C-ROADS

C-ITS EVALUATION: EXPERIENCES AND PRELIMINARY RESULTS FROM C-ROADS ITALY PILOTS

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C-Roads Italy – Implementing bodies

Under the coordination of the Ministero della Infrastrutture e dei Trasporti (MIT) the "Implementing bodies" are the following:

ROAD OPERATORS

Autostrada del Brennero SpA
Brennerautobahn AG

Concessioni Autostradali Venete

Autovie Venete

SERVICE PROVIDERS

TIM

Azcom Technology

VEHICLE OEM

IVECO

FCA

LOGISTIC OPERATOR

CODOGNOTTO

TRAFFIC POLICE

Ministero dell'Interno
DIPARTIMENTO DELLA PUBBLICA SICUREZZA
SERVIZIO POLIZIA STRADALE

POLIZIA STRADALE

EVALUATION & ASSESSMENT

POLITECNICO MILANO 1863

COORDINATION

North Italy Communications S.r.l.

C-Roads Italy – Case Study

C-ITS
- RWW – Closure of a Lane
- IVS - Dynamic Speed Limit
- HLN – Slow or Stationary Vehicle

Truck Platooning
- V2V communication among trucks
- As stand-alone system
- Jointed Implementation

Highway Chauffeur
- Conditionally automated driving
- As stand-alone implementation
- Jointed Implementation

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C-Roads Italy – Case Study

A **platoon of trucks** is composed by different connected trucks, the leading one is driven by a human driver while the following ones grant the longitudinal control task to the automation.

1

2

The **Highway Chauffeur** system is a conditionally automated driving system potentially allowing the driver to exit the driving loop as long as some boundary conditions are met.

C-ITSs are cooperative services that, through V2X communications, allow the vehicles to *speak* with each other or with the infrastructure and vice-versa

3

C-Roads Italy – Framework of the activities

- **Ex-Ante evaluation**: Resulted in two technical reports already public — **Finished**

- **Intermediate phase** → Traffic Modeling — **On-Going**
  - Calibration of the Italian traffic on the involved infrastructures
  - Scripting of the Use Cases, of Truck Platooning and of the Highway Chauffeur system
  - <u>First impact evaluation and support to the field test design</u>

- **Ex-Post Evaluation**→ Field tests design — **On-Going**
  - Coordination of the involved partners to identify the most representative segments
  - Definition of the KPI to be recorded and first sampling
  - <u>Design of the fleet composition, traffic conditions and Use Cases to be actually implemented and analyzed</u>

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C-Roads Italy – Ex-Ante activities

C-ROADS ITALY

Aims

State of the art characterization

- Needed to correctly design the scenarios (e.g. identify feasible time gaps for truck platooning)

First impact assessment of the systems as stand alone

- Needed both to identify KPIs and to have a theoretical background to validate the results that will be obtained at the end of the trial

Definition of the research and sub-research questions

- As defined within the Evaluation and Assessment Plan, research and sub-research questions are necessary to design KPIs and to draw the evaluation hypotheses

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C-Roads Italy – Ex-Ante activities

C-ROADS ITALY

Truck Platooning – Operational Design Parameters		From field tests/testbeds	From modeling works	Research Effort
Air drag coefficient	0,6	✔		++
V below which the aerodynamical benefits become less relevant	50 km/h	✔		+
Feasible time gaps	0.3 ÷ 1 s	✔	✔	++
String-stable time gap	> 0,7 s	✔		+
Minimum safe distance between trucks	≈ 8 m	✔		++
Number of trucks	2 ÷ 4	✔	✔	++
Distance needed for the disaggregation of the platoon	2 ÷ 5 km		✔	+
TTC safety critical value	1,5 s	✔	✔	++
Worst-case latencies considered to assess the robustness of the system	≈ 150 ÷ 200 ms	✔	✔	+
Transmission delay considered while testing the system	0,05 ÷ 0,1 s	✔		+
Feasible difference in braking capability between trucks	≈ 0,883	✔		+

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C-Roads Italy – Ex-Ante activities

