

Japanese AD Safety Assurance Investigation for Global Industry Harmonization

JAMA AD safety Assurance WG, chair
Toyota Motor Corporation
Satoshi Taniguchi

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

Scenario Structure

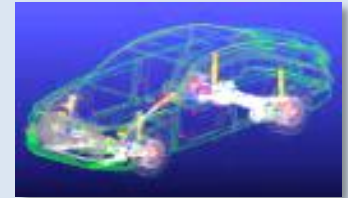
Perception limitation
sensor malfunction



Traffic Disturbance
Traffic participants' unsafe behavior



Vehicle Disturbance
Cause of vehicle instability



Road



Ego Vehicle

Traffic Participants

Surrounding Vehicle

- position
- behavior

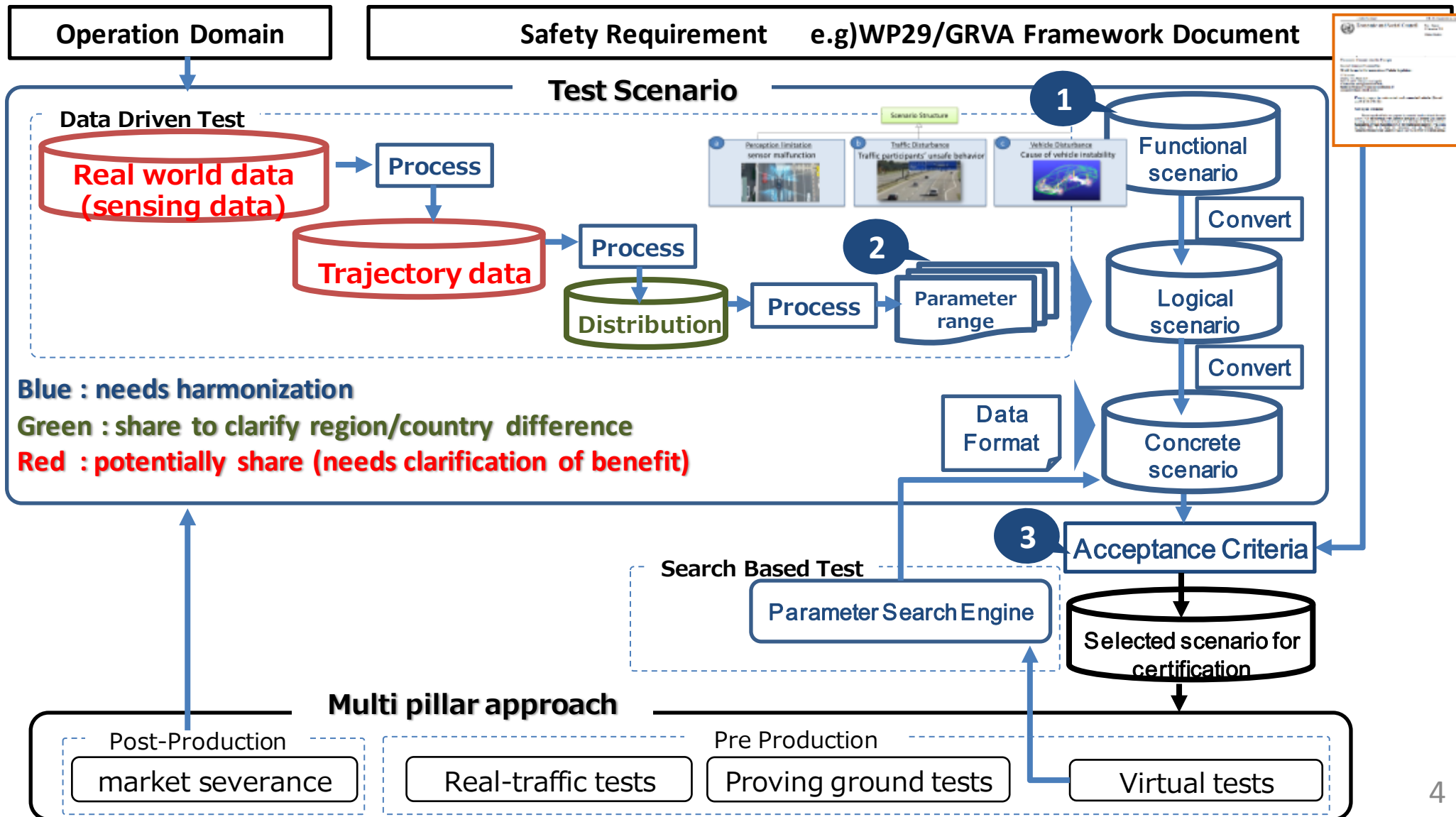
(Category)
Name

(Category)
Name

(Category)
Name

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 requirement

UN



EU



JP



AV, under their OD, shall not cause any traffic accidents resulting in injury or death that are rationally foreseeable and preventable

Discussion points in VMAD

- (A) Foreseeable: empirically predictable scenario w.r.t observed field data
- (B) Preventable: No illegal and No extreme conditions

Output of IWG

Validation method

Consider validation method

Track tests

simulation

On road tests

Test scenario

Selected scenario for certification

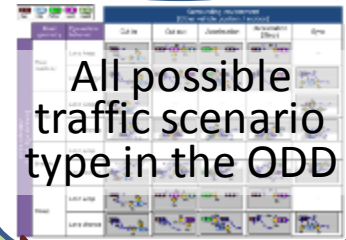
Field data

Accident Taxonomy

Traffic flow observation data

Substantiation

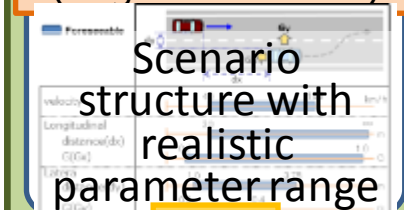
Scenario Structure (Functional Scenario)



