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Scenario-based testing in simulation: Sensitivity analysis of traffic modeling and its influence on the exposed failure regions

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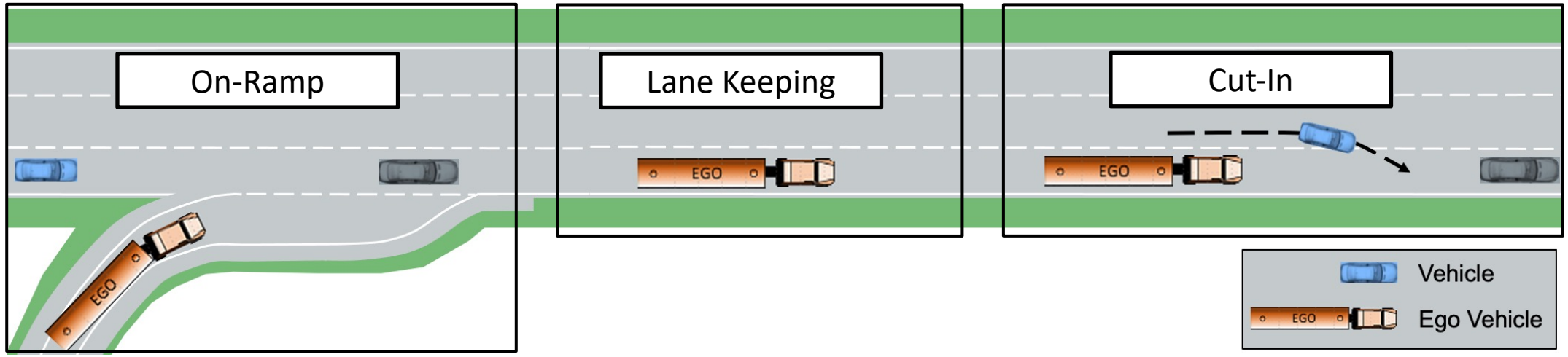
We‘ve got strong brands around the globe

Challenges of Safety Assessment for Highly Automated Driving

- Billions of test kilometers are required to proof the probability of failure of a highway pilot [Winner]
- Not possible only with field tests
- Usage of simulation in addition to field tests
- Scenario-based testing



Agenda

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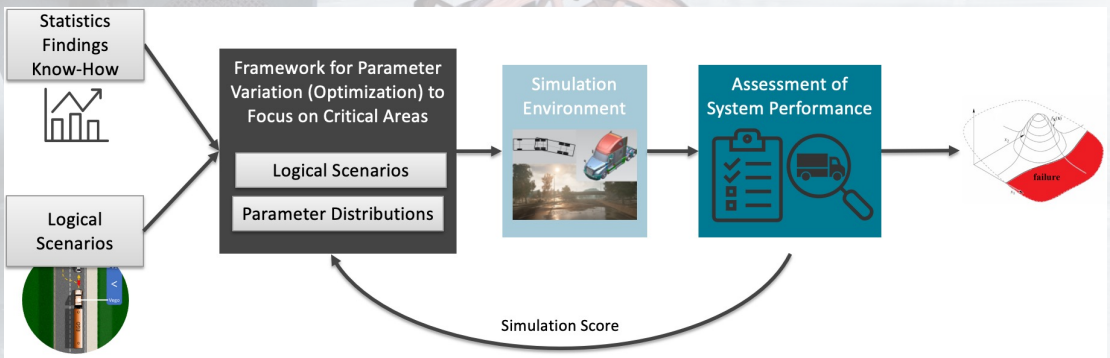
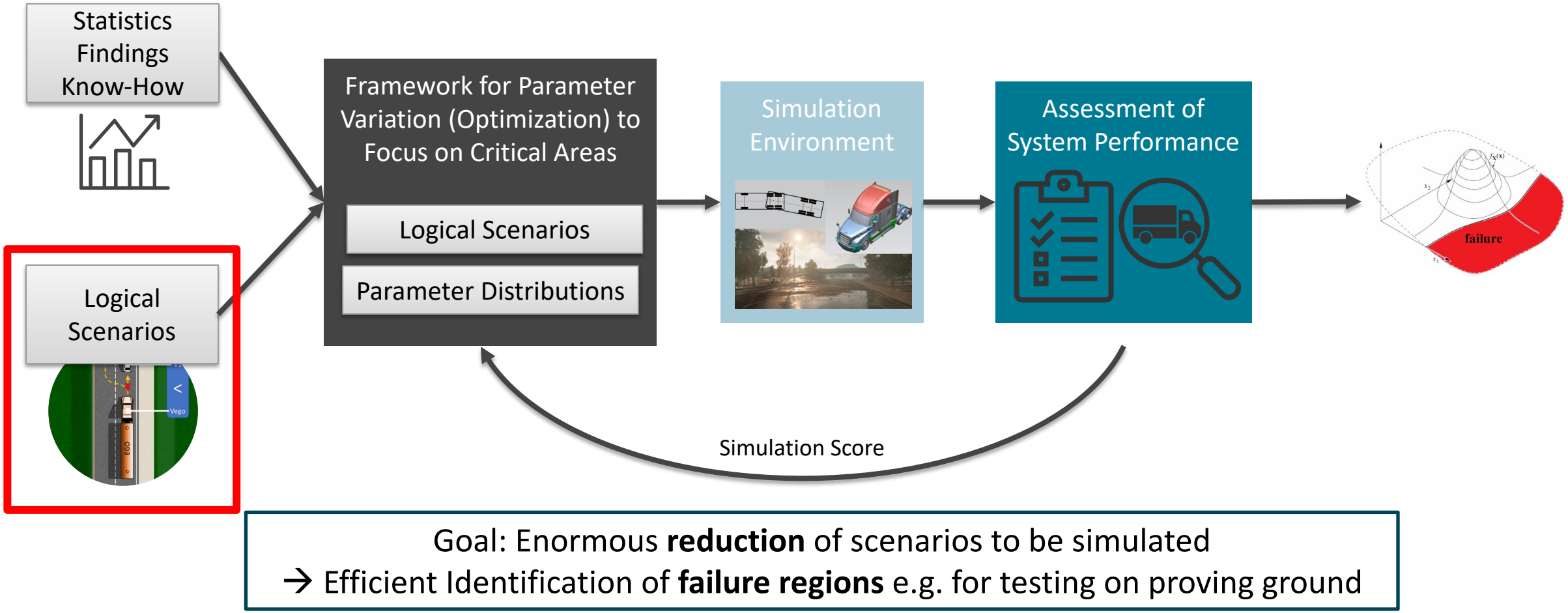
1. Framework for Parameter Variation
2. Logical Scenario On-Ramp
3. Traffic Modeling
4. Sensitivity Analysis of Traffic Modeling
5. Use as a Development Tool
6. Summary



