such as the variation in speed as displayed event draws near or the number of stops at an intersection. By analyzing the speed variation for each system and for each event received, we can observe that **41.5% of vehicles slow down after a DENM is displayed**, and about 1% brake suddenly.
The following figure shows an example of vehicle behavior when receiving a traffic jam event. At two kilometers, the information is given without any noticeable change in speed because the event is far away. We see a deceleration as we get closer to the event (information broadcast on the HMI).



Analysis of the speed of a vehicle at the reception of a DENM - traffic jam

Hasnaa Aniss – University of Gustave Eiffel

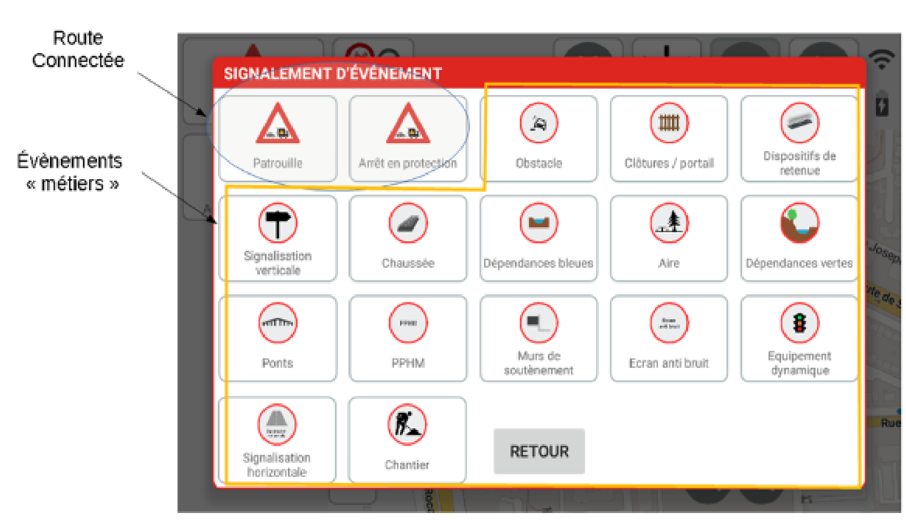
In conclusion, this evaluation permitted to quantify the quality of C-ITS service dissemination by the Coopits application and to implement recommendations to train road operators in the dissemination of these messages and to guide the dissemination of information towards data and energy saving, which guarantees the success of C-ITS services.

Support for organizational and human evolutions in the deployment and post-deployment phase of C-ITS.

The reliability of messages within the InDID project is ensured, for some use cases, by the sender of the messages: the route managers. To be able to report these events, the DIR Ouest (Interdepartmental Management of West Roads) has developed 2 tools in their CEIs (Maintenance and Intervention Centers): a touchscreen tablet with an on-board handrail (MCE) and an on-board Web interface.

The Acceptability and Organizational Impact working group evaluated the reception of these tools by professionals via questionnaires and interviews.

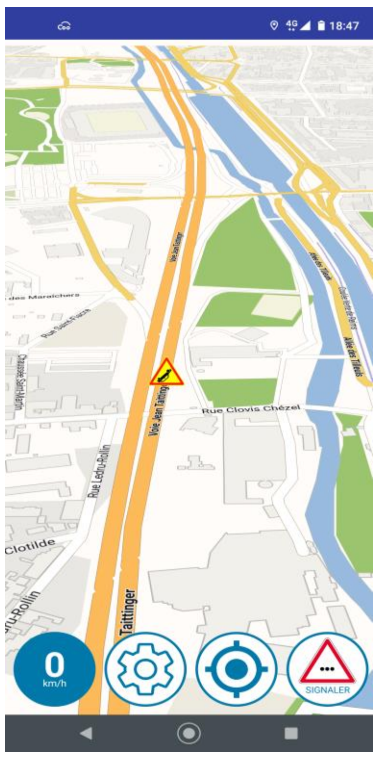
The merging of the two tools (MCE and web interface) has resulted in better adoption of C-ITS than if they had been deployed separately. The teams expressed a strong interest in C-ITS, particularly in the dissemination of information to users. C-ITS functions were also used internally to facilitate the coordination of teams in the field. For future deployments, it is recommended to continue working on the interconnection of tools to improve the safety of agents and users. Consideration should also be given to the integration of the Traffic Management and Engineering Centers (CIGT) into this system.



