Pegasus Symposium 2019

Japanese AD Safety Assurance Investigation for Global Industry Harmonization

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The AD safety challenge

Proving AD safety is a great challenge for industry.
Traditional safety approaches based on long driving distances insufficient.
Innovative AD safety assurance methodologies are needed

Complicated interchange

Traffic

Urban canyon

Recognition

No center zone

Recognition

Narrow tunnel

Recognition

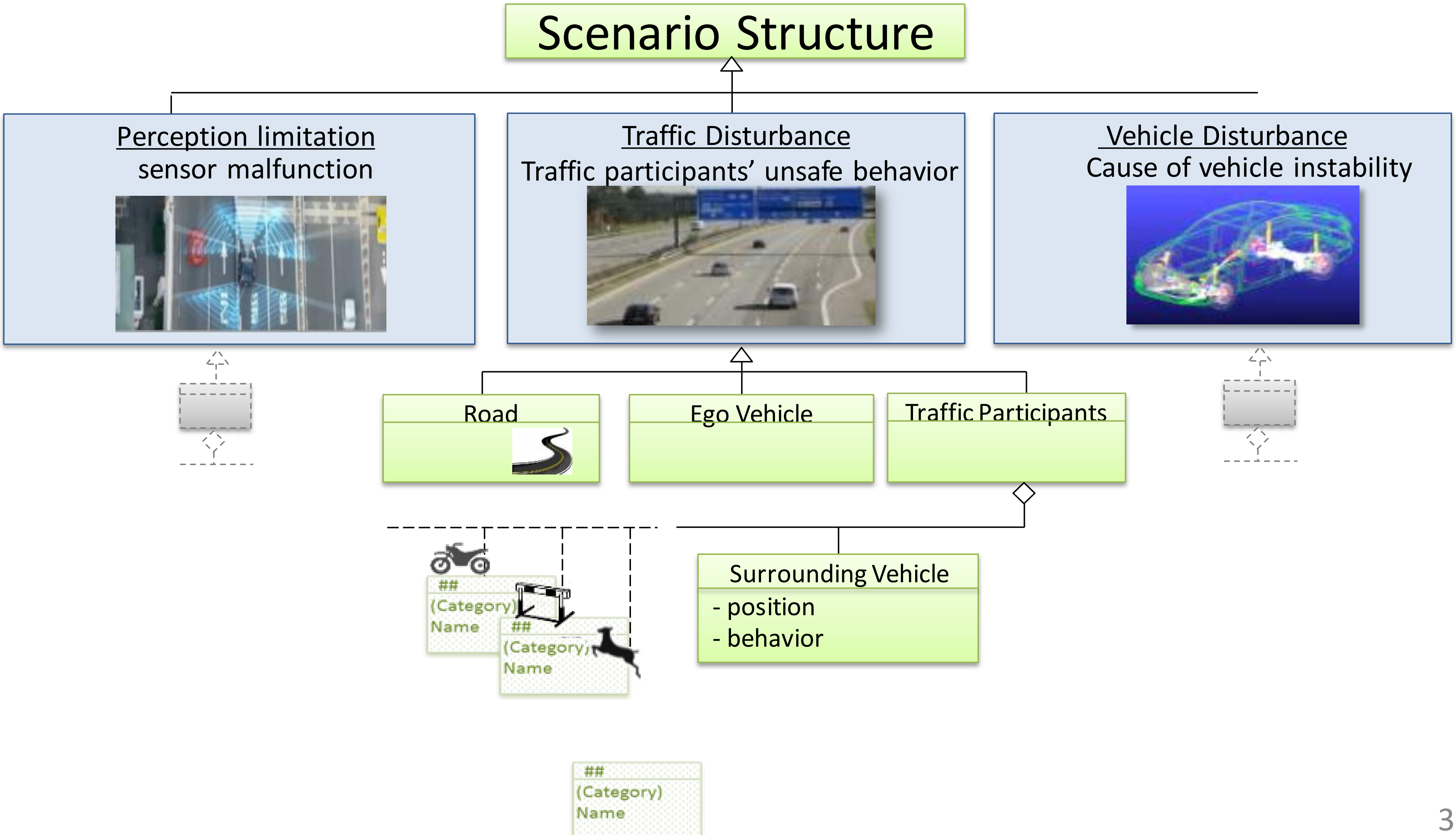
Blind curve

Recognition Dynamics

Prevention palls for wrong-way

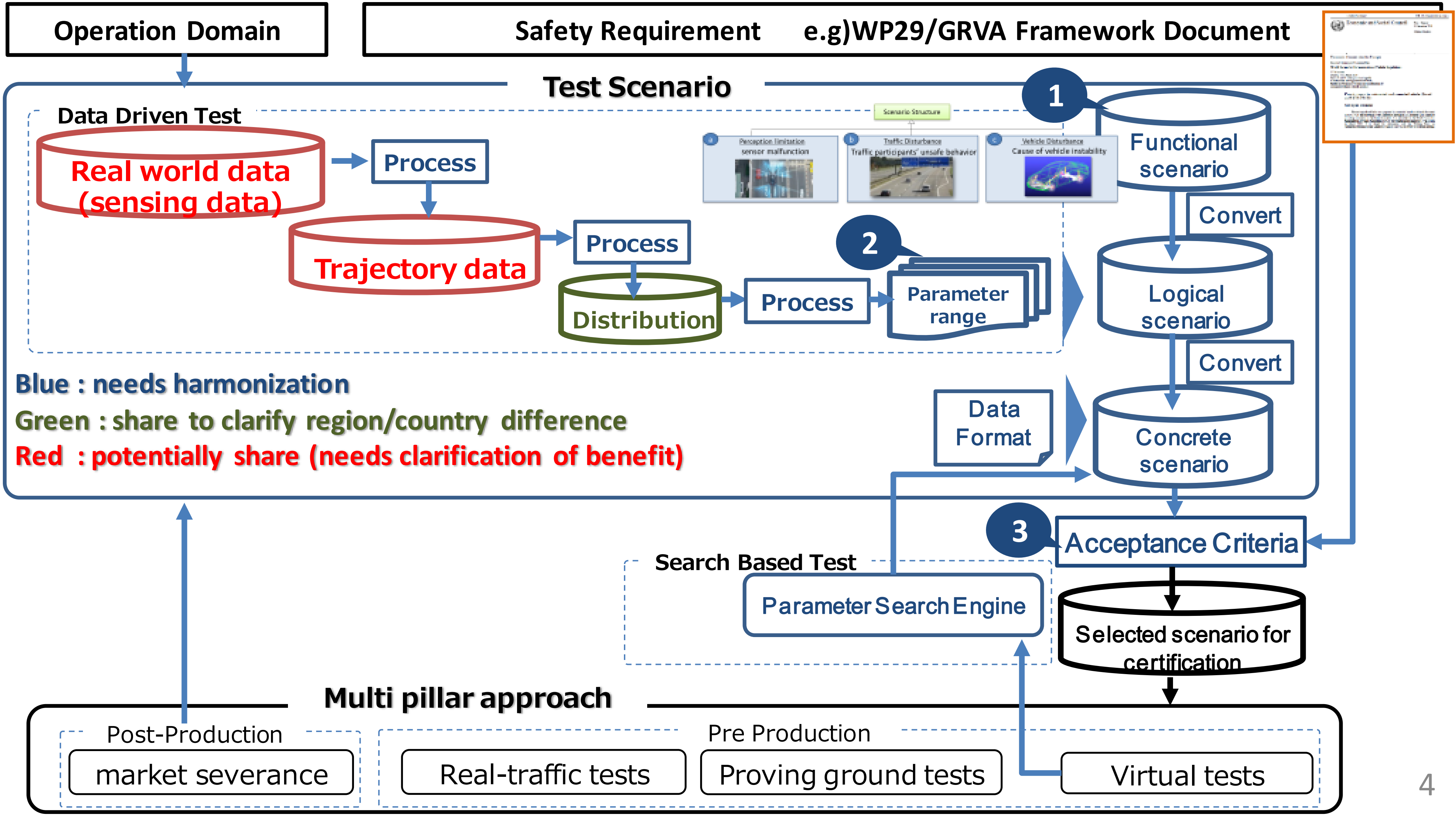
Recognition

Development of an innovative methodology

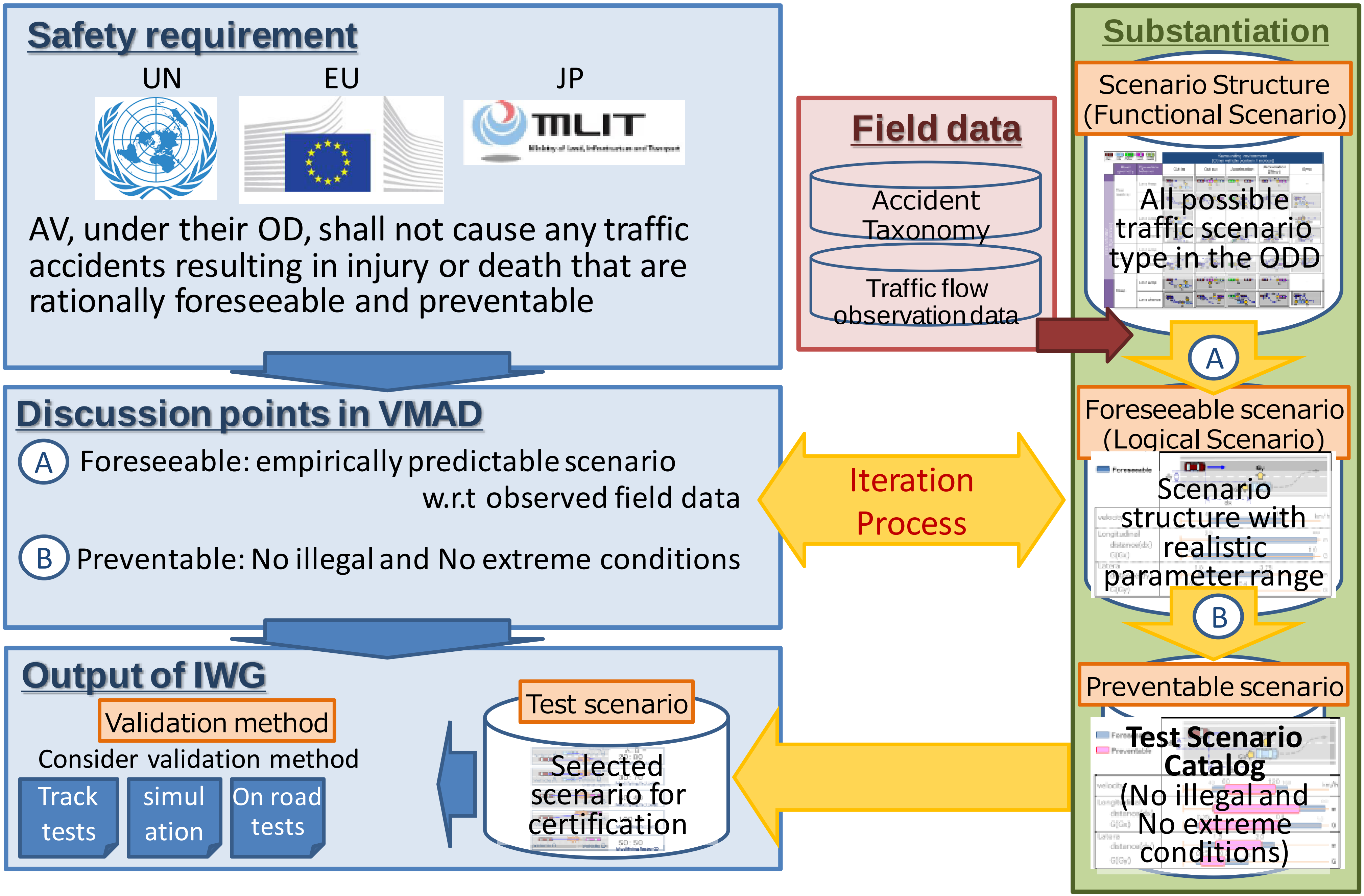


AD Safety Assurance Process based on scenario

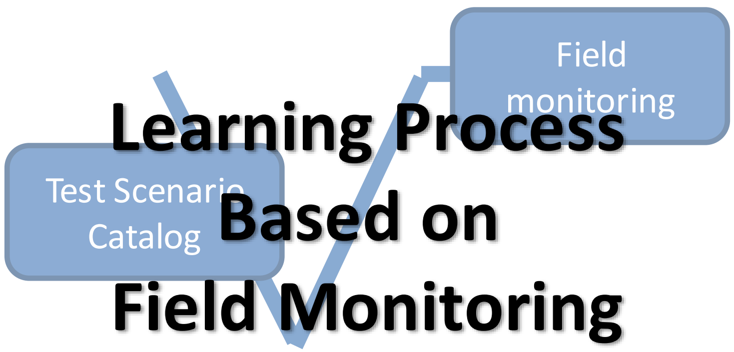
So as to achieve the globally common approach, the key is harmonization of 1) scenario structure, 2)parameter range, and 3)acceptance criteria.



