日本の自動運転安全性評価プロジェクトの概観

自動車工業会　AD安全性評価分科会

谷口　悟史

(satoshi_taniguchi_ad@mail.toyota.co.jp)

1. 自動運転の国際基準調和の動向
2. 安全性評価に対する国内体制
3. 国内協調の活動成果
4. 安全性評価手法の概要
5. 安全性評価手法の詳細
6. 今後の活動について

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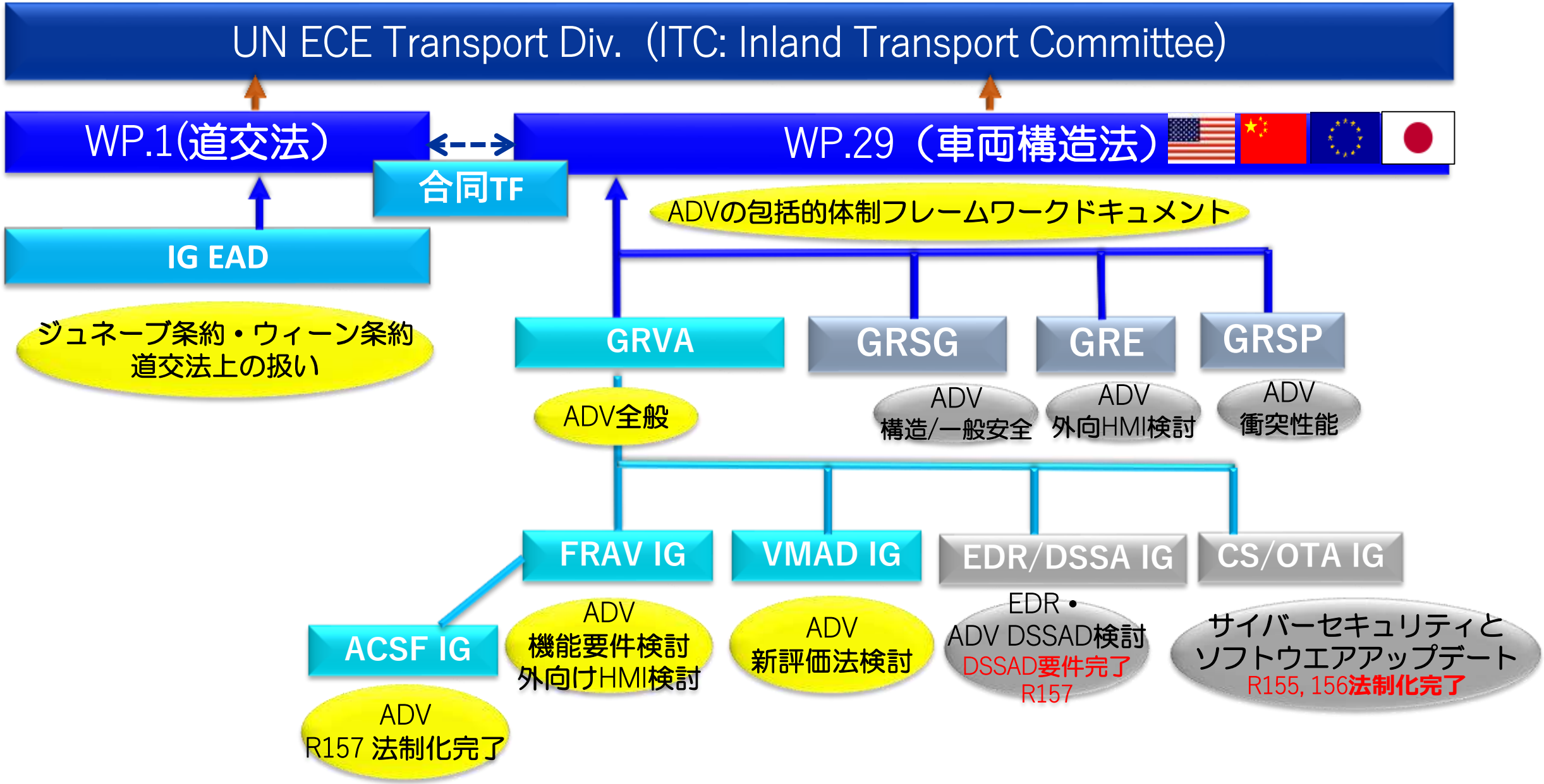
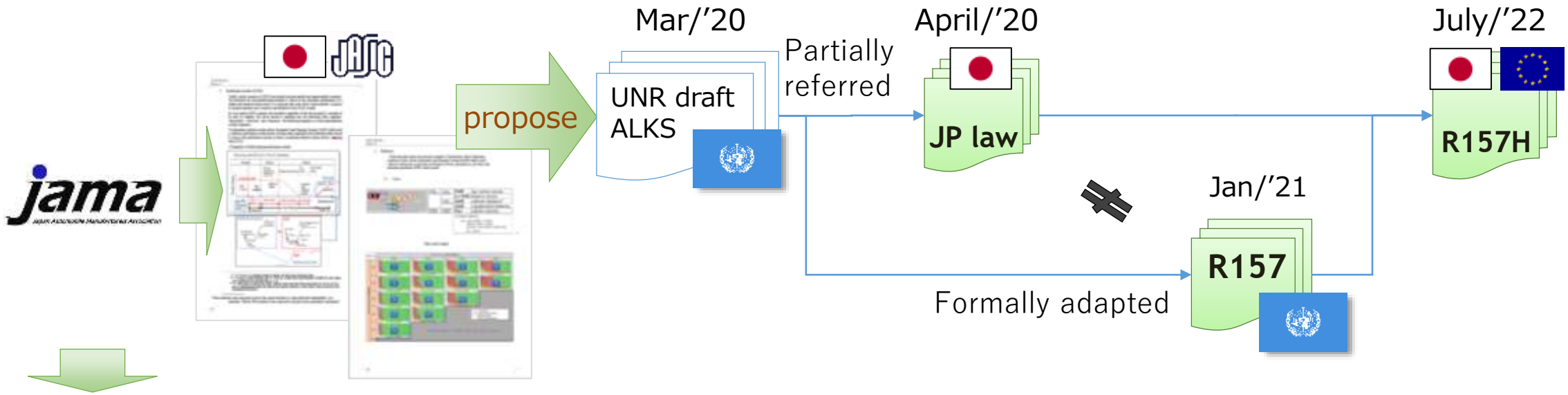
自動運転国連法規議論の組織構成



国際基準調和と国際標準への提案状況

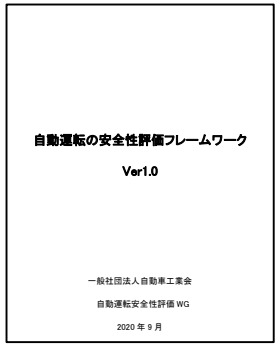
基準



手法

AD安全性評価ガイドライン発行(Oct/'20)

国際標準ISO34502(Mar/'21)



自工会HP http://www.jama.or.jp/safe/automated_driving/

日本語 http://www.jama.or.jp/safe/automated_driving/pdf/framework.pdf

英語 http://www.jama-english.jp/publications/Automated_Driving_Safety_Evaluation_Framework_Ver1.0.pdf

背景説明 http://www.jama.or.jp/lib/jamagazine/jamagazine_pdf/202011.pdf

ISO International Organization for Standardization

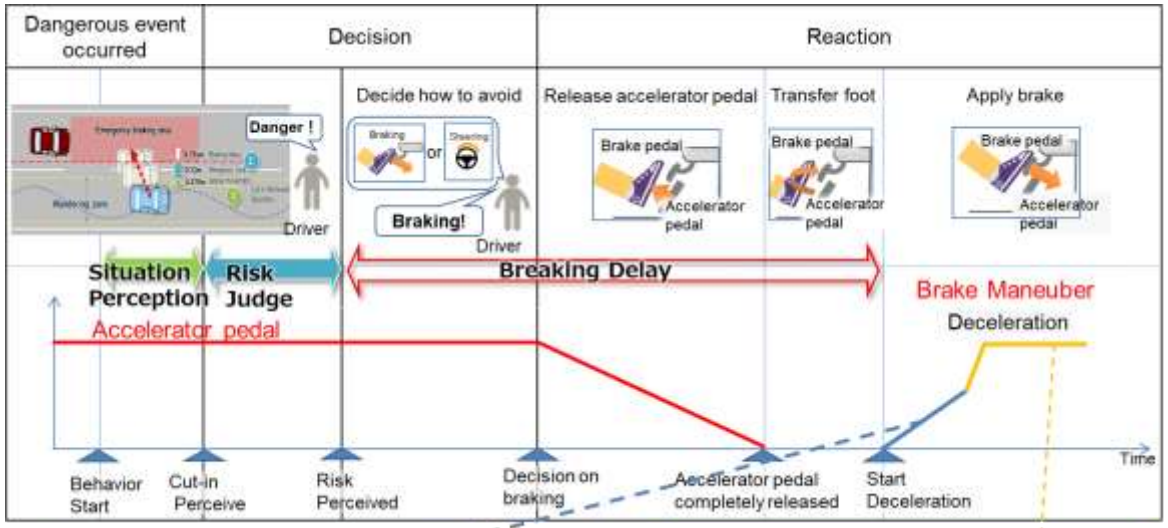
Definition of Preventable and practical implementation of criteria

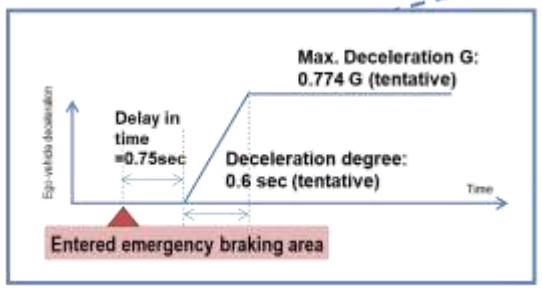
Preventable = Avoidable by a competent and careful human driver

? Does this criteria change depending on country due to different driving culture?