Mehdi CHAHIR – University of Rennes 2

Evaluation of the acceptability of the smartphone application by users.

After its nationwide deployment in April 2023, Coopits was evaluated on its acceptability to the general public. The study included 108 participants, both experienced and novice users. The results revealed a low intention to continue using a technology that is strongly related to user attitudes, which is itself, influenced by the confirmation of expectations, trust in that technology, and subjective norms. The results of the study revealed a noticeable gap between the initial expectations of users and the reality of the application.



The three most anticipated features are: a large number of alerts, the possibility of event reporting (little used but considered very useful), and the "overlay" function. Coopits was evaluated as being rather compatible with the driving environment. The “overlay” function and the reliability of the information transmitted were considered to be major advantages. Confidence in this new technology is therefore good.

The study identified certain areas for improvement to develop Coopits: better ergonomics, a greater number of messages and integration with Android Auto. The evaluation highlighted Coopits' strengths: qualified information, real-time and predictive information on interventions on the tracks (e.g., construction sites), traffic restrictions, diversion routes adapted to the volumes of traffic to be diverted or services related to the infrastructure such as information on the state of traffic lights.

Mehdi CHAHIR – University of Rennes 2

Behavioural and cognitive studies of C-ITS messages for level crossings.

The study was produced in the smart level crossing framework in the SNCF’s Innovation and Research. Since 2017 Carrefour Intelligent project develop a solution to change the level crossing into a smart and connected intersection able to send status messages (open, closed, in work or out of service) and features (speed limit, height, weight, width and profile) to connected vehicles.

In France, there is more than 15 000 level crossings on 25 000 km of national railway line. On this SNCF network, there is around a hundred of collisions per year and between 25 and 45 fatalities per year.

The number of level crossing collisions tend to decrease for 20 years. But if we analyze the past 10 years, the number of collisions at a level crossings stagnate.

Level crossing closed 200m away.

With new technologies as advanced driver-assistance system (C-ITS system), SNCF is convinced that these road safety technologies can reduce the number of collisions at a level crossing.

SNCF decided to carry out an experiment on a driving simulator. Use of a simulator was been justified by the difficulty of carrying out this experiment on the road in the context of real situations (regulation, technical, safety, financial restrictions, etc.)

Level crossing in 200m.

In this research, we developed scenarios related to known accidentology to evaluate the input of these technologies on the behaviour of road users at level crossings.

The route had 12 situations, 11 with C-ITS message, 5 situations about level crossings. All C-ITS situations are generated the same way: an audible signal, a text message and a pictogram on the tablet.

31 subjects was recruited. The objectives of this study are to evaluate:

- The level crossing message comprehension,
- Their impact on driver’s behaviours,
- The cognitive load generated by level crossing messages,
- The acceptability and comprehension of C-ITS devices in the road framework, including level crossing.

As level crossing draws near, behaviours can be classified in two categories:

- Participants who anticipate the potential activation of the level crossing and take suitable decision.
- Participants who are waiting for a concrete clue to react.
- This second category can be put in difficulty, particularly in case of lately closing of the level crossing.

The messages unquestionably have a positive impact on participants who waiting for a clue. They can be a relevant clue for an anticipated reaction.

Virginie Taillandier - SNCF

Evaluation of road safety issues of InDiD use cases.

