PRISSMA Project
Plateforme de Recherche et d'Investissement pour la Sûreté
et la Sécurité de la Mobilité Autonome
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[L4.2 & 4.3] REAL CONDITION TESTS METHODS: INFRASTRUCTURE ANALYSES, PATHWAY SELECTION CRITERIA AND DEFINITION OF RELEVANT SCENARIOS

Méthodologie d'évaluation des tests en conditions réelles et définition des scénarios de tests pertinents - Identifications des critères de choix des parcours, infrastructures et équipements

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Abstract: This document describes the intermediate state of the implementation of proofs-of-concept (POC) that aim at demonstrating the use of simulation tests during the homologation and certification processes of autonomous vehicles. The described method takes into account the specificities of real life testing, in complementarity with simulation and closed loop testing. Two POC are currently under development in the framework of the PRISSMA project.

Résumé : Ce document décrit l'état intermédiaire de la mise en œuvre des preuves de concept (POC) qui visent à démontrer l'utilisation des tests de simulation lors des processus d'homologation et de certification des véhicules autonomes. La méthode décrite prend en compte les spécificités des tests en conditions réelles, en complémentarité de la simulation et des tests en circuit fermé. Deux POC sont actuellement en cours de développement dans le cadre du projet PRISSMA.

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Definitions and Acronyms

Definitions

Dynamic Driving Task (DDT)	All operational and tactical functions performed in real time required for vehicle movement, including [1]: 1) control of the lateral and longitudinal movement of the vehicle, 2) monitoring of the road environment 3) reaction to events in the roadway environment, 4) preparation and reporting of maneuvers, 5) activation of visibility functions. NOTE: Excluded are strategic functions such as trip scheduling, definition of times and positions of departure and arrival points
OEDR	DDT subtasks that include monitoring the driving environment (detecting, recognizing and classifying objects and events), as well as executing an appropriate response to such objects and events [1].
Planned event	A situation that is known in advance, for example, at the time of activation, such as a crossing point (e.g., highway exit, etc.) and requires a transition request [1]. "Planned Event: A scheduled or otherwise anticipated occurrence, such as a construction zone or parade, that may affect the performance of the driving automation system, and about which information is available from an external source (e.g., navigation map, traffic management center) in advance of the ADS-DDT engaging the DDT for that trip."
Unexpected event	A situation that is not known in advance, but which is assumed to be highly likely to occur, e.g., road work, inclement weather, approach of an emergency vehicle, lack of lane markings, falling truck load (collision), and which requires a transition request.

Acronyms

ADS: Automated Driving System
AI: Artificial Intelligence
ALKS: Automated Lane Keeping System
ARTS: Automated Road Transport System
DDT: Dynamic Driving Task
GRVA: Working Party on Automated/Autonomous and Connected Vehicles (at UNECE)
LOM: Loi d'Orientation des Mobilités (French Law: Mobility Orientation Law)
MRC: Minimal Risk Condition
MRM: Minimal Risk Manoeuver
NATM: New Assessment/Test Method
NHTSA: US National Highway Traffic Safety Administration
POC: Proof of Concept
PRA: Preliminary Risk Analysis
ODD: Operational Design Domain
OEDR: Object and Event Detection and Response
RSU: Road Side Unit
UNECE: United Nations Economic Commission for Europe

1 INTRODUCTION

PRISSMA WP4 is focused on real world test of systems of systems integrating AI (automated vehicle, infrastructure, supervision).
This deliverable presents a set of methods and principles to be used to demonstrate the safety of an Automated Road Transport System (ARTS)

The P2C pathway supporting the two experiments: Paris2Connect is a fully operational urban infrastructure on a 3.5 kilometers pathway in the 12th and 13th districts of the capital.
This route connects the 3 stations of Paris Gare de Lyon, Paris Austerlitz and the station of Bercy - POPB. This route is therefore in an urban dense area.

These methods are applied to two type of use cases:

- RATP: Validation of environment analysis algorithms based on infrastructure data in connection with supervision, for an autonomous mobility service
- VALEO: Validation of decision algorithms embedded in a level 4 automated vehicle

The tests in real conditions make it possible to guarantee the representativeness of the tests compared to the target operating site.

Ideally, the work of PRISSMA WP4, which focuses on real-world tests of automated vehicles integrating AI, should have been preceded by the completion of the WP1 project, which establishes a generic methodology for ARTS safety demonstrations. However, to try and meet the PRISSMA schedule, WP4 is being engaged at the same time as WP1. The WP4 project involves two types of use cases, RATP and VALEO, and the methods presented in WP4 will be applied to these cases to demonstrate ARTS safety.

Our approach is two-fold:

- Top down: in the structure of PRISSMA project, WP4 should be based on the WP1 through a generic methodology. A version of deliverable 1.3 is planned for september 2023.
- Bottom-up: exploring complementary of real conditions environment tests with simulations and closed environment. This approach helps to co-construct and validate methodology as deliverables of WP1 take time and need an operational validation.

At the end, the general methodology will give the guidelines to build scenarios for AI evaluation in simulation (WP2), on tracks (WP3) and in real conditions (WP4).

Since the WP4 was engaged simultaneously with WP1, and the methodologies for ARTS safety demonstrations were still being developed during the WP4 project. Therefore the final analyses of the WP4 project will need to consider possible divergences between the methodological principles stated in WP1, his evaluations and the realization that will have been performed in the context of WP4.

2 METHOD PRESENTATION

2.1 Legal context

The French decree 2021-873 of June 2021 29th [2] defines the safety demonstration to be done to deploy and operate an Automated Road Transport System (ARTS).

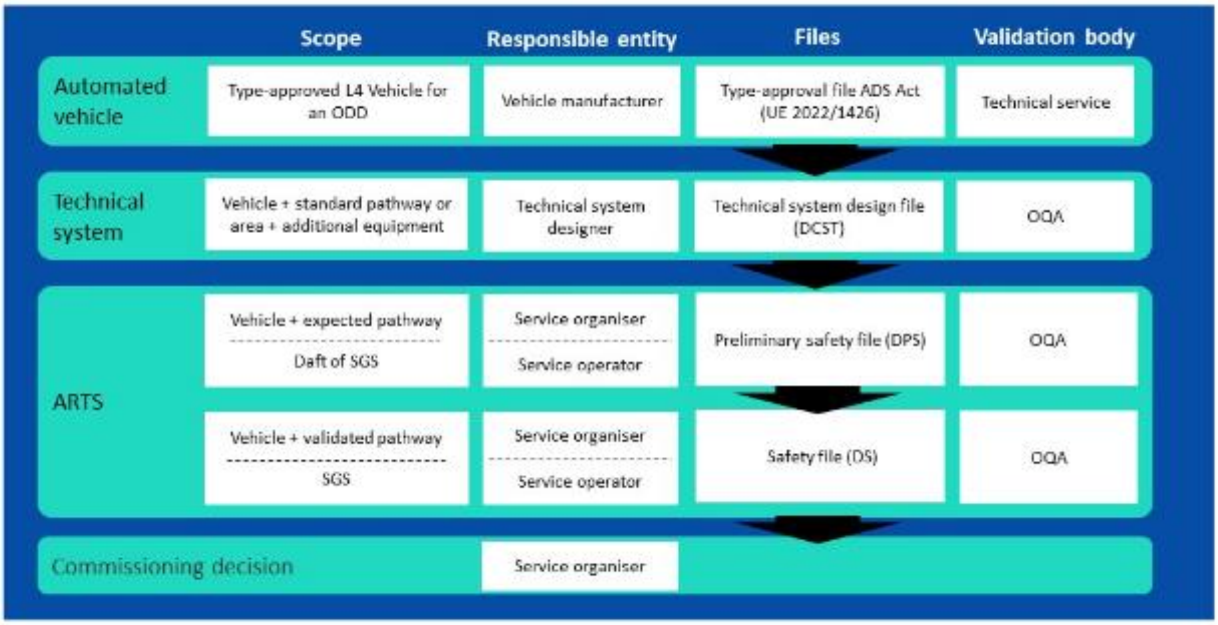


Figure 1: French decree 2021-873 of June 29th, 2021, [2] demonstration steps to obtain commissioning

PRISSMA WP4 focuses on real world tests.

The ADS act (UE 2022-1426) [3] defines the procedures and the requirements for automated driving systems type-approval. The vehicle ADS type-approval documentation will be mainly based on tests done in simulation and on tracks. Moreover, the New Assessment Test Method (NATM) documentation prepared by UNECE GRVA working group recommends the use of real word tests to validate an ADS.

2.2 Principles

The Master document [3] about NATM gives the following information about real-world tests:

The real-world tests of an ADS are done on public roads to assess the capabilities and compliances of the systems with the safety requirements. Usually, the roads are chosen to belong to the ODD of the systems.

These tests are processed with a safety driver who is monitoring the operations and ensure the ADS is functioning safely. The safety driver is able to take control of the driver task when detecting an error.

Real-world testing could be used to assess aspects of the ADS performance related to its capability to drive in real traffic conditions, or to evaluate its performance at some ODD boundaries.

Moreover, real-world testing can be used to encounter or detect unknown traffic scenarios.
However, the ADS shall be mature enough to be released on public roads. It means that its performances have been previously tested by simulation or on tracks.

Strengths	*Weaknesses*
• High environmental validity – allows for validation of the vehicle in its intended ODD(s) and the diverse conditions these may present. • Can be used to test scenarios elements, such as weather and infrastructure (e.g., bridges, tunnels), that are unavailable through track testing • Real-world testing may be used to validate the simulation and track-testing by comparing an ADS' performance within a simulation and track test with its performance on in a real-world environment when executing the same scenario. • Can be used to assess aspects of the ADS performance related to its interaction with other road users, e.g. maintaining flow of traffic, being considerate and courteous to other vehicles. • Model, single software, and toolchain validation	• Restricted controllability – Public-road scenarios afford a limited amount of control over ODD conditions. • Restricted reproducibility – Public-road scenarios are difficult to replicate exactly in different locations. • Restricted repeatability – Public-road scenarios are difficult to repeat exactly over multiple iterations. • Limited scalability – Public-road scenarios may not scale up sufficiently. • Costly but not as costly as track testing – Requires a number of resources and is time-consuming • Potential impact on traffic and safety authorities • New competencies may need to be developed by authorities • Safety risks: on-road testing could subject test personnel and the public to significant risks of unsafe behavior.

Table 1: Strength and Weaknesses of the Real-World Test Pillar of the NATM [3]

Within the PRISSMA project, work packages are defining a complete method to validate an ARTS with a focus on the safety and security of its AI dependant functions. WP4 is focused on real-world tests and the methods shall consider inputs form the other WPs. WP2 is concentrating on simulations and WP3 on track testing. PRISSMA WP1 is currently writing recommendations to define a test program with simulation, track testing and real-world tests.
WP8 is currently producing a taxonomy for the Operational Design Domain and the OD operational domain (cf. Figure 2). The ODD is related to the vehicle design. The OD taxonomy is developed to describe the pathway where the ARTS is deployed. The safety demonstration principle is to prove that the OD (the pathway) is include in the ODD of the vehicle.
The WP8 taxonomy is used to decompose and analyse the pathway of the PRISSMA POC in Paris. From this pathway decomposition, relevant scenarios can be defined.

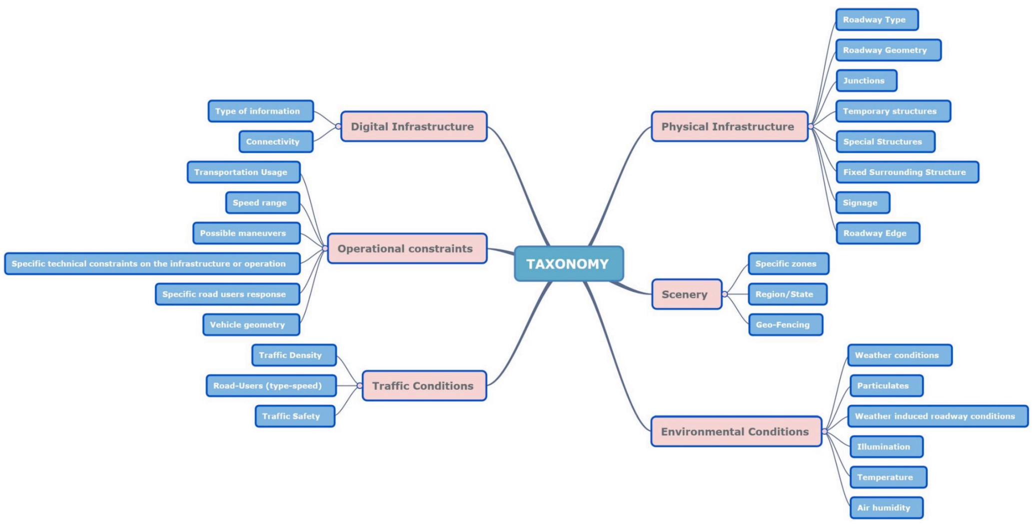


Figure 2: Taxonomy architecture according to L8.11 [4]

2.3 Pathway analysis and selection

The methodology for the analysis and selection of pathways in WP4 are based on the taxonomy defined in the deliverable 8.11. The objective is to describe the P2C pathway by defining the attributes of the taxonomy, mainly: physical infrastructure, scenery, environmental conditions, traffic conditions and digital infrastructure. The sub-attributes of each attribute are presented respectively in Table 2, Table 3, Table 4, Table 5 and Table 6.

Firstly, the P2C pathway is analyzed according to the description of its physical infrastructure, scenery, environmental conditions, traffic conditions and digital infrastructure.

Secondly, based on the description and analysis of the pathway performed in the previous step and the ODD of the vehicle involved in each PoC, a selection of targeted sections of the pathway is carried out. In these sections of the route, the vehicle is expected to operate in a fully autonomous and safe manner.

The result of the analysis and selection of the P2C routes is then used for the identification of scenarios in part 2.4.

Level 1 : 1 - PHYSICAL INFRASTRUCTURE		
N°	Level 2	Description
1.1	Roadway type	Road layout description
1.2	Roadway edge	Road side description
1.3	Roadway geometry	Roadway geometrical characteristics
1.4	Junctions	Type of junctions that may be encountered in the area /that may be supported by the vehicle
1.5	Temporary structures	Type of temporary structures that may be encountered in the area and that can be supported by the vehicle (constructions, works, etc.), i.e. movable structures in the area which may impact the vehicle driving task
1.6	Fixed surrounding structures	Fixed structures in the area which may impact the vehicle driving task
1.7	Special structures	Special structure in the area which may impact the vehicle driving task
1.8	Signage	Road signage that may be encountered in the area and that can be supported by the vehicle (traffic signs, traffic lights, etc.)

Table 2: Sub-attributes of Physical Infrastructure attribute

Level 1 : 2 - SCENERY		
N°	Level 2	Description
2.1	Specific zones	Corresponds to areas that may have specific speed or mobility restrictions (school, hospital, etc.), or that may lead to specific behaviours and scenarios
2.2	Region/State	Corresponds to constraints that may be related to the region/department/state in which the vehicle is travelling (speed, traffic lane, etc.)
2.3	Geofencing	Corresponds to a limitation of the areas in which the travel of ego vehicle is allowed

Table 3: Sub-attributes of Scenery attribute

Level 1 : 3 - ENVIRONMENTAL CONDITIONS		
N°	Level 2	Description
3.1	Weather conditions	type of weather (precipitation level) that may be en- countered in an area/supported by the vehicle (rain, snow, etc.)
3.2	Particulates	type of particulates that may be encountered in an area/supported by the vehicle (smoke, fog, sand, etc.)
3.3	Weather-induced roadway conditions	Roadway conditions that may be experienced in an area/supported by the vehicle (slippery road - rain, ice, snow -, snowy road, submerged road, etc.)
3.4	Illumination	
3.5	Ambient air temperature	temperature range that may be experienced in an area/supported by the vehicle
3.6	Humidity rate(level) in the air	

Table 4: Sub-attributes of Environmental Conditions attribute

Level 1 : 4 -TRAFFIC CONDITIONS		
N°	Level 2	Description
4.1	Traffic Density	Level of traffic possibly encountered on the road
4.2	Road Users (Speed & type)	Type and speed of the other road users
4.3	Traffic Safety	Any specific behaviour of road users that may impact the safety

Table 5: Sub-attributes of Traffic Conditions attribute

Level 1: 5-DIGITAL INFRASTRUCTURE		
N°	Level 2	Description
5.1	Information type	Type of information expected or provided through connectivity
5.2	Connectivity	Category and technology of the connectivity

Table 6: Sub-attributes of Digital Infrastructure attribute

2.4 Relevant scenarios

Globally, the testing environments (i.e. simulation, test tracks or open road) constrain the types of scenarios that can and must be addressed. In order to determine which relevant scenarios will be encountered during PoC operation in open road testing, the scenario methodology described in the deliverable L2.6 is also applied in the scope of WP4. This scenario management activity is broader than the simulation scope and it should allow harmonizing tests in real conditions, tests in closed track environments and tests in simulation.

The first step in all the environments is to identify potentially relevant scenarios regarding AI validation. The second steps in the scope of open road testing (WP4) have been identified during the WP4 workshops:

- Scenarios which could lead to corner cases. Yet they cannot be previously identified and will not necessarily be encountered during the PRISSMA PoC.
- Scenarios which will be encountered frequently during experimentation. The scenario should allow to analyse potential deviation due to environmental elements.

A first set of scenarios is identified on the basis of the pathway analysis of the PoC and joint expertise of PoC leading teams and scenario designers.

For each scenario, the methodology is applied. A classification is made as functional, logical and concrete scenarios. At a functional level the proposal is to categorize by type of scenario (crossing, change lane, occluded pedestrian, etc.). Subsequently the main task is to describe the logical scenario containing the relevant key frames necessary to describe the scenario:

- The first key frame is the initial scene
- Intermediate key frames identifying each step of the scenario with its trigger and KPI
- The final key frame

The identified logical scenarios allow to set the structure to gather all the concrete scenarios that are going to be encountered during the real-world tests with all their variations.

This methodology allows to collect data in a structured way and potentially compare results with the ones encountered in simulated and controlled environments.

2.5 ADS operational and tactical manoeuvres

This structured scenario approach will allow treating and tracing requirements which will be assigned to open road testing by PRISSMA methodology (WP1).

The ADS operational and tactical manoeuvres described in this section help to identify the characteristics (attributes) of the ODD of a given ADS. Table 7 presents a working list of tactical and operational manoeuvre behaviours defined by NHTSA [5].

