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# MOOVE & MOSAR Projects: a scenario library for designing & validating ADS

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**Abstract** – Significant work is undertaken, since the middle of the 2000s, to review validation approaches for automated driving development systems. At the industry level, the main stream has been the extension of conception-validation approaches applied to on-board electronics (ISO 26262 standard) to automated functionalities (safety of the intended functionalities - SOTIF). At this stage, the general consensus seems to be that existing validation approaches are not able to cope with automation challenges. At the core of automation is the revolutionary concept that a system takes the lead on driving over the human, which requires a change in concepts and approaches and a change in scale of risks to be considered. It's therefore relevant to deal with a method based on multi-scenario approach, combining accidentology data and expertise in order to build a set of representative data from case tests for simulation. This is what the MOSAR Scenario Library is aiming for.

**Keywords:** ADAS, Design, Validation, Safety, Scenario.

## Introduction

New validation approach still needs to take into account existing methods and have to combine knowledge to obtain a good representability in tests: as millions of kilometers are being collected for

validation purposes, the automotive industry has come to the consensus that validating ADS on relevant and representative driving scenarios and events, combined with accidentology data and expertise knowledge, would give better safety and security assessment than performing a full scale evaluation on the whole collected data set.

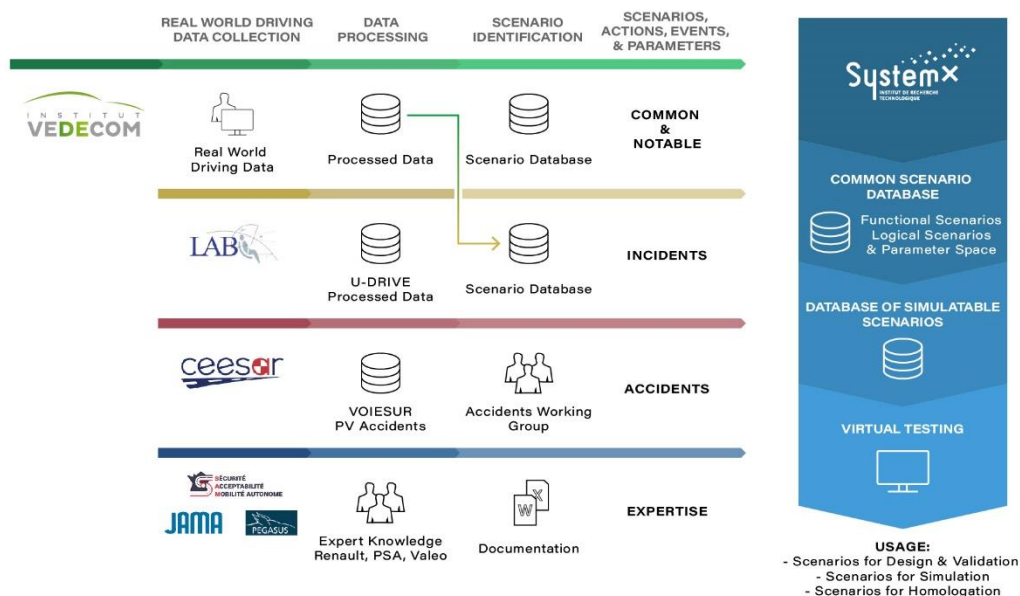


Figure 1. Combining data source and knowledge to a scenario library for ADS design & validation

# VEDECOM & SystemX Collaboration

In this context, VEDECOM, a research institute dedicated to the individual, carbon-free and sustainable mobility, has begun in 2016 to collect driving data and extract relevant scenarios. To this end, VEDECOM has elaborated an architecture integrating multiple heterogeneous sensors as well as the vehicle instrumentation. Furthermore, a model of the vehicle surrounding allows for scenarios classification and statistic inference.

This work is completed by SystemX, a research institute dedicated to the digital engineering of complex systems. Addressing AD safety and scenarios standardization, SystemX has created a road scenario library and developed MOSAR, for "Methods and tools for Safety Assessment and Robustness analysis". Based on a "Software as a

Service" (SaaS) architecture and a common data model, the Scenario Manager allows SystemX partners to describe their scenarios, through a web interface, in a secure and shared Scenario Library. Next, these scenarios can be used for design, simulation, validation and homologation activities.

