NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Modeled Exploration of Proposed Safety Assessment Metrics for ADS

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A Typical Automated Driving System (ADS) Safety Assessment Approach

Establish a set of test scenarios.

Deploy test subject in the scenario.

- High-fidelity simulation
- Controlled track testing
- Real-world test

Observe and Analyze Outcomes

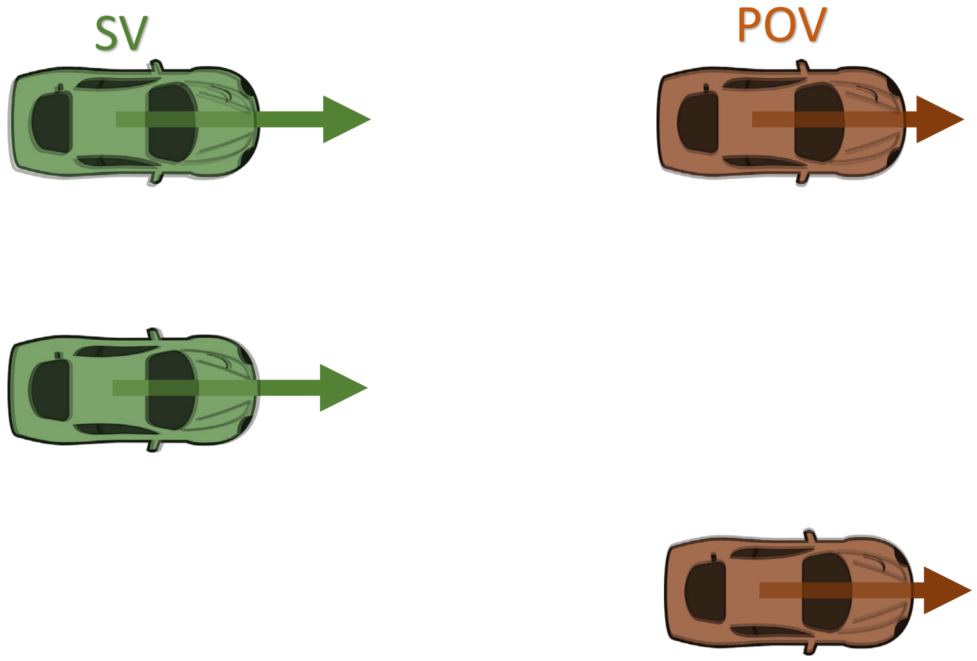
- Whether a collision occurs
- **Proposed metric behavior**

Classic Time-to-Collision (TTC) as a metric

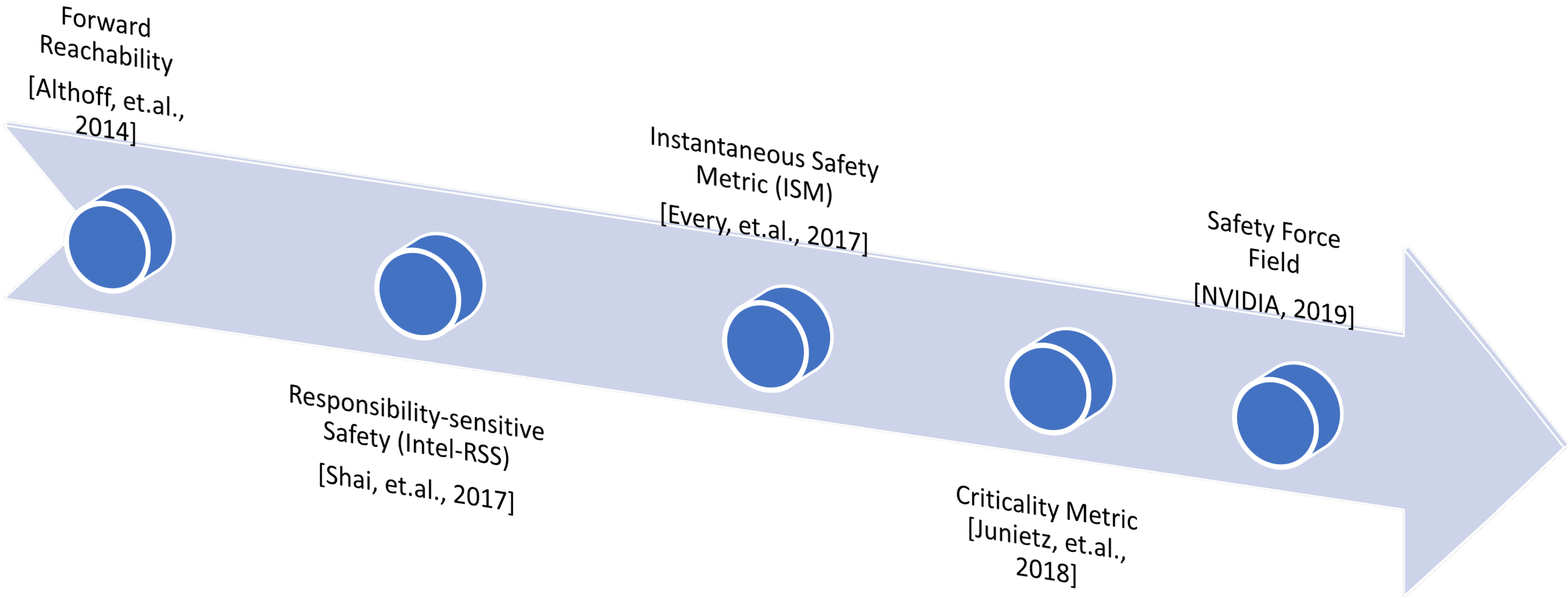
The Time-to-Collision metric [Lee, 1976] for longitudinal motion safety assessment has dominated the field for decades.

