SAKURA
Safety Assurance KUdos for Reliable Autonomous Vehicles

Data collection, storage and Scenario database

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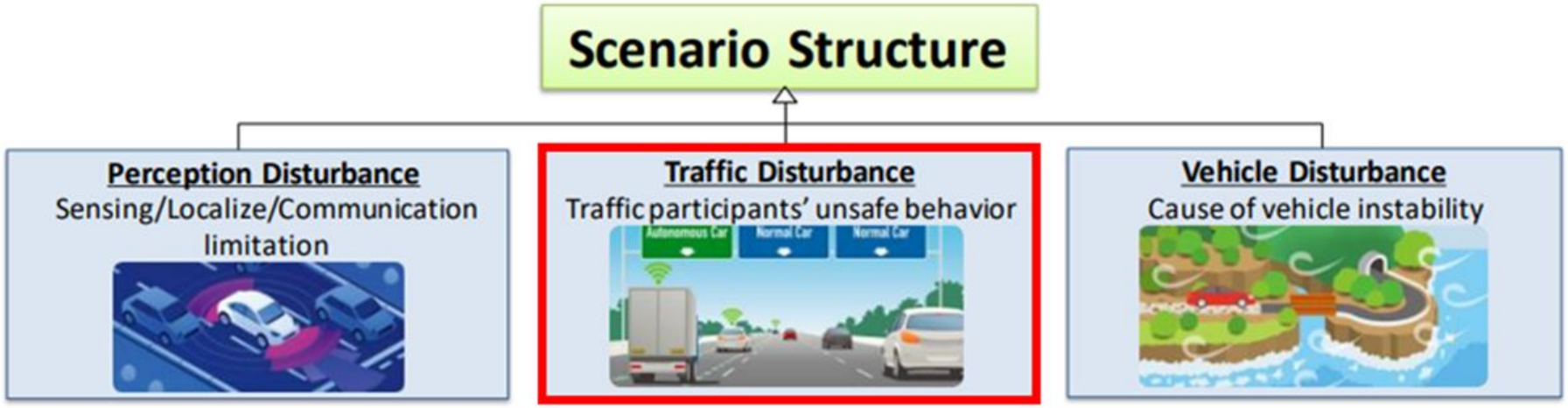
Outline

1. Introduction
2. Traffic data collection and storage
3. Reasonably foreseeable range and preventable range
4. Development of SAKURA scenario database
5. Summary

1. Introduction

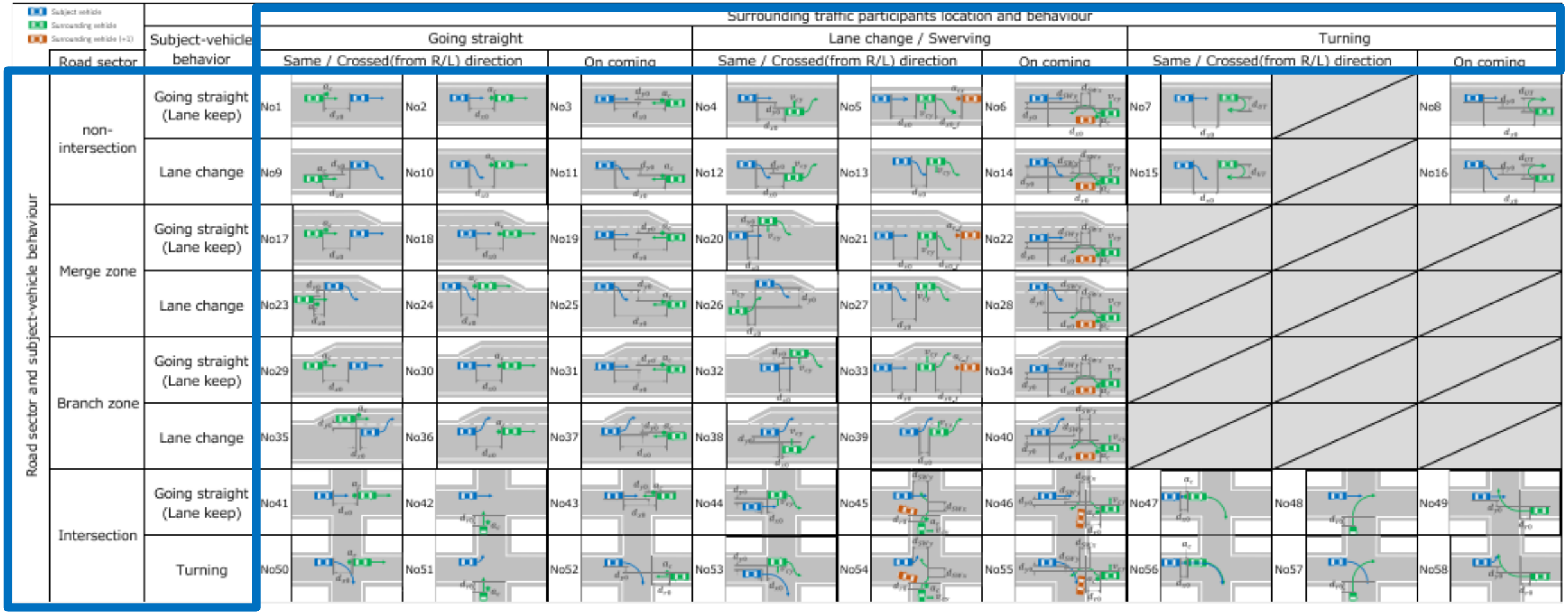
Introduction

- ✓ The SAKURA Project developed the processes and evaluation methods necessary for assessing the safety of autonomous driving systems using a scenario-based approach.
- ✓ Development of a scenario database, a foundational tool to make evaluation scenarios for safety assessment. And actual traffic data collection and storage for setting parameters of evaluation scenarios.
- ✓ Targeted at critical traffic disturbance scenarios
  (Cutting in, cutting out, and deceleration of surrounding vehicles)



Traffic Disturbance Scenario Framework （58 Scenarios）

Surrounding traffic participants location and behavior



Road sector and ego-vehicle behavior

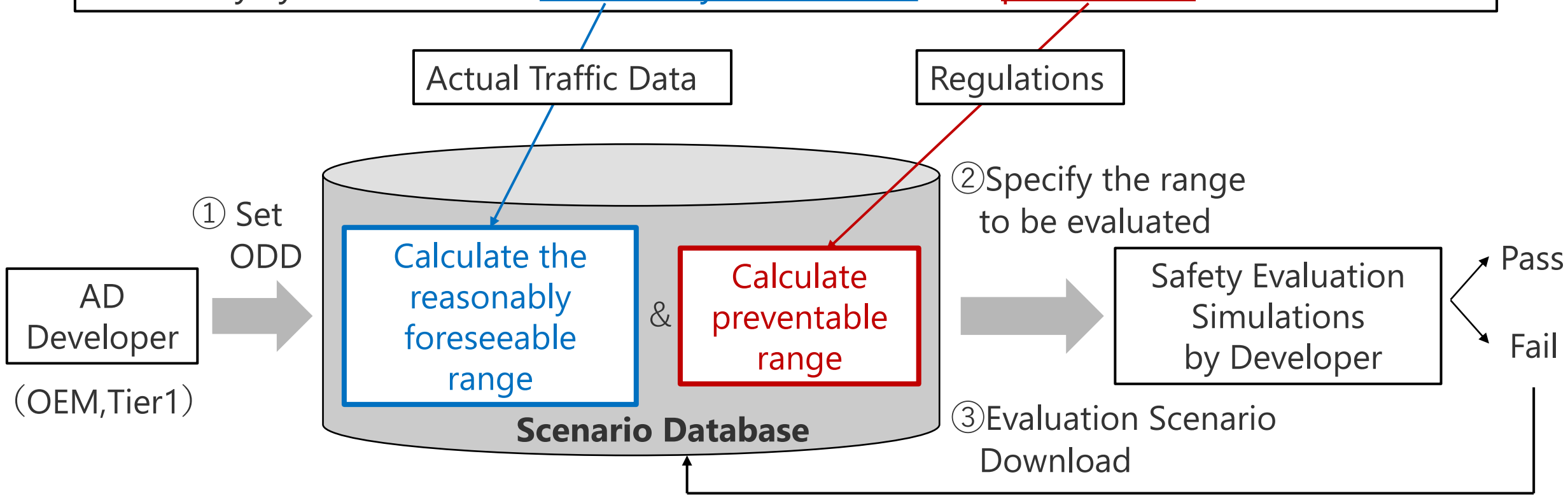
JAMA Automated_Driving_Safety_Evaluation_Framework_Ver4.0

These scenarios are the scope of the scenario database

What is Scenario Database?

【UN/ECE WP29, Ministry of Land, Infrastructure, Transport and Tourism】
Fundamental Approach to the Safety of Autonomous Vehicles

Within the Operational Design Domain (ODD) of autonomous vehicles, Accidents caused by systems that are reasonably foreseeable and preventable must not occur.