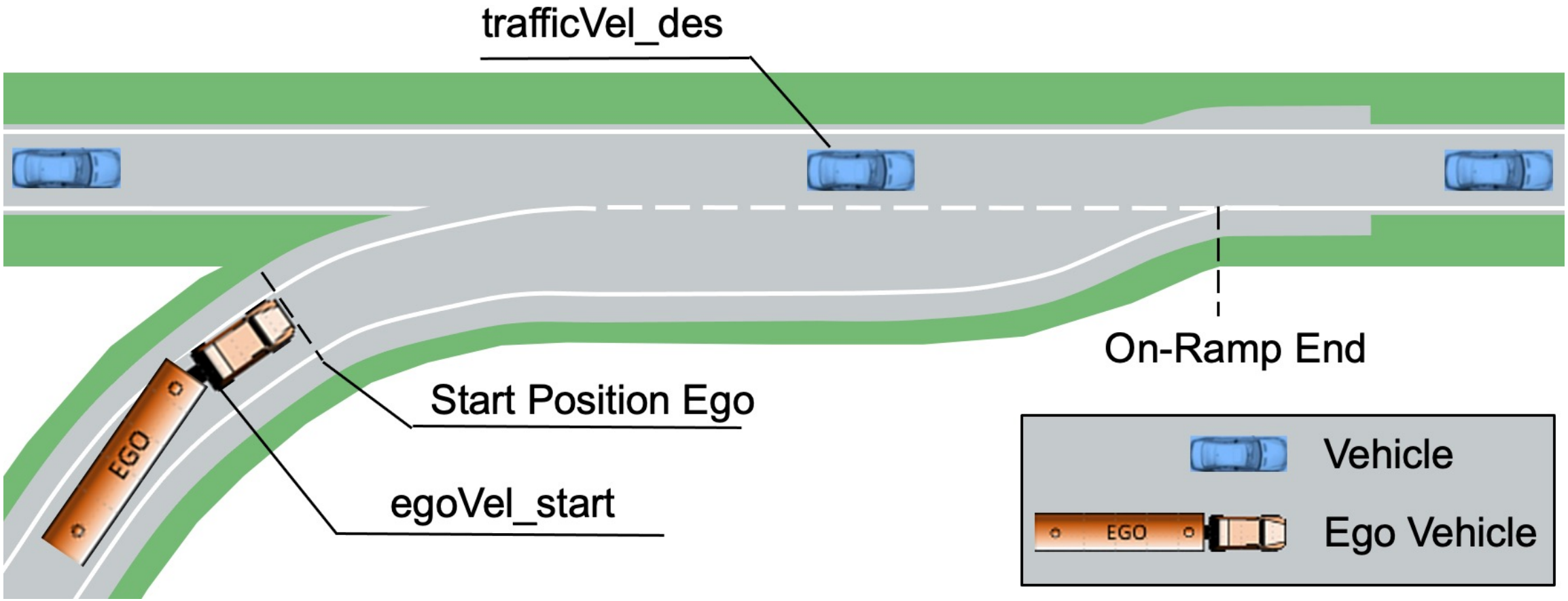
1. Framework for Parameter Variation



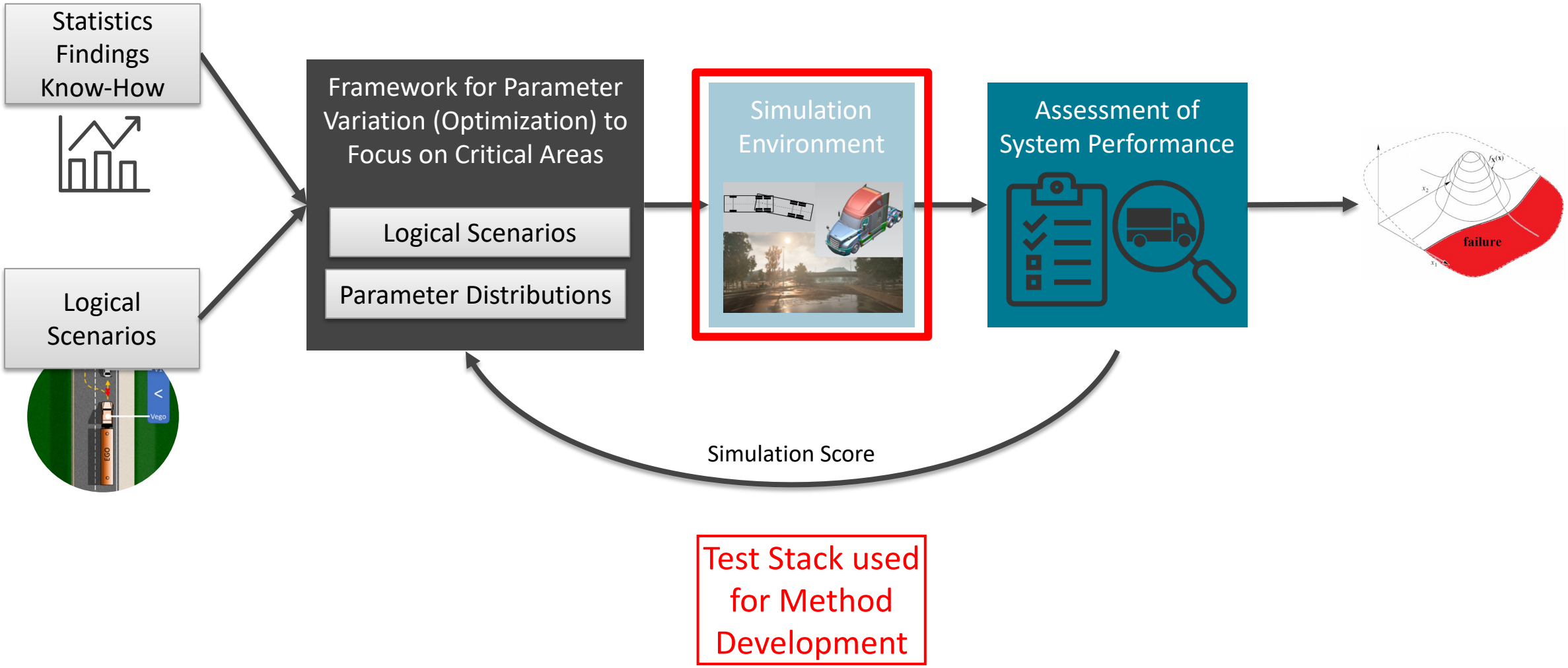
Goal: Enormous **reduction** of scenarios to be simulated
→ Efficient Identification of **failure regions** e.g. for testing on proving ground

[Rasch, Maximilian & Ubben, Paul & Most, Thomas & Bayer, Veit & Niemeier, Roland. (2019). Safety Assessment and Uncertainty Quantification of Automated Driver Assistance Systems using Stochastic Analysis Methods. NAFEMS World Congress, Canada]