$$TTC = \frac{dx}{dv}$$

$$TTC = \infty \, ?$$



Introduction of Safety Assessment Metric Concepts within the Non-collision Regime

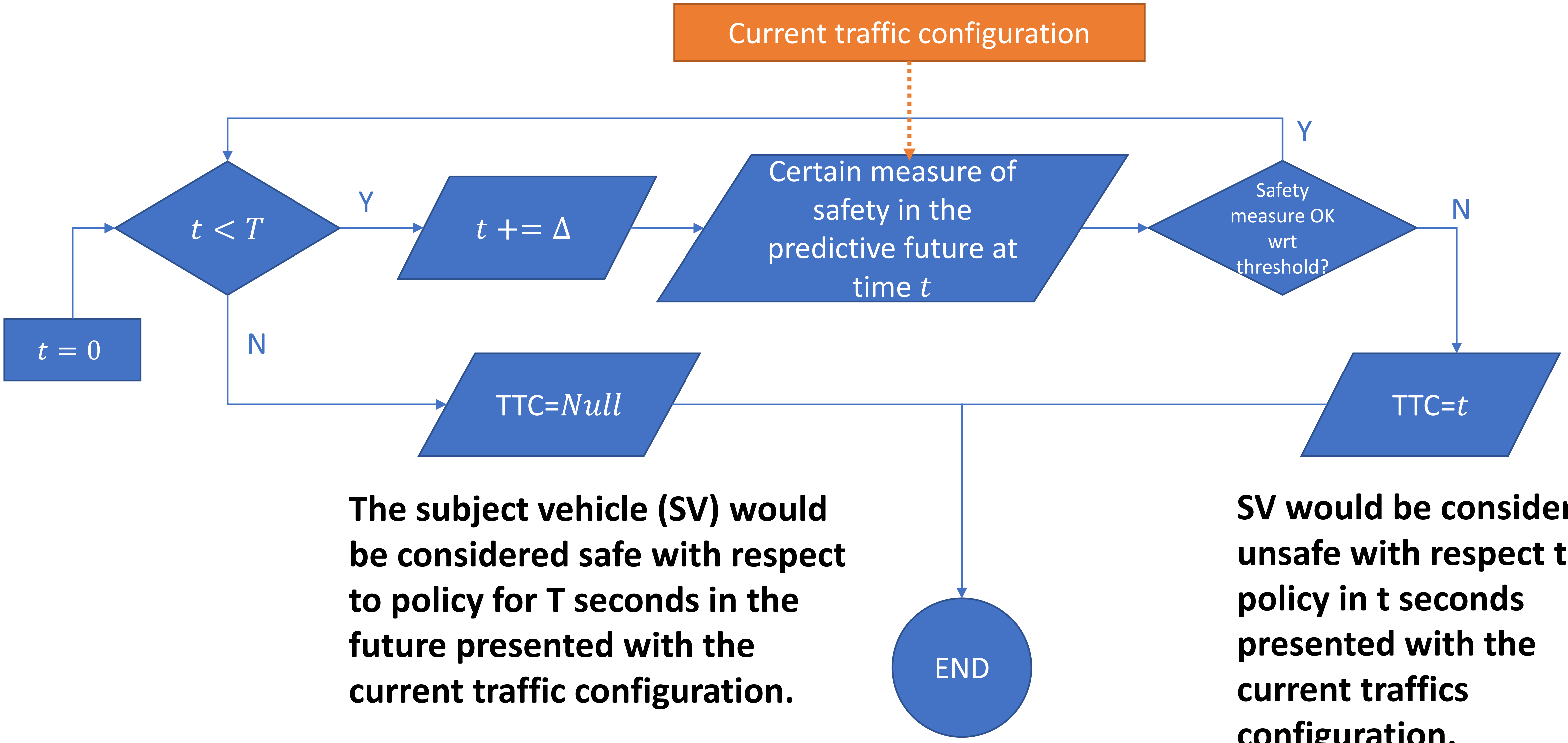


Overview

Some suggest that ADS safety assessment metrics can be used to influence ADS safe driving policy choices through casting them as certain optimization / constraint fulfillment problem

Modeled exploration of such perspective provides an opportunity to intrinsically understand the relation among various existing and proposed metrics/methods.

A Unified Safety Measure of TTC beyond Longitudinal Dimension



