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Murat Erdogan

Veoneer

Use-case study:

An AEB use-case approach for robustness and safety using AI and ML for autonomy

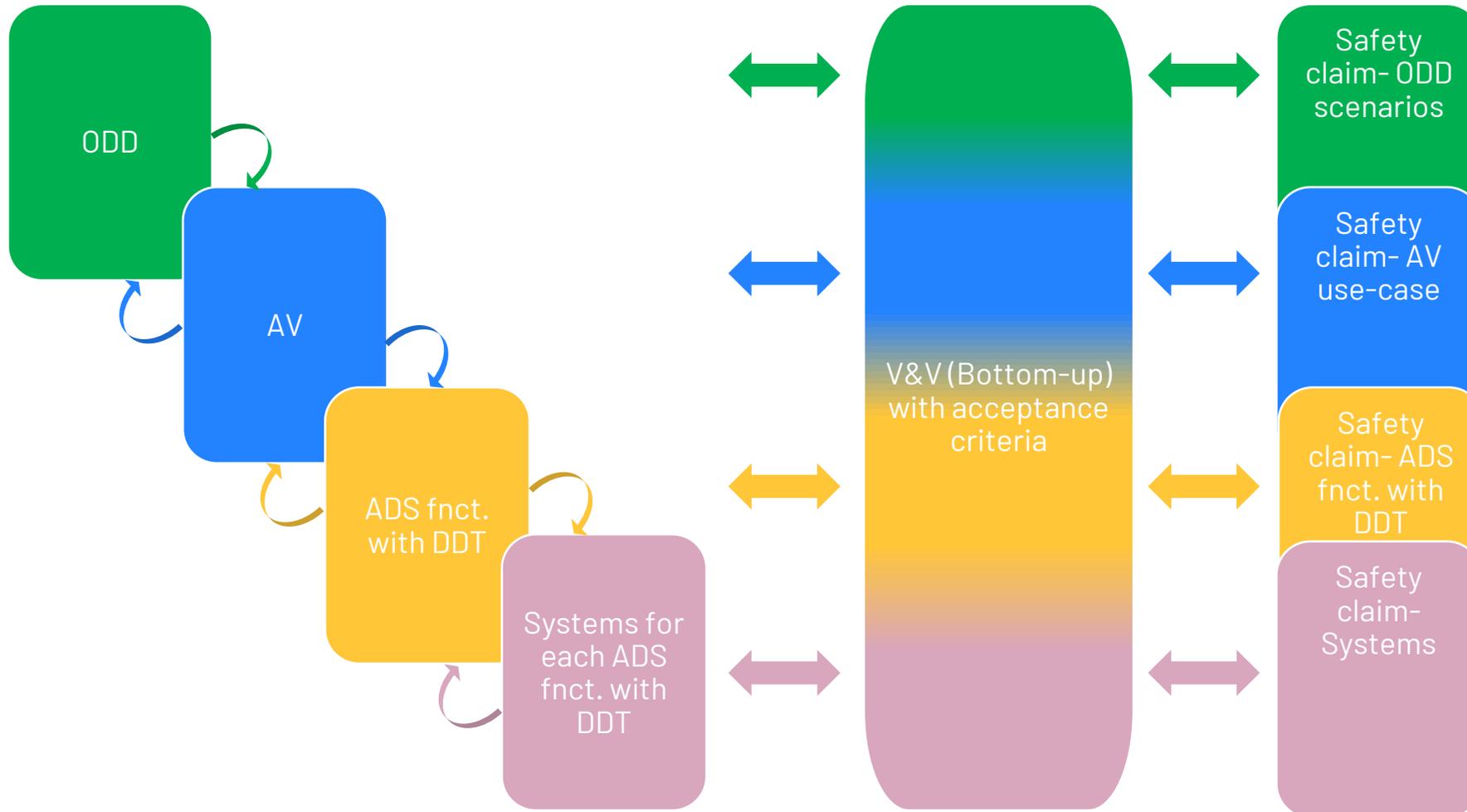
Intro...

- My Job at Veoneer in the domain of Safety, SOTIF and Cybersecurity
- My participation to Research Projects like ESPLANADE, VEDLIoT and SALIENCE4CAV
- My participation to Standardization work around ISO 26262, ISO/SAE 21434, ISO/PAS 21448, ISO TS 5083 and ISO PAS 8800
- Reading scientific Papers related to Safe ADS
- “a little” Personal opinion

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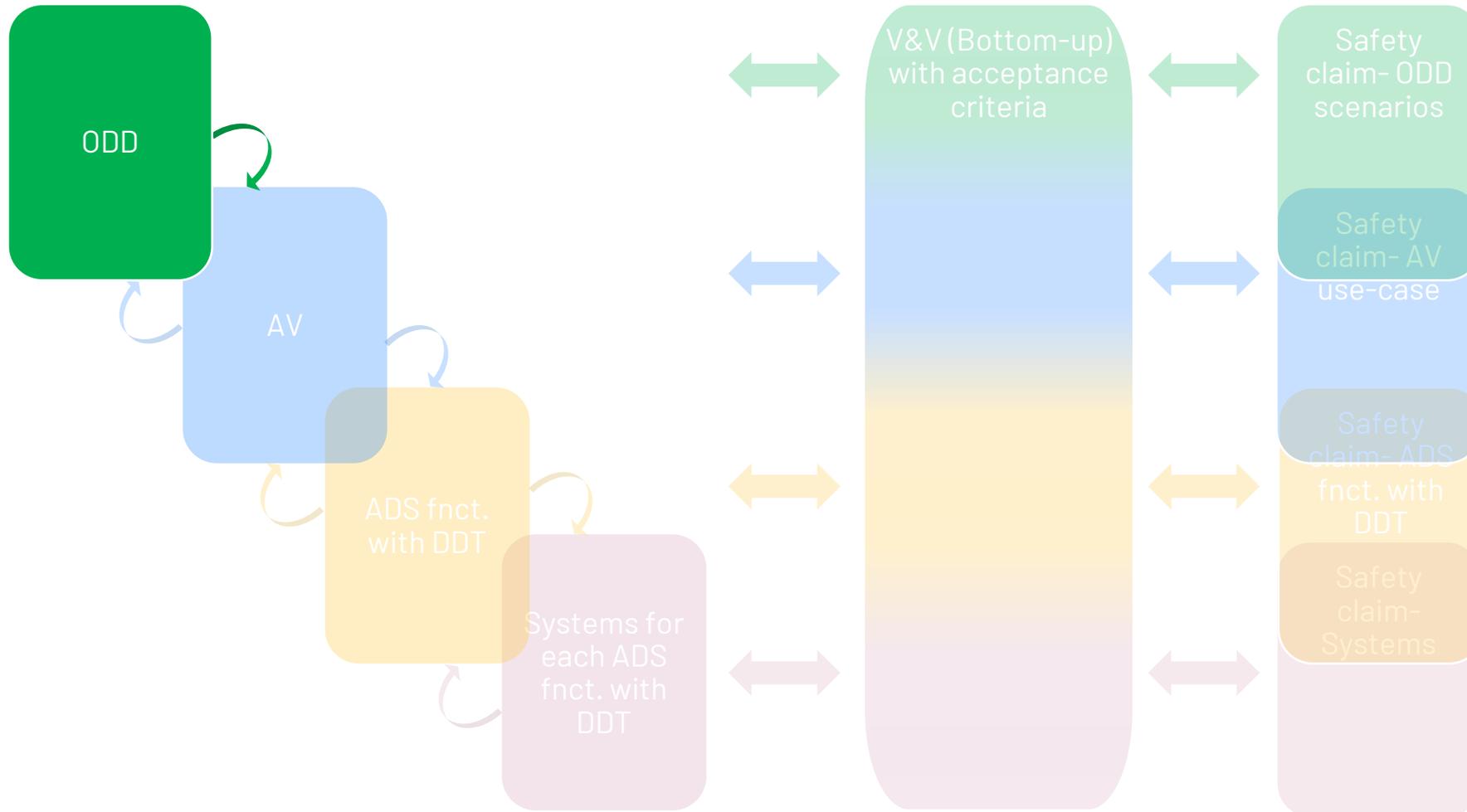
Process assumption

High-level process assumptions



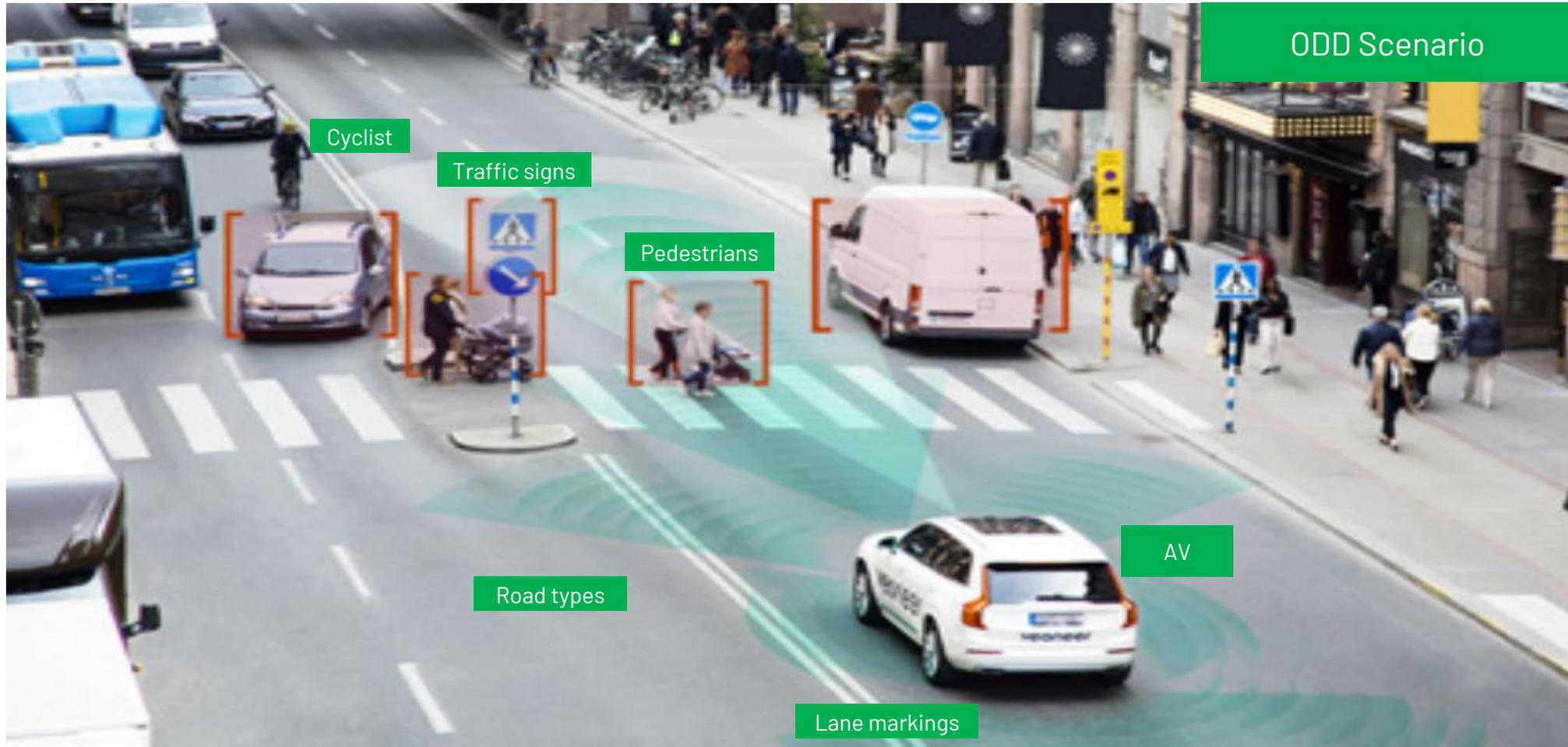
Ref.: [1], [2], [3]

ODD- Operational Design Domain



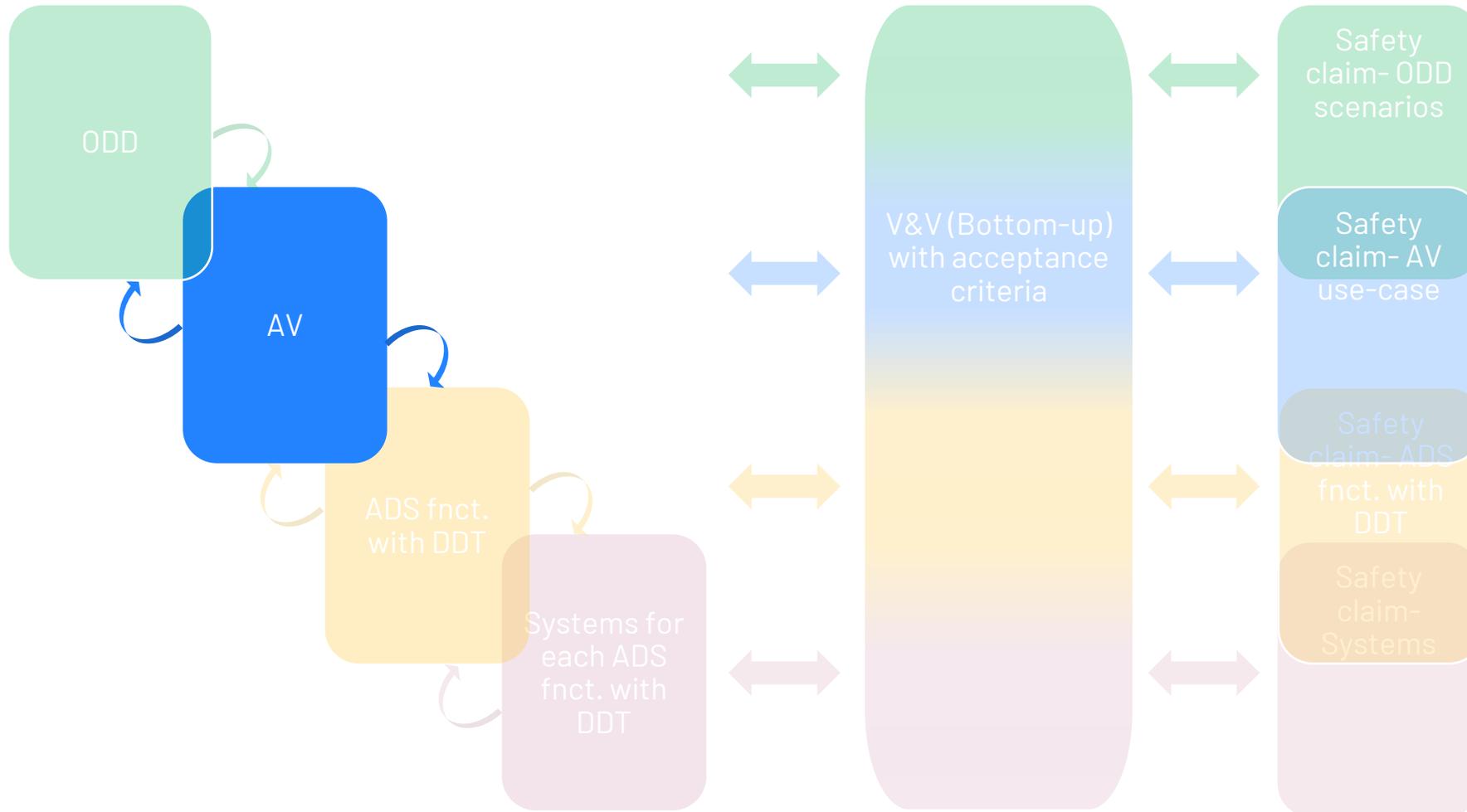
Ref.: [1], [2], [3]

ODD ex.: City, Highway, country road etc...



