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IEEE P2846: Assumptions for use in safety-related models

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The AV Safety Assurance Standards Hive of Activity

How did you define/develop/test
Systematic Process Standards

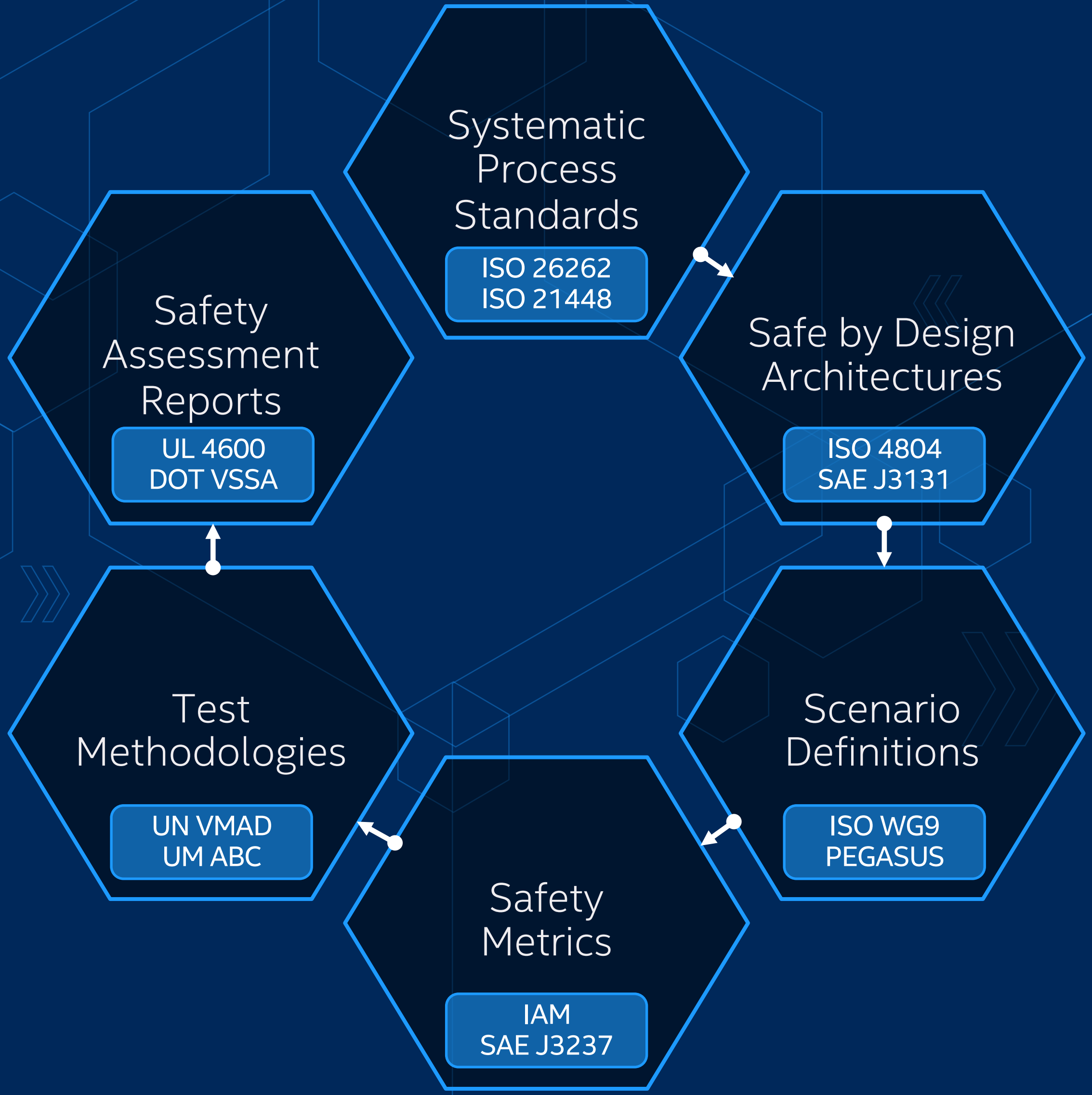
The design of what you built
Safe by Design Architectures