The subject vehicle (SV) would be considered safe with respect to policy for T seconds in the future presented with the current traffic configuration.

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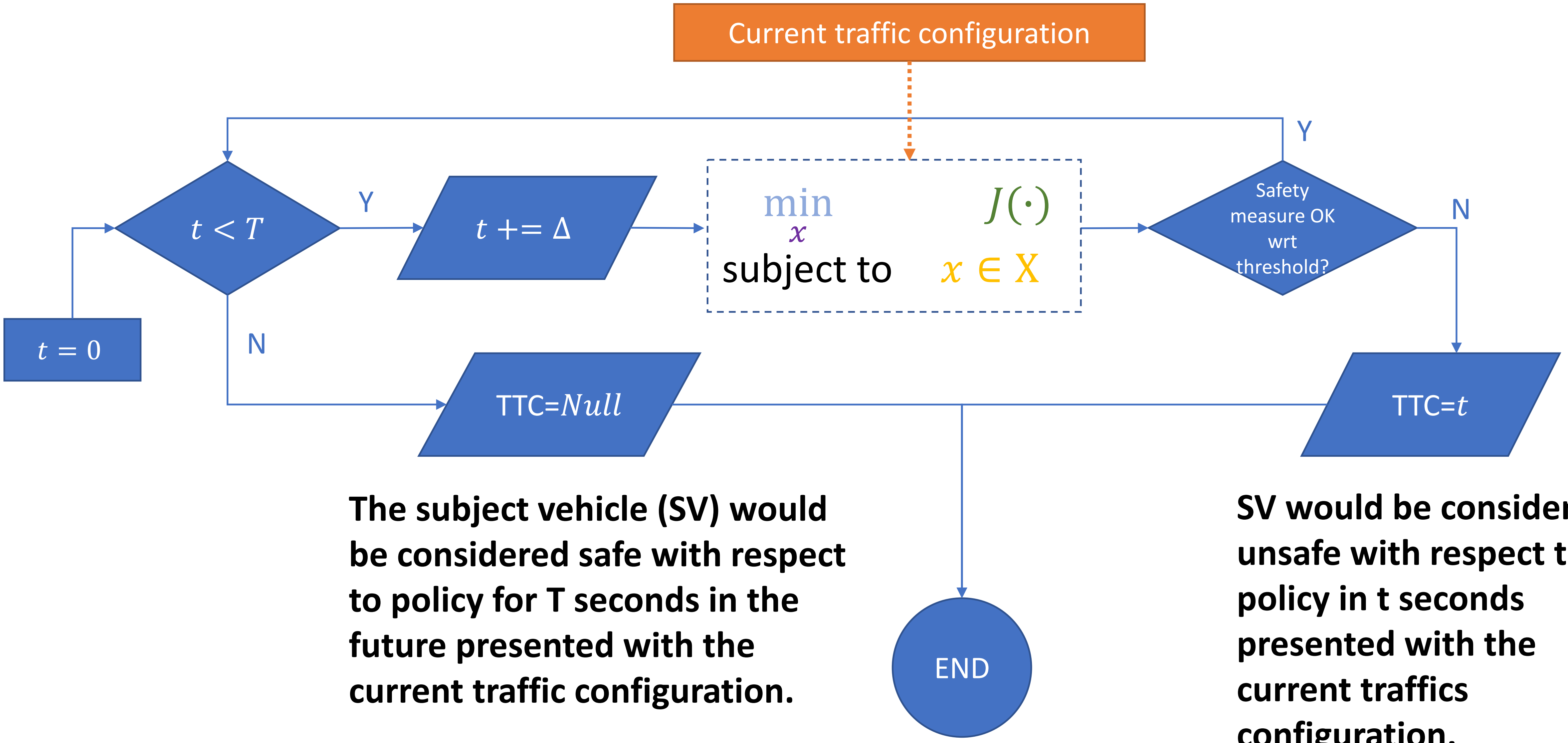

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A Typical Optimization Problem

The operator

The controlled variable

Target function

$$\min_{x} \quad J(\cdot)$$
$$\text{subject to} \quad x \in \mathrm{X}$$

The constraints

Model the Operator

$$\min_{x} \quad J(\cdot)$$
$$\text{subject to} \quad x \in \mathrm{X}$$

How aggressive can real-world traffic be?