Scenario Database assists in practicing safety approaches

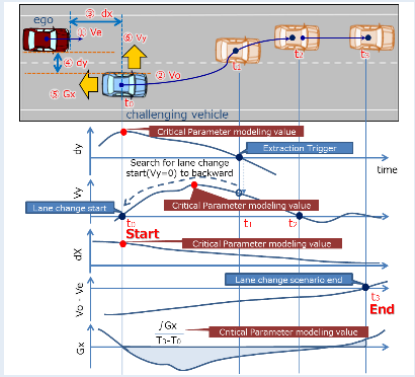
Overall Process

Scenario Database

【Step1】 Actual Traffic Data Collection

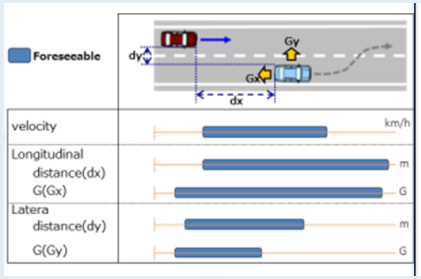
Traffic Disturbance Data

【Step2】 Traffic Disturbance Data Processing

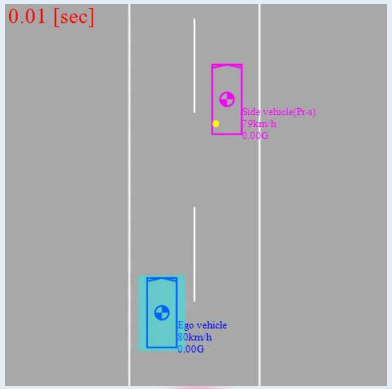


【Step3】 Parameter Distribution Creation

Reasonably foreseeable range



【Step4】 Test Scenario Generation



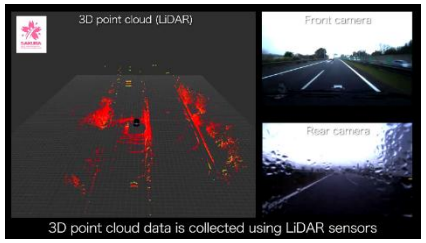
Measurement and Data Processing

Scenario Parameter Definitions

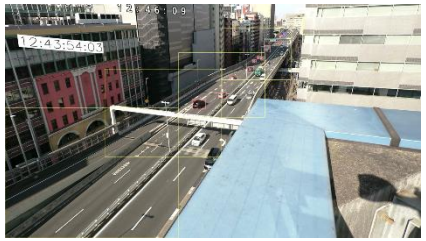
Analysis and Parameter Range Identification

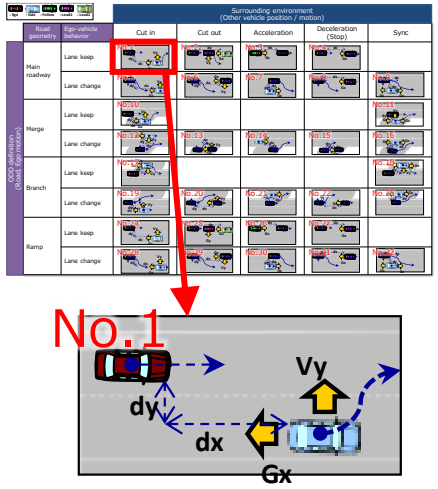
Evaluation Scenario Creation

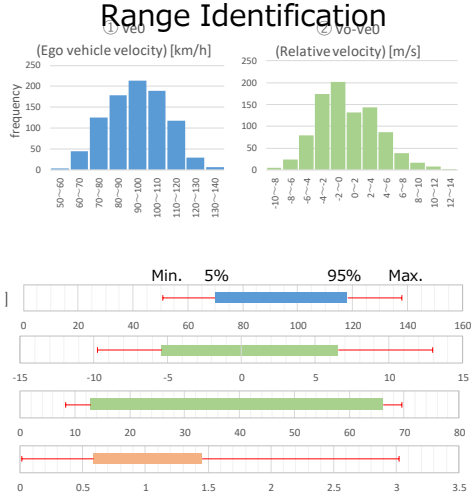
Test vehicle

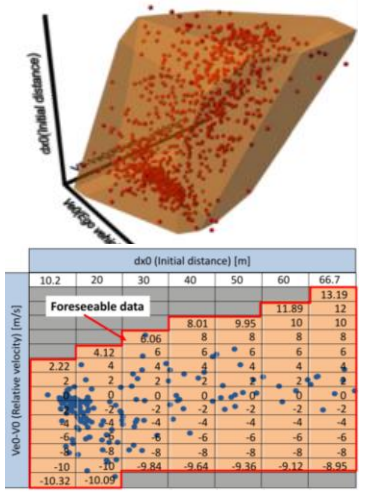


Fixed location camera









2. Traffic data collection and storage

Actual Traffic Data Collection

Comparison Table

	Test vehicle	Fixed location camera
Natural traffic data	Test Driver（not natural）	General driver
Scenario Coverage Rate	Efficiently collect data across a wide range of scenarios	Efficiently collect data related to road structure such as merges and branches
Securing measurement locations	No restrictions	Obtaining permission to install cameras is difficult
Occlusion	Obstructed by surrounding vehicles	Observations from high places can reduce occlusion
Accuracy	Difficult to ensure the positional accuracy of the reference vehicle angle and other parameters	Because it is fixed to the structure, it is relatively easy to ensure accuracy

2 methods for traffic data collection,
each with has its advantages and disadvantages

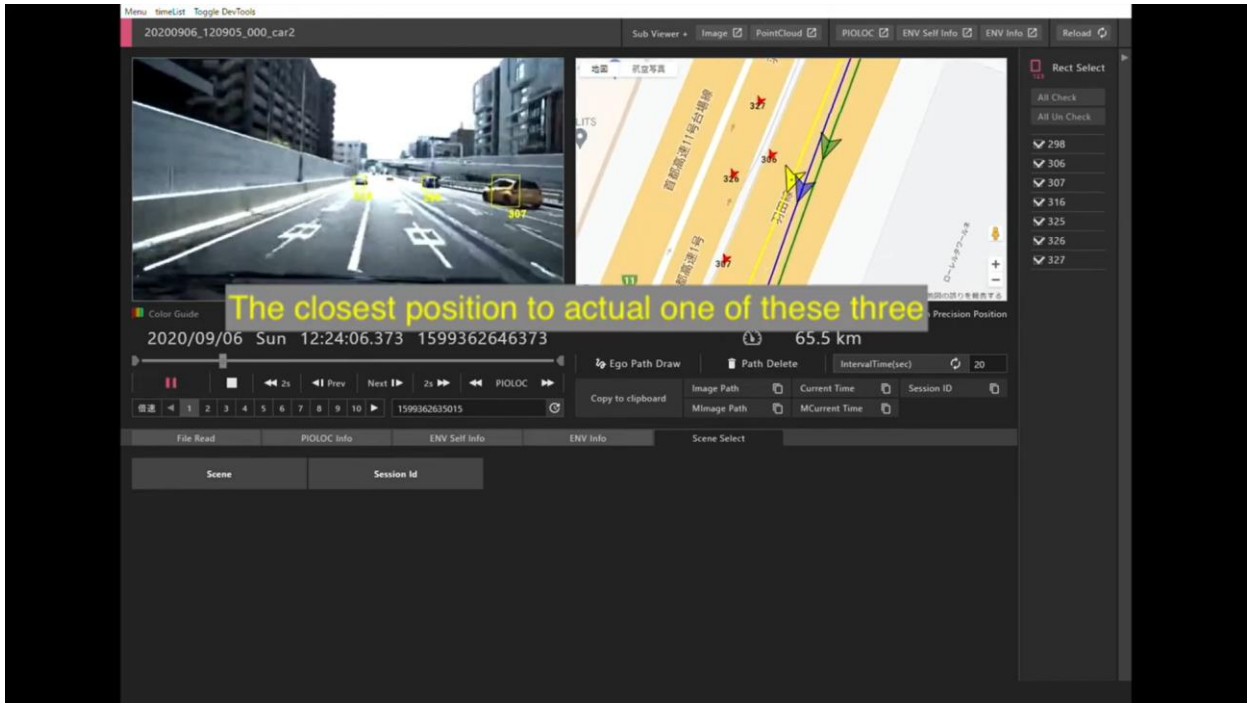
Traffic data collection using test vehicles

SAKURA Test Vehicle Specification

Surrounding vehicles data is acquired by multiple LiDARs and cameras.
GNSS / IMU is used to obtain information on the position of the vehicle.

Trajectory extraction from collected traffic data

Higher accuracy of vehicle trajectory



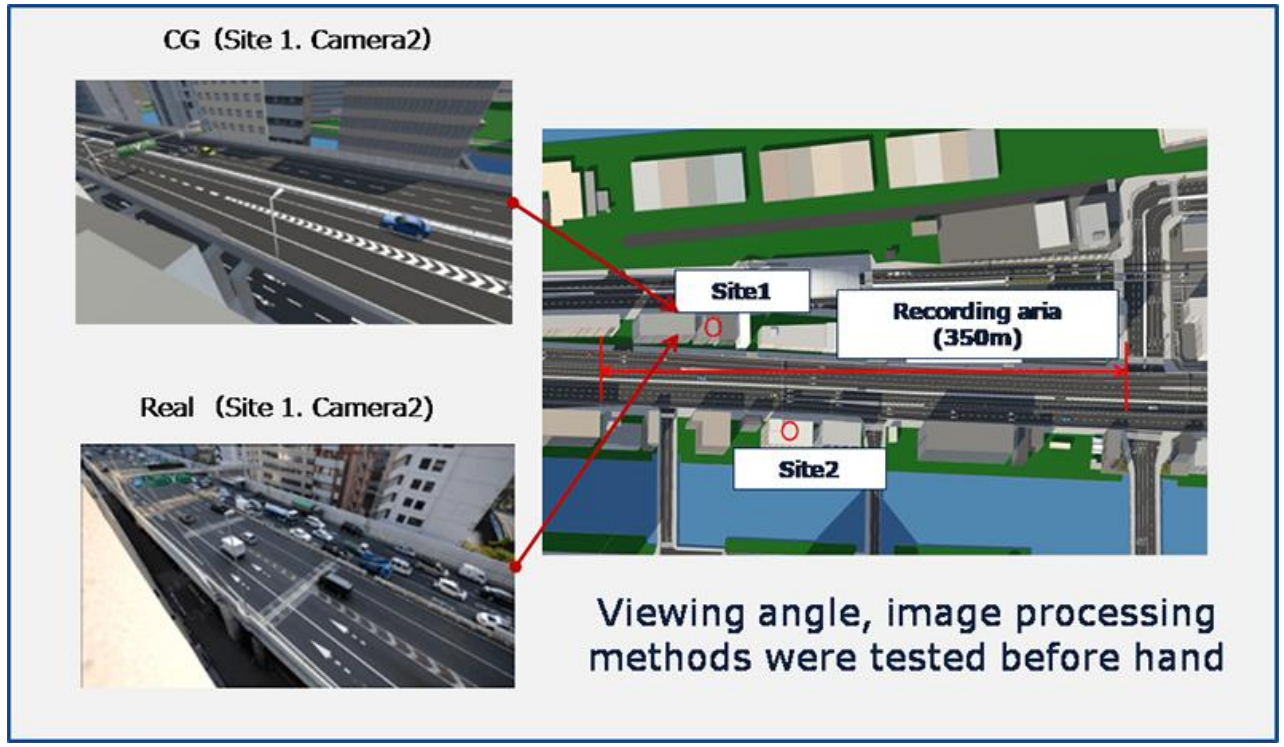
Yellow line : map maching
Green line : GNSS
Blue line : high-precision algorithm
- High-precision map
- Detect the distance to the white line