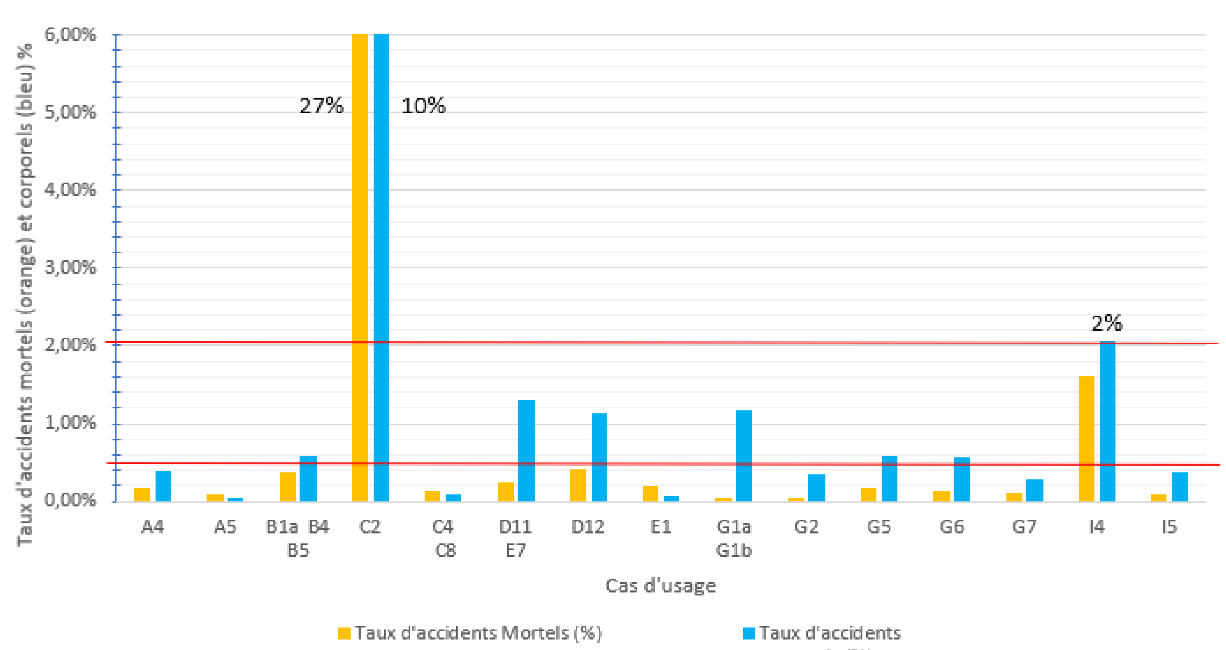
This is a study that evaluates the accident issues of InDiD use cases of interest for road safety, before their large-scale deployment, based on four databases of traffic accidents in France (VOIESUR, BAAC, SNCF for use cases relating to level crossings and OCSTI for use cases relating to law enforcement).

The use cases evaluated are as follows: A4, A5; B1a, B4, B5; C2, C4, C8; D11, D12; E1, E7; G1a, G1b, G2, G5, G6, G7; I4, I5; K1, K4, K6; L2, L5b, according to the official categories.

The assessment of these accident issues complements and enriches that carried out within the framework of the previous C-ITS project: SCOOP. It covers all road users involved in accidents: ordinary road users, road management agents, law enforcement officers (gendarmerie) over two comparative periods (2011 and more recently 2018-2021); focuses on use cases oriented towards vulnerable users (pedestrians) and automated vehicles as an evolution of current private vehicles, with connected services as contributors to improving road safety. And it sheds light on the distribution of driver failure types for most use cases as well as the distribution of personal injury accidents by infrastructure types for overall use cases.

The main result of the study are the interclassification of use cases in frequency and severity: the problems of overspeed, inappropriate speed (C2), pedestrians crossing outside protected crossings (I4) and show the highest stakes in terms of frequency and severity.

Then come the use cases relating to road works (B1a, B4, B5), intersections with traffic lights (G1a, G1b), traffic jams (D11, E7) and the arrival of an emergency vehicle (D12) which require measures to improve road safety.



Frequency (%) of injury accidents (in blue) and fatal accidents (in orange) involving at least one passenger vehicle, a truck, a motorcyclist, or a pedestrian/cyclist, by use case.

The other use cases (toll management (C4, C8), insertion (G5, G6), pedestrians at bus stations (I5), wrong-way traffic (A5), vehicles in critical situations (A4), etc.) present lower overall accident stakes, but if the frequency of accidents can be low, in the event of an accident the severity can be very high.

Regarding the use cases relating to level crossings (K1, K4, K6): the accident stakes (frequency and severity) for all victims (including in trains), are higher for the K1 use case (information on the condition of the level crossing, mainly on the closure). As for the use cases relating to the activities of the police forces (L2, L5b): the accident stakes are higher for the L2 use case (police vehicle parked, as part of missions).

