

Supplemental version for presentation

Proposal of Traffic Scenarios for Highway Driving

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1. Traffic Scenario Overview
 2. Functional Scenario Derivation
- Appendix. Basic Concept of Parameter

Japan

First of all...

Supplement for presentation

NATM Master Document (VMAD 15-03) says;

***5.11 Identifying Scenarios:** Scenario-based validation methods **must include** an adequate representation/coverage of relevant, critical, and complex scenarios to effectively validate an ADS. There are number of approaches for identifying scenarios to validate the safety of an AV. ~~*

The most important thing in considering Functional Scenario is "How do we cover the all of relevant, critical, and complex situations that need to be subject to effectively validate an ADS safety?"

There are so many different factors that can affect the traffic situation, and so many, that is possible to imagine an infinite number of situations. What must be covered are NOT all things in nature, but rather situations that are critical to the effective validate of ADS safety.

Japan considering that the purpose of creating a Functional Scenario is to *systematically organize* such situations and *construct a Functional Scenario logically* to cover all the situations that need to be subject to safety validate.

1. Traffic Scenario Overview

NATM needs to be established so as to assure free of unreasonable risk.
This chapter oversee how the traffic scenario abstraction layer can provide the logical decomposition of risk to establish NATM

- 1-1. Whole structure of Scenarios
- 1-2. Over view of abstraction layer
- 1-3. Functional scenario
- 1-4. Logical scenario

1-1 Whole structure of Scenarios

Functional Scenario:

Scenarios with the highest level of abstraction, outlining the core concept of the scenario, such as a basic description of: *the ego vehicle's actions; the interactions of the ego vehicle with other road users and objects; roadway geometry; and other elements that compose the scenario (e.g. environmental conditions etc.)*.

Traffic Disturbance Scenario

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



Other Elements



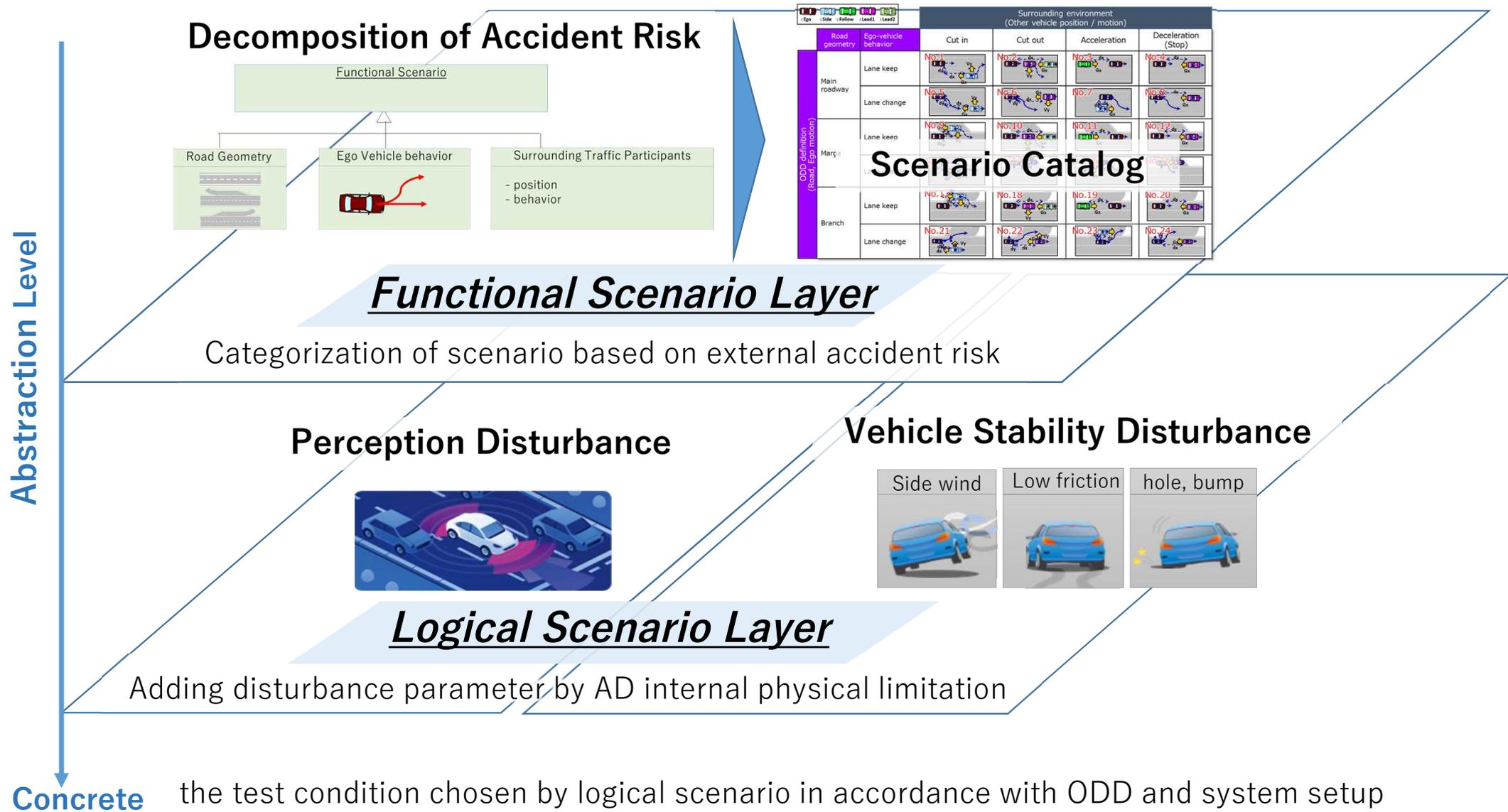
Logical Scenario:

Building off the elements identified within the functional scenario, developers generate a logical scenario by selecting value ranges or probability distributions for each element within a scenario (e.g., the possible width of a lane in meters). The logical scenario description covers all elements and technical requirements necessary to implement a system that solves these scenarios.

Adding the Disturbance Parameter

Perception disturbance
Vehicle Stability disturbance

1-2 Over view of traffic scenario abstraction layer



Why Focused on collision ?

The accident as collisions occur ONLY with other vehicles/objects.

The scenario where regarding the interaction with other vehicles/objects is core of functional scenario.

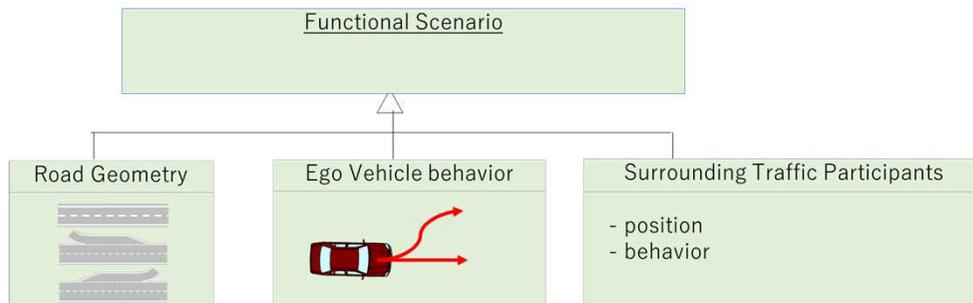
The traffic disturbance scenario is logically delivered to cover all interaction with other vehicles/objects situations within ODD.

Other elements (such as perception or vehicle stability) are treated as parameters and are considered in the logical scenario.

1-3 Functional Scenario

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

Decomposition of Accident Risk

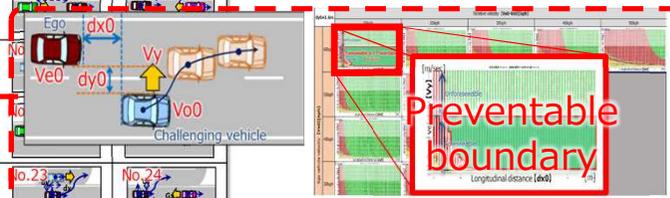
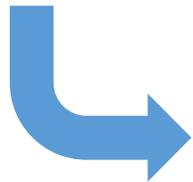