★Exhibition Area

Test vehicles collected about 3200-hour data while driving on the Metropolitan Highway and Intercity Highways

Traffic data collection by fixed location cameras（1/2）

- ✓ To achieve high trajectory accuracy, high-quality cameras are installed at higher positions (such as building's rooftop).
- ✓ Before the measurement, the camera installation location is selected using a simulation, and the accuracy is verified by the simulation.

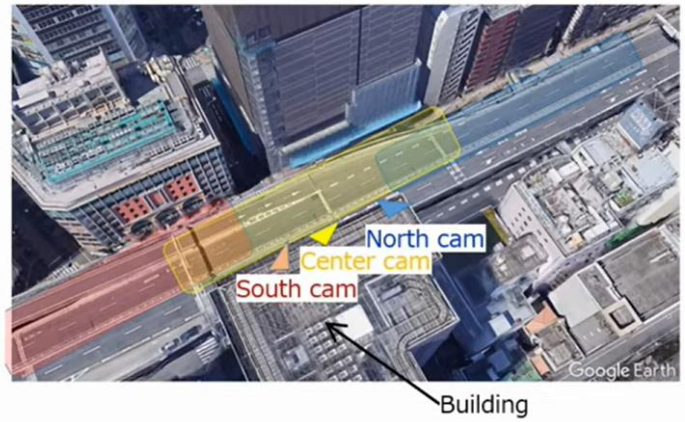


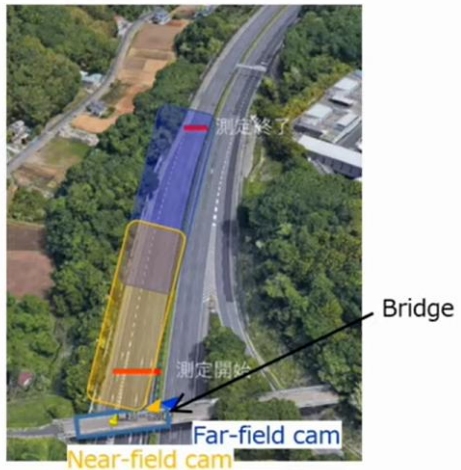
Fixed location cameras collected data at 10 locations, such as merge and branch roads, which are highly location-dependent.

Traffic data collection by fixed location cameras（2/2）

Installation of fixed location cameras

Videography style

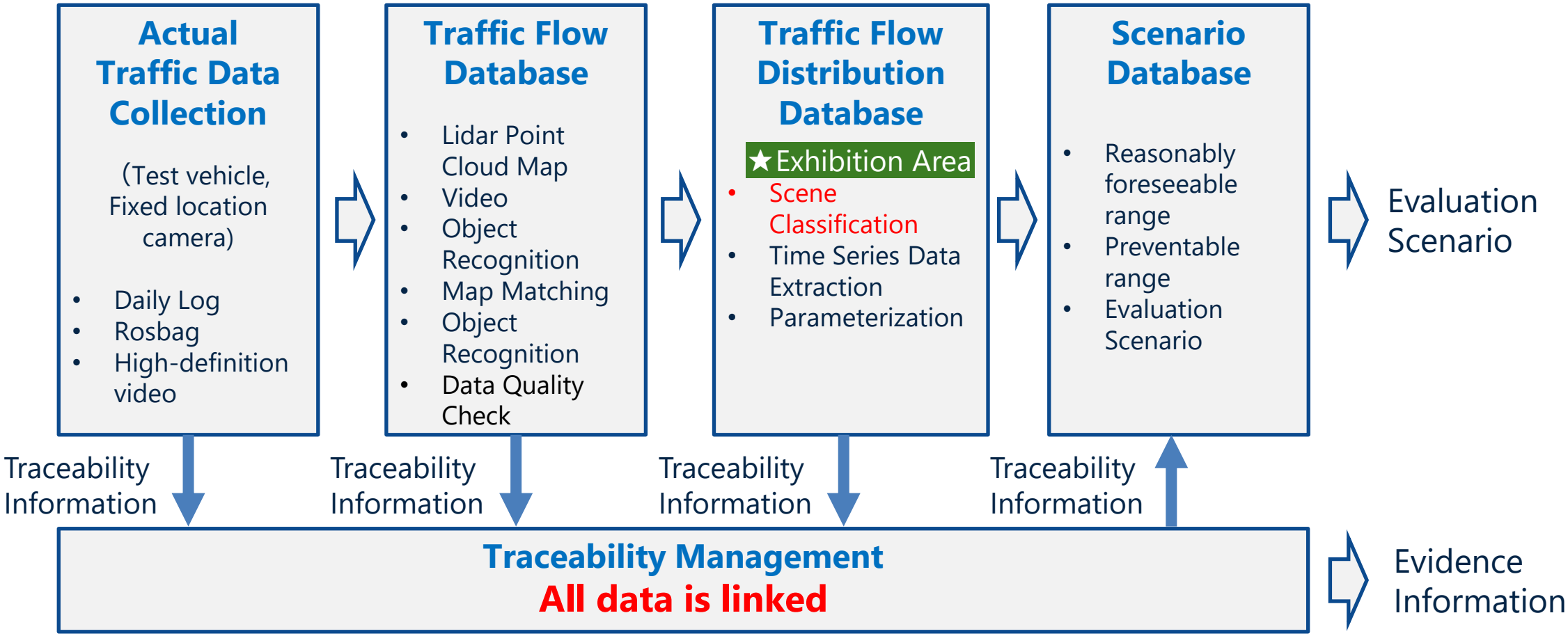




Case1: Taken from the roof of a building (ex. urban area)

Case2: Taken from a bridge or bank above the road (ex. suburb area)

Data Flow and Storage

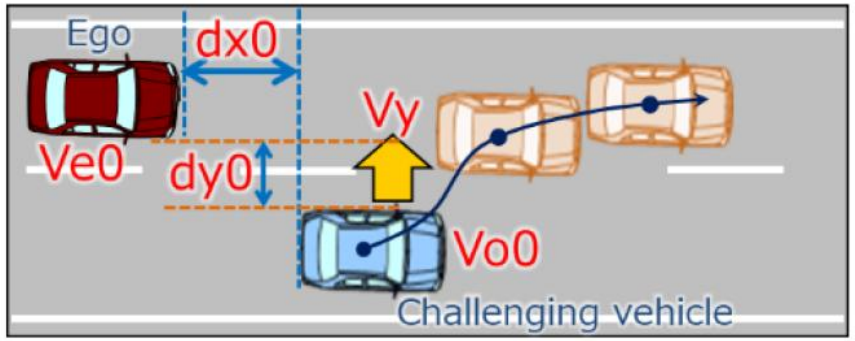


Implement traceability function to enhance the transparency and explainability of evaluation scenario creation

3. Reasonably foreseeable range and preventable range

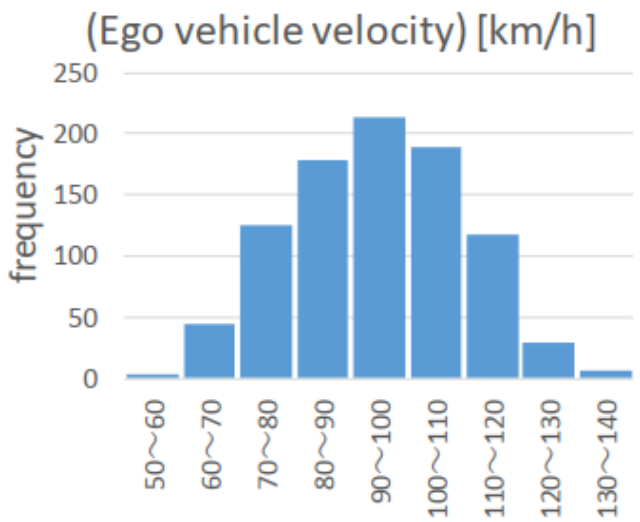
Reasonably foreseeable range：Cut-in Scenario