This work is the first stage of a three steps approach:

- At first gather driving scenarios and data before any availability of L3 AD Systems.
- Then, add scenarios from prototype L3 and L4 AD Systems in the frame of the PFA (French Automotive Association) Project.
- And finally, when systems will be sold, get new scenarios from public vehicles.

The goal of this paper is to present the activities of both research institutes toward the construction of a large driving dataset and a standardized scenario library.

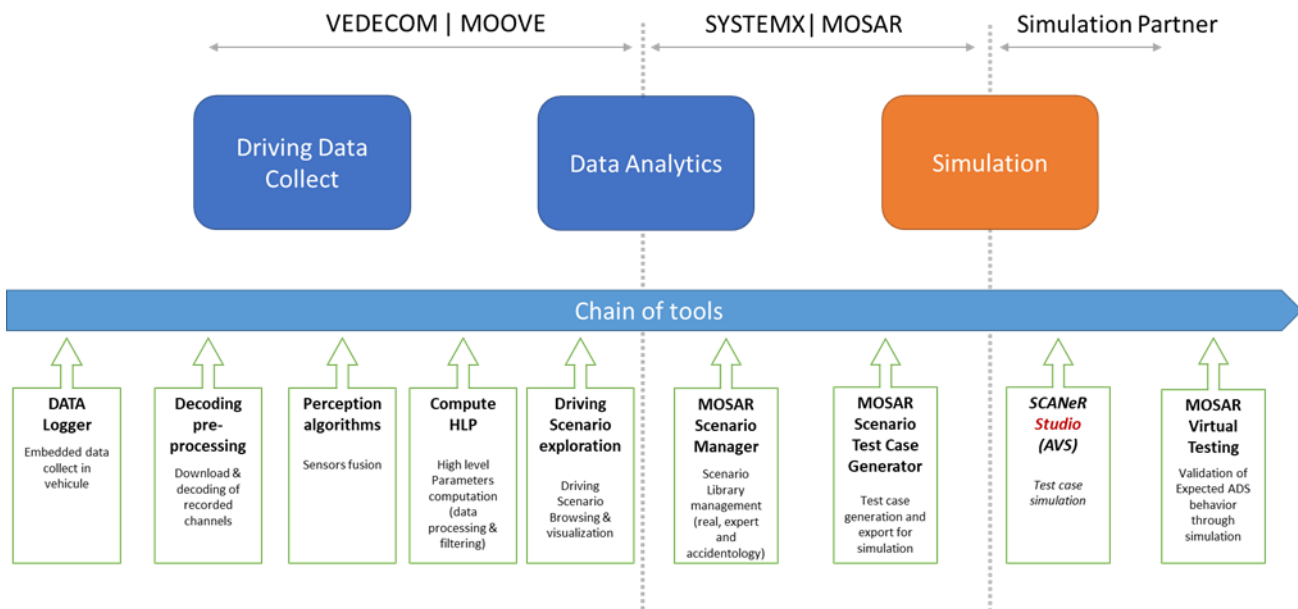


Figure 2. Value chain from data collection to simulation

## Driving scenarios collection & extraction

### Scenarios based on driving situations and environment analysis

To handle and safely manage critical situations the human driver needs to interact and take the environment into account. This environment includes other road users, the road infrastructure and weather. To validate Automated Driving Systems, we need a full representation of the vehicle's environment. This can be achieved by the acquisition of a database on open road, using a vehicle equipped with a set of various sensors. The

VEDECOM institute launched the MOOVE project in 2016 with the objective of acquiring and analyzing such a database in order to identify and classify notable driving situations.

### MOOVE database acquisition

The MOOVE database was recorded using six C4 Picasso equipped with the same data acquisition system. 24 different sensors are part of this data acquisition system, including cameras, radars, lidars, GNSS, etc. Equipped vehicles were driven by professional drivers who strictly respect traffic regulations, thus behaving close to what is required from the Autonomous Vehicle.

The database was recorded mostly on divided roads. Over 1.000.000 km have been recorded so far all-over Western Europe (17 different countries). This

represents more than 16,000 hours of recordings, a 280 TByte database and over 40,000 recordings. The acquisition was focused on 2 main situations:

- Traffic jam conditions: mainly in the Paris region and other European main cities, but also on holidays departure days
- Fluent highways: Most Western Europe highways were recorded in a fast-flowing traffic context.