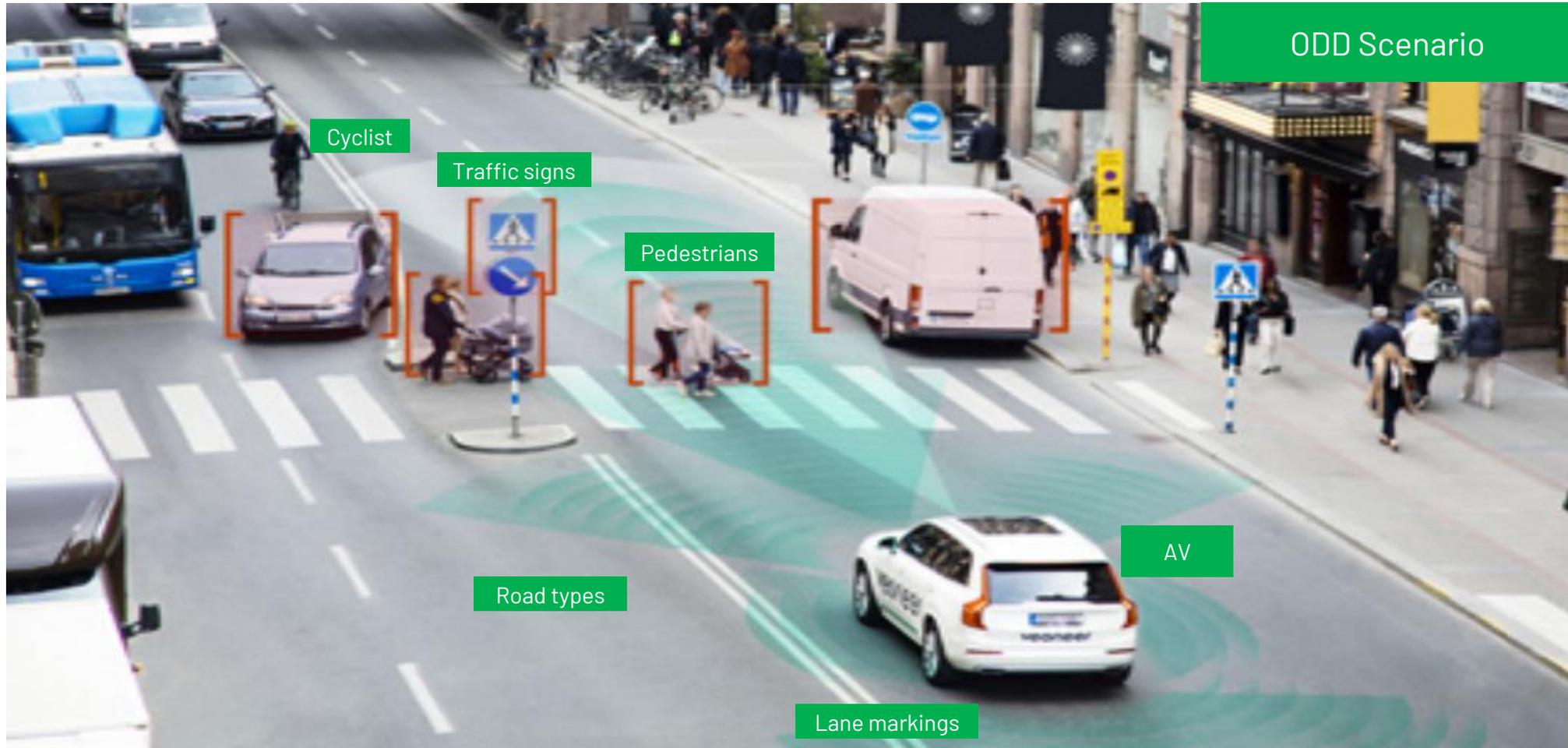
Define
Scenarios for
ODDs

High-level process assumption- AV



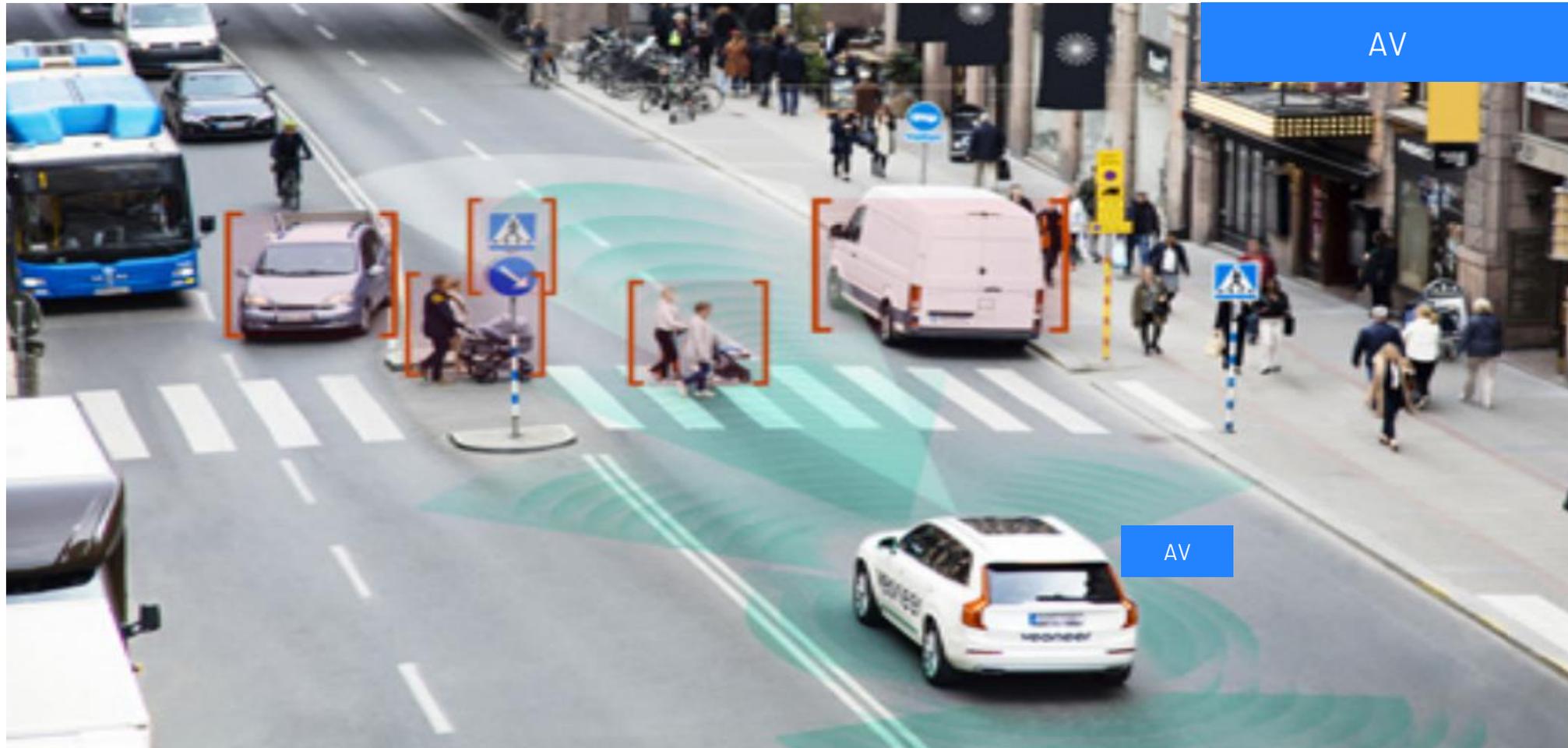
Ref.: [1], [2], [3]

ODD ex.: City, Highway, country road etc...