Everyone maintains the current states.

$$J(\cdot)$$

Cooperative collision avoidance.

$$\max_{u_0,u_1} J(\cdot)$$

Cooperative collision.

$$\min_{u_0,u_1} J(\cdot)$$

Traffic objects maintain the current states.

Test subject seeks for collision avoidance.

$$\max_{u_0} J(\cdot)$$

Test subject seeks for collisions.

$$\min_{u_0} J(\cdot)$$

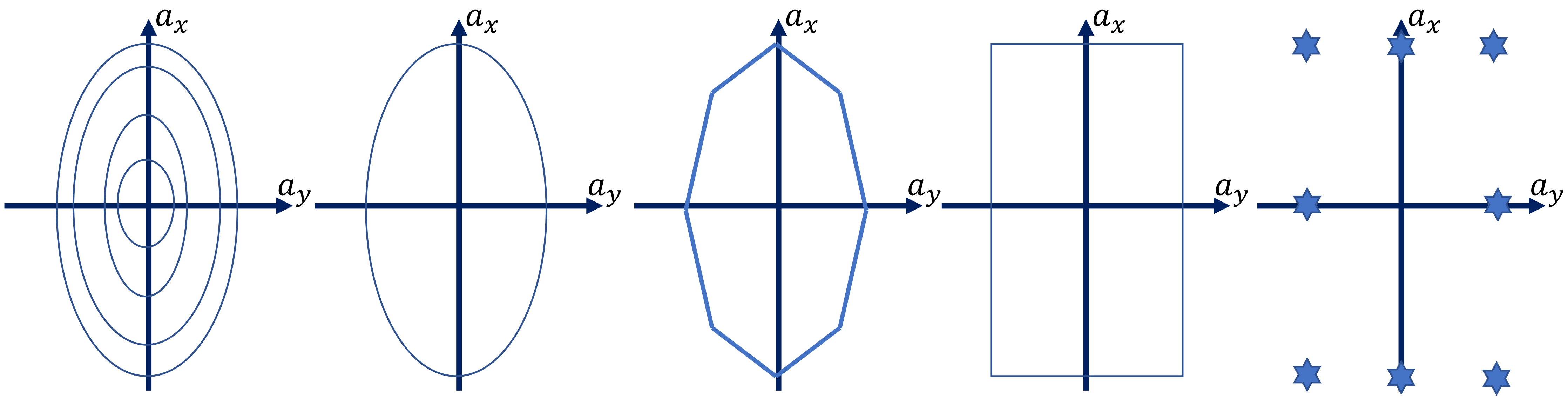
The traffic object creates the worst-case scenario and the test subject seeks for collision avoidance.

$$\min_{u_1} \max_{u_0} J(\cdot)$$

Model the Constraints

$$\begin{aligned} \min_{x} \quad & J(\cdot) \\ \text{subject to} \quad & x \in X \end{aligned}$$

What can a vehicle do?

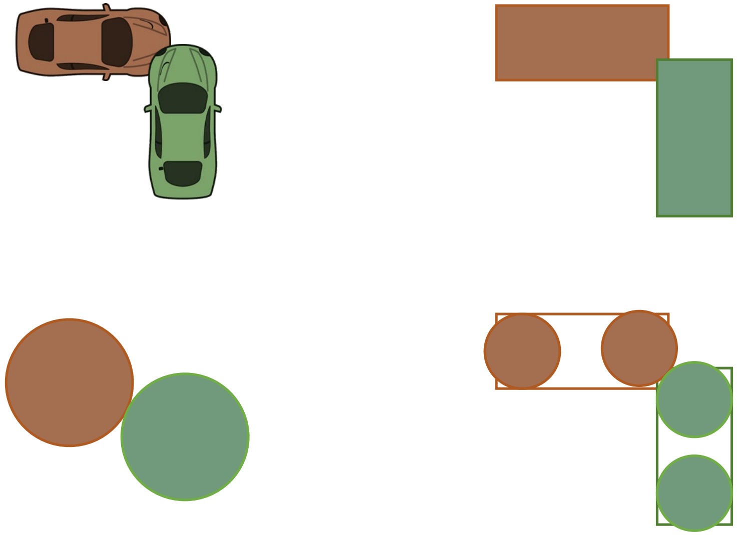


Model the Target Function

$$\min_{x} \; J(\cdot) \quad \text{subject to} \quad x \in X$$

How to model measure of safety?

