Japan Automobile Research Institute

Alignment of SOTIF and Scenario-based Safety Evaluation Framework

SafeComp2025 2025-09-11

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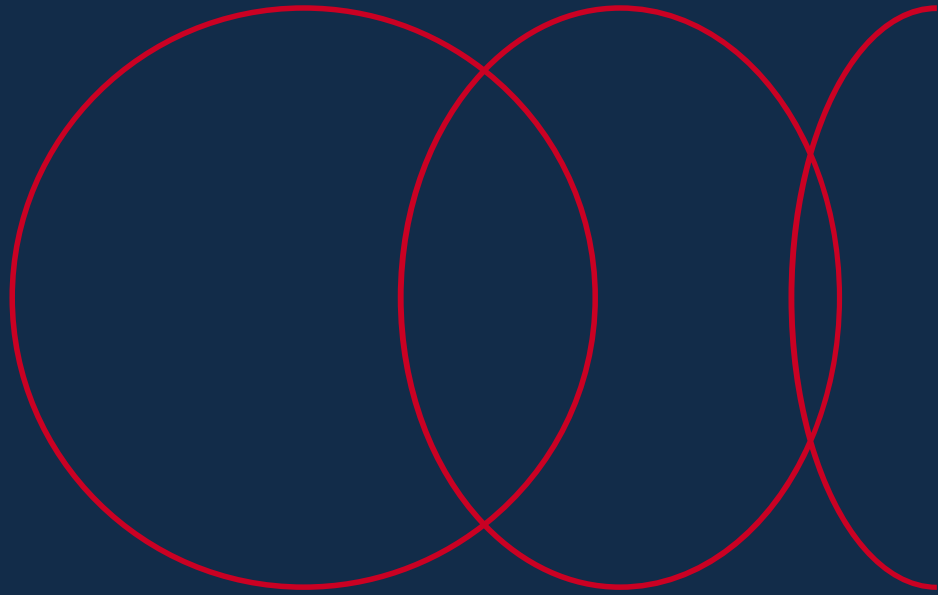
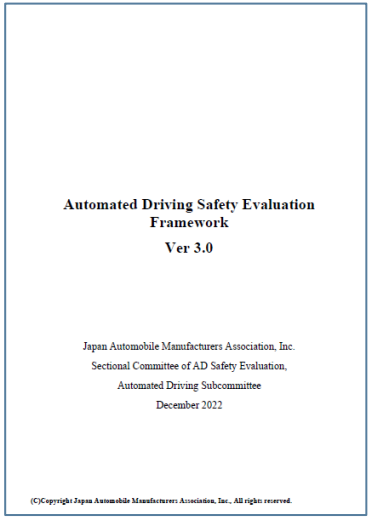
Summary of the paper



Summary of this paper

- Scenario-based safety evaluation has become increasingly important for the verification and validation of Automated Driving Systems (ADS).
- **Automated Driving Safety Evaluation Framework (ADSEF)** is a scenario construction and evaluation methodology for ADS L3-L5 developed within the SAKURA project (funded by **the Ministry of Economy, Trade and Industry (METI) of Japan**).
- To apply ADSEF in practice, it is essential to align it with existing safety standards, in particular ISO 21448 (SOTIF).
- However, ADSEF does not provide clear guidelines for its use in conjunction with SOTIF.


Automated Driving Safety Evaluation Framework

Ver 3.0

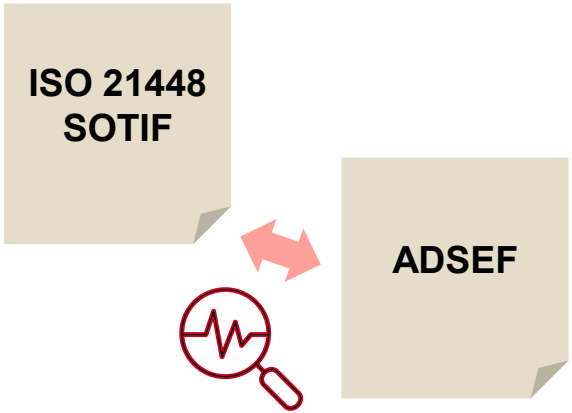
Japan Automobile Manufacturers Association, Inc.
Sectional Committee of AD Safety Evaluation,
Automated Driving Subcommittee
December 2022

SAKURA
Safety Assurance KUdos for Reliable Autonomous Vehicles

Our work

- In this paper, we have analyzed their relationship in terms of their underlying **safety principles** and **safety requirements**, and made the following contributions:

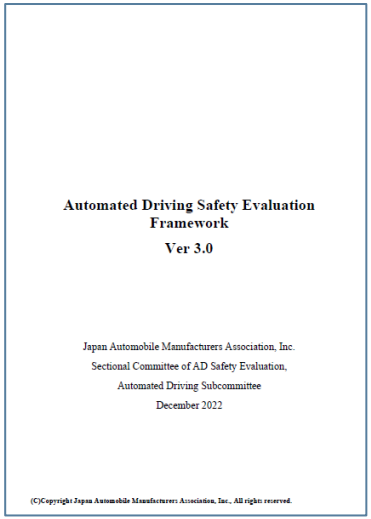
  - A comprehensive review/analysis of ADSEF and clarification of the difference between SOTIF and ADSEF.
  - Clarification of the extent to which ADSEF covers SOTIF under the relevant clauses.



ADSEF

- Automated Driving Safety Evaluation Framework Ver 3.0
- ADSEF is a scenario construction and evaluation methodology for ADS L3-L5 developed within the SAKURA project.
- Created by JAMA (Japan Automobile Manufacturers Association, Inc. Members are only Japanese OEMs)
- This is a **Japanese proposal** for ISO 34502:2022 Road vehicles — Test scenarios for automated driving systems — Scenario-based safety evaluation framework
- ADSEF is free, and anybody can download it from the JAMA website:

  https://www.jama.or.jp/english/reports/framework.html



jama
Japan Automobile Manufacturers Association

SAKURA
Safety Assurance KUdos for Reliable Autonomous Vehicles

SAKURA project (Safety Assurance KUdos for Reliable Autonomous Vehicles)

- SAKURA website https://www.sakura-prj.go.jp/

SAKURA RESEARCH PROJECT

SAKURA
Safety Assurance KUdos for Reliable Autonomous Vehicles

The SAKURA project (Safety Assurance KUdos for Reliable Autonomous vehicles) is one of the coordinated initiatives funded by the Ministry of Economy, Trade and Industry (METI) of Japan, under the strategies defined by the Committee on Business Discussions on Autonomous Driving Technologies. This committee was established in February 2015 and oversees All-Japan initiatives by industry, academia and government sectors, including a Roadmap for Deployment of Autonomous Driving Services, demonstration tests and efforts for harmonization areas.

The first phase of the SAKURA project occurred from mid-2018 until the end of March 2021, whereas the second phase commenced in April 2021 and shall continue for four years. The con-tents included in this homepage relate to the results of the first phase of the SAKURA project. The second phase of the SAKURA project will take into consideration the outcomes and results from this homepage.