Chapter 2 elaborates this process

Functional Scenario Catalog

		Surrounding environment (Other vehicle position / motion)			
		Cut in	Cut out	Acceleration	Deceleration (Stop)
Road geometry	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
Merge	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

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



1-4 Logical Scenario

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

		Surrounding environment (Other vehicle position / motion)				
		Cut in	Cut out	Acceleration	Deceleration (Stop)	
ODD definition (Road, Ego motion)	Main roadway	Lane keep	No.1	No.2	No.3	No.4
		Lane change	No.5	No.6	No.7	No.8
	Merge	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

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



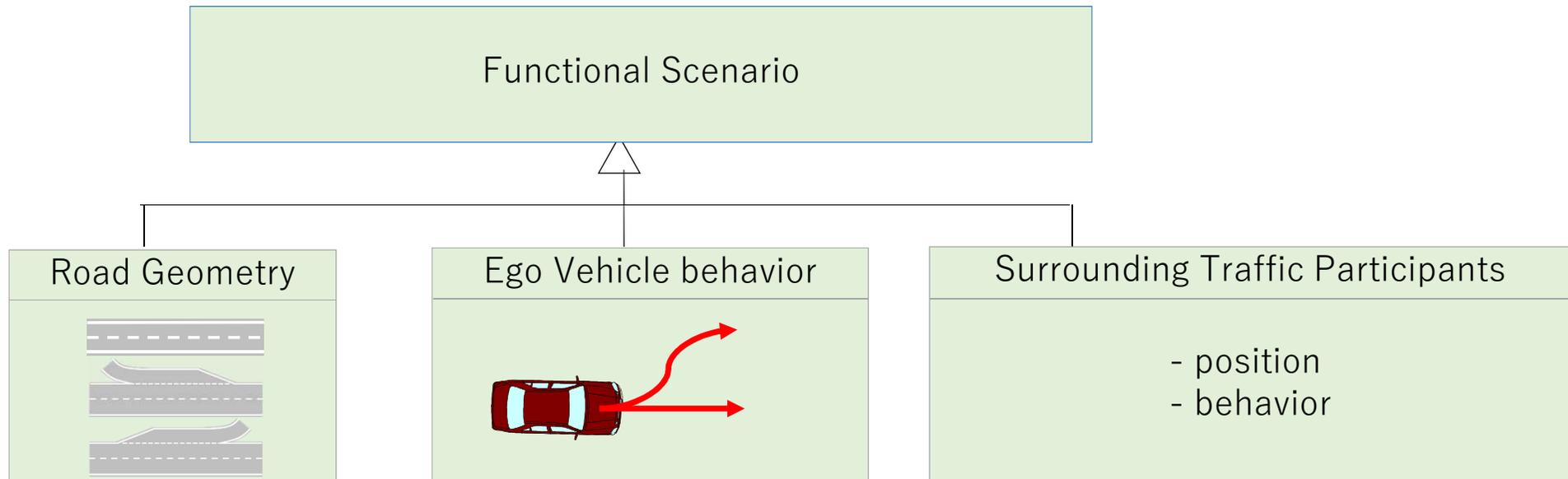
2. Functional Scenario Derivation

Functional scenario is the core to clarify the holistic category of accident risk evaluation. In this chapter the detail deviation step is clarified.

- 2-1. Component of functional scenario
- 2-2. Component 1 of 2: Road geometry and Ego-vehicle behavior
- 2-3. Component 2 of 2: Surrounding Traffic Participants' position and behavior
- 2-4. Consolidation of Functional Scenario Component
- 2-5. Functional Scenario Proposal