Collision $J(\cdot) = \inf_{i=1,\dots,k} d(x_i, x_0)$

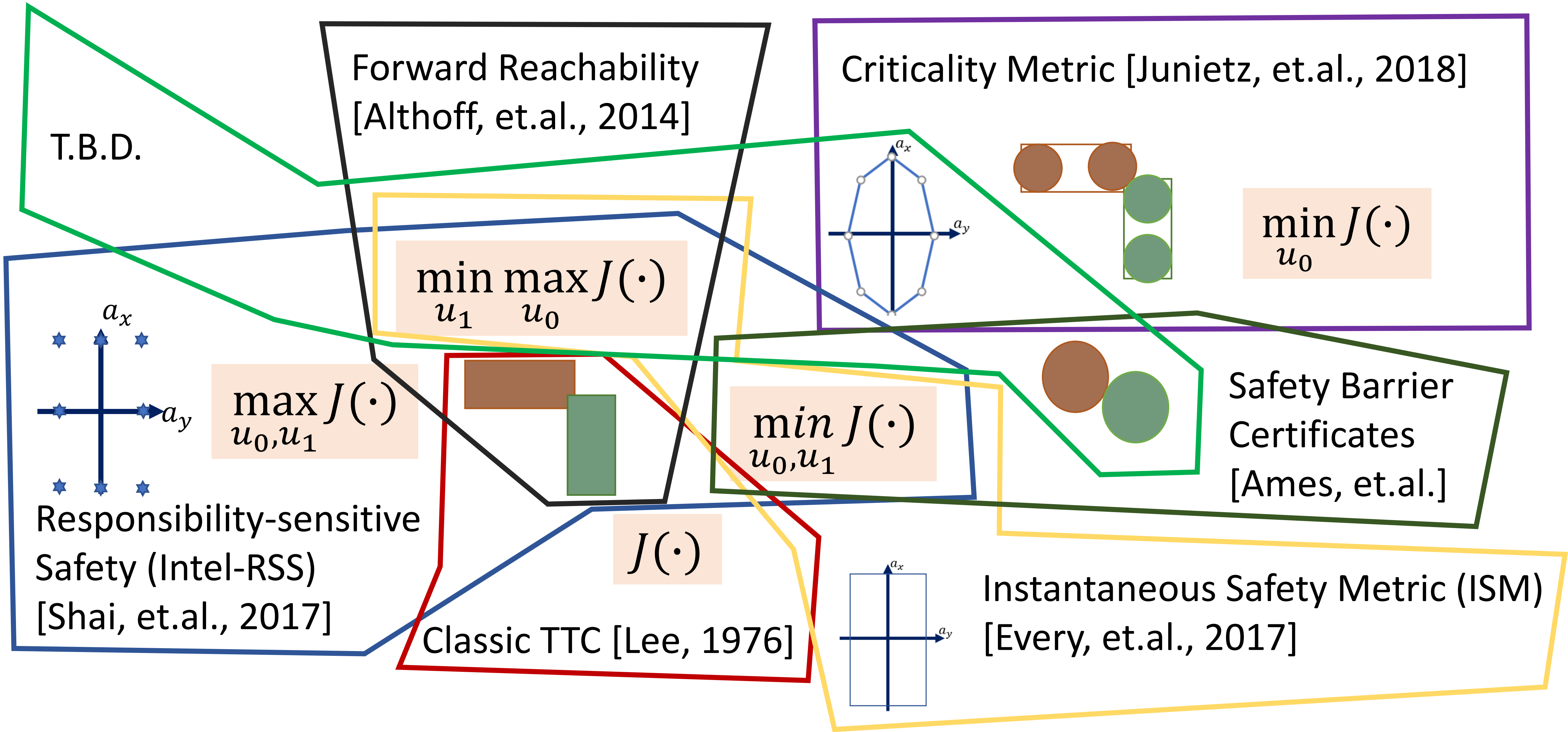


Artificial Target $J(\cdot) = \inf_{i=1,\dots,k} \{w^T R_i\}$

A weighted summation of various safety-related terms

$w_1 \times$ longitudinal margin + $w_2 \times$ lateral margin + $w_3 \times$ longitudinal acceleration + $w_4 \times$ lateral acceleration [Junietz, et.al., 2018]