Data Flow by SAKURA RESEARCH PROJECT

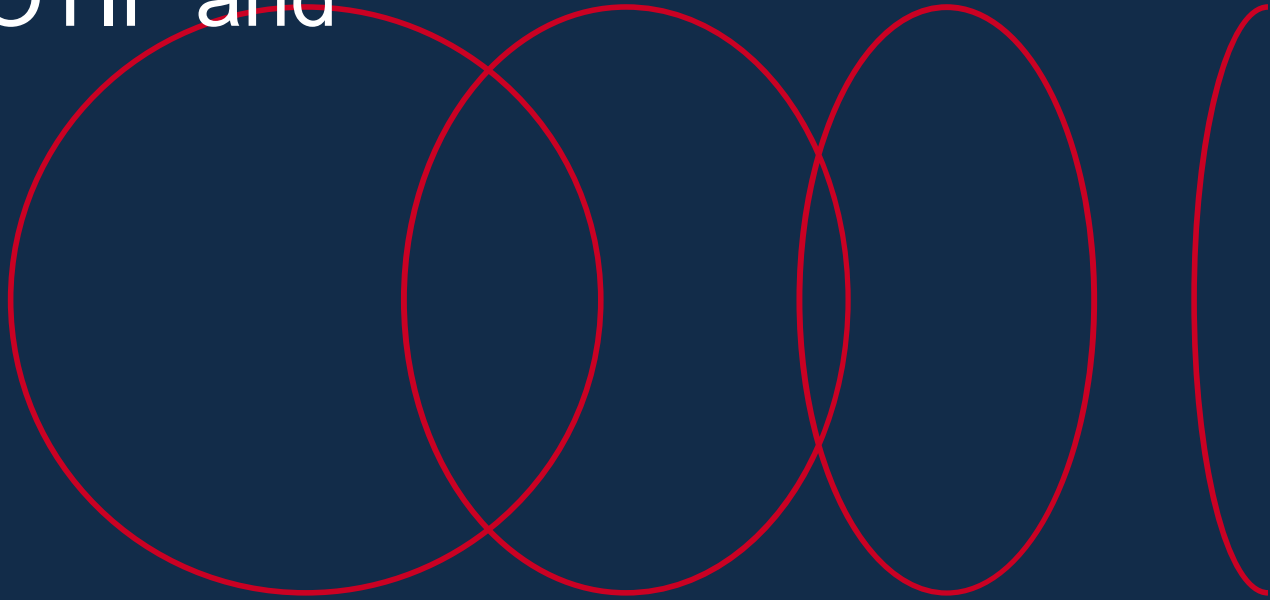
Traffic Data Acquisition and Analysis

Scenario Analysis

Scenario Database

ADSEF relates to all these activities; however, Ver 3.0 is mainly focus on the Scenario Analysis part.

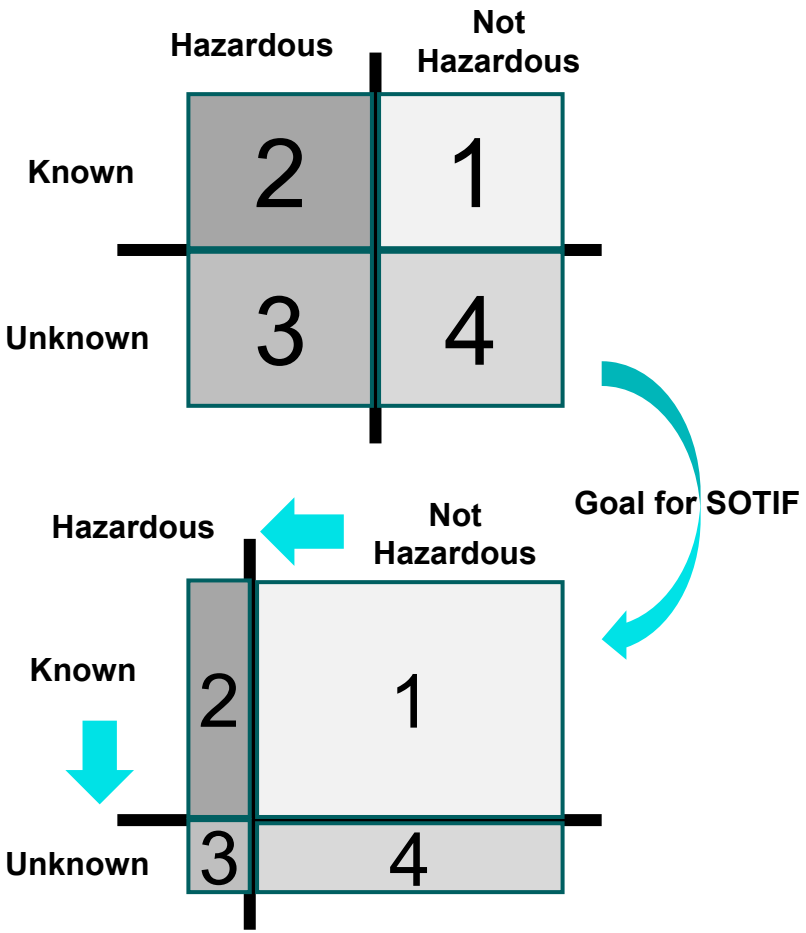
Overview of SOTIF and ADSEF



SOTIF scenario classification

- SOTIF scenarios are classified into four different areas.
  - Area 1: known but hazardous scenarios,
  - Area 2: known hazardous scenarios,
  - Area 3: unknown hazardous scenarios,
  - Area 4: unknown not hazardous scenarios.

- The ultimate goal of SOTIF activities is to reduce the risk resulting from hazardous (areas 2 and 3) or unknown scenarios (areas 3 and 4) through extensive analysis and testing.

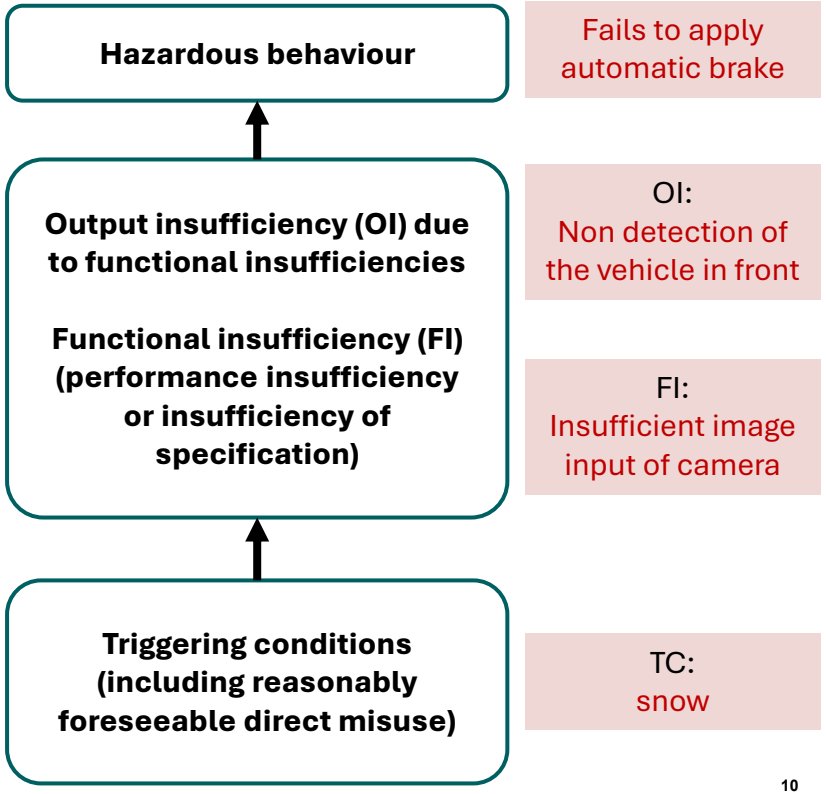


ISO 21448 – Safety of the Intended Functionality (SOTIF)

SOTIF considers a hazard caused by Functional Insufficiencies (FIs), not by malfunctions i.e.:

- The insufficiencies of specification of the intended functionality at the vehicle level.
- The insufficiencies of specification or performance insufficiencies in the implementation of electric and/or electronic (E/E) elements in the system.