The evaluation is rich in lessons in terms of the accidentological interclassification of use cases, the distribution of the location of injured accidents for use cases, which can be deployed everywhere (motorways, in urban and rural areas), the distribution of the types of human failures at the origin of accidents (detection and prognosis in particular) according to the use cases, with the aim of making choices in terms of improving road safety thanks to the connected services, among others. The injured accidents that occur so far in certain situations described by the use cases could be eliminated or occur with less severity for the victims.

Laura Bigi - LAB

Results of the socio-economic analysis.

The socio-economic analysis is based on the comparison of different C-ITS technology deployment scenarios: the deployment of short rang connectivity (ITS-G5), long rang connectivity (4G), hybrid connectivity ITS-G5 & 4G and a 5G approach based on both long and short range communication (with network slicing). The comparison with a based scenario will highlight the most interesting investment.

A probability calculation of treatment of use cases is carried out using several assumptions for the deployment of roadside unit (distinguished by network typology), different assumptions for the penetration of vehicle on-board unit, and data from the impact study of the European Commission carried out by the Ricardo study office. According to these assumptions, we can value the costs of a national deployment, and the benefits of the use cases evaluated. The overall result of the socio-economic analysis is done by adding up all the cost, benefits items and is expressed under the Net Present Value (NPV). Thanks to the NPV, we can easily rank projects that have been evaluated the same way, to choose the best financial return for the society. Project's scenarios are compared to based scenario, if this is negative, invests are most important than potential benefits.

According to these models, every scenario reduces the accidents rate on the roads. However, the most effective scenarios are those combining several technologies, with short and long-range communication (ITS-G5+4G or 5G). Conversely, scenarios based on a unique mean of communication are, according to our model, the least relevant. We can explain this result, on one hand, by a lower effectiveness of the use cases regarding to a more limited scope, and, on the other hand, by the equipment cost (of vehicles especially) not offset by the potential benefits of these same use cases.

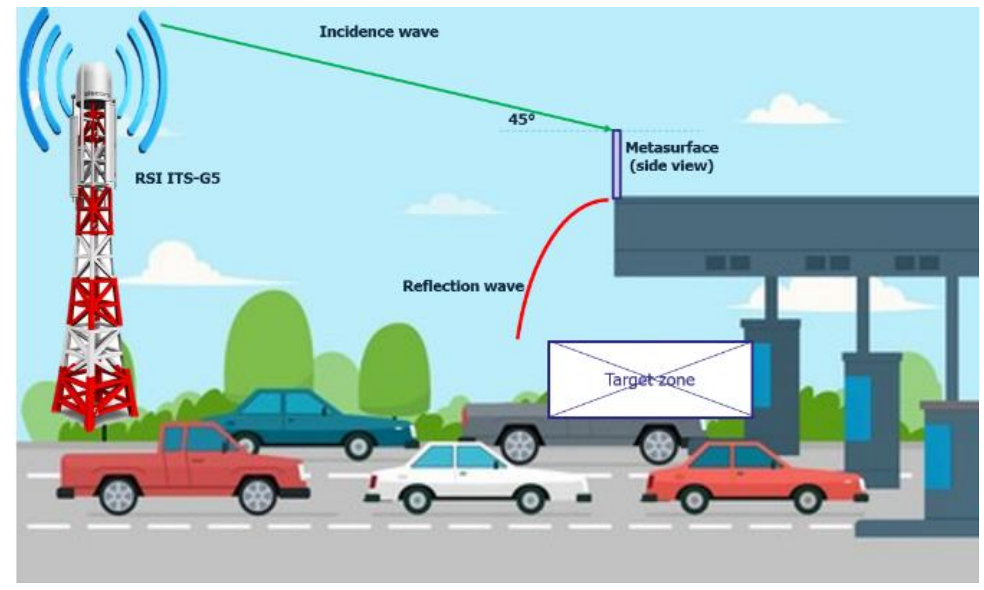
Jamel Chakir - DGTIM

Evaluation of exposure to electromagnetic waves.

The evaluation of exposure to electromagnetic waves remains a matter of concern, even if it tend to be reduced as research carried out. It is now possible to conclude that all the scientifically established data on the emissions of wireless devices and their deployment do not support a significant risk and an exceedance of the recommended exposure levels. The results give E-Field exposure levels not exceeding **0.8 V/m** for a recommended threshold value of 61 V/m. To protect the road agents who wears the ITS-G5 device during their on-site intervention, a measurement of the specific absorption rate (SAR) was also carried out. While the limit recommended by ICNIRP is 0.4 W/kg, the specific absorption rate is **0.193 W/kg.**

After the protection of the general public, the Sanitary Impacts working group studied the connectivity problem of the C-ITS system in a complex environment.