2. Logical Scenario On-Ramp

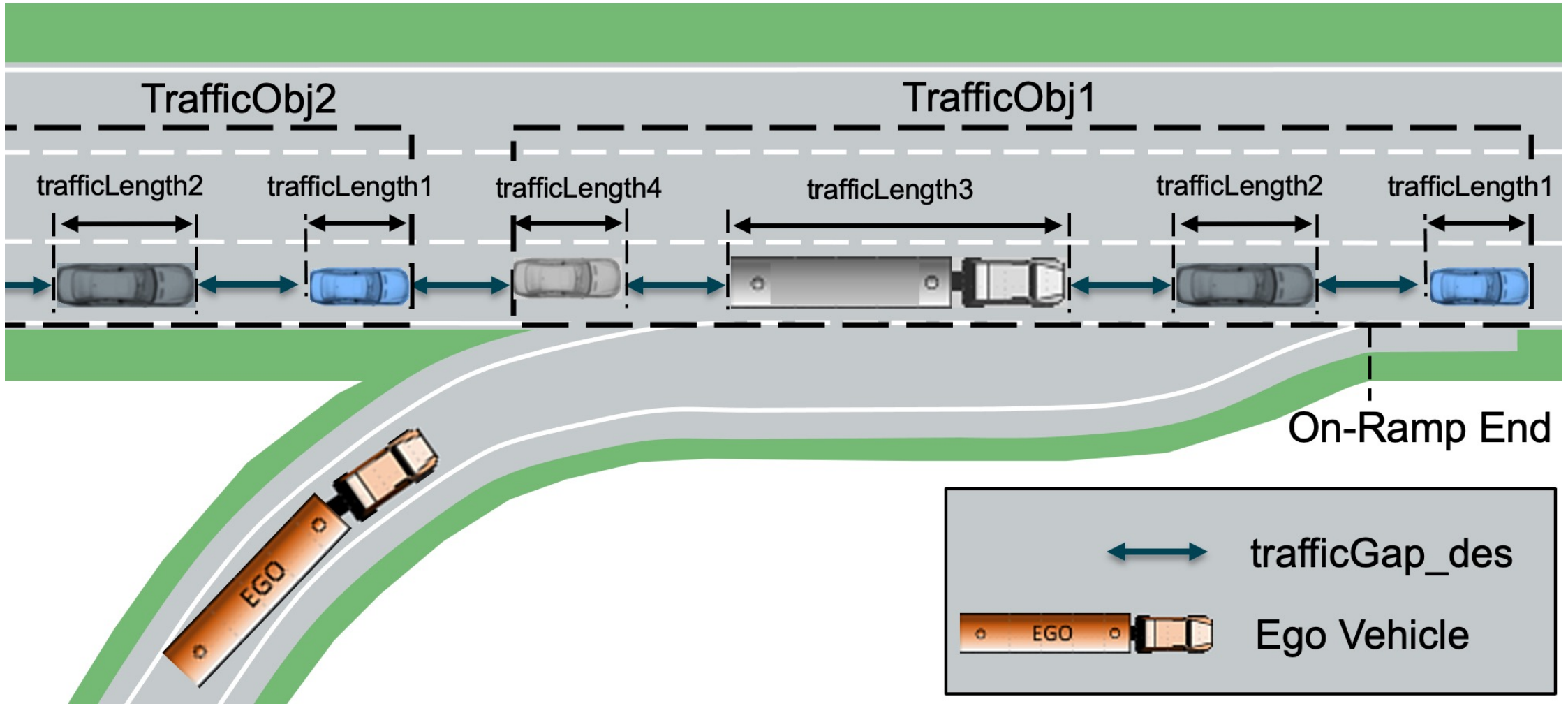


Framework for Parameter Variation

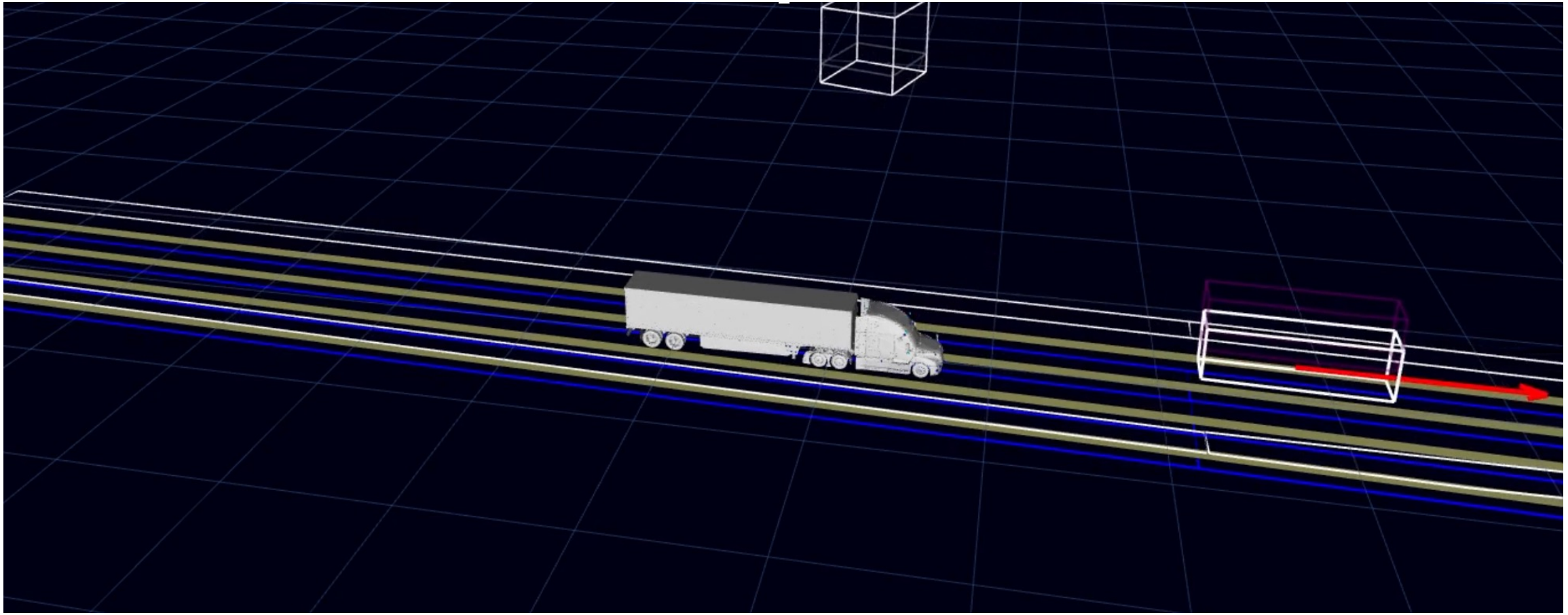


Test Stack used for Method Development

3. Traffic Modeling



3. Simulation Environment



3. Intelligent Driver Model (IDM)

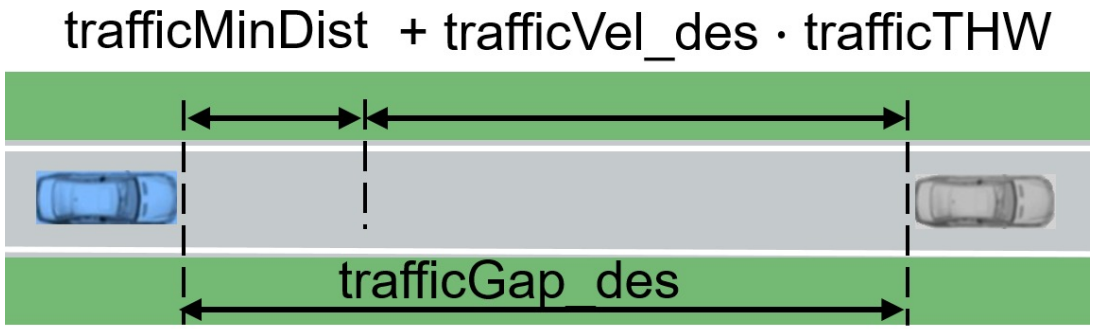
- Continous and accident-free traffic model

Modification of the traffic modeling:

- IDM is an accident-free model -> unrealistically high vehicle deceleration
  - ➢ **Limitation of the braking acceleration b**

3. Intelligent Driver Model (IDM)

- Desired gap size:



$$\text{trafficGap\_des} = \text{trafficMinDist} + \text{trafficVel\_des} \cdot \text{trafficTHW}$$

- Steady-state gap s_g for $\dot{v} = \Delta v = 0$:

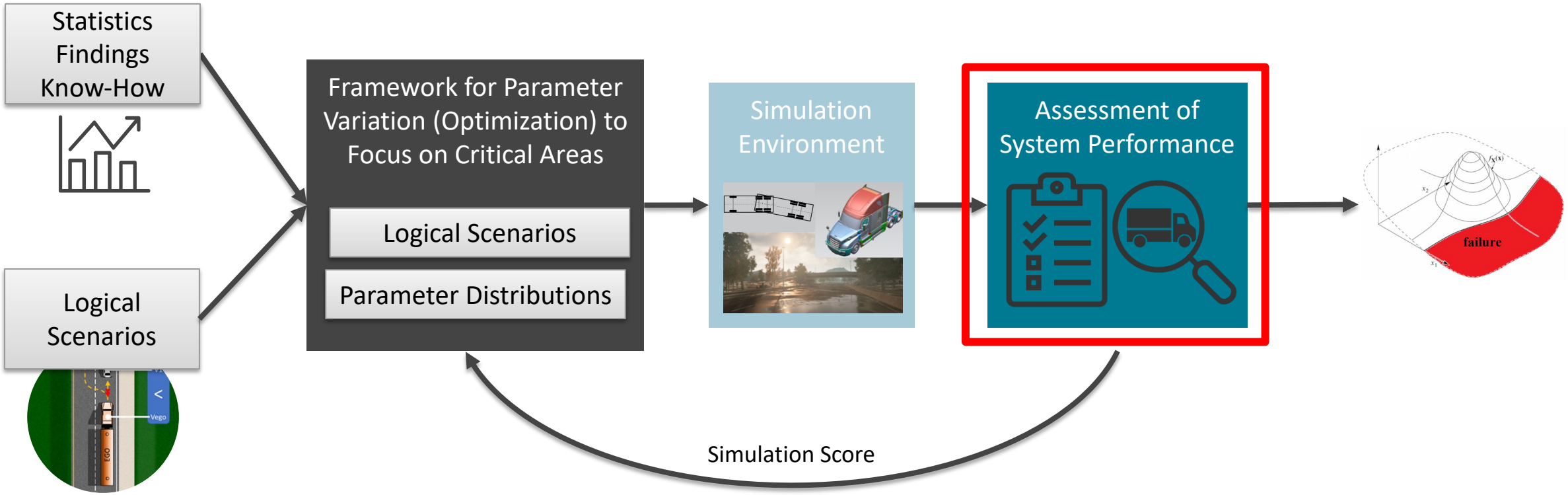
$$s_g \gg \text{trafficGap\_des} \quad \text{für } v \approx \text{trafficVel\_des}$$

Modification of the traffic modeling:

- **Limitation of the vehicle sight distance:**

$$d_{\text{lim}} = \min(\text{trafficGap\_des}, d_{\text{max}})$$

Framework for Parameter Variation

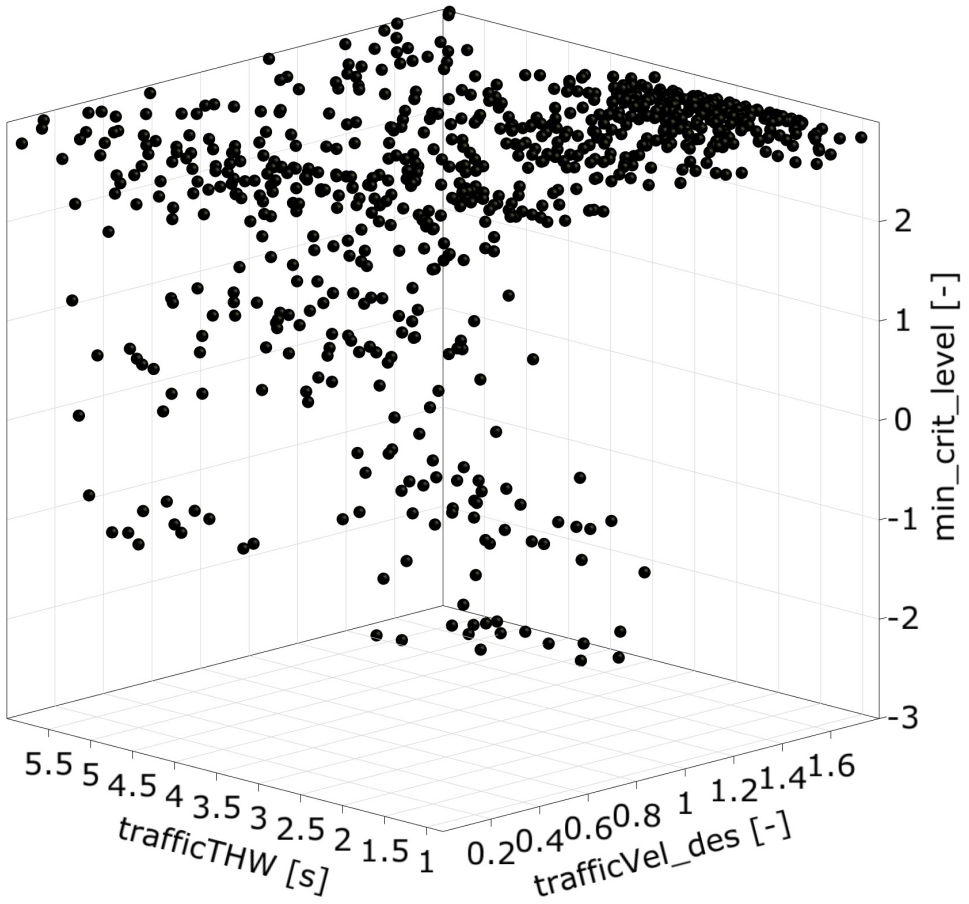


4. Criticality Level to Assess the System Performance

Level 3
No collision
Uncritical

Level 0
Collision
None to slight damage

Level -3
Collision
High severity



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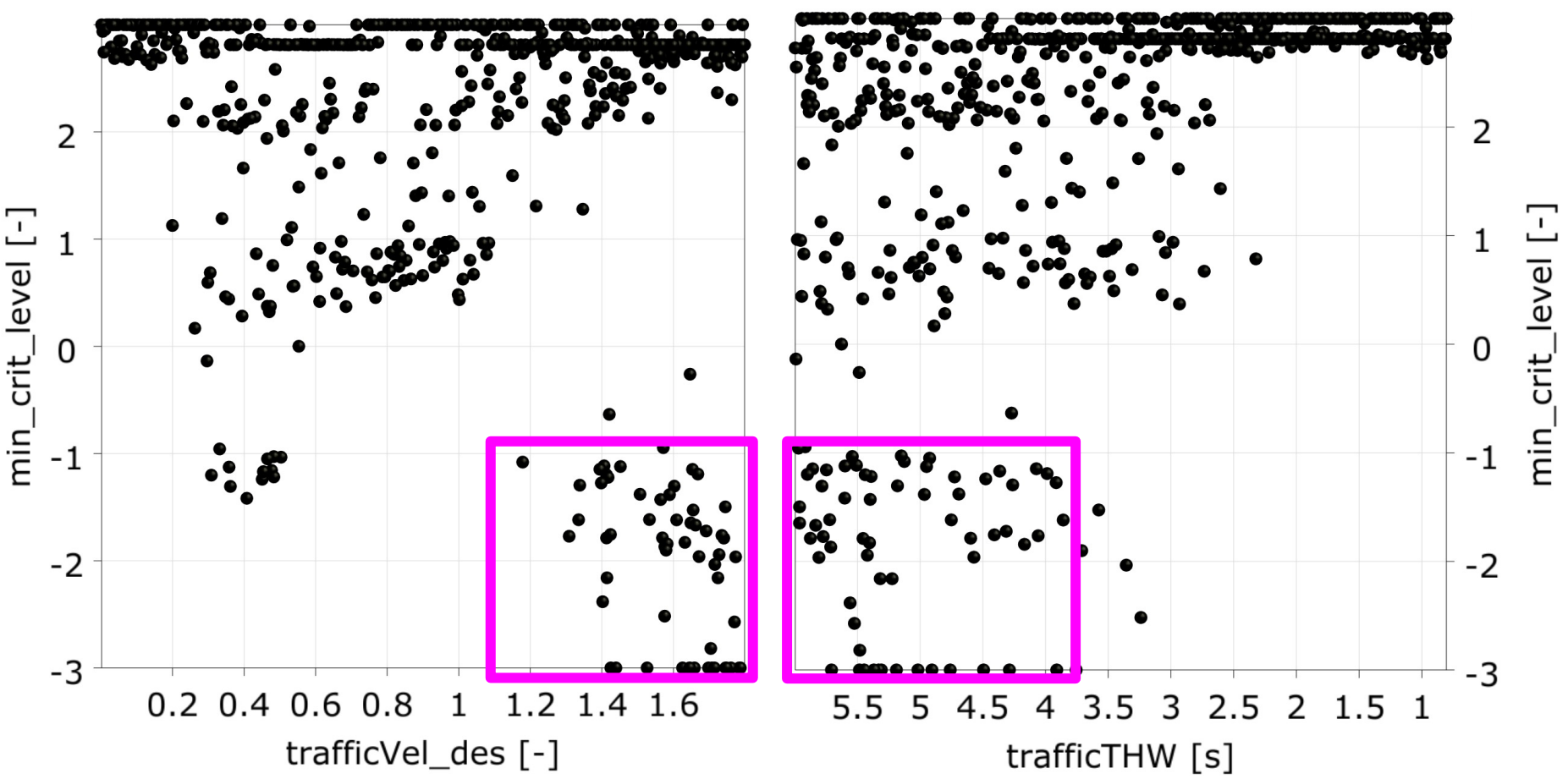
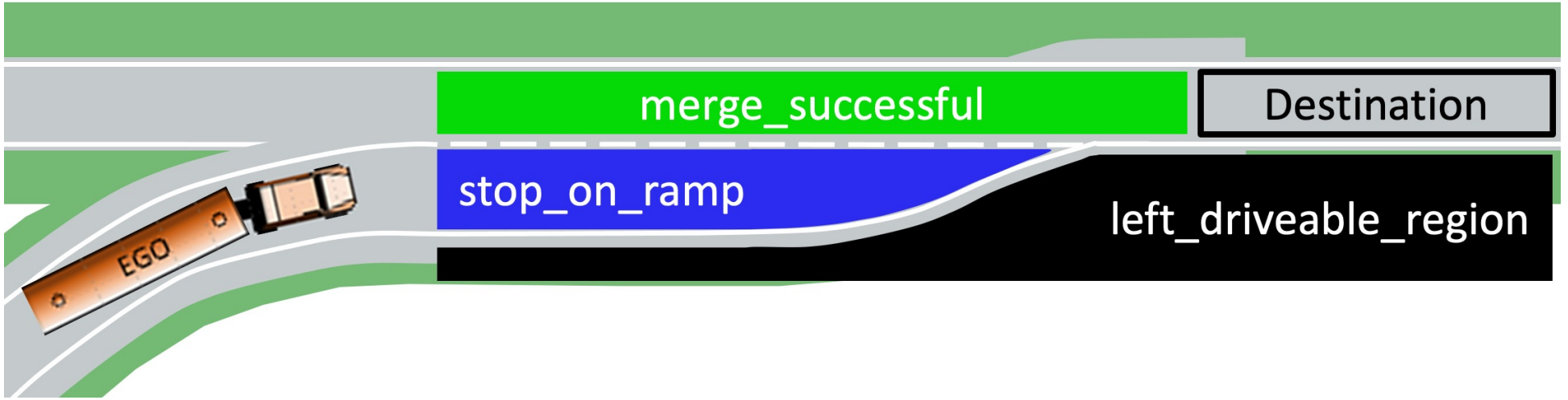
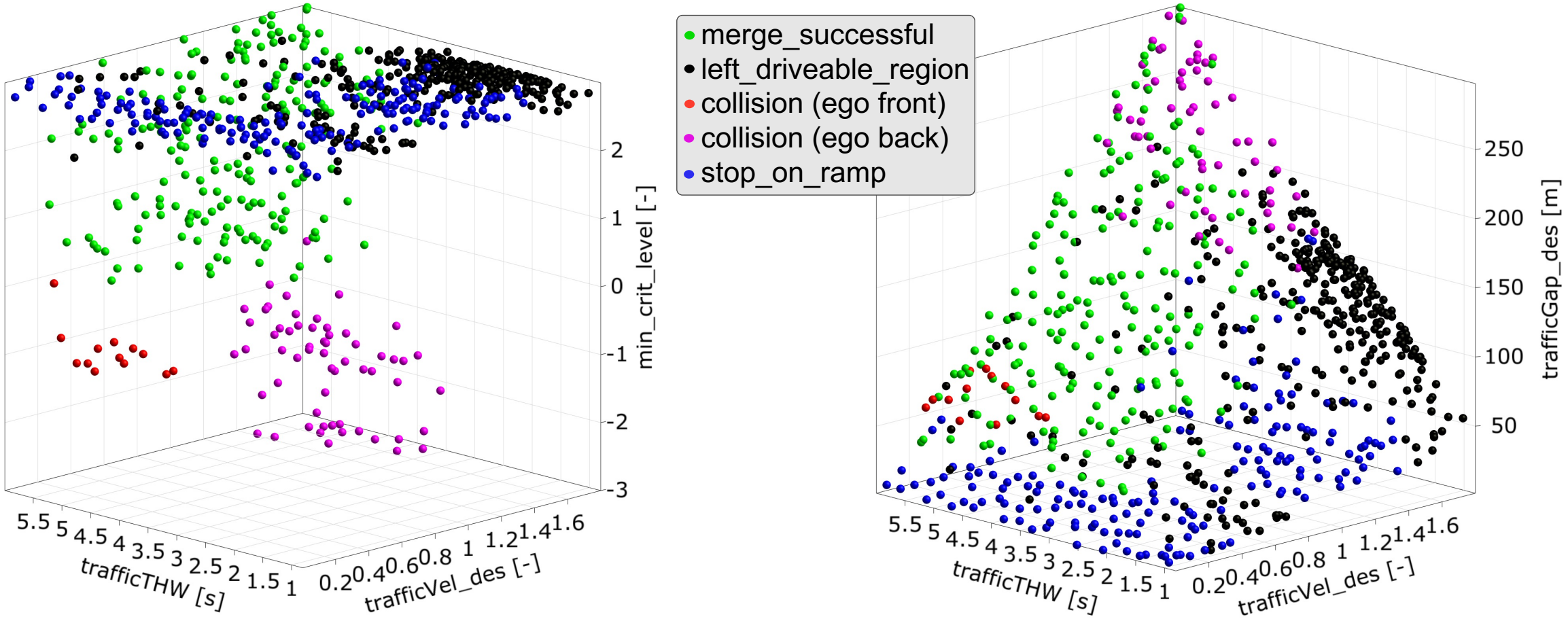