Highway Chauffeur – Impacts arising from the available literature		From field tests/testbeds	From modeling works	Research Effort
Potential capacity increase/decrease	(- 2,5) ÷ (+ 7) %	✔	✔	+
Impact on the surrounding vehicles	Up to 20 vehicles	✔		+
Take-over times	3 ÷ 10 s	✔		++
Reduction of safety critical scenarios cut-in related	Up to 83,1 %		✔	-
Reduction of safety critical scenarios while approaching an obstacle	Up to 28 %		✔	+
Potential fuel savings	0 ÷ 28 %	✔		-
Time needed for a steady lateral control after the take-over transition	Up to 40 s	✔		+
Market penetration able to affect the traffic flow	≈ 5 ÷ 10 %		✔	-

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C-Roads Italy – Ex-Ante activities

Main output – Jointed implementation

Main changes in behavior

Lane change

- Lane change point
- Maximum Steering Angle/Action
- Maximum deceleration
- Minimum Time To Collision
- Number of interrupted lane change
- Istantaneous acceleration/deceleration
- Maximum lateral acceleration
- Time Gap/Relative speed difference chosen for the lane changing maneuvers
- Traffic densities beyond which the lane change maneuver is hindered
- Lateral position standard deviation
- Maximum jerk
- Number of lane changes/100 km

Longitudinal behavior / Speed Adaptation

- Average Speed & Speed Standard Deviation
- Instantaneous acceleration/deceleration
- **Time gaps held**
- Time gap accuracy/stability
- Minimum Time To Collision
- **Number of Cut-ins/Km for each time gap**
- Maximum jerk
- Number of emergency braking per km
- **Time needed for platoon-related maneuvers to be carried out**
- **Number of headway adaptation/100 km**

System disengagement

- **Number of Cut-ins/Km for each time gap**
- **Number of dissolutions/disengagement for each time gap**
- **Time needed to dissolve the platoon**
- **Traffic densities below which the formation can be maintained**
- **Number of kilometers with the system engaged/disengaged**
- **Disengagement/dissolution starting point**
- **Number of vehicles able to pass through the signalized section with the system engaged**
- **Take-over time (mean and maximum)**