In the SOTIF-related hazardous event model, the Triggering Condition (TC) of a scenario activates an FI, resulting in a subsequent system reaction referred to as an Output Insufficiency (OI).



ADSEF Safety Principles

- WP29-177-19 “Framework document on automated/autonomous vehicles”‘s Safety Vision: https://unece.org/DAM/trans/doc/2019/wp29/WP29-177-19e.pdf

> **4. Safety Vision**
>
> The level of safety to be ensured by automated vehicles is defined as “an automated vehicles shall not cause any non-tolerable risk”, meaning that automated vehicle systems, under their operational domain (OD), shall not cause any traffic accidents resulting in injury or death that are reasonably foreseeable and preventable. Based on this principle, this framework sets out a series of vehicle safety topics to be taken into account to ensure their safety.

- From this WP29-177-19 Vision, the ADSEF proposes ADSEF Safety Principles using four classified areas.
  - Area A: Foreseeable Preventable scenarios
  - Area B: Foreseeable Unpreventable scenarios
  - Area C: Unforeseeable Preventable scenarios
  - Area D: Unforeseeable Unpreventable scenarios

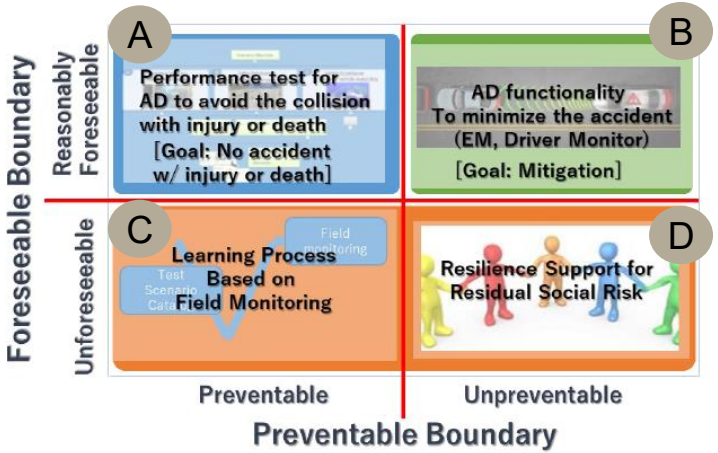
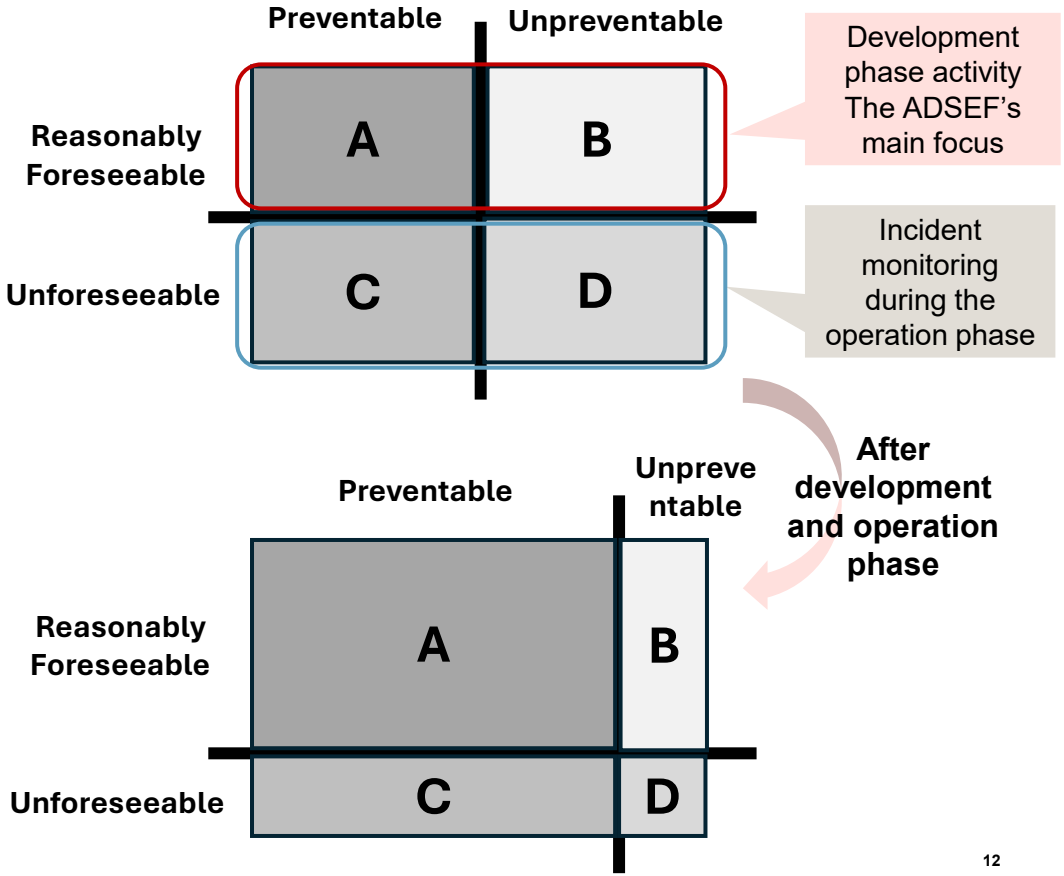


Figure 3. Safety approach in context with foreseeability and preventability matrix

ADSEF Safety Principles

- ADSEF also has a similar concept to evolve the four quadrants throughout the development and operation phase.
- To reduce Unforeseeable areas, ADSEF only explains that this is achieved through incident monitoring during the operation phase activity.
- However, the current ADSEF does not mention concrete analysis and V&V methods for development and operation phase activities to reduce Unforeseeable areas.



ADSEF Physics Principles Approach

The ADSEF Physics Principles Approach decomposes DDT into three subtasks (Perception, Judgment, and Operation), which are associated with relevant disturbance factors and the underlying physics principles shown in the Table below. ADSEF constructs the scenario structure by combining these disturbance factors.