4. Introduction of a Classification of Scenario Results

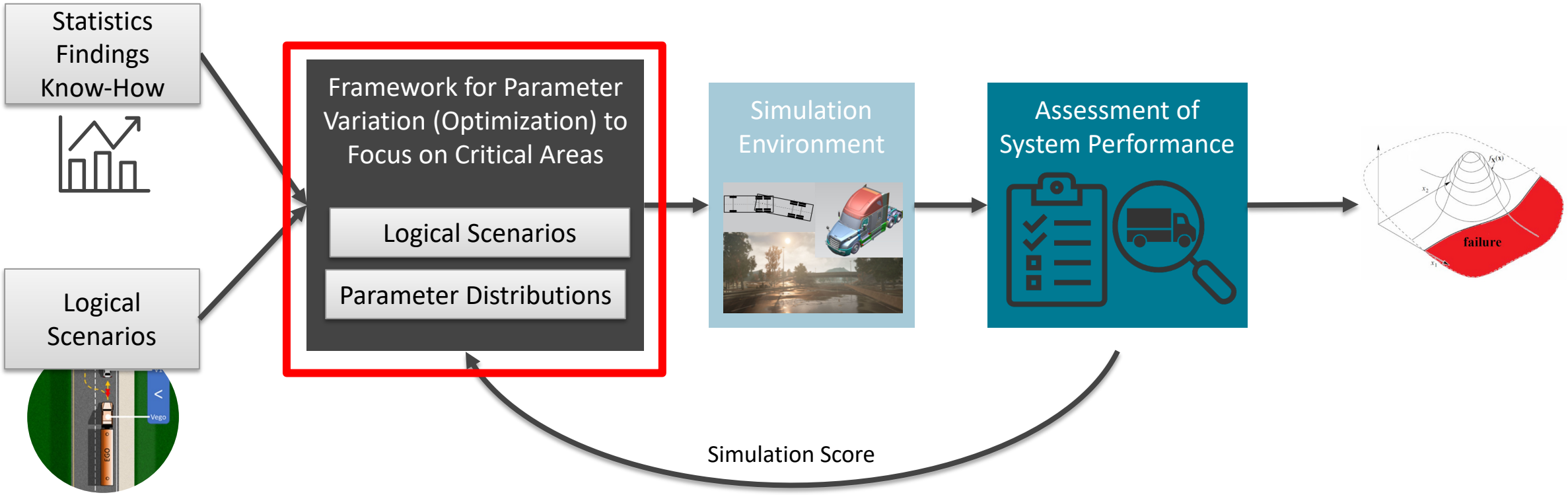
- Observer implemented in the simulation environment
- Qualitative classification of vehicle behavior



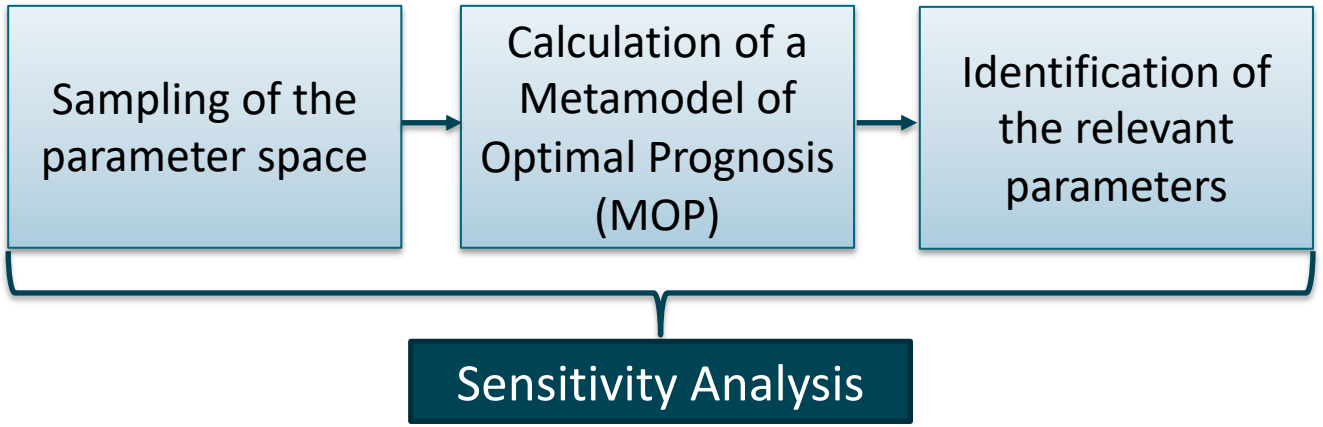
4. Parameter Variation Results with Classification