What scenarios should you test
Scenario Definitions

What is Pass or Fail in a scenario
Safety Metric

How you tested the scenario
Test Methodologies

Why you think it's safe
Safety Assessment Reports



The AV Safety Assurance Standards Hive of Activity

Safety Assurance is a Framework

However, following these standards only ensures an AV built to best practices…

…not necessarily one that achieves acceptable risk

Only IEEE 2846 provides a framework for acceptable risk

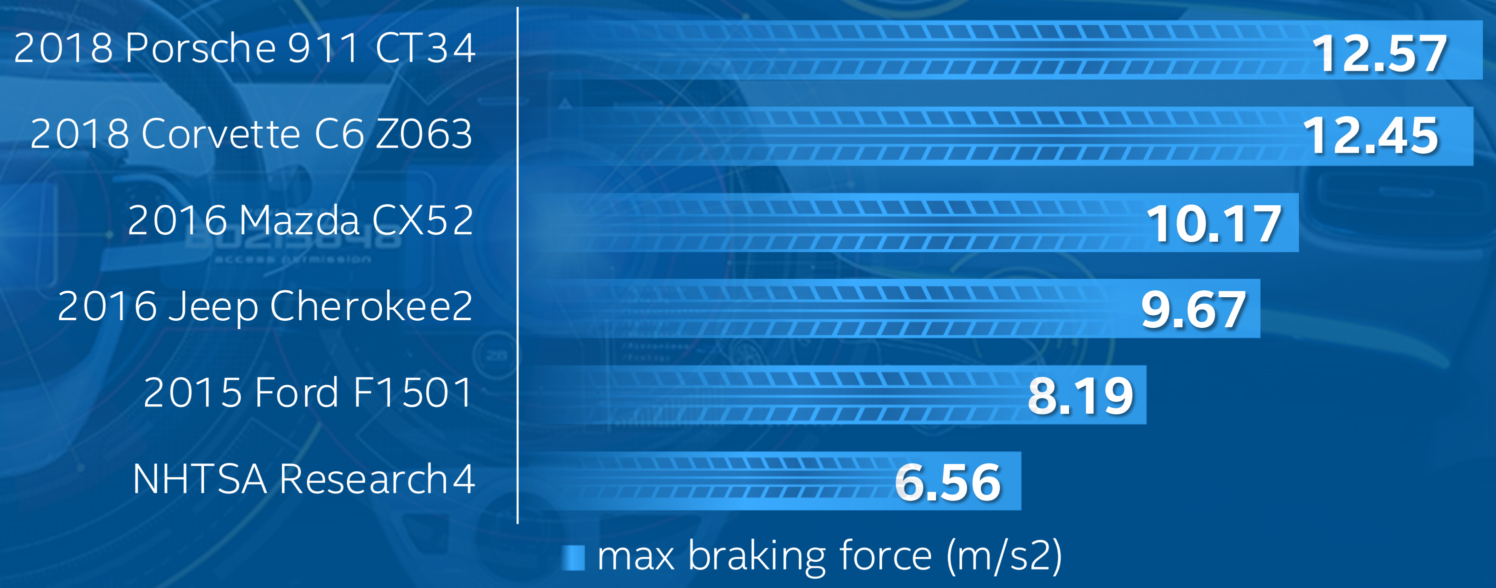
Not all safety model parameters can be measured or known. Ex:

$$d_{min} = \left[v_r \rho + \frac{1}{2} \alpha_{max} \rho^2 + \frac{(v_r + \rho \alpha_{max})^2}{2\beta_{min}} - \frac{v_f^2}{2\beta_{max}} \right]_+$$

β_{max} is a parameter that represents an assumption about what is a reasonable and foreseeable expectation of braking of the leading vehicle

What should the value of $\boldsymbol{\beta}_{max}$ be?

Different braking capability means different stopping distances



1 https://www.brembo.com/en/company/news/50-special
2 https://www.motortrend.com/cars/mazda/cx-5/2016/small-crossover-comparison-big-test/
3 https://special-reports.pickuptrucks.com/2015/01/2015-annual-physical-braking.html 4 https://one.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/VRTC/ca/capubs/nhtsalvabs5.2-5.3final.pdf
Calculations were made using initial velocity, v_i (100kph or 60mph) and stopping distances, d, with the formula: force= v_i / (d*(2/v_i))

Parameters vs. Values

- Industry will define the Parameters
- Government needs to pick the values

PARAMETER	VALUE
Speed Limit	55 mph
Assumed Maximum Braking Leading Vehicle	6.56 m/s^2
Minimum Sound Requirements for Electric Vehicles	62 dB(A)
Assumed Maximum Acceleration Occluded Pedestrian	1.0 m/s^2

IEEE P2846: Assumptions

for models in safety-related av behavior

Industry and Government must align on what are the reasonable and foreseeable assumptions that an AV's safety model should use when operating in the real world.