2-1. Component of functional scenario

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



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



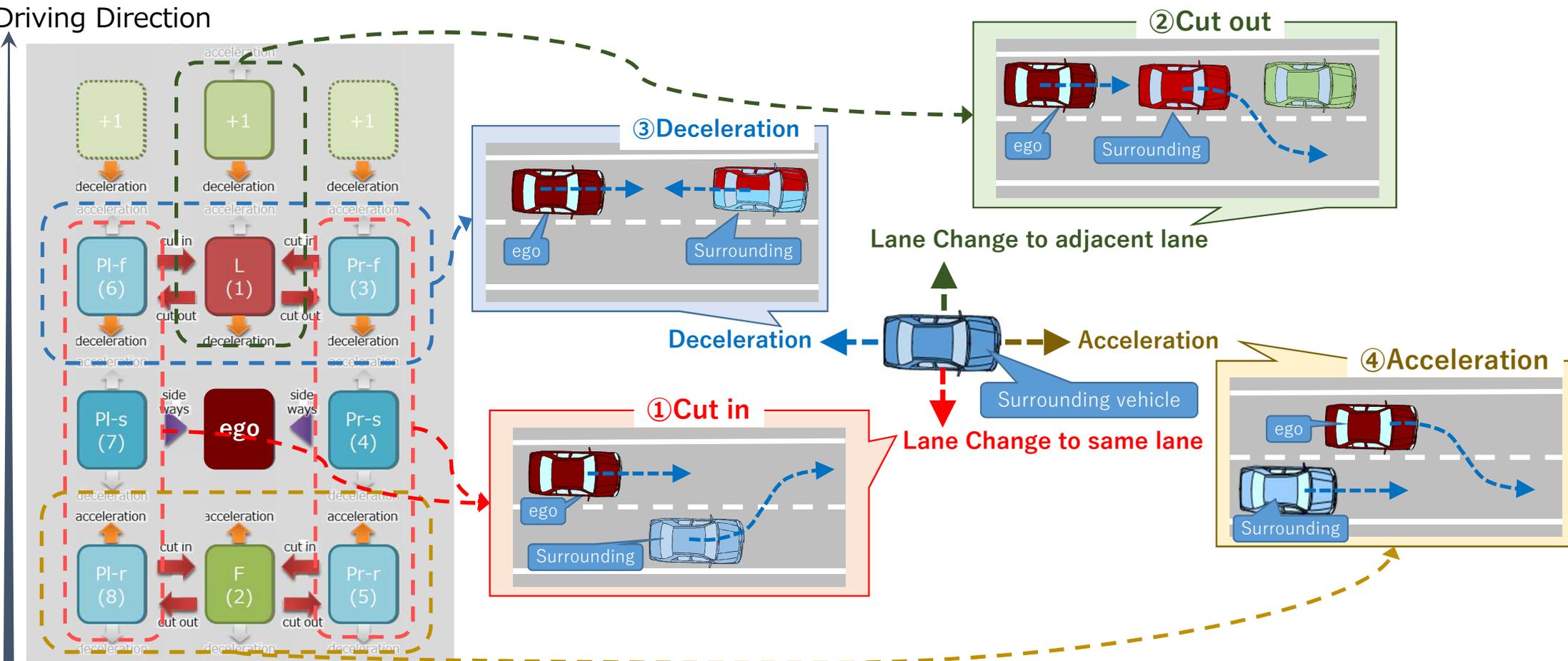
- Road geometry is classified into 3 types (main road, merging, departure).
- Ego-vehicle behavior can be simplified as lane keeping and lane changing.

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



2-3. Surrounding Traffic Participants' position and behavior [Component 2 of 2]

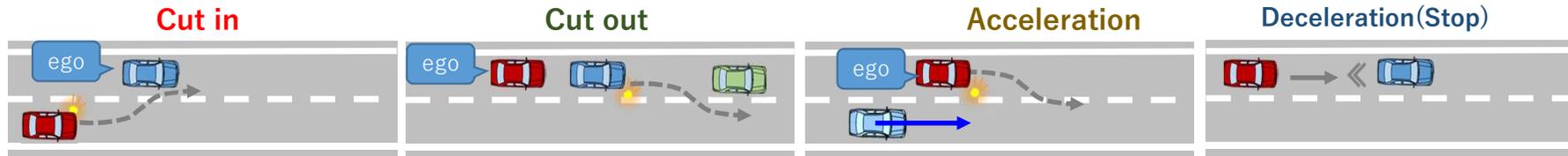
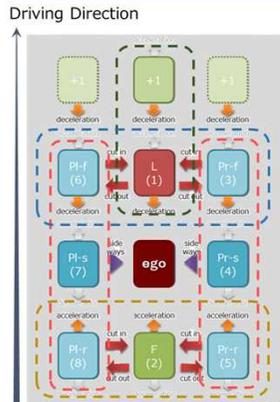
The surrounding traffic participants' 4 behavior with respect to 8+1 position which can cause collision needs to be evaluated.