All possible traffic scenario type in the ODD

A

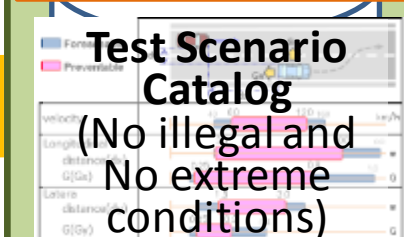
Foreseeable scenario (Logical Scenario)



Scenario structure with realistic parameter range

B

Preventable scenario



Test Scenario Catalog (No illegal and No extreme conditions)

Iteration Process

Safety Argumentation Matrix

Foreseeable

Scenario Base Approach

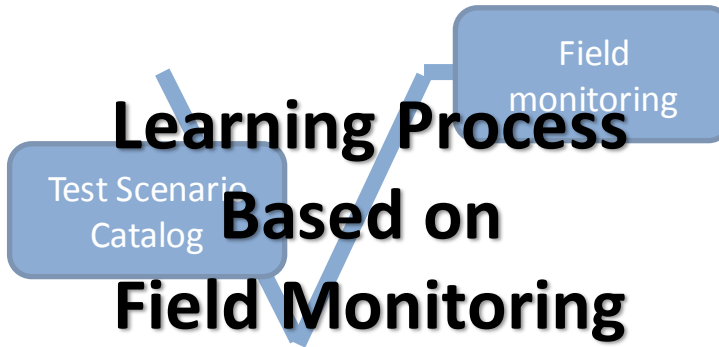


AD functionality
To minimize the accident
(EM, Driver Monitor)

[Goal: Mitigation]

Unforeseeable

Learning Process
Based on
Field Monitoring



Resilience Support for
Residual Social Risk



Preventable

Unpreventable

Development of SOTIF Safety Structure based on the safety requirement

Layer0

[Vision] In bringing down the number of road fatalities, reducing harmful emissions from transport and reducing congestion

EU: "On the road to automated mobility: An EU strategy for mobility of the future"

[Vision] To realize society where traffic accidents caused by automated driving system resulting in injury or death become zero

JPN: Guideline regarding Safety Technology for Automated Vehicles

Layer1

[Safety Requirement] Within ODD, AD shall avoid accidents resulting in injury or death wherever foreseeable and preventable

EU: Guideline on the exemption procedure for the EU approval of automated vehicles

JPN: Guideline regarding Safety Technology for Automated Vehicles

Layer2

G1: The ODD shall be clearly defined.

G2: **6 SOTIF Identification and evaluation of hazard**
Within ODD, the potential unacceptable level of risk shall be systematically identified and eliminated.



E1.1: ODD

8 SOTIF Function change to reduce risk

5 Definition of function and system

G2.1 Within ODD, AD shall be confirmed to avoid the all foreseeable and preventable accident in field test, track test, or simulation

G2.2 **10 SOTIF verification**
AD shall have the function to mitigate foreseeable and unpreventable accidents resulting in injury or death

G2.3 AD shall be updated based on the observation by authority and industry in order to avoid recurrence of the foreseeable and preventable accident resulting injury or death.

G2.4 The foreseeable and unpreventable accident resulting injury or death needs to be compensated by the social resilience support.

G2.1: All rationally foreseeable scenarios are extracted
7 identification and evaluation of triggering event

G2.2: Among foreseeable scenarios, all rationally preventable accident scenarios are extracted