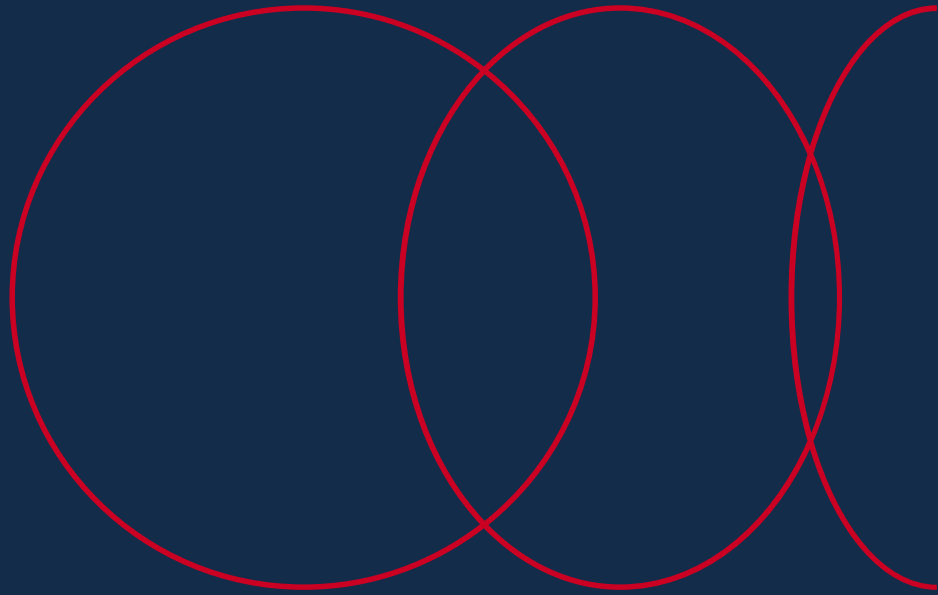
This Table is extracted from ADSEF Figure 1.

Task	Processing results	Disturbance	Governing physics principles
Perception	Own position, surrounding traffic environment positional information and other traffic information	Perception disturbance	Light, radio wave, infrared light propagation principles that affect camera, mili-wave radar and LiDAR sensors, respectively
Judgement	Path, speed plan instructions	Traffic disturbance	Kinematics describing the motion of traffic participants, objects and systems of groups of objects, without reference to the causes of motion
Operation	Movement instruction allocation for each ACT for achieving path and speed plan instructions	Vehicle control disturbance(*)	Dynamics, concerned with forces applied on the vehicle's body and tires, and their effects on motion.

(*): ADSEF text used Vehicle motion or movement disturbance. This wording does not match the ADSEF table and text.

Comparison Results

1. Safety Principle level
   1.1 Hazardous Event Model
   1.2 Four Quadrants
   1.3 Task Models



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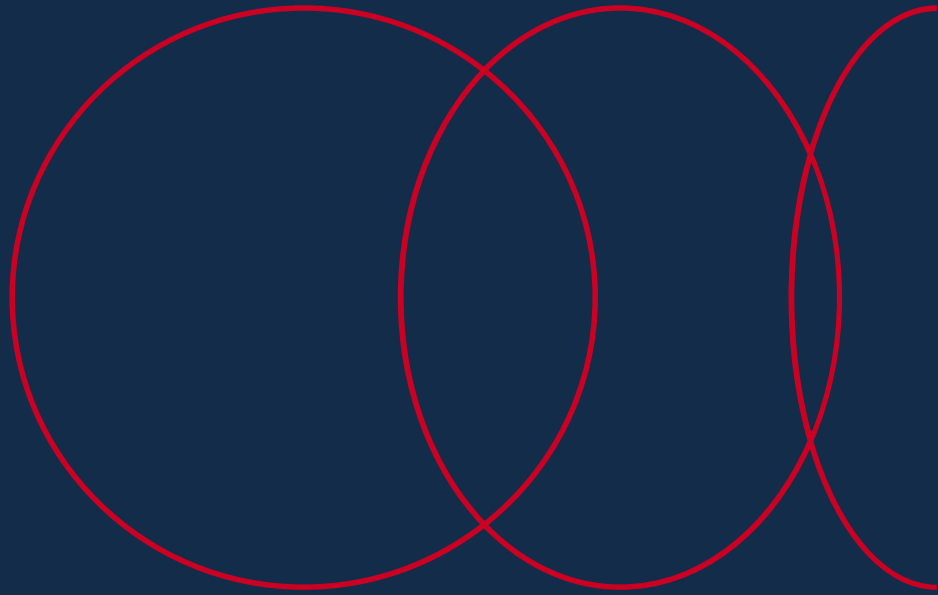
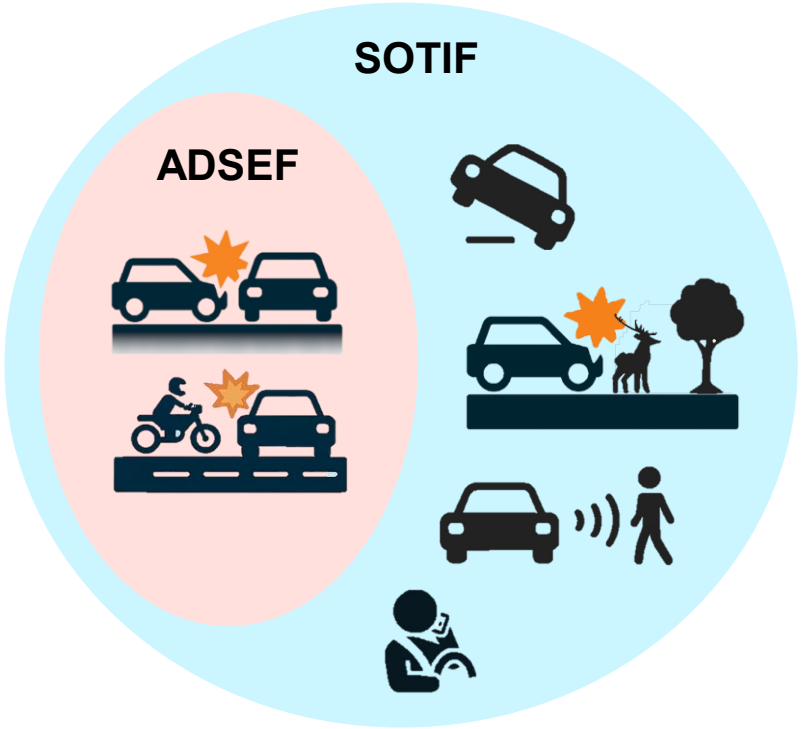


Hazardous Event Model – Coverage of accident scenarios



- ADSEF V3.0 currently focuses on scenarios in which collisions with surrounding vehicles or motorcycles.
- SOTIF takes a broader perspective and includes any scenario that could cause harm to the ADS.
- SOTIF includes accidents involving:
  - only the ego-vehicle (e.g., rollover),
  - collisions with animals or other non-vehicle entities
  - collisions with static objects,
  - misuse scenarios where human interaction leads to unintended ADS behavior.