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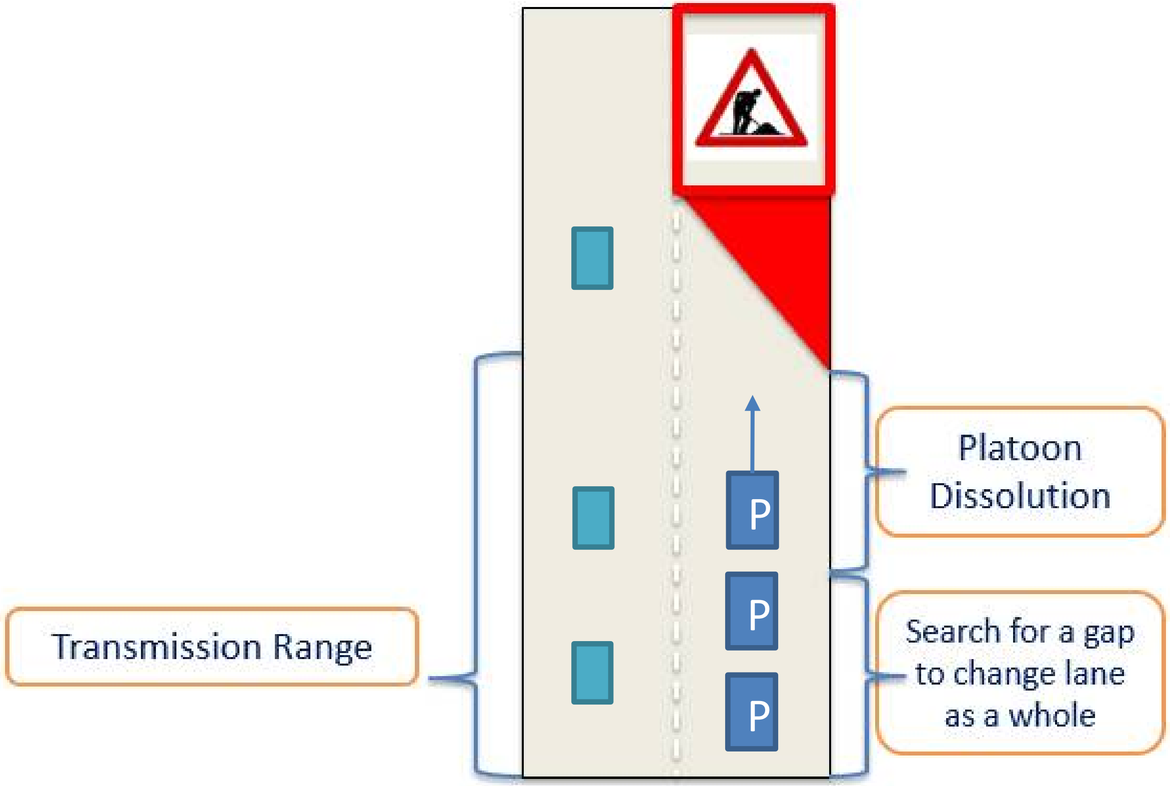
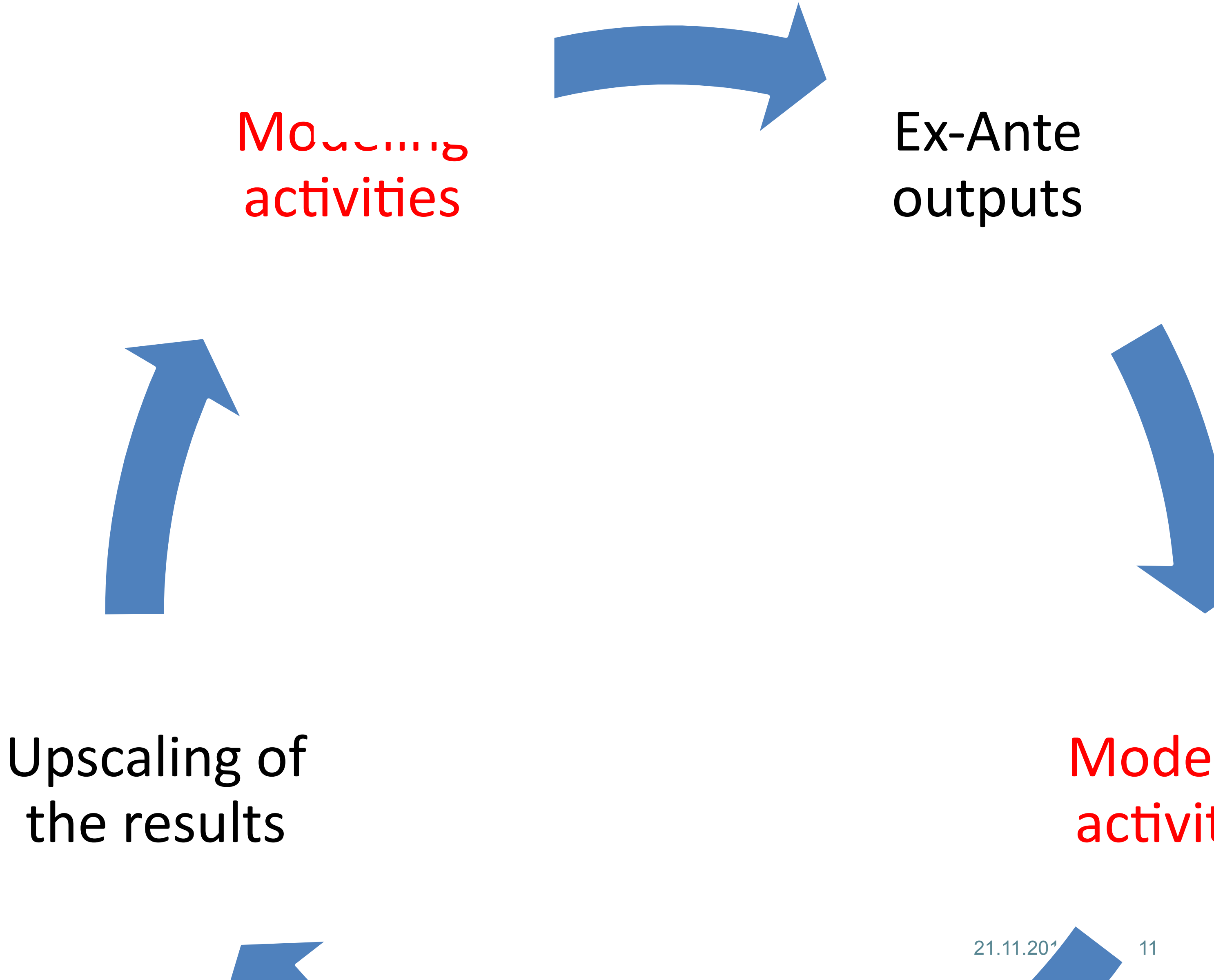
C-Roads Italy – Ex-Ante activities