In the InDiD project, we have developed use cases for approaching a toll gate, taking the automated driving vehicle into consideration. The toll barrier is a complex area from the point of view of the propagation of electromagnetic waves: their environment is very metallic, obstructing the cover and the risk of radio disturbances is non-negligible due to the presence of existing radio systems (electronic toll collection equipment).

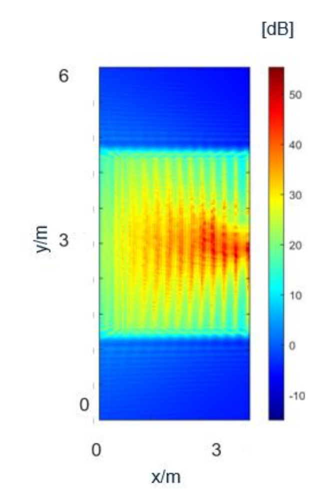


Scenario of integration on the toll roof.

When deploying the ITS-G5, we could easily be tempted to deploy more RSU to ensure sufficient coverage and performance of the C-ITS system, which would result in a high level of electromagnetic (EM) wave exposure.

In this context, we suggested an exposure management methodology that not only minimizes the levels of exposure to EM waves, but also ensures good coverage of C-ITS in the toll station.

The proposed solution consists of a surface consisting of a reflector that would allow a deflection of the wave so that the area under the toll is also covered. The reflector is placed on the roof to reflect the waves in the form of curved beam, under the roof. The contribution of this solution is considerable, compared to a simple device, for example place the emission horn below the metal roof. The difference in electric field levels is directly proportional to the difference in exposure to EM. Up to 50 dB of difference in power level (or 300 times less) is observed in some areas.



Difference in electric field distribution levels (in dB) at z=3500 mm in the xOy plane, under the toll barrier at 5.9 GHz

This clearly shows that the meta-surface-based connectivity solution is very beneficial in minimizing the exposure level while ensuring good performance of the ITS-G5 system. In addition, it provides an additional degree of freedom for the deployment of UBRs in a constrained or highly metallic environment where the flow of electromagnetic waves is difficult to manage.

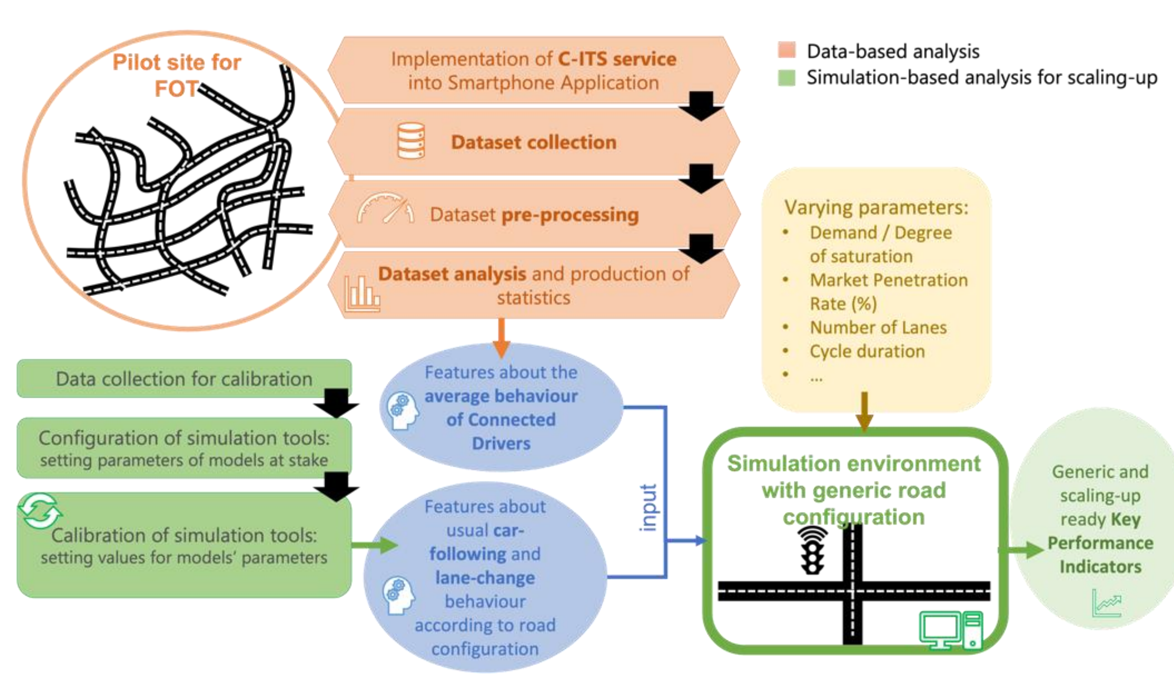
Divitha Seetharamdoo, Narimane Awada Mislmani – University of Gustave Eiffel

