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Advances on the Criticality Analysis for Automated Driving Systems

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PROJECT of the PEGASUS FAMILY

VERIFICATION VALIDATION METHODS

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Federal Ministry for Economic Affairs and Climate Action
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Criticality Analysis in the VVM Assurance Framework

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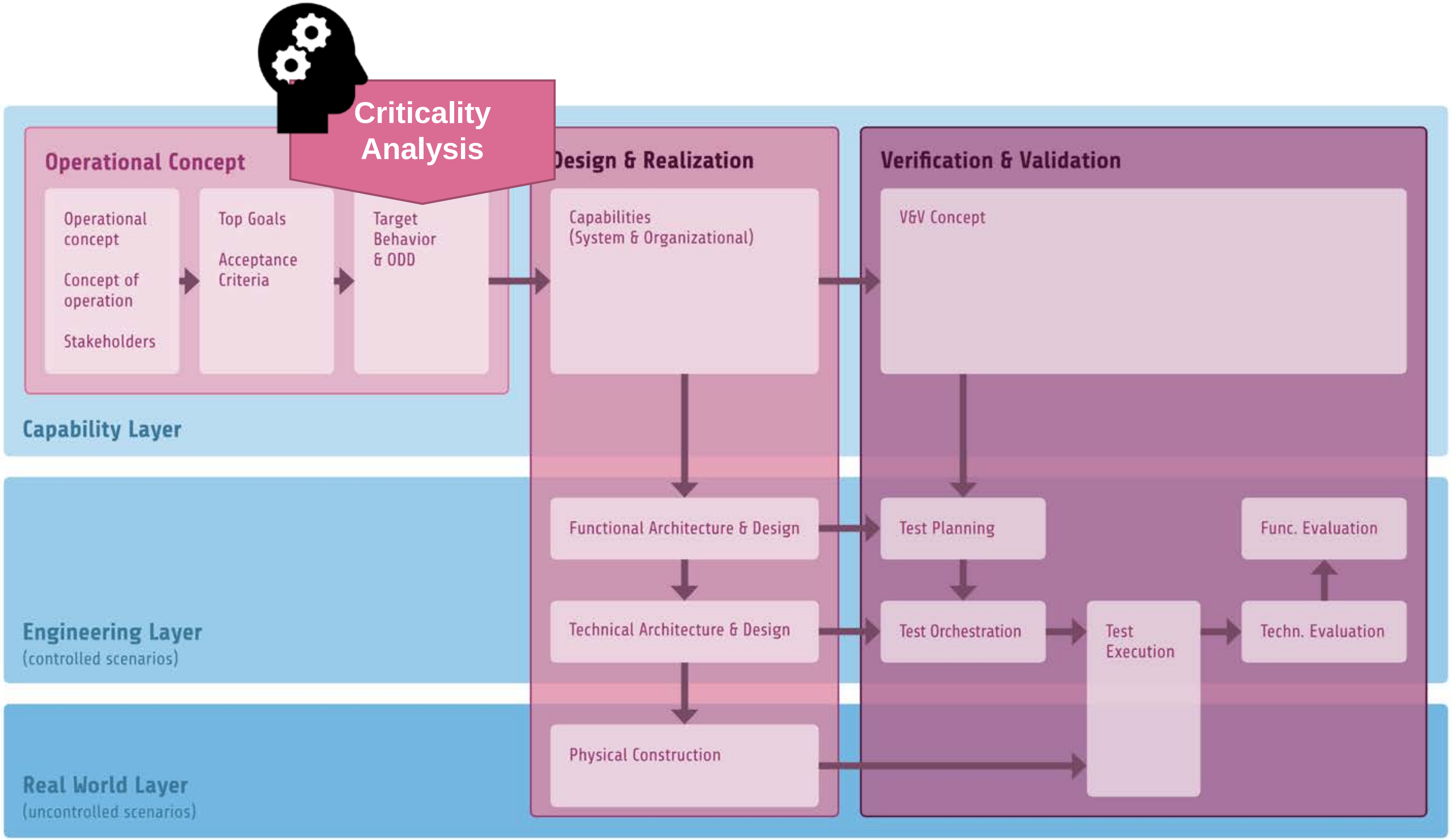