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

2-4. Consolidation of Functional Scenario Component

Surrounding Vehicle Position and Behavior



Surrounding Traffic Participants' Position and Behavior		Cut in	Cut out	Acceleration	Deceleration (Stop)
Main roadway	Lane keep	No.1	No.2	No.3	No.4
	Lane change	No.5	No.6	No.7	No.8
Merge	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

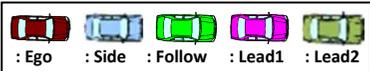
Road geometry and Ego-vehicle behavior	Road geometry	Ego-vehicle behavior
		Lane keep

Road Geometry and Ego Vehicle Behavior

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

2-5. 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
	Merge	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



Appendix. Basic concept of parameter (as the level of logical and concrete scenario)

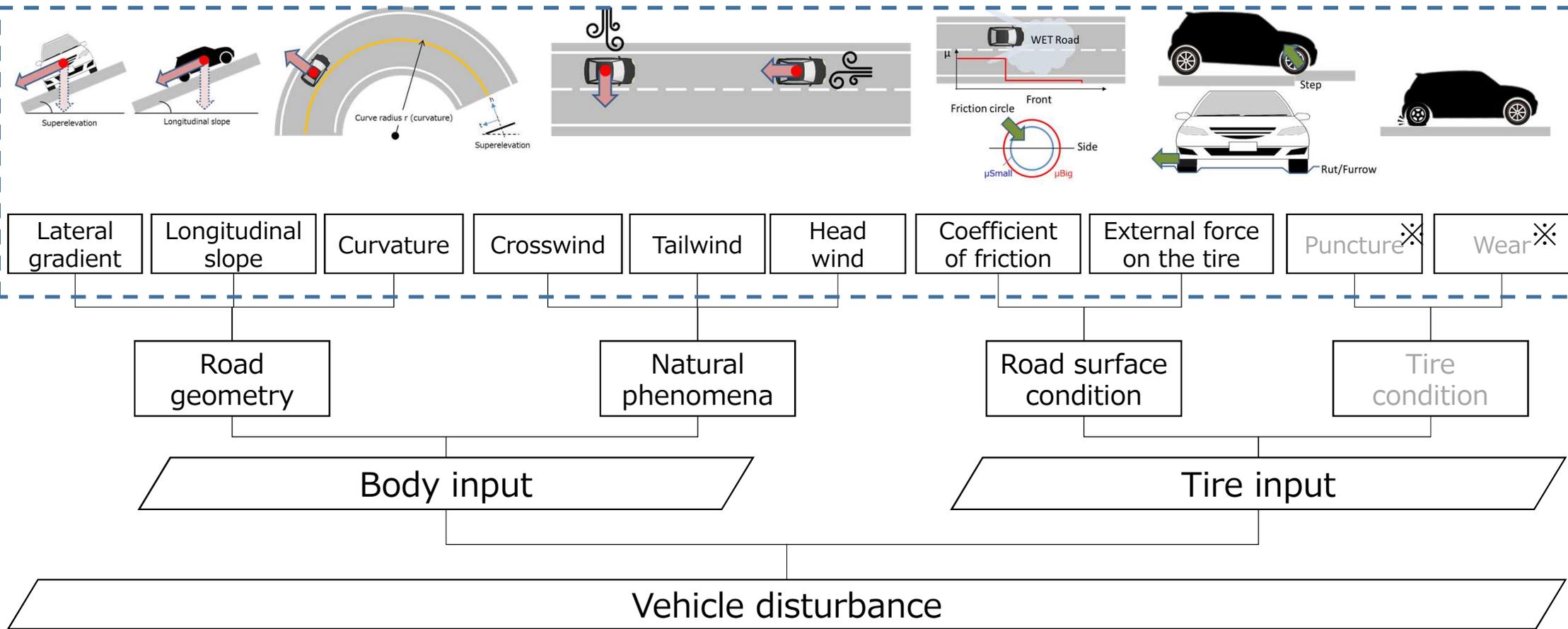
The structure of disturbance parameter based on the AD physics can provide the complementary factor in addition to external traffic risk.