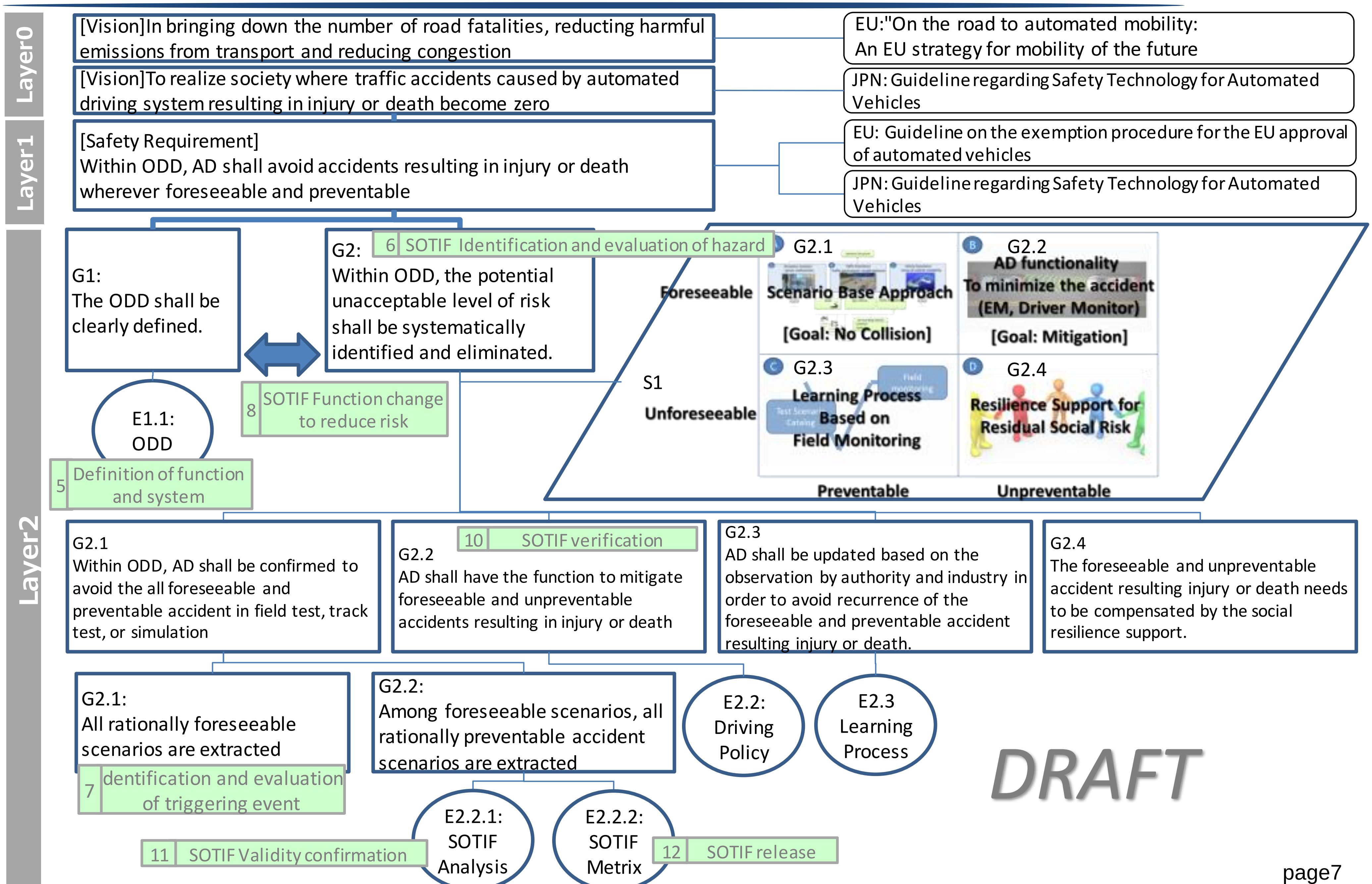
Certification Test Scenario Derivation Process



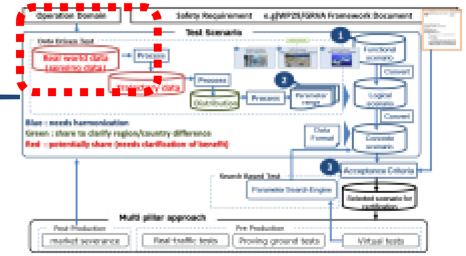
Safety Argumentation Matrix

	Preventable	Unpreventable
Foreseeable	 **Scenario Base Approach** **[Goal: No Collision]**	 **AD functionality** **To minimize the accident** **(EM, Driver Monitor)** **[Goal: Mitigation]**
Unforeseeable	 **Learning Process Based on Field Monitoring**	 **Resilience Support for Residual Social Risk**