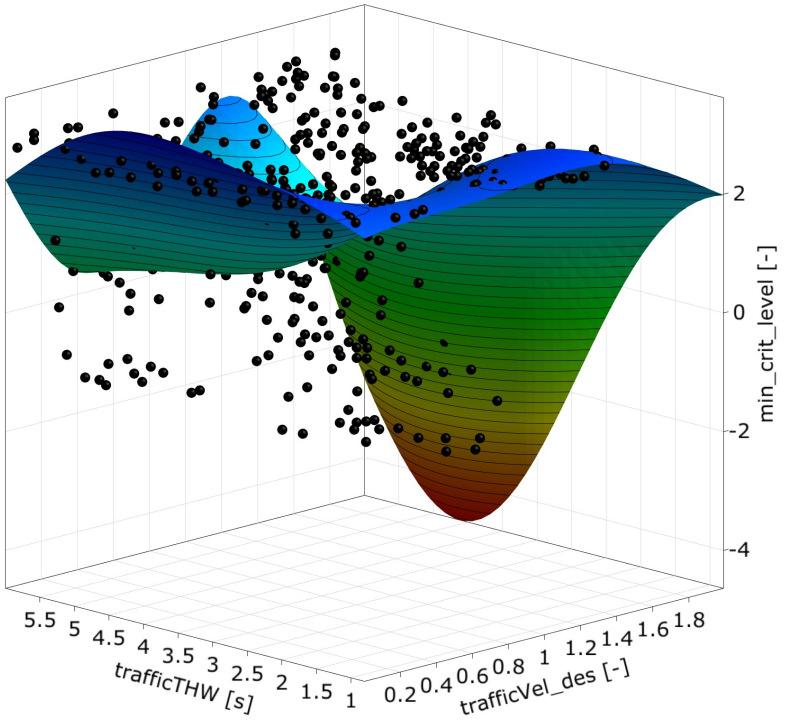


Framework for Parameter Variation



4. Sensitivity Analysis of Traffic Modeling





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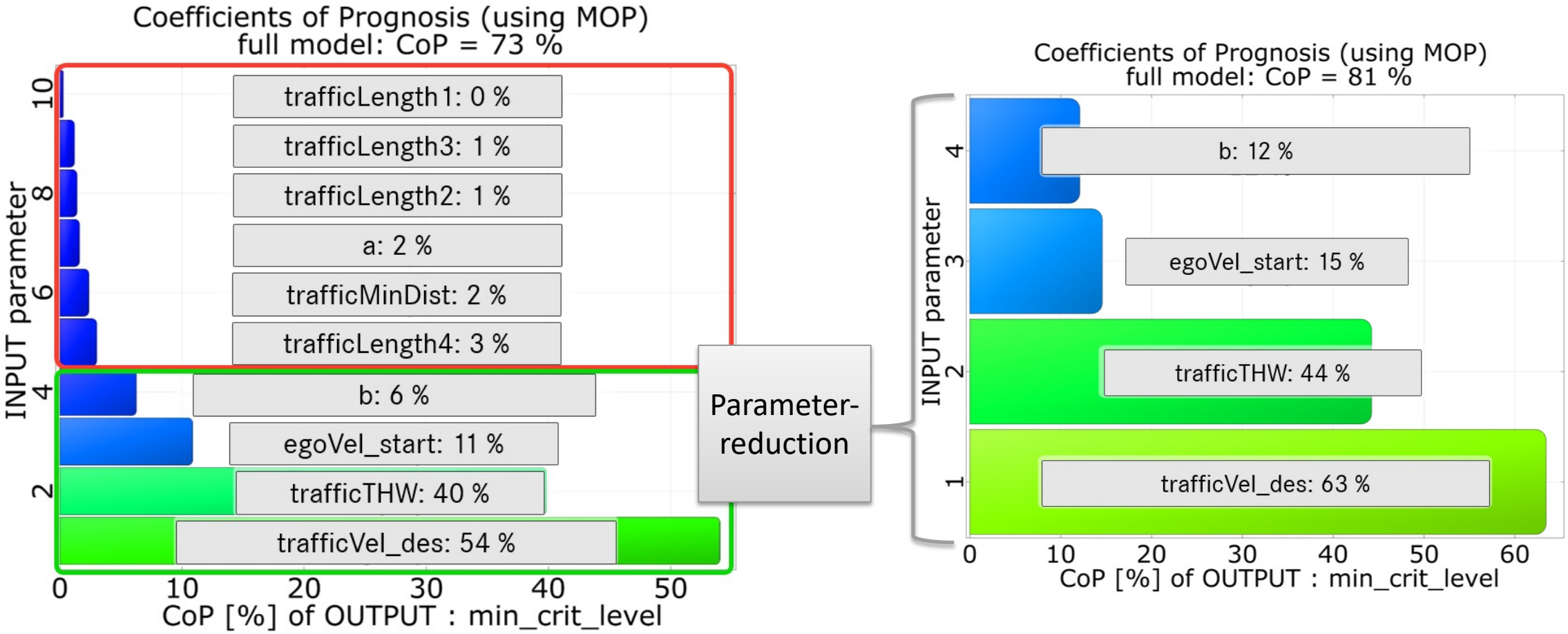
4. Identification of the relevant Parameters