Maneuvers	Description
Parking	ADS comes to a complete stop within a vacant parking spot; may be further qualified by parallel or perpendicular orientations, lot type (closed/open), initiation conditions, etc.
Maintain Speed	ADS maintains a safe speed set through longitudinal control with acceptable following distances
Vehicle Following and distance control	ADS identifies and follows a target vehicle at acceptable following distance while staying within a lane through longitudinal and lateral control
Lane Keeping	ADS stays within a lane through lateral control
Lane Switching/Overtaking	ADS crosses lanes or overtakes an upcoming vehicle based on a projected path or hazard (for example, overtaking slower or stopped vehicle)
Enhancing Conspicuity	ADS controls vehicle blinkers, headlights, horn, or other methods used to communicate with other drivers

Obstacle Avoidance	ADS identifies and responds to on-road hazards, such as pedestrians, debris, animals, etc
Lane Merge (Low-Speed Merge/High-Speed Merge)	ADS merges into a lane, for example from an exit ramp, by identifying a vacant lane position and matching speed
Navigate Roundabouts	ADS determines right-of-way, enters, navigates, and exits a roundabout, and communicates with other road users as necessary
Navigate Intersection	ADS determines right-of-way, enters, navigates, and exits intersections, including signalized, stop signs, 4/3/2-ways, and communicates with other road users as necessary; may include left or right turns across oncoming traffic
Navigate Crosswalk	ADS determines right-of-way, enters, navigates, and exits pedestrian crosswalks, and communicates with other road users as necessary
Navigate Work Zone	ADS determines right-of-way and traffic patterns, enters, navigates and exits work zone, and communicates with other road users as necessary
Navigate On/Off Ramps	Drive on on/off-ramps, which are typically one-way, steeply curved, and banked road segments
N-Point Turn	ADS makes a heading adjustment that involves alternating between forward and reverse movement and adjusting steering to reposition the vehicle within a tight space
U-Turn	ADS determines right-of-way, initiates, and completes a U-turn, and communicates with other road users as necessary
Follow Driving Laws	ADS complies with traffic regulations and local rules, for example, distances to be respected, speed limits, etc. These may be driving standards that vary from one region to another
Route Selection	ADS uses various information to choose the route to follow between two objectives (updating the route plan established at the strategic level)

Nota: the maneuver "Route Planning" is not included in this list and has been replaced by "Route selection", as we assume that "Route Planning" is part of strategic behaviors. Right-of-way decisions (ADS obeys directional restrictions; e.g. one-way roads and actively managed lanes) are also not considered, as we assume that they are part of "Follow driving laws".

Table 7: A working list of tactical and operational maneuvers of an ADS (non-exhaustive list, subject to change or completion). Adapted from [5]

2.6 Vehicle ODD and OEDR

2.6.1. ODD

The tactical and operational behaviors of ADSs presented in section 2.5 vary depending on where and how the ADS is intended to operate. The operating domain in which an ADS is designed to safely operate is commonly referred to as the Operational Design Domain (ODD). The ODD defines the conditions (i.e. roadway types, speed range, weather conditions, etc.) under which an ADS is designed to safely perform its Dynamic Driving Task (DDT). Therefore, the ODD will need to be closely monitored and any exit from the ODD must lead to a DDT fallback.

The deliverable L8.11 proposed a taxonomy for describing the ODD of an ADS, which is composed of six main attributes:

- **Attribute 1 – physical Infrastructure** - includes all the information related to the configuration, the state and the equipment of the physical infrastructure: Roadway type, roadway surface, roadway edge, roadway geometry, junctions, temporary structures, fixed surrounding structures, special structures and characteristics, signage;
- **Attribute 2 – Scenery** - includes all the information related to the scene, going beyond the physical infrastructure: specific zones, region/states, geo-fencing;
- **Attribute 3 – Environmental Conditions** – includes all information related to weather conditions, particulates, illumination, temperature, weather-induced roadway conditions, air humidity;
- **Attribute 4 – Traffic Conditions** – includes all information related to traffic conditions: traffic density, road users, traffic safety;
- **Attribute 5 – Digital Infrastructure** – includes all information related to digital infrastructure and connectivity (which are necessary to safely perform the DDT: Type of information, connectivity;
- **Attribute 6 – Operational Constraints** – includes all information related to vehicle capabilities: maximal/authorized speed, maneuvers, vehicle dimensions, etc.

For more details about the ODD taxonomy, the reader is referred to deliverable L8.11. Although the deliverable L8.11 provides a taxonomy for an ODD definition, the definition itself can be presented in different formats or languages. An ODD definition can be presented as a tabular checklist (see example in Figure 3) or as a textual guide (see example in Figure 4).

Although a tabular format may be easy to fill in, it may not capture the dependencies between ODD attributes; for example, "motorway road type" is an acceptable ODD attribute, but only when there is no precipitation. In a textual format, it is possible to capture conditional dependencies of ODD attributes.

In the scope of the PRISSMA project, a template in .xls format for the definition of ODD attributes is proposed. This template uses the checklist format, but the textual format can be used as a complement to capture the dependencies between ODD attributes of the ADS in the PoCs.

Attribute	Sub-attribute	Sub-attribute	Capability
Drivable area type	Motorways (M)	—	Yes
	Radial roads (A-roads)		Yes
	Distributor roads (B-roads)		Yes
	Minor roads		No
Lane specification	Number of lanes	—	Yes, minimum of two lanes
	Lane dimensions		Minimum 3.7 m
	Lane type	Bus lane	No
		Traffic lane	Yes
		Cycle lane	No
		Tram lane	No
		Emergency lane	No
		Other special purpose lane	No
	Direction of travel	Right-hand traffic	No
		Left-hand traffic	Yes

Figure 3: an example checklist for an ODD definition [6]

Drivable area

For drivable area type, we allow [motorways, radial roads, distributor roads].
We do not allow [minor roads].

Drivable area lane specification

For lane specification we allow at least [two] lanes with at least [3.7 m] width.
For lane type we allow [traffic lane].
We do not allow [bus lane, cycle lane, tram lane, emergency lane].
For direction of travel, we allow [left hand traffic].

Figure 4: an example of a textual description, with the additional possibility for capturing the dependencies between the attributes of the ODD [6]

2.6.2. OEDR

In complement to the ODD, the Object and Event Detection and Response (ODER) constitutes an important safety element of the ADS to be considered for testing in real conditions. Referred to [5], OEDR is the ability of an ADS to detect any circumstance that is relevant to the immediate driving task, as well as the implementation of the appropriate system response to such circumstance. In other words, [1] has defined OEDR as the subtasks of the DDT (Dynamic Driving Task) that include monitoring the driving environment (detecting, recognising, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to those objects and events (i.e., as needed to complete the DDT and/or DDT fallback).

When an ADS is operating within its ODD, its OEDR functions should be able to detect and react to other vehicles (both inside and outside its path), pedestrians, cyclists, animals and objects that could interfere with the safety of the vehicle. The OEDR of an ADS should also be able to cope with a wide range of reasonably foreseeable situations, including emergency vehicles, temporary work zones, and other unusual conditions (e.g., police manually directing traffic or other first responders or construction workers controlling traffic) that may impact the safe operation of an ADS.

Once an ADS has correctly detected a safety-critical object or event, it shall implement an appropriate response. Ideally, this will be a stable control action or maneuver that allows the ADS to maintain a safe avoidance distance from all relevant obstacles in the immediate proximity of the event, and continues to operate within the relevant rules and etiquette of the road, as far as possible. The identified responses that theoretically meet these criteria are presented in Table 8 and the list of objects and events and their corresponding possible responses are presented in Table 9.

Response	Description
Follow Vehicle	Implement lateral and/or longitudinal control actions to maintain a safe following distance from an immediate lead vehicle, while continuing to follow the current lane of travel
Accelerate	Implement longitudinal control actions to increase speed, as appropriate and lawful.
Decelerate	Implement longitudinal control actions to decrease speed, as appropriate.
Stop	Implement longitudinal control actions to decelerate in a safe and stable manner to a complete stop
Yield	Relinquish right-of-way to another road user
Change Lane	Implement longitudinal and/or lateral control actions to shift into an adjacent lane
Abort Lane Change	Cancel the maneuver to shift into an adjacent lane (remain in or return to original lane)
Pass	Implement longitudinal and/or lateral control actions to shift into an adjacent lane to accelerate to desired speed
Abort Pass	Cancel maneuver to shift into an adjacent lane (remain in or return to original lane)
Turn	Implement lateral and longitudinal control actions to transition from current road/lane to connecting road/lane
Shift Within Lane	Implement lateral and/or longitudinal control actions such that the ADS does not follow the center (or near-center) of the current lane but remains fully within the current lane.
Shift Outside of Lane	Implement lateral and/or longitudinal control actions such that the ADS partially or fully moves outside of the current lane of travel

	(i.e., one or more wheels cross the lane boundary)
Move Out of Travel Lane/Park	Implement lateral and longitudinal control actions such that the ADS fully exits the current active lane of travel onto a shoulder or parking lane and stops
Transition to MRC: - Return Control to Fallback-ready User - ADS Implements Minimal Risk Maneuver	 - Return longitudinal and lateral control to human occupant/driver (while providing sufficient warning) - Implement lateral and/or longitudinal control actions to achieve a minimal risk condition

Table 8: Possible responses and their corresponding description [5]

Objects	Events	Possible responses
Roadway User		
Vehicles	- Lead vehicle decelerating - Lead vehicle stopped - Lead vehicle accelerating - Changing lanes - Cutting in - Cutting out - Turning - Parking - Encroaching opposing vehicle - Encroaching adjacent vehicle - Entering roadway	- Follow vehicle, decelerate, stop, change lane, pass - Decelerate, stop, change lane, pass - Accelerate, follow vehicle - Yield, decelerate, follow vehicle - Yield, decelerate, stop, follow vehicle, change lane - Accelerate, decelerate, stop, change lane, pass - Decelerate, stop, change lane, pass - Decelerate, stop, change lane, pass - Decelerate, stop, shift within lane, shift outside of lane, change lane - Yield, decelerate, stop, shift within lane, shift outside of lane, change lane - Yield, decelerate, stop, change lane, pass /
Pedestrians	- Crossing road (inside or outside crosswalk) - Walking on shoulder	- Yield, decelerate, stop /
Pedal-cyclists	- Riding in lane - Riding in adjacent lane - Riding in dedicated lane - Crossing road (inside or outside crosswalk) - Riding on shoulder	- Yield, follow, change lane, pass - Yield, shift within lane - Shift within lane, change lane - Yield, decelerate, stop /

Non-Roadway User		
Animals	- Static in lane - Moving into/out of lane - Static/Moving in adjacent lane - Static/Moving on shoulder	- Decelerate, stop, change lane, pass, shift within lane, shift outside of lane - Decelerate, stop, change lane, pass, shift within lane, shift outside of lane / /
Debris	- Static in lane	- Decelerate, stop, change lane, pass, shift within lane, shift outside of lane
Other dynamic objects (e.g., shopping carts)	- Static in lane - Moving into/out of lane	- Decelerate, stop, change lane, pass, shift within lane, shift outside of lane - Decelerate, stop, change lane, pass, shift within lane, shift outside of lane
Signs and Signals		
Traffic signs	- Stop sign - Yield sign - Speed limit sign - Crosswalk sign - School zone - Access restriction ((e.g., one-way) - Work zone - Railroad crossing - Road humps	- Decelerate, stop - Decelerate, yield, stop - Accelerate, decelerate - Decelerate, yield, stop - School zone: Decelerate, yield, stop - Access restriction: Stop, turn, change lane, transition to MRC (ADS), move out of travel lane/park - Decelerate, yield, change lane, shift within lane, shift outside of lane - Decelerate, yield, stop - Decelerate, yield
Traffic signals	- Intersection (at grade) signal - Railroad crossing signal - School zone signal	- Decelerate, stop, accelerate, yield, turn - Decelerate, stop - Decelerate, yield, stop
Vehicle signals	- Turn signals, warning signals	/
Other Object of Interest		
Emergency vehicles	- Static - Passing on shoulder - Encroaching - Driving wrong direction - Violating precedence/right-of-way	- Decelerate, yield, stop, change lane, pass, shift within lane, shift outside of lane - Decelerate, yield, stop, change lane, shift within lane, shift outside of lane - Decelerate, yield, stop, change lane, shift within lane, shift outside of lane - Decelerate, yield, stop, change lane, shift within lane, shift outside of lane - Decelerate, yield, stop
School buses	- Lights and signs activated	

	- Stopped in lane or adjacent lane - Stopped in opposing/ undivided lane	- Yield, stop - Yield, stop
Other traffic control devices	- Cones, barrels, handheld, signs, flags, or hand signals (by safety officials)	- Dependent on scenario configuration
Other events of interest	- Operating outside of ODD	- Transition to MRC (fallback-ready user or ADS)

Table 9: List of objects and events and their corresponding possible responses [5]

2.6.3. Summary list of behavioral competencies

An ADS is responsible for performing its OEDR functions when engaged and operating in its defined ODD. It is therefore recommended to have a documented process for assessing, testing and validating the OEDR capabilities of an ADS considering its behavioral competency and its crash avoidance capability:

- Behavioral competency refers to the ability of an ADS to operate in the traffic conditions that it will regularly encounter including the line keeping of the vehicle, respect of the traffic laws, following reasonable road etiquette and responding to other vehicles or hazards (i.e. nominal driving). Prior work conducted by California PATH define a set of minimum behavioral competencies for ADSs [7], which can serve as a basis. Nevertheless, this list of behavioral competencies would be expanded to describe the set of behavioral competences that a given ADS should demonstrate and perform routinely will depend on the ADS in question, its ODD, and the assigned fallback method (minimum risk condition). It is recommended to consider all known behavioral competencies when designing, testing and validating an ADS.
- Based on its ODD, an ADS should be able to address relevant pre-crash scenarios that involve loss of control, through tracking, lane change/merge, head-on and reverse travel, rear-end collisions, run-off road, and low-speed situations such as reversing and parking. It is therefore recommended to establish a documented process for evaluation, testing and validating the ADS collision avoidance capabilities. An ADS can be expected to respond to many pre-crash scenarios, some of which have been identified by NHTSA in previous work. A summary list of behavioral competencies of an ADS is given in Table 10.

Categories of Behavioral Competencies	Specific Behavioral competencies
Tactical Maneuvers	
General	- Follow driving laws - Enhancing conspicuity (e.g., blinkers)
Parking (Note: ODD may include parking garages, surface lots, parallel parking)	- Navigate a parking lot, locate spaces, make appropriate forward and reverse parking maneuvers
Lane Maintenance & Vehicle Following (Note: ODD may include high and low speed roads)	- Vehicle following, including stop and go, lead vehicle changing lanes, and responding to emergency braking - Speed maintenance, including detecting changes in speed limits and speed advisories

	- Lane centering - Detect and respond to encroaching vehicles - Enhancing conspicuity (e.g., headlights) - Detect and respond to vehicles turning at non-signalized junctions
Lane Change (Overtake, Merge) (N.B: (Note: ODD may include high and low speed roads)	- Lane switching, including overtaking or to achieve a minimal risk condition - Merge for high and low speed - Detect and respond to encroaching vehicles - Enhancing conspicuity (e.g., blinkers) - Detect and respond to vehicles turning at non-signalized junctions - Detect and respond to no passing zones
Navigate Intersection/Roundabout/Ramp (Note: ODD may include signalized and non-signalized junctions)	- Navigate on/off ramps - Navigate roundabouts - Navigate signalized intersection - Detect and respond to traffic control devices - Navigate crosswalk - U-Turn - Vehicle following through intersections, including stop and go, lead vehicle changing lanes, and responding to emergency braking - Navigate rail crossings - Detect and respond to vehicle running red light or stop sign - Vehicles turning - same direction - LTAP/OD at signalized junction and non-signalized junction - Navigate right turn at signalized and non-signalized junctions
Navigate Temporary or Atypical Condition	- Detect and respond to work zone or temporary traffic patterns, including construction workers directing traffic - Detect and respond to relevant safety officials that are overriding traffic control devices - Detect and respond to citizens directing traffic after an incident - N-point turn
OEDR Capabilities	
Vehicles	- Detect and respond to encroaching, oncoming vehicles - Vehicle following - Detect and respond to relevant stopped vehicle, including in lane or on the side of the road - Detect and respond to lane changes, including unexpected cut-ins

	- Detect and respond to cut-outs, including unexpected reveals - Detect and respond to school buses - Detect and respond to emergency vehicles, including at intersections - Detect and respond to vehicle roadway entry - Detect and respond to relevant adjacent vehicles - Detect and respond to relevant vehicles when in forward and reverse
Traffic Control Devices and Infrastructure	- Follow driving laws - Detect and respond to speed limit changes or advisories - Detect and respond to relevant access restrictions, including one-way streets, no-turn locations, bicycle lanes, transit lanes, and pedestrian ways (See MUTCD for more complete list)) - Detect and respond to relevant traffic control devices, including signalized intersections, stop signs, yield signs, crosswalks, and lane markings (potentially including faded markings) (See MUTCD for more complete list) - Detect and respond to infrastructure elements, including curves, roadway edges, and guard rails (See AASHTO Green Book for more complete list)
Vulnerable Road Users, Objects, Animals	- Detect and respond to relevant static obstacles in lane - Detect and respond to pedestrians, pedalcyclists, animals in lane or on side of road
Failure Modes	
ODD Boundary	- Detect and respond to ODD boundary transition, including unanticipated weather or lighting conditions outside of vehicle's capability
Degraded Performance/ Health Monitoring, Including Achieving Minimal Risk Condition	- Detect degraded performance and respond with appropriate fail-safe/fail-operational mechanisms, including detect and respond to conditions involving vehicle, system, or component-level failures or faults (e.g., power failure, sensing failure, sensing obstruction, computing failure, fault handling or response) - Detect and respond to vehicle control loss (e.g., reduced road friction) - Detect and respond to vehicle road departure - Detect and respond to vehicle being involved

	in incident with another vehicle, pedestrian, or animal - Non-collision safety situations, including vehicle doors ajar, fuel level, engine overheating
Failure Mitigation Strategy	- Detect and respond to catastrophic event, for example flooding or debilitating cyber attack

Table 10: Summary List of Behavioral Competencies proposed by NHTSA [4]. The PRISSMA project can refer to this list as the state of the art. The behavioral competencies listed here provide a high-level description and may not be complete, the development of a test scenarios will certainly require more details of the ODD.

2.7 Test organisation

There are two possible frameworks to operate tests in real conditions on an automated road transport system:

- The experimentation frame with the PACTE law:

  The tests fall under the PACTE law (prior acceptance, contracting, request for authorization to the DGEC, preparation of the experiment, dry run).

As soon as the operating safety and operational objectives (speed, supervision system, etc.) have been validated, the tests can be implemented.