Development of SOTIF Safety Structure based on the safety requirement



Traceability between ODD and scenario

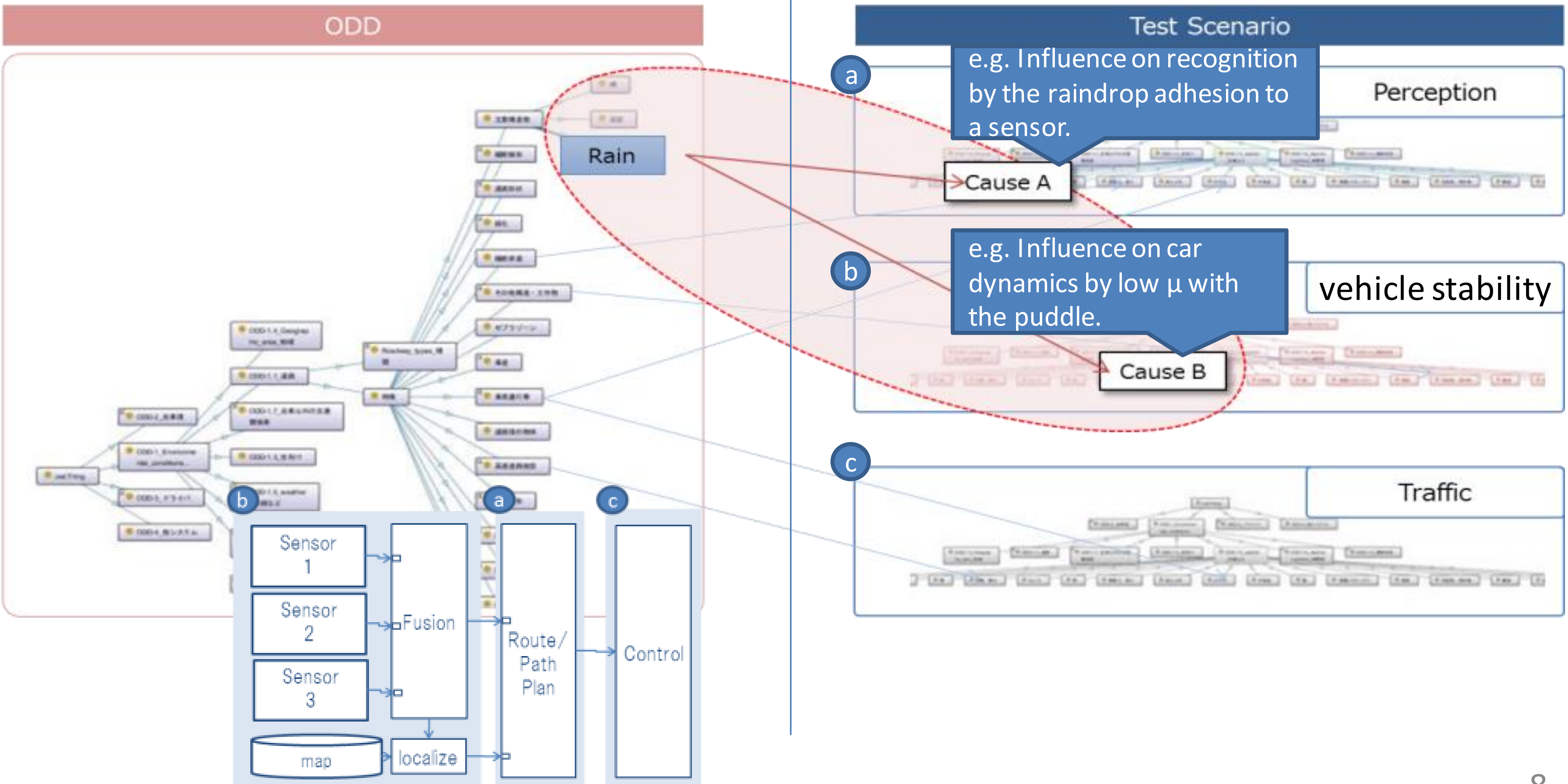


View from outside of system

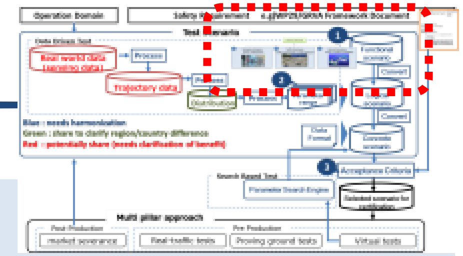
⇒Needs to be understandable for users

View from inside of system

⇒needs to be scientific and holistic



Traffic Scenario Structure



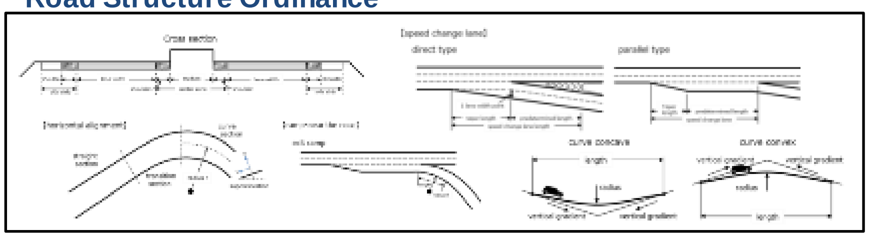
(a) Extract the most demanding parameter from real environment data for each road geometry classification based existing laws and regulations.

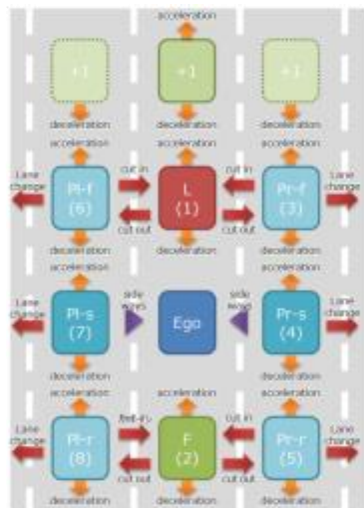
(b) Define 8+1 position around ego-vehicle and movement which can invade the ego trajectory.

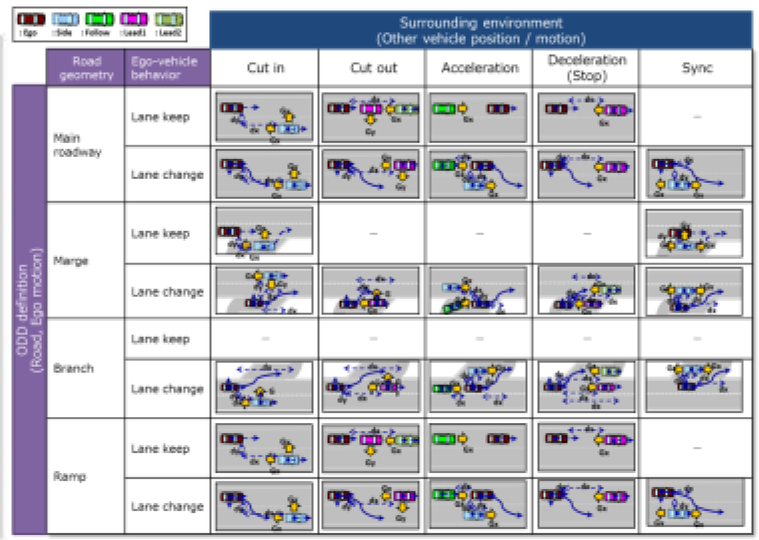
(a) Road geometry ✖ Ego-vehicle behavior ✖ (b) Traffic participants' position ✖ surrounding vehicle behavior

		Ego-vehicle behavior	
		Lane keep	Lane change
Road geometry	Main roadway	Free Driving Following	Lane change Overtaking
Road geometry	Merge	Merging in front	Merge
Road geometry	Branch	---	Branch
Road geometry	Ramp	Free Driving Following	Lane change Overtaking

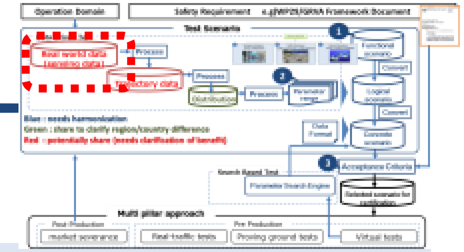
Road Structure Ordinance





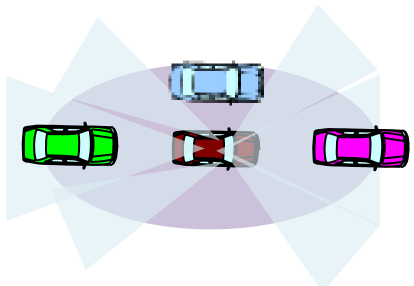


Traffic Data colllection

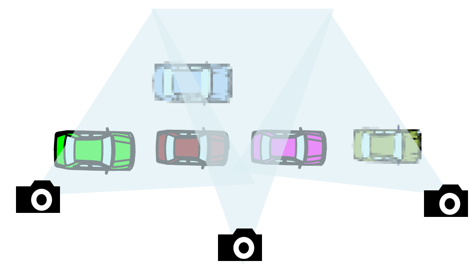


Third party is collecting the driving data and establishing the data processing technique so as to extract the foreseeable critical parameter combination and range.