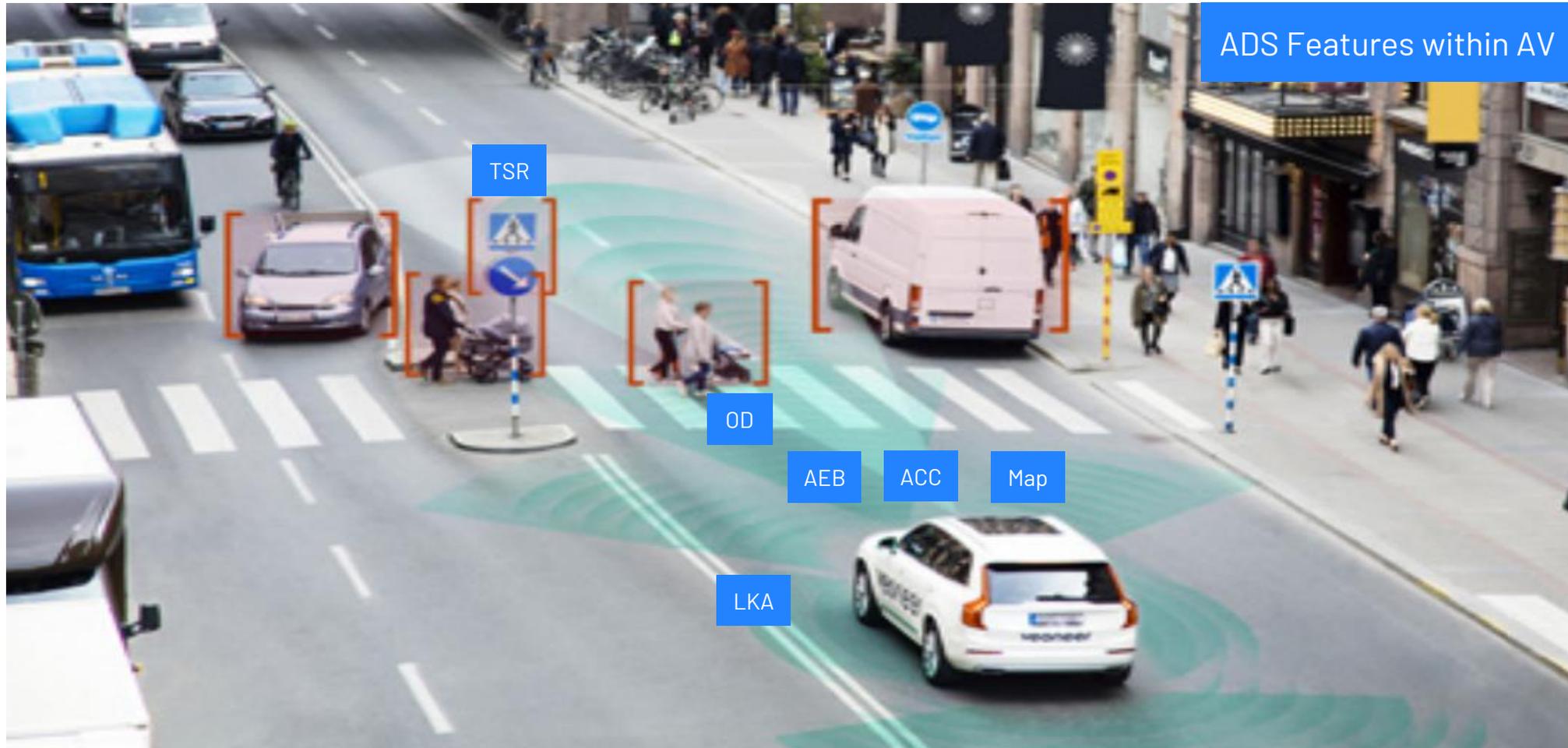
Define
Scenarios for
ODDs

AV- Autonomous Vehicle



Define
Scenarios for
ODDs

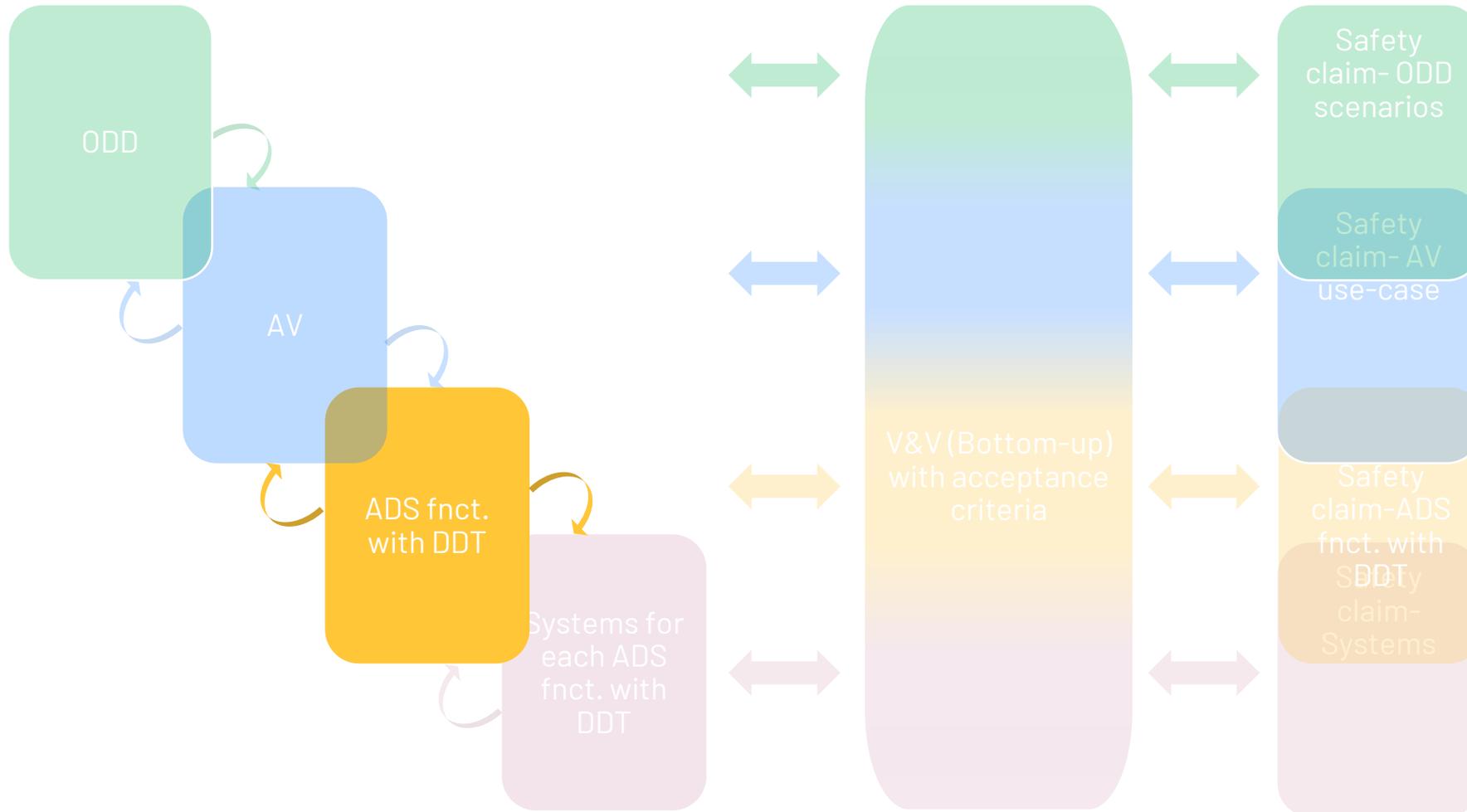
ADS Features within AV: e.g. AEB, ACC, LKA, TSR etc..



Define Scenarios for ODDs

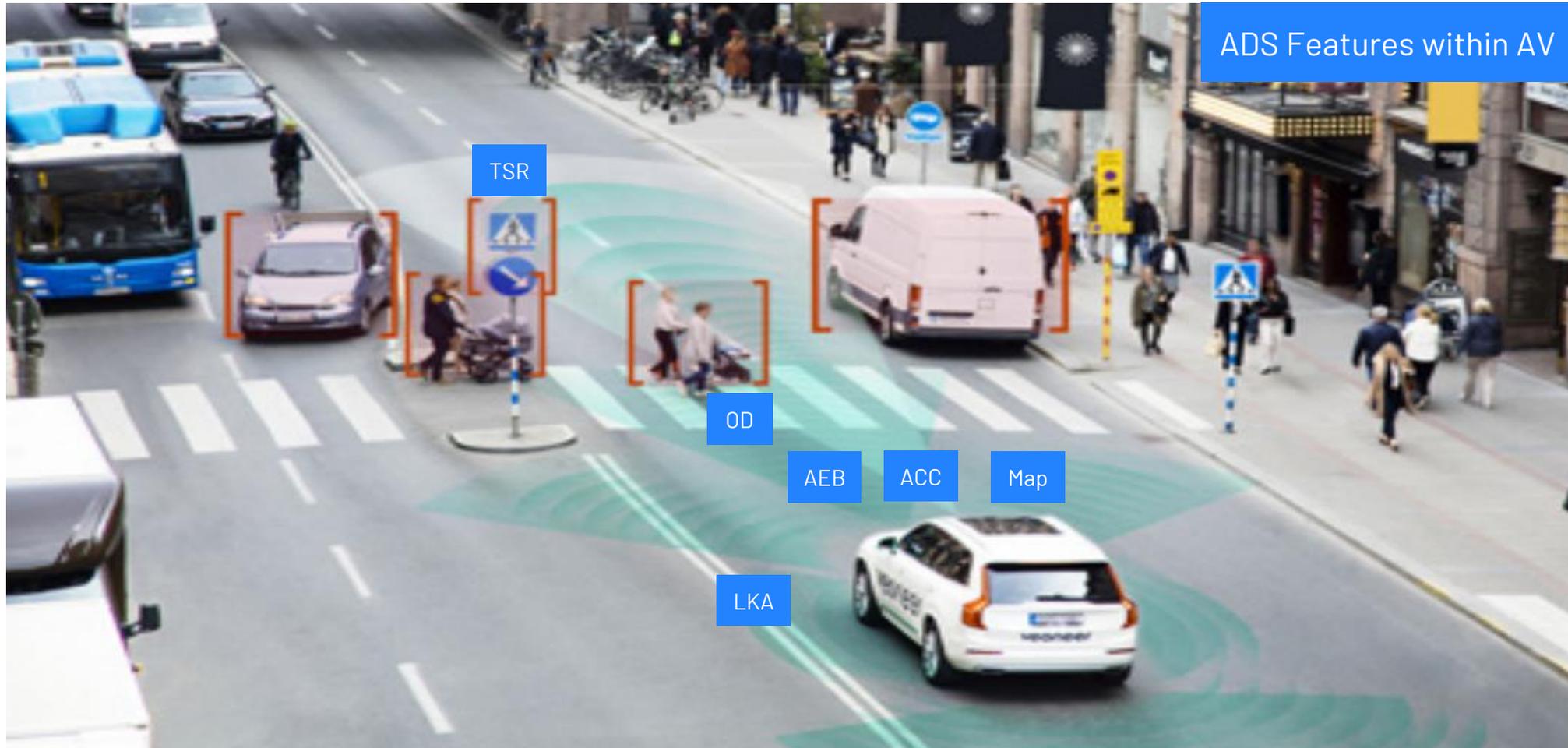
Define ADS Features within AV

High-level process assumptions- ADS fnct. with DDT



Ref.: [1], [2], [3]

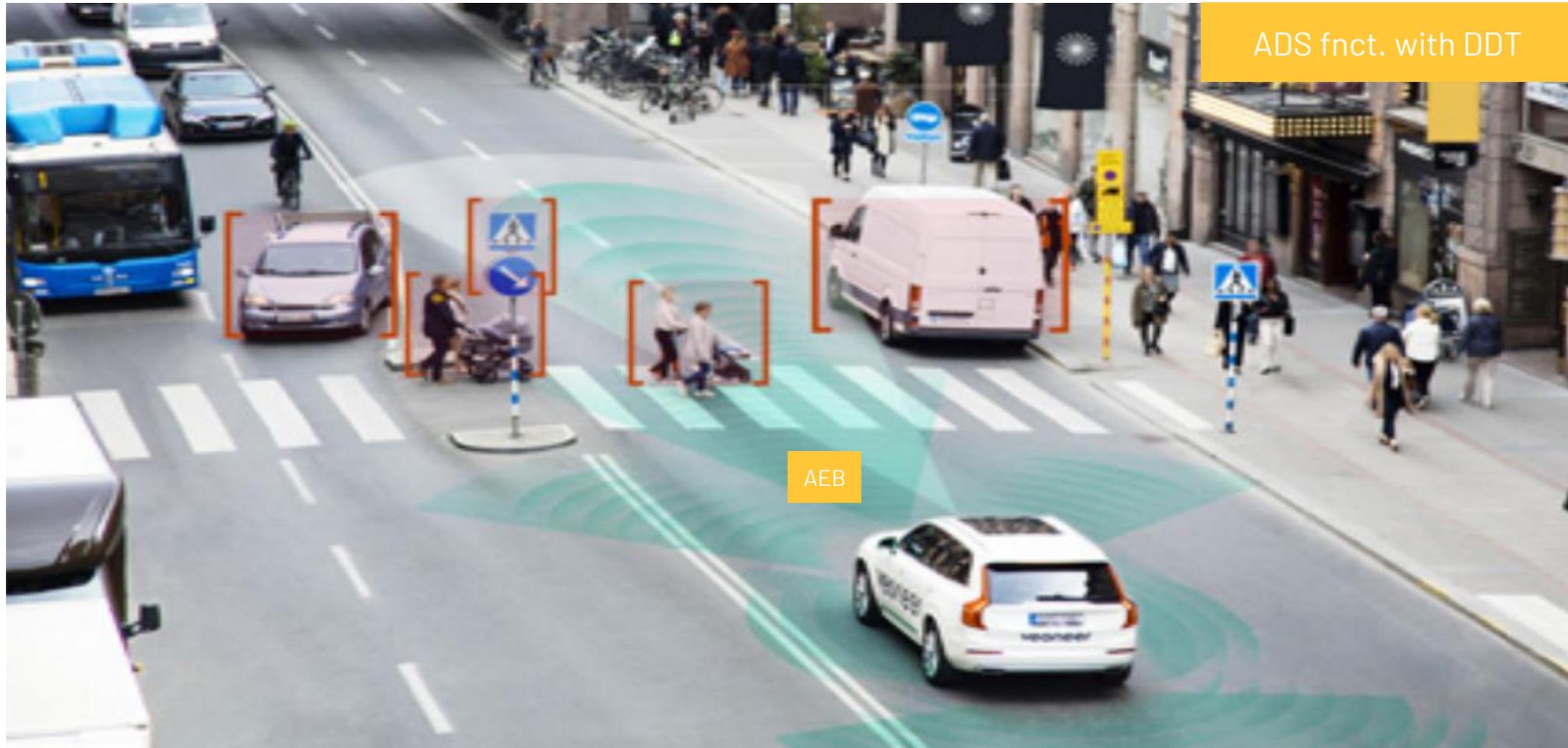
AV with ADS Features: e.g. AEB, ACC, LKA, TSR etc..



Define Scenarios for ODDs

Define ADS Features within AV

Safe ADS with DDT: e.g. AEB- Car-to-Pedestrian (CP)

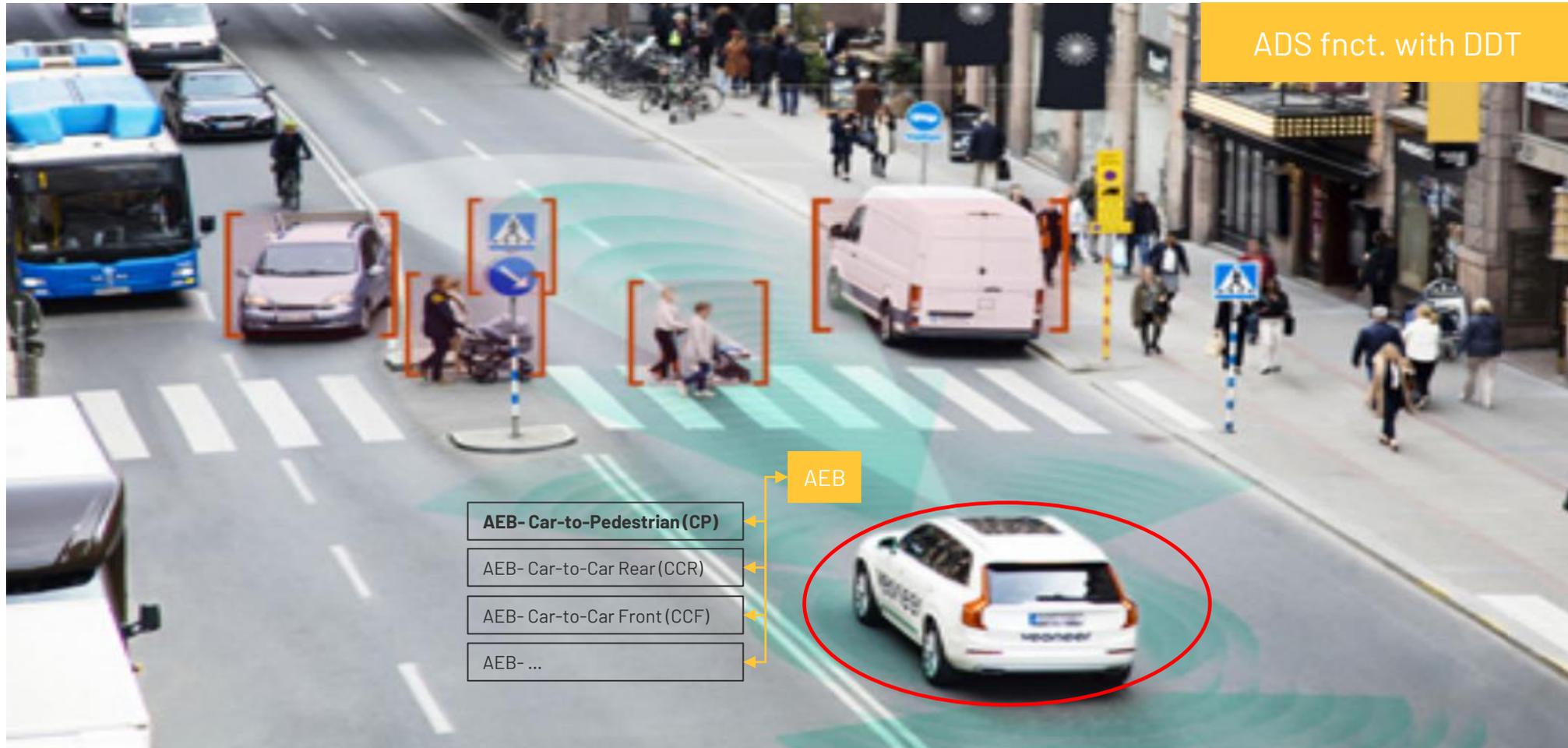


Define
Scenarios for
ODDs

Define ADS
Features
within AV

Define ADS
fnct. with
DDT

Safe ADS with DDT: e.g. AEB- Car-to-Pedestrian (CP)