- The permanent framework with the Transport Code:

  In the STRMTG guide on the missions of the AQO (approved qualified organization), it introduces a pre-trial file (DPE) made by the service organizer which contains the following items:
  - titles and descriptions of the trials;
  - locations and routes involved;
  - scheduled dates or periods for the trials;
  - identification of the subsystem(s) or innovation(s) concerned and provision, where appropriate, of updates of their descriptive documents in the preliminary safety file (DPS);
  - relevant elements of the safety demonstration produced after the preliminary safety file (DPS)
  - safety file (DS);
  - presentation of the organization of the tests;
  - identification of the risks for people during the tests;
  - analysis of the risks linked to the tests;
  - description and justification of the precautions taken.

  For pre-commissioning testing, the AQO's assessment includes definition of the test program and the associated safety test specifications.

  The AQO must ensure that the risks to third parties on the pathway are controlled in the case that these tests involve vehicles circulation in automated mode of driving, formalize his agreement for the realization of these tests.

  For his assessment mission, the AQO approved for the technical domain “Global Assessment on the safety of the systems” can call upon AQOs for other technical areas.

The organization of the tests then follows the following procedure:

- Analysis of the requirements
- Description of the functional and logical scenarios (in Mosar) to be tested on the road or in the field among all the scenarios evaluated in simulation
- Validation of the scenarios in simulation
- Pre-selection of scenarios to be validated on the road or green on the basis of the probability of occurrence during the test runs
- Calculation of the test protocol and the associated test resources
- Elaboration of an analysis base concerning the identification of the variations in the system behavior and the implementation of a traceability on the environmental variations
- Carrying out runs to test the reliability of the AI bricks
- In post-processing, identification of the scenarios encountered
- Analysis of the results
    - Verification of what has been validated in simulation and on closed road
    - Return to the simulation with validation elements on open road of the encountered scenarios in order to contribute to a level of confidence / credibility in simulation

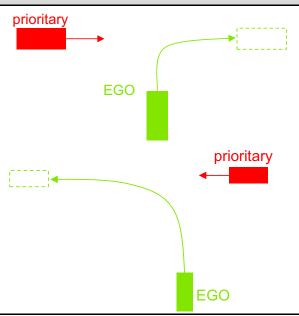
2.8 Focus on AI validation

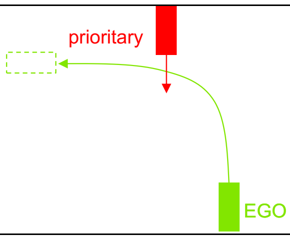
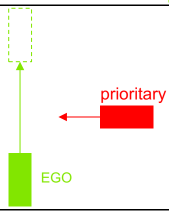
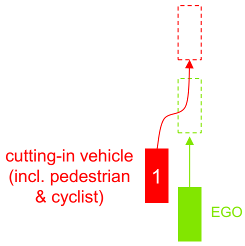
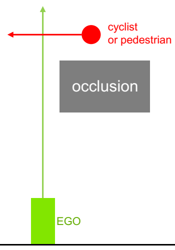
The focus here is on the performance of the ADS AI, not the performance of the automated road transport system.
To validate the performance of AI, the following metrics and pass/fail criteria are proposed. They focus on the behavioral performance of the automated driving system (i.e. performance of the vehicle driving task "DDT"), as it could be observed by the end-user or by an exterior examiner who have no prior knowledge about the vehicle.

Such performance of driving is the result of the performance of AI which may be used in one, several or all sub-systems of the ADS, depending on the automated vehicle/robot under test.
These metrics are extracted from the EU ADS regulation 2022/1426 (targeting ADS of fully automated vehicles, including for example robot-shuttles), applicable from September 2022.

- **Quantitative metrics**

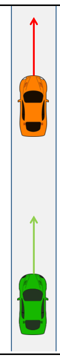
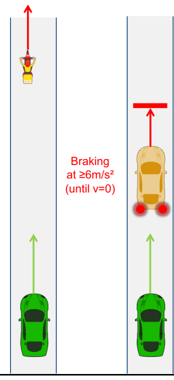
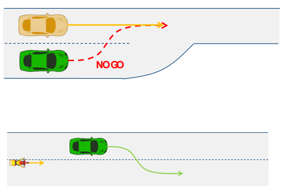
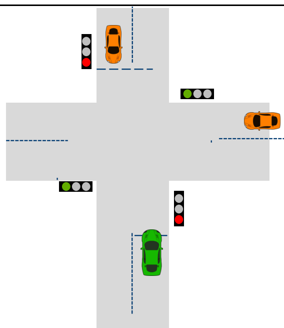
- **Qualitative metrics**

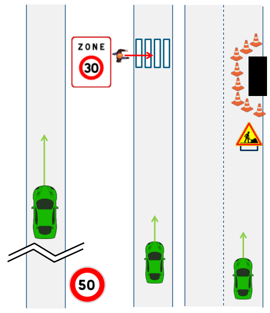
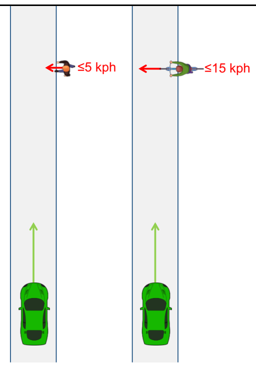
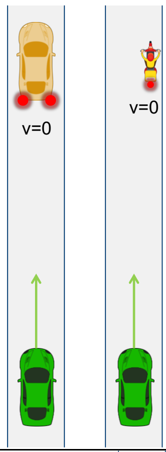
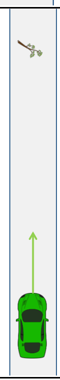
ID	Type of interaction/maneuver		Illustration	Pass criteria
QN_KPI_1	**Turning & Crossing at intersections**	Merging with privileged traffic during **turning (right or left)**		$TTC \geq TTC_{dyn} = \frac{(v_e + v_a)}{2 \cdot \beta} + \rho$ With: v_e : speed of the fully automated vehicle v_a : speed of the privileged approaching traffic β : maximum admissible deceleration for the privileged approaching traffic (3 m/s^2) ρ : reaction time of the privileged approaching (1.5s)

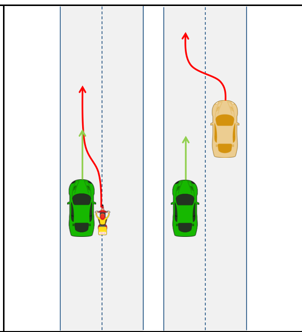
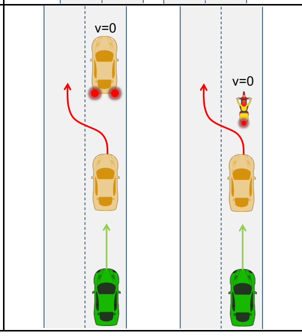
QN_KPI_2		Turning manoeuvre crossing the opposite traffic direction		$$TTC \geq TTC_{int} = \frac{v_c}{2 \cdot \beta} + \rho$$ With: v_c : speed of the privileged conflicting traffic β : maximum admissible deceleration for the privileged crossing traffic (3 m/s^2) ρ : reaction time of the privileged crossing traffic (1.5s)
QN_KPI_3		Crossing with privileged traffic		$$TTC \geq TTC_{int} = \frac{v_c}{2 \cdot \beta} + \rho$$ With: v_c : speed of the privileged conflicting traffic β : maximum admissible deceleration for the privileged crossing traffic (3 m/s^2) ρ : reaction time of the privileged crossing traffic (1.5s)
QN_KPI_4		Cutting in vehicles, pedestrians and cyclists travelling in the same direction		AV avoids collision with cutting-in road user at least when below conditions are fulfilled : $$TTC_{cut-in} \geq \frac{v_{rel}}{2 \cdot \beta} + \rho + \frac{1}{2}\tau$$ With: TTC_{cut-in} : time to-collision at the moment of the cut-in of the vehicle or cyclist by more than 30 cm in the lane of the fully automated vehicle v_{rel} : relative speed [m/s] between the fully automated vehicle and the cutting-in vehicle (positive if the ADS is faster than the cutting-in vehicle). β : maximum deceleration of the fully automated vehicle (assumed to be equal to 2.4 m/s^2 for fully automated vehicles transporting standing or not fastened vehicle occupants; 6 m/s^2 for other fully automated vehicles) ρ : time required by the fully automated vehicle to initiate an emergency braking and assumed to be equal to 0.1 s τ : time to reach the maximum deceleration β (assumed to be equal to 0.12 s for fully automated vehicles transporting standing or not fastened vehicle occupants; 0.3 s for other fully automated vehicles) The compliance with this equation is required only for road users cutting in, and only if the inserting road users were visible at least 0,72 seconds before cut-in
QN_KPI_5	Collision mitigation	Obstructed pedestrian/cyclist crossing in front of EGO vehicle		At impact, speed (v) reduced such as : $$\|\Delta v \geq 20km/h\|$$

- ## Qualitative metrics

ID	Type of interaction/maneuver	Illustration	Pass criteria

QL_KPI_1	Lane keeping	a) with a passenger car target as well as a power-two-wheeler (PTW) target as the other vehicle b) with a lead vehicle swerving in the lane c) with another vehicle driving close beside in the adjacent lane			AV does not leave its lane and maintains a stable motion inside its lane (across the speed range and different curvatures within its system boundaries)
QL_KPI_2	Follow a lead vehicle	a) across the entire speed range b) using a passenger car target a PTW target as well as a bicycle target as lead vehicle, provided standardised PTW targets suitable to safely perform the test are available c) for constant and varying lead vehicle velocities (realistic speed profile); d) for straight and curved sections of road; e) for different lateral positions of lead vehicle in the lane; f) with a deceleration of the lead vehicle of at least 6 m/s² mean fully developed deceleration until standstill			- AV maintains and restores a stable motion and a safety distance to a vehicle in front - AV avoids a collision with a lead vehicle which decelerates up to its maximum deceleration.
QL_KPI_3	Lane change	a) with the AV performing lane change to the adjacent (target) lane b) merging at lane end c) merging into an occupied lane	a) with different vehicles, including a power two-wheeler (PTW) approaching from the rear b) in a scenario where it is possible to execute a lane changing manoeuvre in regular operation c) in a scenario where a lane changing manoeuvre in regular operation is not possible due to a vehicle approaching from the rear d) with an equally fast vehicle following behind in the adjacent lane, preventing a lane change e) with a vehicle driving beside in the adjacent lane preventing a lane change f) in a scenario where a lane change manoeuvre during a minimal risk manoeuvre is possible and executed g) in a scenario where the AV reacts to another vehicle that starts changing into the same space within the target lane, to avoid a potential risk of collision		- AV does not cause an unreasonable risk to safety of the vehicle occupants and other road users during a lane change procedure - AV is able to assess the criticality of the situation before starting the lane change manoeuvre throughout the entire operational speed range
QL_KPI_4	Intersections (T,X, multi-ways or roundabout)	a) with and without traffic lights b) with different rights of way	a) without a lead vehicle b) with a passenger car target as well as a PTW target as the lead vehicle/other vehicle c) with and without approaching or passing vehicles		AV detects and adapts to a variation of different road geometries which can occur within the intended ODD across its whole speed range

QL_KPI_5	National traffic rules & changes in road infrastructure	a) different speed limit signs, so that the AV has to change its speed according to the indicated values b) signal lights and/or stop instructed by a road safety officer/enforcement agents with situations of going straight, turning left and right c) pedestrian and cyclist crossings with and without pedestrians/cyclist approaching/on the road d) temporary modifications: e.g., road maintenance operations indicated by traffic signs, cones and other signalisation, access restrictions	a) without a lead vehicle b) with a passenger car target as well as a PTW target as the lead vehicle/other vehicle		- AV complies with national traffic rules - AV adapts to a various permanent and temporary changes of the road infrastructure (e.g. road construction sites) in the entire speed range
QL_KPI_6	Collision avoidance	a) with a stationary passenger car target b) with a stationary PTW target c) with a stationary pedestrian target d) with a pedestrian target crossing the lane with a speed of 5 km/h, also in the presence of other objects relevant in the ODD (e.g. a ball, a shopping bag, etc.) e) with a pedestrian target moving a speed of up to 5 km/h within and partially occupying the lane of the AV and following the same or the opposite direction of the fully automated vehicle f) with a pedestrian target swerving in the same lane of the fully automated vehicle g) with a cyclist target crossing the lane with a speed of 15 km/h h) with a cyclist target which is travelling in the same direction with a speed of 15 km/h i) with the fully automated vehicle turning right and crossing the path of the cyclist travelling in the same direction with a speed of 15 km/h j) with a target representing a blocked lane k) with a target partially within the lane l) with one or more different types of unpassable objects relevant in the ODD (e.g., a dustbin, a fallen bicycle or scooter, a fallen traffic sign, a stationary or moving ball, etc.) m) with multiple consecutive obstacles blocking the lane relevant in the ODD (e.g., in the following order: ego- vehicle / motorcycle / car) n) on a curved section of road			AV avoids a collision with a stationary vehicle, road user or fully or partially blocked lane up to the maximum specified speed of the AV
QL_KPI_7	Response to Passable objects	"Passable object" in AV trajectory (passable object = such an object, that may be rolled over without causing an unreasonable risk to the vehicle occupants or other road users, e.g., a manhole lid or a small branch)	a) without a lead vehicle b) with a passenger car target as well as a PTW target as the lead vehicle/other vehicle		AV is not initiating an Emergency Braking with a deceleration demand greater than 5 m/s² due to a passable object in the lane relevant (for the ODD up to the maximum specified speed of the AV)

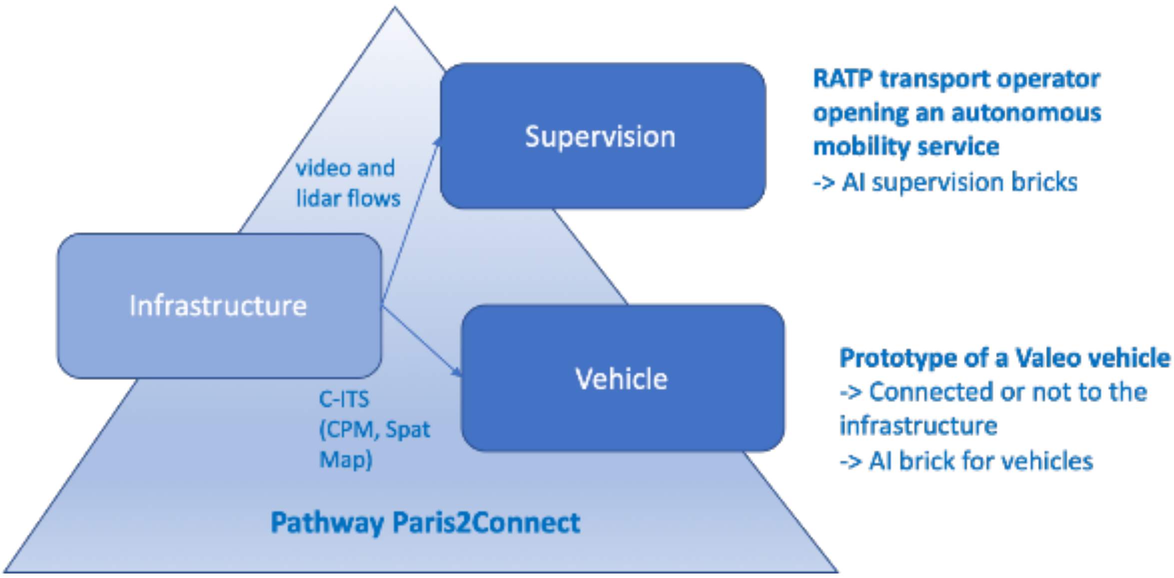
QL_KPI_8	Response to cut-in	a) with different TTC, distance and relative velocity values of the cut-in manoeuvre, covering types of cut-in scenarios in which a collision can be avoided and those in which a collision cannot be avoided b) with cutting-in vehicles travelling at constant longitudinal speed, accelerating and decelerating c) with different lateral velocities, lateral accelerations of the cut-in vehicle d) with a passenger car, PTW as well as bicycle targets as the cutting-in vehicle, provided standardised PTW targets suitable to safely perform the test are available		AV is capable of avoiding a collision with a vehicle or other road user cutting into its lane up to a certain criticality of the cut-in manoeuvre (criticality threshold defined in ***QN_KPI_4***)
QL_KPI_9	Response to cut-out	a) with a stationary passenger car target centred in lane b) with a PTW target centred in lane c) with a stationary pedestrian target centred in lane d) with a target representing a blocked lane centred in lane e) with multiple consecutive obstacles blocking the lane (e.g. in the following order: ego-vehicle – lane change vehicle – motorcycle – car).		AV is capable of avoiding a collision with a stationary vehicle, road user or blocked lane that becomes visible after a preceding vehicle avoided a collision by an evasive manoeuvre

In a further step, new metrics/KPI that are more specific to the AI performance assessment may be added (provided by Confiance.AI project, for example).

3 PROOF OF CONCEPT (POC) DEVELOPED

2 Proof Of Concept (POC) are developed:

- RATP: Validation of environment analysis algorithms based on infrastructure data in connection with supervision, for an autonomous mobility service
- VALEO: Validation of decision algorithms embedded in a level 4 automated vehicle



4 POC 1: RATP USE CASE

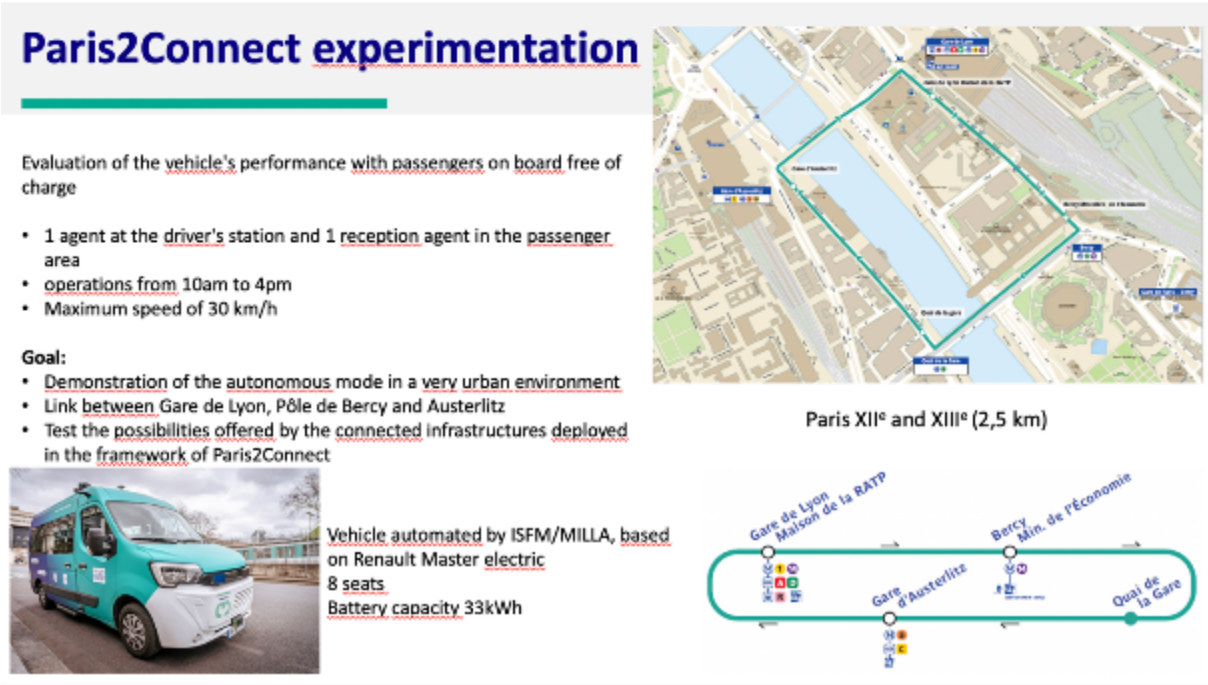
4.1 Experimentation form

The AI validation will focus on:

- The supervision and operating system
- The connected infrastructure

The automated vehicles themselves are not included

The experimentation will be carried out on the course equipped with the connected infrastructure of Paris2Connect. This will support the work for PRISSMA.