In this chapter the basic concept of the disturbance structure is introduced.

- 1-1. Structure of Vehicle Stability Disturbance
- 1-2. Parameter from Vehicle Stability Disturbance
- 2-2. Effect of Perception Disturbance
- 2-2. Perception Disturbance Structure

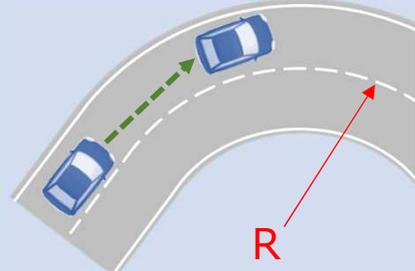
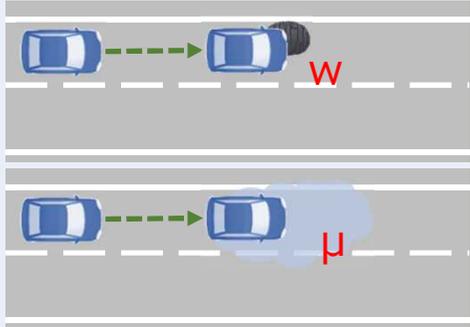
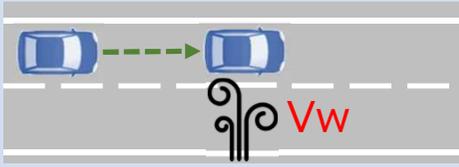
Appendix1-1. Structure of Vehicle Stability Disturbance

The following is a list of events that disrupt vehicle behavior on highways due to events unrelated to the intention of the vehicle (driver) or events that do not interact with traffic participants, and these cannot be measured accurately by NDS(Naturalistic Driving Study) data.



※It can be addressed by functional safety, by detecting a flat tire before it induces

Appendix1-2. Parameter from Vehicle Stability Disturbance

Disturbance	Description	Vehicle Stability Disturbance Parameter					
<p>Road Geometry</p>	<p>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.</p>	 <p>The diagram shows a blue car navigating a right-hand curve. A dashed green arrow indicates the car's path. A red arrow labeled 'R' points from the center of the curve to the road's edge, representing the radius.</p>	<table border="1" data-bbox="1456 406 2184 486"> <tr> <td>Curvature</td> <td>【R】 Radius</td> </tr> </table> <p>Within the road structure ordinance</p>	Curvature	【R】 Radius		
Curvature	【R】 Radius						
<p>Road surface condition</p>	<p>Road friction changes with pot holes, puddles, etc. Checking for lane departure by changing the direction of the vehicle due to reduced tire force.</p>	 <p>The top diagram shows a car approaching a pothole labeled 'w'. A dashed green arrow shows the car's path veering to the right. The bottom diagram shows a car on a wet road labeled 'μ'. A dashed green arrow shows the car's path veering to the right.</p>	<table border="1" data-bbox="1456 710 2184 829"> <tr> <td>External force on the tire</td> <td>【w】 Pothole width</td> </tr> </table> <table border="1" data-bbox="1456 885 2184 1013"> <tr> <td>Wet road</td> <td>【μ】 Coefficient of friction</td> </tr> </table> <p>Below the road repair target value</p>	External force on the tire	【w】 Pothole width	Wet road	【μ】 Coefficient of friction
External force on the tire	【w】 Pothole width						
Wet road	【μ】 Coefficient of friction						
<p>Natural phenomena</p>	<p>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.</p>	 <p>The diagram shows a car on a straight road. A blue squiggly line representing a gust of wind is shown hitting the car from the left. A dashed green arrow shows the car's path veering to the right. The wind speed is labeled 'Vw'.</p>	<table border="1" data-bbox="1456 1117 2184 1189"> <tr> <td>Crosswind</td> <td>【Vw】 wind speed</td> </tr> </table> <p>Wind speed without speed regulation</p>	Crosswind	【Vw】 wind speed		
Crosswind	【Vw】 wind speed						