Criticality Analysis in VVM

- **Criticality** (of a traffic situation) is the combined risk of the involved actors when the situation is continued **[1]**

- **Main Goal:** decomposition of **operational domain** (OD) w.r.t. **criticality**
  - Identification and formalization of influencing factors associated with increased criticality → **criticality phenomena** (CP)
  - Improve understanding of criticality phenomena by analysis of underlying **causal relations** → derivation of **target behavior & ODD**
  - Abstraction leads to classification of scenarios
    → **contribution** to **scenario-based verification & validation**

- **Employed Tools for Criticality Analysis:**
  - Ontologies, criticality metrics, simulation
  - Acquisition & management of knowledge and data
  - Data Analysis, causal inference

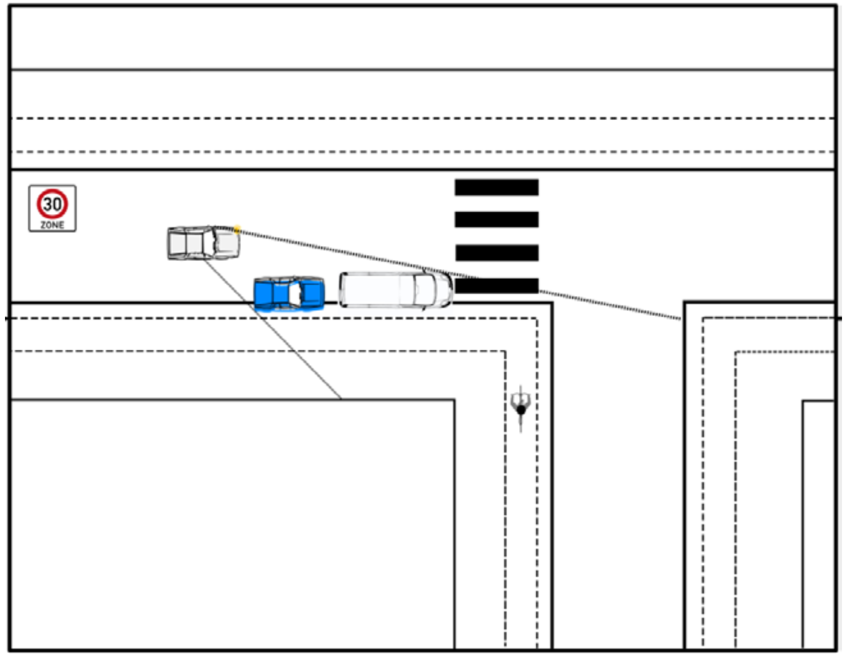
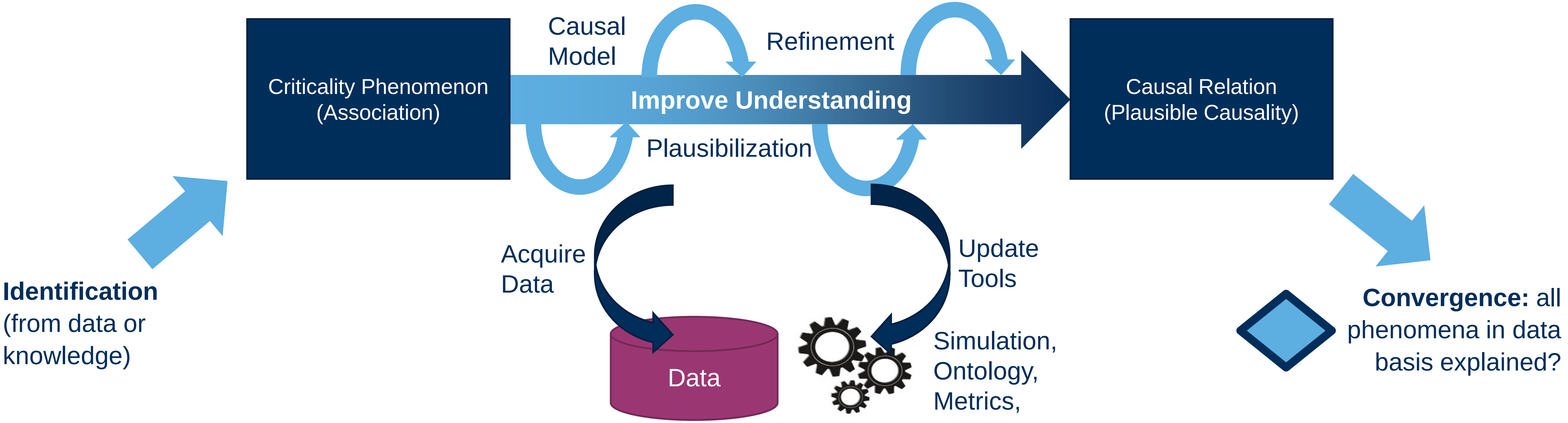