4.2 Description of pre-test requirement levels

a. Regulatory requirements:
   The tests fall under the PACTE law
b. Safety requirements:
   Run the vehicle and operate the whole experiment without risk to passengers, third party users or RATP staff
c. Quality of service requirement: no KPI, but qualitative requirements:
   i. The most pleasant passenger experience possible
   ii. Regularity of service

4.3 Zoom on what to test in PRISSMA

– Input of scenarios in MOSAR
– 3 topics to validate the relevance of infra data processing
   iii. Crowd detection
   iv. Traffic jam detection
   v. Bicycle detection

Detailed description of the RATP demonstrator

What the system considers: areas covered by infrastructures, data produced, alerts that go back to the supervision - parameters for generating an alert - number of vehicles and stopping times or very slow speed.

Reminder of the use cases of the P2C project for computer vision:

Within the Paris2Connect project, 4 use cases have been defined in order to measure the relevance and efficiency of the use of image analysis algorithms in the context of autonomous vehicle deployment:

- Evaluation of road flow and congestion: the challenge of this use case is to detect the vehicles present on the image and thus determine the flow of vehicles on a given section, with the aim of alerting the Autonomous Vehicle Supervision when congestion is created that impacts the traffic of the autonomous vehicle.
- Identification of objects or people on the path of the autonomous vehicle: the challenge is to detect the lasting presence of any immobile object located on the path of the autonomous vehicle blocking its passage or causing slowdowns.
- Identification of groups of people near the lanes used by the autonomous vehicle: the challenge is to detect groups of people over a certain period of time, to evaluate the level of dynamism and to send an alert to the Autonomous Vehicle Supervision.
- Identification of special vehicles circulating in the lanes or near the autonomous vehicle: the challenge of this use case is to detect the presence of special vehicles (firefighters, police, ambulance, autonomous vehicle) and thus to alert the Autonomous Vehicle Supervision in case of abnormal behavior, such as a prolonged presence

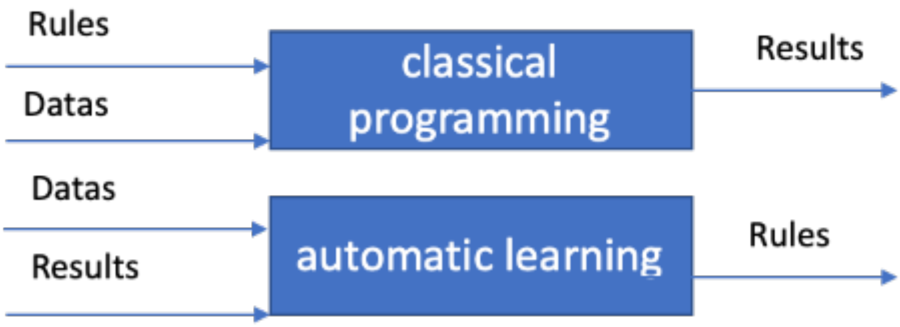
These use cases and the data from these image analyses are intended:

- To contribute to the anticipation of changes in the movement of the autonomous vehicle.
- To provide the autonomous vehicle with additional and complementary information.
- To assist the Autonomous Vehicle Supervision in the detection of events and to carry out relevant suspicions.
- To provide additional information and analysis to help in the selection of the most suitable types of sensors.

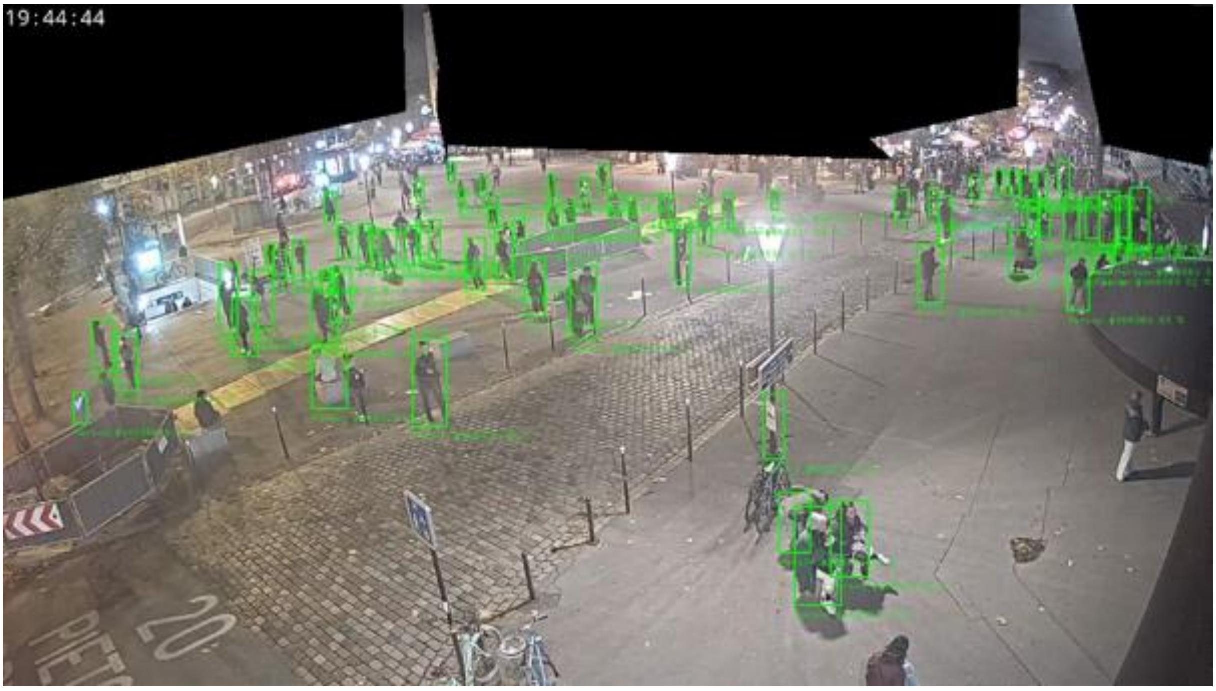
The different detection methods:

During this project, for computer vision by video camera, two detection methods are implemented.
The first one, and the one that will be mainly used for the different use cases, is the detection by Artificial Intelligence, or AI.
Indeed, some problems cannot be solved by classical programming algorithms, because they are too complex to be coded by an exhaustive list of rules and conditions.

Machine Learning and Deep Learning algorithms, which are both part of the AI category, try to solve this kind of problem. There are all kinds of them, whose fundamental principle is to try to "calibrate" themselves according to the data, as illustrated on this diagram:



Each algorithm has its own operation and parameters, but ultimately, they are "learning machines".
Thus, in this document, when we speak of detection by AI, we are referring to detection by a Machine Learning algorithm under supervised learning, i.e. it has been provided with a large number of examples.



However, this has its disadvantages:

- As it is a supervised learning, the machine is not able to learn alone, without human intervention, which requires if we want to improve the results of the algorithm to provide again a large number of examples and
- The AI is not able to detect objects for which it has not been trained.

Results:

Here are the rates obtained for the detections based on video detections:

PERSON (100 Objects)		
Very good Detection	Very false Detection	Right classification
69%	25%	100%
20%	0%	100%
100%	25%	100%
80%	20%	100%
94%	6%	100%
93%	0%	100%
75%	40%	100%
92%	0%	100%
67%	33%	100%
100%	0%	100%
79%	15%	100%

VEHICLE (107 Objects)		
Very good Detection	Very false Detection	Right classification
100%	0%	100%
100%	0%	100%
100%	0%	100%
100%	0%	100%
100%	0%	83%
80%	0%	100%
90%	0%	89%
71%	9%	80%
100%	0%	100%
88%	0%	100%
100%	0%	100%
100%	0%	100%
71%	0%	100%
100%	14%	83%
80%	11%	100%
100%	0%	100%
80%	0%	100%
92%	2%	96%

In addition, tests were performed in parallel, using pre-selected video sequences, to determine if, in the presence of an event described by the use cases, the function block correctly triggered an event.

	Congestion	Crowd	Special vehicles
Event Trigger Rate	100%	100%	100%

Useful parameters for detection:

- AI detection:
    - Min Height/Min Width:
        - Value that can range from 0% to 100%, representing the minimum height/width of the object type as a percentage of the image height/width.
        - Default value: 0%/0%.
        - Current values:

	Person	Bike	Bus	Moto	Car	Truck	Special vehicles
Min. height/Min. width	4%/1%	4%/1%	4%/1%	4%/1%	4%/1%	4%/1%	4%/1%

    - Max. height/Max. width:
        - Value from 0% to 100%, representing the maximum height/width of the object type as a percentage of the image height/width.
        - Default value: 100%/100%.
        - Current values:

	Person	Bike	Bus	Moto	Car	Truck	Special vehicles
Max. height/ Max. width	30%/30%	30%/30%	80%/80%	30%/30%	50%/50%	80%/80%	70%/70%

    - Minimal score:
        - Value that can go from 0% to 100%, representing the minimum confidence rate to be reached to validate the detection of an object by the AI.
        - Default value: 85%.
        - Current values:

	Person	Bike	Bus	Moto	Car	Truck	Special vehicles
Minimal score	30	25	25	25	40	50	85

    - Minimum Ratio/Maximum Ratio:
        - Value that can range from 0 to 10, representing the minimum and maximum ratio between the height and width of an object for it to be considered by the AI
        - Default value:
            - Minimum ratio: 0
            - Maximum ratio: 10

- Suspect Object Detection:
  - Min Height/Min Width:
    - Value that can range from 0% to 100%, representing the minimum height/width of the suspicious object/obstacle in the height/width of the image.
    - Default value: 0%/0%.
    - Current value: 3%/2%.
  - Max Height/Max Width:
    - Value that can range from 0% to 100%, representing the maximum height/width of the object type as a percentage of the image height/width.
    - Default value: 100%/100%.
    - Current value: 90%/90%.
  - Duration of immobility (s):
    - Free value representing, in seconds, both the duration used for the calculation of the background image (4 times the set duration, at each new configuration save/load) but also the duration of immobility of an object necessary to trigger an event.
    - Default value : 1 second
    - Current value : 300 seconds

Parameters for the functions:

- Intrusion function:
  - Number of objects:
    - Free value representing the number of detected objects that must be present in the defined area in order to trigger an event.
    - Used for the use cases: Engorgement / Crowds / Special vehicles
    - Default value: 1
  - Minimum duration(s):
    - Free value representing, in seconds, the minimum presence time of the number of objects (parameter defined just above) in a zone before triggering an event.
    - Used for the use cases: Blocking / Crowding / Special vehicles
    - Default value: 1 second
  - Maximum distance between 2 objects:
    - Value that can range from 0% to 100%, representing the maximum distance in percentage of the image between objects for them to be considered part of a crowd.
    - Default value: 10%.

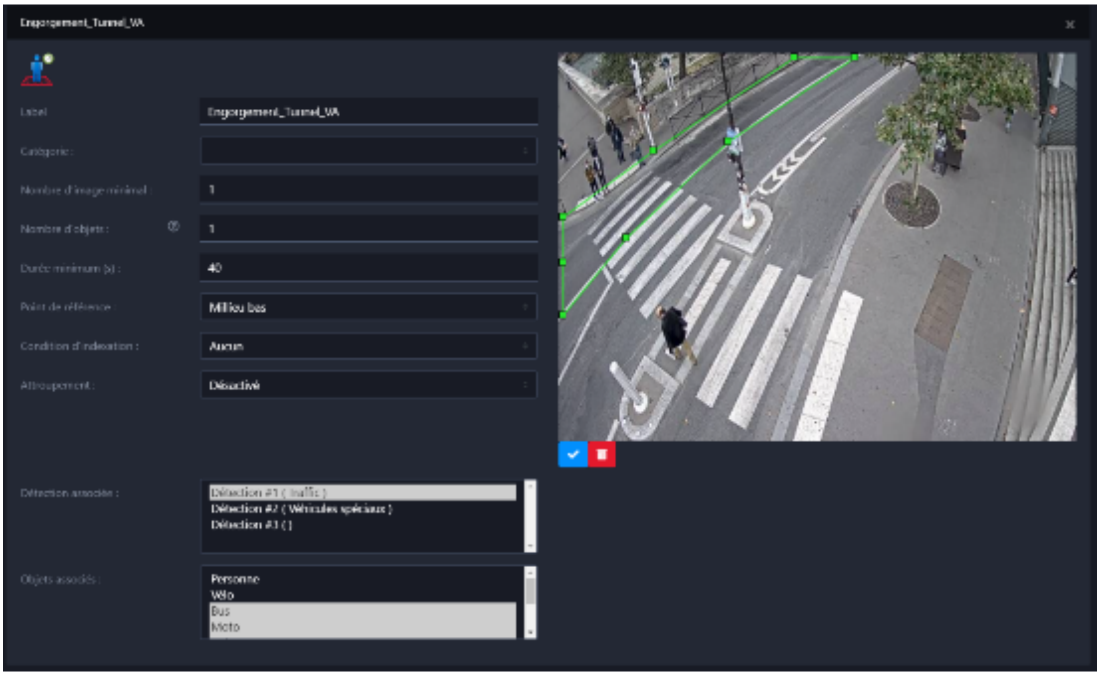
Useful parameters for the options:

Tracking Threshold:

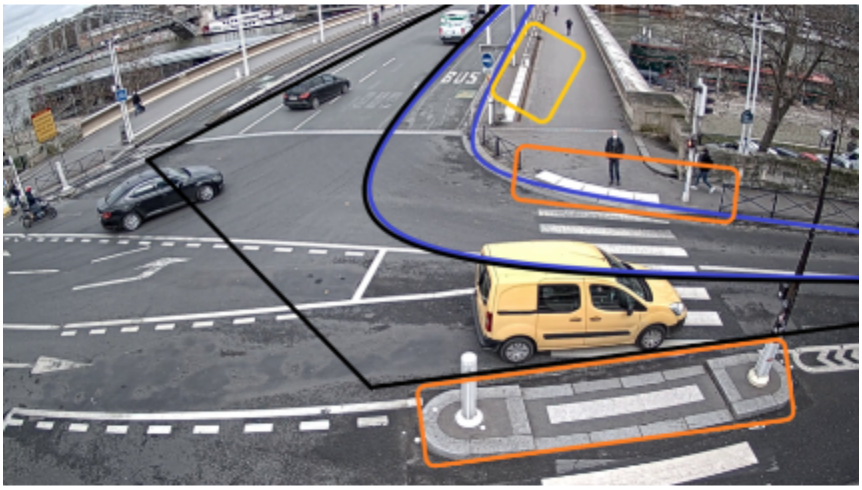
- A value that can range from 0% to 100%, representing the maximum distance as a percentage of the image that the object can travel between two images and still be identified as the same object.
- Default value: 10%.