E2.2: Driving Policy

E2.3 Learning Process

11 SOTIF Validity confirmation

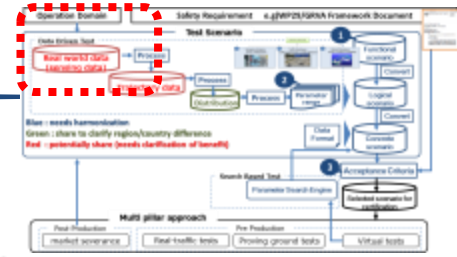
E2.2.1: SOTIF Analysis

E2.2.2: SOTIF Metrix

12 SOTIF release

DRAFT

Traceability between ODD and scenario

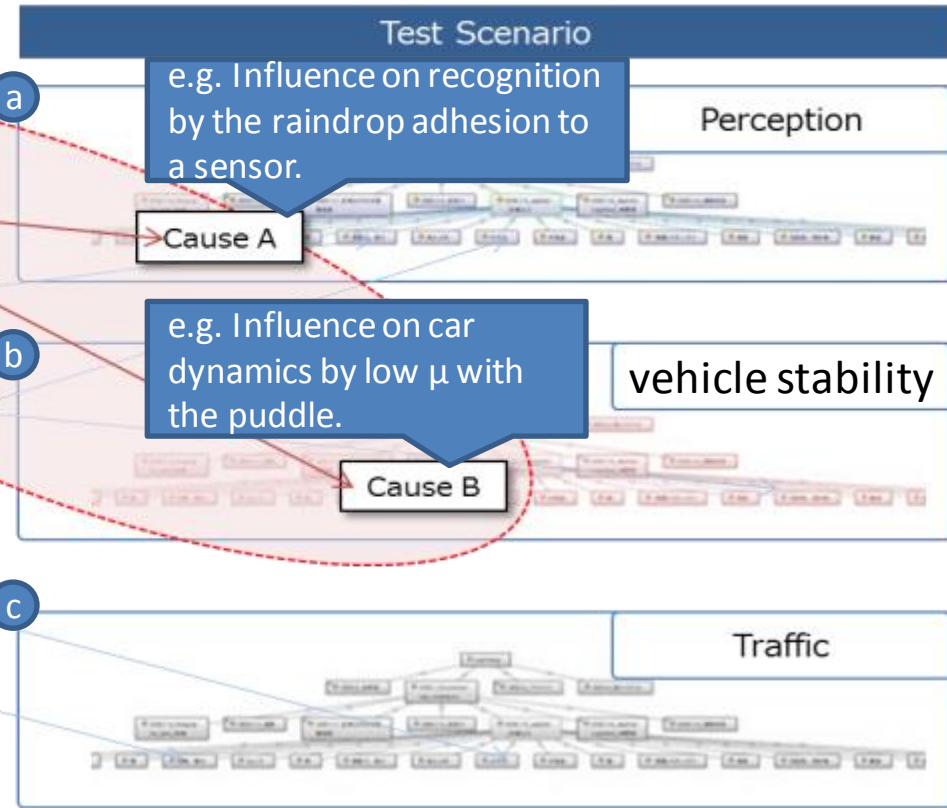
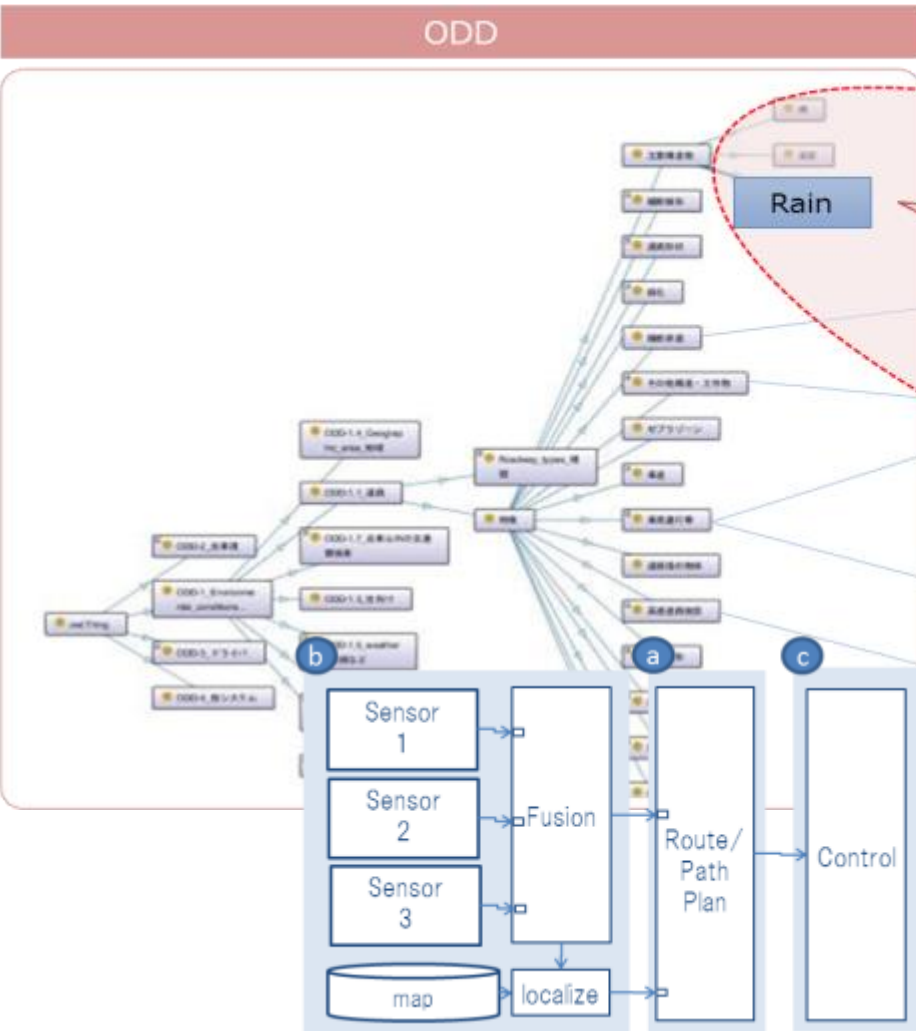


View from outside of system

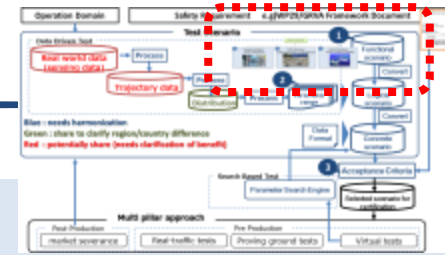
⇒ Needs to be understandable for users

View from inside of system

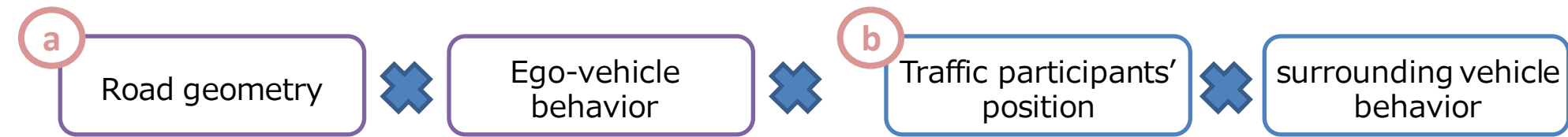
⇒ needs to be scientific and holistic



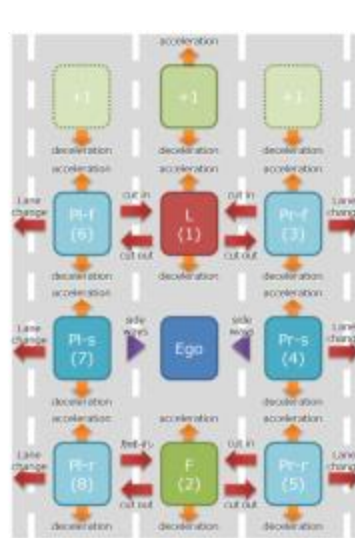
Traffic Scenario Structure



- 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.