Should Not: sufficient capability of drivers is harmonized globally through international driver license.

Competent and careful human driver & state of art tech combined model for ALKS defined in UN157.





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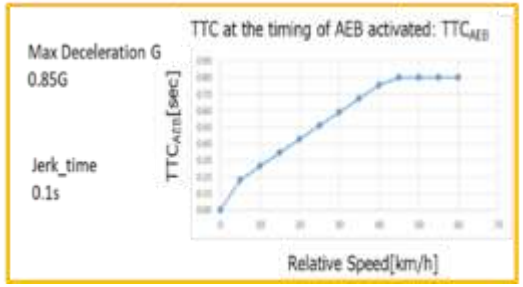
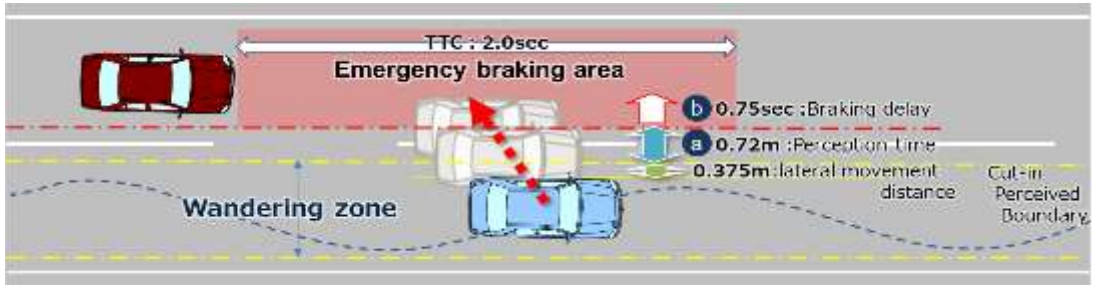
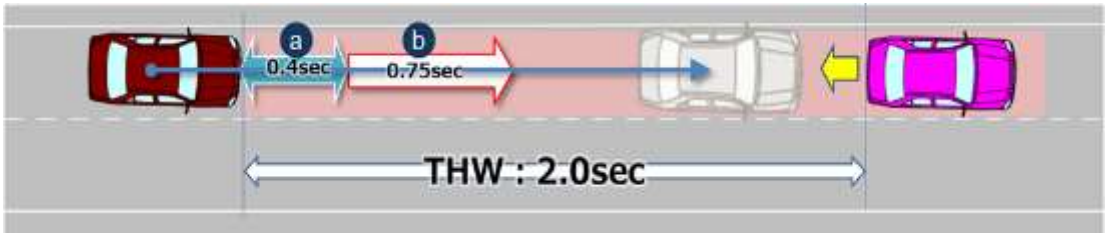
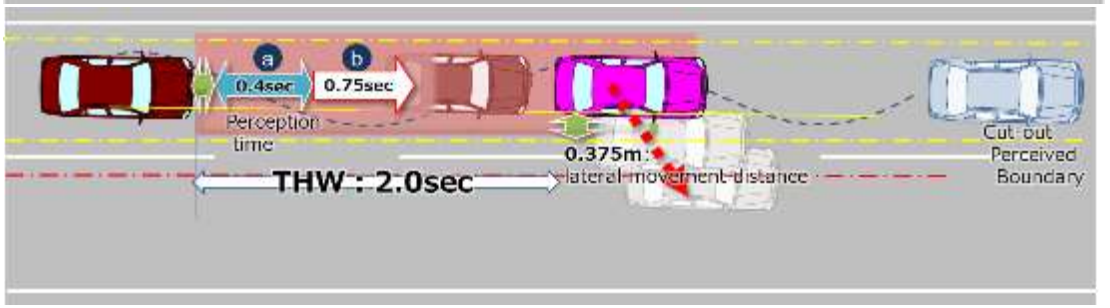




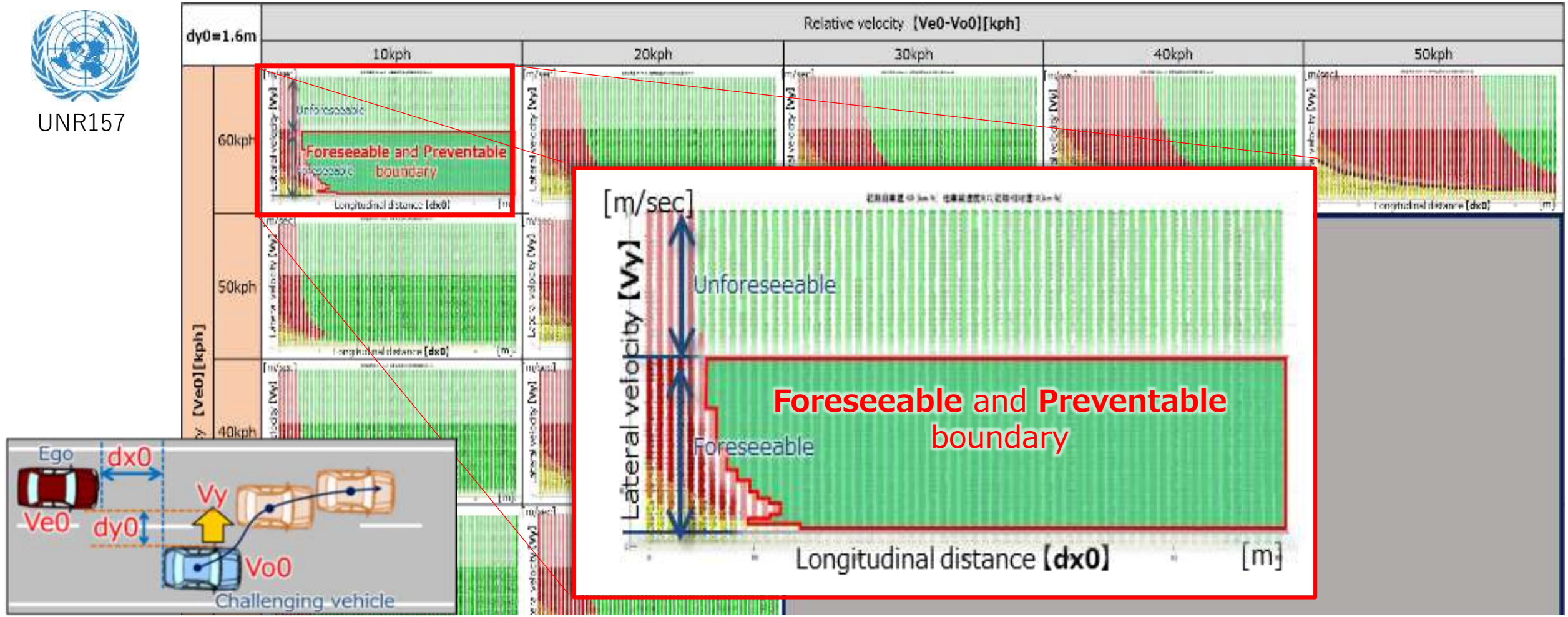




Foreseeable and Preventable Boundary

Preventable and foreseeable criteria is implemented into the ALKS regulation as quantitative pass fail boundary.

UNR157



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自動運転の安全性に対する国際協調の国内対応体制

Regulation
Safety criteria & Test requirements

Regulation

Standard
Test Scenario Derivation Process

Standard

Technical Standard
Specification of driving maneuvers and test scenarios.

Technical Standard

DIVP SIP Cabinet Office

DIVP™ Objectives

- *Open Standard Interface*
- *Reference platform with reasonable verification level*
- *Environment & Sensor paired models based approach*

SAKURA METI

SAKURA Objectives

- *Standardized engineering process*
- *Scenario based safety assurance methodology*
- *Scenario database*

Japan White Paper on AD safety assurance

STRATEGY

RESEARCH

STANDARDIZATION

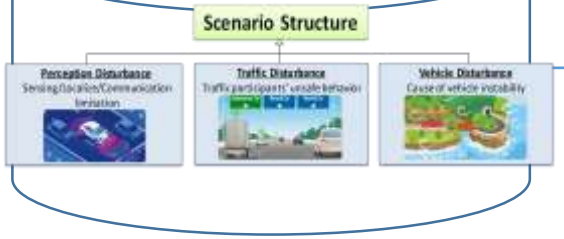
jama

SAE OF JAPAN

自動運転の安全性に対する国内協調体制

SAKURA

安全性評価シナリオＤＢ



DIVP

■ センサ弱点シナリオDB
■ 仮想環境

・一般道で特に課題となる優先複合シナリオのフィードバック
・実路走行中のセンサーデータフィードバック

・安全性評価シナリオＤＢ-仮想環境-実システムの結合
・シナリオIF、simulation IF、評価目的に応じた
スケーラブルなsimulationアーキテクチャの検討

ＯＤＤ定義

ハザード解析&リスク評価

トリガリング条件分析

実装

単体・結合
性能評価

単体・結合
機能評価

認証

Field Monitoring

金沢大学 KANAZAWA UNIVERSITY

システムの公道評価(FOT)

ＡＤシステム検証データ

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国内協調の活動成果オーバービュー

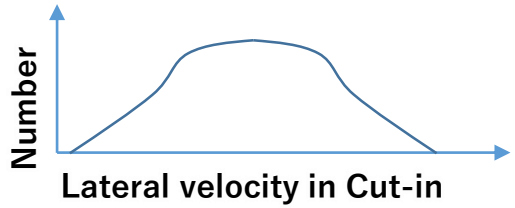
① Scenario DB

Scenario Model

Scenario Data Format

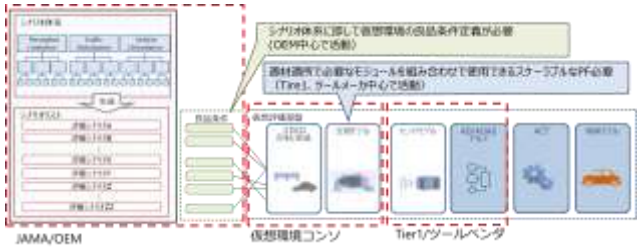
```
Concrete Scenario
Entity
Init
  ego
    speed:60km/s
  lead
    speed:60km/s
    ahead_of:30m
Scene1
  lead
    lanechange:2nd->1st, speed:60->30km/s, rate=3.0m/s
```