- Number of images before disappearance of unique id:
    - Free value representing the number of images, and therefore the time, during which the AI will keep detected objects in memory, allowing an object to disappear for a few moments and be correctly re-identified when it reappears.
    - Default value: 10
    - Current value: 15
- Delay between treatment (ms) :
    - Free value corresponding, in milliseconds, to the delay between two images processed by the detection algorithms (AI and obstacles). In other words, it allows to control the number of images per second.
    - Default value: 50 ms
    - Current value: 200 ms

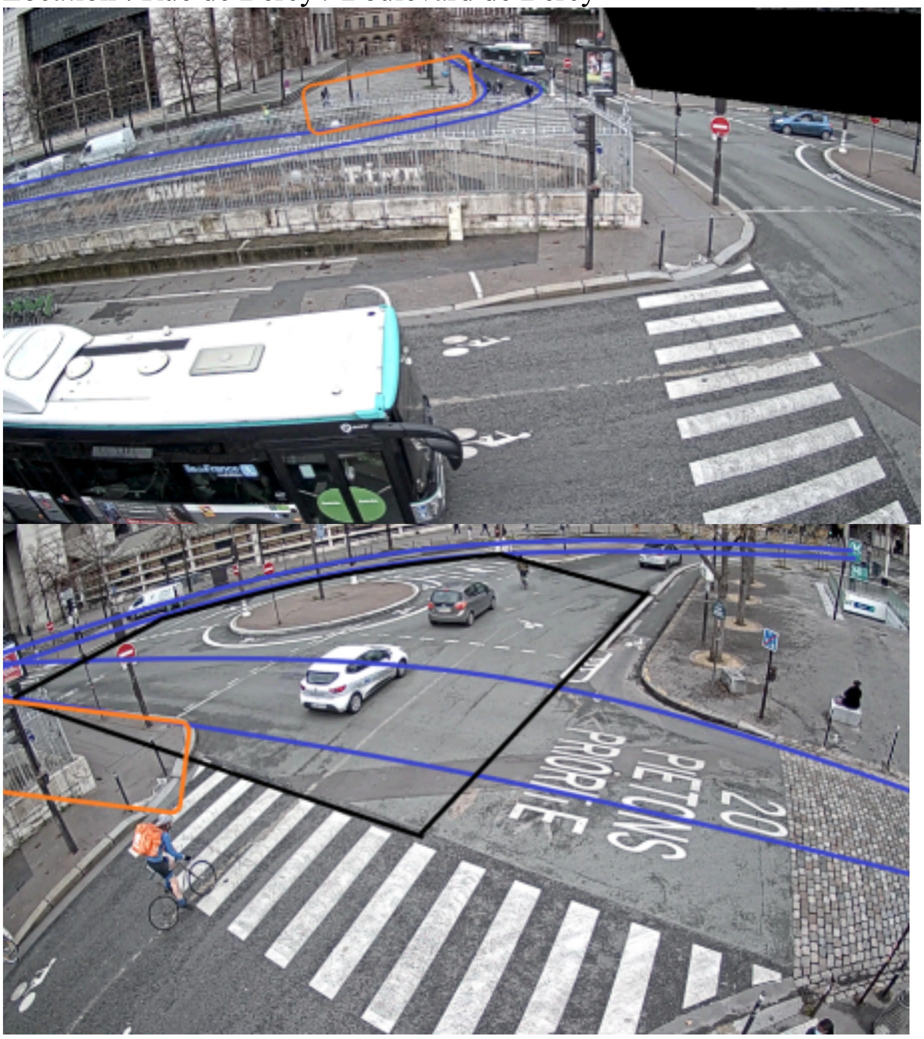
Annex 1: screen capture on supervision platform + locations on image

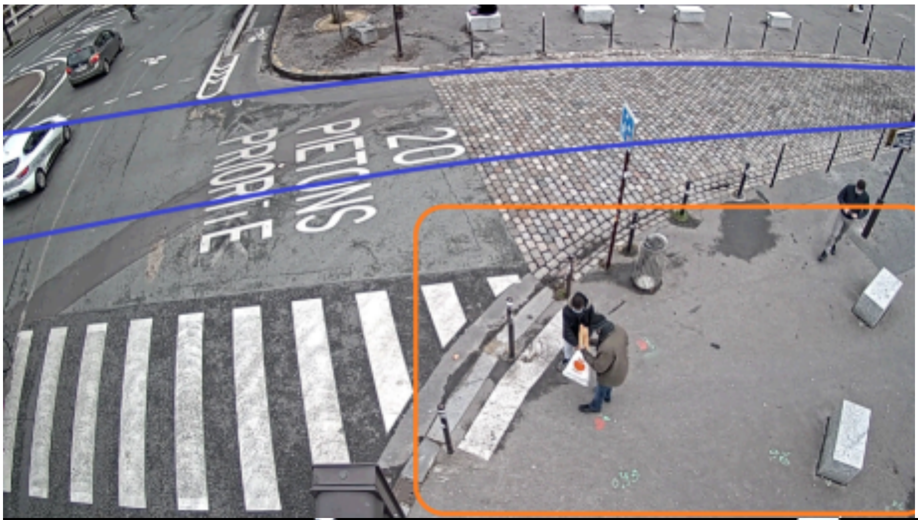


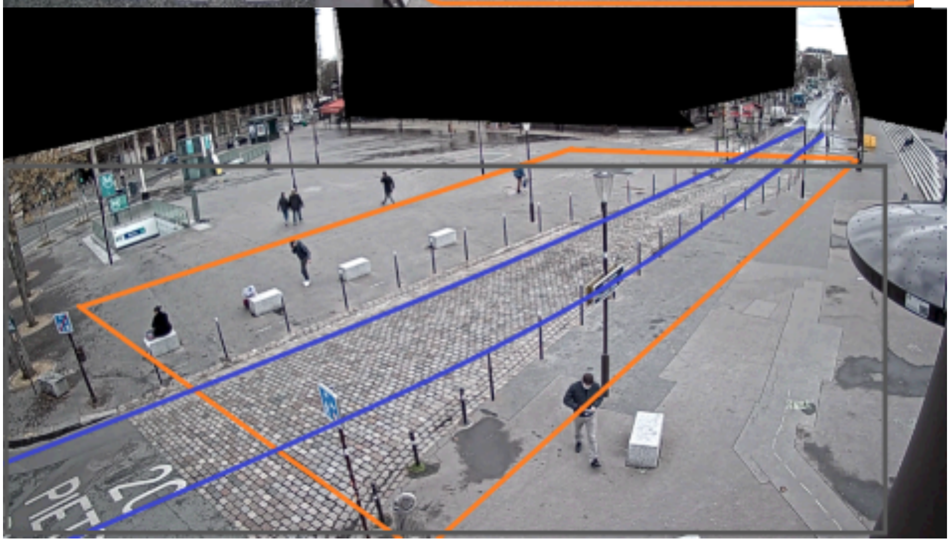
Annex 2 – Locations for RATP use cases
Smartpole n°1 detections zones with AI
Location : Quai d'Austerlitz / Pont Charles de Gaulle



Smartpole n°4 detections zones with AI
Location : Rue de Bercy / Boulevard de Bercy



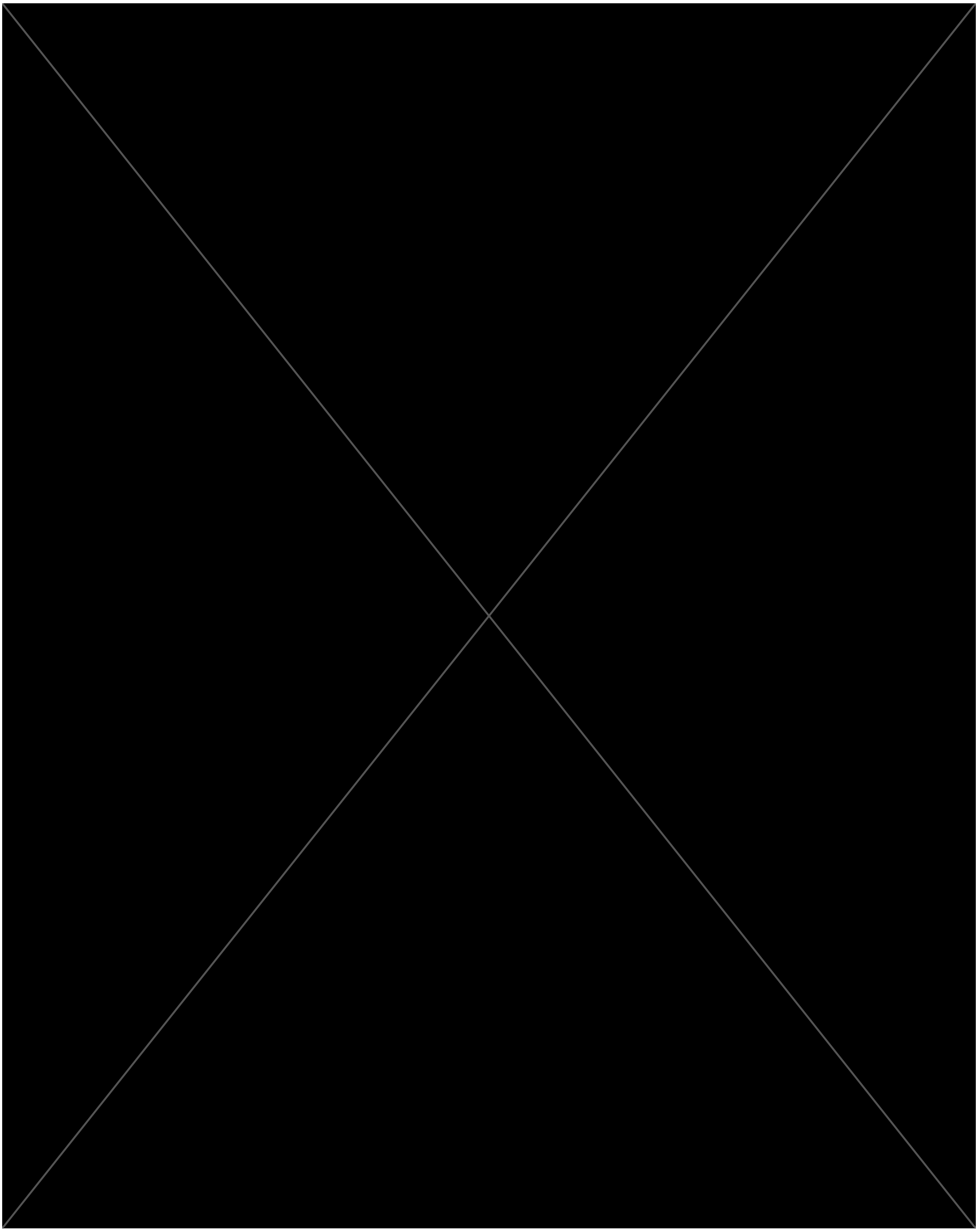


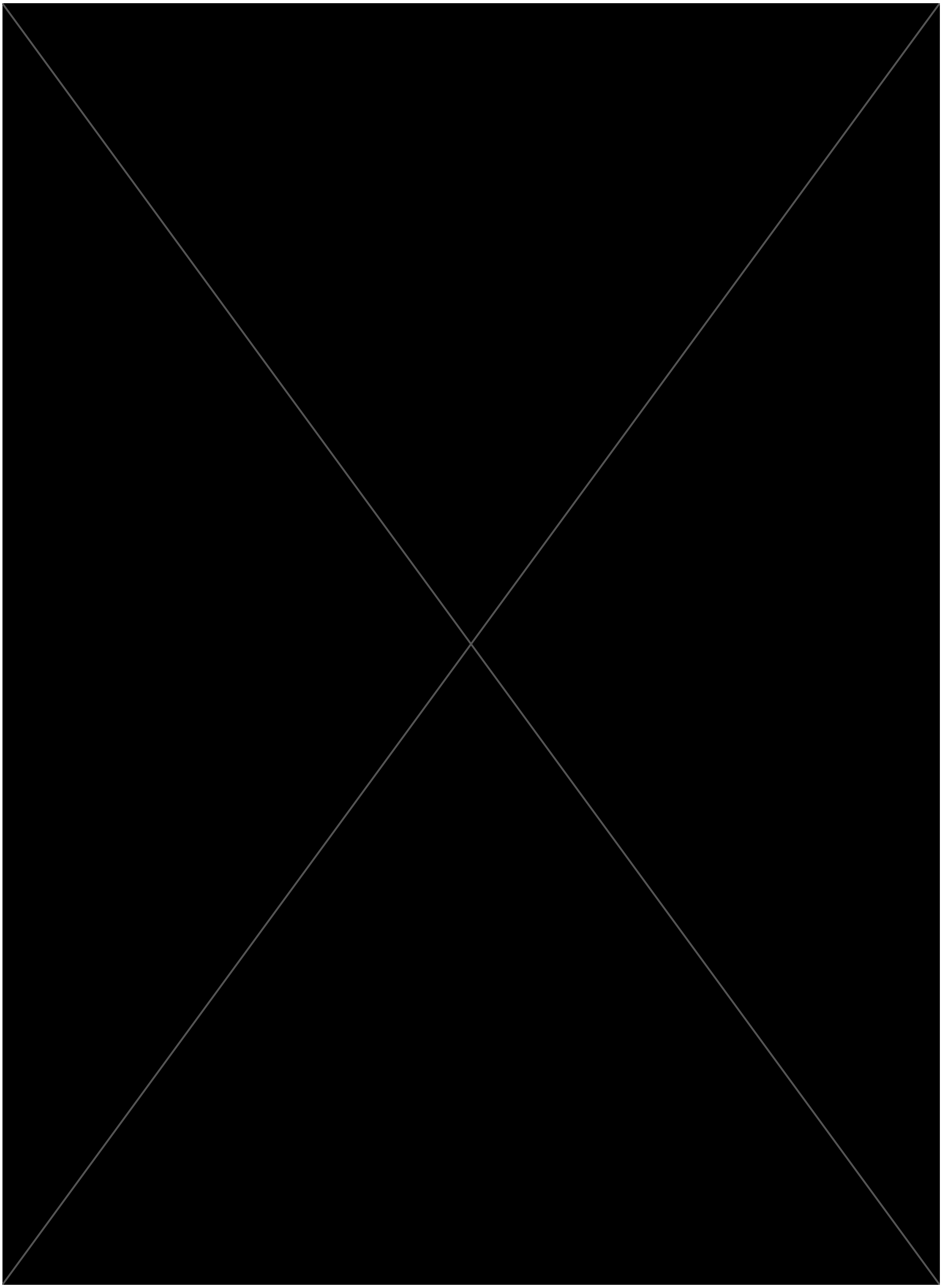


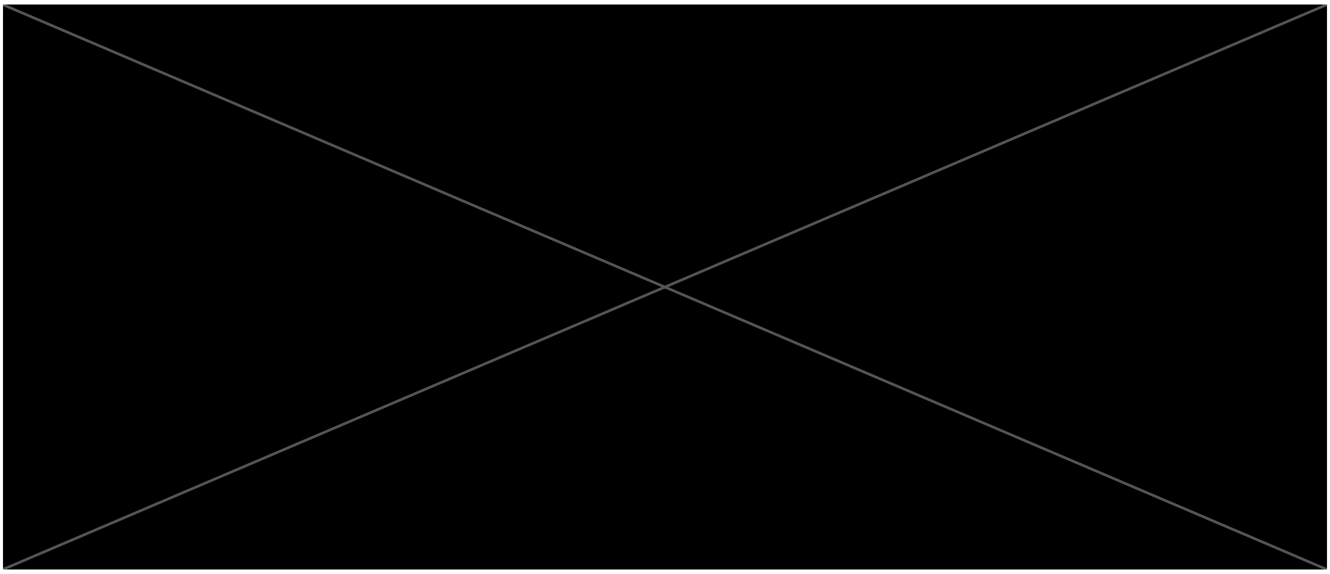
Example of JSON in algorithm output:

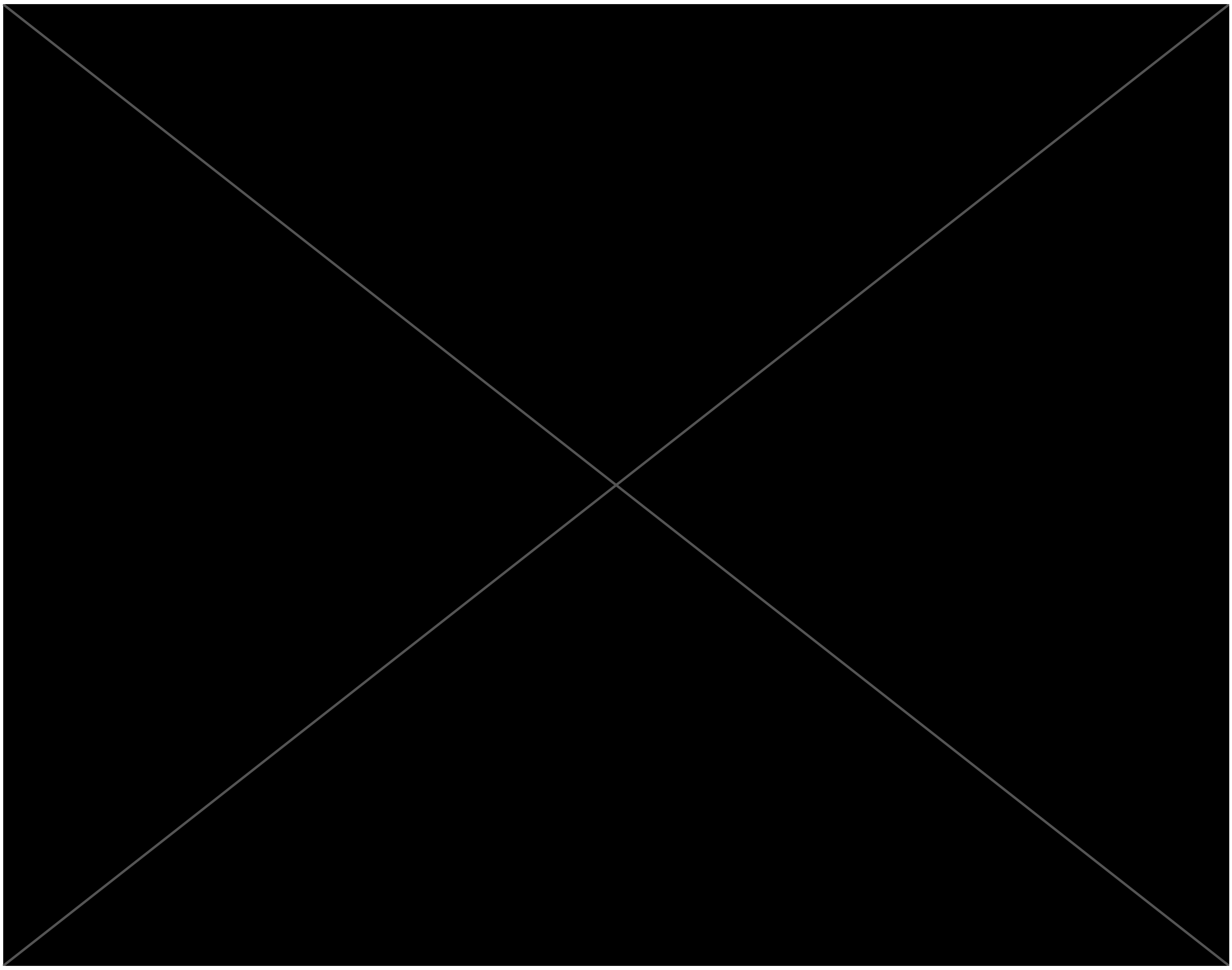

```
{	"records": [{
		"key": "0d65c2c1-9459-4d35-8807-91755eda976f",
		"value": {
			"typeEvent": "obstacle",		//Type de l'evenement : Peut etre obstacle, trafficjam, crowd ou emergency
			"eventId": "6889b336-6795-4ae1-867b-abeeaac79da8",		//ID Unique de l'evenement : Vous permet de savoir si un evenement est un nouvel evenement ou une mise à jour d'un evenement déjà en cours
			"cameraLabel": "SP11-CAM-01",		//Label caméra qui a détecté l'evenement
			"cameraId": "675c66e0-f46a-4e98-8e89-d9af344bfc86",		//ID unique de la caméra dans notre logiciel (car Label non unique)
			"zoneLabel": "Obstacle_Tunnel_VA",		//Label de la fonction qui a déclenché l'évènement
			"criticity": 0		//Non rempli
			"messageTime": "2021-08-18T14:05:41Z",		//Heure UTC de génération du message json
			"eventStart": "2021-08-18T14:05:41Z",		//Heure UTC du déclenchement de l'évènement
			"latitude": 0.0,		//Latitude déclarée du SP - FLOAT
			"longitude": 0.0,		//Longitude déclarée du SP  - FLOAT
			"score": 60,		//Taux de confiance estimé du résultat (=60% en dur pour les obstacle / moyenne des taux de confiance des objets présents dans l'evenement pour les autres evenements) - Type Integer [0-100]
			"trafficjam": {		//Engorgement

			},
			"obstacle": {		//Obstacle
				"objects": [{		// Liste des objets de l'évènement (Array JSON)
```