Performance analysis for InDiD use cases according to environmental and traffic impact.

The Traffic and Environment working group reproduced the traffic at the microscopic level via simulation. Thanks to this simulation, two sets of use cases were evaluated:

- Use cases relating to an approaching downstream obstacle on highway with a lane-change recommendation.
- Use cases relating to an approaching congested area with a dangerous end of queue and speed recommendation.

During the simulation, the different scenarios vary the market penetration rate, modifications in traffic demand or road configuration, etc.

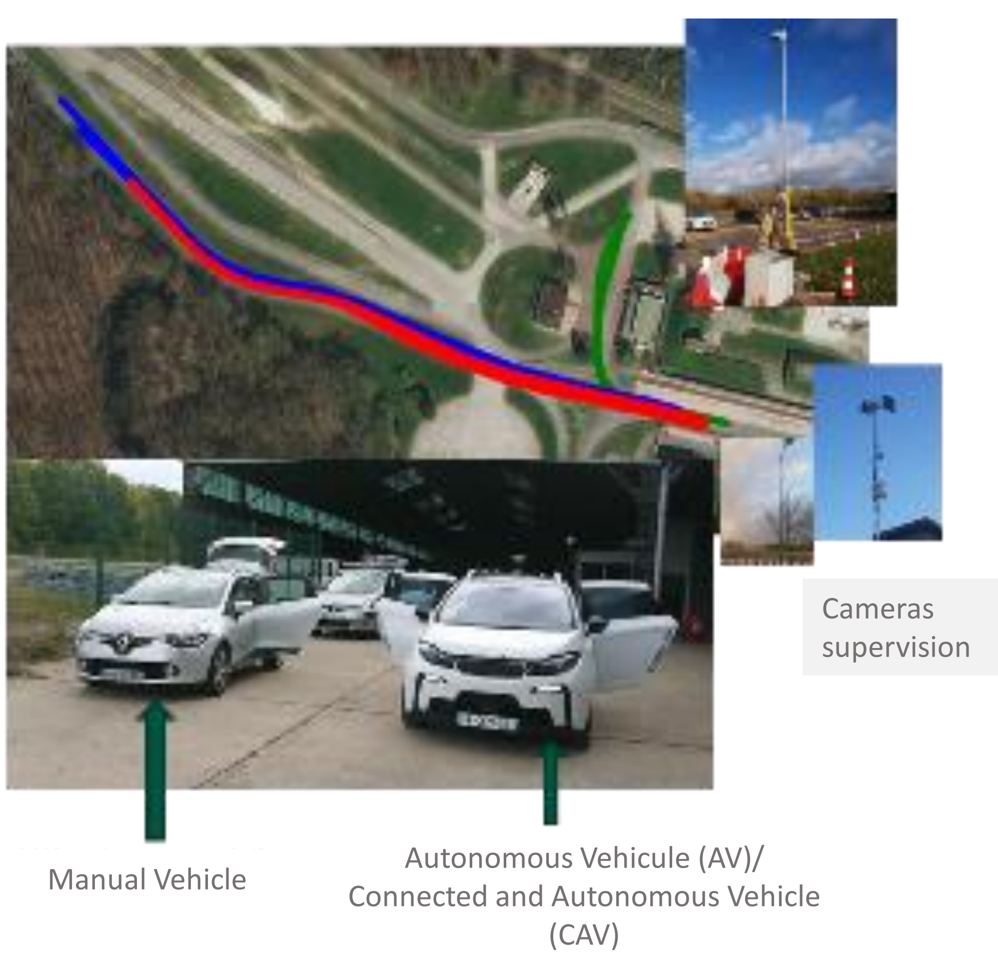


Global methodology adopted for impact assessment on traffic, safety and the environmental efficiency.