Figure: Urban intersection scenario with occlusion (© Neurohr et al. **[1]***)*

Criticality Analysis – Basic Concept



Assumptions:

- set of criticality phenomena is limited and manageable → *finiteness of artefacts*
- relevant phenomena leave traces in growing data basis → *saturation of artefacts*

Example: from Association to Causality

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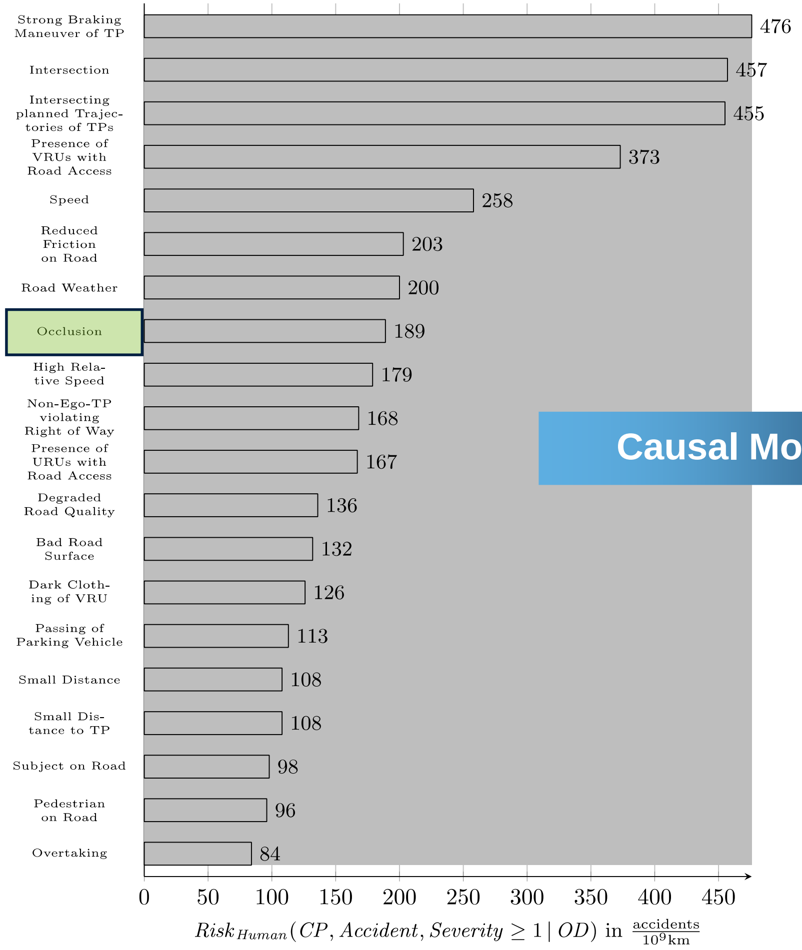