<u>Instrumented vehicles</u>



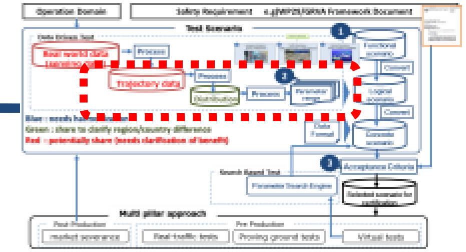
<u>Fixed camera</u>



Ongoing data collection

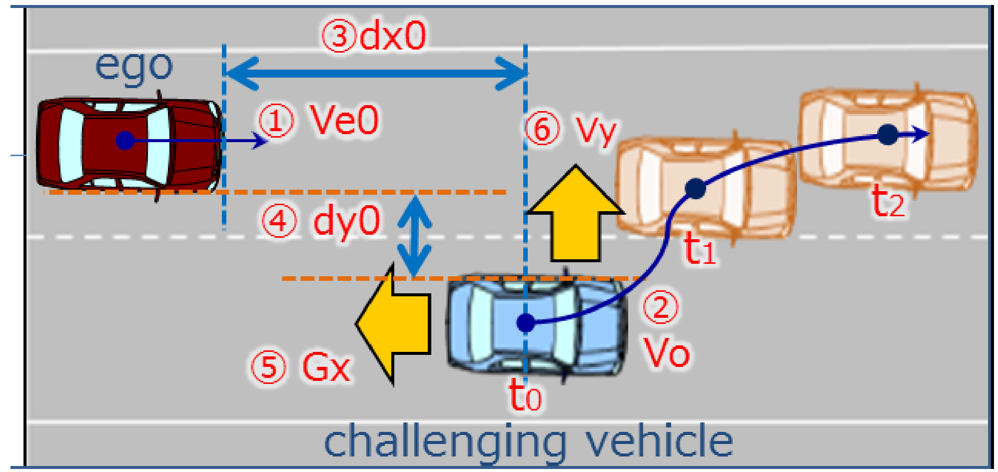
Data Source	TUAT Driving Recorder Data (~2018~)	JAMA Driving Recorder Data (2008)	Driving Database (2017)	On road Recognition Database (2017)	Instrumented Vehicle Data Correction (2018~)	Fixed Location Camera (2018~)
◎ / ◎ Parameter available (Mobileye/Lidar) ○ Video only △ visible × Not recorded	△ △ ○ △ × Ego × × × ×	△ ○ ○ ○ × Ego × × × ×	△ ○ ◎ ○ ○ Ego ○ △ ○ △	△ ○ ◎ ○ △ Ego △ △ △ △	△ ◎ ◎ ◎ ◎ Ego ◎ ◎ ◎ ◎	○ ○ ○ ○ ○ Ego ○ ○ ○ ○
Logging Device	-	60 vehicles	30 vehicles	6 vehicles	3 vehicles	3 cameras / each location
Driver	Taxi driver	Ordinal driver	Ordinal driver	Staff	Staff	-

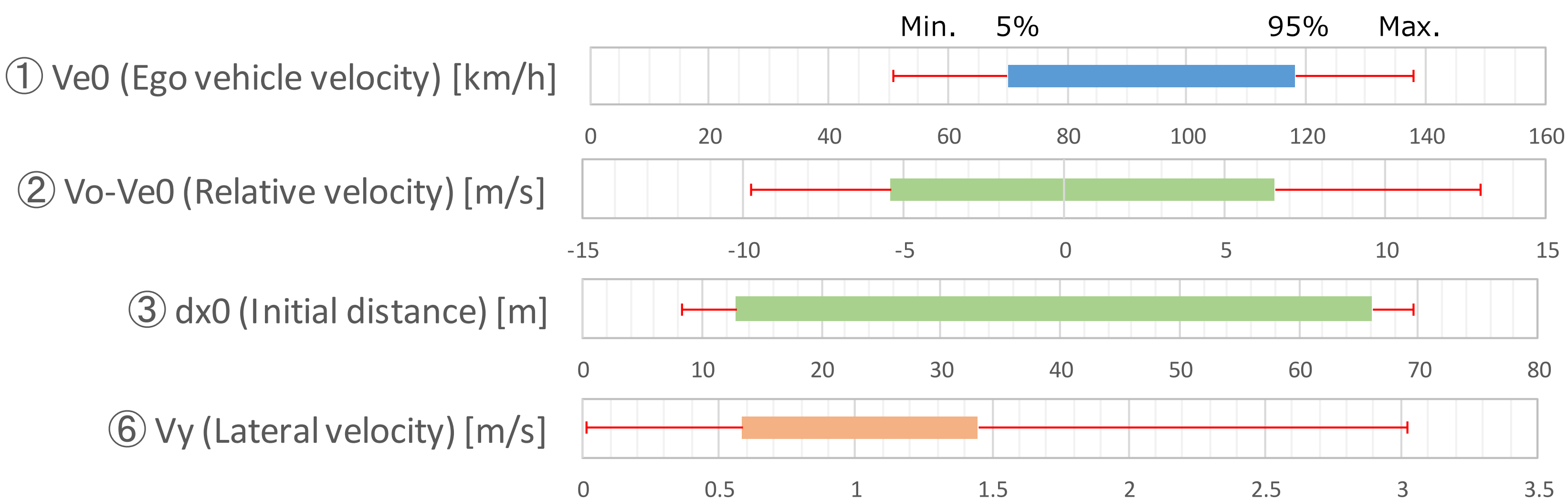
Parameter selection and application to data set



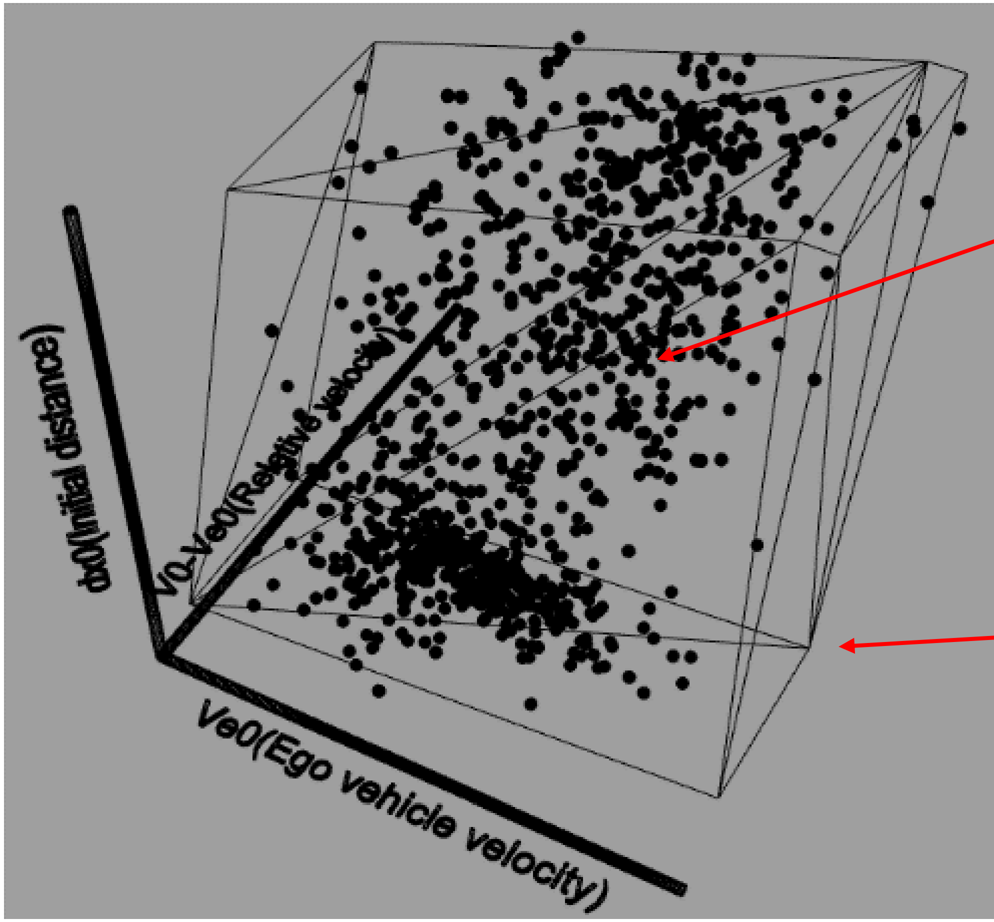
We adopted the parameter selection methodology, which is investigated with NFF Henze and Znamiec. The paper has been submitted to ITSC2019 (Under revision)

Parameter		Name
①	**Ve0**	**Ego vehicle velocity**
②	**Vo－Ve0**	**Relative velocity**
③	**dx0**	**Initial distance**
④	dy0	Initial lateral distance
⑤	Gx	Deceleration
⑥	**Vy**	**Lateral velocity**