Parameter Distribution



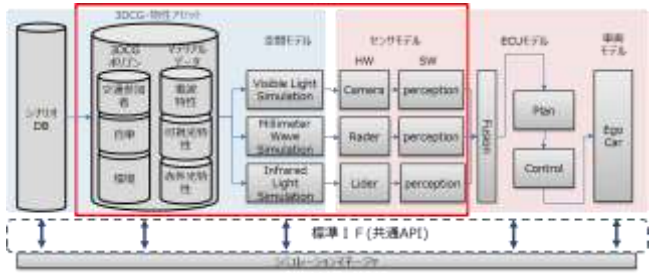
② Virtual Testing Platform

Simulation Requirement



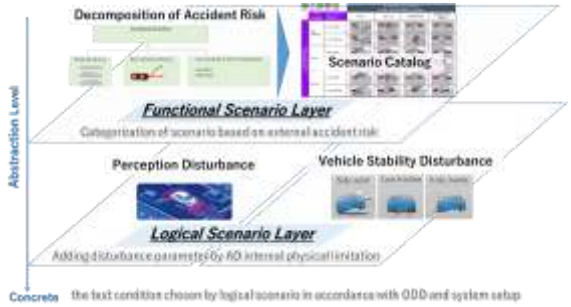
Simulation Validation Method & Criteria

Simulation

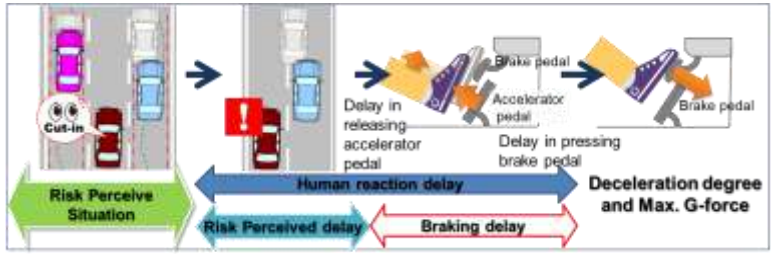


③ Validation Method & Criteria

Scenario Structure



Competent & Careful Human Driver



シナリオベースアプローチの概要

Data Driven Test

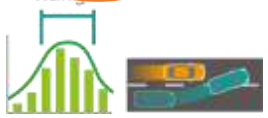
Real world data

Process

Distribution

selection

Parameter range

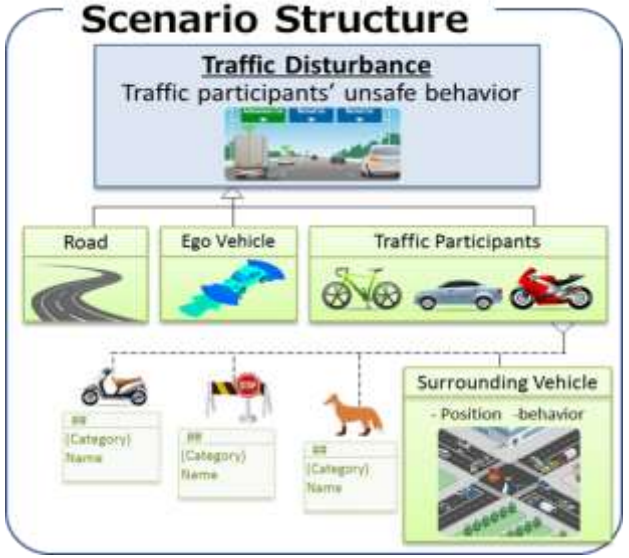


1 Scenario Structure

2 Foreseeable Scenario

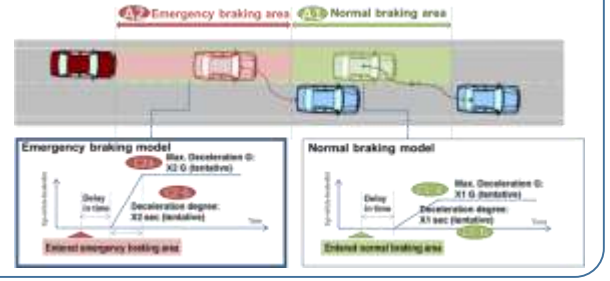
3 Preventable Scenario

Scenario Structure



Comparison between...