Figure: Highest human risk CP in urban areas according to GIDAS (© Babisch et al. [6])

Causal Modeling

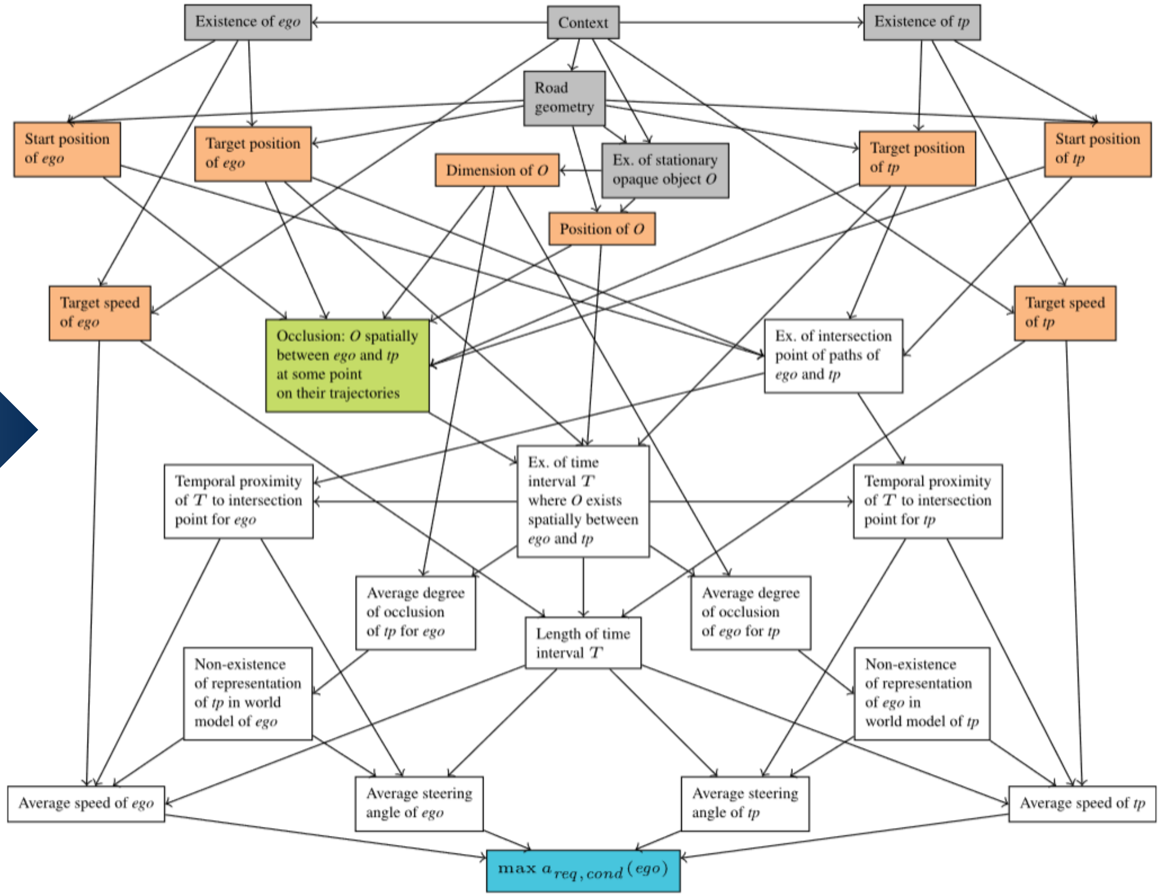