3D cloud of correlated parameters

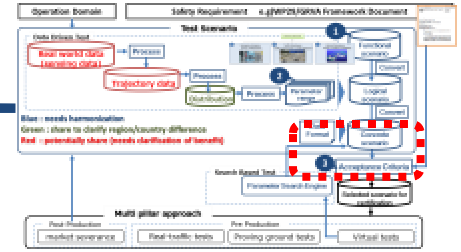


Values for ego-vehicle velocity, initial distance, and relative velocity for each cut-in case detected in the traffic data

3D space containing 95% percentile values of the data points

The relationship between the parameters that correlate (ego-vehicle velocity, initial distance, and relative velocity) needs to be considered when generating concrete scenarios

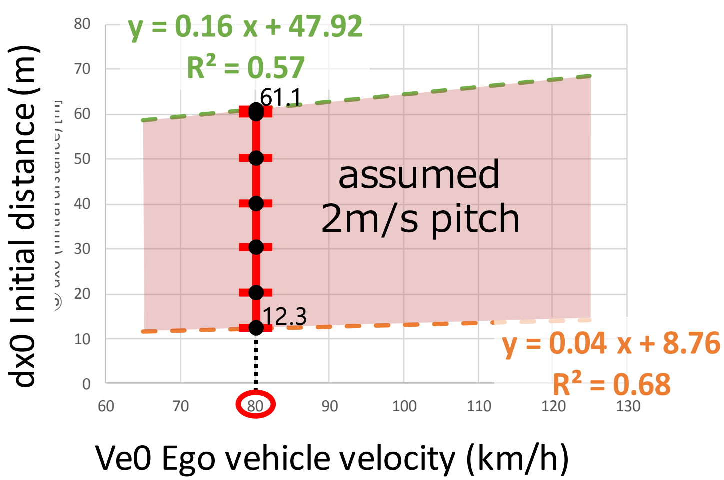
Case study1 : Generation of concrete scenario

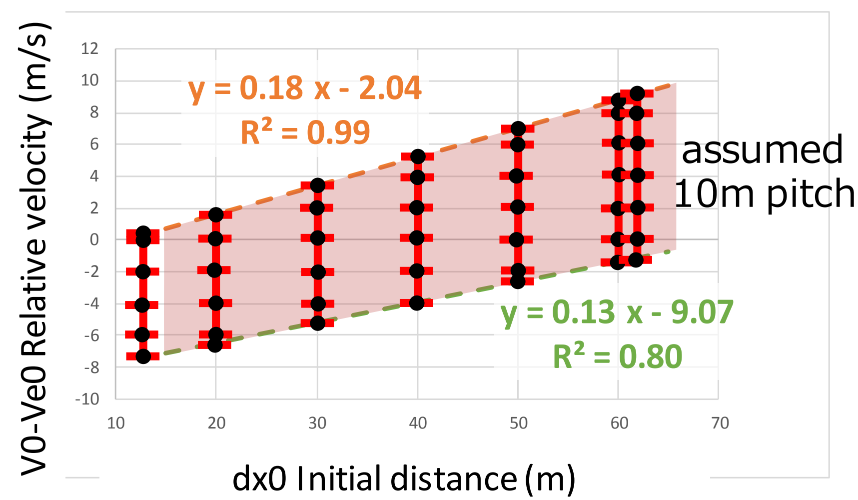


For pre-set initial ego-vehicle velocity of 80 km/h and lateral velocity of 1.45 m/s, initial distances of 12.3 to 61.1m and their respective correlating relative velocity values need to be considered

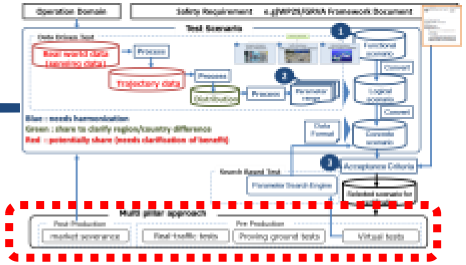
Parameter	Unit	Value
①Ve0(Ego vehicle velocity)	km/h	80
②V0-Ve0(Relative velocity)	**m/s**	**see table**
③dx0(Initial distance)	**m**	**see table**
⑥Vy(Lateral velocity)	m/s	1.45

		③dx0 (Initial distance) [m]						
		12.3	20	30	40	50	60	61.1
②V0-Ve0 (Relative velocity) [m/s]	Min	-7.49	-6.50	-5.21	-3.93	-2.64	-1.35	-1.21
	Max	0.19	1.58	3.39	5.21	7.02	8.83	9.03





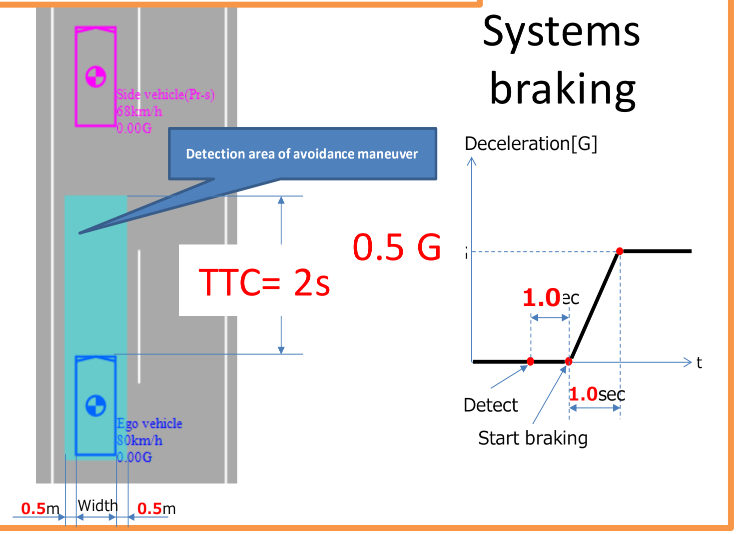
Case study1 : Precondition and Results



Exemplary safety criterion (0.5G braking)

AD vehicle function

Systems braking



Simulation results

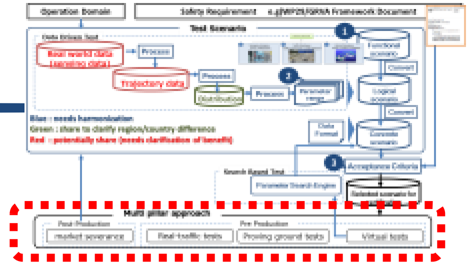
Ve0=80km/h, Vy=1.45m/s

②V0−Ve0 (Relative velocity) [m/s] \ ③dx0 (Initial distance) [m]	12.3	20	30	40	50	60	61.1
						✘ 8.83	✘ 9.03
					✘ 7.02	✘ 8	✘ 8
				✔ 5.21	✘ 6	✘ 6	✘ 6
			✔ 3.39	✔ 4	✔ 4	✔ 4	✔ 4
	✔ 0.19	✔ 1.58	✔ 2	✔ 2	✔ 2	✔ 2	✔ 2
	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0
	✔ −2	✔ −2	✔ −2	✔ −2	✔ −2	✔ −1.35	✔ −1.21
	✔ −4	✔ −4	✔ −4	✔ −3.93	✔ −2.64		
	✔ −6	✔ −6	✔ −5.21				
	✔ −7.49	✔ −6.50					