Competent and Careful Driver and AD Collision avoidance



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rate=3.0m/s
```

Evaluation Environment

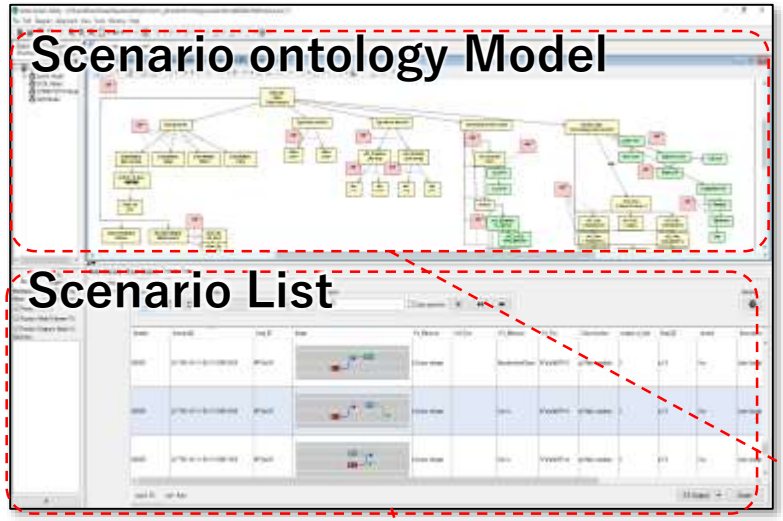
Real-traffic tests

Proving ground tests

Virtual tests

Scenario DB の機能概要

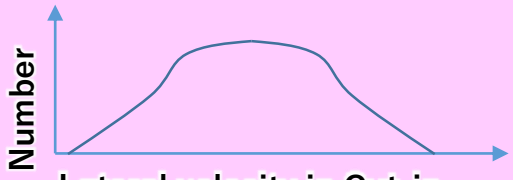
① Scenario Structure

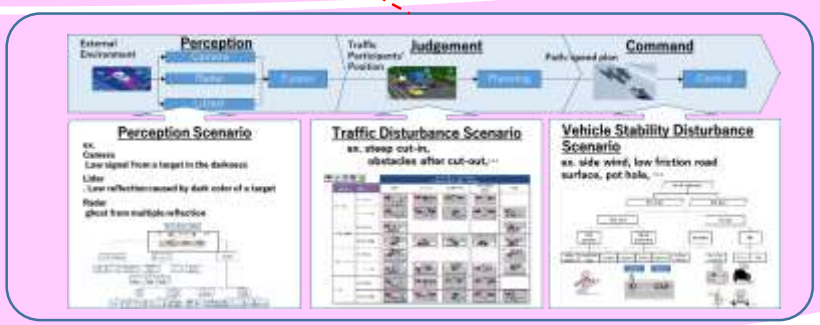


②Test Selection & Environment Allocation

③Test Criteria & Analysis Result

Scenario Parameter Distribution

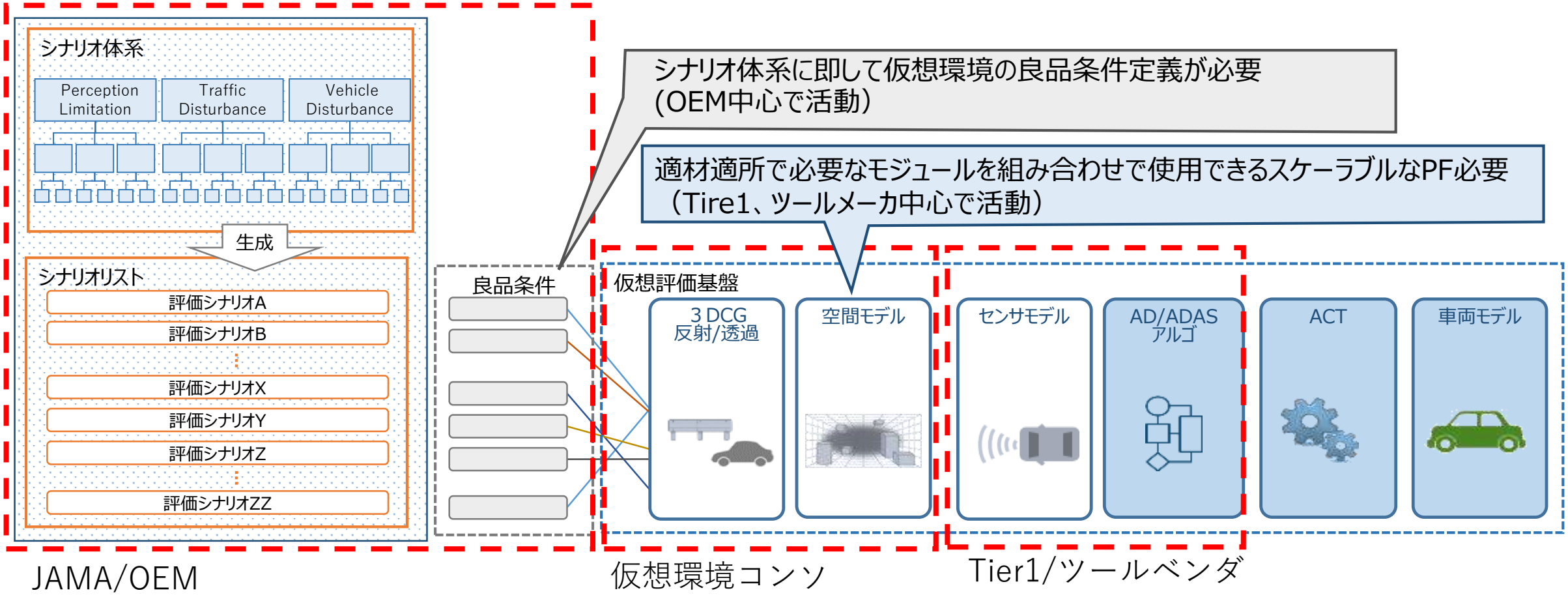




安全性評価仮想評価環境の課題

- ✓ 個社の開発投資単独ではスピード、コストともにTech Company等の規模に対して優位性の確立は難しい。
- ✓ 個社での精度検証と説明性確保はオーバーヘッドが大きい

仲間を作って連携・検討していく仕組みが必要



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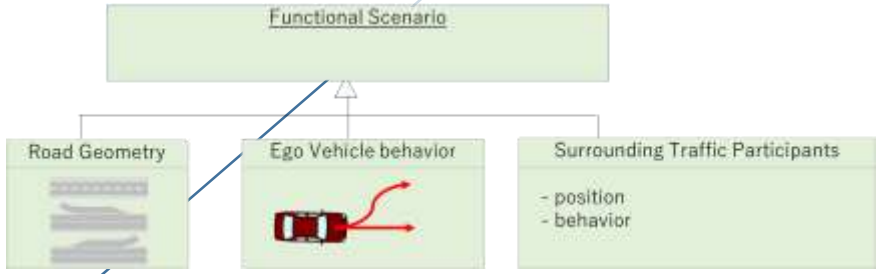
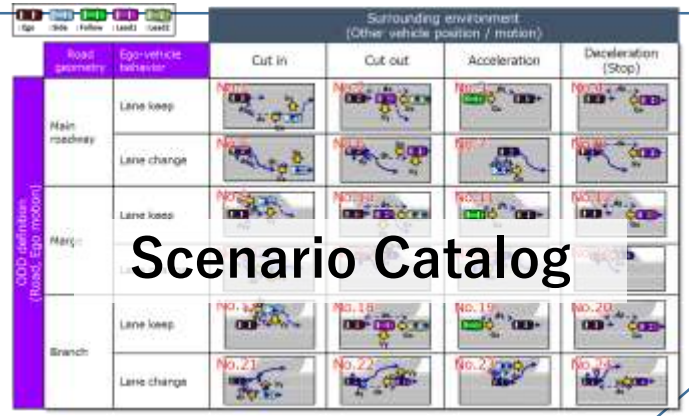
4-1 Over view of traffic scenario abstraction layer

Abstraction Level

Decomposition of Accident Risk





Scenario Catalog

Functional Scenario Layer

Categorization of scenario based on external accident risk

Perception Disturbance

Vehicle Stability Disturbance

Logical Scenario Layer

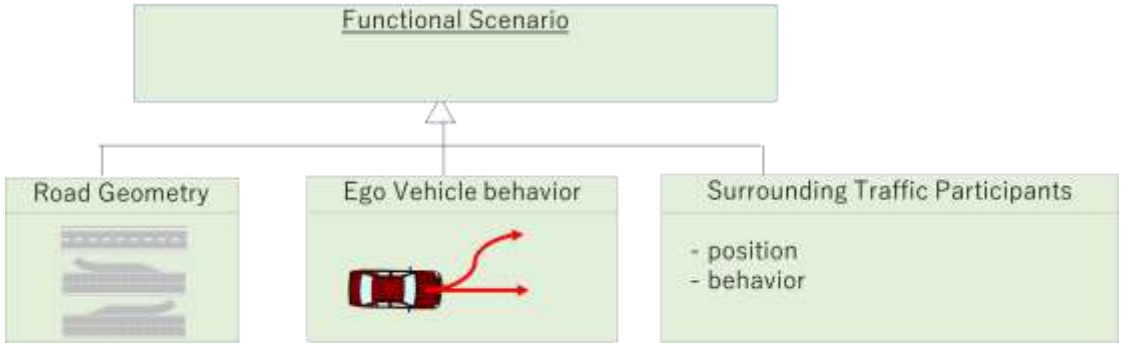
Adding disturbance parameter by AD internal physical limitation

Concrete the test condition chosen by logical scenario in accordance with ODD and system setup

4-2 Functional Scenario

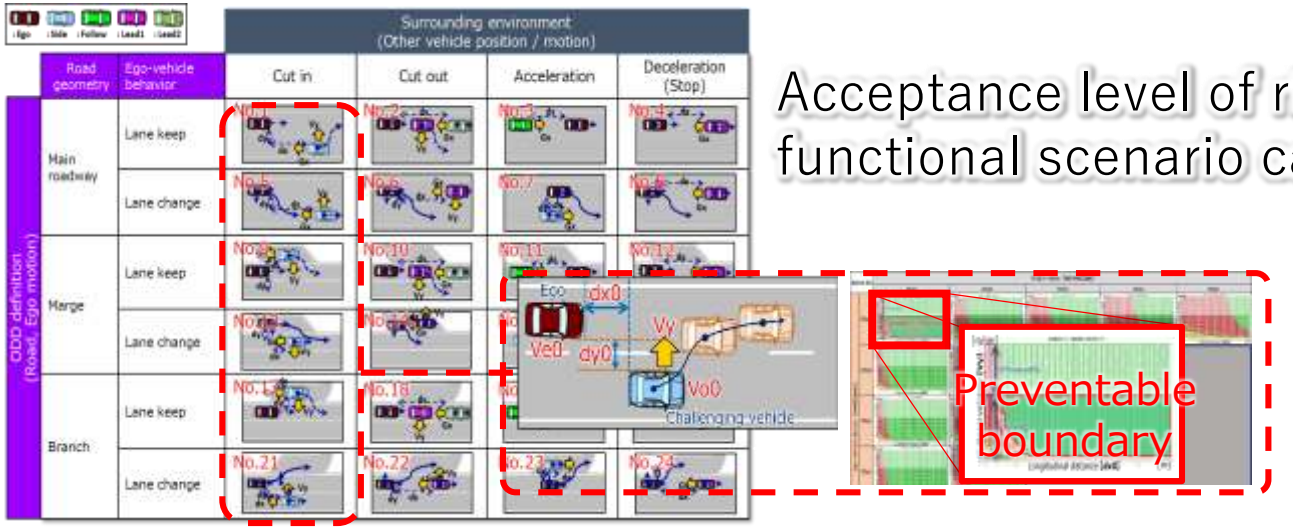
Classification of traffic disturbance, which clarify the external accident risk caused by the traffic participant and obstacle.

Decomposition of Accident Risk



Chapter 2 elaborates this process

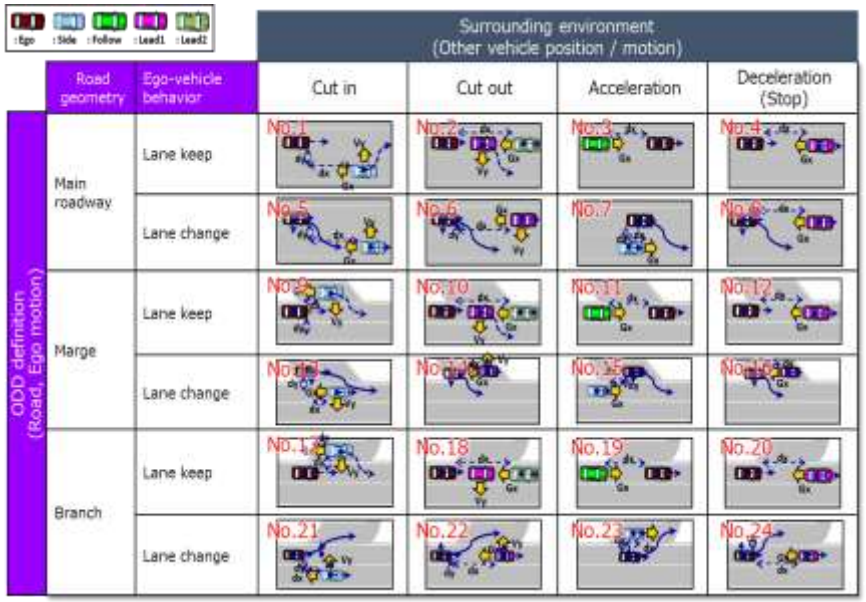
Functional Scenario Catalog



Acceptance level of risk by safety principle belongs to functional scenario category

4-3 Logical Scenario

Adding the disturbance parameter derived from the difficulty of ADS according to sensor & vehicle control physics.



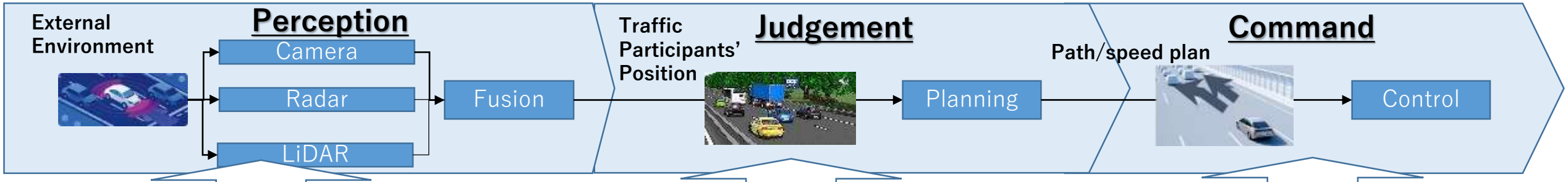
Perception Disturbance

Factors that may interfere with or degrade monitoring of the driving environment
(e.g., inclement weather, absence of road markings)

Vehicle Stability Disturbance

factors impacting vehicle control
e.g., strong wind, road surface conditions

4-4. Scenarios that account for safety-relevant root causes for DDT

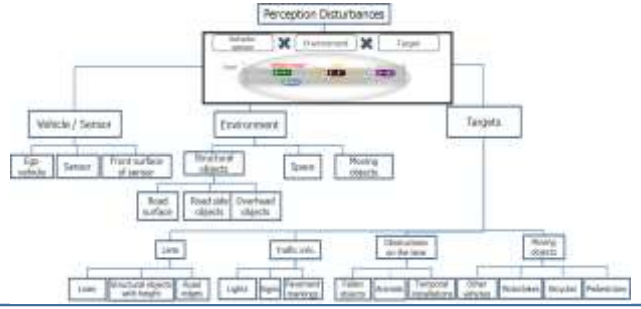


Perception Scenario

ex.
Camera
Low signal from a target in the darkness

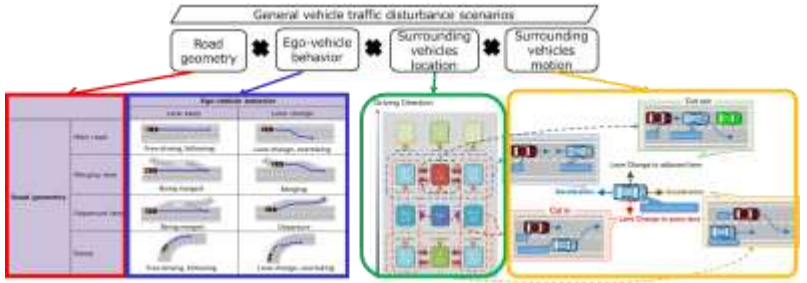
Lidar
. Low reflection caused by dark color of a target

Radar
ghost from multiple reflection



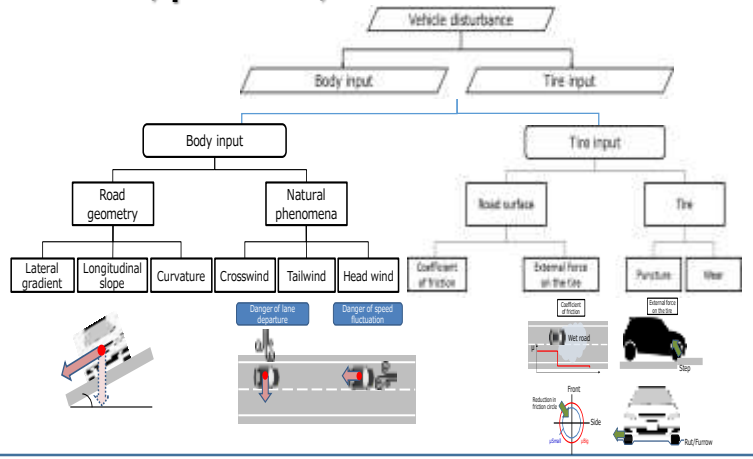
Traffic Disturbance Scenario

ex. steep cut-in,
obstacles after cut-out,…



Vehicle Stability Disturbance Scenario

ex. side wind, low friction road surface, pot hole, …