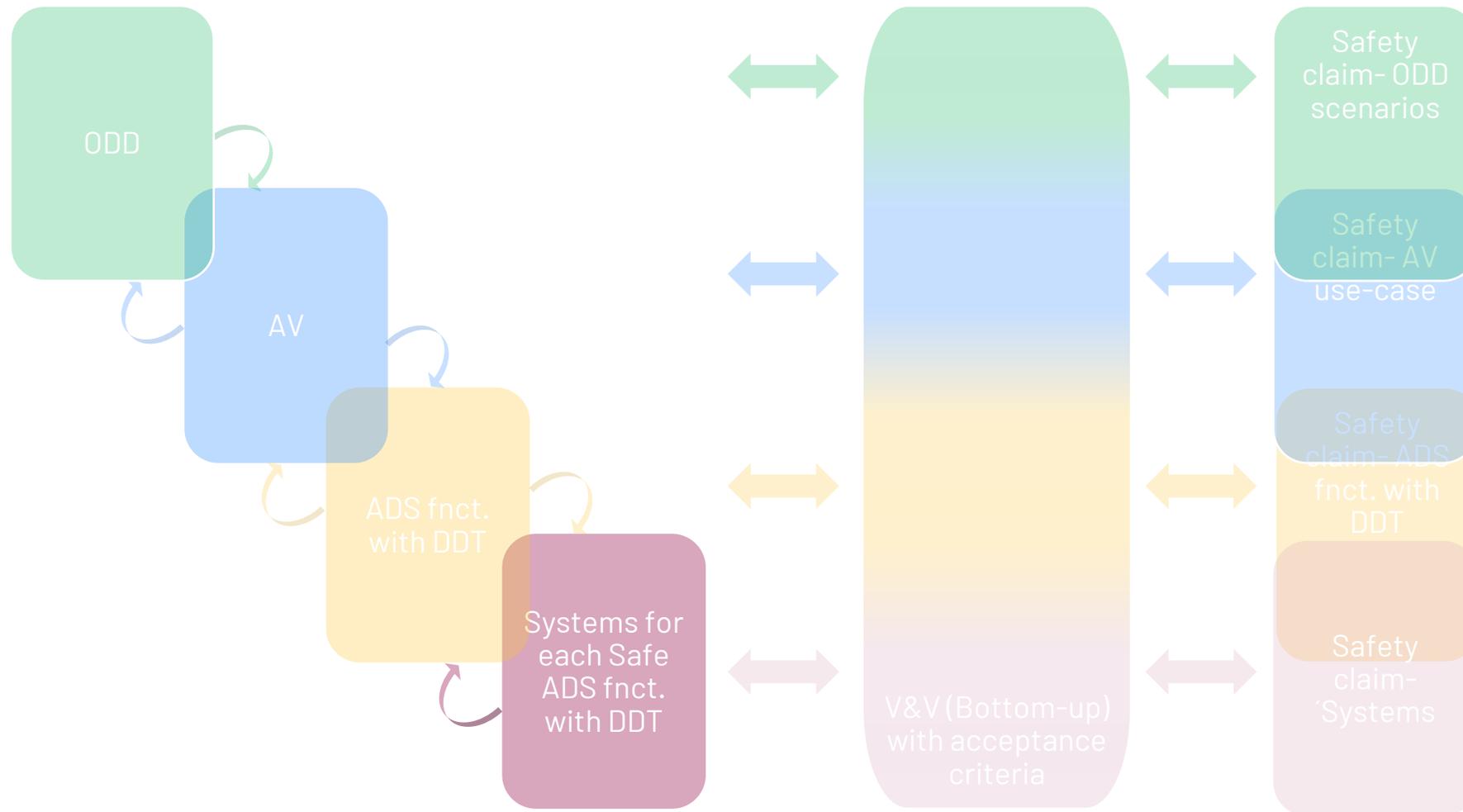


Define Scenarios for ODDs

Define ADS Features within AV

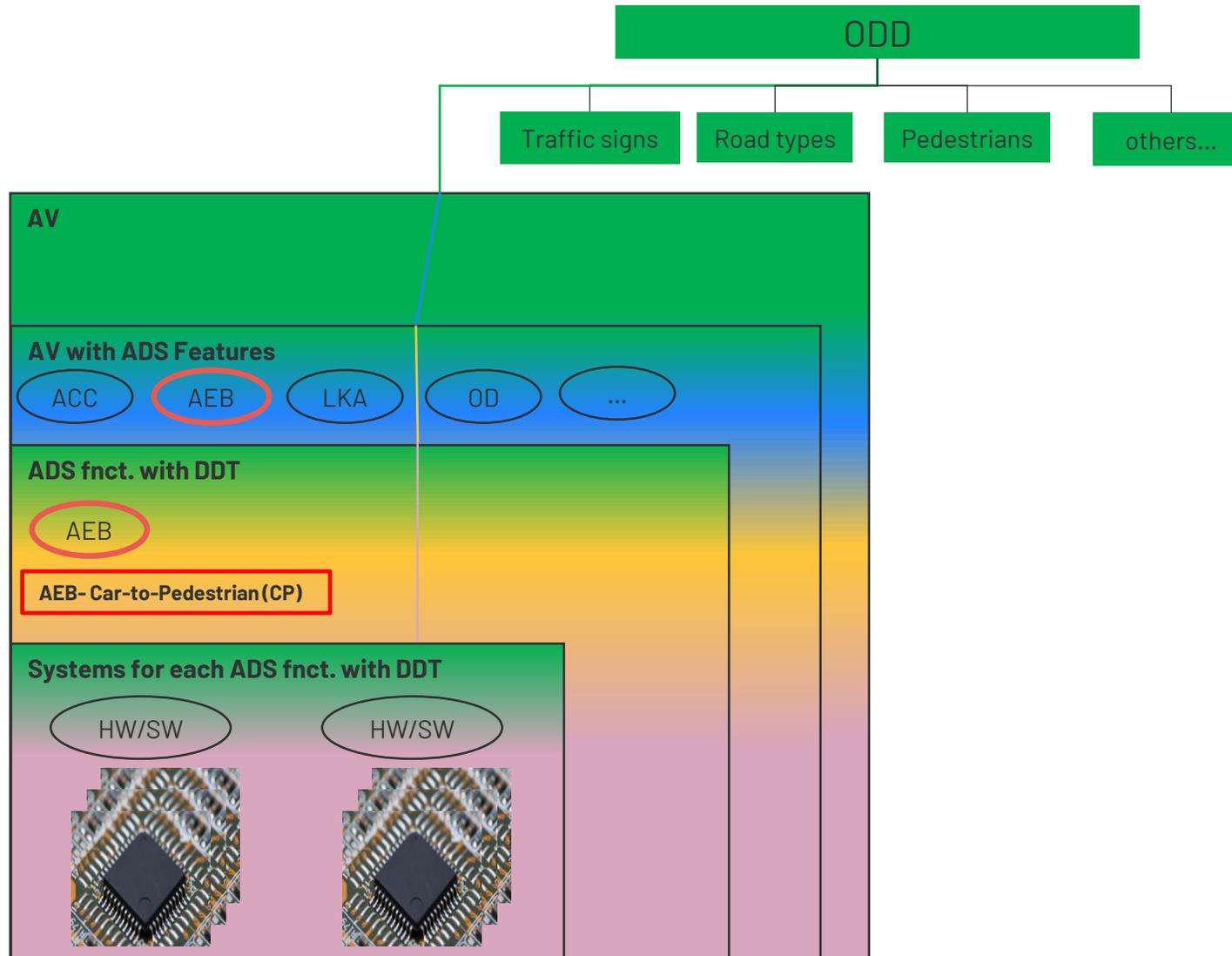
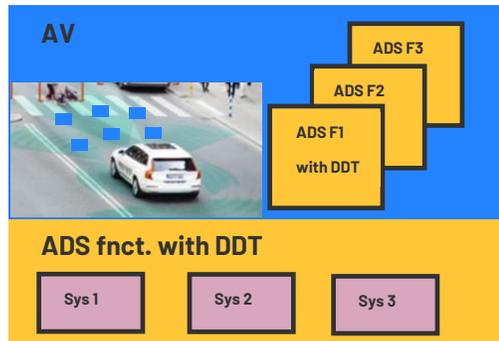
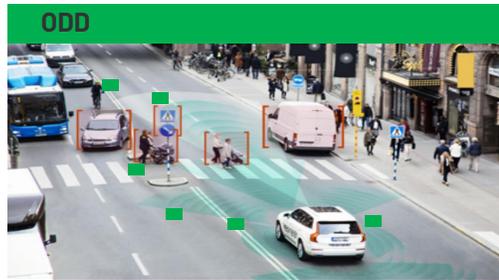
Define ADS fnct. with DDT

High-level process assumptions



Ref.: [1], [2], [3]

Holistic system design overview (very simplified)



Define ODD Scenarios

Define ADS Features within AV

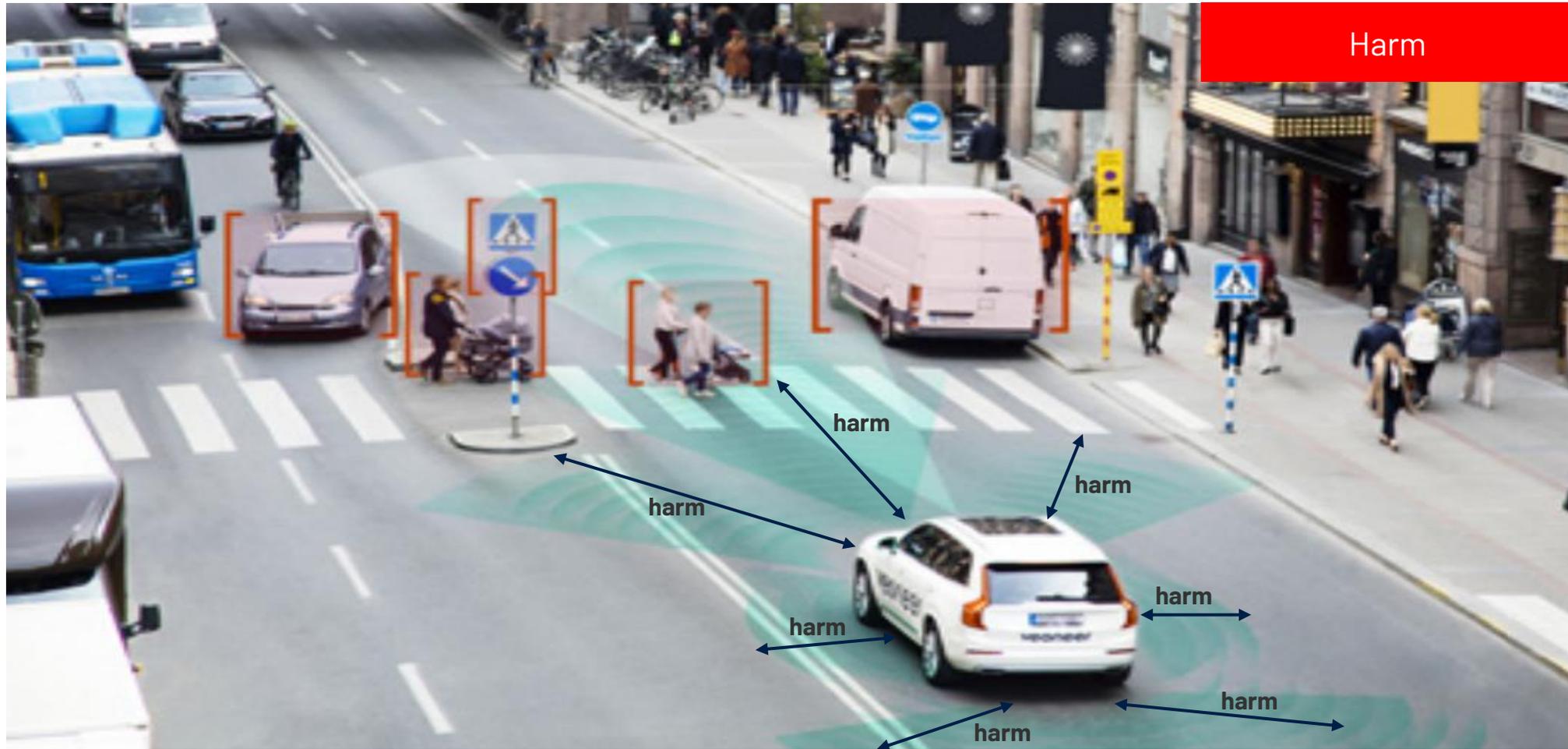
Define ADS fct. with DDT

Design Systems for each ADS function with DDT

Ref.: [6], [7], [8]

Assumption of a generic simplified causal-chain of harm

Harm



Ref.: [4]