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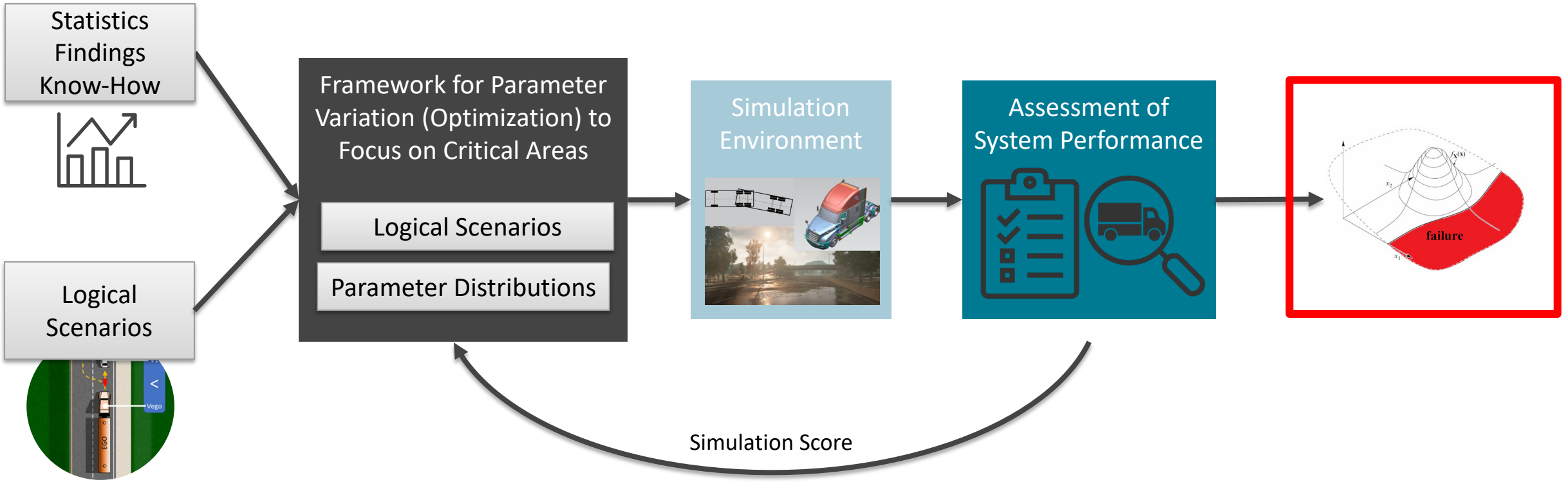
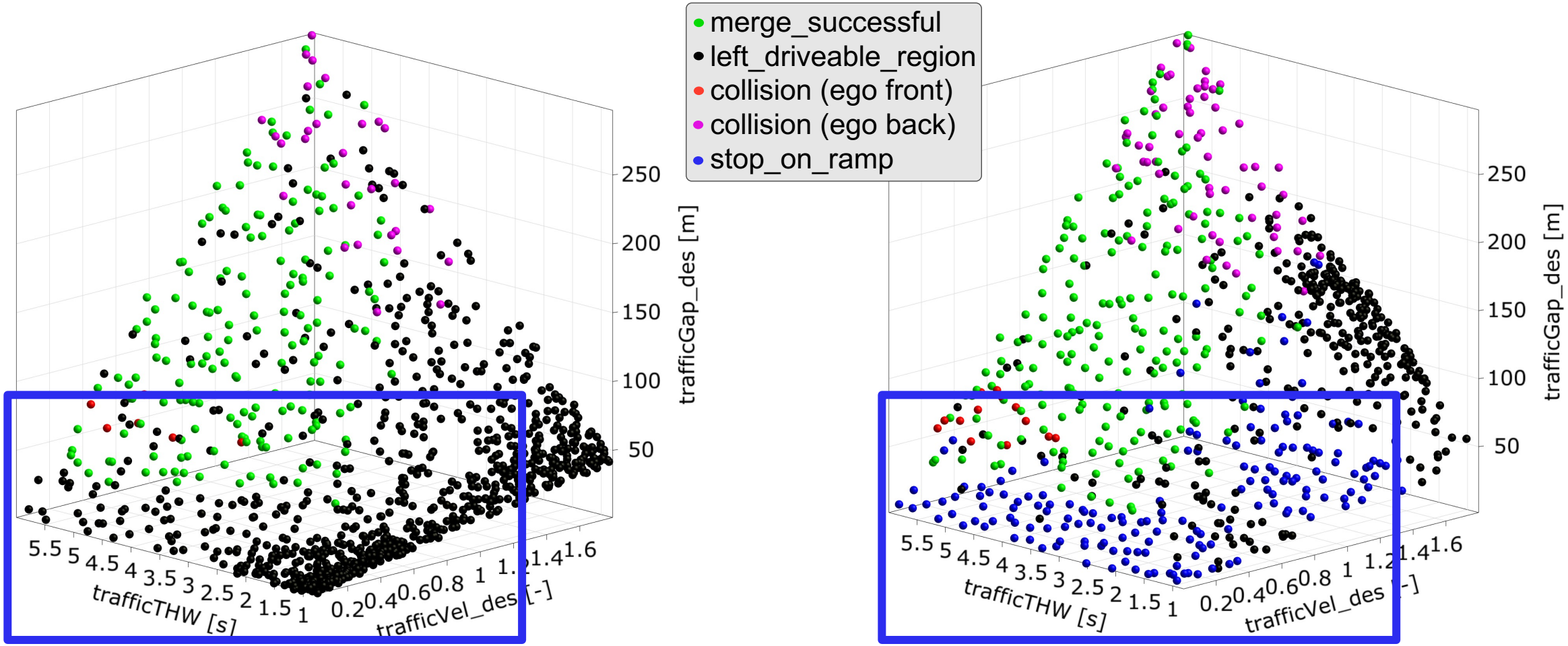