>30 Entities

representing OEM's, MaaS Providers, Tier 1's, Suppliers, Universities and Governments, globally!
Liaison agreement with ISO and soon SAE and ITU

arm, Aurora, Baidu 大脑, DENSO, Edge Case Research, Exponent, FCA Fiat Chrysler Automobiles, foretellix verifying autonomous systems, Google, Huawei, Horizon Robotics, Infineon, intel, John Deere, kontrol, Motional, National Taiwan University, NIST, nuro, NVIDIA, NXP, Prover Technology, Qualcomm, SAE ITC, Uber ATG, M UMTRI, Valeo, VW, Waymo

Newest Members: AMD, Ford, Honda, Rivian, Zoox

Key Term: Safety-Related Model

- **safety-related model:** Representation of safety-relevant aspects of driving behavior, based on reasonably foreseeable assumptions about other road users behavior.

  NOTE 1: Examples of safety-related models can include those related to motion planning, as well as on-board and off-board safety checkers and analyzers;

  NOTE 2: Safety-related models could apply to both ADS as well as representations of other road users.

  NOTE 3: Safety-related models can take many forms. Example formulations may include; definition of a driving policy; definitions as a formal mathematical equation, or as a set of more conceptual rules, or as a set of scenario-based behaviors, or a combination thereof.

Methodology

- Identify kinematic properties of road users
- Formulate into bounded assumptions that shall be used in safety-related models
- Identify representative high-level scenarios
- Perform example scenario analysis to illustrate how assumptions can be mapped to scenarios

Derive the Minimum Set of Assumptions

Road Users' Kinematic Description and Notation	
Notation	Description
v^{lat}, v^{lon}	lateral and longitudinal velocity of a road user
$\alpha^{lat}, \alpha^{lon}$	lateral and longitudinal acceleration of a road user
β^{lat}, β^{lon}	lateral and longitudinal deceleration of a road user
h	heading angle (yaw) of a road user
h'	heading angle rate of change (yaw rate) of a road user
ρ	response time of a road user
λ	lateral margin for small lateral movements performed by a road user when moving in forward motion

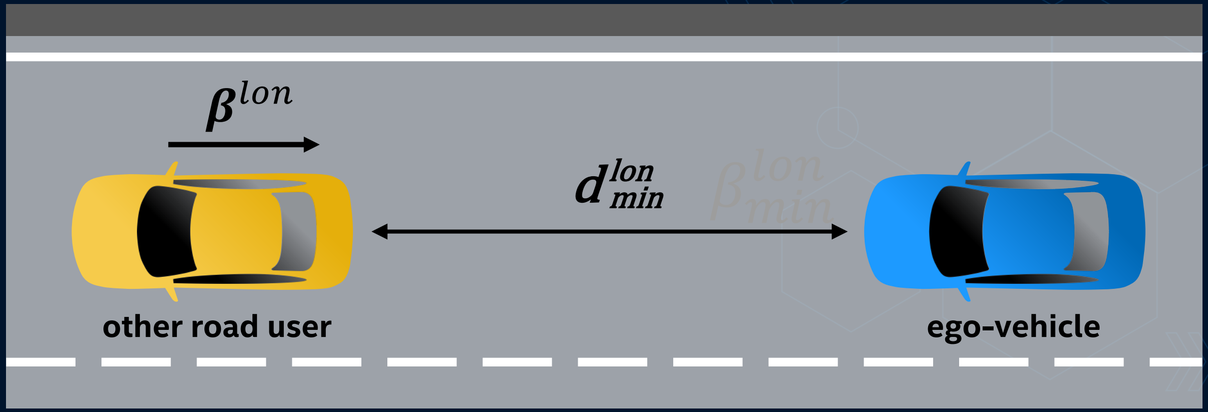
Minimum Set of Assumptions	
Pedestrians	Vehicles
$\lvert v^{lon}(t)\rvert \leq v^{lon}_{max}$	$\lvert v^{lon}(t)\rvert \leq v^{lon}_{max}$
$\lvert v^{lat}(t)\rvert \leq v^{lat}_{max}$	$\lvert v^{lat}(t)\rvert \leq v^{lat}_{max}$
$\alpha^{lon}(t) \leq \alpha^{lon}_{max}$	$\alpha^{lon,}(t) \leq \alpha^{lon}_{max}$
$\alpha^{lat}(t) \leq \alpha^{lat}_{max}$	$\alpha^{lat}(t) \leq \alpha^{lat}_{max}$
$\beta^{lon}(t) \leq \beta^{lon}_{max}$	$\beta^{lon}(t) \leq \beta^{lon}_{max}$
$\beta^{lon}(t) \geq \beta^{lon}_{min}$	$\beta^{lon}(t) \geq \beta^{lon}_{min}$
$\beta^{lat}(t) \geq \beta^{lat}_{min}$	$\beta^{lat}(t) \geq \beta^{lat}_{min}$
$\lvert h(t)\rvert \leq h_{max}$	$\lvert h(t)\rvert \leq h_{max}$
$\lvert h'(t)\rvert \leq h'_{max}$	$\lvert h'(t)\rvert \leq h'_{max}$
$\lvert \lambda\rvert \leq \lambda_{max}$	$\lvert \lambda\rvert \leq \lambda_{max}$
$\rho \leq \rho_{max}$	$\rho \leq \rho_{max}$