Finally, recordings contain a wide range of driving conditions, the vehicle fleet being driven on an almost daily basis for at least 3 years.

### MOOVE data modelling

A taxonomy of a hundred High Level Parameters (HLP) have been defined by VEDECOM. These parameters define every object and actor of the road scene. The developed algorithms use these parameters for:

- Detection of events (movement of vehicles in their lane, change of lane, overtaking, etc.),
- Detection of the driver’s actions to follow a route or to react to the behaviour of other vehicles,
- Reconstruction of the road infrastructure components (navigable road limits, traffic lanes, marking lines, road signs, etc.),
- Reconstruction of a temporal sequence and the climatic conditions in which the scenario takes place.

Knowing that the sensors have their limit of technological performance, each parameter, event, action or temporal sequence is the subject of algorithm development by VEDECOM, to make it as robust as possible (computations knowing the future, optimized filters, single-sensor data fusion, multi-sensor data fusion, trajectory prediction...). To validate them, manual annotations of the signals using field reality videos are used to detect false positives and false negatives.

In order to analyze driving situations, the MOOVE project developed a specific method using raw

signals from acquired data and enabling automatic detection of scenarios.

The MOOVE’s method of data collection enables us to record more than 500 signals from the 24 different sensors. These raw signals are low level information, close to the sensor’s output. In order to have an easily usable database, a data model containing high level information about the Ego (vehicle equipped with the data acquisition system) vehicle’s driving environment was built

These High Level Parameters (HLPs), which are defined independently of the data source and gathered in 4 different layers (see Figure 3), are then used to detect specific events. The events represent constraints from the ego vehicle’s environment related to other road users, Infrastructures or even obstacles on the road [Lio18].

Time sequences of events form driving scenarios. By detecting these time sequences, we are able to detect, extract and analyze these scenarios.

### Driving scenarios identification & classification

The definition of the scenarios was carried out using two sources: a list of predefined common scenarios (coming from existing classifications), and new unusual, rare, scenarios observed during driving, called “Notable”, in the MOOVE database. With this definition table (see Figure 3 for a sample of these scenarios), the driving environment can be analyzed for each scenario. First, relevant scenarios need to be identified and then extracted from the database. This is done by cross checking specific values of HLPs, according to a set of expert rules. The events obtained from this step can be linked in a time sequence in order to create a scenario. Using these rules, a maximum of different occurrences can be detected within the database. A statistical description of the identified scenarios can then be provided.

FUNCTIONAL SCENARIO	Classes Scenarios					
	Elementaire 1 actor (1)	2 actors or more (2)	0/1 actor (3) + permanent roadway infrastructure	0/1 actor (4) + temporary infrastructure	0/1 acteur (5) + environment conditions	2 actors or more + permanent roadway infrastructure (6)
2VEHICLE CUT IN FRONT	M2.1.1 Cut in Simple 	M2.2.1 Cut in then lead break 	M2.3.1 Cut in (Erd Df) Merge 	M2.3.4. Cut in Two Lanes Merge 	M2.4.1 Cut in Due To Neutralized Lane 	M2.6.1 Cut in Ease End Of Merge 
		M2.2.2 : Cut in In Congested Lane 	M2.3.2 Cut in Y Junction 	M2.3.5 : Cut in From Emergency Lane 		
		M2.2.3 : Cut in Exit Out Of Busy Lane 	M2.3.3 Cut in Zebra 	M2.3.7 Cut in Right Priority (Paris Ring Road) 		
		M2.2.4 : Cut in Overtake Slower Vehicle 	M2.3.6 : Cut in Bifurcation Or Exit Lane 			
		M2.2.5 : Cut in Overtake No Check 				

Figure 3. Driving scenario identification & classification

## Driving Scenario analysis example

Using the previous set of rules, 400,000 different cut-ins were detected for instance. This allowed us to analyze the distribution of given sets of HLPs, events, and actions. The description of the scenarios (functional, and logical) and the distribution of these specific values characterizing a scenario are the output of the MOOVE project and the input of the MOSAR Scenario Library in SystemX project.