By logically structuralizing scenarios in accordance with the **physics principles** of the AD system, it is possible to provide a holistic coverage of **the safety-relevant root causes** for given dynamic driving tasks.
ISO34502 applies this rationale to develop three scenario categories: perception (perception disturbance scenario), judgement (traffic disturbance scenario) and command (vehicle stability disturbance scenario).

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～Functional Scenario Derivation～
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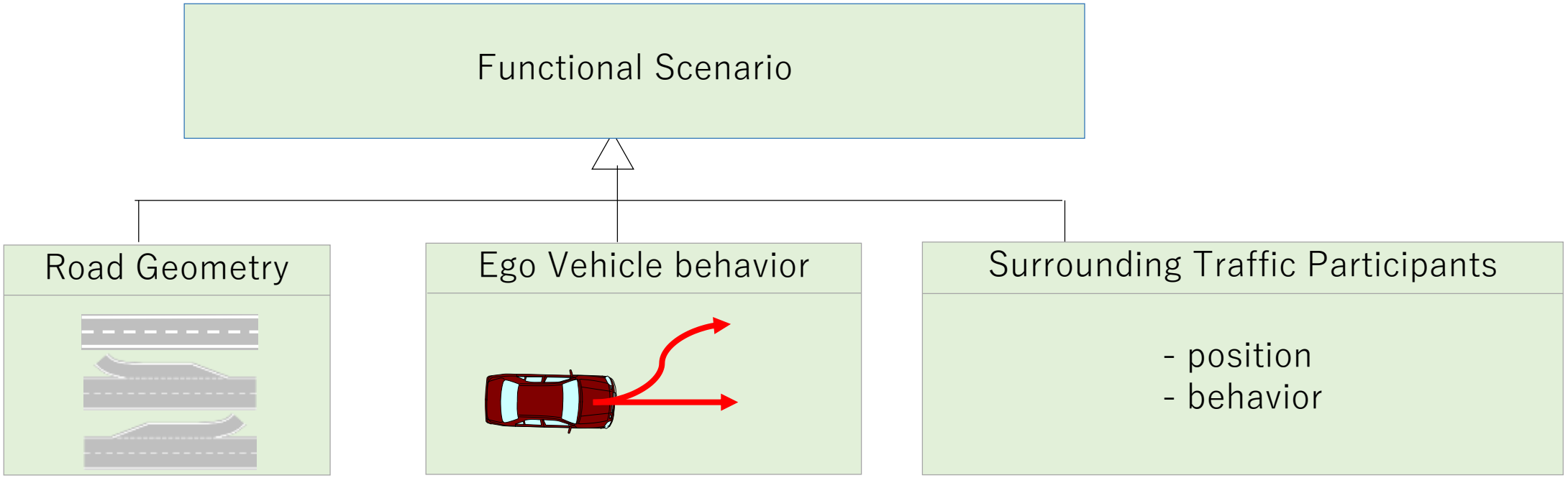
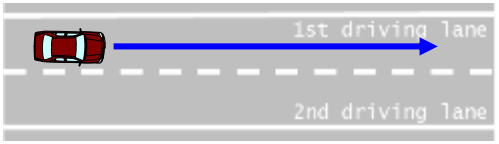
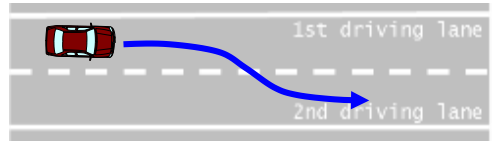
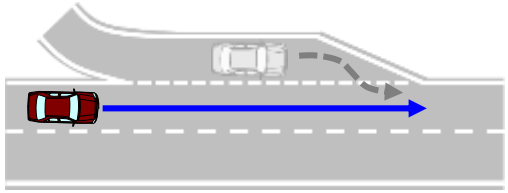
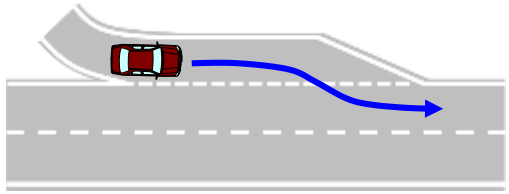
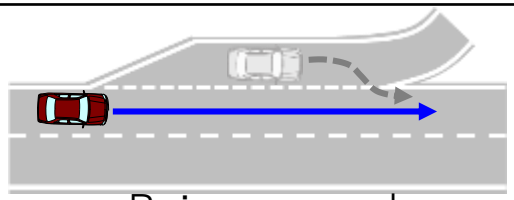
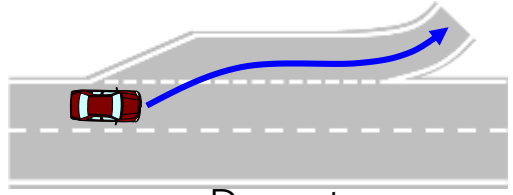
Component of functional scenario

This accident risk can be logically decomposed into road geometry, ego-vehicle behavior and other traffic participant's position/motion.



Road geometry and Ego-vehicle behavior [Component 1 of 2]

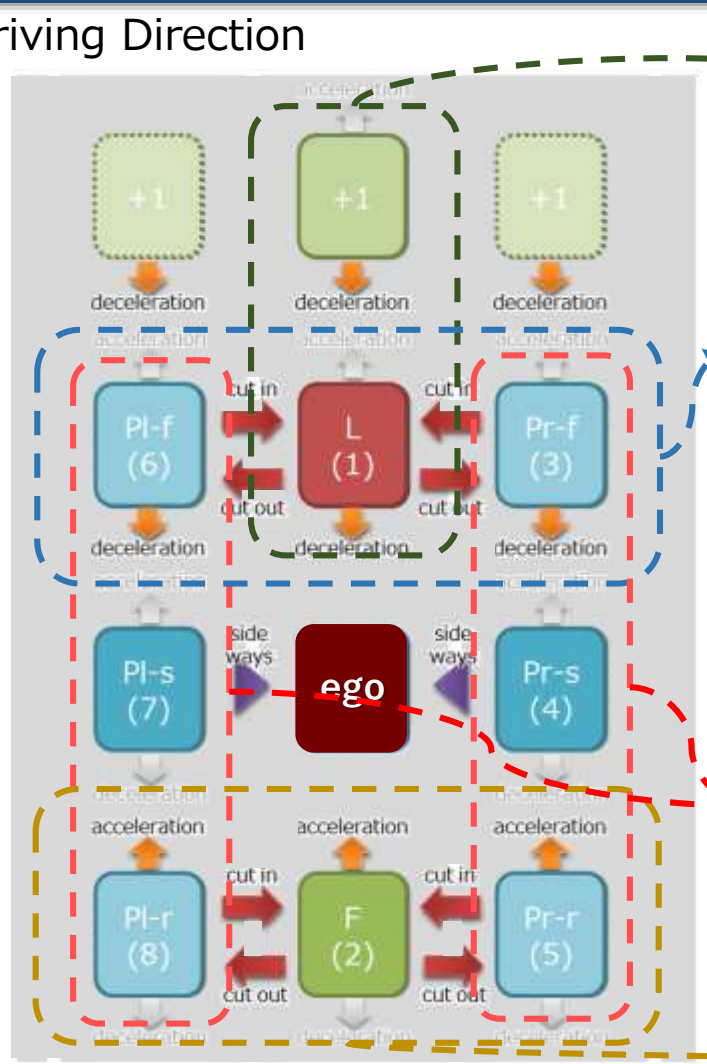
- Road geometry is classified into 3 types (main road, merging, departure).
- Ego-vehicle behavior can be simplified as lane keeping and lane changing.

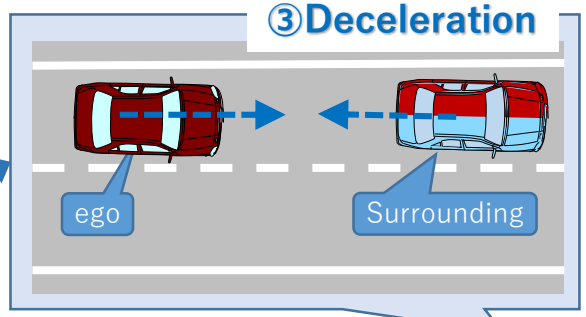
		Ego-vehicle behavior	
		Lane keep	Lane change
Road geometry	Main road	 Free driving Following	 Lane change Overtaking
	Merging lane	 Being merged	 Merging
	Departure lane	 Being merged	 Departure

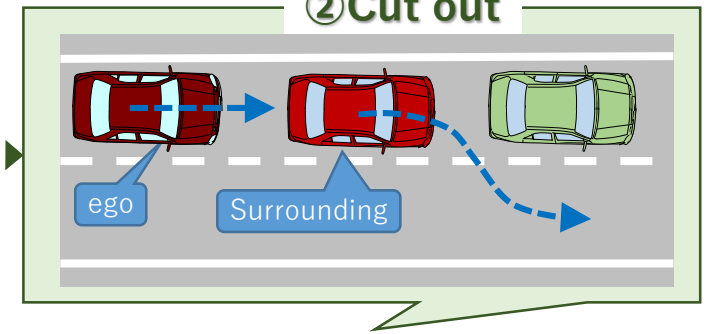
Surrounding Traffic Participants' position and behavior [Component 2 of 2]

The surrounding traffic participants' 4 behavior with respect to 8+1 position which can cause collision needs to be evaluated.

Driving Direction



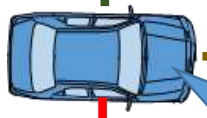




Lane Change to adjacent lane

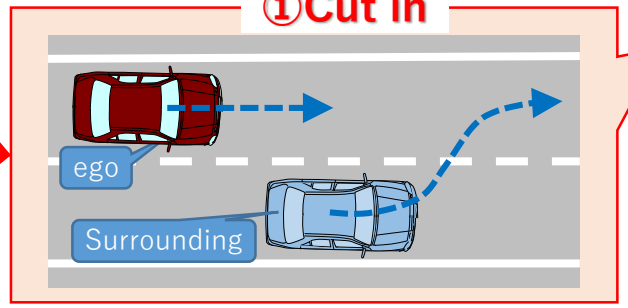
Deceleration

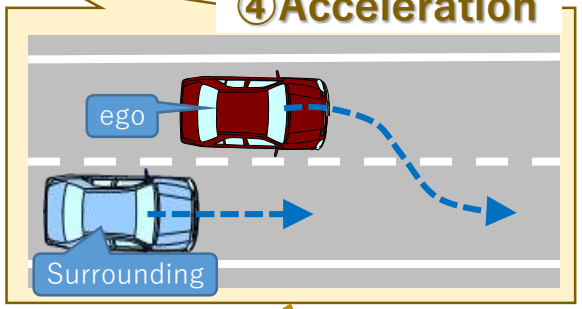
Acceleration



Surrounding vehicle

Lane Change to same lane



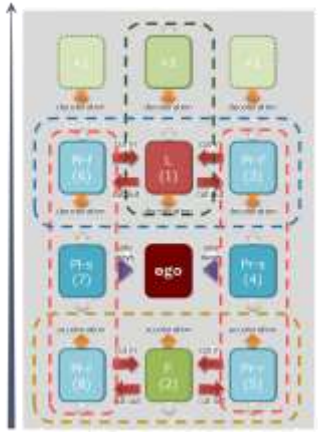


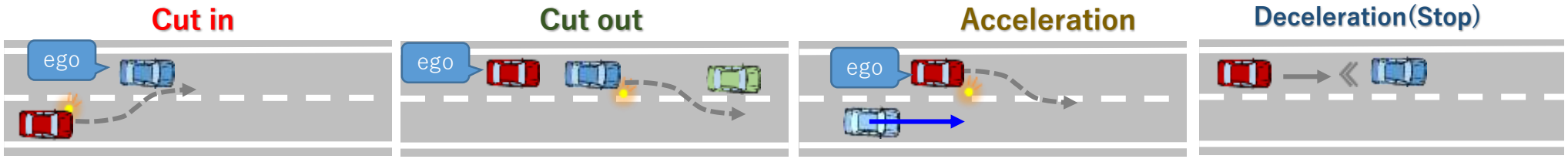
NOTE) Not only the vehicle but also the static object and pedestrian are also covered by this framework

Consolidation of Functional Scenario Component

Surrounding Vehicle Position and Behavior

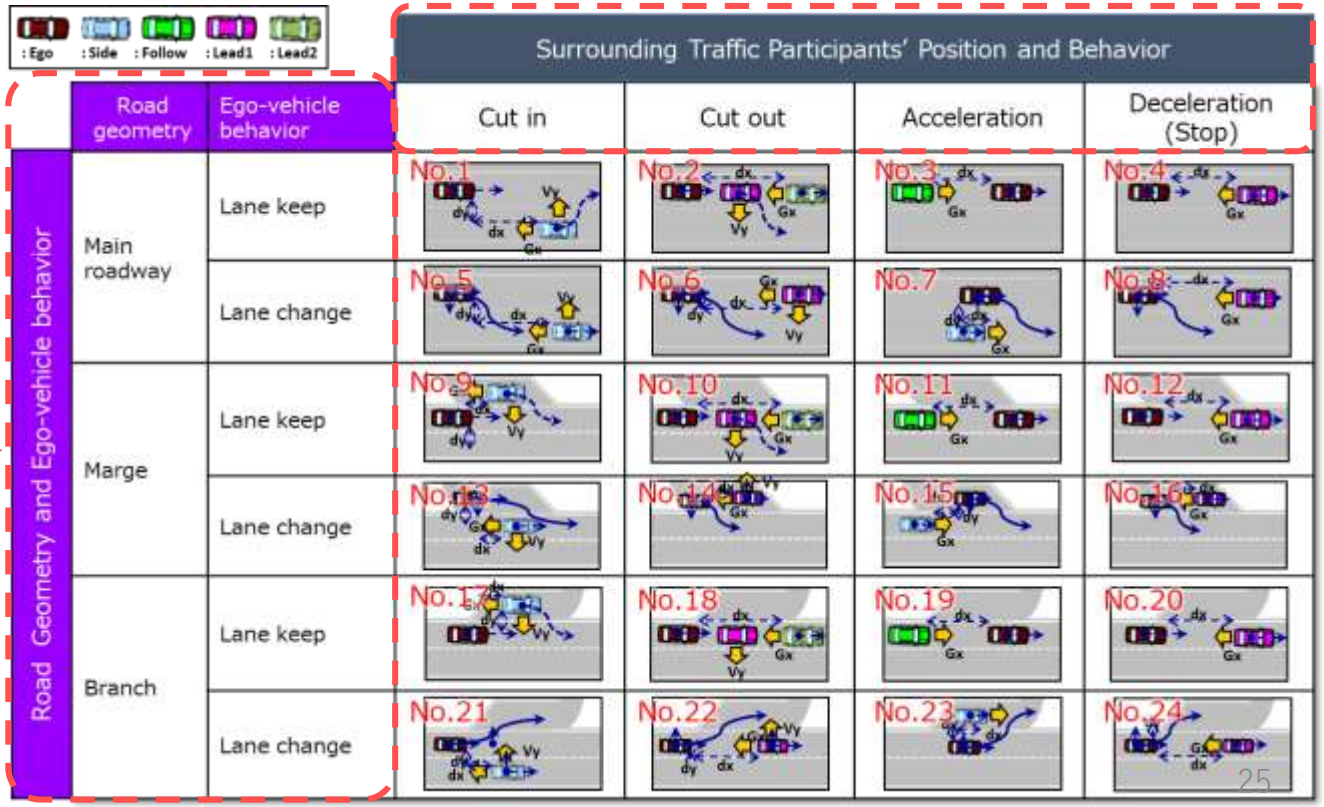
Driving Direction



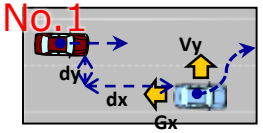
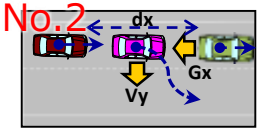
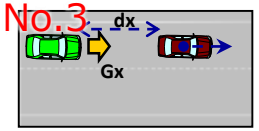
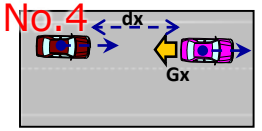
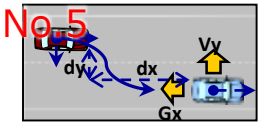
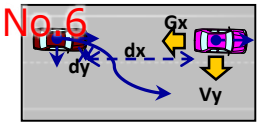
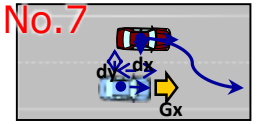
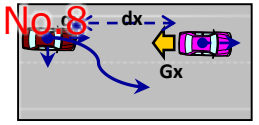
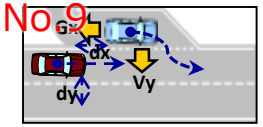
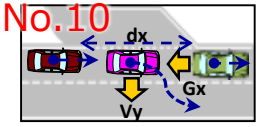
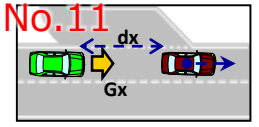
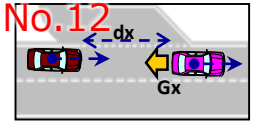