Identify Representative High-Level Scenarios

Scenario Name
Ego Vehicle Driving Next to Other Road Users
Ego Vehicle Driving Longitudinally Behind Another Road User
Ego Vehicle Driving Between Leading and Trailing Road Users
Ego Vehicle's Path Intersecting with VRU Crossing the Road
Ego Vehicle's Path Intersecting With Other Road User's Path Moving In Opposite Direction
Ego Vehicle Negotiating an Intersection With Non-Occluded Road Users
Ego Vehicle Negotiating an Intersection With Occluded Road Users

Perform Scenario Analysis to Identify Assumptions

Normative Assumptions are represented by parameters in safety models

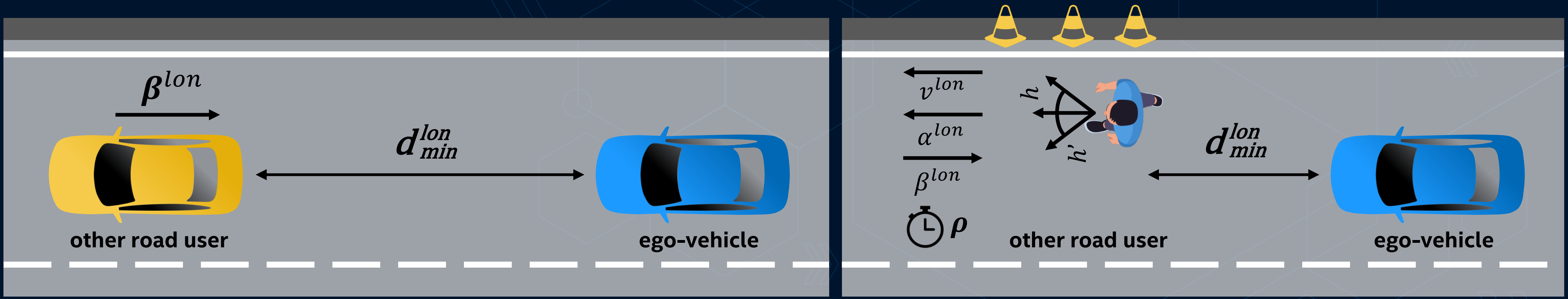


Car Following Scenario

ASSUMPTION	PARAMETER
Maximum assumed longitudinal deceleration	$\lvert\beta^{lon}(t)\rvert \leq \beta^{lon}_{max}$