Proposed Metrics in Context



Observations from Modeled Metrics

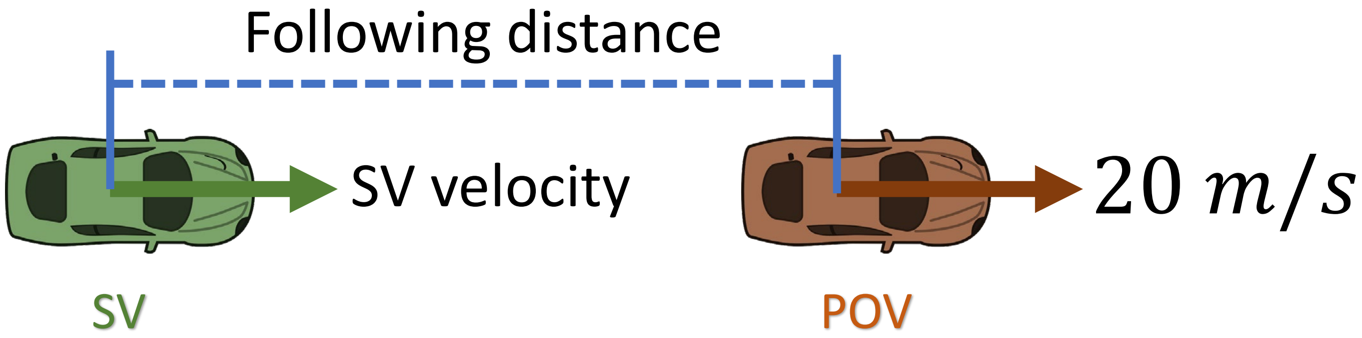
Coupling various designs of components in an optimization and /or constraint fulfillment formulation, one can derive infinitely many ADS safe operation policy alternatives.

Optimization problems are generally non-convex.

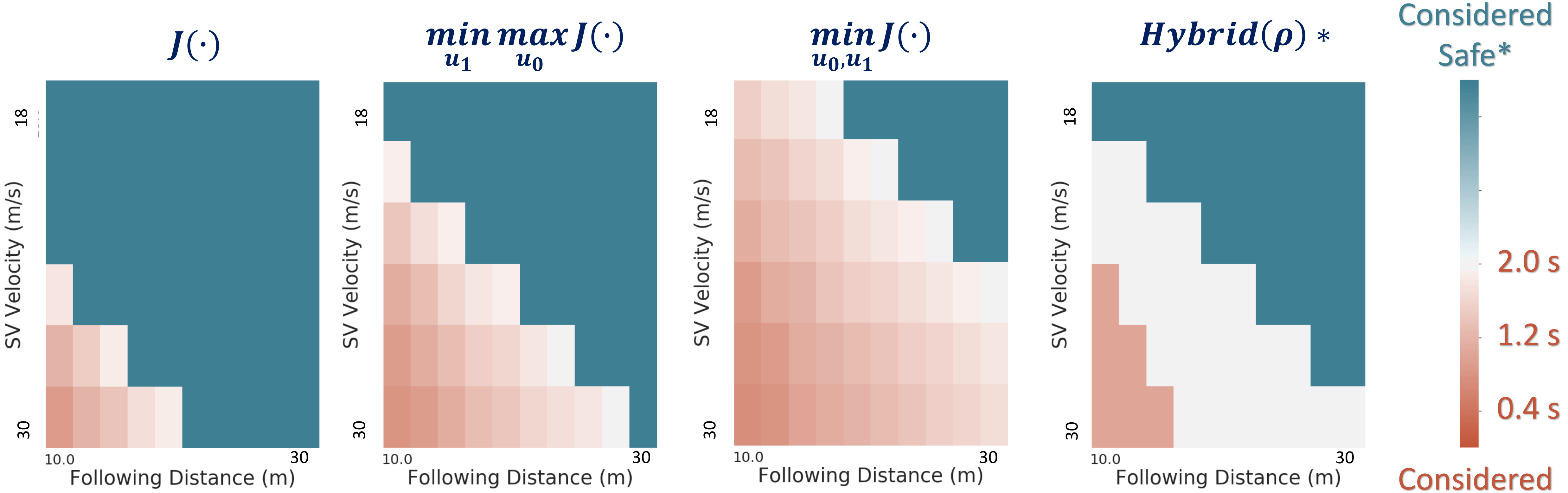
Various simplifications, assumptions are then proposed either explicitly or implicitly to make a trackable solution in practice.