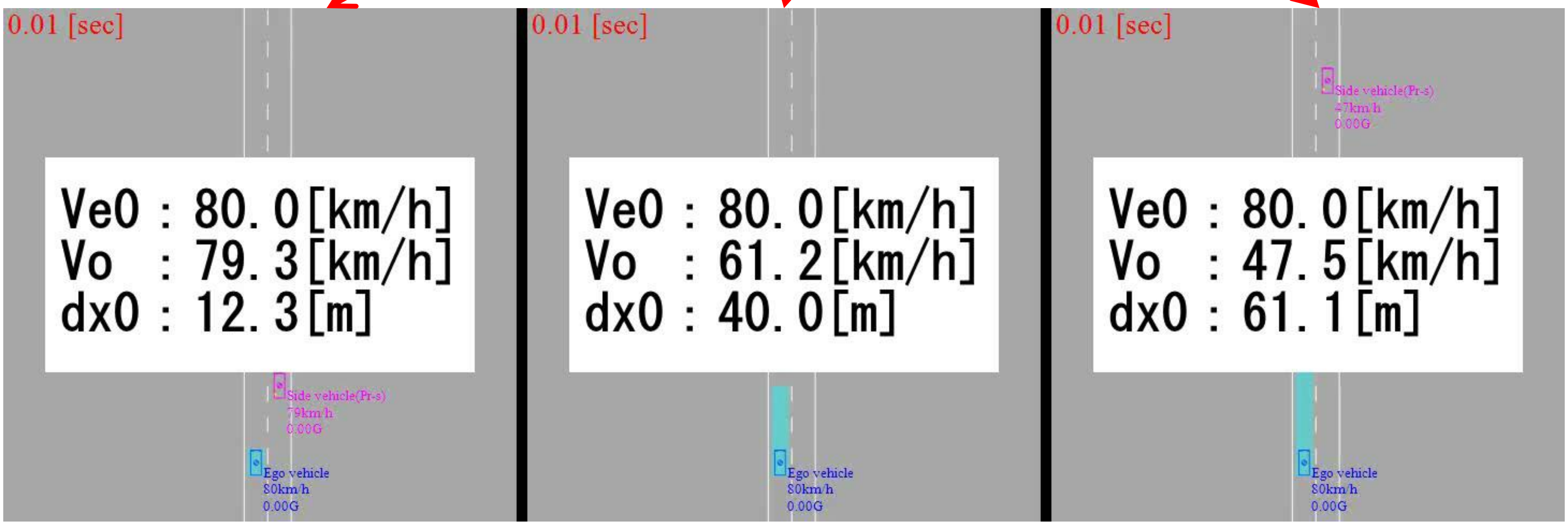
✔ : Success (non−crash), ✘ : Fail (Crash)

Within the parameter ranges defined and incorporated to the simulations, some cases could not prevent a crash based on the applied (example) safety criterion with mid-level performance braking capabilities.

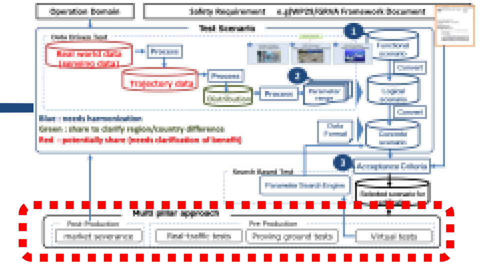
Case study simulation results (videos)



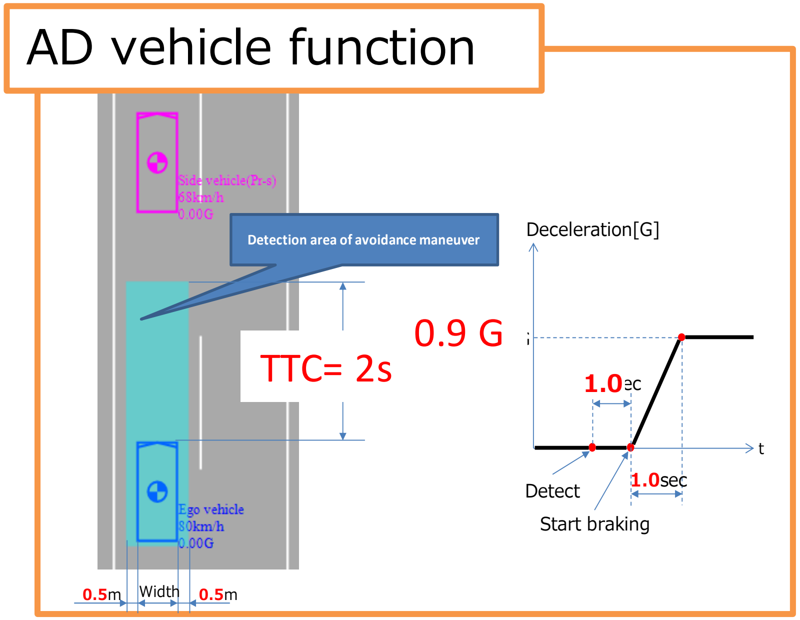
	③dx0 (Initial distance) [m]						
	12.3	20	30	40	50	60	61.1
②V0−Ve0 (Relative velocity) [m/s]						✗ 8.83	✗ 9.03
					✗ 7.02	✗ 8	✗ 8
				✓ 5.21	✗ 6	✗ 6	✗ 6
			✓ 3.39	✓ 4	✓ 4	✓ 4	✓ 4
	✓ 0.19	✓ 1.58	✓ 2	✓ 2	✓ 2	✓ 2	✓ 2
	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0
	✓ −2	✓ −2	✓ −2	✓ −2	✓ −2	✓ −1.35	✓ −1.21
	✓ −4	✓ −4	✓ −4	✓ −3.93	✓ −2.64		
	✓ −6	✓ −6	✓ −5.21				
	✓ −7.49	✓ −6.50					



Case study2 : Precondition and Results



Exemplary safety criterion (0.9G braking)