911 scenes from actual traffic data

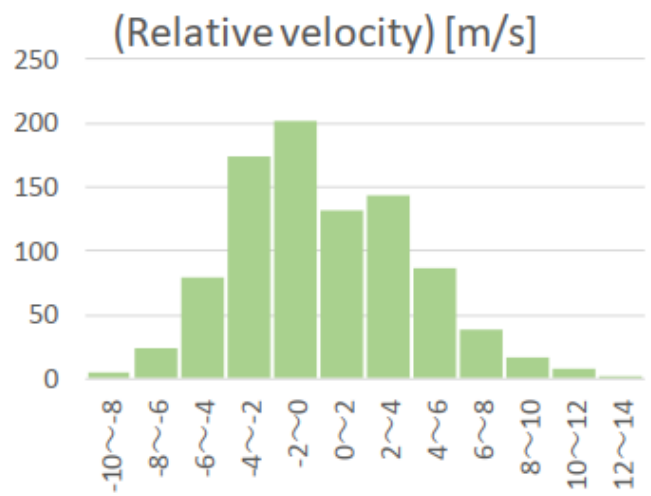


Initial condition	Initial velocity	**Ve0**	Ego vehicle velocity
		Ve0-Vo0	Relative velocity
	Initial distance	**dy0**	Latteral distance[x]
		dx0	Longitudinal distance
Vehicle motion	Lateral motion	**Vy**	Lateral velocity

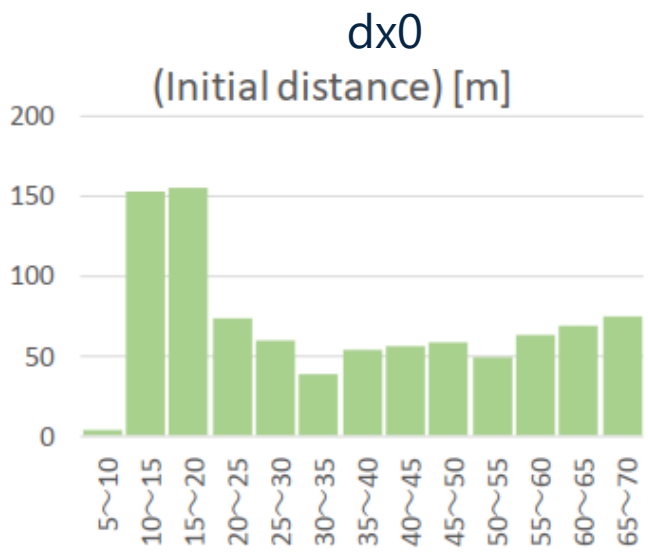
Ve0



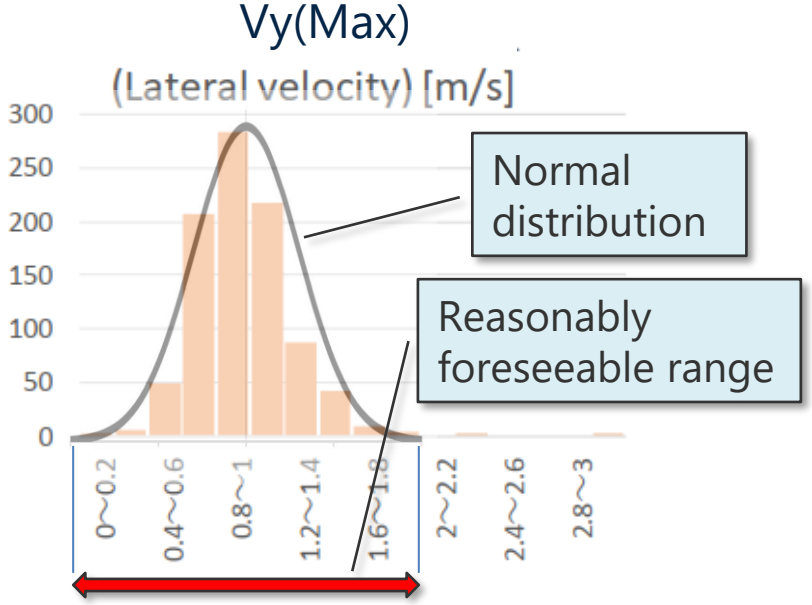
Ve0-Vo0



dx0



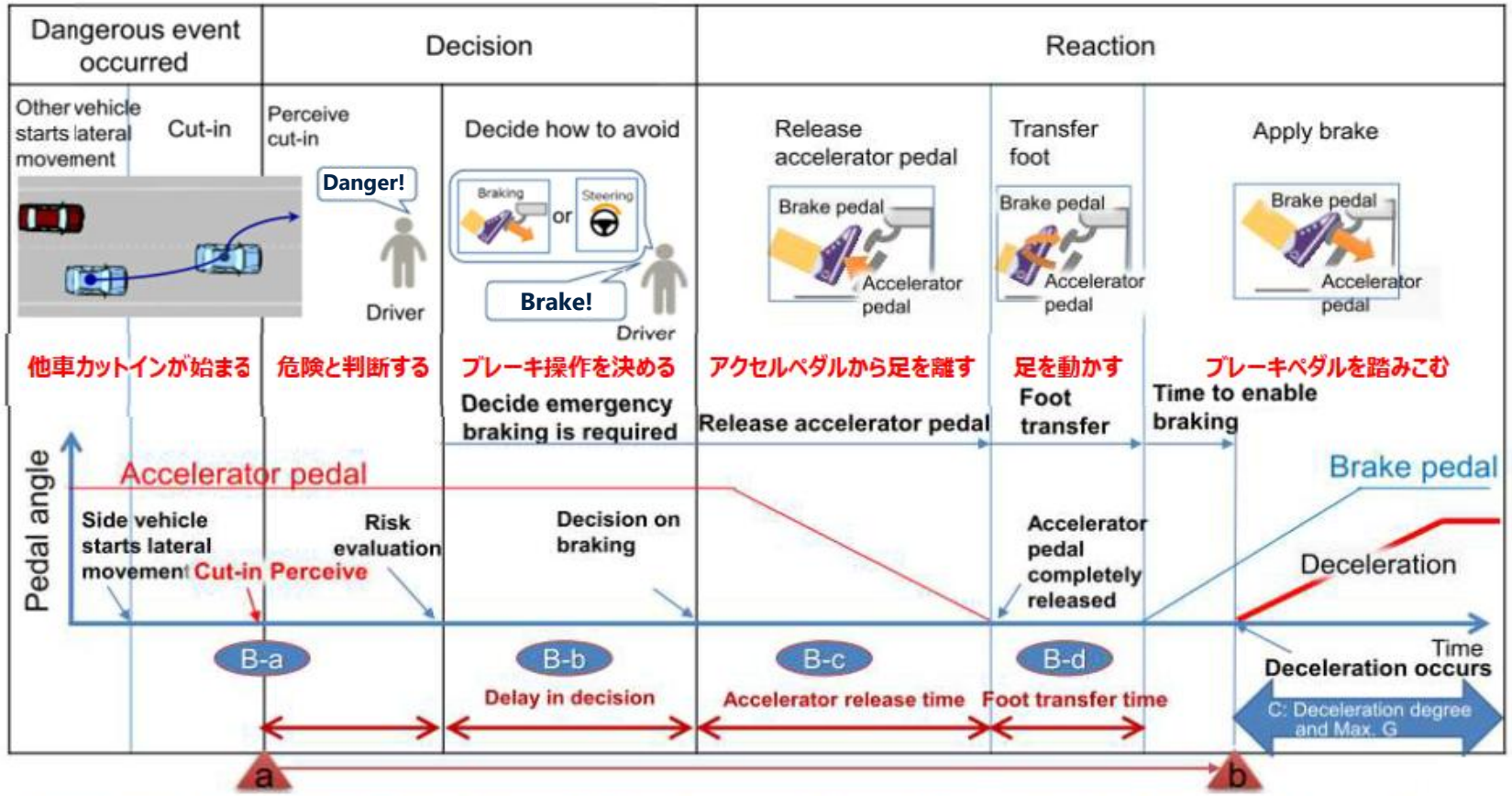
Vy(Max)



Preventable range：C&C driver

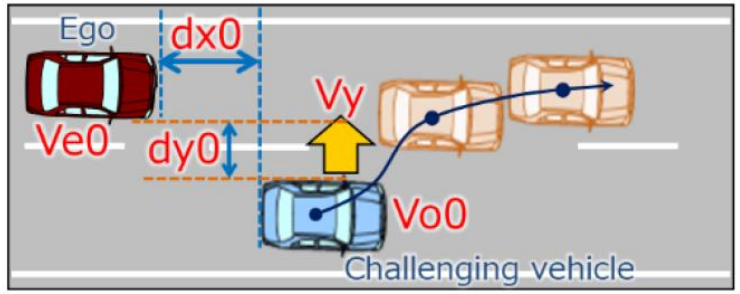
Autonomous driving must be able to avoid accidents that a C&C driver can avoid.