## Scenario Library

With the introduction of the ISO SOTIF 21448 capitalisation of existing challenging scenarios in a common database has become essential. In this context, French SystemX research institute is building the French AD Scenario Library, following standard scenarios data format and using a specific Software as a Service platform called MOSAR.

### Scenarios and standardization: data format, standard definition

With the objective to define for French automotive industry a shared scenario catalogue for Automated Driving Systems (ADS) of SAE autonomy level 3 and more, we decided to agree on the following term definition. We based our work on the following articles [Ulb15, Gey14, Hun17], that reflect idea close to the German PEGASUS project views and on the norms and standards from the software and system engineering community. Some definitions are already in ISO 21448 SOTIF standard, other are proposed for ISO 34501, 34502, 34503, 34504 standard concerning ODD and Scenarios standardisation for ADS.

Scenario Data Model was created from this basis and from SystemX participation to OPENSCENARIO discussions at ASAM. Scenario description parameters were chosen to be compliant with the maximal number of parameters used in the different input databases.

Class	Goal	Composition	Requirement
<b>Header</b>	Specify global information	Human-readable scenario description and overview picture	Mandatory
<b>Attribute</b>	Specify specific information	Traceability information from source database. Accidentology information (number of injured people, accident main explanatory factors etc.). Attachment to complete description	Optional
<b>Road Infra-structures</b>	Specify the Road parameters	Geometry, Traffic signals, road marking etc. Overview picture	Mandatory
<b>Actors</b>	Specify the Actors parameters	Color of the vehicle, type of vehicle, size, number of occupants etc.	Mandatory
<b>Story-board</b>	Describe the temporal evolution of the scenario participants	Overview pictures for each step	Mandatory
		Actors behaviour (position in lanes, dynamics, maneuvers etc.)	Mandatory
		Environment (weather, road state and traffic)	Optional

Table 1. Scenario parameters ranges

## First scenarios in the scenario library

This scenarios library will include at the beginning:

- Common and notable scenarios coming from MOOVE project, i.e. scenarios collected from real life driving. Common scenarios are most popular one (cut-in, cut-out, lane following ...). Notable scenarios are rare scenarios declared dangerous by MOOVE expert drivers. This represents more than 100K concrete scenarios.
- Incident scenarios are added by detecting Safety Relevant Event (SRE) and Safety Critical Event (SCE) as defined by VTTI [Din06, Per17].
- Accident scenarios: In tune with the foreseeable first developments of AD functions, the accidents that occurred on highways and divided roads, involving at least a passenger car or commercial vehicle, were selected from VOIESUR to be the background of the present study. From this sample, accidents that occurred on highway interchange, on- and off-ramps, were excluded. All in all, this represents 258 raw accidents and 2,429 road accidents once weighted to be representative of the national census.

## MOSAR – Scenario Manager

MOSAR “Methods and tOols for Safety Assessment and Robustness analysis” is an IRT SystemX platform supporting a software application called “Scenario Manager”. In Software as a Service (SaaS) mode, this software offers some features to manage scenarios, in containers that can be private, shared with partners or shared in public mode.

Based on a common data model, the Scenario Manager allows IRT SystemX partners to describe their scenarios, through a web interface, into a secure and shared Scenario Library. Next, these scenarios can be used for Design, Simulation, Validation and Homologation activities.

MOSAR is supported by the French Automotive Manufacturers association, and has been referenced by OICA (International Organization of Motor Vehicle Manufacturers) [PFA19].

## Conclusion

This paper presents a full process from data acquisition on cars to a scenario library to collect and capitalized relevant scenarios for Traffic Jam Chauffeur (SAE Level 3) design and validation. Such a scenario library will be necessary to comply with ISO 21449 Safety Standard (SOTIF), or to comply with SAE Level 3 Audit during the Homologation procedure.

These tools, process, and scenarios library are being industrialized for the use of French manufacturers PSA and Renault. They are sustainable for

automotive industry, and because this task is huge, it is probably not possible to continue alone for region extension.

In the close future, this scenario library will be adapted for urban and peri-urban automated driving systems, and will be fulfilled with relevant scenarios coming real world driving of Level 3 and Level 4 Automated Systems experiment in SAM project (SAM is a French project of more than 15 experimentations on Automated Driving Systems, beginning in 2019).

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