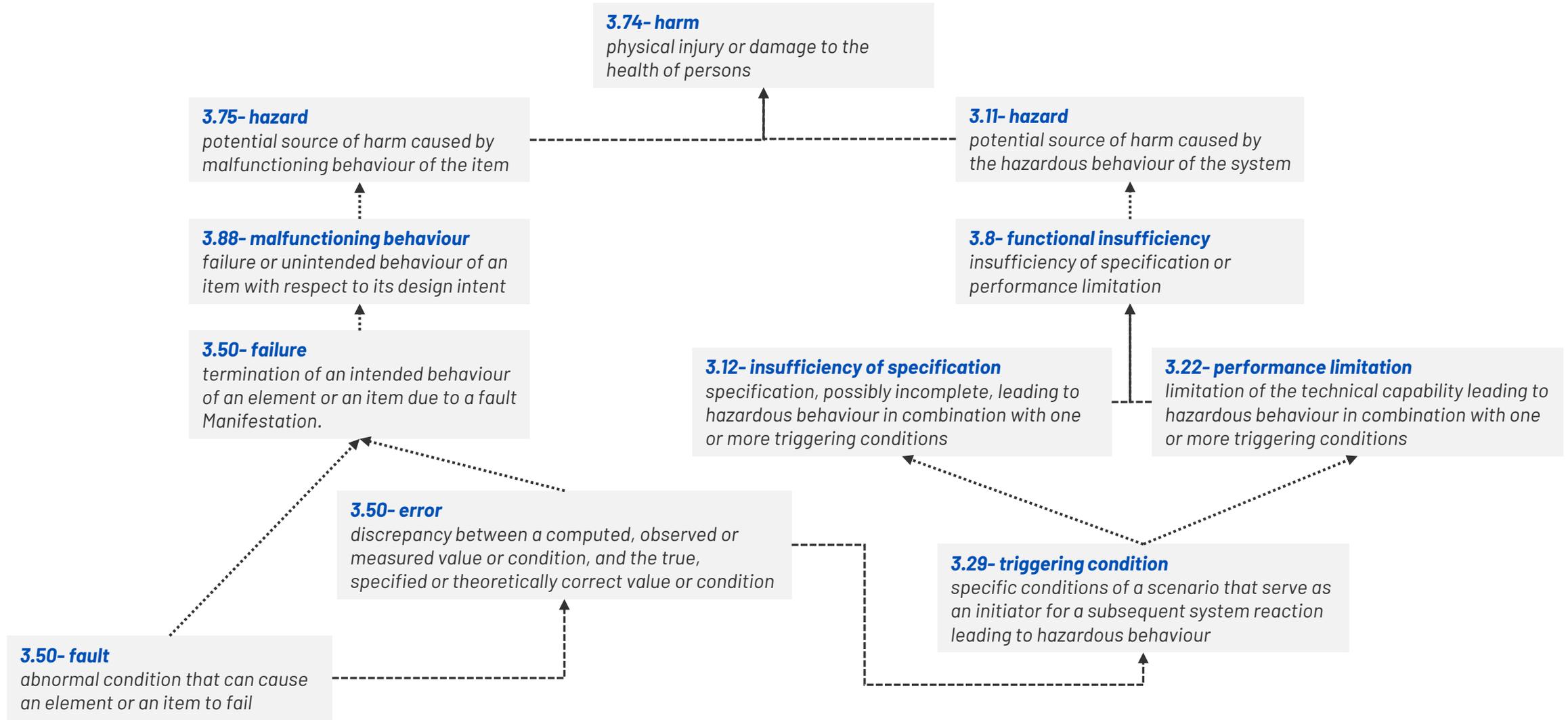
Simplified causal chain of harm

ODD

AV

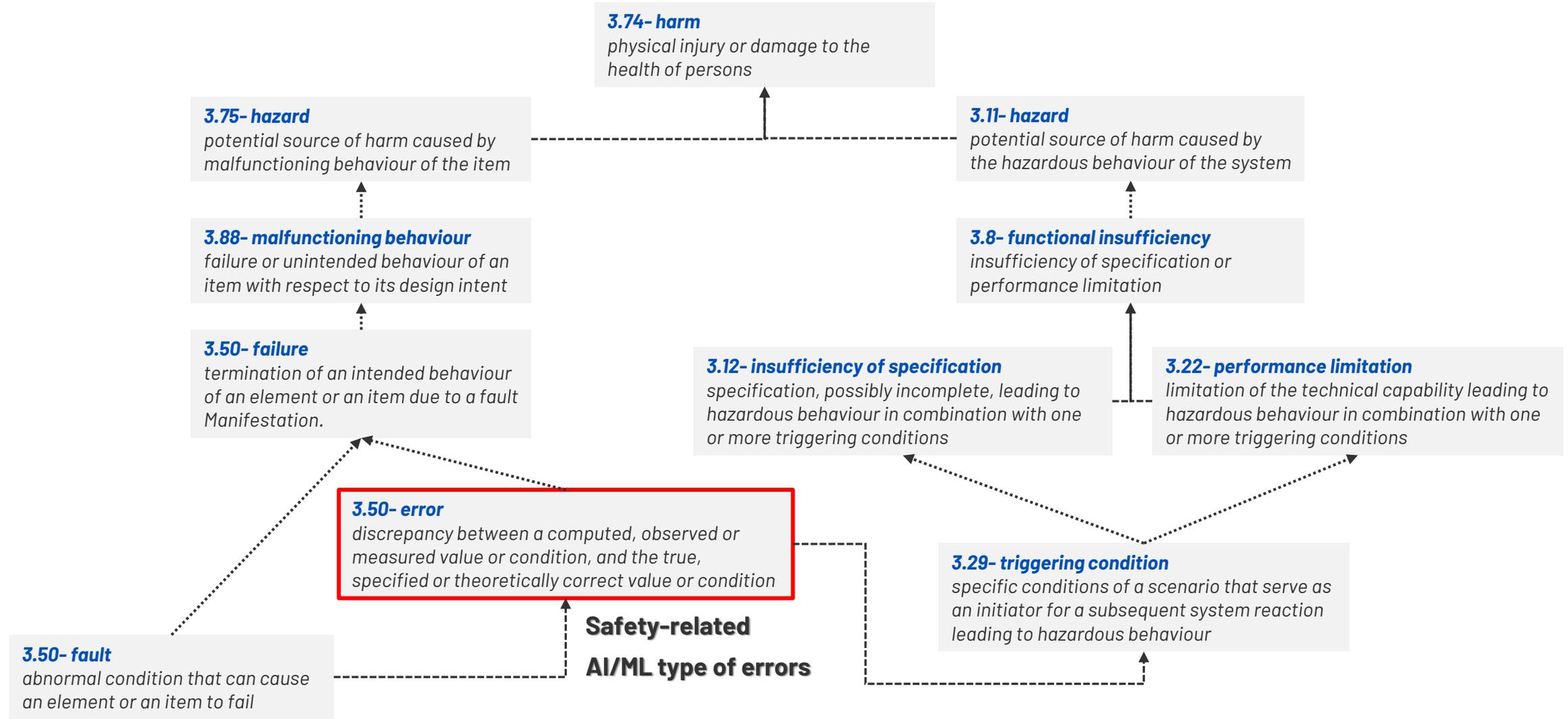
ADS fnct. with DDT

Systems



Ref.: [9], [10]

Simplified causal chain of harm



Ref.: [9], [10]

Safety-related ML errors: ex.: FP, FN

ADS fnct. with DDT
Systems

3.4.2- error
discrepancy between a computed, observed or measured value or condition, and the true, specified or theoretically correct value or condition

**Safety-related
AI/ML type of errors**

Safety-related ML errors
Examples:
- False positive
- False negative
- incorrect classification
- Inaccurate estimation
- ...

Insufficiencies
Examples:
- Bias
- Lack of robustness
- Lack of generalization
- Variance
- Prediction uncertainty
- ...

Causes
Examples:
- Scalable oversight
- Distributional shift
- Under specification
- Overtraining
- ...

Ref.: [12],[13],[14]

Use-case application: AEB Pedestrian detection

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AEB- Use Case: Car-to-Pedestrian (CP)

(illustrative representation of the use case scenario within a sample Safe ODD)

Item
definition

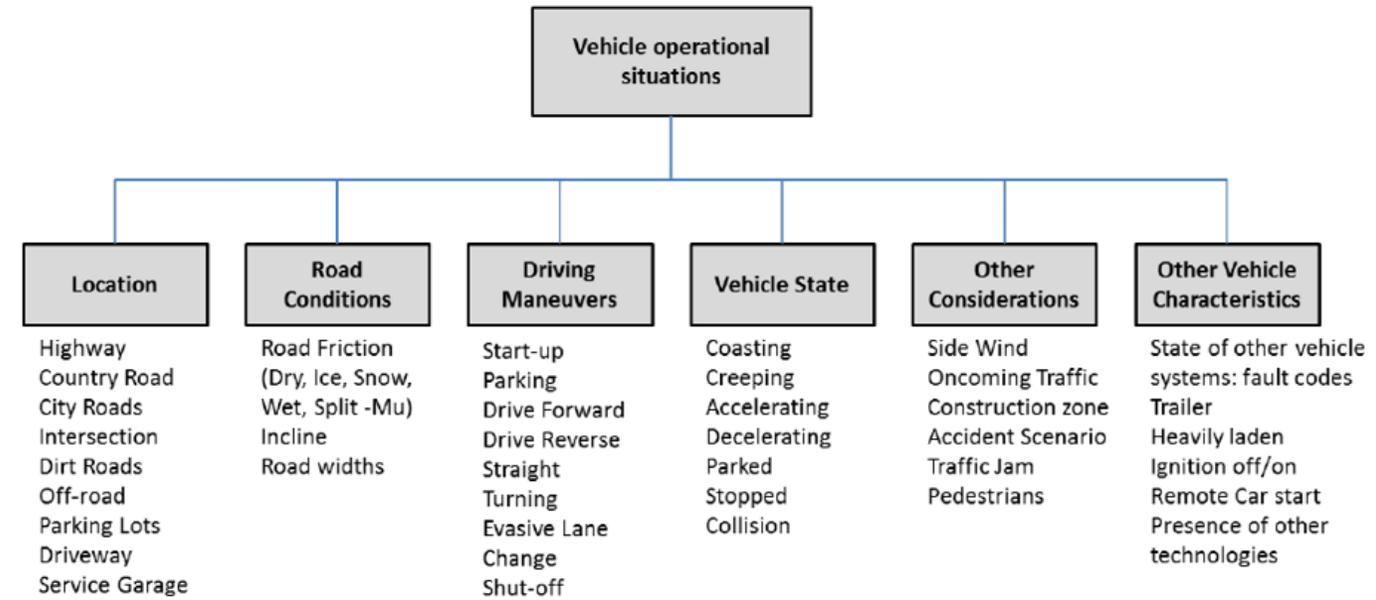
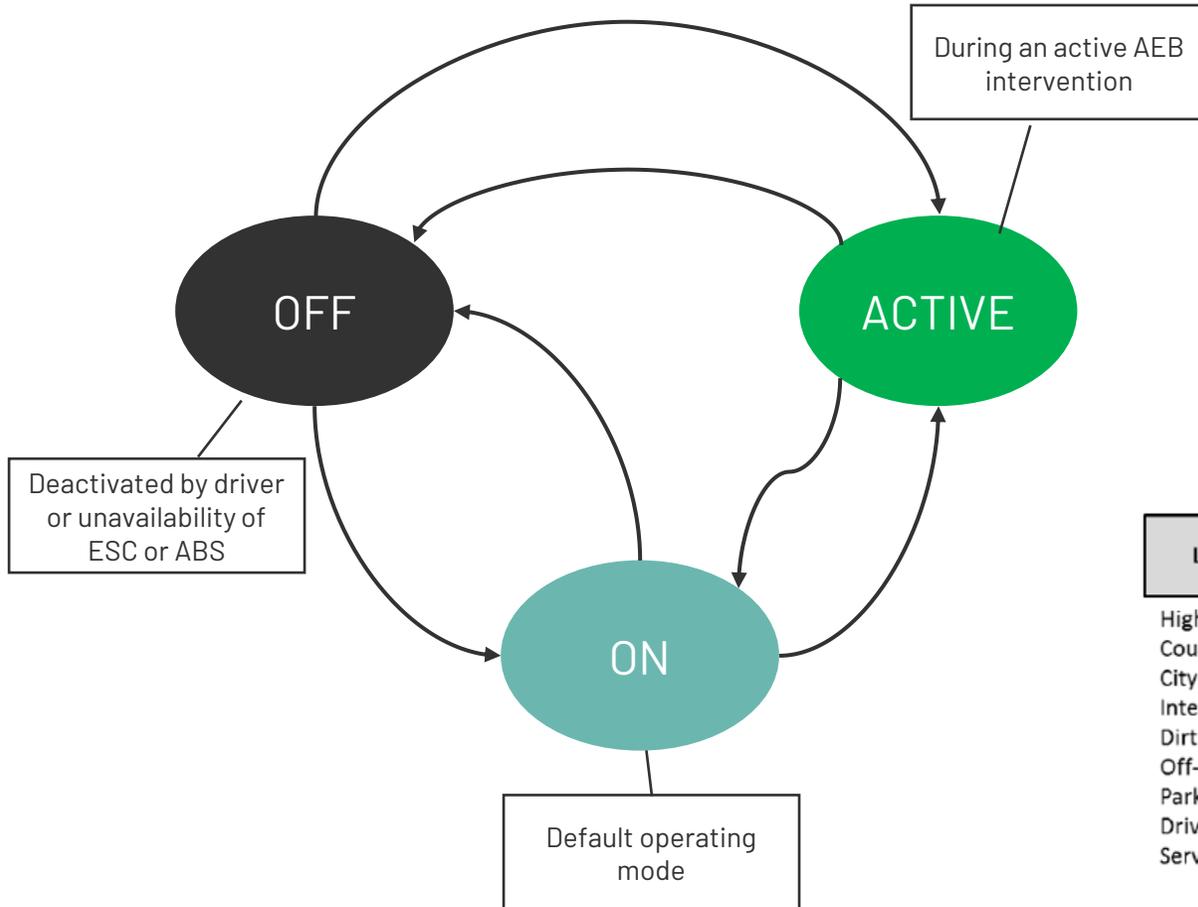


Ref.: [tbd]

AEB Use-case: Car-to-Pedestrian(CP)

Operational modes and operational situations

Item definition



Ref.: [15]

AEB Use-case: Car-to-Pedestrian(CP)

Ref.: [6],[7],[15]

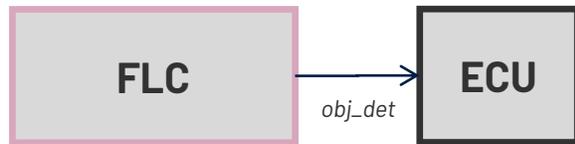
Preliminary architectural model

ODD: Scenario = City

ADS feature within AV: AEB, Use-case: Car-to-Pedestrian (CP)