Example: Lead Vehicle Following

The *Lead-vehicle Following* Scenario



Example: Lead Vehicle Following



Everyone maintains the current states.	The traffic object is aggressive.	Everyone is aggressive.

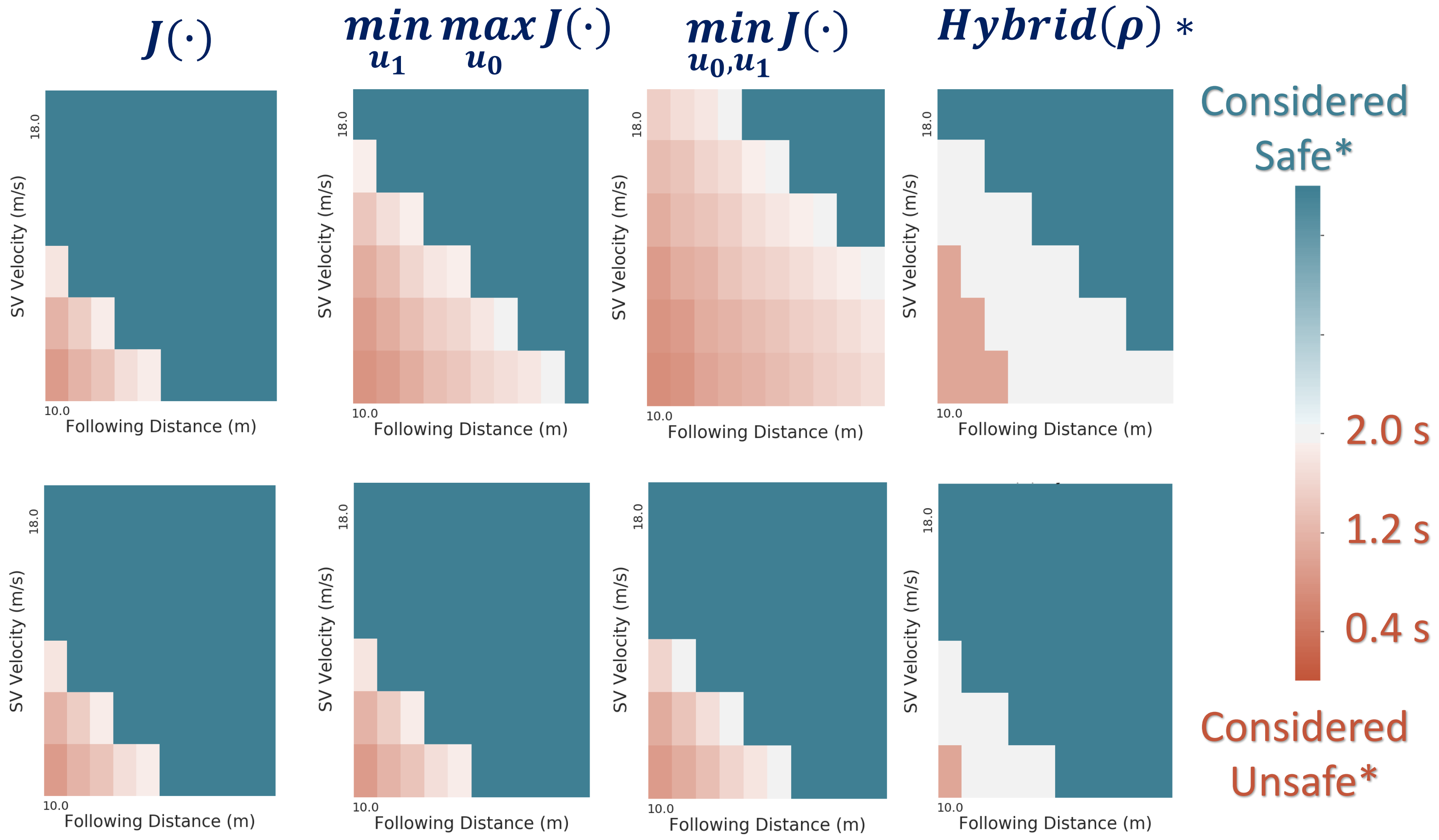
$$* \, Hybrid(\rho) = \begin{cases} \min_{u_0,u_1} J(\cdot, t), J(0) = J_0, & t < \rho \\ \min_{u_1} \max_{u_0} J(\cdot, t-\rho), J(0) = \min_{u_0,u_1} J(\cdot, \rho), & t \geq \rho \end{cases}$$

* With respect to cost function, safe driving policy threshold, established constraints, and optimization method

Example: Lead Vehicle Following

- **EV control profile**: The acceleration capability is a function of velocity determined by a combined analysis of real electrical vehicle tests and simulations.