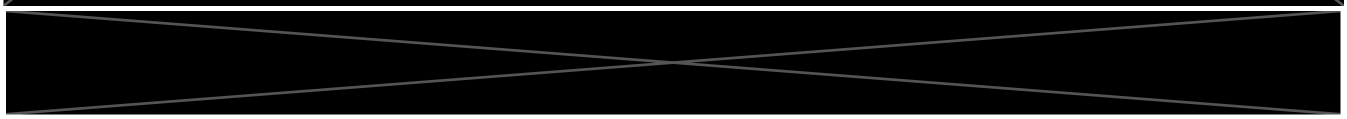
```
                                        "x": 962,               //Position X en pixel Haut / Gauche du rectangle englobant (par rapport
au Haut / Gauche de l'image) - Type Integer
                                        "y": 36,                //Position X en pixel Haut / Gauche du rectangle englobant (par rapport
au Haut / Gauche de l'image) - Type Integer
                                        "width": 99,            //Largeur du rectangle englobant (en pixel) - Type Integer
                                        "height": 44            //Hauteur du rectangle englobant (en pixel) - Type Integer
                                }]
                        },
                        "crowd": {                              //Attroupement
                                "occupancy": 8,                 //Pourcentage d'aire occupée par les rectangles englobants des objets par
rapport à l'aire de la zone de détection) - Type Integer [0-100]
                                "objects": [{                   //Liste des objets ayant déclenchés l'évènement
                                        "type": "Person",       //Type d'objet détecté (personne / véhicule)
                                        "id": 9,                //Identifiant unique IA  - Type Integer
                                        "x": 389,               //Position X en pixel Haut / Gauche du rectangle englobant (par rapport
au Haut / Gauche de l'image) - Type Integer
                                        "y": 368,               //Position X en pixel Haut / Gauche du rectangle englobant (par rapport
au Haut / Gauche de l'image) - Type Integer
                                        "width": 106,           //Largeur du rectangle englobant (en pixel) - Type Integer
                                        "height": 156,          //Hauteur du rectangle englobant (en pixel) - Type Integer
                                        "score": 96             //Taux de confiance retourné par l'algo d'IA - Type Integer [0-100]
                                },
                                {
                                        "type": "Person",
                                        "id": 19,
                                        "x": 388,
                                        "y": 535,
                                        "width": 115,
                                        "height": 148,
                                        "score": 41
                                }],
                                "moving": true                  //Attroupement agité ou non
                        },
                        "emergency": {                          //Véhicule d'urgence

                        }
                }
        }]
}
```

