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21. September 2023, SafeComp 2023

Concept and metamodel to support cross-domain safety analysis for ODD expansion of autonomous systems

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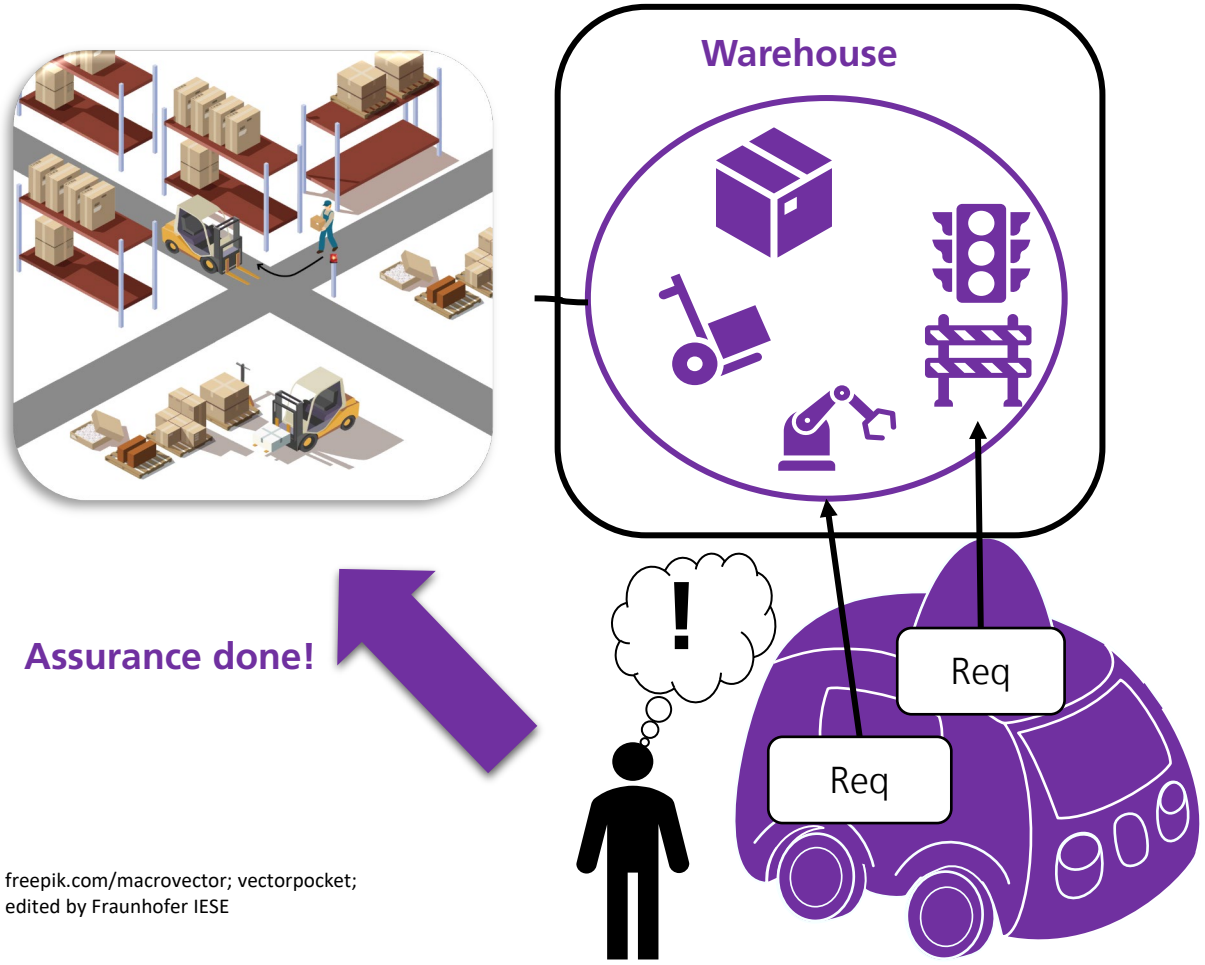
Operational Design Domain (ODD) Extension