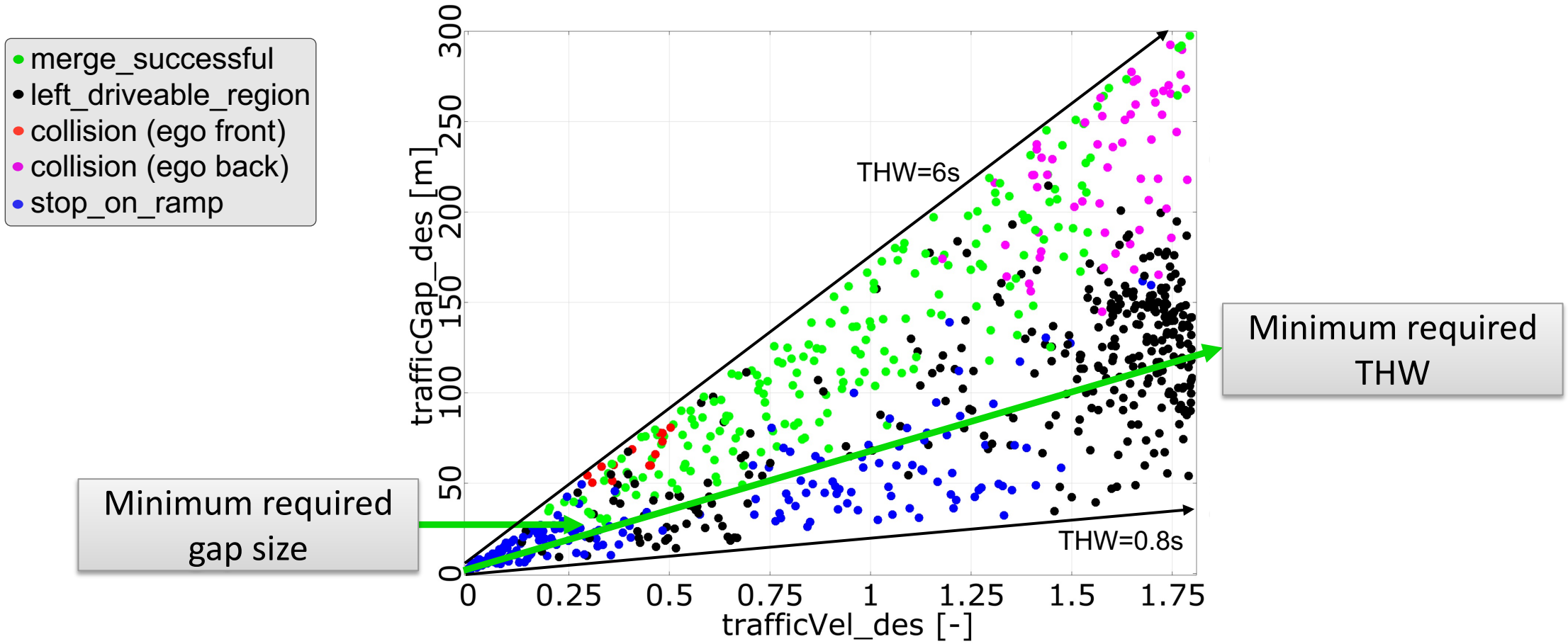
5. Comparison of Development Versions

- Evaluate the impact of new features in development



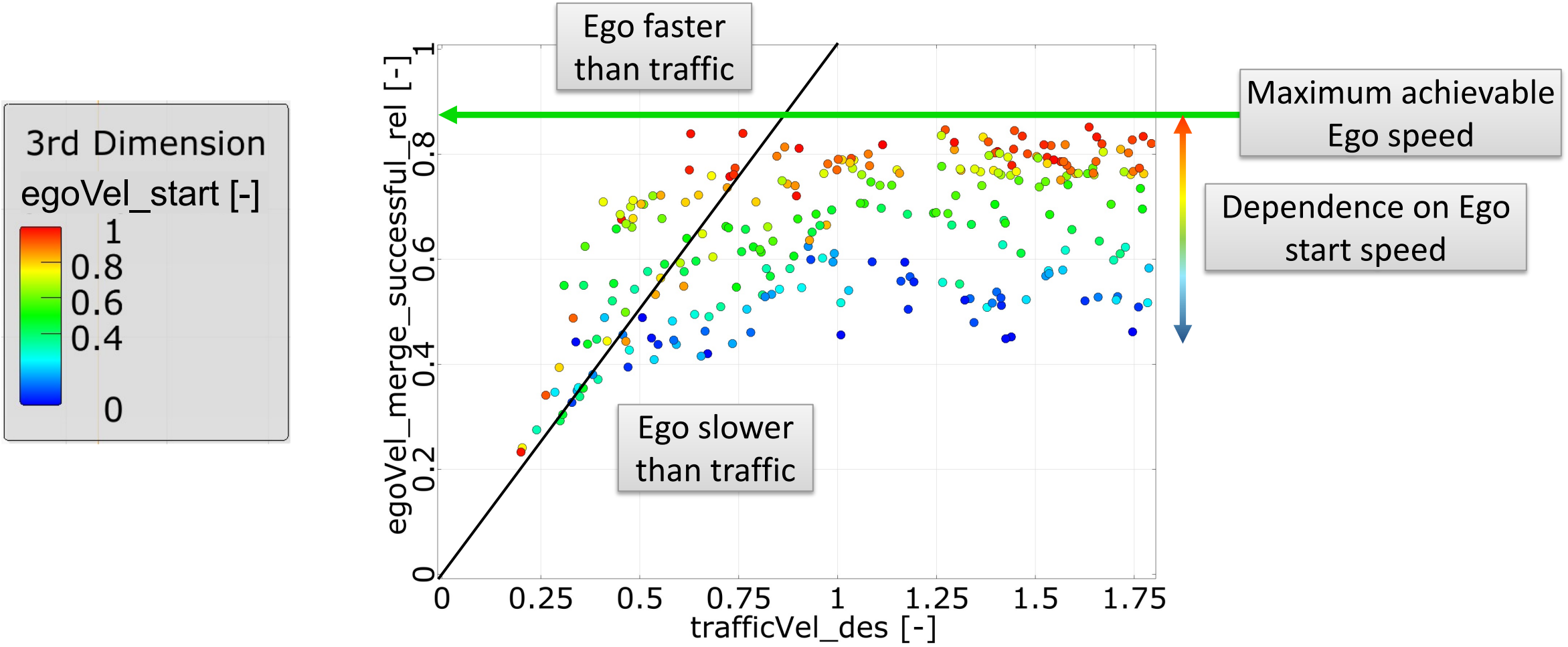
5. Analysis of Vehicle Behavior

- Examine the influence of traffic speed and THW on the identified regions



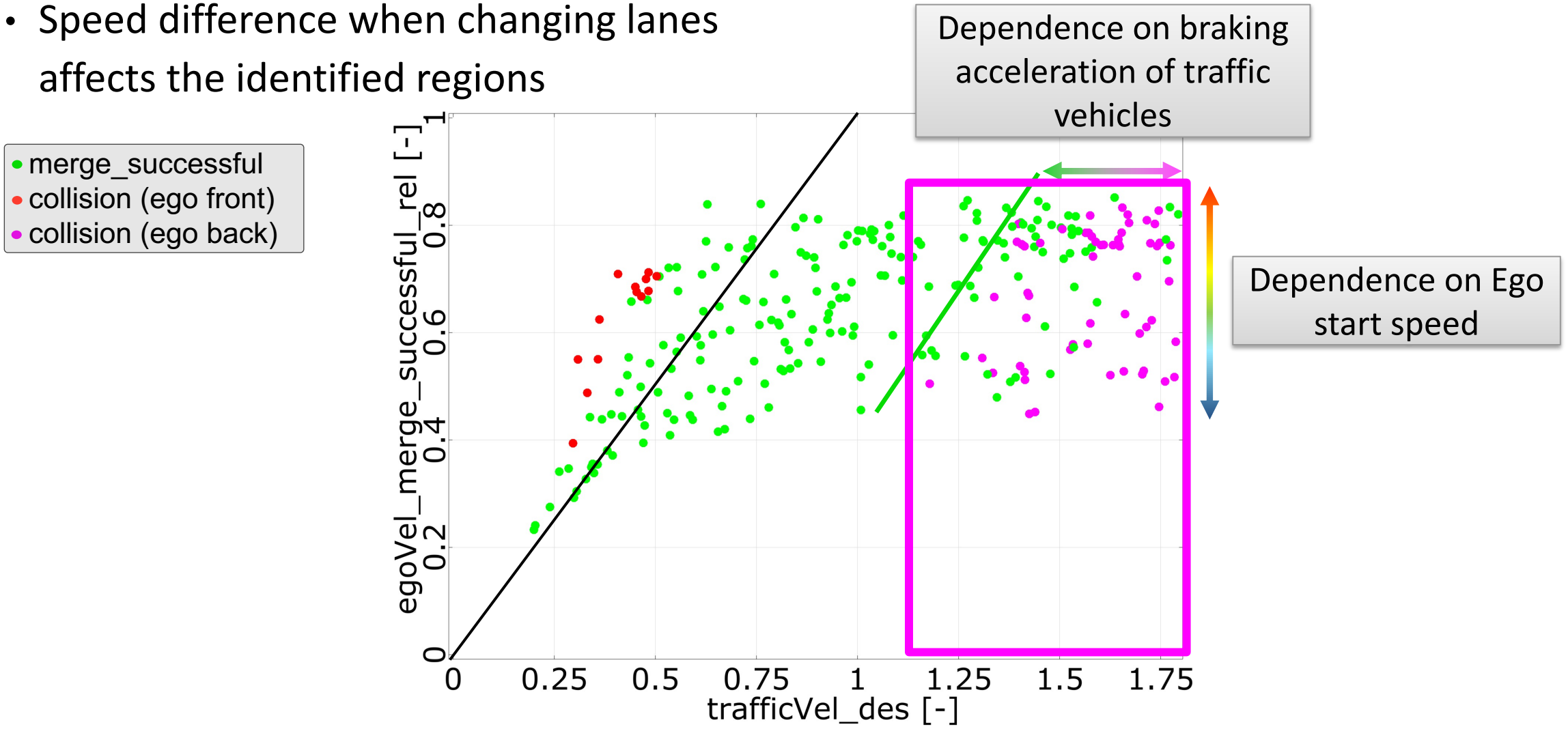
5. Influence of the Ego Start Speed

- Speed of the Ego at the time of the lane change for performed merges



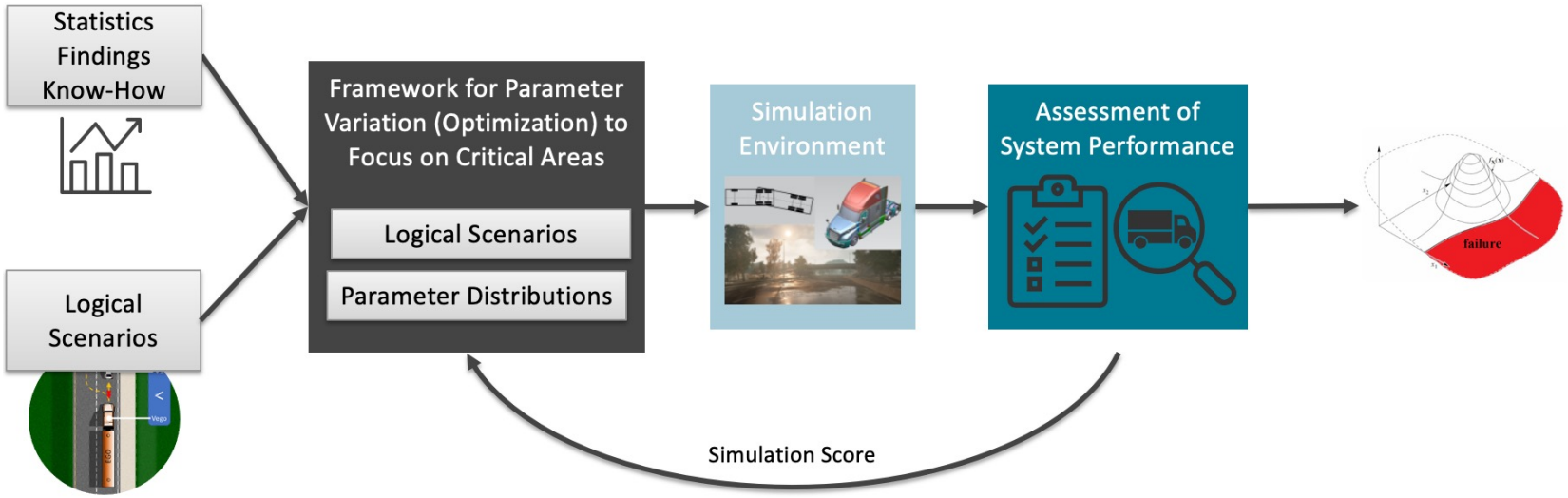
5. Influence of the Traffic Braking Acceleration

- Speed difference when changing lanes affects the identified regions



6. Summary

- Clear classification of scenarios with qualitative metrics
- Testing tool to identify possible failure regions and visualize results for functional development
- Ability to analyze the dependence of the failure regions on the parameters



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Thank you for your attention!