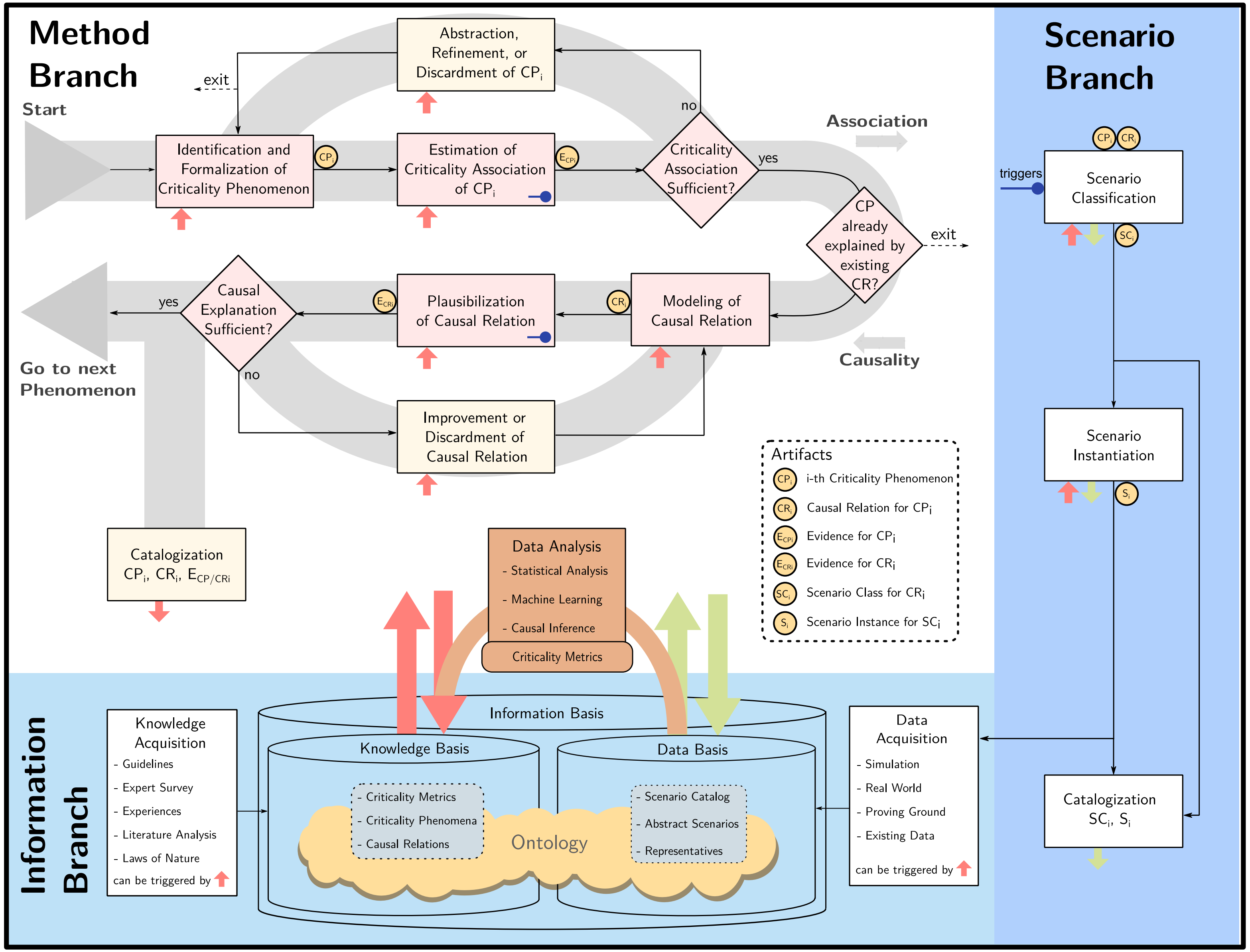


Figure: Causal relation for „occlusion“ (© Neurohr et al. [1])