C&C driver (competent and careful human driver) model in Cut-In Scenarios

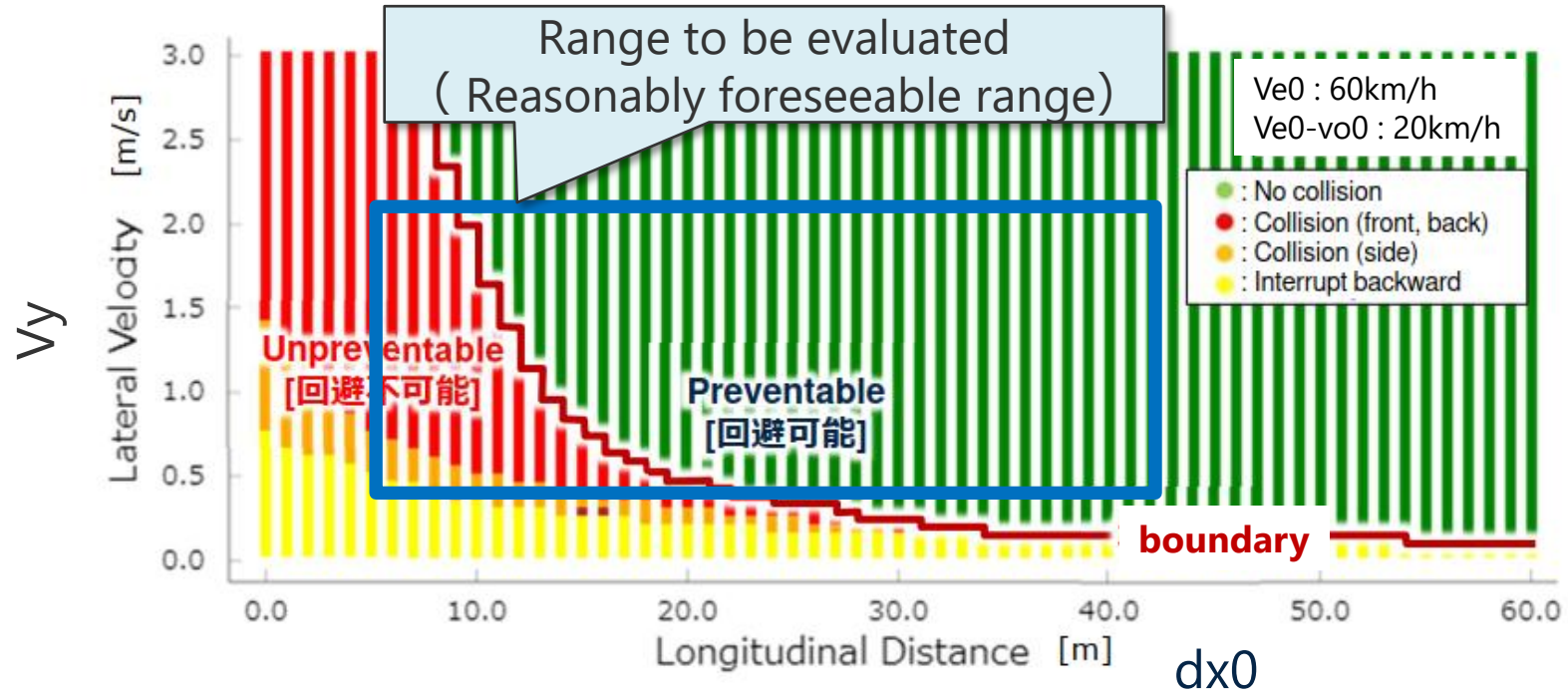


(WP29 GRVA 4th VMAD IWG: Safety Criteria Study on Innovative Safety Validation Methods of Automated Driving Systems)

Preventable range：UN Regulation No.157 ALKS Cut-in



Initial condition	Initial velocity	**Ve0**	Ego vehicle velocity
		Ve0-Vo0	Relative velocity
	Initial distance	**dy0**	Latteral distance[x]
		dx0	Longitudinal distance
Vehicle motion	Lateral motion	**Vy**	Lateral velocity



Confirmation of the range of reasonably foreseeable and preventable

Selection of Evaluation Scenarios

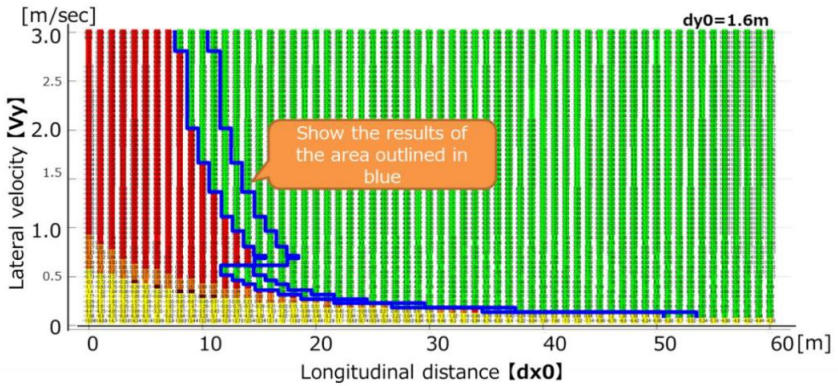
3 approaches to select evaluation scenarios for efficient evaluation

JAMA Automated_Driving_Safety_Evaluation_Framework_Ver3.0

Annex G

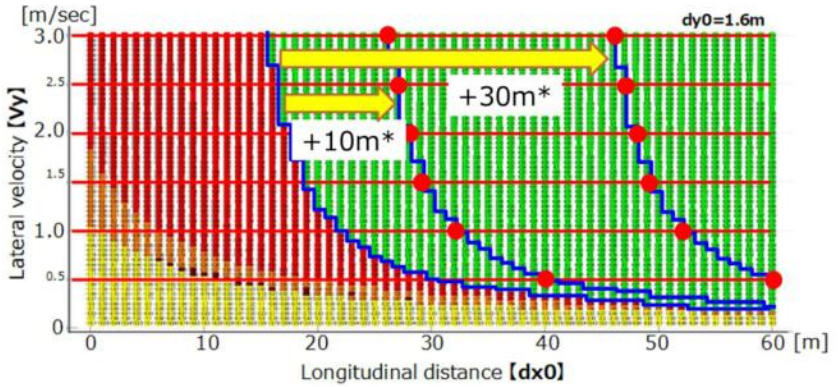
Validation of Simulation Tools and Simulation Test Methods Related to UN Regulation No. 157

（1）Close to the Preventable /Unpreventable Threshold



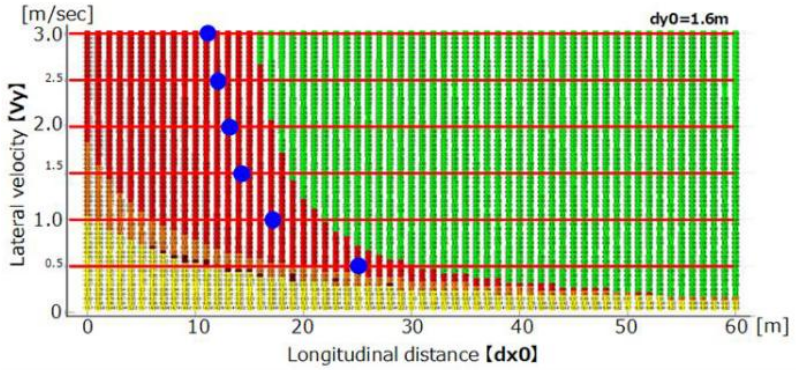
Evaluating the preventable/unpreventable boundary in detail

（2）Preventable Territory

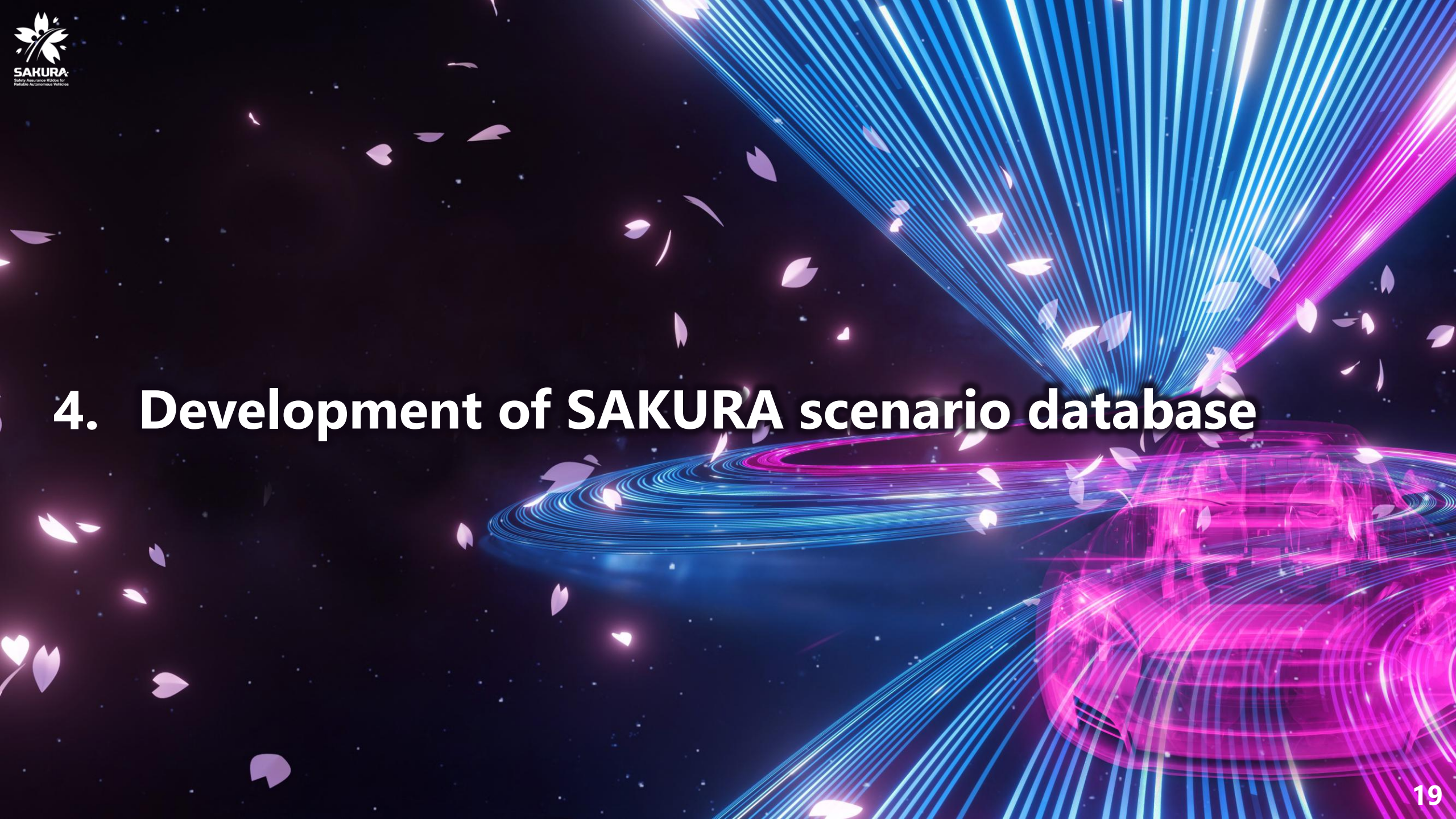


Rough sample evaluation in preventable territory

（3）Unpreventable（Collision）Territory



Confirm the best effort (controls for collision avoidance are not stopped) within the unpreventable territory



4. Development of SAKURA scenario database

Needs for Scenario Database by AD developers

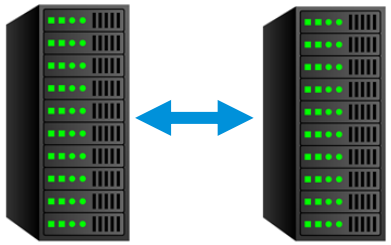
Implement high-priority features into the scenario database based on needs of AD Developers.