Appendix2-1. Effect of Perception Disturbance

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

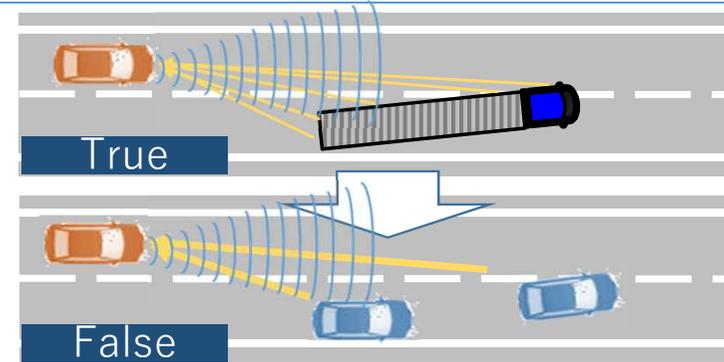
Examples

Camera



Fail to detect the leading object because of low contrast against the back ground road and sky.

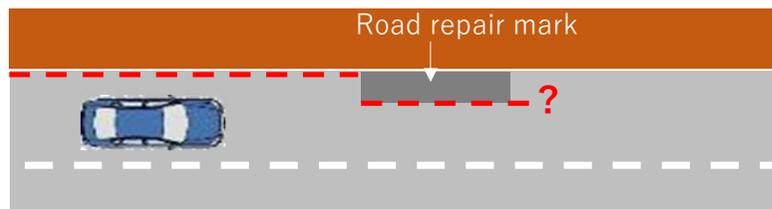
radar



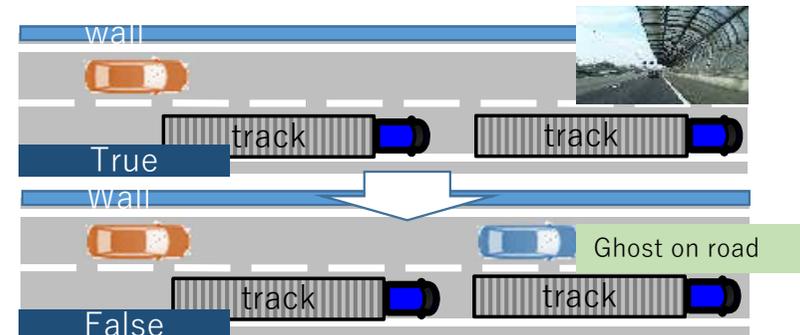
Output two separate sensor objects from one object in real because of low sensor resolution

false positive

perceive the imaginary object

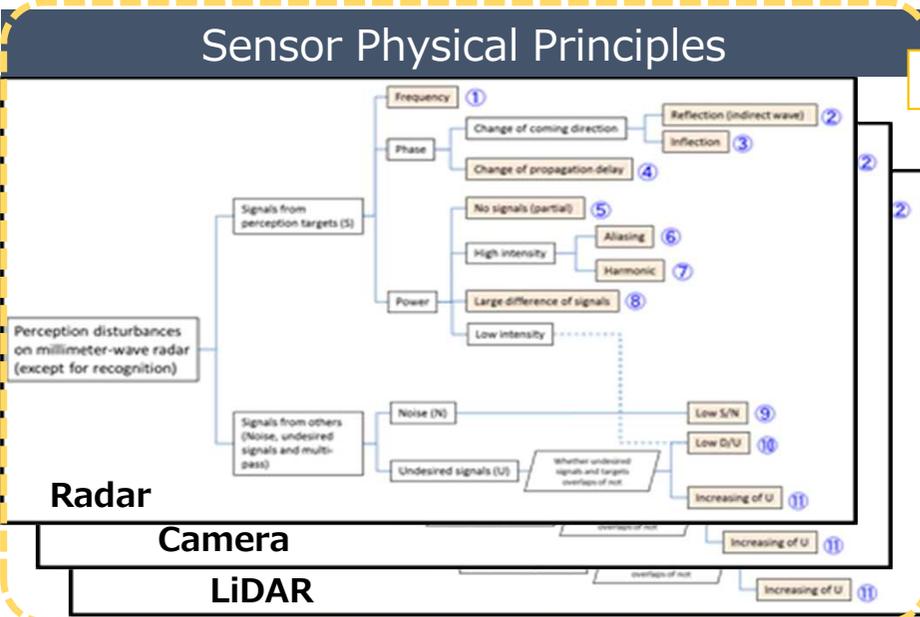


road repair mark can make the confusion with real road edge.