Simulation results

Ve0=80km/h, Vy=1.45m/s

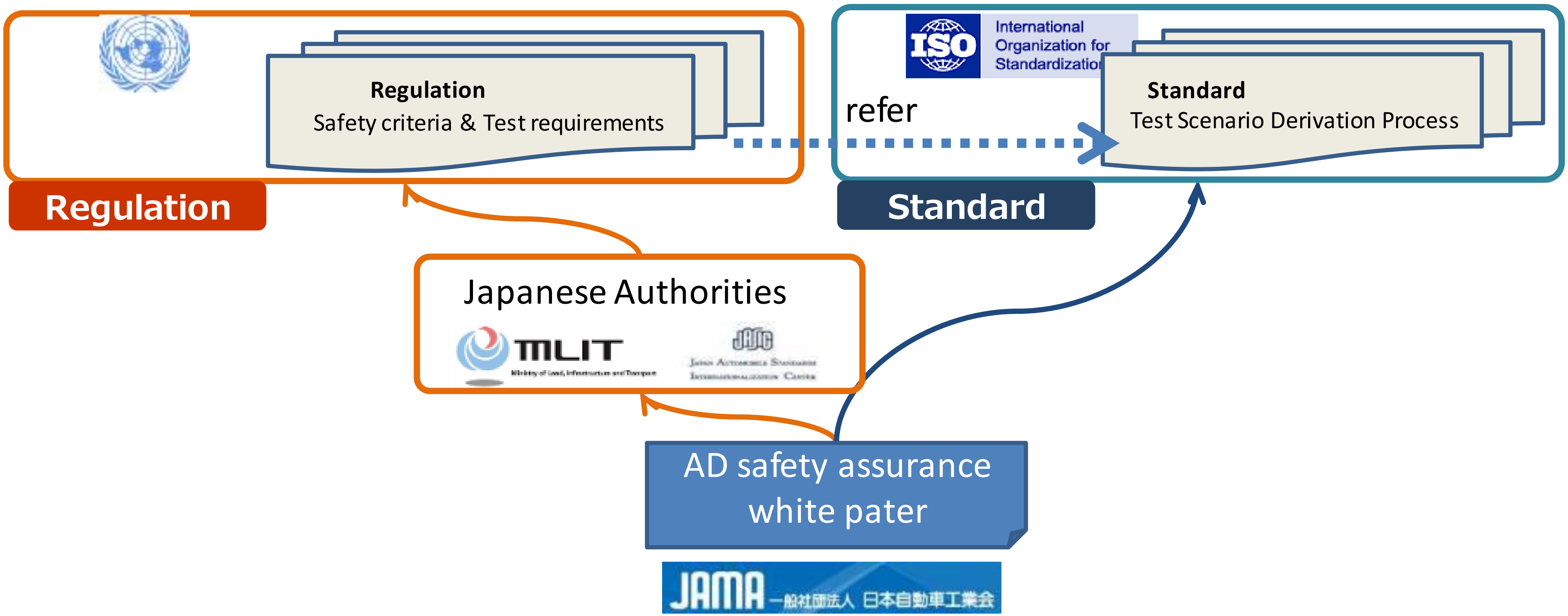
②V0−Ve0 (Relative velocity) [m/s]	③dx0 (Initial distance) [m] 12.3	20	30	40	50	60	61.1
						✔ 8.83	✔ 9.03
					✔ 7.02	✔ 8	✔ 8
				✔ 5.21	✔ 6	✔ 6	✔ 6
			✔ 3.39	✔ 4	✔ 4	✔ 4	✔ 4
	✔ 0.19	✔ 1.58	✔ 2	✔ 2	✔ 2	✔ 2	✔ 2
	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0	✔ 0
	✔ −2	✔ −2	✔ −2	✔ −2	✔ −2	✔ −1.35	✔ −1.21
	✔ −4	✔ −4	✔ −4	✔ −3.93	✔ −2.64		
	✔ −6	✔ −6	✔ −5.21				
	✔ −7.49	✔ −6.50					

✔ : Success (non−crash), ✘ : Fail (Crash)

This case study illustrates the process we are applying to generate cases that can be applied to design AD systems with the potential to prevent all possible foreseeable scenarios.

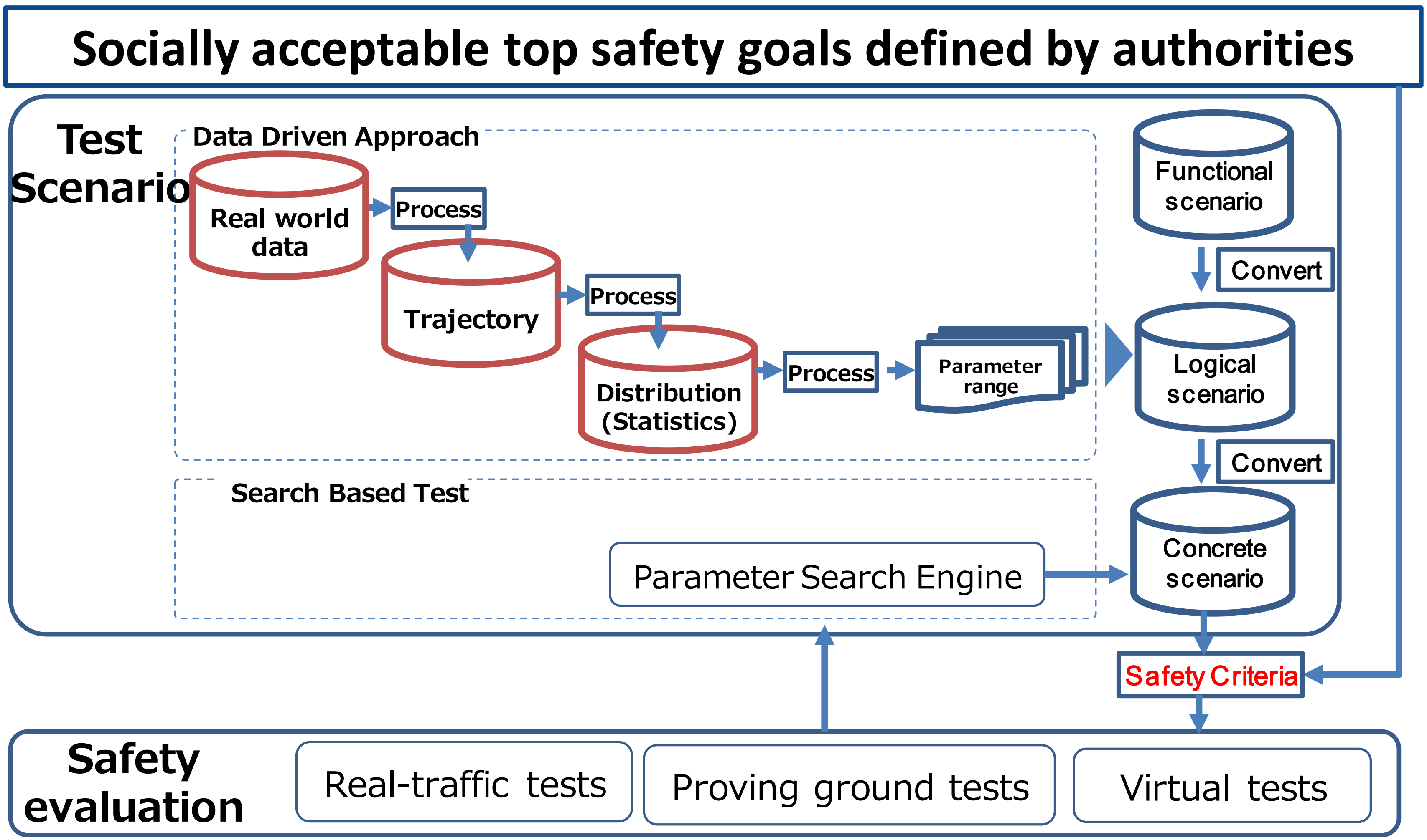
Summary (1)

JAMA is developing, in continuous communication with the Japanese authorities and related research and standardization institutions, a comprehensive strategy to tackle AD safety-related challenges.



Summary (2)

JAMA and JARI, under the auspice of the Japan Ministry of Economy, Trade and Industry, are collecting data and developing engineering methodogies and processes for specific AD safety assurance purposes.



Summary (3)

We are **willing to continue collaborating** with our international industrial partners to harmonize the activities that will lead to a safer and global AD society.

Thank you!

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