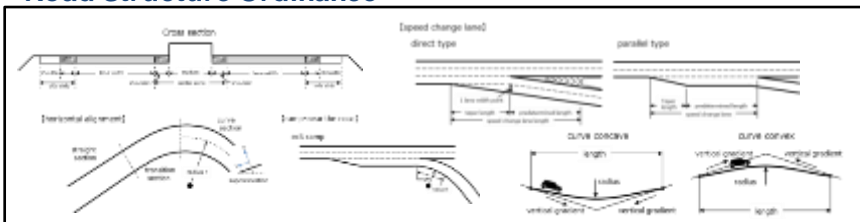


		Ego-vehicle behavior	
		Lane keep	Lane change
Road geometry	Main roadway	Free Driving Following	Lane change Overtaking
	Merge	Merging in front	Merge
	Branch	---	Branch
	Ramp	Free Driving Following	Lane change Overtaking

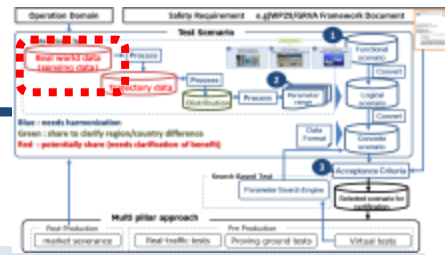


		Surrounding environment (Other vehicle position / motion)				
Road geometry	Ego-vehicle behavior	Cut in	Cut out	Acceleration	Deceleration (Stop)	Sync
Main roadway	Lane keep					-
	Lane change					
Merge	Lane keep	-	-	-	-	
	Lane change					
Branch	Lane keep	-	-	-	-	-
	Lane change					
Ramp	Lane keep					-
	Lane change					

Road Structure Ordinance

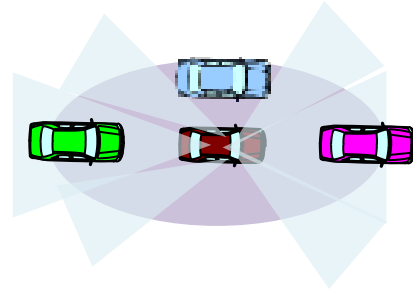


Traffic Data collection

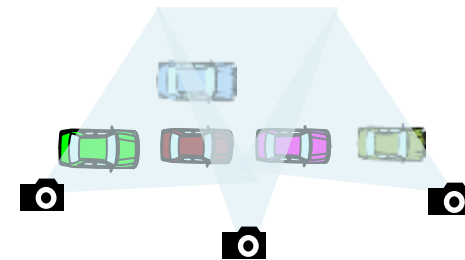


Third party is collecting the driving data and establishing the data processing technique so as to extract the foreseeable critical parameter combination and range.

Instrumented vehicles



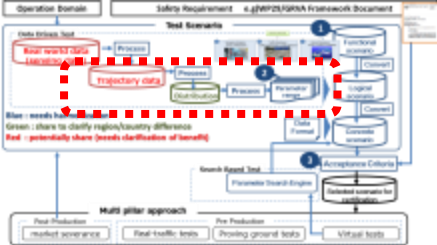
Fixed camera



Ongoing data collection

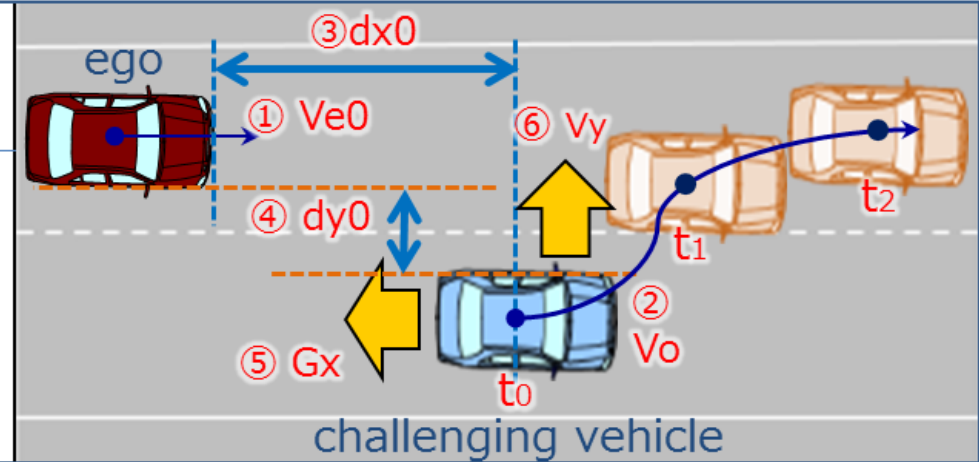
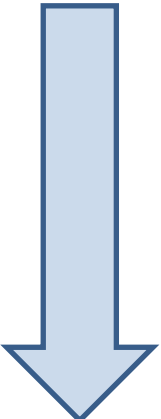
Data Source	TUAT Driving Recorder Data (~2018~)	JAMA Driving Recorder Data (2008)	Driving Database (2017)	On road Recognition Database (2017)	Instrumented Vehicle Data Correction (2018~)	Fixed Location Camera (2018~)
● / ● Parameter available (Mobileye/Lidar) ○ Video only △ visible ✗ Not recorded	△ △ ○ △ ✗ 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