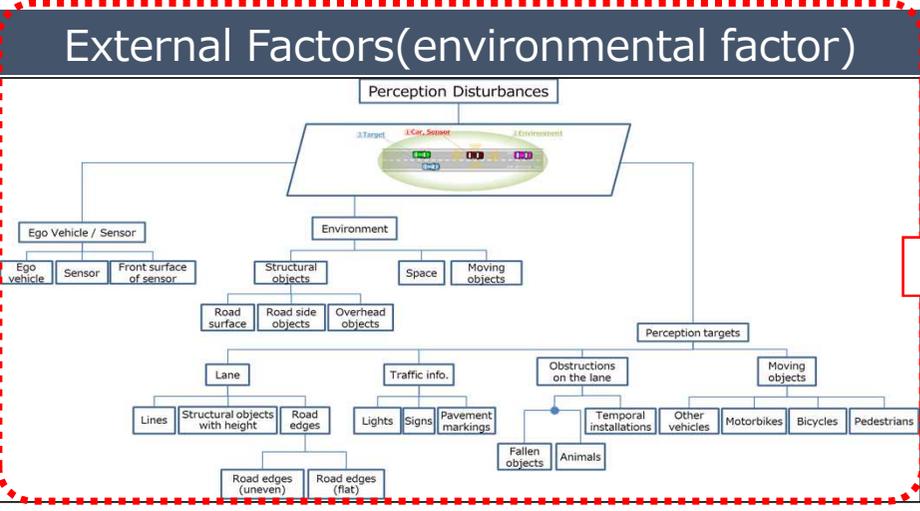


Output imaginary object because of too much input from road surface, road side, and over head objects in surrounding environment.

Appendix2-2. Perception Disturbance Structure



Causal factors for perception disturbances	Physical principles (Perception of signals / Sensor orientation)	Signals from perception targets (S)										Signals from others			Physical principles (Recognition)			
		Frequency	Phase		Change of propagation delay	No signals (partial)	Power			Large difference of signals	Noise (N)		Undesired signals (U)	Recognition process				
			reflection (indirect wave)	inflection			High intensity	Aliasing	Harmonic		Low S/N	Low D/U	Increasing of U					
Ego vehicle / Sensor	Sensor																	
	Front surface of sensor																	
	Structural objects	Road surface																
		Roadside objects																
		Overhead objects																
	Space	Spatial obstacles																
		Radio wave and light in space																
	Moving objects	Reflection																
		Screen																
	Lanes	Lines	Color, Material															
Shape																		
Structural objects with height		Color, Material																
		Shape - Large reflection intensity																
Road edges (flat)		Color, Material																
		Shape																
Road edges (uneven)		Color, Material																
		Shape																
Obstructions on the lane		Traffic lights																
		Traffic signs																
	Pavement markings																	
	Fallen objects	Color, Material																
		Shape																
	Animals	Color, Material																
		Shape																
	Temporal installations	Color, Material																
		Shape - Large reflection intensity																
	Moving objects	Other vehicles	Color, Material															
Shape - Large reflection intensity																		
Motorbikes		Color, Material																
		Shape, Size																
Bicycles		Color, Material																
		Shape, Size																
Pedestrians		Color, Material																
		Shape, Size																



Select sufficient parameter in accordance with AD sensor setup and ODD

The diagram shows an ego car equipped with a camera, LiDAR, and radar. The camera is positioned on the roof, LiDAR is on the front, and radar is on the front bumper. They are detecting another car (target) in the environment. The radar beam is shown as a blue cone, LiDAR as red lines, and the camera as a blue rectangle. The target car is shown in blue.