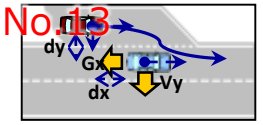
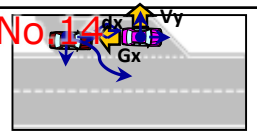
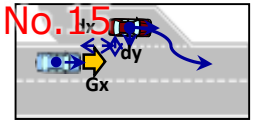
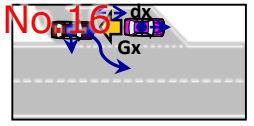
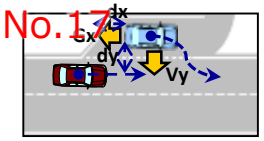
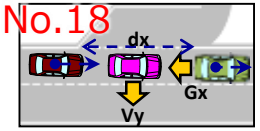
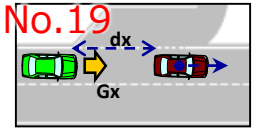
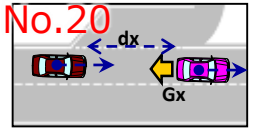
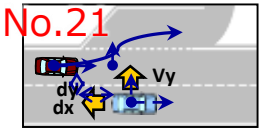
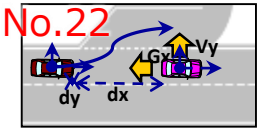
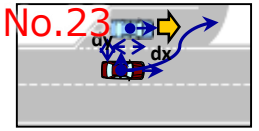
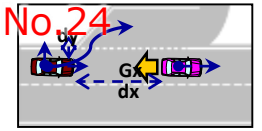


Road Geometry and Ego Vehicle Behavior

		Ego-vehicle behavior	
		Lane keep	Lane change
Road geometry	Main road	Free driving, following	Lane change, overtaking
	Merging lane	Being merged	Merging
	Departure lane	Being merged	Departure



24 Functional Scenarios Proposal

			Surrounding Traffic Participants' Position and Behavior			
	Road geometry	Ego-vehicle behavior	Cut in	Cut out	Acceleration	Deceleration (Stop)
Road Geometry and Ego-vehicle behavior	Main roadway	Lane keep	No.1 	No.2 	No.3 	No.4 
		Lane change	No.5 	No.6 	No.7 	No.8 
	Marge	Lane keep	No.9 	No.10 	No.11 	No.12 
		Lane change	No.13 	No.14 	No.15 	No.16 
	Branch	Lane keep	No.17 	No.18 	No.19 	No.20 
		Lane change	No.21 	No.22 	No.23 	No.24 

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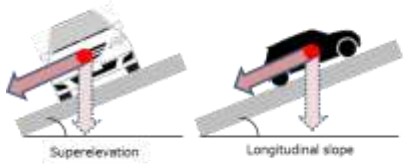
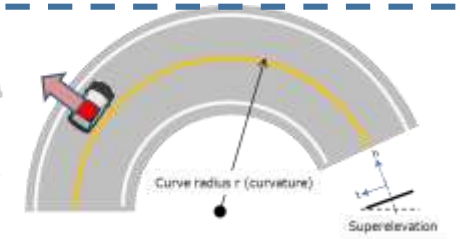
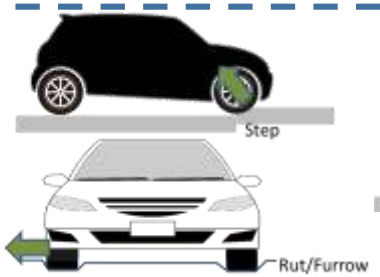
5. 安全性評価手法の詳細
～Logical Scenario Derivation～
6. 今後の活動について

Structure of Vehicle Stability Disturbance







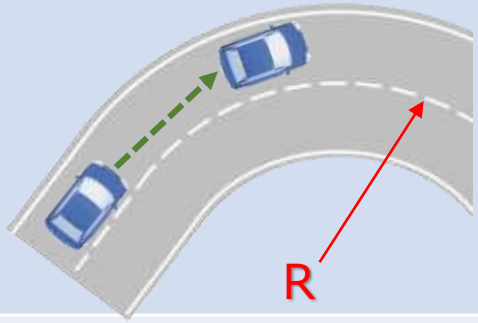
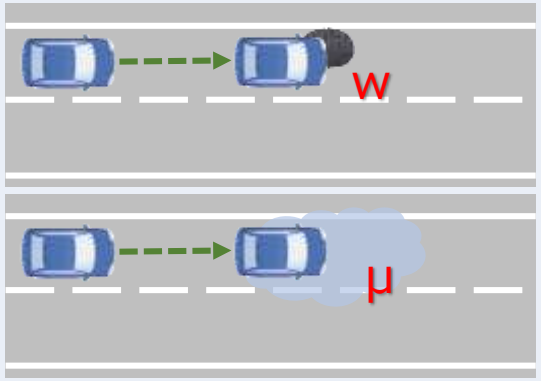
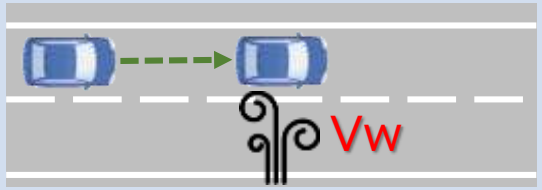
Lateral gradient | Longitudinal slope | Curvature | Crosswind | Tailwind | Head wind | Coefficient of friction | External force on the tire | Puncture | Wear

Road geometry | Natural phenomena | Road surface condition | Tire condition

Body input | Tire input

Vehicle disturbance

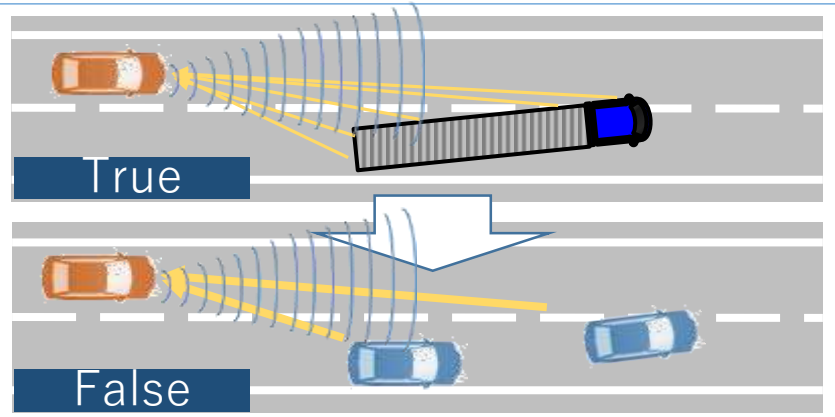
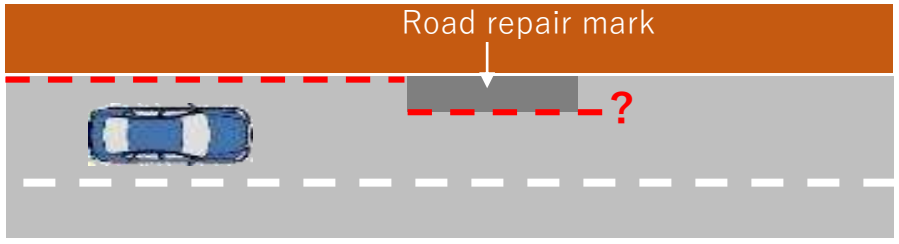
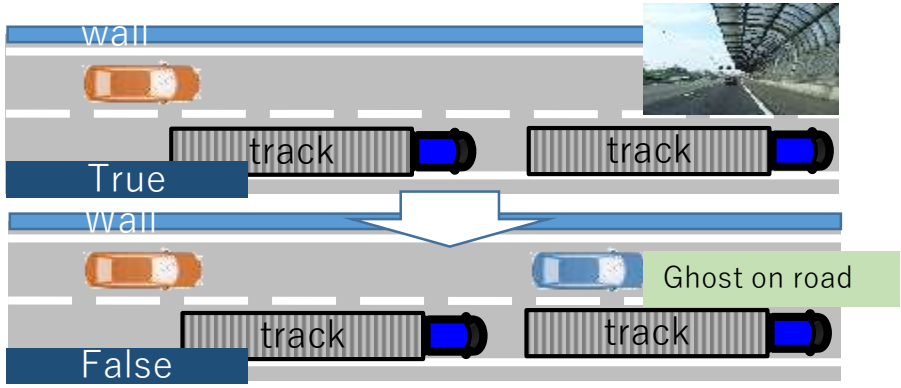
Parameter from Vehicle Stability Disturbance

Disturbance	Description	Vehicle Stability Disturbance Parameter
Road Geometry	In a curve, the lateral force is generated by inertia forces. It changes the direction of the force acting on the body of the vehicle and checks for lane departures.	 Curvature: 【R】Radius Within the road structure ordinance
Road surface condition	Road friction changes with pot poles, puddles, etc. Checking for lane departure by changing the direction of the vehicle due to reduced tire force.	 External force on the tire: 【w】Pothole width Wet road: 【μ】Coefficient of friction Below the road repair target value
Natural phenomena	Caused by naturally occurring gusts of wind, lateral forces. Check to see if vehicle is pushed by the wind and does not veer out of the lane.	 Crosswind: 【Vw】wind speed Wind speed without speed regulation