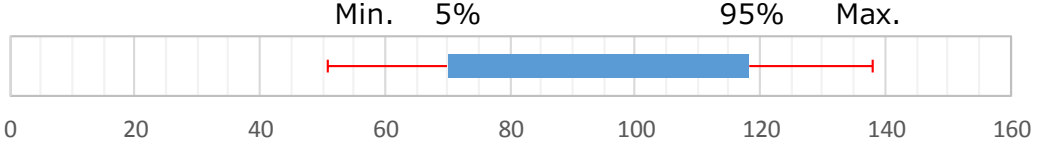


We adopted the parameter selection methodology, which is investigated with NFF Henze and Znamiec. The paper has been submitted to ITSC2019 (Under revision)

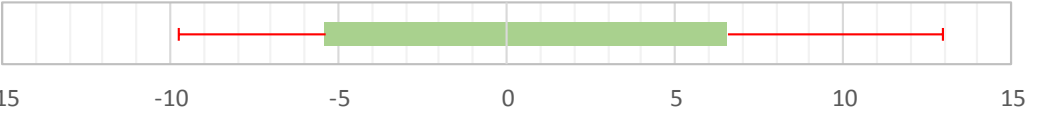
Parameter	Name
① V_{e0}	Ego vehicle velocity
② $V_o - V_{e0}$	Relative velocity
③ dx_0	Initial distance
④ dy_0	Initial lateral distance
⑤ G_x	Deceleration
⑥ V_y	Lateral velocity



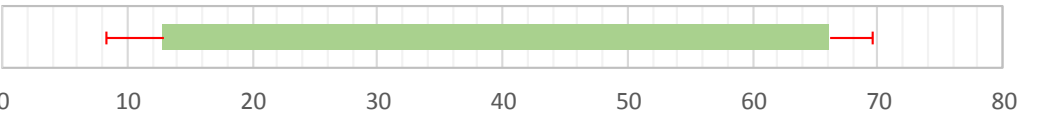
① V_{e0} (Ego vehicle velocity) [km/h]



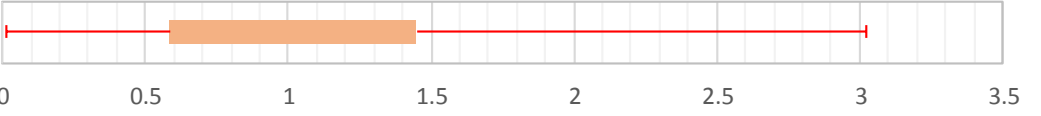
② $V_o - V_{e0}$ (Relative velocity) [m/s]

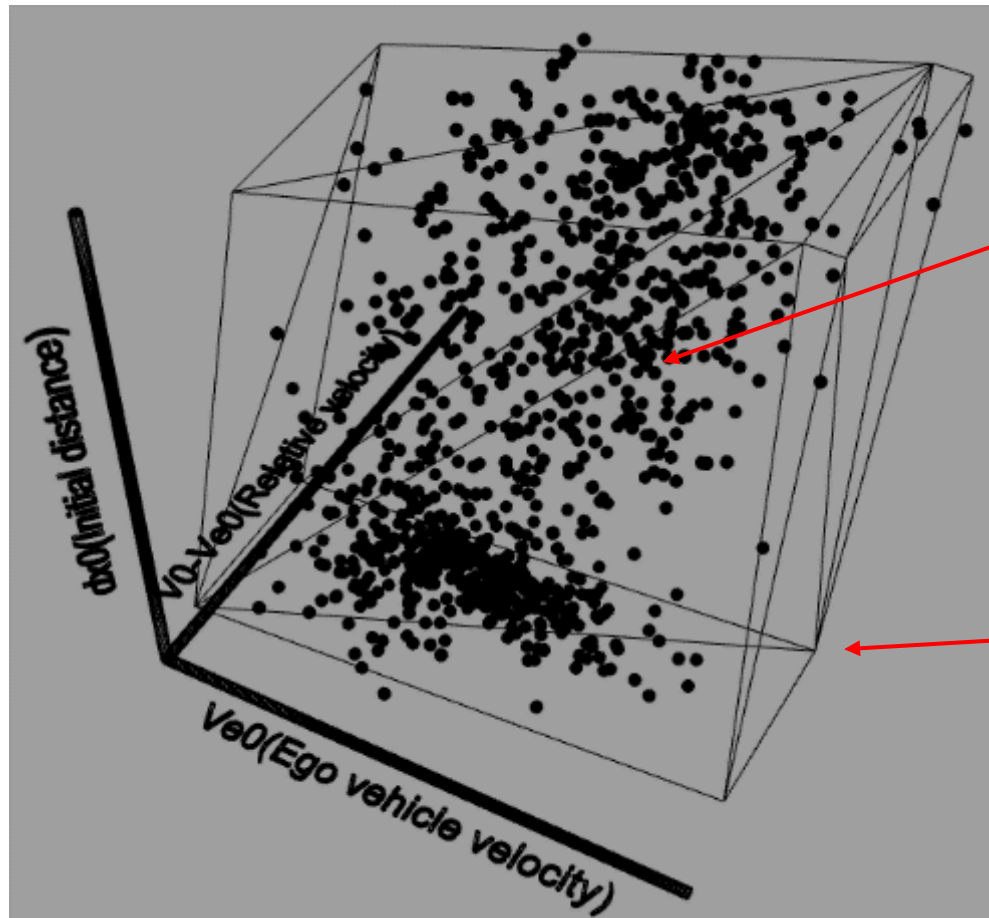


③ dx_0 (Initial distance) [m]