Jointed implementation - Example



C-Roads Italy – Modeling



C-Roads Italy – Modeling

Use Cases can be more suitable for an assessment through modeling or through trials

Through modeling: No strong dependance on compliance levels, no strong hypotheses on the punctual change in behavior

- RWW – Closure of a Lane
- HLN – Slow or Stationary vehicle
- Truck Platooning related Use Cases
- Highway Chauffeur related Use Cases

Through trials: Strong bound with the compliance rates, continuous change in behavior along a segment

- IVS – Dynamic Speed Limit
- HLN – Weather Condition Warning

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C-Roads Italy – Modeling

Use Cases can be more suitable for an assessment through modeling or through trials

Through modeling: With the results from field tests, an hypothetic compliance rate can be defined – **an accurate upscaling can be performed**

Behavioral feedbacks

Through trials: Strong bound with the compliance rates, continuous change in behavior along a segment

IVS – Dynamic Speed Limit

HLN – Weather Condition Warning

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C-Roads Italy – Modeling

Use Cases can be more suitable for an assessment through modeling or through trials

Through modeling: Validation of the behavioral hypothesis

- RWW – Closure of a Lane
- HLN – Slow or Stationary vehicle
- Truck Platooning related Use Cases
- Highway Chauffeur related Use Cases

Behavioral feedbacks

Through trials: Punctual Use Cases will still be implemented within the field tests

C-Roads Italy – Modeling

Calibration of the model

- Traffic Data Analysis
- Calibration through sensor data (Limited amount of days available)

✓

Design of the scripted tools

- Script to simulate Truck Platooning
- Script to simulate the take-over maneuver of the Highway Chauffeur

✓

Actual simulations

- Scenario definition (TP, CAV, CV)
- Output for the field test design
- Results for the impact assessment

ongoing

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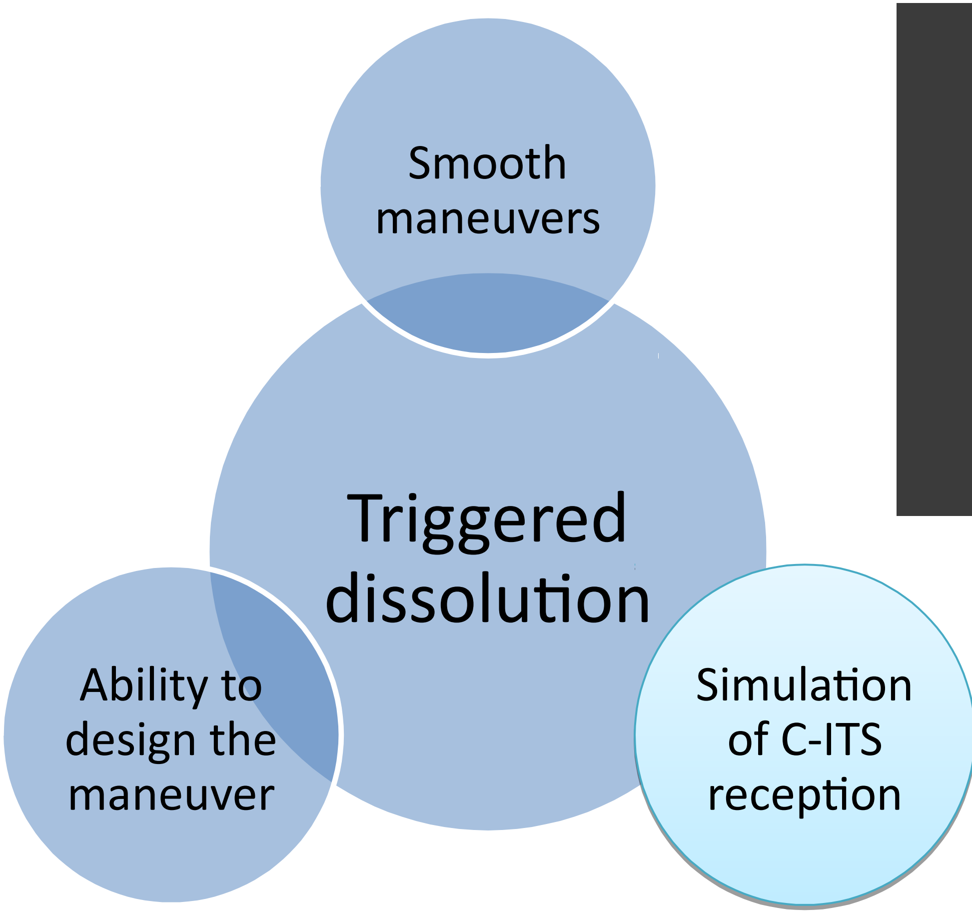
C-Roads Italy – Modeling