Comparison Results

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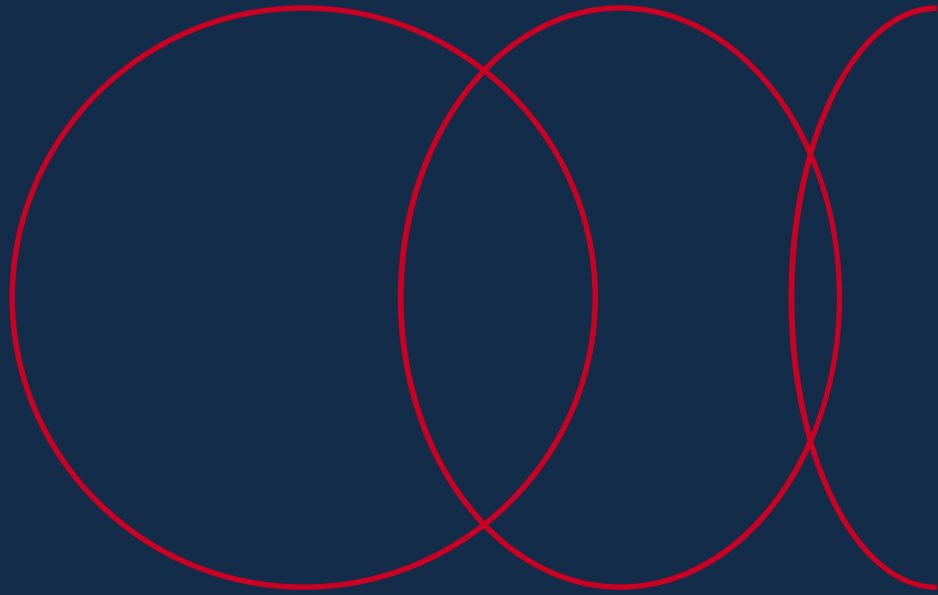
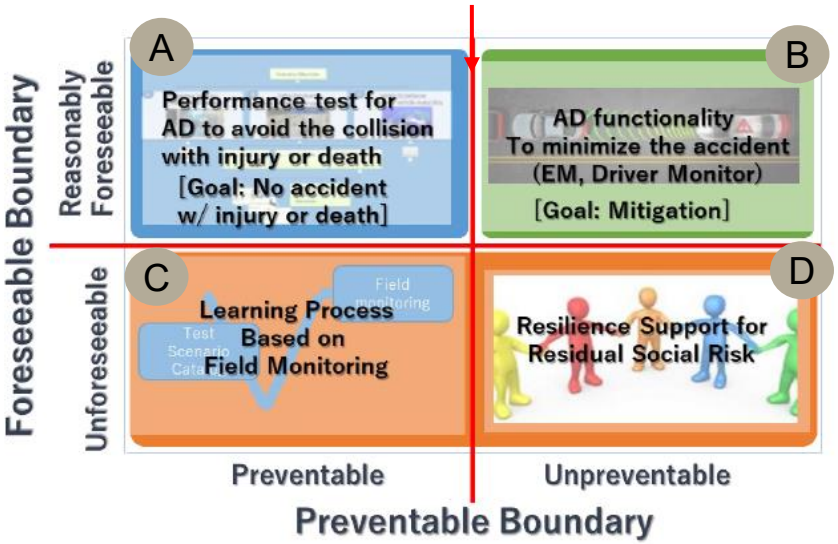


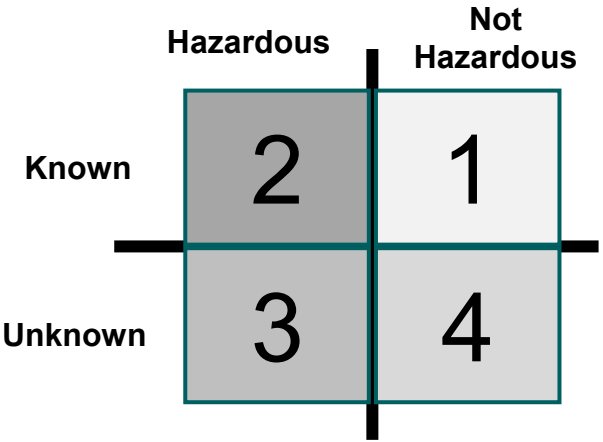
Four Quadrants

To align ADSEF with SOTIF, it is important to understand the relationship between each of the four quadrants.



ADSEF Four Quadrants

Relation?



SOTIF Four Quadrants

Four Quadrants relation between ADSEF and SOTIF

- The timing after all evaluations are completed, the relation between SOTIF and ADSEF four quadrants is as shown in this figure.
  - 1. Critical scenario/Not critical scenario: If there is any possibility that a potential accident could occur, the scenario is considered a Critical Scenario.
  - 2. Preventable/Unpreventable: If C&C driver's performance model could avoid the accidents.
  - 3. Failed evaluation/Passed evaluation: The result of ADS evaluation of acceptability.

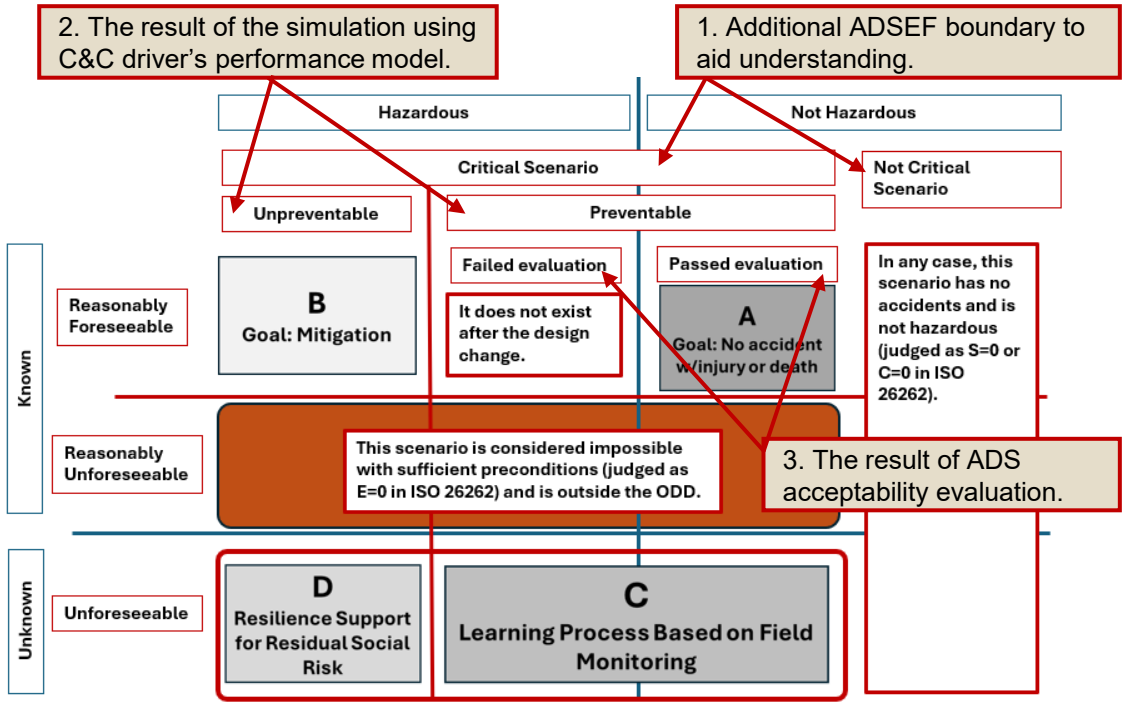


Figure. Combined Quadrants Principle

Blue lines: SOTIF boundaries
Red lines: ADSEF boundaries

Four Quadrants relation between ADSEF and SOTIF

Our analysis result is as follows:

- **Known/Unknown (SOTIF)**
  - Known = Reasonably Foreseeable + Reasonably Unforeseeable.
  - Unknown = Unforeseeable.
- **Hazardous/Not Hazardous(SOTIF)**
  - Hazardous = Unpreventable + Critical Scenario could not pass the evaluation (*this scenario shall not exist after design modification)
  - Not Hazardous = Preventable + Not Critical Scenario

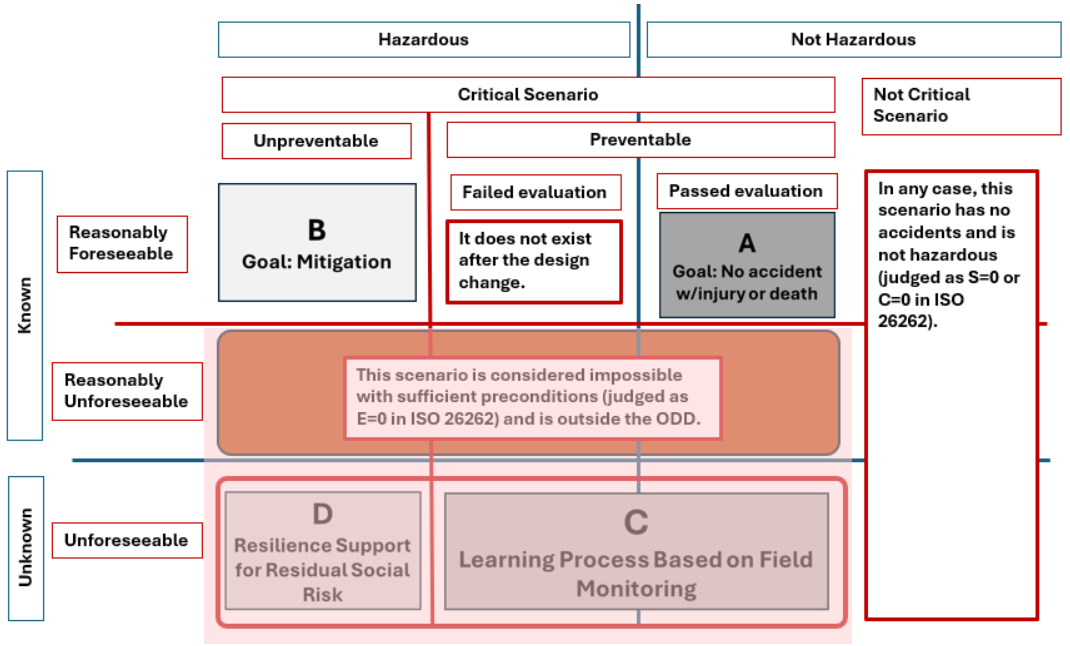


Figure. Combined Quadrants Principle

ADSEF does not provide a clear method to reduce these scenarios. Therefore, ADSEF is required to combine other methodologies to meet SOTIF requirements.

Blue lines: SOTIF boundaries
Red lines: ADSEF boundaries

Comparison Results

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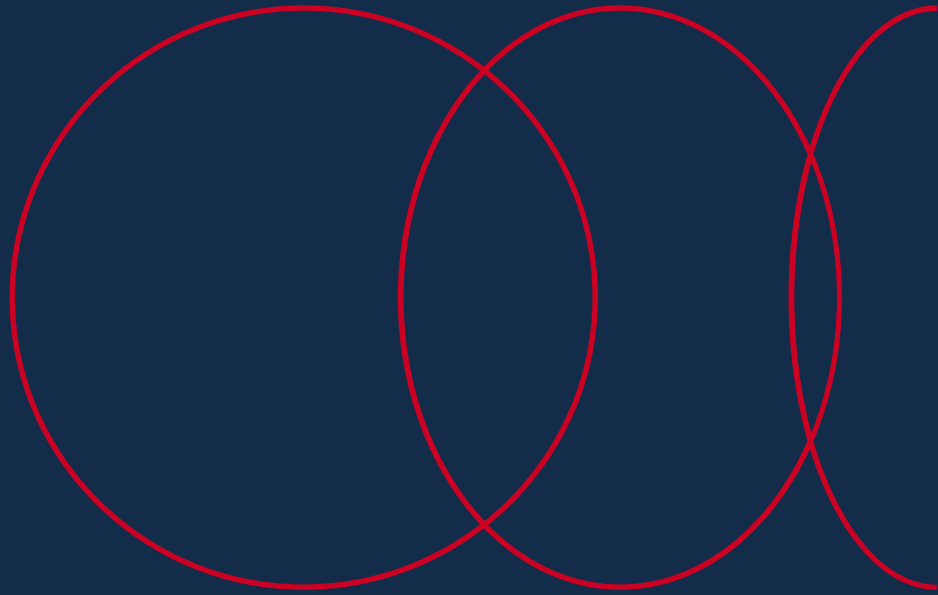
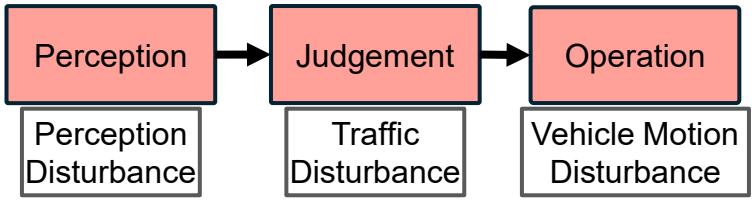


Task Models

We analyzed how much ADSEF's Disturbance analysis using Perception-Judgement-Operation Model could cover TC/FI/OI analysis using Sense-Plan-Act Model in SOTIF.

ADSEF

Perception-Judgement-Operation Model

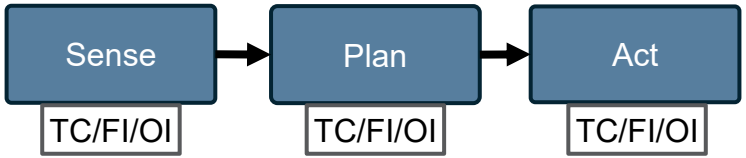


Relation?

SOTIF

Sense-Plan-Act Model

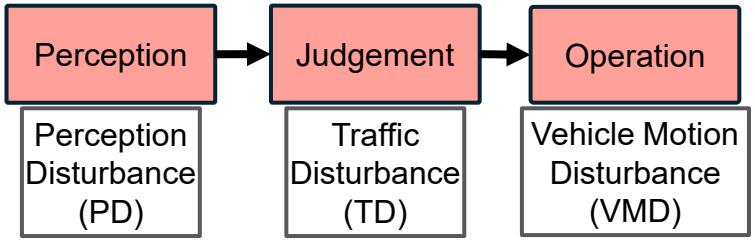
The key system elements and their interactions.