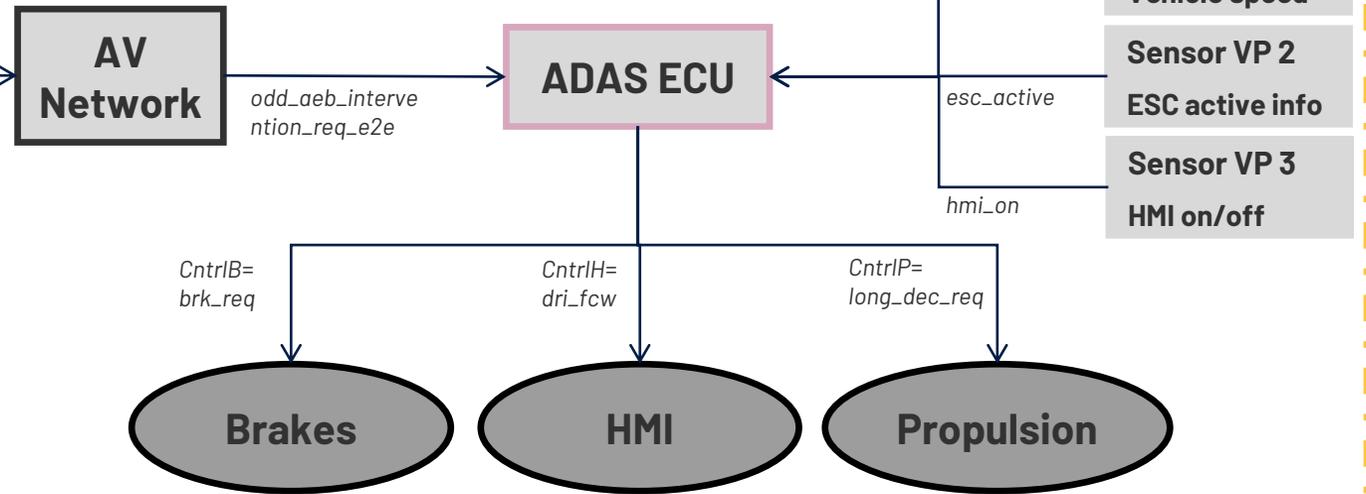
System 1

ADS Sensor/Perception Platform



System 2

ADS Vehicle Platform



ODD
 AV
 Safe ADS fcnct. with DDT
 Safe systems

AEB Use-case definition: Car-to-Pedestrian(CP)

HARA (extremely tailored view for the use case)

Item definition

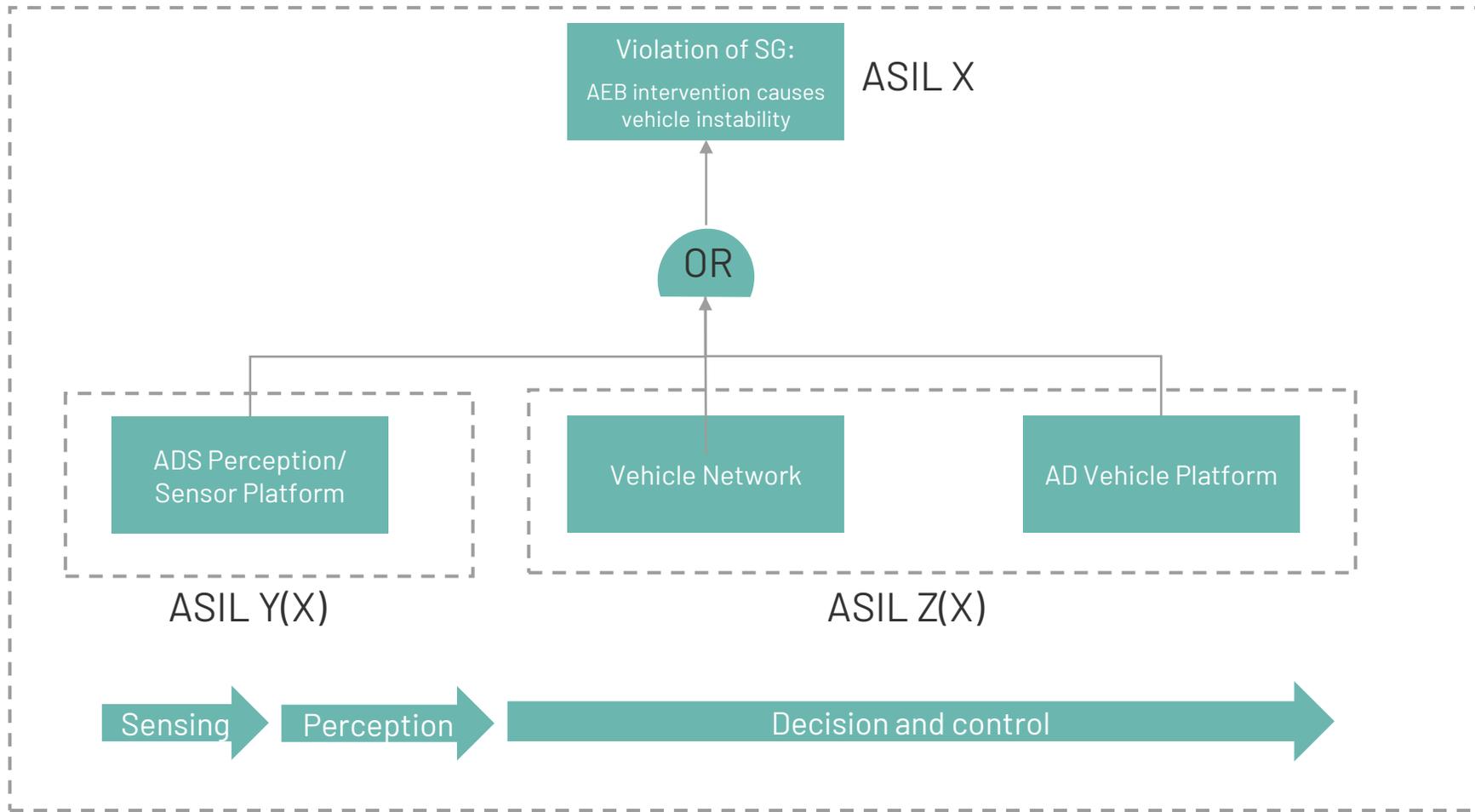
AEB HARA

Hazard ID	Sub-functn	Functn specific failure mode	Hazardous event	S	E	C	ASIL	SG	Safe state	FTTI
AEB_01	Apply full brake at collision threat	AEB full brake is applied with inappropriate brake force distribution	Driver loses control over ego vehicle and collides with e.g., other vehicle, pedestrian or road structure	SX	EX	CX	ASILX	AEB intervention shall not cause vehicle instability	AEB inactive	XXX ms

Ref.: [15]

AEB Use-case: Car-to-Pedestrian(CP)

Simplified FTA on preliminary architectural assumption for the use case



Item definition

AEB HARA

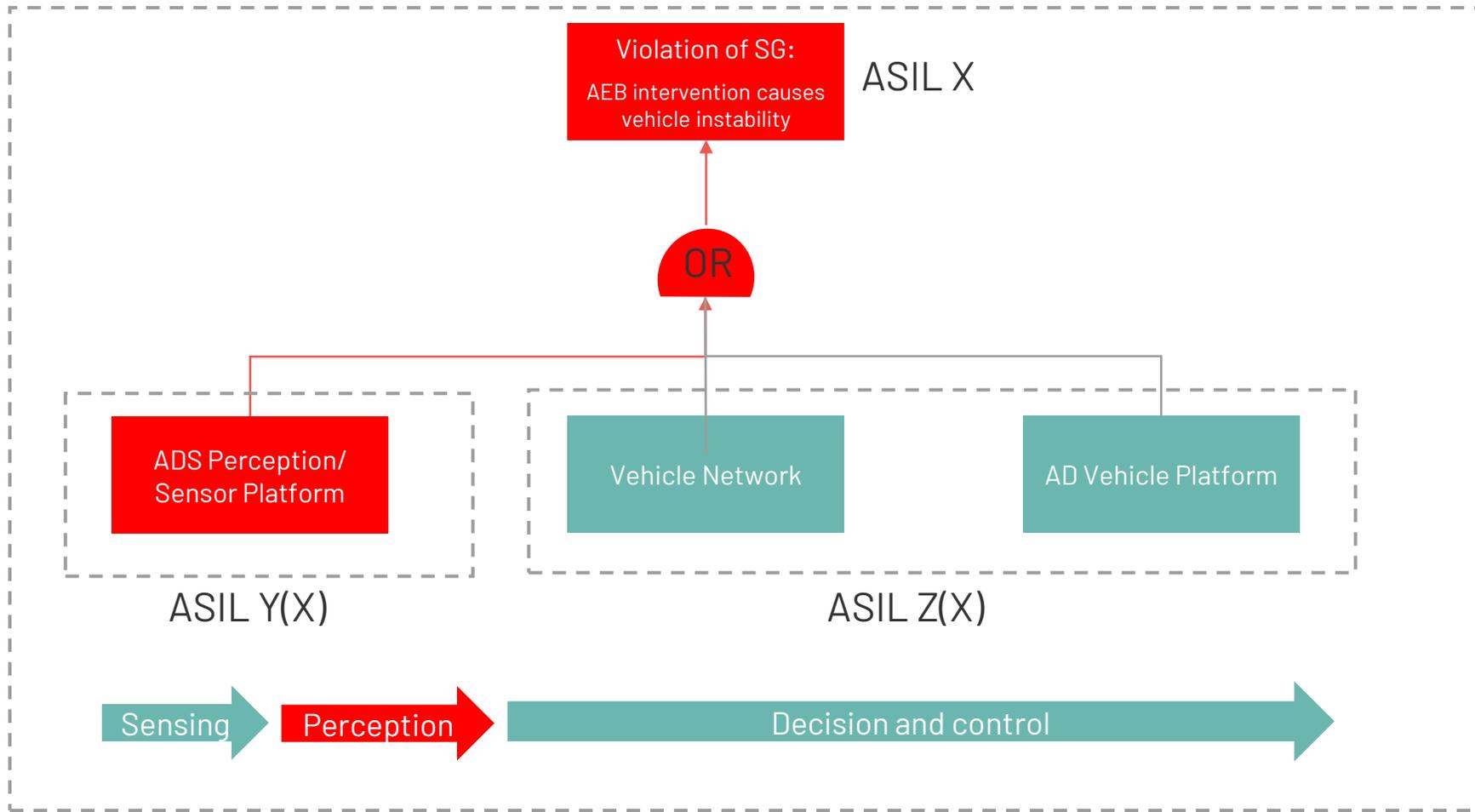
AEB FSC

AEB TSC-L10

Ref.: [6], [7], [15]

AEB Use-case: Car-to-Pedestrian(CP)

Simplified FTA on preliminary architectural assumption for the use case



Item definition

AEB HARA

AEB FSC

AEB TSC-L10

Ref.: [6], [7], [15]

AEB Use-case: Car-to-Pedestrian(CP)

Ref.: [6],[7],[15]

Safety-related architectural view for the use-case

ODD: Scenario = City

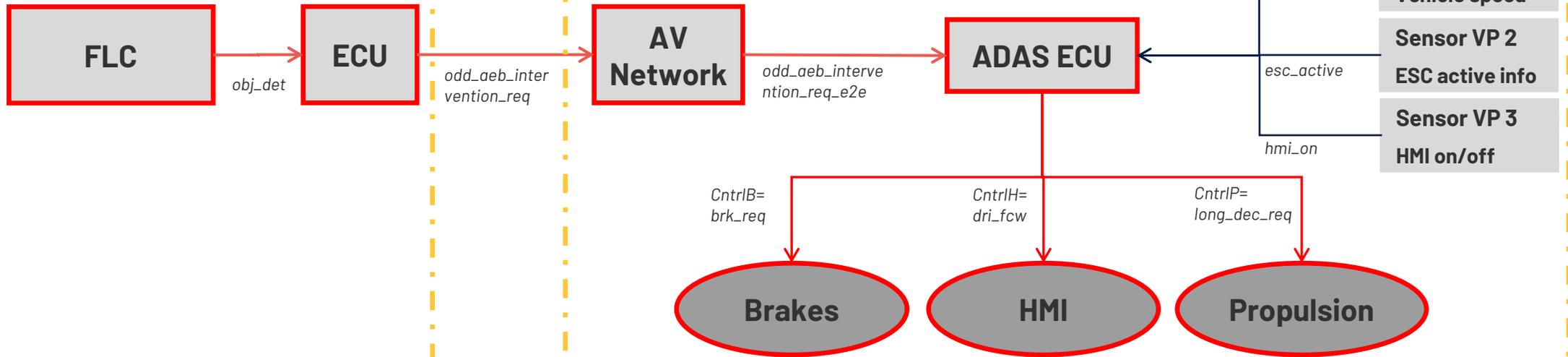
ADS feature within AV: AEB, Use-case: Car-to-Pedestrian (CP)

System 1

ADS Sensor/Perception Platform

System 2

ADS Vehicle Platform



AEB Use-case: Car-to-Pedestrian(CP)

Perception errors of the CNN classifier within the FLC

Ref.: [6], [7], [15]

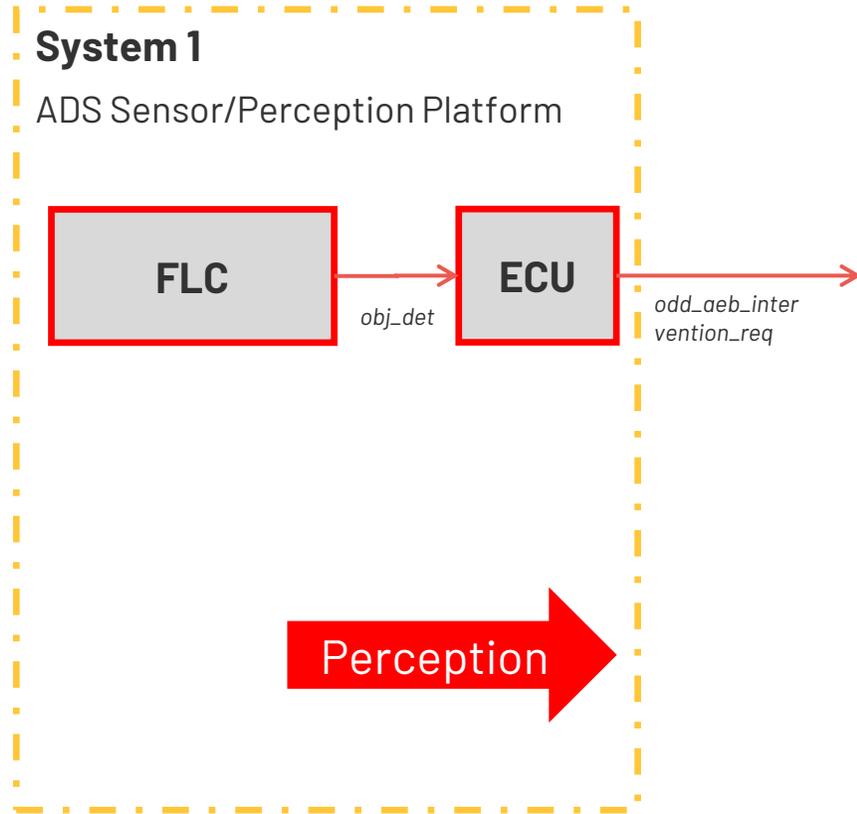
Item definition

AEB HARA

AEB FSC

AEB TSC-L10

AEB TSC-L20



Safe ADS fnct. with DDT

Safe systems

AEB Use-case: Car-to-Pedestrian(CP)

Safety-critical view of the holistic design- FLC critical AI/ML signal pattern

Ref.: [6], [7], [15]

Item definition

AEB HARA

AEB FSC

AEB TSC-L10

AEB TSC-L20

ADS Sensor system missions

- **Perception**
 - Detect traffic participants
 - **Detect pedestrians**
 - Detect cyclists
 - ...
 - Detect Road environment
 - Detect ...