- **Naive control profile**: The acceleration capabilities are constant for all speeds.



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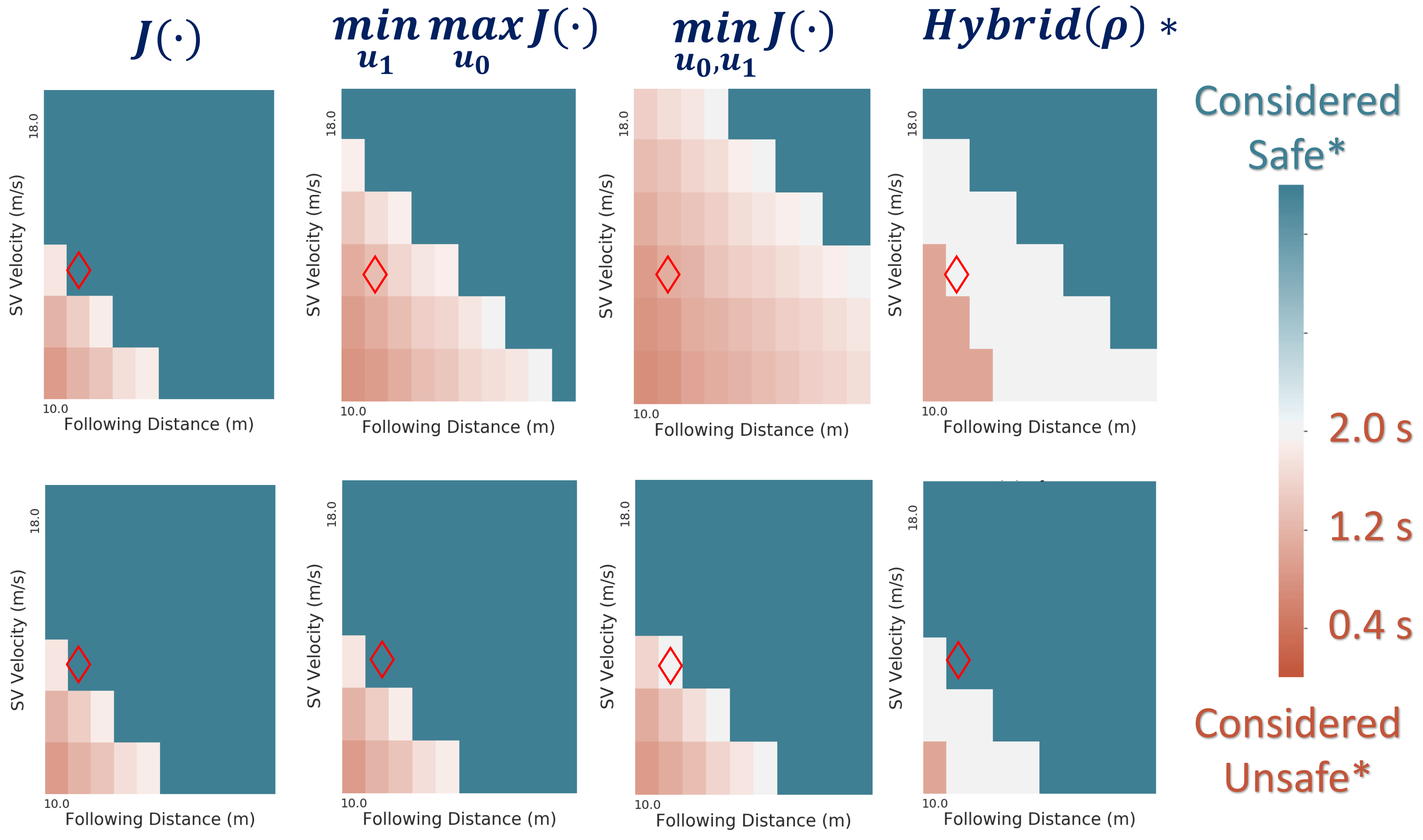
Example: Lead Vehicle Following

Presented with the **same traffic scene**, one can arrive at **completely different safety assessment results** with **different assumptions** of traffic patterns and vehicle control capabilities.



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Preliminary Observations

Establishing a clear, single “ADS safety assessment metric” is not trivial

More considerations are needed to establish meaningful, public acceptable, practical constraints, and cost functions as well as consistent assumptions/simplifications.

A simultaneous solution of multiple driving policies with respect to various metrics could also be considered.

This would need cooperation among multiple engineering and non-engineering disciplines.

Thanks

QUESTIONS