⑥ V_y (Lateral velocity) [m/s]



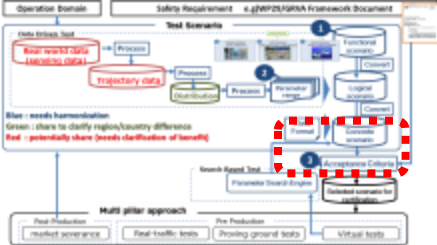


Values for ego-vehicle velocity, initial distance, and relative velocity for each cut-in case detected in the traffic data

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

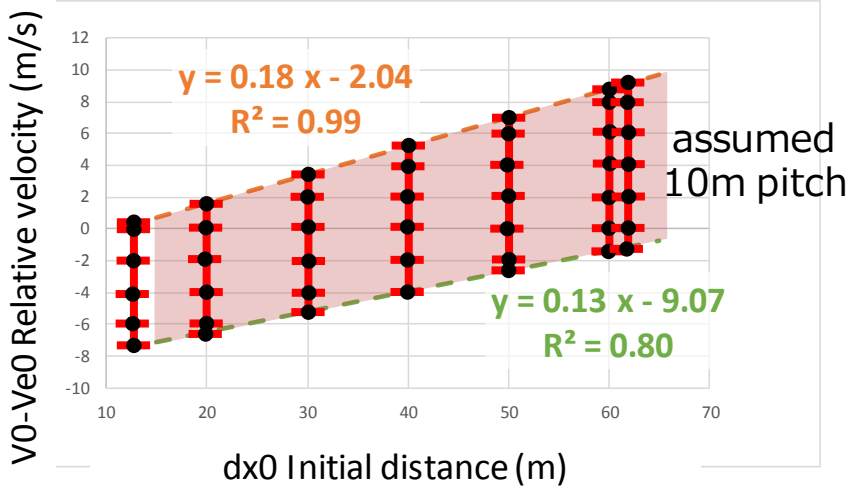
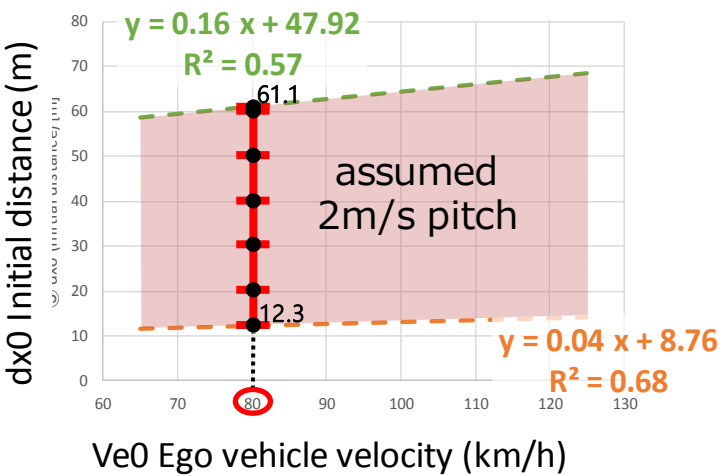
Case study1 : Generation of concrete scenario



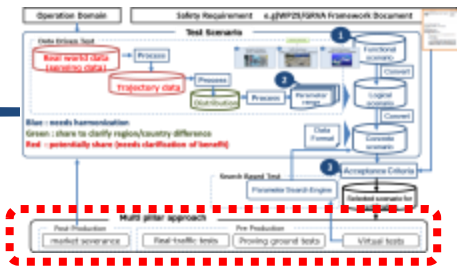
For pre-set initial ego-vehicle velocity of 80 km/h and lateral velocity of 1.45 m/s, initial distances of 12.3 to 61.1m and their respective correlating relative velocity values need to be considered

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

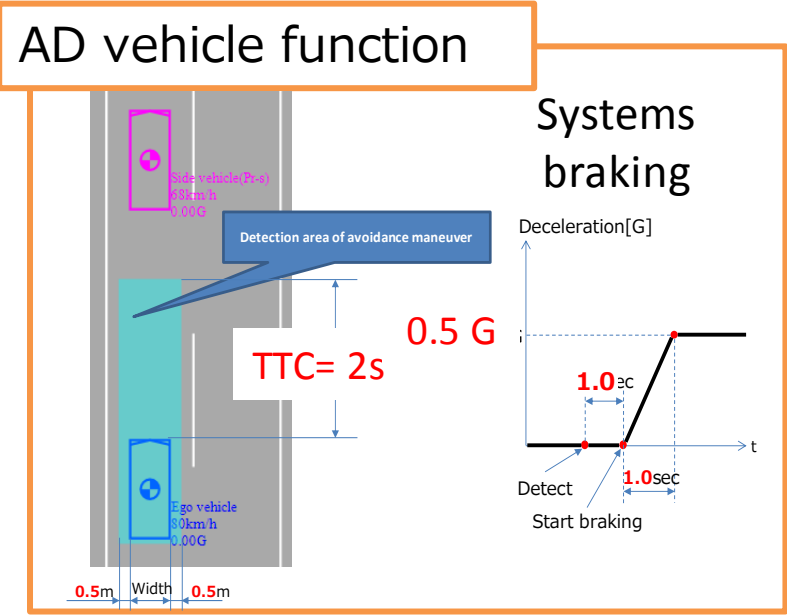
		③ dx0 (Initial distance) [m]						
		12.3	20	30	40	50	60	61.1
② V0-Ve0 (Relative velocity) [m/s]	M in	-7.49	-6.50	-5.21	-3.93	-2.64	-1.35	-1.21
	M ax	0.19	1.58	3.39	5.21	7.02	8.83	9.03