Effect of Perception Disturbance

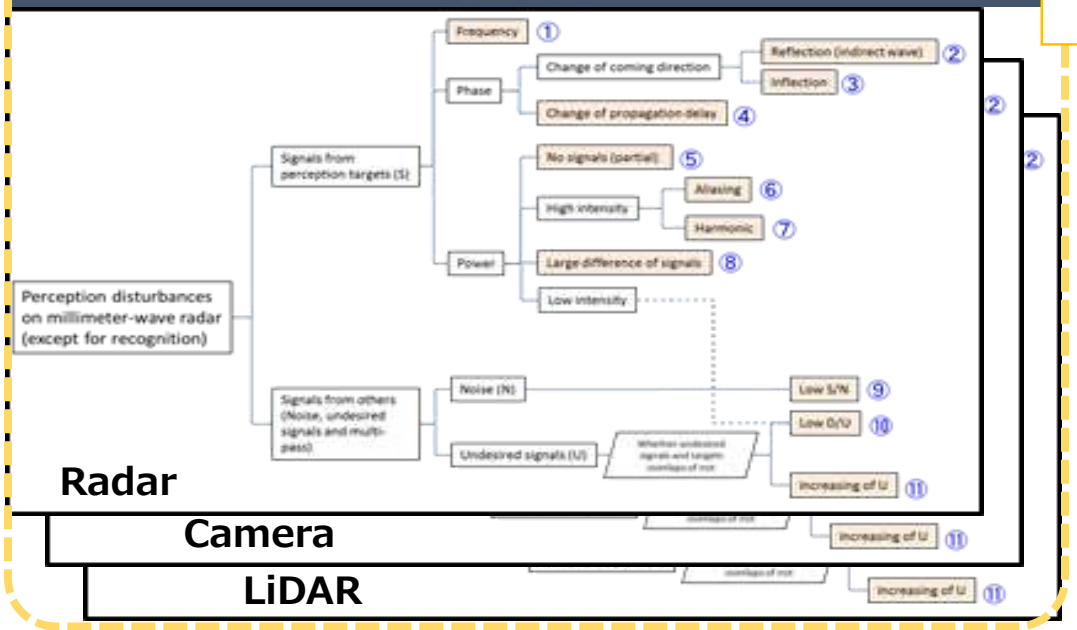
『fail to perceive the existing object』 or 『perceive the imaginary object』 can be happened by perception disturbance.

Examples

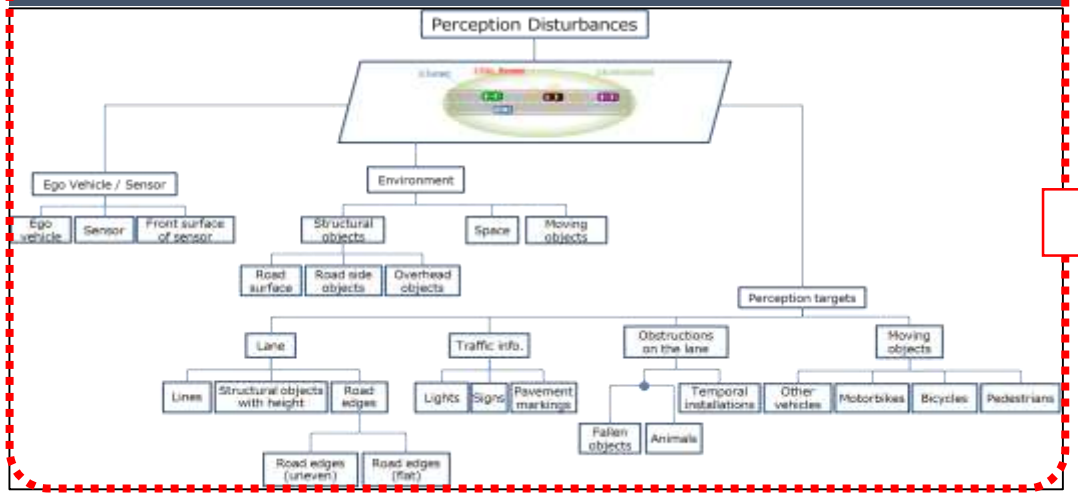
	Camera	radar
false negative **fail to perceive the existing object**	 Fail to detect the leading object because of low contrast against the back ground road and sky.	 Output two separate sensor objects from one object in real because of low sensor resolution
false positive **perceive the imaginary object**	 road repair mark can make the confusion with real road edge.	 Output imaginary object because of too much input from road surface, road side, and over head objects in surrounding environment.

Perception Disturbance Structure

Sensor Physical Principles

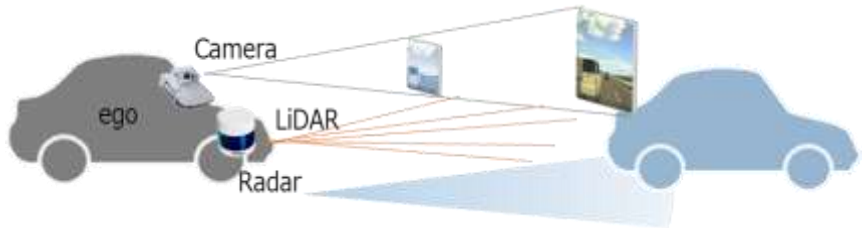


External Factors(environmental factor)



Millimetre-wave Radar			Physical principles (Perception of signals / Sensor orientation)											Physical principles (Recognition)
			Signals from perception targets (S)								Signals from others			
			Frequency	Phase: Change of coming direction: Reflection (indirect wave)	Phase: Change of coming direction: Inflection	Phase: Change of propagation delay	Power: No signals (partial)	Power: High intensity: Aliasing	Power: High intensity: Harmonic	Power: Large difference of signals	Noise (N): Low S/N	Undesired signals (U): Low D/U	Undesired signals (U): Increasing of U	Recognition process
Causal factors for perception disturbances	Ego vehicle / Sensor	Ego vehicle	Change of position											
		Sensor	Variation in assembly		○	○					○	○	○	
			Failure of sensor itself	○				○	○				○	
		Front surface of sensor	Sticking objects		○	○					○			
			Changes in characteristics		○	○					○			
	Environment	Structural objects: Road surface	Shape								○	○	○	
			Road condition									○	○	
			Material									○	○	
		Structural objects: Roadside objects	Reflection	○				○				○	○	
			Screen				○				○			
			Background											
		Structural objects: Overhead objects	Reflection									○	○	
			Screen				○							
			Background											
		Space	Spatial obstacles				○				○	○	○	
			Radio wave and light in space									○	○	
		Moving objects	Reflection	○				○	○			○	○	
			Screen											
			Background											
	Perception targets	Lanes: Lines	Color, Material											
			Shape											
			Dirty / Worn											
			Relative position											
		Lanes: Structural objects with height	Color, Material								○			
			Shape - Large reflection intensity					○						
			Shape -Small reflection intensity											
			Dirty											
			Relative position											
		Lanes: Road edges (flat)	Color, Material											