Analysis Results

ADSEF

Perception-Judgement-Operation Model



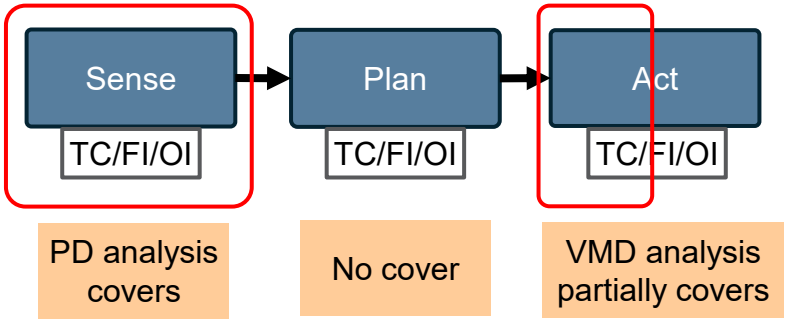
C&C Driver Model

*Perception-Judgement-Operation model is used for the C&C Driver Model as well.

SOTIF

Sense-Plan-Act Model

The key system elements and their interactions.

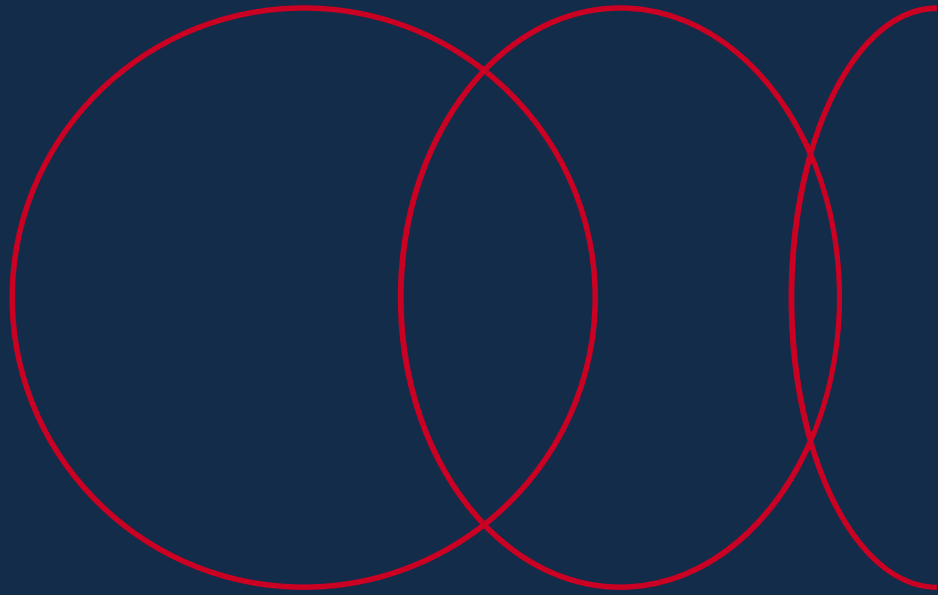


Human Misuse Process (Annex B)

In this case, both models applied to the human driver and matched the definition

Comparison Results

2. Relationship to SOTIF clauses



ADSEF - SOTIF - ISO 34502

- ISO 34502 uses a part of the concept and methodology from ADSEF.
- ISO 34502 - 4.1.3 requires that the document shall be applied in combination with ISO 21448.
- Since there is no specific explanation of how ADSEF can be used in combination with ISO 21448, an analysis was conducted to demonstrate the relationship between ADSEF and SOTIF clearly.

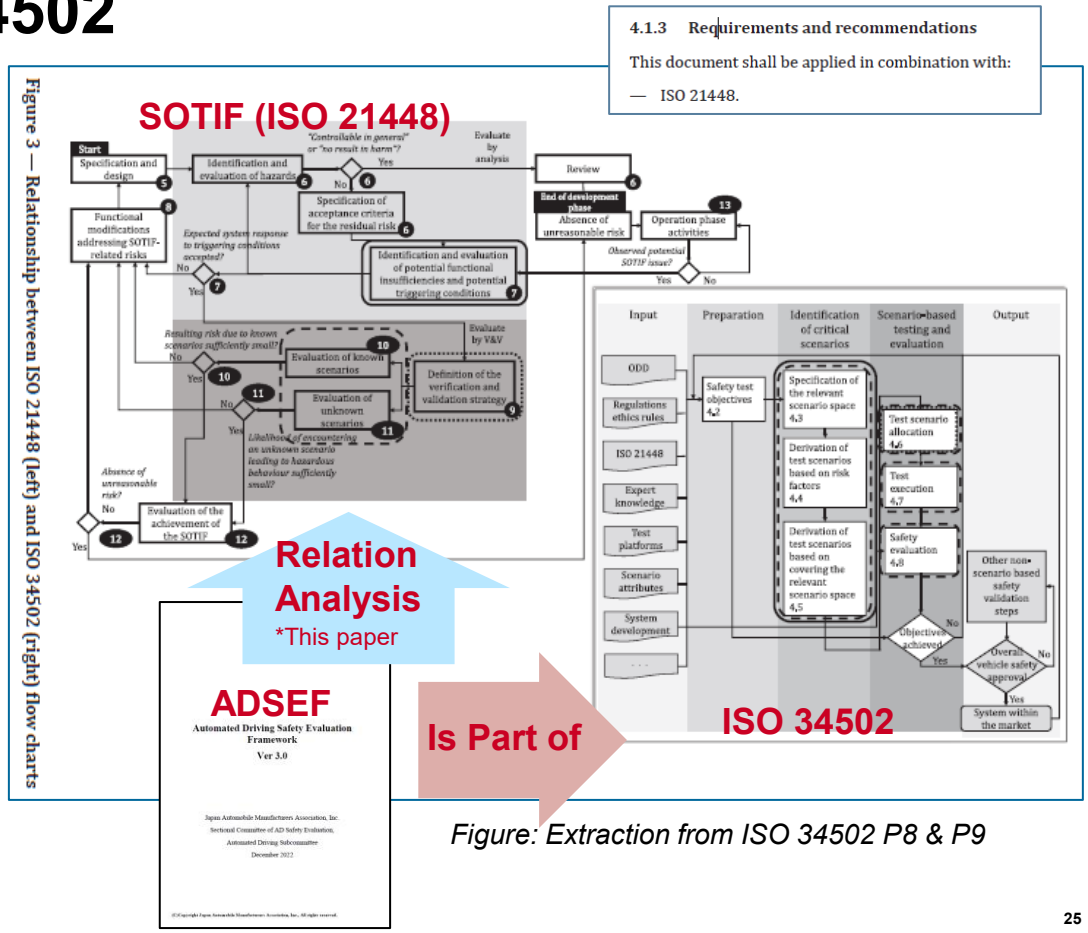
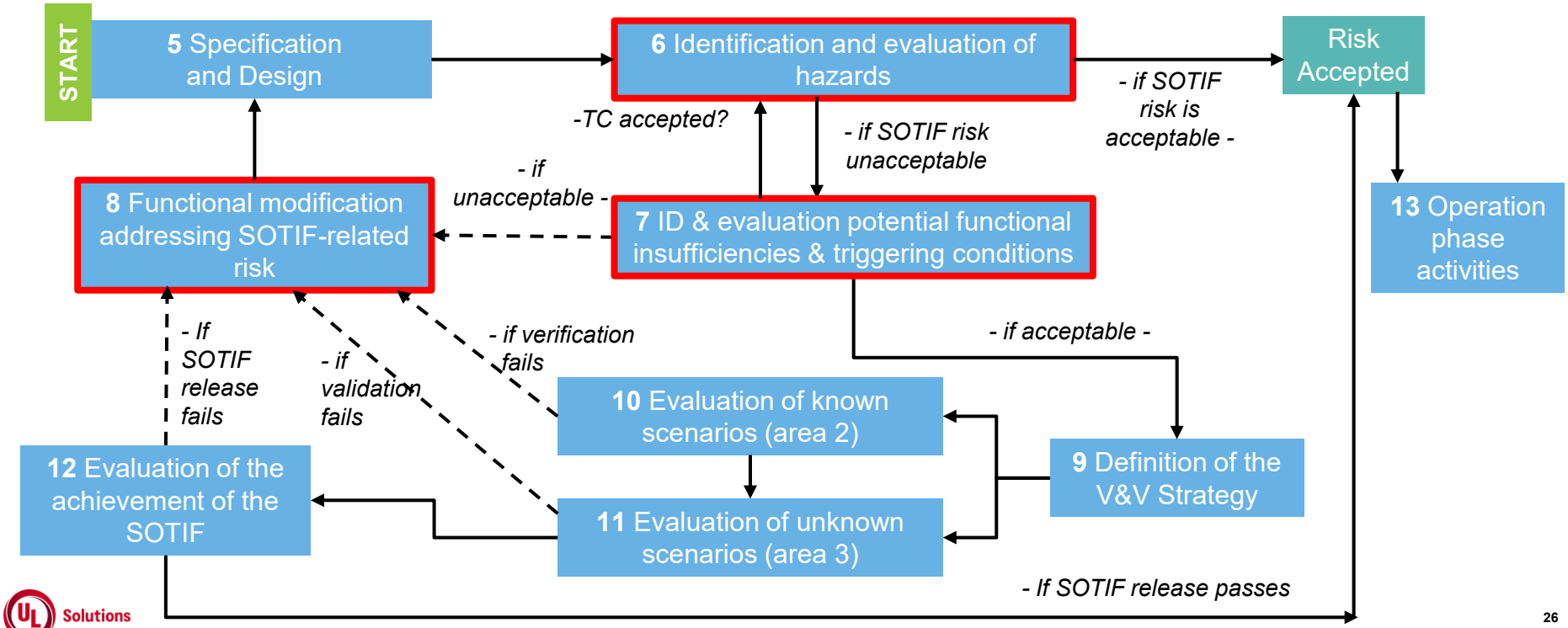