1. Based both on the headway/time gap and on the time window from the start of the dissolution.
2. Designed according to identified implementation logics
3. Effective both in free flow conditions and in congested conditions.

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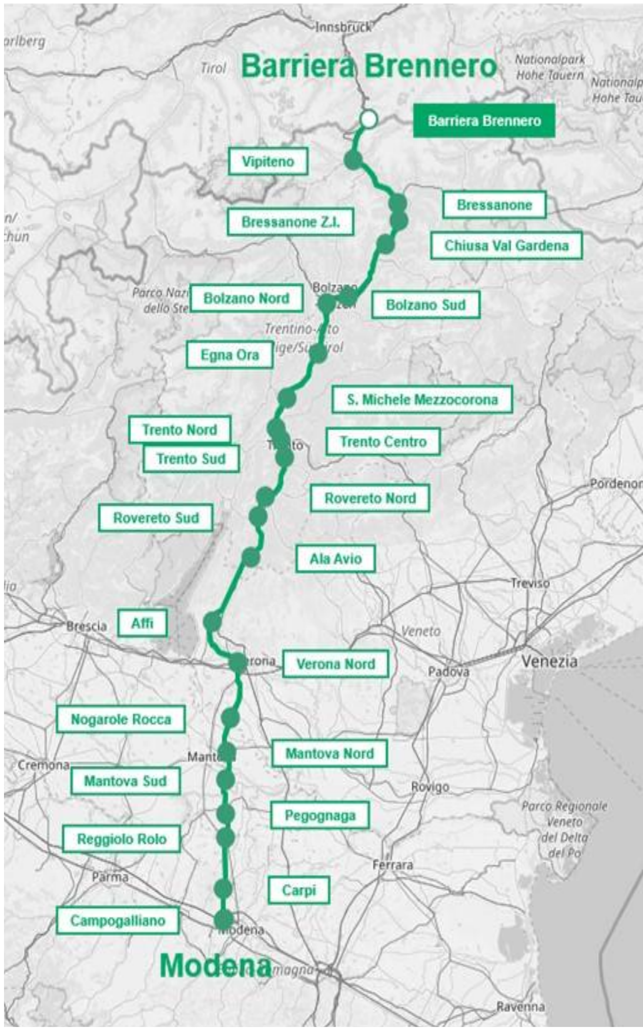
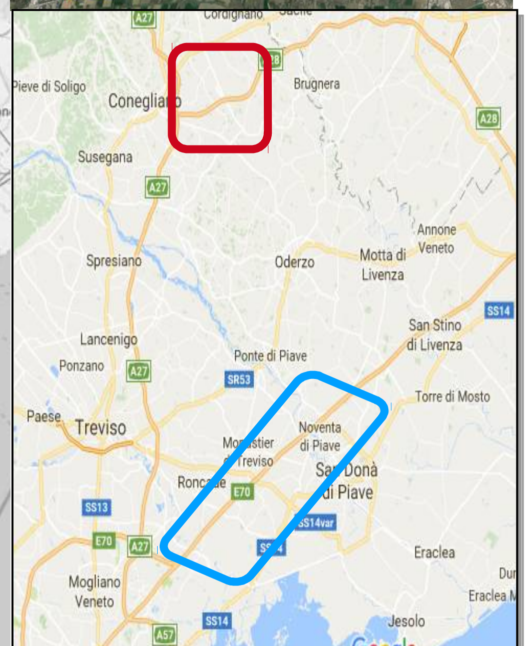
C-Roads Italy – Field Test Planning