			Shape											
			Dirty											
			Relative position											
		Lanes: Road edges (uneven)	Color, Material											
			Shape											
			Dirty											
			Relative position											
		Traffic info.	Traffic lights	-										
			Traffic signs	-										
			Pavement markings	-										
		Obstructions on the lane: Fallen objects	Color, Material											
			Shape											
			Relative position / Movement											
		Obstructions on the lane: Animals	Color, Material											
			Shape											
			Relative position / Movement											
		Obstructions on the lane: Temporal installations	Color, Material											
			Shape - Large reflection intensity											
			Shape -Small reflection intensity											
			Dirty											
			Relative position											
		Moving objects: Other vehicles	Color, Material											
			Shape - Large reflection intensity											
			Shape -Small reflection intensity											
			Dirty											
			Relative position											
		Moving objects: Motorbikes	Color, Material											
			Shape, Size											
			Sticking objects											
			Relative position											
		Moving objects: Bicycles	Color, Material											
			Shape, Size											
			Sticking objects											
			Relative position											
		Moving objects: Pedestrians	Color, Material											
			Shape, Size								○			
			Relative position								○			

Select sufficient parameter in accordance with AD sensor setup and ODD



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国連法規の今後

Lv3 low speed lane keep

are added to ALKS member for next step

Lv3 Highway Chauffeur

Lv4 MaaS

国際標準の動向

Regulation

WP29(Vehicle Type Approval)

GRVA(Automated Driving):Post ALKS

FRAV
(Functional Requirement)

VMAD
(Validation Methodology)

refer ?

? US Government is less aggressive about national regulation

- State laws
- Demonstrations

- “AV 2.0” guidance
- “AV TEST” initiative
- Research Grant

refer ?

Standard

ISO34502

DTR4804

ISO21448

P2846

Safety Validation Guideline

Safety Case Guideline

PSDO

Input to SAE J-docs

Safety Assurance Guideline

David Schutt

ORAD

MoU(June/’20)

ANSI/UL4600
(Safety Case)

オールジャパン　活動マイルストーン

	プロジェクト連携の目標	各プロジェクト目標	
		SAKURA	DIVP
’23～			
STEP 4	**定着化** 海外プレイヤー(OEM, Tech Company)を含めた **基盤技術活用によるエコシステム強化**		
‘22			
STEP 3	ＡＤシステム検証データからシナリオのカバレッジを検証・改善する**シナリオフィードバックループを確立。**	**一般道シナリオDB フレームワーク確立** ➢ シナリオDBと仮想環境の標準IF定義	**Step2** ➢ 複合要因の一致性確立
‘21			
STEP 2	シナリオDB（SAKURA）、仮想環境（DIVP）、ADソフト（金沢大）を結合し、CI環境*を立ち上げ、**プロジェクト間のPDCAサイクルのシナジーを確立** *Contiguous Integration	**ChaufferシナリオDB フレームワーク確立** ➢ 認識外乱、車両外乱	**Step1** ➢ 優先１０不調要因の一致性確立 ※False Negative False Positive
‘20			
STEP 1	各プロジェクトのプロトタイプ構築	**ALKSシナリオDB フレームワーク確立** ➢ 交通外乱24シナリオ	**Step0 ノミナル一致性** ➢ ALKS, NCAPシナリオ(6シナリオ)