For the first set of use cases, the experiment demonstrated that these use cases have a positive impact on road safety when traffic demand is low, but the impact is limited when the vehicle density is high. These use cases also have a positive impact on traffic, in some cases the early warning of the obstacle allows the speed to be increased by 10 km/h. There is also a positive impact on fuel consumption and pollutant emissions (NOx and PMx).
For the second set of use cases, the simulation reproducing a traffic jam at different speeds showed an improvement in safety, the anticipated slowdown inversely proportional to the traffic demand. As the speed is reduced, the impact on pollutant emissions is always positive. The more the slowdown is anticipated, the greater the benefits.
In this study, we were able to observe the benefits of deploying C-ITS services by taking into account certain conditions: the market penetration rate, the density of road traffic and the configuration of the road.

Pierre-Antoine Laharotte – University of Gustave Eiffel

Impact study of connected infrastructure on lane merging for autonomous vehicle.



Lane merging can be an accident-prone situation. In the InDiD project, event messages and connected vehicles can make it possible to approach this area in a peaceful manner, especially since these messages have also been developed with the anticipation of the arrival on the market of the autonomous vehicle.

In this experimentation, we studied the benefit of the connected infrastructure to assist an autonomous vehicle (AV) when dealing with a complex situation as crossing a lane merging securely. After the development of a suitable methodology for several scenarios, the use case of cooperative collision risk warning at a lane merge was evaluated with a Connected and Automated Vehicle (CAV) and a connected infrastructure on a closed circuit.

Two scenarios were studied to compare the behaviour of an automated vehicle (AV) without connectivity and an automated vehicle assisted by the connected infrastructure. Due to the complexity of the experiment, only a limited number of trials could be done. Nevertheless, we can confirm several initial assumptions on both scenarios. We could observe that:

1. The AV was unable to deal with situations of interaction with a manual vehicle. Those situations create an important uncertainty leading to potentially dangerous reactions due to the lack of anticipation by the AV.
2. The benefits of the connected infrastructure to enable the CAV in adopting the appropriate strategy and avoid conflict when driving though the merging zone. For example, we could demonstrate that the AV can start a lane changing to avoid a potential collision keeping its cruising speed.

Pierre MERDRIGNAC – VEDECOM

Support for organizational and human changes –
Analysis of the technology - human – organization system in the pre-deployment phase of autonomous vehicles.

The aim of this study was to assess the potential impact of InDiD use cases addressed to the Automated Driving Vehicle (ADV) for road managers, and, more broadly, to apprehend their perceptions of the ADV. Two versions of the same questionnaire were distributed to professionals working for French road managers who agreed to take part in the study. A total of 124 participants responded.

In the questionnaire, participants were first asked to freely evoke words related either to the "automated driving vehicle" (ADV) or to the "autonomous vehicle" (AV).

Participants spontaneously evoked elements linked to the functioning and perceived consequences of the ADV/AV, revealing two opposing trends. A comparison of perceptions for ADV and ADV suggests a greater variety in the vocabulary associated with ADV, probably linked to a lower level of familiarity with this terminology.

Participants expressed a generally neutral attitude towards ADV/AV, with divergent knowledge and moderate involvement in the subject. They anticipated the need to adapt road infrastructures to the arrival of ADVs/AVs, particularly in terms of intelligent transport systems and traffic information.

Finally, participants found the InDiD use cases dedicated to ADVs useful, but seemed divided as to their ease of implementation. More generally, these use cases raise organizational questions. For example, which actors should disseminate the information required for these services to function properly? How often should these services be provided or updated? What would be the organizational impact of deploying such services for road managers? What would be the legal liability of a road manager who failed to provide information on these services?

Mehdi CHAHIR – University of Rennes 2, Kévin NADARAJAH - CEREMA, Nicolas MEMBRADO - CEREMA & Stéphanie BORDEL - CEREMA