Routes involved





Double approach

Planned	On the route

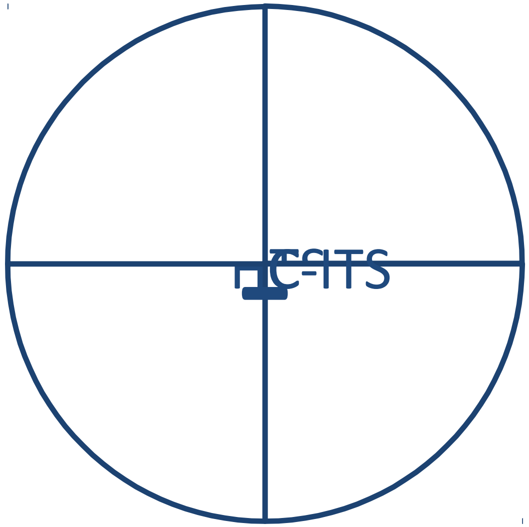
Data collection

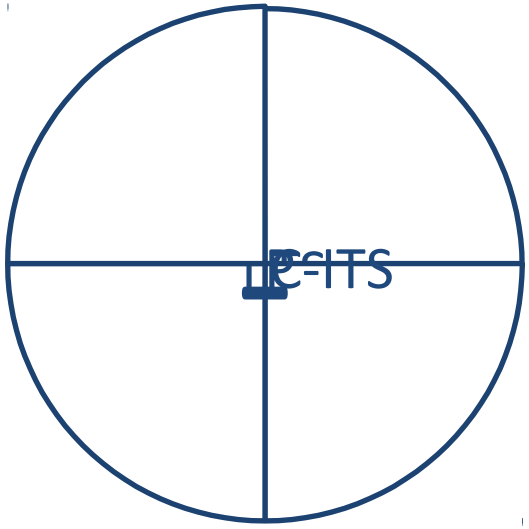
Sensors + Can Bus	Can Bus + self reporting

C-Roads Italy – Field Test Planning

7 Light vehicles

- **2** Equipped with the Highway Chauffeur system and for the reception of C-ITS
- **5** Equipped only for the reception of C-ITS





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C-Roads Italy – Field Test Planning
Planned approach

Fleet of vehicle passing through each Use Case

- **1 HC vehicle** with the system activated with C-ITS reception
- **1 HC vehicle** with the system activated without C-ITS reception
- **3 cooperative vehicles** with C-ITS reception
- **2 cooperative vehicles** without C-ITS reception
- **4 trucks** equipped for truck platooning, with different compositions

Having the whole fleet passing through the same section should ensure that every vehicle is driving through the same traffic conditions and through the Use Case layout, this way the data collected from the Can Bus should be comparable.

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C-Roads Italy – Field Test Planning
On the route approach