AEB Use-case: Car-to-Pedestrian(CP)

Safety-critical view of the holistic design- FLC critical AI/ML signal pattern

Ref.: [6],[7],[15]

Item definition

AEB HARA

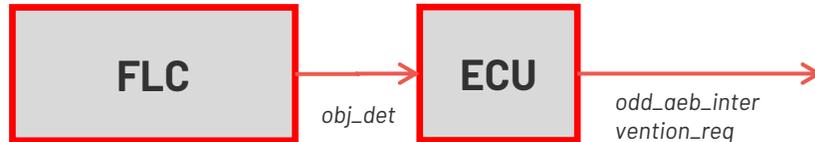
AEB FSC

AEB TSC-L10

AEB TSC-L20

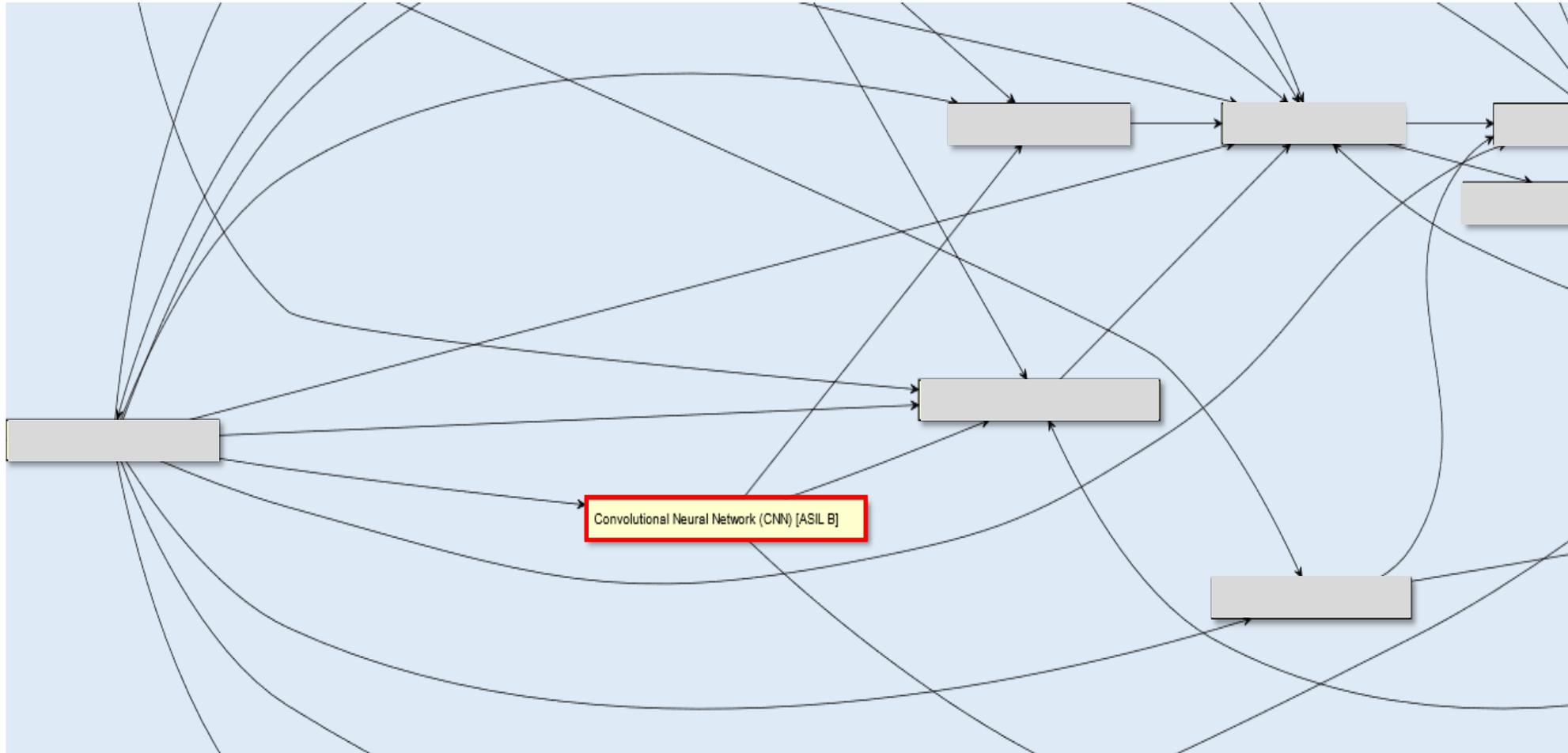
Safety related signals (tailored view) :

- Frame number
- Object ID
- Objects position in x-axis
- Objects position in y-axis
- Objects velocity in x-axis
- Objects velocity in y-axis
- Objects width
- Objects length
- Objects yaw angle
- Objects yaw rate
- etc...



AEB Use-case: Car-to-Pedestrian(CP)

OD architectural design combining Code and Reqs



Item definition

AEB HARA

AEB FSC

AEB TSC-L10

AEB TSC-L20

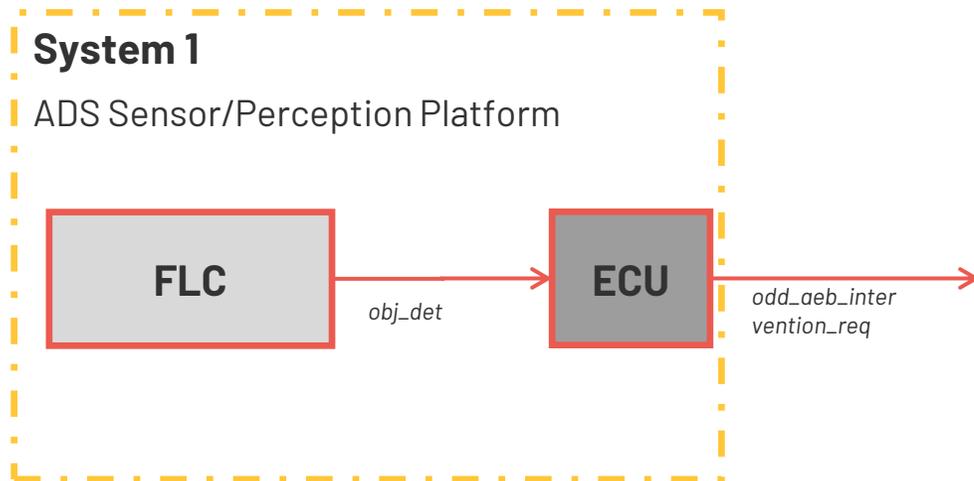
System FTA

System DFA

Ref.: [13]

AEB Use-case: Car-to-Pedestrian(CP)

Preliminary item architectural model- FLC critical AI/ML signal pattern



Failure mode examples:

- Safety-related E/E errors
 - Fail to communicate object properties correctly
 - **Ghost object output (FP)**
 - Wrong object ID
 - Wrong longitudinal position of dynamic object
 - Erroneous confidence level of objects
 - etc...

Item definition
AEB HARA
AEB FSC
AEB TSC-L10
AEB TSC-L20



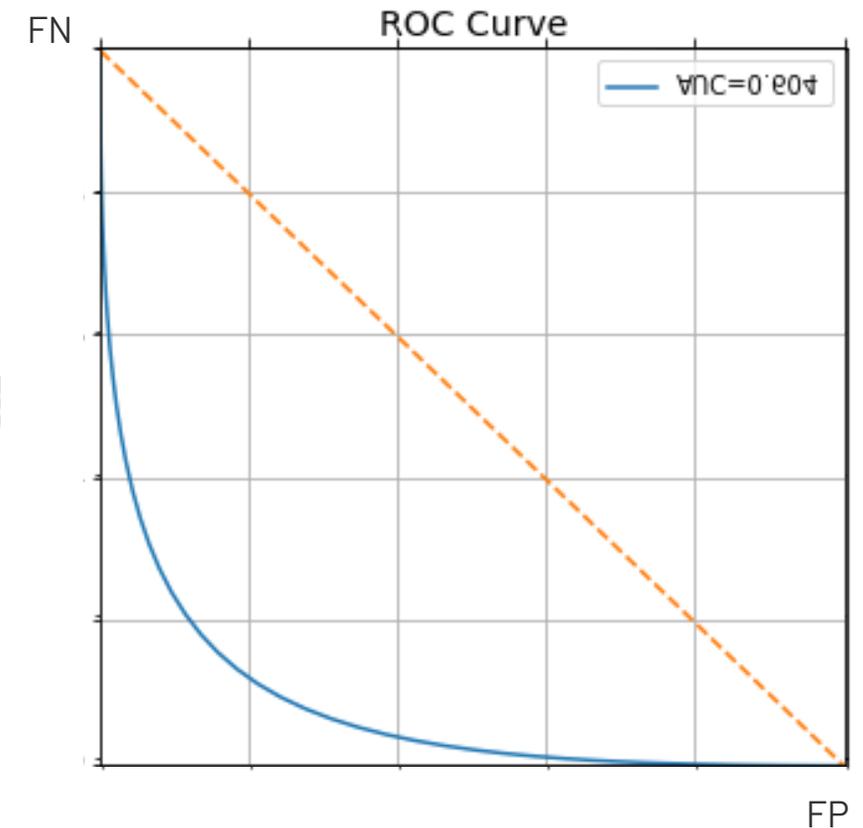
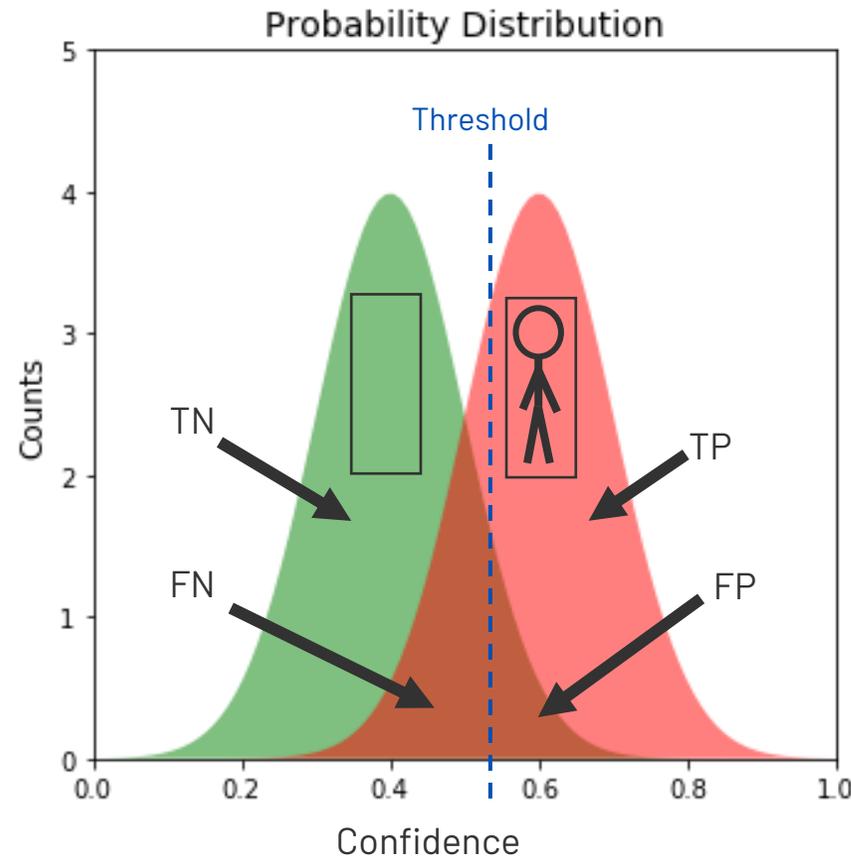
Safe systems

Ref.: [13]

Statistical Behaviour

Algorithmic Performance – The ROC curve

- All classifiers have a ROC curve.
- ISO-26262 does not deal with performance-related safety, its more ISO 21448.
- The CNN classifier errors originated from ML-errors



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	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering.			You are not driving when these automated driving features are engaged – even if you are seated in "the driver's seat".		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.			When the feature requests, you must drive.	These automated driving features will not require you to take over driving.	
	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance.	These features provide steering OR brake/acceleration support to the driver.	These features provide steering AND brake/acceleration support to the driver.	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met.		This feature can drive the vehicle under all conditions.
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering OR • adaptive cruise control	• lane centering AND • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

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Lessons learned 1

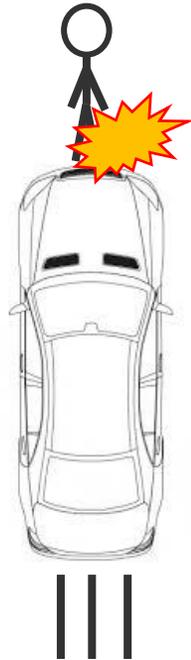
Bad ADAS function

The driver **is expected** to operate the vehicle, and take full responsibility.