Perform Scenario Analysis to Identify Assumptions

Normative Assumptions are represented by parameters in safety models



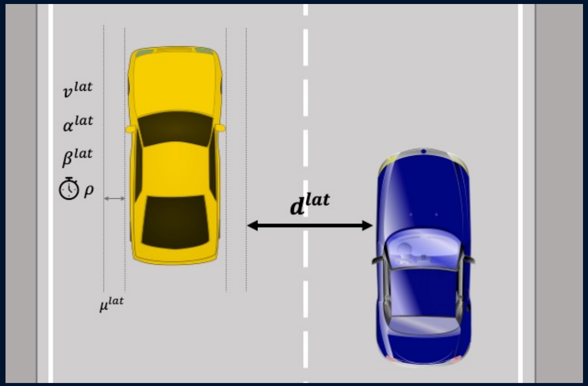
Car Following Scenario

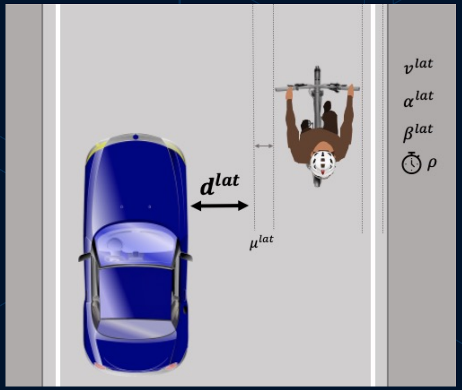
Pedestrian Following Scenario

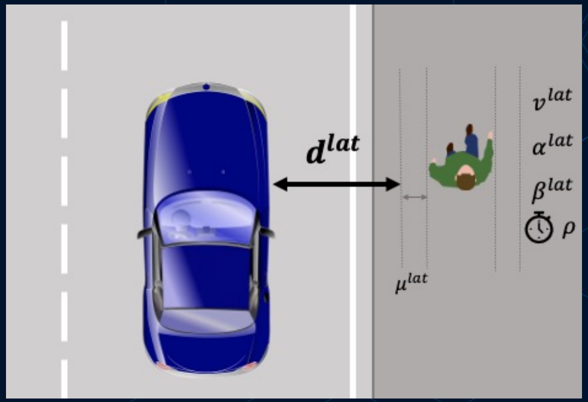
ASSUMPTION	PARAMETER
Maximum assumed longitudinal deceleration	$\lvert\beta^{lon}(t)\rvert \leq \beta^{lon}_{max}$
Maximum assumed longitudinal velocity	$\lvert v^{lon}(t)\rvert \leq v^{lon}_{max}$
Maximum assumed longitudinal acceleration	$\lvert\alpha^{lon}(t)\rvert \leq \alpha^{lon}_{max}$
Maximum assumed heading angle rate change	$\lvert h'(t)\rvert \leq h'_{max}$

Perform Scenario Analysis to Identify Assumptions

Normative Assumptions are represented by parameters in safety models





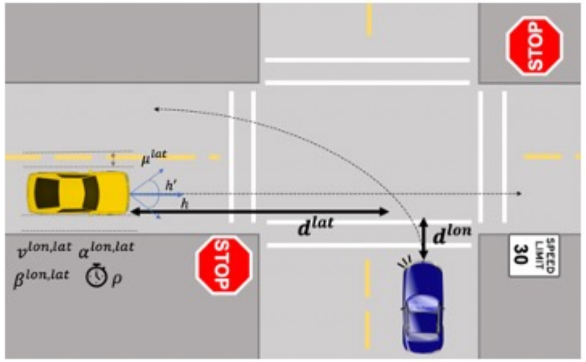


Ego Vehicle Driving Next to Other Road Users

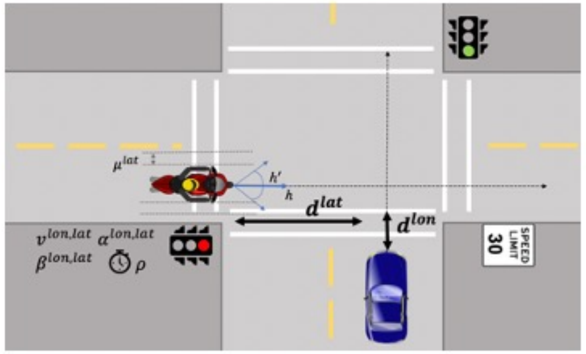
ASSUMPTION	PARAMETER
Maximum assumed lateral deceleration	$\beta^{lat}(t) \geq \beta^{lat}_{min}$
Maximum assumed lateral acceleration	$\alpha^{lat}(t) \leq \alpha^{lat}_{max}$
Maximum assumed response time	$\rho \leq \rho_{max}$
Maximum assumed lateral position fluctuation	$\lvert\mu^{lat}\rvert \leq \mu^{lat}_{max}$

Perform Scenario Analysis to Identify Assumptions

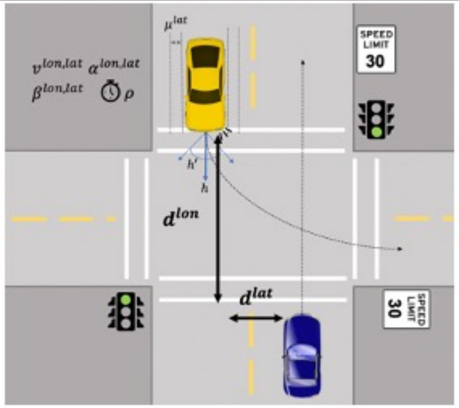
Scenario Schematic Examples



Ego vehicle turning left at intersection with priority. Other vehicle at intersection driving straight