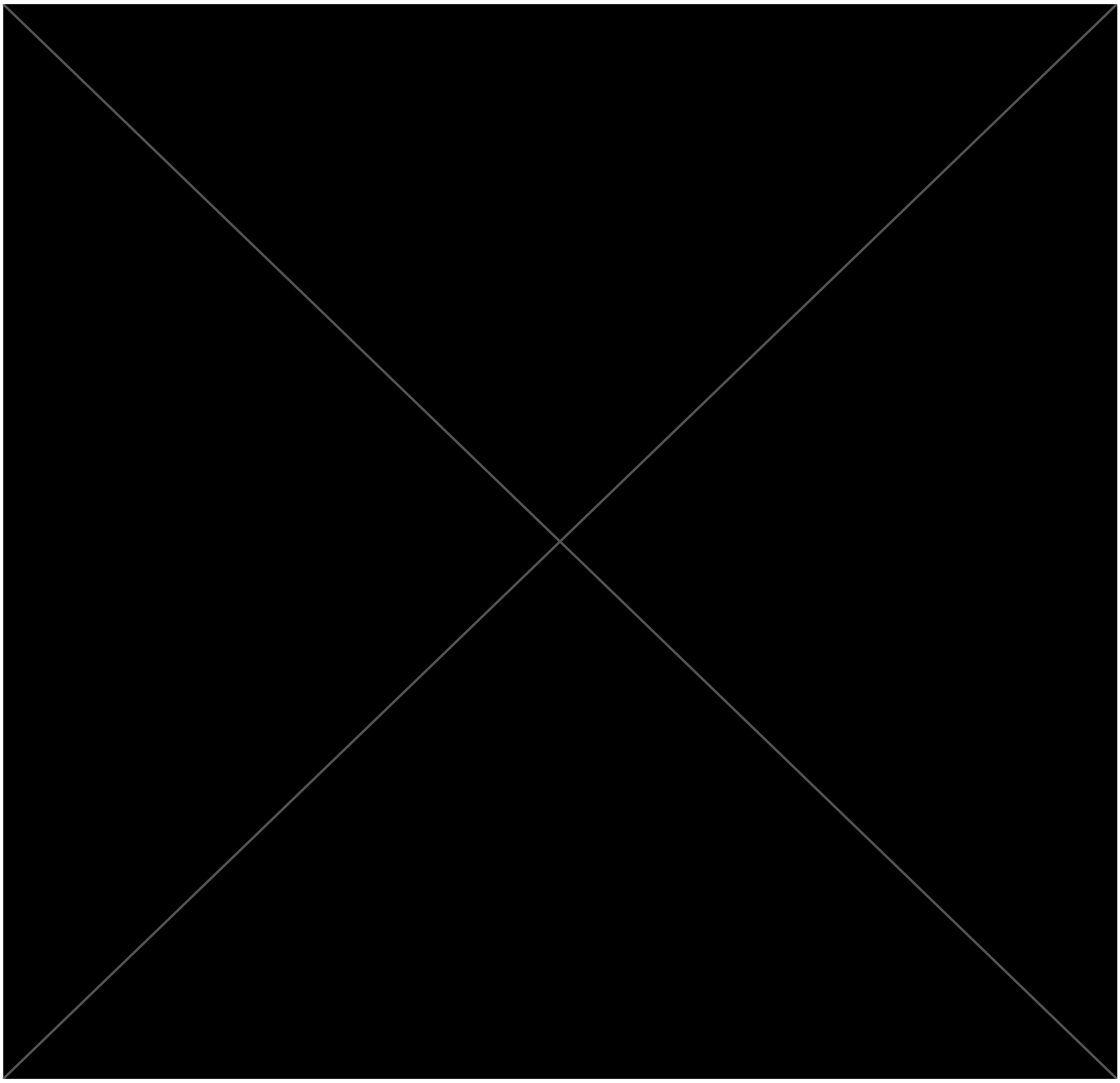


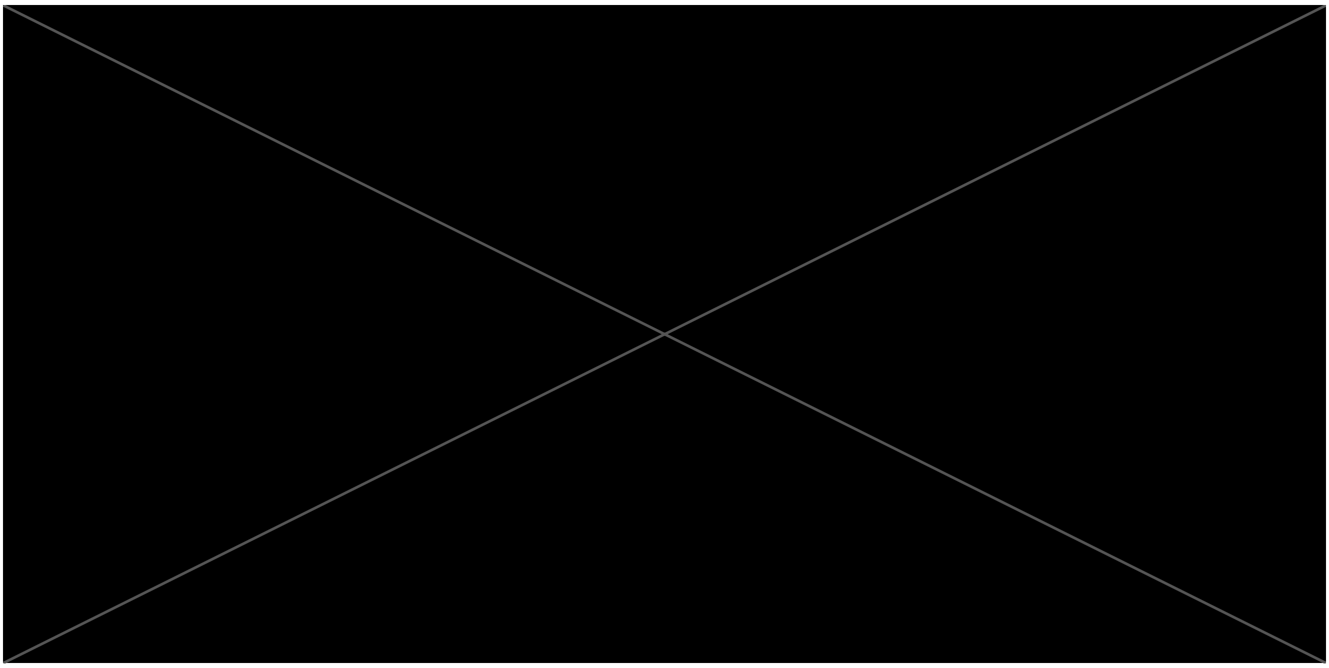


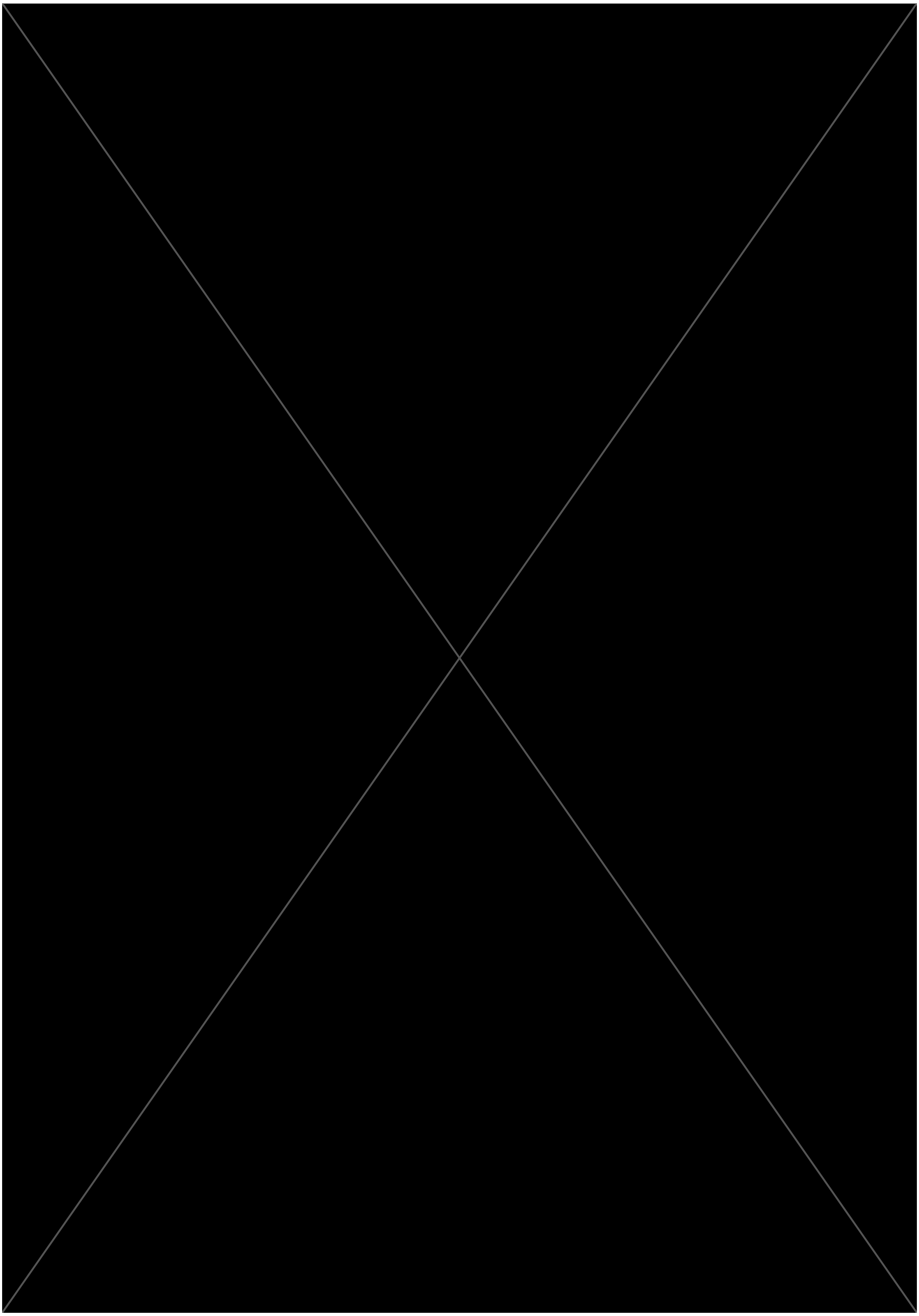


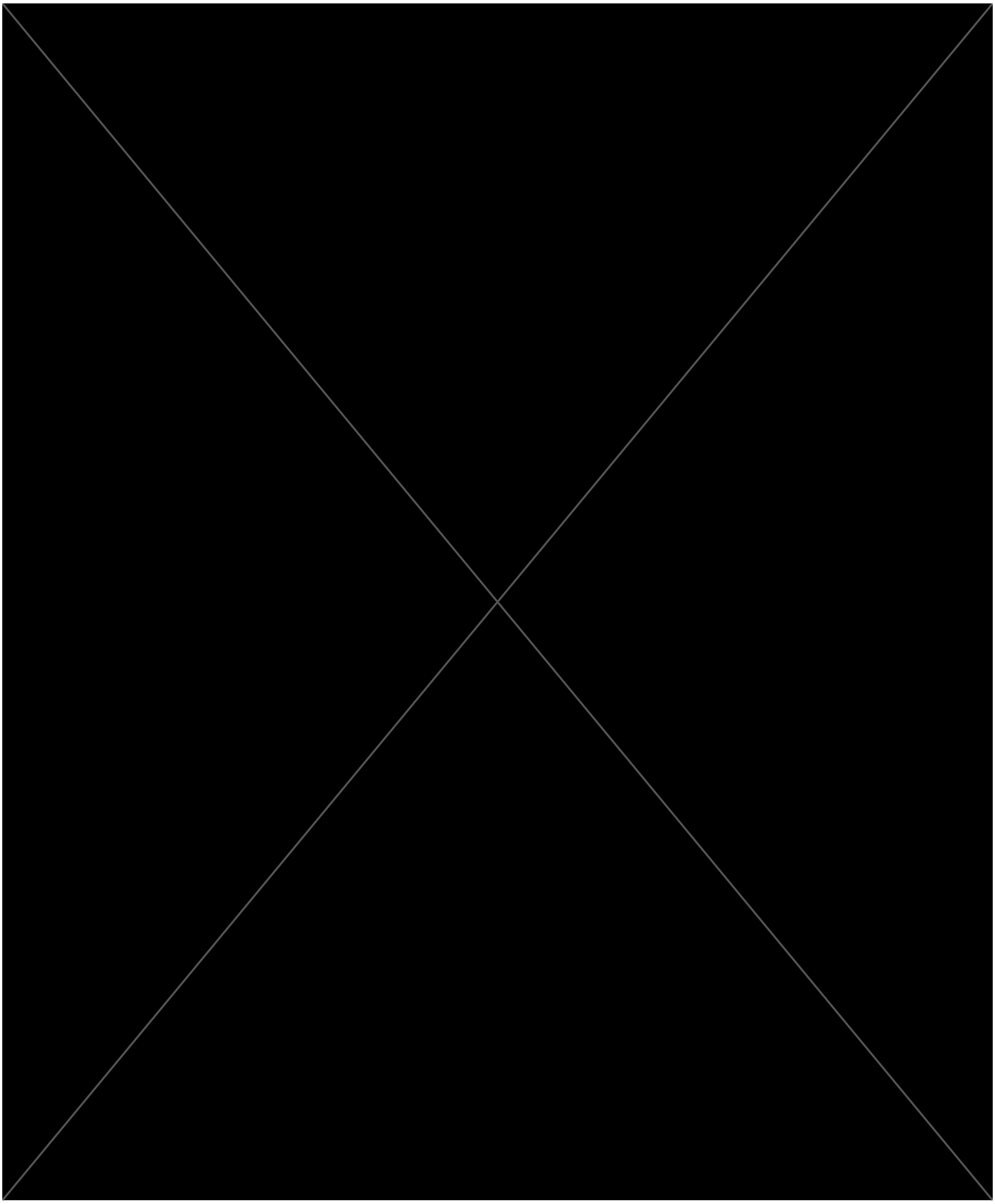


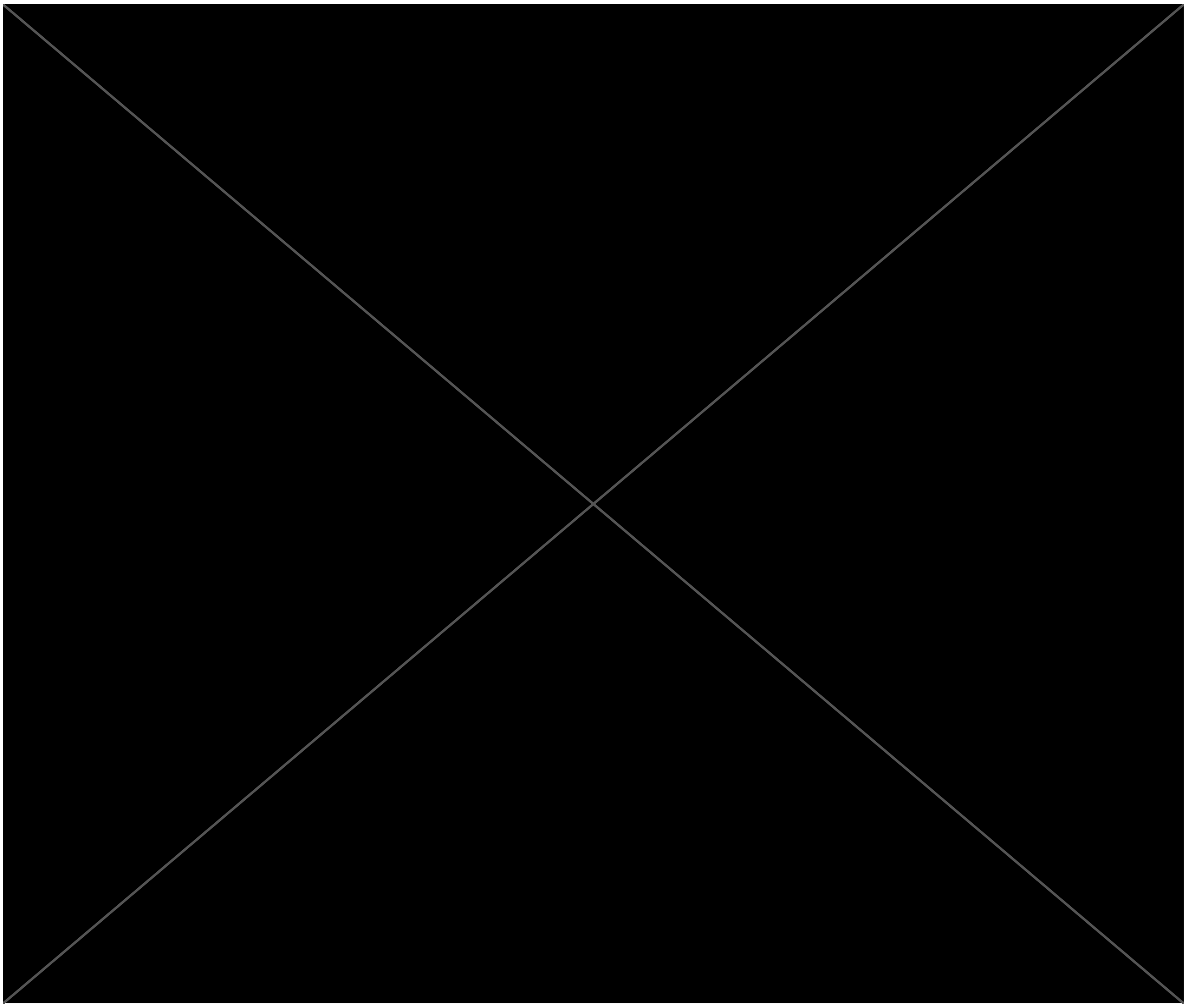












6 CEREMA – EVALUATION METHODOLOGY

Measurement protocol

Before testing, it is necessary to follow a methodology to define use cases to be tested. This methodology will follow the steps as below, based on use cases defined in this deliverable (i.e. POCs RATP & VALEO)

Methodology steps:

1- Choice of areas
2- Settings map
3- Measures & KPI
4- Results

Purpose of testing

In that part, the purpose will be to evaluate AI application, and decision maker through testing of use cases described in this deliverable.

Series of test have to evaluate AI capabilities and to figure out safety level.

AI demonstration can be identified in these main domains:

- Environment:
  To be able to detect and analyse all objects in environment (sidewalk, marked crosswalk, pole…)
- Object(s) or element(s) trajectories:
  To be able to detect a trajectory until decision (example: capacity to identify and to avoid a pedestrian)
- Vehicle trajectories:
  To be able to control trajectories of the vehicle depending on constraints in environment (example: capacity of the vehicle to avoid a hole on the road)

Description of the test protocol

Testing will follow current use cases of the POCs in this deliverable.

Preliminary conditions

For the realization of the L4.4, it will be necessary to get the full participation from partners, and all means and data to be able to evaluate AI and to provide solid results.

1st needs:

➔ Nature of experimentation: description based on Paris2Connect project
  - Security analysis: itinerary & list of the risks
  - Legal and feasibility analysis

➔ Data availability and accessibility

➔ Settings of infrastructure:
  - Driving permissions in autonomous mode: for RATP & Valeo
  - Application form for experimentation
  - Respect of RGPD
  - Permission to make videos

Material:

➔ Traffic measuring: counting and speed

➔ Travel time

➔ GPS tracking

➔ Behaviour analysis (based on video)

Test protocol methodology

Protocol will follow the methodology proposed.

1- Choice of areas (P2C experimentation)
   - Itinerary and road conditions
   - Identification of restricted areas
   - Identification of environment
   - Traffic trends and people concentration

2- Settings map

    - Dashcam
    - Radars
    - Sensors
    - Camera
    - …

3- Measures & KPI
    - Selection and definition
    - Acceptable, understandable and workable
    - Data mini: 100 lifecycles & 15 effective days (or 3 weeks driving tests mini)
    - Functional interactions:
        1- Drawing of instrumentation: schema & characteristics
        2- Instrumentation protocol
        3- Experimental protocol

4- Results
    - Observation zone(s)
    - Behaviour analysis
    - Conclusions

Instrumentation of the vehicle

Instrumentation will have to use the instrumentation from current vehicles used in both POCs described in this deliverable.

Additional instrumentation will be to be defined depending on necessity to collect additional data if missing, or to complete the scope of data collection.

Test implementation

The approach is to realize testing based on current use cases identified in the Paris2Connect project (POC RATP & POC VALEO):

1- Evaluation of road flow and congestion
2- Identification of objects or subjects on the path of the autonomous vehicle
3- Identification of groups of people near the lanes used by the autonomous vehicle
4- Identification of special vehicles circulating in the lanes or near the autonomous vehicle
5- Identification of people & vehicles trajectories (prediction)
6- Trajectory planning

Use cases	RATP	VALEO
1	X	X
2	X	X
3	X	
4	X	
5		X
6		X

Each use case can be hinged around a group of actions/experimentations defined for evaluation following the presentation sheet as below:

	Title:					
	Identification:					
	Version:					
	Specification covered:					
	Initial conditions: **Stakeholders:**					
	Type of scenario:					
	Requirement covered:					
N°	**Stakeholder**	**Action**	**Results -> Expected**	**Results -> Observed**	**Verdict**	**Requirement Covered: Yes/No**
1						
2						
3						
4						
5						
6						
	Conclusion:					
	Comment (to do):					

Methodology for PRISSMA will be realized with the same base of methodology applied on SAM project as well.

7 CONCLUSION

PRISSMA WP4 L4.2 & 4.3 has defined here the frame to prepare L4.4.

This deliverable [L4.2 & 4.3] develop the two use cases used to demonstrate the next step driving tests in real conditions. Here is defined itinerary, infrastructures and equipment in a regulation frame. Purpose is now to apply this methodology in real conditions as accurate as possible.

Vehicles, systems and itineraries are now identified to be able to drive in real traffic conditions to evaluate AI mechanisms.

This deliverable is in line with schedule and delivered on time following the original PRISSMA planning.

NEXT STEP L4.4 SHOULD ESTABLISH A LIST OF PROCEDURES AND GUIDES TO APPLY TESTS IN REAL CONDITIONS, AND EVALUATION METHODS AS WELL.

REFERENCES

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ANNEXE 1 – P2C DESCRIPTION

The itinerary concerned is Paris2Connect (P2C), a fully operational urban infrastructure on a 3.5-kilometre route in the 12th and 13th arrondissements of Paris, connecting the Austerlitz, Lyon and Bercy stations (see **Erreur ! Source du renvoi introuvable.**).

The following sections describe the main physical and digital infrastructure elements of P2C environment. The characteristics of the ADS exhibited by the tactical and operational behaviours presented in section... may depend on these infrastructure elements, which are essential part of the ADS's ODD environment.

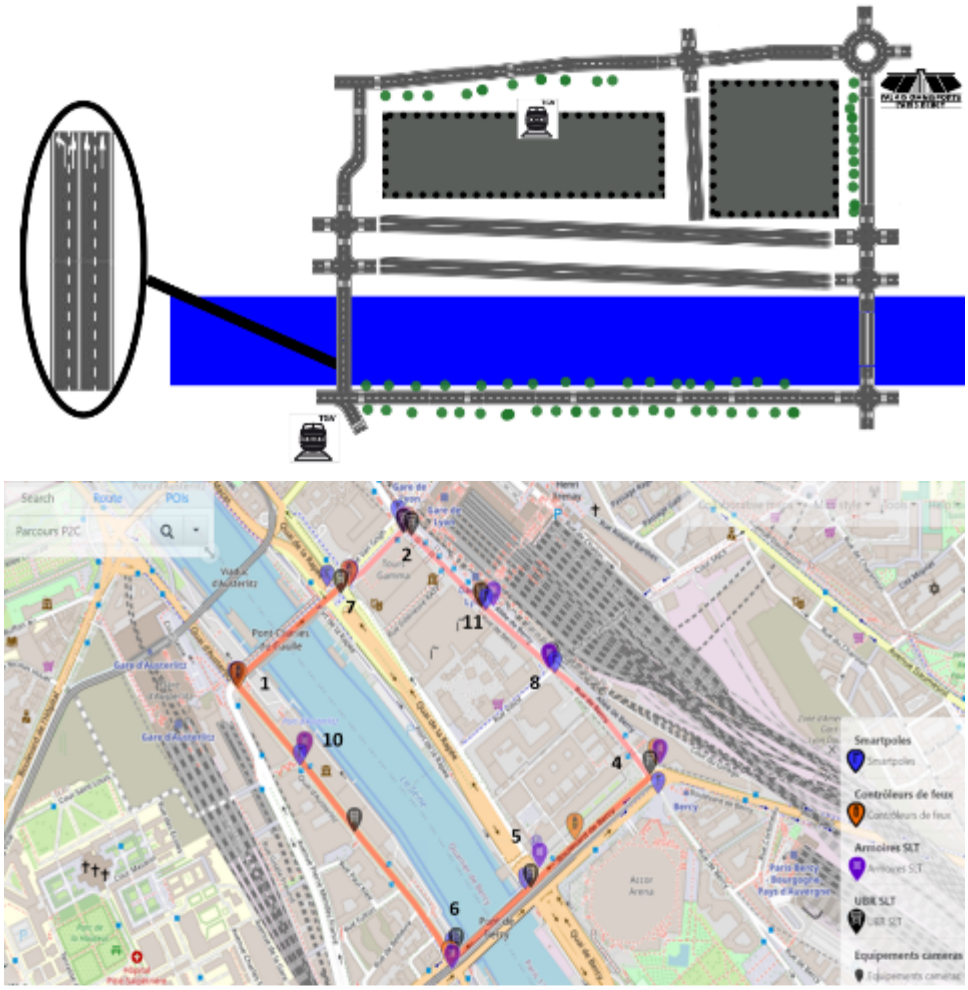

Figure 5: Paris2Connect pathway[]

1.1.1. Paris2Connect physical infrastructure

Section n°1 (Austerlitz/ Pont CDG) "Marker start section section 230m)

Roadway Type:

- **Road category:** 1 way, 4 lanes (1 bus lane, 1 turn left lane) + 1 bicycle lane.
- **Specific infrastructure configuration:** crossing at the departure
- **Roadway general orientation:** South-West bound/North-East bound
- **Ego allowed to drive on traffic lane n°1, n°2 and n°3**
- **Use of lanes:** - use of traffic lane n°1: Ego lane
  - use of traffic lane n°2: Bus lane
- **Traffic lanes direction:** - direction of traffic lane n°1: Ego direction
  - direction of traffic lane n°2: Ego direction

- direction of traffic lane n°3: Ego direction
- **Type of pavement surface:** Asphalt
- There is **no luminance of the road surface**
- There is road **marking contrast**
- **Element of infrastructure adjacent to the lane 1 on its right side:** sidewalk/river
- **Width of the lane n°1:** 3
- There is **no cross slope**
- **Length of the link section:** 230 m
  - **Slope:** 0

Junctions:
- **Number of branches of the intersection branch:** 4
- **Angle of the crossing lane:** 90°
- **Priority rules:** traffic lights

Temporary structures:
- There is **no workzone**

Special structures:
- **Crossing of vulnerable users:** crosswalk, bicycle crossing
- There is a **marking of cycle zone on the ego lane**

Signage:
- Traffic lights
- Closing devices: NA
- Connected equipment RSU/Camera 360/Thermal Cam/ Lidar (cf. Section..)

Paris2Connect scenery:
- Specific zones: Railway station

Paris2Connect environmental conditions:
- There is no illumination variation

Paris2Connect traffic conditions:
- Traffic density: on the traffic lane n°1: Middle/high depending on the conditions
  on the traffic lane n°2: Middle/high depending on the conditions
  on the traffic lane n°3: Middle/high depending on the conditions
- Road-users type: on the traffic lane n°1: bicycle, 2 Wheel Drive, Light vehicles, Heavy vehicles
  on the traffic lane n°2: bicycle, 2 Wheel Drive, Light vehicles, Heavy vehicles
  on the traffic lane n°3: bicycle, 2 Wheel Drive, Light vehicles, Heavy vehicles
- Road-users speed:

1.1.1.1.Signage (Road signage that may be encountered in the area and that can be supported by the vehicle (traffic signs, traffic lights….)

- **Vertical traffic signs:**
- **Traffic lights:**
- **Road markings (horizontal markings):**
- **Guidance equipment:**
- **Boundary markers:**
- **Closing devices:**
- **Dynamic signs:**
- **Temporary signs:**
- **Connected equipment:** in order to deploy a mutualised infrastructure covering the different uses of a smart city, the P2C infrastructure is equipped with 9 “smart poles”, which are Signify BrightSite poles. BrightSite is a platform that can host connected lighting, as well as a 4G/5G or Wi-Fi connectivity infrastructure. The smart poles can be equipped with sensors and cameras to collect data related to the urban environment. In the framework of PRISSMA project, these connected masts integrate video cameras (i.e. surveillance camera and/or Closed-Circuit Television (CCTV)), LIDAR sensors and/or thermal cameras, and UBRs. (cf. Figure ..). Some characteristics of each installed sensor in P2C is presented in Table .. and for more details the reader is referred to Appendix …

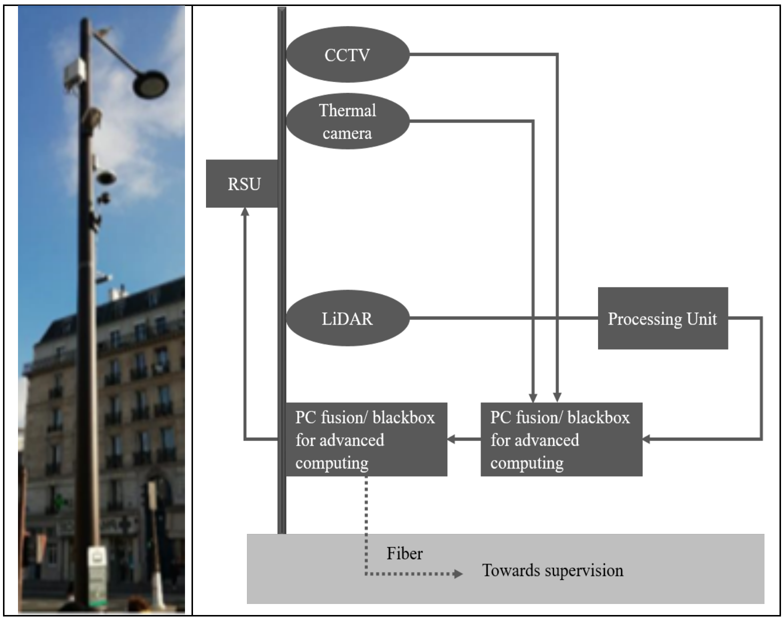

Figure: Type and layout of connected equipment in smart pole no.6 at “1 Quai de la Gare” (December 2020)

Connected equipment	Characteristics
LiDAR 	Type: M8-Quanergy Connection: PoE Operating temperature: -20°C to +60°C Fiel of View (FoV): Horizontal: 360°, Vertical: 12.4° (-1.6°/14°)

RSU 	Type: NeoGLS Connection: Ethernet PoE 100Mbps full duplex, 2x ITS 5G, GPS, modern cellular (2G/3G/4G) Operating temperature: -40°C to +70°C Support ITS stack: ETSI Geonet, CAM, DENM, SPAT, MAP, and POI standards
Industrial switch 	Type: AXIS T8504-E Outdoor PoE Switch 60 W per port, total 150 W SFP port Plug-and-play installation Rugged enclosure VAPIX support
PC fusion + Industrial blackbox 	Type: SPC-5200 Connection: 4 port USB 3.1 Gen 2 supports up to 10Gbps data transfer Storage: 1 SATA III (6Gbps), 1 SATA II (Mini PCIe Type, 3Gbps) Operating temperature: -40°C to +70°C
Camera 360° 	Type: AXIS P3717-PLE 8 MP, 360° multidirectional camera, 1 IP address 360° IR illumination, remote zoom and focus Axis Lightfinder and Forensic WDR Axis Zipstream to reduce bandwidth and storage requirements
Camera 360° + PTZ 	Type: AXIS Q6010-E Network Camera 360° camera with PTZ control 4x 5 MP sensors, 20 MP total resolution Interchangeable and tilting lenses Requires AXIS Q60-E PTZ Network Camera Automatic control included
Thermal camera 	Type: FLIR TERMICAM2 V2X Connection: Ethernet, PoE, QPL, Wi-Fi Operating temperature: -34°C to +74°C Number of detection zones: 24 vehicle detection zones, 8 cyclist detection zones, 8 pedestrian detection zones, 6 traffic data collection zones, 6 contraflow detection zones

Table: Some characteristics of installed equipment in P2C. More characteristics are presented in Appendix....

The perception functions of each equipment involve a variety of complementary technologies:

- Image processing from the visible spectrum (Camera)
- Processing of images from the infrared spectrum (IR camera)
- Optical distance measurement (LIDAR)

The localisation of the different equipment is done in **Erreur ! Source du renvoi introuvable.**, **Erreur ! Source du renvoi introuvable.** and **Erreur ! Source du renvoi introuvable.**.