	High-priority needs（features）	Corresponding section of the use case
1	Select the scenario to evaluate for safety from the scenario catalog	A
2	Create an evaluation scenario that matches the ODD (such as vehicle speed)	B
3	Quantify the “reasonably foreseeable range” in accordance with the ODD	C
4	Define the “preventable range”, using C&C driver model	D
5	Need diverse evaluation scenarios, including stricter ones (e.g., for robustness verification)	E
6	Need evaluation scenarios in a format compatible with various safety assessment simulations	F
7	Need evidence that led to the derivation of the evaluation scenario	G
8	Display the “reasonably foreseeable range” and “preventable range” overlaid so that the evaluation results can be visualized	H

User Use Cases that meet the needs

cloud

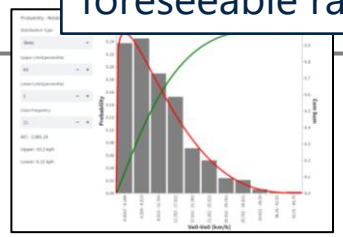
Scenario Database



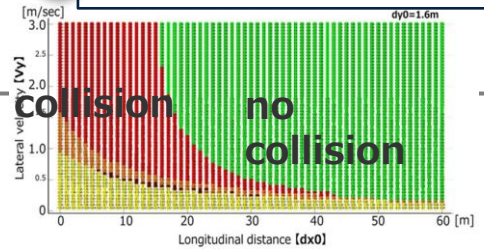
・Traffic data
・ Trajectory data, etc.

A • Select the evaluation scenario from the scenario catalog
B • Set ODD （Vehicle speed, weather conditions, etc.）

C Reasonably foreseeable range



D Preventable range



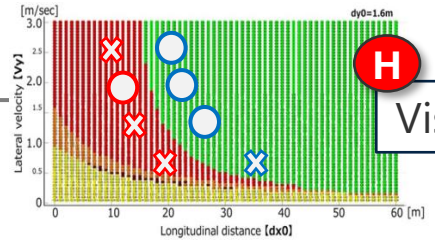
AD System Developer

E • Set the parameters for the evaluation scenarios
• Set the range to be evaluated （Boundary, strict, etc.）

F •Download Evaluation Scenario (OpenSCENARIO)
G •Evidence for Evaluation Scenario Derivation （Trajectory, etc.）

Safety Assessment Simulation

Simulation Evaluation Results



H Visualization of Evaluation Results

AD Developer's Feedback on Scenario Database

Current Approach	1	Reasonably foreseeable range and preventable range indicated by third-party organizations is useful for demonstrating safety to obtain authorities' approval.	-
	2	Expand the number of data and scenarios continuously. Especially on general roads, vulnerable road users	Under improvement
	3	Expect Reasonably foreseeable range and preventable range for large vehicles	Under improvement
	4	Increase the number of search tags of ODD, when calculating the reasonably foreseeable range to improve development efficiency (Vehicle speed, weather conditions, road type, etc.)	Under improvement
Future Expectations	5	Display reasonably foreseeable range and preventable range overlaid on the graph to set the parameters of the evaluation scenario efficiently	Completed
	6	Overlay actual accidents and near misses on graphs showing the reasonably foreseeable range and preventable range to examine validity of evaluation scenarios	Future consideration
	7	Expect evaluation scenarios to be directly applied to actual traffic scenes	Future consideration
	8	Expect that the evaluation scenario can be input into any safety assessment simulation, also the trajectory data.	Future consideration
	9	Expect that parameters for evaluation scenarios can be set using indicators related to risk levels such as TTC.	Future consideration

Continue to improve functions to meet these expectations for the future

Reference) Operation Interface of Scenario Database

★Exhibition Area

A Select the evaluation scenario from the scenario catalog

Select No.4 Cut-in Scenario from 58 Scenarios

Scenario selection

Select Scenario

Select Scenario Number

Select ScenarioNumber

Select ScenarioNumber

No2 Non-intersection-GoingStraight-Deceleration

No4 Non-intersection-GoingStraight-Swerving

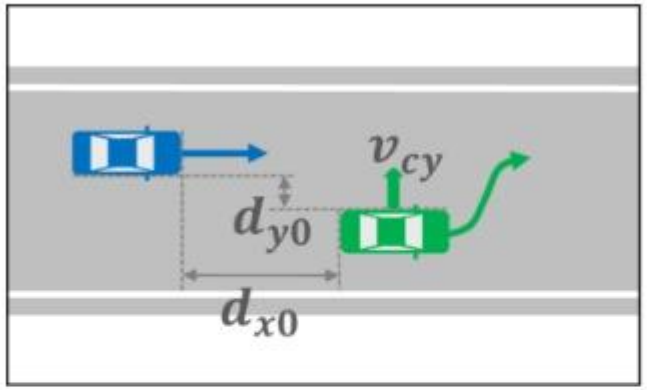
No5 Non-intersection-GoingStraight-Swerving

No9 Non-intersection-LaneChange-Acceleration

No10 Non-intersection-LaneChange-Deceleration

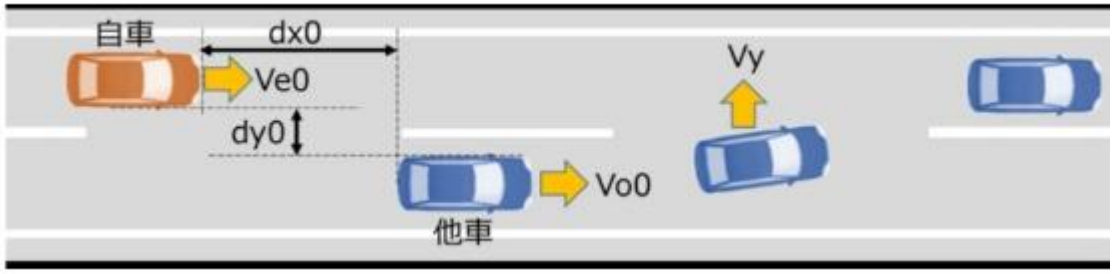
No12 Non-intersection-LaneChange-Swerving

No4 Non-intersection-GoingStraight-Swerving



Parameters

Parameter	Description
Ve0	
Vo0	
Ve0-Vo0	
dx0	
Vy	



Reference) Operation Interface of Scenario Database

B Set ODD（Vehicle speed, weather conditions, etc.）

Indication of the range of each parameter

The full range of parameters for actual traffic data is displayed, so narrow the range to match the ODD

Narrow down the ODD
(Future consideration)

Number of data matching the ODD

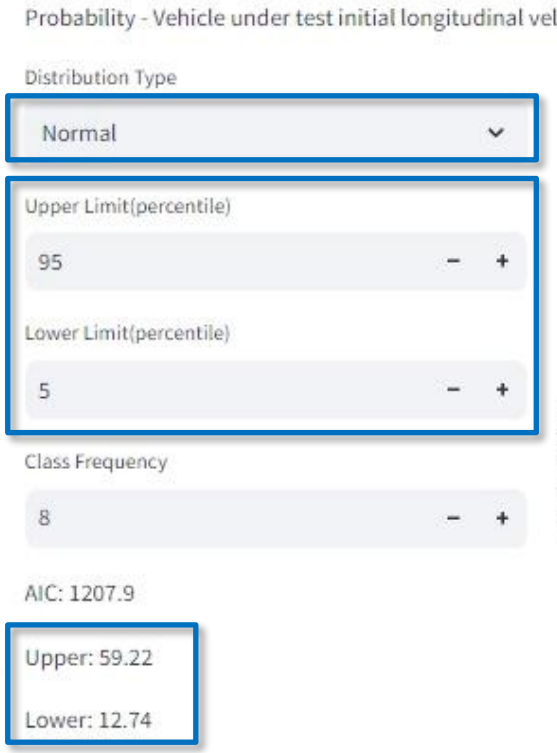
Reference) Operation Interface of Scenario Database