Criticality Analysis – Detailed Flowchart

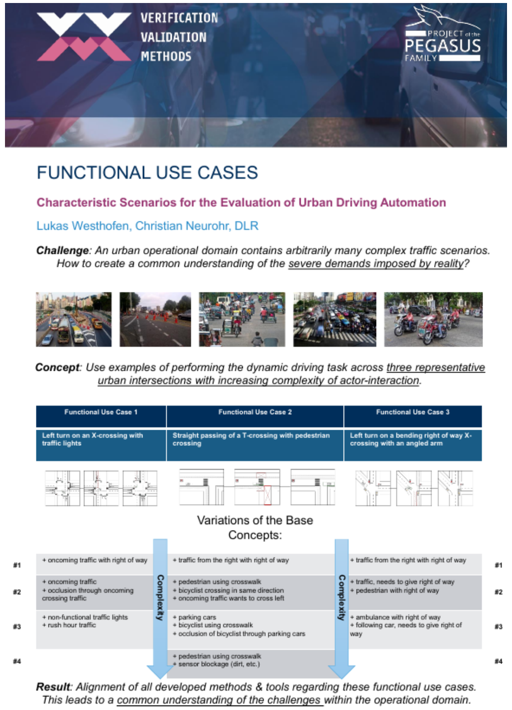


- **Method Branch** – identification, formalization, relevance estimation of criticality phenomena, modeling and plausibilization of causal relations, criticality metrics
- **Information Branch** – knowledge and data management for the criticality analysis, ontologies.
- **Scenario Branch** – use scenarios as the 'substrate' of the criticality analysis, a means for structuring processes and description of reality

Figure: Criticality analysis flowchart (© Neurohr et al. [1])

Criticality Analysis – Contributions

- **Contributions within VVM:**
  - Definition of [Functional Use Cases]
  - Ontology and CP for OD decomposition → input for data formats and ODD specification
  - Specification of data collection drives → data acquisition
  - Target behavior and safety argument:
    - CP identified and formalized → source for hazard analysis
    - CP causal relations modeled and plausibilized → source for hazard analysis
    - CP strength of association measured by suitable criticality metrics
    - ISO 21448 compliance: identification & evaluation of triggering conditions
    - Abstract scenarios featuring CP used in scenario-based verification and validation



- **Projects and Standardization:**
  - SET Level – Simulation Use Case, Mid Term & Final Events
  - ISO 34502 – „Road vehicles – Test scenarios for automated driving systems“
  - OpenSCENARIO v2.0 – Abstract scenario, criticality metrics, 6-layer model

Annex E
(informative)

Derivation and structuring of scenarios using criticality analysis

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Vielen Dank für Ihre Aufmerksamkeit!

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PROJECT of the PEGASUS FAMILY

VDA LEITINITIATIVE

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autonomes und vernetztes Fahren

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aufgrund eines Beschlusses des Deutschen Bundestages

Criticality Analysis – Selection of Scientific Contributions

VERIFICATION VALIDATION METHODS

- **[1] „Criticality Analysis for the Verification and Validation of Automated Vehicles“**
  - IEEE Access, 2021, Links: ResearchGate, IEEExplore
- **[2] „6-Layer Model for a Structured Description and Categorization of Urban Traffic and Environment”**
  - IEEE Access, 2021, Links: ResearchGate, IEEExplore
- **[3] „Using Ontologies for the Formalization and Recognition of Criticality for Automated Driving”**
  - IEEE OJITS, 2022, Links: ResearchGate, IEEExplore
- **[4] „Criticality Metrics for Automated Driving: A Review and Suitability Analysis of the State of the Art”**
  - Archives of Computational Methods in Engineering, 2022, ResearchGate, SpringerLink
- **[5] „Grasping Causality for the Explanation of Criticality for Automated Driving“**
  - arXiv (Preprint), 2022, Links: ResearchGate, arXiv
- **[6] „Leveraging the GIDAS Database for the Criticality Analysis of Automated Driving Systems“**
  - Journal of Advanced Transportation, 2023, ResearchGate, Hindawi