Case study1 : Precondition and Results



Exemplary safety criterion (0.5G braking)



Simulation results

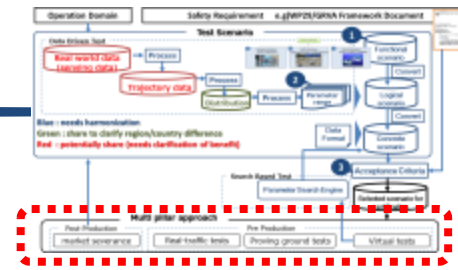
$V_{e0}=80\text{km/h}$, $V_y=1.45\text{m/s}$

		③dx0 (In itia l d istance) [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						

✓ : 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	
		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						

0.01 [sec]

Ve0 : 80.0 [km/h]
Vo : 79.3 [km/h]
dx0 : 12.3 [m]

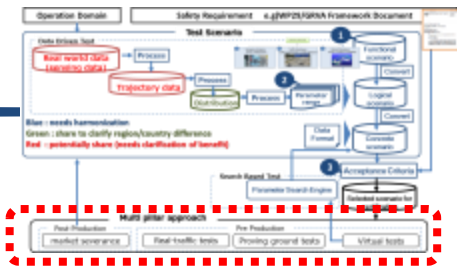
0.01 [sec]

Ve0 : 80.0 [km/h]
Vo : 61.2 [km/h]
dx0 : 40.0 [m]

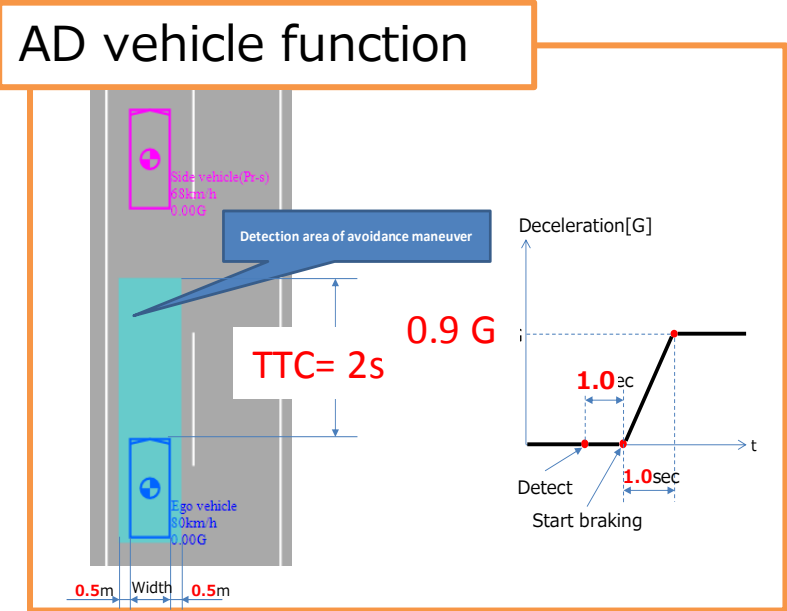
0.01 [sec]

Ve0 : 80.0 [km/h]
Vo : 47.5 [km/h]
dx0 : 61.1 [m]

Case study2 : Precondition and Results



Exemplary safety criterion (0.9G braking)



Simulation results

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

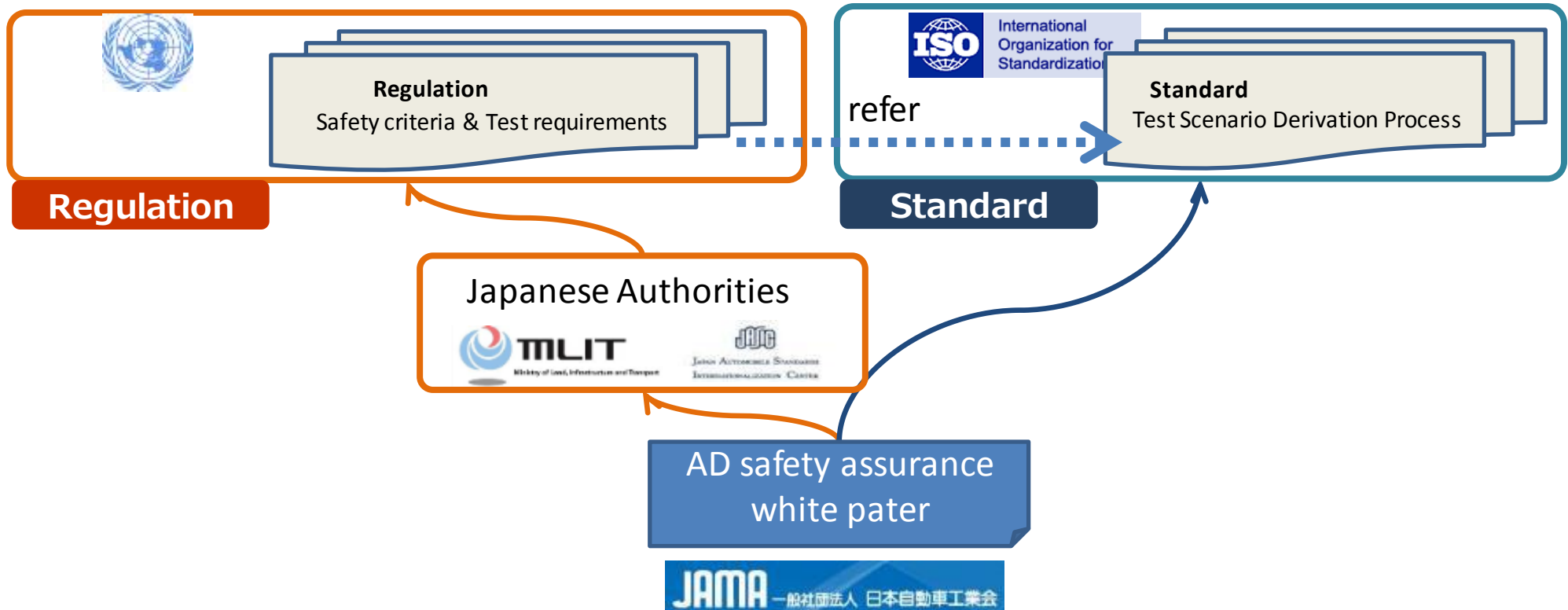
		③dx0 (In itia l distance) [m]						
		12.3	20	30	40	50	60	61.1
②V0-Ve0 (Relative velocity) [m/s]							✓ 8.83	✓ 9.03
					✓ 7.02	✓ 8	✓ 8	
				✓ 5.21	✓ 6	✓ 6	✓ 6	
			✓ 3.39	✓ 4	✓ 4	✓ 4	✓ 4	
	✓ 0.19	✓ 1.58	✓ 2	✓ 2	✓ 2	✓ 2	✓ 2	
	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0	
	✓ -2	✓ -2	✓ -2	✓ -2	✓ -2	✓ -1.35	✓ -1.21	
	✓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