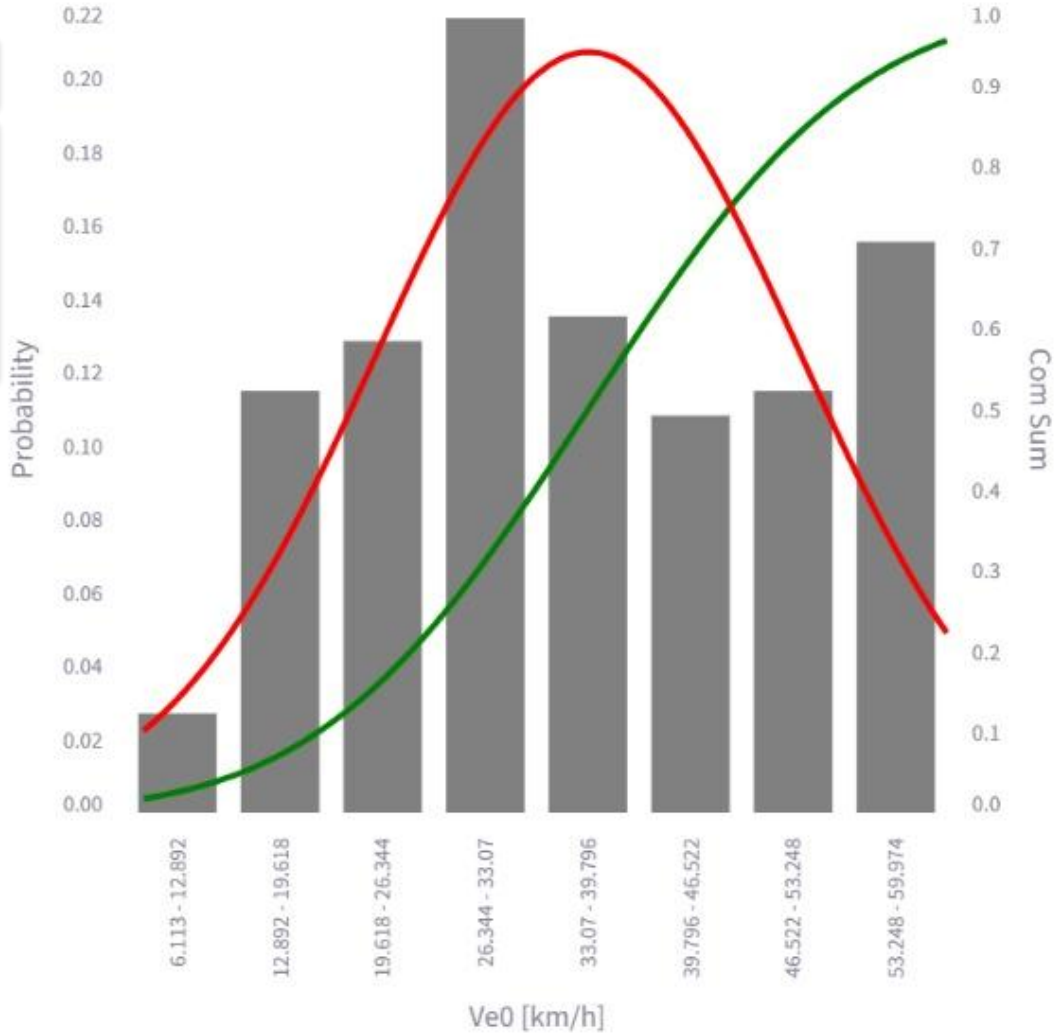
C Reasonably foreseeable range

Select distribution type

Set the probability distribution using percentile values

Reasonably foreseeable range





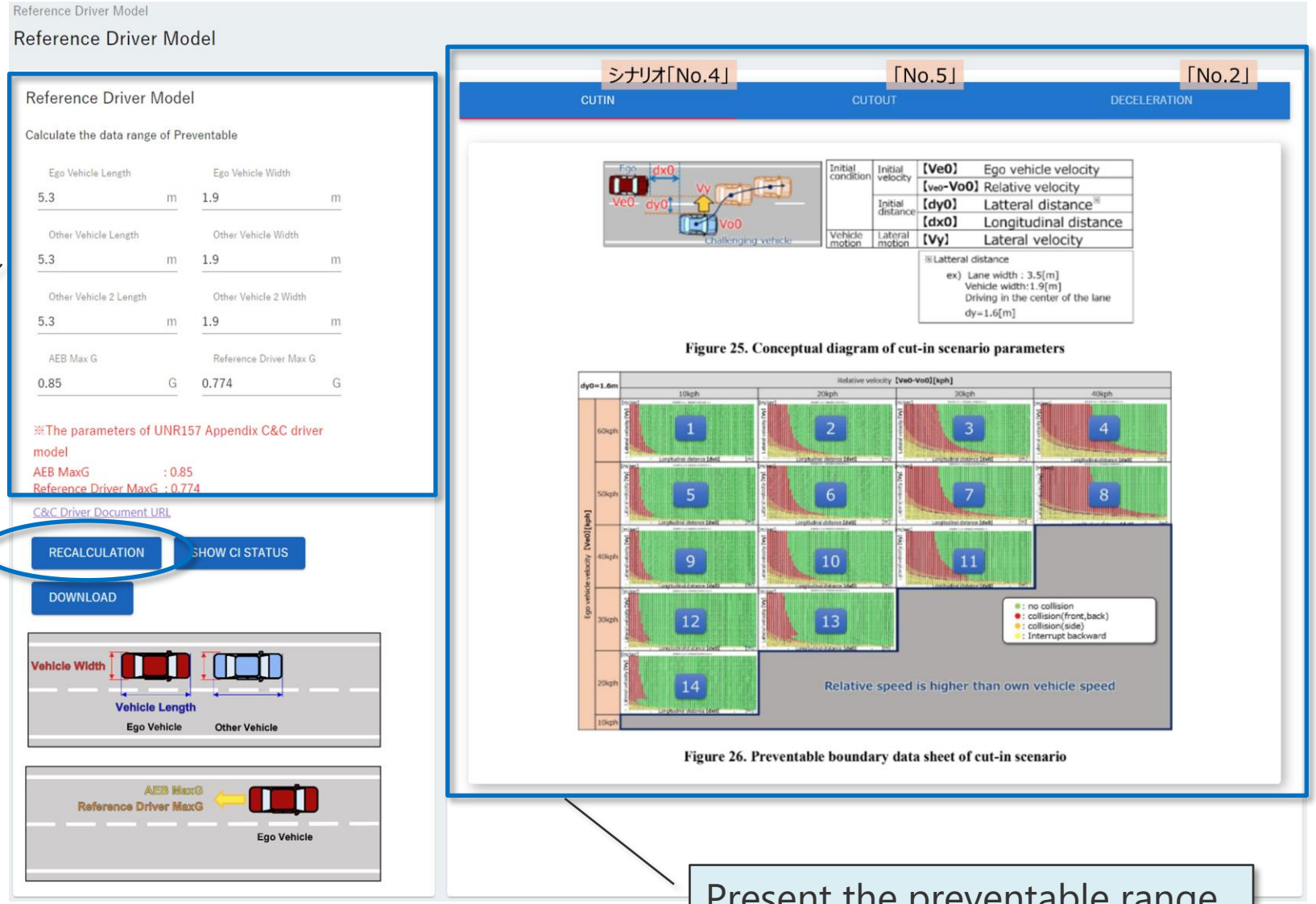
Reference) Operation Interface of Scenario Database

D Preventable range

Set vehicle size and brake deceleration for the C&C driver model

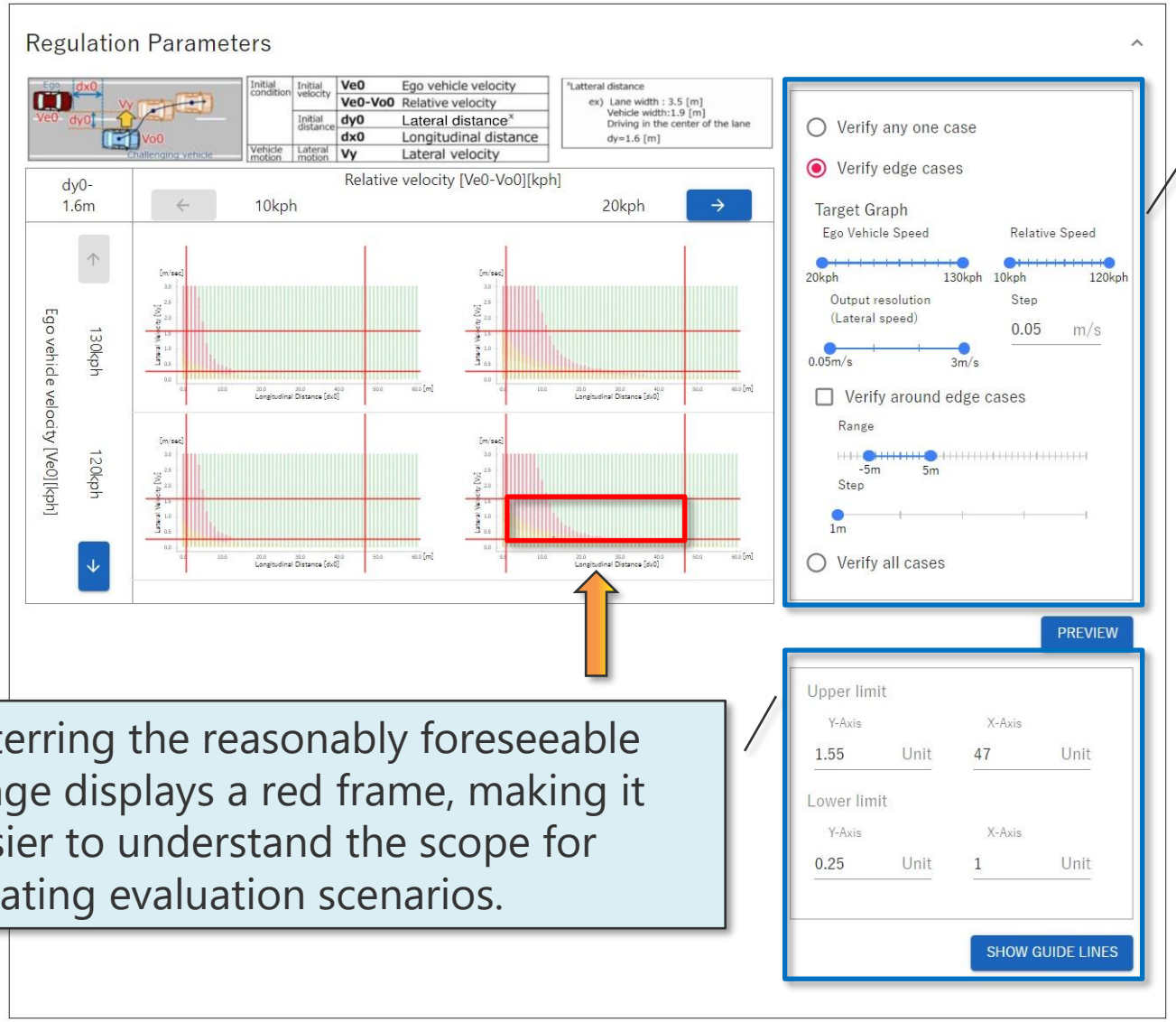
Calculation Instructions

Present the preventable range



Reference) Operation Interface of Scenario Database

E Set the parameters for the evaluation scenarios (1/2)