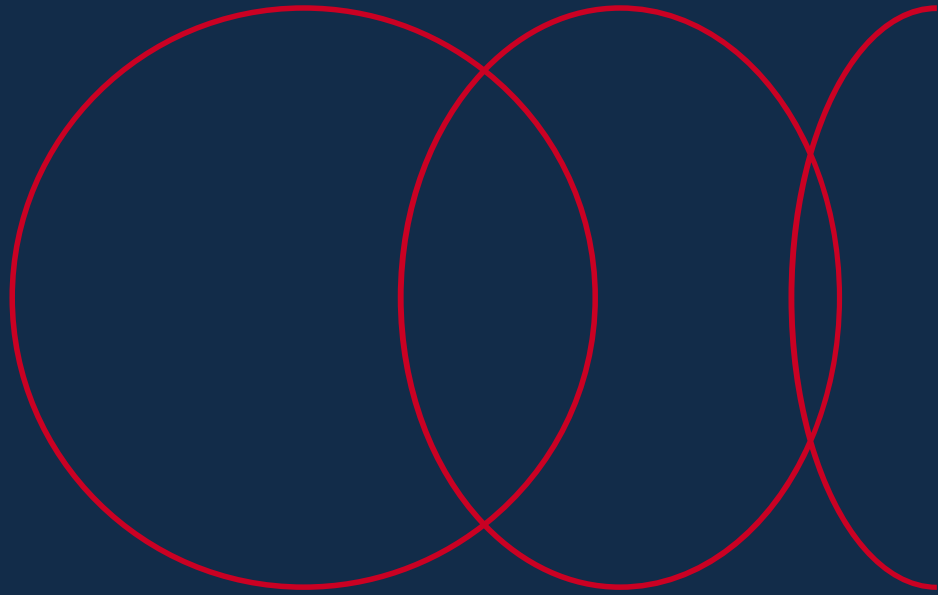
Figure: Extraction from ISO 34502 P8 & P9

Relation Analysis Results

ADSEF can contribute to a part of Clauses 6, 7, and 8. ADSEF does not have address V&V-related methods to meet SOTIF. ADSEF is required to combine other methodologies to meet the whole SOTIF requirement.



Conclusion



ADSEF critical gaps to meet SOTIF

The following critical gaps were found through our analysis.

✖ : These gaps may not be feasible to improve due to the nature of Physics Principles Approach

Gap No	Critical Gap Description
1 ✖	**Misuse** scenarios **are out of scope.**
2	Potential accident scenarios involving other than surrounding vehicles or motorcycles are out of scope.
3 ✖	The current ADSEF does not mention analysis, V&V, and operation phase activities to reduce Unforeseeable areas. In case the system designers are missing any scenarios that are still in Unforeseeable but could be allocated to Reasonably Foreseeable, **only using the ADSEF method is not enough to analyze the issues with the specified behaviour of the vehicle.**

Gap No	Critical Gap Description
4 ✖	ADSEF's disturbance analysis using Perception-Judgement-Operation model can cover **a portion of TC/FI/OI analysis using SOTIF Sence-Plan-Act model but not everything.**
5	The scope of ADSEF's contribution to SOTIF clauses is limited; ADSEF can contribute to SOTIF Clause 6 for **defining AC using the C&C human driver model**, and to Clause 7 for the **limited part of TC/FI analysis using the Physics Principle Approach** and **evaluation of SOTIF Acceptability using simulation based on the defined AC**. Especially, the current ADSEF does not provide a clear method to define quantitative VTs and an evaluation method for arguing that AC is met for all scenarios comprehensively, and does not cover reducing the scenarios allocated to Unforeseeable. Therefore, this makes it difficult to understand how ADSEF could be applied to SOTIF clauses beyond Clause 9.

Future Work

- Developing more detailed SOTIF application guidelines for ADSEF based on the analysis results reported in this paper to make it easier for practitioners to apply ADSEF.

- The ADSEF development team is creating the next version 4.0 this year. We hope that our findings will offer valuable suggestions for the next version of ADSEF and provide insight for practitioners to apply ADSEF to SOTIF.

Acknowledgments: This work has been partially supported by the SAKURA project, which is funded by the Ministry of Economy, Trade and Industry (METI) of Japan, and we would like to thank the relevant parties involved in this project.

Thank you

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