Hitting a pedestrian is the driver's fault.

The ADAS function, that should help the driver avoid pedestrians, **performs badly**.

The human drives unsafely.



Unsafe ADAS function

The driver is not expecting the ADAS function to suddenly brake or steer to avoid an imaginary pedestrian.

The drivers have limited controllability over the situation, and the severity is high.

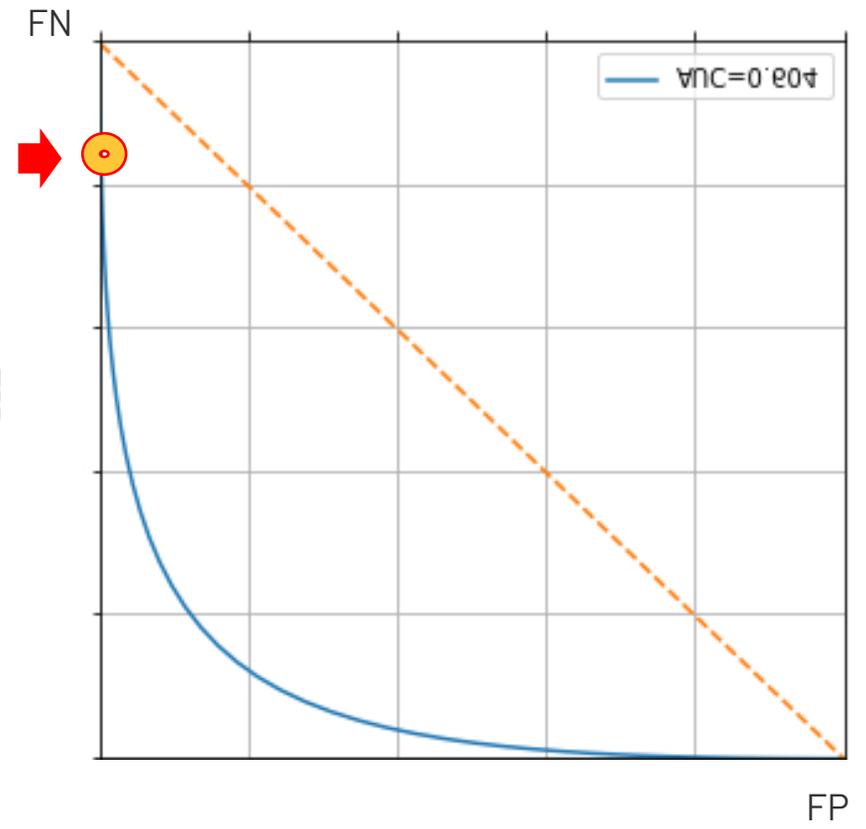
The ADAS function is **unsafe**.

Avoiding FPs is the primary objective in ADAS

ADAS FN/FP Compromise

Avoiding FPs is the primary objective in ADAS

- FPs ~ Fraction of FPs/exposed object??
- FNs ~ Fraction of FNs/exposed object??



Ref.: [16]

	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You are not driving when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	

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	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR • adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

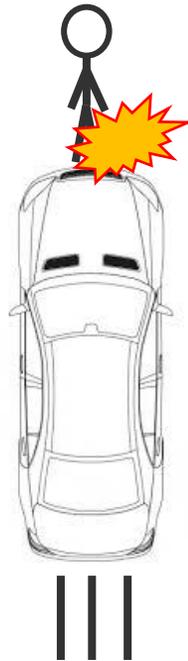
Lessons learned 2

Unsafe

The ADS **is expected** to operate the vehicle for the entire DDT.

Hitting a pedestrian is the ADS' fault.

The ADS behaves **unsafely**.



Unsafe

The ADS function causes an accident due to the ghost object.

The ADS function behaves **unsafely**.

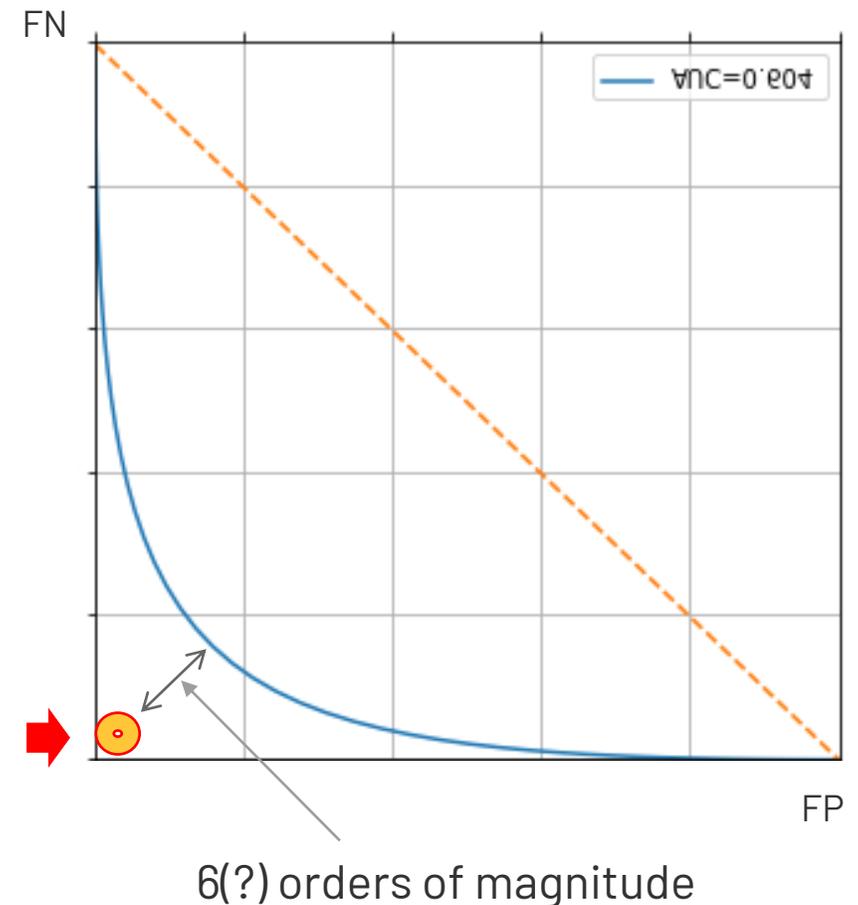


Avoiding both FPs and FNs is safety-critical in ADS!

ADS FN/FP Compromise

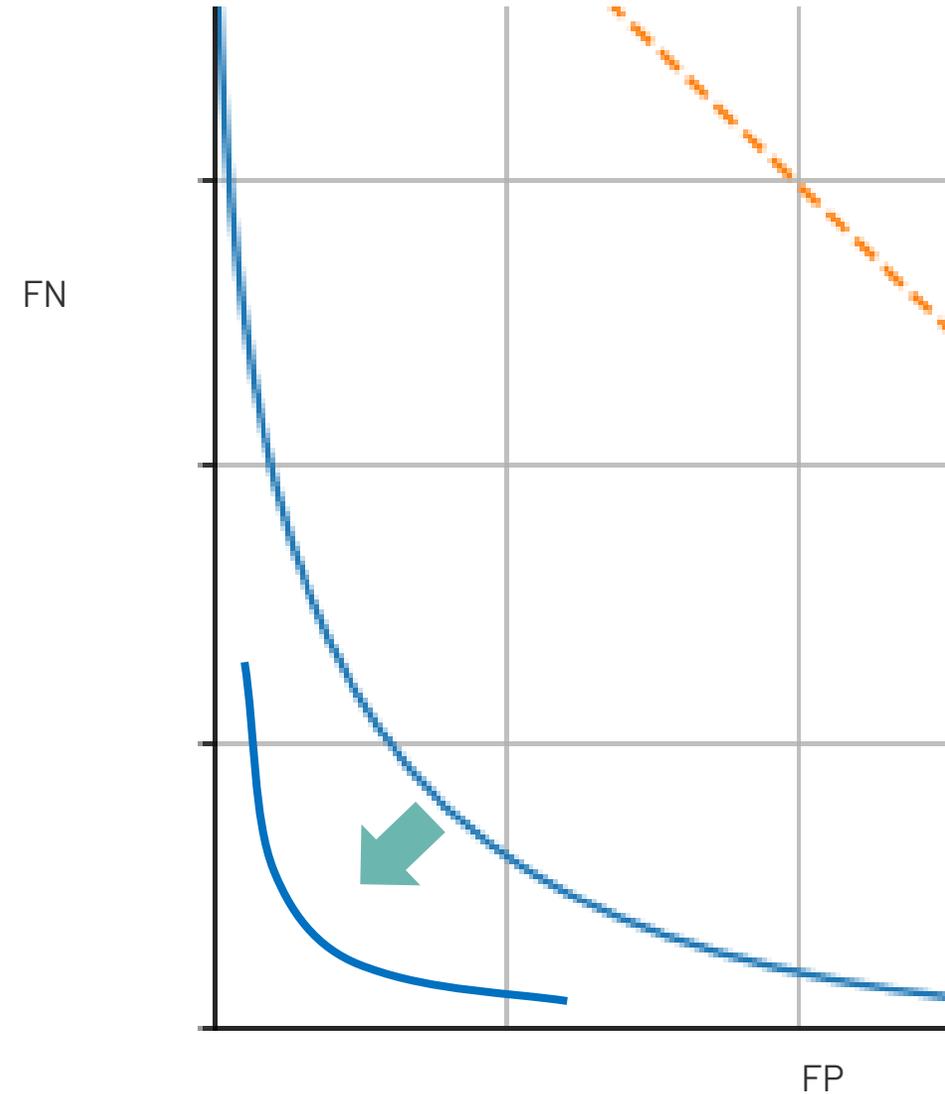
- FPs ~ Fraction of FPs/exposed object??
- FNs ~ Fraction of FNs/exposed object??

Avoiding both FPs and FNs
is safety-critical in ADS!



Question

- What shall be done to improve the ROC-curve for both FN/FP type of safety-related ML-errors?
 - Training data set?
 - Assure sufficient/complete data set?
 -



Conclusion and Outlook

- Collaboration
- Safety claim for ADS
- Safety claim for ADAS
- Research
- Regulations and laws
- New Standards like ISO TS 5083 and ISO PAS 8800

References

Ref. Nr.	Organisation, Conference	Title	Publisher	Publishing date, location
1	ISO 26262: 2018	Road vehicles- Functional Safety	International Organization for Standardization	2nd Edition: 2018
2	ISO/PAS 21448	Road vehicles- Safety of the intended functionality	International Organization for Standardization	2019
3	AMLAS	Assurance of ML for Autonomous Systems AMLAS	Institute for Safe Autonomy, University of York	
4	SAE J3016	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles	Society of Automotive Engineers	2021
5	Euro NCAP	AEB Pedestrian	NCAP Consortium	Introduced in 2016, updated in 2020
6	Automotive ISO 26262: Functional Safety Adaptation and Integration	A system of systems approach to meet the challenges of innovative and forward-looking ADAS safety-related systems	Murat Erdogan	2018, Berlin
7	Vehicle motion control and x-by-wire Operational Safe Systems	Functional safety of automated vehicles: challenges and possible approach for level 3 and higher automation	Murat Erdogan	2019, Berlin
8	OSS. 5- Functional and Operational Safe Systems for Level 5 Automation	Functional safety assessment and challenges for highly automated systems from the perspective of an automotive system supplier	Murat Erdogan	2021, Detroit
9	ISO 26262: 2018	Road vehicles- Functional Safety	International Organization for Standardization	2nd Edition: 2018
10	ISO/PAS 21448	Road vehicles- Safety of the intended functionality	International Organization for Standardization	2019

References

Ref. Nr.	Organisation, Conference	Title	Publisher	Publishing date, location
11	Fraunhofer IKS	A causal model of safety assurance for machine learning	Prof. Simon Burton	2022, Munich
12	ISO/AWI PAS 8800	Road Vehicles – Safety and artificial intelligence	International Organization for Standardization	
13	Veoneer	Generic Vision Platform 4: GVP 4 Technical Safety Concept	Andreas Lundberg, Johan Otterström	2022, Linköping
14	Auto.AI Europe 2021	How to use data captured in a controlled environment to improve sensor performance?	Murat Erdogan	2021, Berlin
15	Veoneer	Active Safety Platform: AEB Functional Safety Concept	ASP Team	2022
16	Veoneer	Safety: functional, performance and reliability	Thorbjörn Jemander	2021, Linköping
17	Springer Nature 2021	Ergo, SMIRK is Safe: A Safety Case for a Machine Learning Component in a Pedestrian Automatic Emergency Brake System	Markus Borg, Jens Henriksson, Kasper Socha, Olof Lennartsson, Elias Sonnsjö Lönegren, Thanh Bui, Piotr Tomaszewski, Sankar Raman Sathyamoorthy, Sebastian, Brink and Mahshid Helali Moghadam	15th September 2022
18	33rd IEEE Intelligent Vehicles Symposium	Uncertainty Aware Data Driven Precautionary Safety for Automated Driving Systems Considering Perception Failures and Event Exposure	Magnus Gyllenhammar, Gabriel Rodrigues de Campos, Fredrik Sandblom, Martin Torngren and Håkan Sivencrona	June 5th-9th 2022, Aachen/Germany

Thank You!

The logo for Veoneer, featuring the word "veoneer" in a white, lowercase, sans-serif font. The logo is positioned in the bottom right corner of the slide, partially overlapping a large, light teal curved shape that sweeps across the right side of the dark blue background.