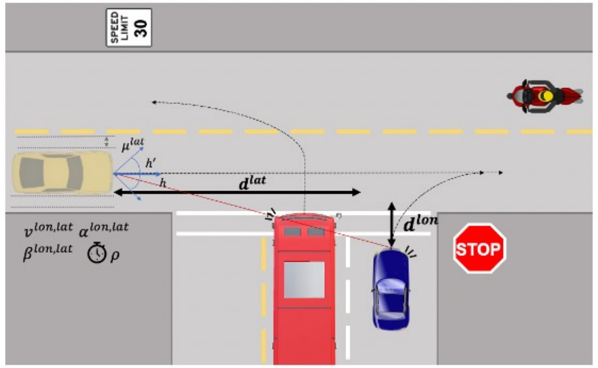
Ego vehicle driving straight at intersection with priority. Other motorcycle at intersection going against the controlling signal



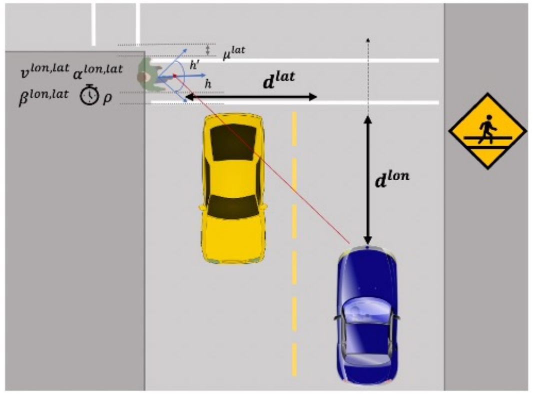
Ego vehicle driving straight at intersection with priority. Other vehicle, in opposite direction, turning left

Perform Scenario Analysis to Identify Assumptions

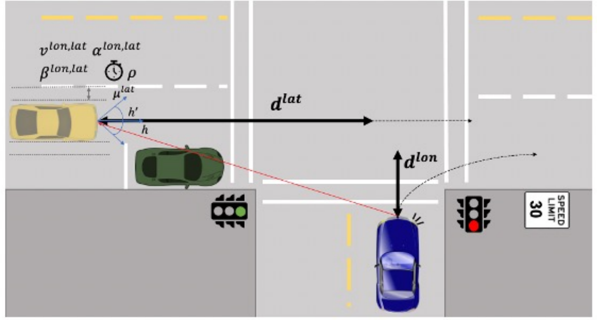
Scenario Schematic Examples



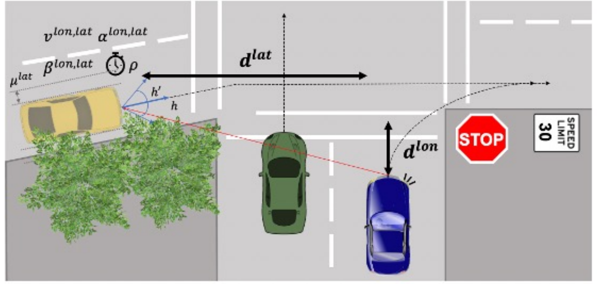
Ego vehicle turning right at intersection, and another road user is blocking visibility of potential incoming traffic



Ego vehicle turning left at intersection, and another road user is blocking visibility of potential incoming pedestrians at crosswalk



Ego vehicle turning right at intersection with limited visibility due to a parked vehicle



Ego vehicle turning right at intersection with limited visibility due to static and dynamic objects in the scene

Outline of the Standard

- Clause 1: Introduction
- Clause 2: Normative references
- Clause 3: key terms and definitions
- Clause 4: Normative minimum set of assumptions that shall be considered by safety-related models.
- Clause 5: Common Attributes of Suitable Safety-Related Models (Informative)
- Clause 6: Verification Methods for Assumptions used in safety-related models (Informative)
- Annex: Example Application Areas: Formal Models and Scenario Based Simulation

Status of the Standard

- April: Technical Editor Secured – Candidate Draft End of April
- May: SAE ORAD and ISO TC 22 / SC 32 / WG 8 Reviews
- June: Revised Draft addressing SAE and ISO feedback
- July: Draft Standard Approved within Working Group
- July – September: IEEE Public Commenting / Society Approval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