✓ : 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.

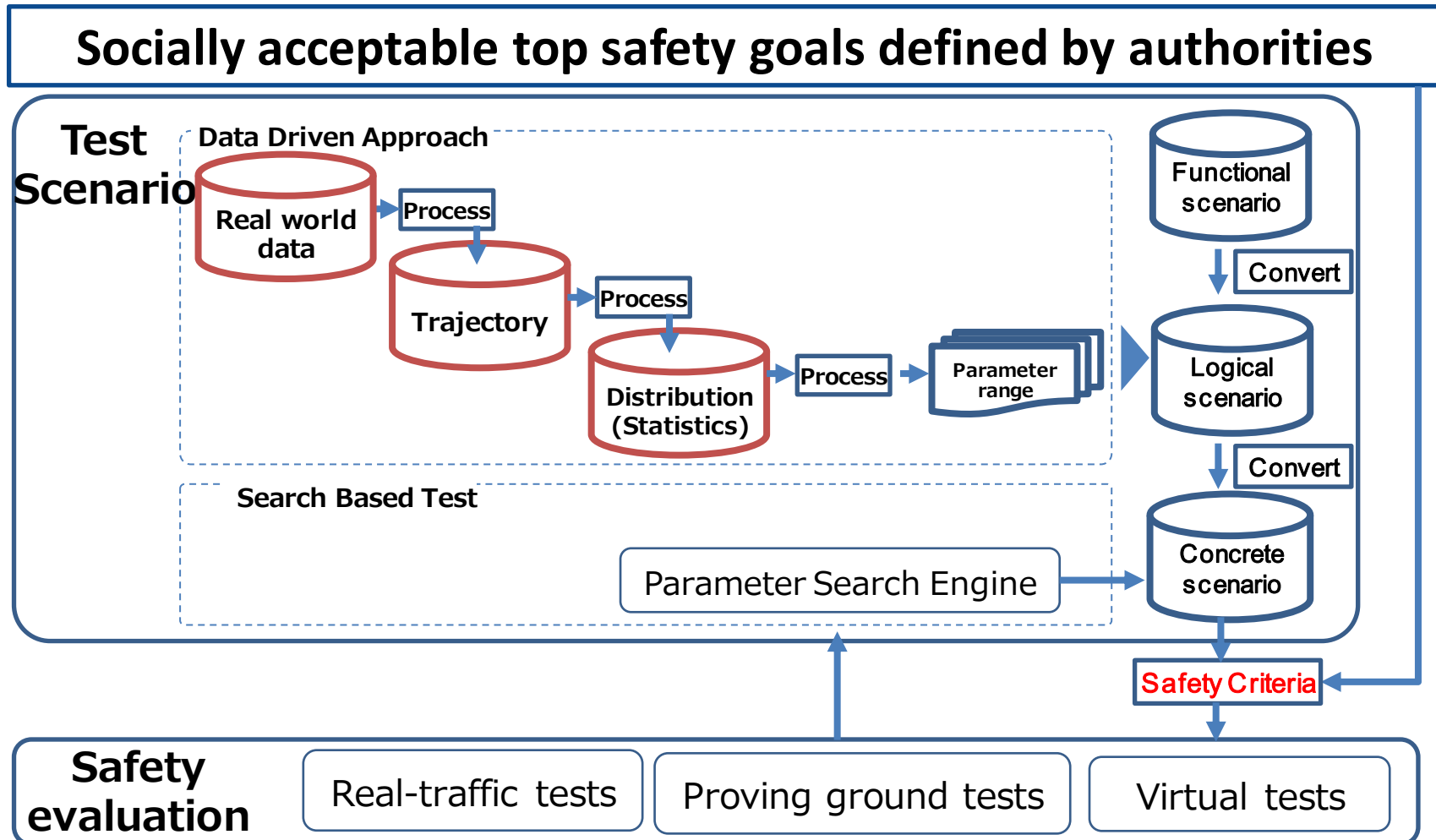
Summary (1)

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 methodologies 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!

satoshi_taniguchi_ad@mail.toyota.co.jp