The integration of most of the technical components in the masts allows the aesthetics of the city to be preserved. Each mast has a specific configuration, adapted to the needs of its location. The whole equipment is also certified according to the EN40 standard for durability in all installation conditions. To ensure the comfort and safety of the citizens, these smart poles also include a Philips LED.

Localisation	Quai d'Austerlitz / Pont Charles de Gaule	Rue Van Gogh / Rue de Bercy	Boulevard de Bercy / Rue de Bercy	Pont de Bercy / Boulevard de Bercy	Pont de Bercy / Quai d'Austerlitz (Quai de la Gare)	Pont Charles de Gaulle / Quai de la Râpée / Rue Van Gogh	Rue de Bercy (tronçon sud)	Quai d'Austerlitz	Rue de Bercy (tronçon nord)
Arrondissement	75013	75012	75012		75013		75012	75013	**75012**
Smart pole	1	2	4	5	6	7	8	10	**11**
ID	1317038/39	1214324	1203994/93	1205229	1304522	New	1214110/11	1317209	**1214344/45**
Latitude	48.8417663	48.844352	48.8401312	48.8386671	48.8377131	48.8433801	48.8419886	48.8405341	**48.842952**
Longitude	2.3678487	2.3722477	2.379152	2.3756078	2.3737169	2.3704375	2.3764636	2.3696361	**2.3747177**
Cameras	Camera Axis P3717 PLE (6m)	Camera Axis P3717 PLE (6m)	Camera Axis P3717 PLE (6m)	Camera Axis Q6010/Q6075 (6m)	Camera Axis P3717 PLE (6m)	Camera Axis P3717 PLE (6m)	Camera Axis P3717 PLE (6m)	Camera Axis P3717 PLE (6m)	**Camera Axis P3717 PLE (6m)**
Thermal cameras					Camera ThermiCam2 345 (6m)			Camera ThermiCam 2 345 (6m)	**Camera ThermiCam 2 345 (6m)**
LIDAR	Quenergy MQ8 (3m)		Quenergy MQ8 (3m)	Quenergy MQ8 (3m)		Quenergy MQ8 (3m)	Quenergy MQ8 (3m)		
RSU	NeoGLS (6m)	NeoGLS (6m)	NeoGLS (6m)	NeoGLS (6m)	NeoGLS (6m)	NeoGLS (6m)	NeoGLS (6m)	NeoGLS (6m)	
Switch	AXIS	AXIS	AXIS	AXIS	AXIS	AXIS	AXIS	AXIS	**AXIS**
PC fusion	SPC 5200	SPC 5200	SPC 5200	SPC 5200	SPC 5200	SPC 5200	SPC 5200	SPC 5200	**SPC 5200**
Processing unit	SPC 5200		SPC 5200	SPC 5200		SPC 5200	SPC 5200		
Sound sensor	-	-	-	-	**SecurAxis**	-	-	**SecurAxis**	-

Table 11: Localisation of the different smart poles and the corresponding installed equipment []

Crossroads	1st choice of installation										
	Domain	Support number	Support type	GPS coordinates (X)	GPS coordinates (Y)	Approximate installation height	Cable length 12G 1.5mm²	Number of available drivers	SLT Cabinet No.	GPS coordinates (X)	**GPS coordinates (Y)**

						UBR (m)					
478	SLT	S04318	BP42 with poles	2,37385821900822	48,8377070124592	6	122	4	FS00478	2,373465455228710	48,837295792974
1293	SLT	PC23653	Square pole	2,37107064739737	48,8396044216246	3	173	4	FS01293	2,36979197743108	48,8406537470631
1630	SLT	S22276	Square pole	2,36795562786468	48,8417703902277	3	30	8	FS01630	2,36801215488015	48,8417127024408
814	SLT	S21419	BP31	2,37069634455272	48,8432933417832	3	72	4	FS00814	2,37127131357128	48,8435579621002
1177	SLT	S23557	BP31	2,37225363602214	48,8442585304213	3			FS01177	2,37226208166744	48,8441598885994
1177	SLT	S23575	Square pole	2,37272530249517	48,8441280570218	3	54	5	FS01177	2,37226208166744	48,8441598885994
1654	SLT	S23399	Square pole	2,37446259352554	48,8431671651311	3	53	4	FS01654	2,37493933099277	48,8430077354984
654	SLT	PC21792	Square pole	2,37631050057168	48,8421882930189	3	26	6	FS00654	2,337624347508270	48,8420788181753
664	SLT	S05772	BP31	2,37898794852825	48,8404988689303	4	38	6	FS00664	2,37916853236935	48,8405795254498
243	**SLT**	**S11647**	**BP31**	**2,37597737747482**	**48,8386962029536**	**4**	**120**	**7**	**FS00243**	**2,37597590514986**	**48,8389907158335**

Table 12: Localisation of RSUs []

1.1.2. Paris2Connect digital infrastructure

1.1.2.1. Information type (type of information expected or provided through connectivity)

ITS messages exchanged in I2V: the message formats exchanged are based on the ETSI CAM (ETSI 2016 and 2019), DENM (ETSI 2016 and 2019), MAPEM (2016-03), SPATEM (2016-03), IVIM (2016 and 2019), POI and CPM (2019-12) standards. However, in the PRISSMA projects and the current autonomous vehicles tests, only MAPEM (2016-03), SPATEM (2016-03) and CPM (2019-12) messages are used. The validation tests of the exchanged messages through connectivity have been completed successfully, but there are still some outstanding issues with Valeo regarding the CPM messages.

- **SPAT and MAP messages:** the standard currently used in the RSU is CEN TS 19091:2017 (commonly referred to as the 2016 Spatem/Mapem standard). The classic data fields are used: intesectionGeometry, lane ingress (approaching the traffic light) and optionally egress (path after the traffic light). The format of the transmitted data will be standardised to the SPAT, MAP and GLOSA format.
- **CPM:** CPM exchanges can be done via the RSUss when the vehicle is in hybrid ITS 5G/ 4G operator mode, but also by retrieval from the ITS server via JSON APIs.

The message content is encoded with the type presented in **Erreur ! Source du renvoi introuvable.**, based on the protocol version and messageId.

Message type	Protocol version
CAM	Protocol version 1: ETSI EN 302-637-2 v 1.3.1
	Protocol version 2: ETSI EN 302-637-2 v 1.4.1
DENM	Protocol version 1: ETSI EN 302-637-3 v 1.2.1

	Protocol version 2: ETSI EN 302-637-3 v 1.3.1
SPATEM/MAPEM	ETSI TS 103 301 V1.1.1 + SAE J2735 03-2016
IVIM	ISO TS 19321
POI	C-Roads
CPM	ETSI TR 103-562

Table 13: Protocol version of the supported messages []

– **1.1.2.2. Connectivity (category and technology of the connectivity)**

Fibre

– Connection of 9 masts in star to the "Maison de la RATP"
– Star mode / Single mode / Single fiber / 1 GB/s Ethernet lighted link for sensors deployed on the masts

Ethernet

– 1 GB/s Ethernet link is used to collect data from the various camera types and fusion PCs deployed at the masts

Hybrid RSUs

– Hybrid ITS 4G and 5G operators
– A RSU management platform enables the supervision of the operation of this equipment, the provision of traces of PCAPs issued and also access to the data exchanged via JSON APIs (facilitating tests).

Private 4G network evolving to 5G

A private network supported by a smart pole infrastructure based on small cells is deployed in 2.6 GHz in band 41. Configured SIM cards can be made available to support the implementation of use cases to be defined.All the messages can be retrieved from NeoGLS platform, which acts as a server and accepts multiple connections from clients.

The API is based on TCP communication. The client connects to the endpoint and sends a SUBSCRIPTION message in JSON. The server registers the subscription and sends a SNAPSHOT to the client. Then the connection remains open and the server sends UPDATES and KEEPALIVE messages to the client. The client will receive a message or a keepalive at least every 55 seconds.

The client can update its subscription at any time by re-sending the subscription message. In that case, the client receives a new snapshot. The message format used depends on the endpoint:

- JSON endpoint on port 6688: The communication is JSON only.
- UPER endpoint on port 6699: The subscription is made with JSON. The server answers in a binary format using ASN1 ETSI messages.

Format of subscription messages: the subscription request made to the API must be in JSON minified format. The API will determine the end of the request when a line feed is received (CRLF). There must be no line feed within the JSON body. The format of the subscription messages is presented in figure …

```
{     "doFilterPosition": boolean      > Determines whether the client
subscribes to an area or to all the messages present in the server
      "position": array                > Represents the center of the
                                         subscription area (not required
                                         if doFilterPosition is false)
                                         (format: [lon,lat])
      "radius": number                 > Represents the radius (m) of
                                         the subscription area (not
                                         required if doFilterPosition is
                                         false)
      "events": boolean                > Filter DENM type
      "ivis": boolean                  > Filter IVIM type
      "pois": boolean                  > Filter POI type
      "stations": boolean              > Filter CAM type
      "spats": boolean                 > Filter SPATEM type
      "maps": boolean                  > Filter MAPEM type
      "cpms": boolean                  > Filter CPM type
}
```

Figure: the format of the subscription messages. The framed part is the one concerned by the PRISSMA project

Format of the messages: on the JSON endpoint, messages are sent in a minified JSON format, separated by a Line Feed (LF). Each message is a JSON object containing several fields, which depend on the type of the message.

- **Format of the snapshot: a**s CPM and SPATEM messages are short-term repeated messages, they are not present in the snapshot. However, maps are array type, which include a list of active maps in the subscribed area. (Each element of the table is a MAP JSON object)
- **Format of the update**

Name	Type	Description
method	string	Indicates the nature of the update - "create_objectName": spat/map/cpm was created on the server - "update_objectName": spat/map/cpm was updated on the server - "delete_objectName": spat/map/cpm was deleted on the server
spat/map/cpm	object	The SPATEM/MAPEM /CPM JSON object that was created, updated or deleted

- **SPATEM JSON object format**

Name	Type	Description
id	number	Intersection Id
timestamp	number	Reference time of the signal state timing present in the message
sendingStationId	number	ID of the sending station
region	number	Intersection region
revision	number	Message revision
protocolVersion	number	Protocol version (unused)
states	array	State list for each signal group of the intersection
id	number	Signal group ID
state	number	Current state of the traffic light for this signal group unavailable (0), dark (1), stop-Then-Proceed (2), stop-And-Remain (3), pre-Movement (4), permissive-movement-allowed (5), protected-Movement-Allowed (6), permissive-clearance (7), protected-clearance (8), caution-Conflicting-Traffic (9)
ttc	number	Time before change on this signal group based on the server clock (in milliseconds). Present only if the timing is known. Can be negative.
nextChange	number	Time of change : Absolute time of the next state change on this signal group (in milliseconds since 1st January 1970).
nextChanges	array	List of next phases if supported by the traffic light controller.
state	number	State of this phase for this signal group
ttc	number	Time before change on this signal group based on the server clock (in milliseconds). Present only if the timing is known. Can be negative.
nextChange	number	Time of change : Absolute time of this state change on this signal group (in milliseconds since 1st January 1970).

- **MAPEM JSON object format**

Nom	Type	Description
protocolVersion	number	Protocol Version in the ItsPduHeader
id	number	Intersection Id
timestamp	number	Reference time of the geometry present in the message
sendingStationId	number	ID of the sending station
region	number	Intersection region
revision	number	Message revision
lanes	array	List of lanes in the intersection
id	number	Id of the lane
signalId	string	Id of the signal, corresponding to the SPAT signal Id
approachId	number	Id of the approach (group of lanes)
left	bool	True if this lane allows a left turn at its end
straight	bool	True if this lane allows to go straight ahead at its end
right	bool	True if this lane allows a right turn at its end
speedLimit	number	Speed limit on this lane (km/h)
ingress	bool	True if this lane is ingress
egress	bool	True if this lane is egress
geom	array	List of points representing the lane. Each point is an array of numbers where the first value is the longitude and the second value is the latitude (in WGS84).
isVehicleLane	bool	True if this lane allows the traffic of vehicles
isBusLane	bool	True if this lane allows the traffic of buses
isBikeLane	bool	True if this lane allows the traffic of bikes
connections	array	List of connected lanes
intersectionId	number	IntersectionId of the connected lane. 0 if the connected lane is in the same intersection.
laneId	number	LaneId of the connected lane. 0 if the connected lane is unknown, but the action is still possible.
action	number	Turn direction leading to the connected lane. (LEFT = 0, STRAIGHT = 1, RIGHT = 2)
id	number	Id of the connection
caution	bool	True if taking this path has to be executed with caution (e.g. : pedestrian crossing on a right or left turn)

- **CPM JSON object format**

Name	Type	Description
protocolVersion	number	Protocol version field of the CPM header
stationId	number	StationId field of the CPM header
timestamp	number	Reference timestamp of perceived object detection time
stationType	number	Type of the sending station unknown = 0 pedestrian = 1 cyclist = 2 moped = 3 motorcycle = 4 passengerCar = 5 bus = 6 lightTruck = 7 heavyTruck = 8 trailer = 9 specialVehicles = 10 tram = 11 roadSideUnit = 15
latitude	number	Latitude of the sender (°)
longitude	number	Longitude of the sender (°)
altitude	number	Altitude of the sender (m) [-1000 ; 8000]
semiMajorConfidence	number	Semi major confidence [0; 4095] (centimeters)
semiMinorConfidence	number	Semi minor confidence [0; 4095] (centimeters)
semiMajorOrientation	number	Semi major orientation [0; 3601] (0.1 degrees)
segmentNumber	number	Number of this segment in the range [1 ; segmentAmount]. Must be present if the CPM is split in several messages. All CPMs of a same group have to be sent with the same stationId and timestamp.
segmentAmount	number	Segment count in total. Must be present if the CPM is split in several messages. All CPMs of a same group have to be sent with the same stationId and timestamp.
originatingStationType	number	Type of the originating station. The station container must be present in accordance to this field rsu = 1, vehicle = 2
originatingRsu	object	Description of the originating RSU. Incompatible with « originatingVehicle ».
intersectionId	number	Id of the intersection where the detecting RSU is located, if applicable.

intersectionRegion	number	Region of the intersection where the detecting RSU is located, if applicable.
roadSegmentId	number	Id of the road segment where the detecting RSU is located, if applicable.
originatingVehicle	object	Description of the originating vehicle. Incompatible with « originatingRSU »
speed	number	Speed of the detecting vehicle, if applicable (in km/h).
speedConfidence	number	Speed confidence of the detecting vehicle, if applicable (cm/s).
heading	number	Heading of the detecting vehicle, if applicable (in degrees).
headingConfidence	number	Heading confidence of the detecting vehicle, if applicable (0,1°).
sensors	array	Definition of sensors
id		Sensor identifier. Must be unique in the list
type		Type of sensor undefined = 0, radar = 1, lidar = 2, monovideo = 3, stereovision = 4, nightvision = 5, ultrasonic = 6, pmd = 7, fusion = 8, inductionloop = 9, sphericalCamera = 10, itssaggregation = 11
detectionArea	object	Describes the detectionArea of the sensor
type	number	Type of the detection area polygon = 3 circular = 4 ellipse = 5 rectangle = 6
polygonPoints	array	Mandatory if « detectionAreaType » is 3. Describes the polygon area in an array of coordinates in degrees. [[lon1, lat1], [lon2, lat2]]
circularCenter	array	Describes the center of the circular area. If absent, the CPM coordinates are used. [lon, lat]
circularRadius	number	Mandatory if « detectionAreaType » is 4. Describes the radius of the circular area in meters.
eorCenter	array	Describes the center of the ellipse or rectangle

		area. If absent, the CPM coordinates are used. [lon, lat]
eorMinorLength	number	Mandatory if « detectionAreaType » is 5 or 6. Describes the small side of the ellipse or rectangle in meters.
eorMajorLength	number	Mandatory if « detectionAreaType » is 5 or 6. Describes the big side of the ellipse or rectadngle in meters.
eorMajorOrientation	number	Mandatory if « detectionAreaType » is 5 or 6. Describes the orientation of the major side of the rectangle or ellipse in degrees.
eorHeight	number	Describes the height of the detection area rectangle or ellipse.
perceivedObjects	array	Array of perceived objects
id	number	Identifier of the perceived object
measurementTime	number	Time when the position of the perceived object was measured. (milliseconds since 1st January 1970)
objectAge	number	Duration since when this object was first detected [0; 1500] (milliseconds)
confidence	number	Percentage of confidence associated to the object
xDistance	number	Distance between the referencePosition and the perceived object on the x axis in meters, as described in ETSI TR 103 562 §6.6
xDistanceConfidence	number	Confidence on the provided xDistance, in centimeters.
yDistance	number	Distance between the referencePosition and the perceived object on the y axis in meters, as described in ETSI TR 103 562 §6.6
yDistanceConfidence	number	Confidence on the provided yDistance, in centimeters.
xSpeed	number	Speed of the perceived object on the x axis in km/h, as described in ETSI TR 103 562 §6.6
xSpeedConfidence	number	Confidence on the provided xSpeed, in cm/s.
ySpeed	number	Speed of the perceived object on the y axis in km/h, as described in ETSI TR 103 562 §6.6
ySpeedConfidence	number	Confidence on the provided ySpeed, in cm/s.
referencePoint	number	The reference point on the perceived object relative to which the measurement data is provided. Defaults to « mid » mid = 0 bottomLeft = 1 midLeft = 2 topLeft = 3 bottomMid = 4

		topMid = 5 bottomRight = 6 midRight = 7 topRight = 8
yawAngle	number	Yaw angle of the perceived object, with reference to the x axis.
sensorIds	array	List of sensorIds that were used to measure the perceived object data.
width	number	First dimension of the object as provided by the sensor or environment model. Dimension contained in the plane which is perpendicular to the direction indicated by the yawAngle. [0;1023] (0.1 meter)
widthConfidence	number	Confidence on the width value. [0; 102] (0.01 meter)
height	number	Vertical dimension of the object as provided by the sensor or object model. [0;1023] (0.1 meter)
heightConfidence	number	Confidence on the height value. [0; 102] (0.01 meter)
length	number	Second dimension of the object as provided by the sensor or environment model. Dimension contained in the plane which contains the direction indicated by the yawAngle. [0;1023] (0.1 meter)
lengthConfidence	number	Confidence on the length value. [0; 102] (0.01 meter)
status	number	Indicates if the object is or has been dynamic dynamic = 0, hasBeenDynamic = 1, static = 2
classification	array	List of possible object classes and their confidence.
class	number	Object class Vehicle = 1 Person = 2 Animal = 3 Other = 4
classConfidence	number	Confidence of the sensor regarding the class of the detected object. [0;100]
type	number	Type within the class (as stated in ETSI TR CPM) [0;255]
typeConfidence	number	Confidence of the sensor regarding the type of the detected object. [0;100]