Data from un-planned events

Can Bus Data

High number of kilometers driven through the whole trial

Pre-compiled sheets to be handled to the drivers

Analysis only on events ascribable to the Use Cases

Focus of the analysis only on relevant scenarios

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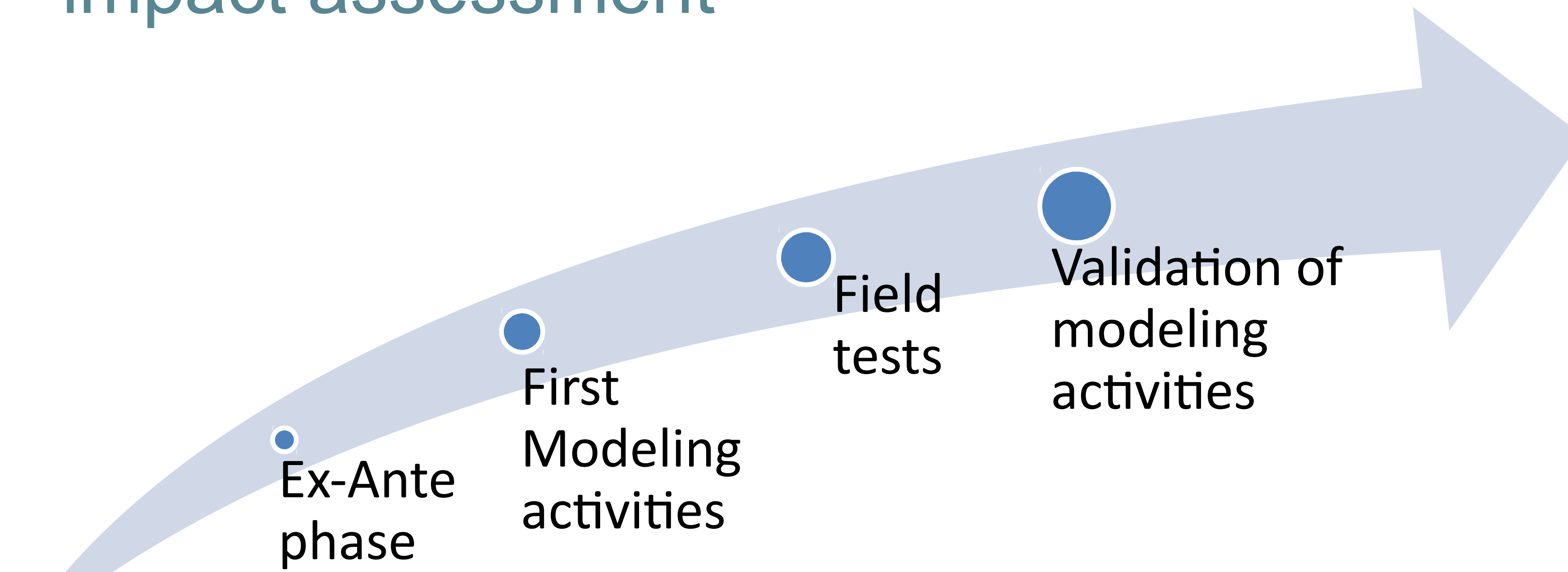
C-Roads Italy – Overview of the impact assessment



- Definition of implementation logics and **KPIs**
- First set of results to identify the best **operational logics**
- **Main impact assessment** and behavioral validation
- **Widening and upscaling** of the results

C-Roads Italy – Ex-Ante activities

Jointed implementation KPI

Main changes in behavior	
Lane change	• Lane change point • Maximum Steering Angle/Action • Maximum deceleration • Minimum Time To Collision • Number of interrupted lane char • Istantaneous acceleration/decele • Maximum lateral acceleration • Time Gap/Relative speed difference chosen for the lane changing maneuvers
Longitudinal behavior / Speed Adaptation	• Average Speed & Speed Standard • Instantaneous acceleration/decel • **Time gaps held** • Time gap accuracy/stability • Minimum Time To Collision • **ber of Cut-ins/Km for each** • um jerk
System disengagemer	• **nber of Cut-ins/Km for each** • **umber of dissolutions/disenga** **time gap** • **Time needed to dissolve the pla** • **Traffic densities below which th be maintained** • **Number of kilometers with the s**

Expected results according to the EAP

- **Traffic Efficiency**: Journey time, segment capacity, change in bottleneck congestion, **performance of the two systems**, etc.
- **Environment**: CO_2 emissions, fuel consumption, **number of kilometers in formation**, etc.
- **Safety**: Number and severity of crashes, number of safety-critical events (TTC), **number of take-over maneuvers**, etc.

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References

Studer L., Agriesti S., Gandini P., Marchionni G., Ponti M. (2019). Impact assessment of cooperative and automated vehicles. In: Lu, M. (Ed.) (2019). Cooperative Intelligent Transport Systems: Towards High-Level Automated Driving. IET (Institution of Engineering and Technology), London. ISBN: 978-183953-012-8 (Print) / 978-183953-013-5 (eBook)

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Studer L., Agriesti S., Ponti M. et al., “Evaluation approach for a combined implementation of Day 1 C-ITS and Highway Chauffeur—v.1.0.,” Ex-Ante Evaluation Report, C-Roads Italy Platform, 2018.

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THANK YOU FOR YOUR ATTENTION

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