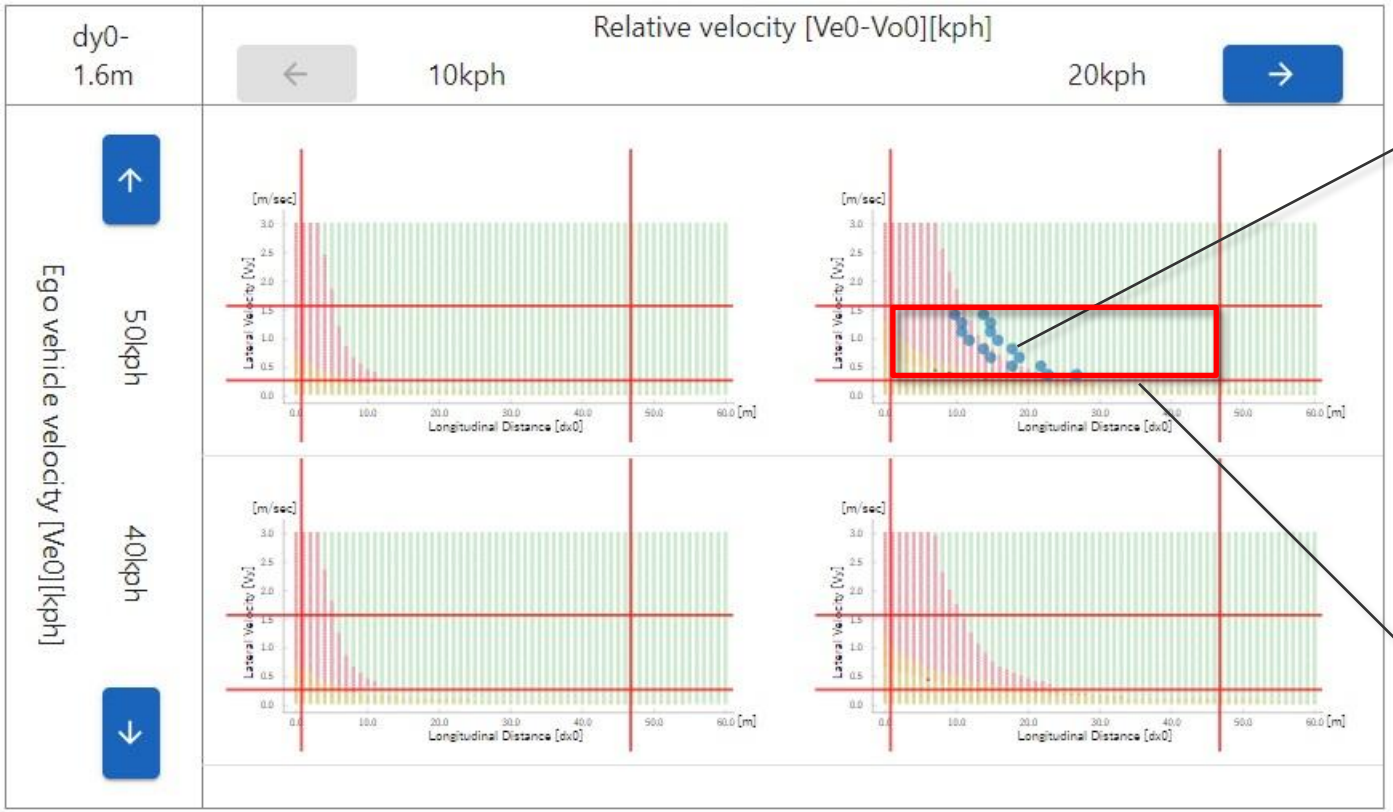


Create evaluation scenarios near the boundary between “preventable range” and “unpreventable range”

Entering the reasonably foreseeable range displays a red frame, making it easier to understand the scope for creating evaluation scenarios.

Reference) Operation Interface of Scenario Database

E Set the parameters for the evaluation scenarios (2/2)



Within the scope of reasonably foreseeable range, create evaluation scenarios offset on both sides of the boundary line.

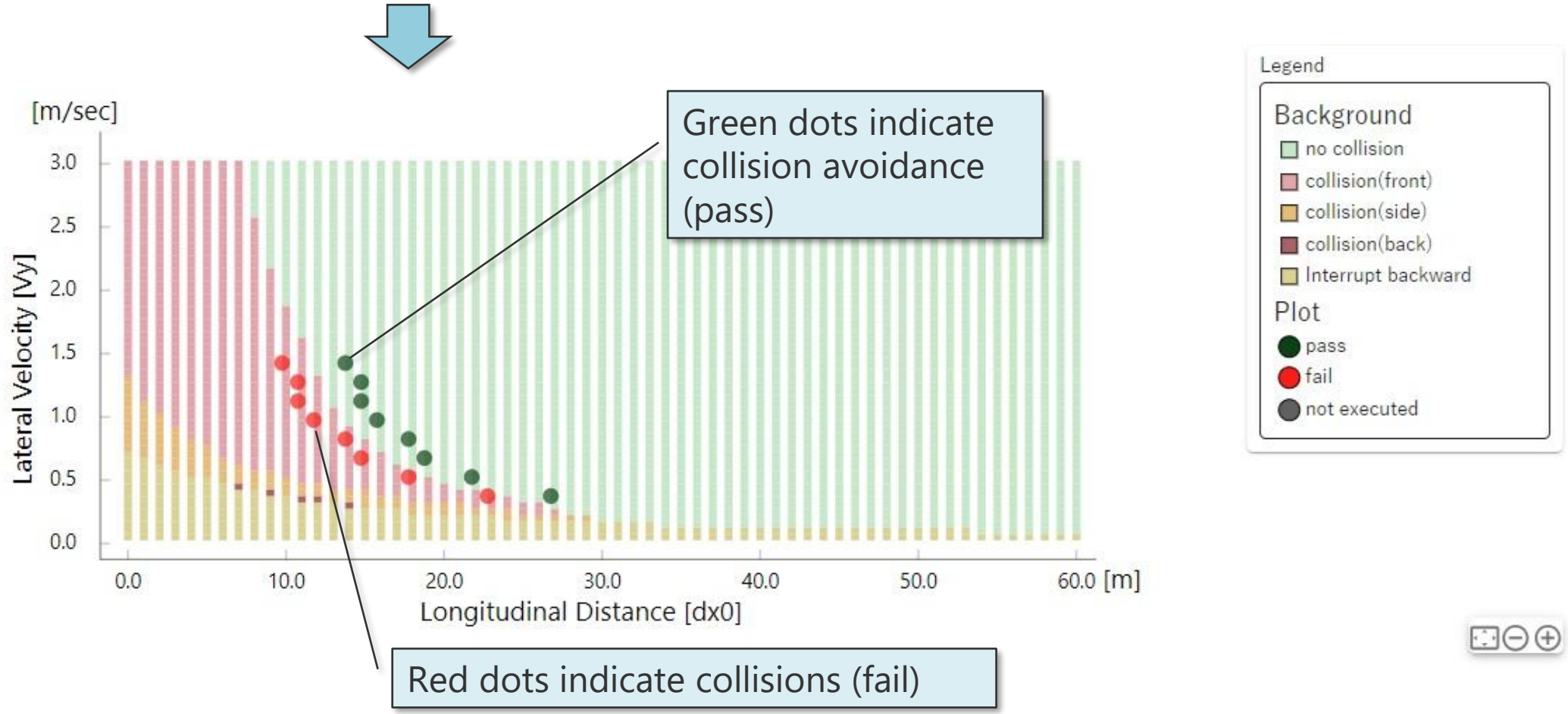
Right side ：preventable
Left side ：unpreventable

Red box：
reasonably foreseeable range

Reference) Operation Interface of Scenario Database

H Visualization of Evaluation Results

Return simulation evaluation results to the scenario database




SAKURA
Safety Assurance KUdos for
Reliable Autonomous Vehicles

5. Summary

Summary

- ✓ Developed a prototype scenario database for creating evaluation scenarios for safety assessment of AD systems using a scenario-based approach.
- ✓ Confirmed that this approach is useful based on feedback from AD developers. Continue to improve functions to meet the growing expectations for the future.
- ✓ As AD capabilities evolve and traffic environments change with the spread of AD, it is necessary to consider a mechanism for continuously updating scenarios to reflect these changes.
- ✓ Continuing to collect actual traffic data will be a significant burden, we also need to improve the efficiency of scenario updates. This includes utilizing new technologies like AI and combining virtual data generated from real data.

Thank you for your attention.

METI
Ministry of Economy, Trade and Industry

Acknowledgement
The Ministry of Economy, Trade, and Industry of Japan funded this research through the SAKURA project.