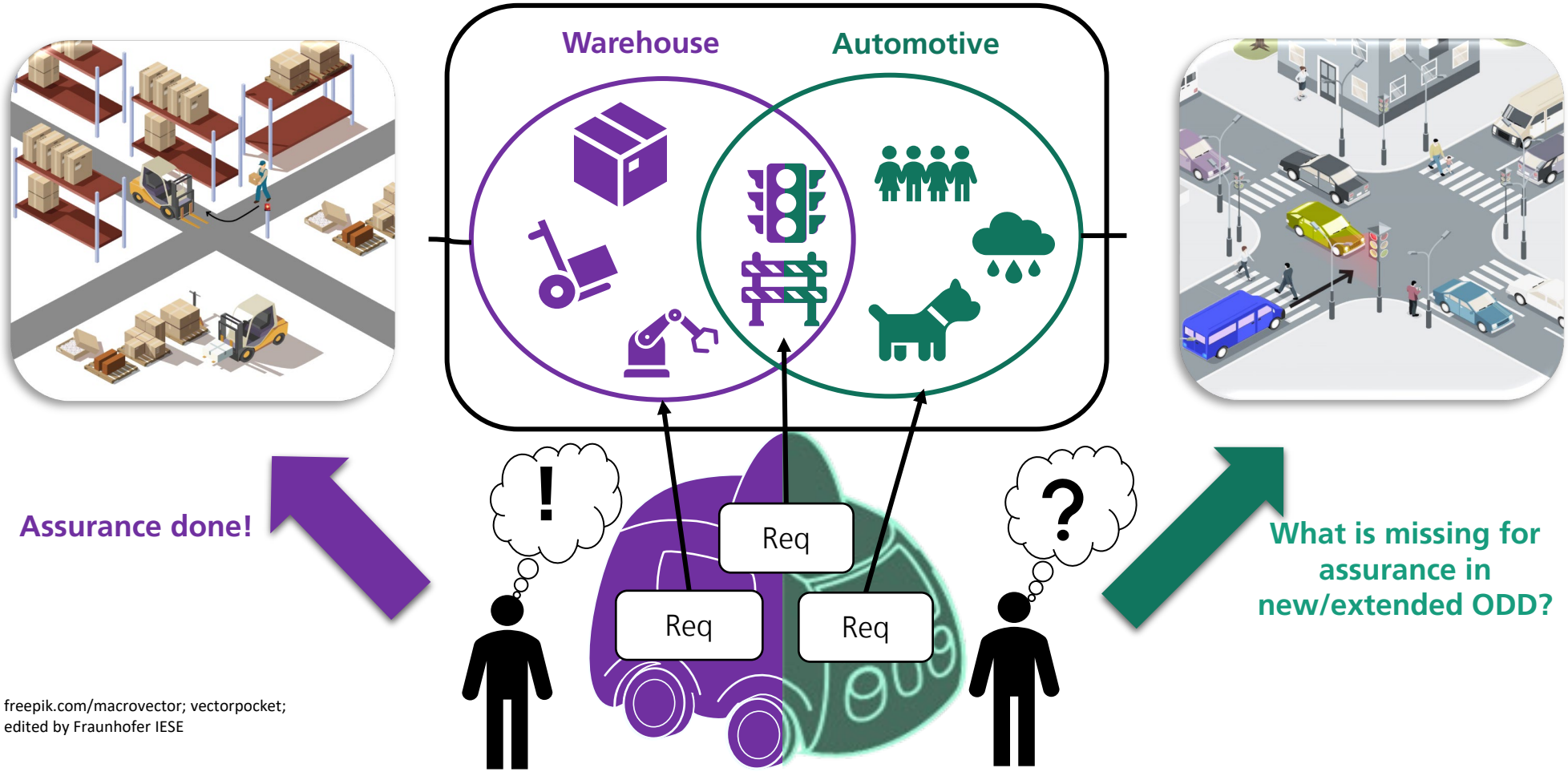
Motivation



freepik.com/macrovector; vectorpocket;
edited by Fraunhofer IESE

Operational Design Domain (ODD) Extension

Motivation



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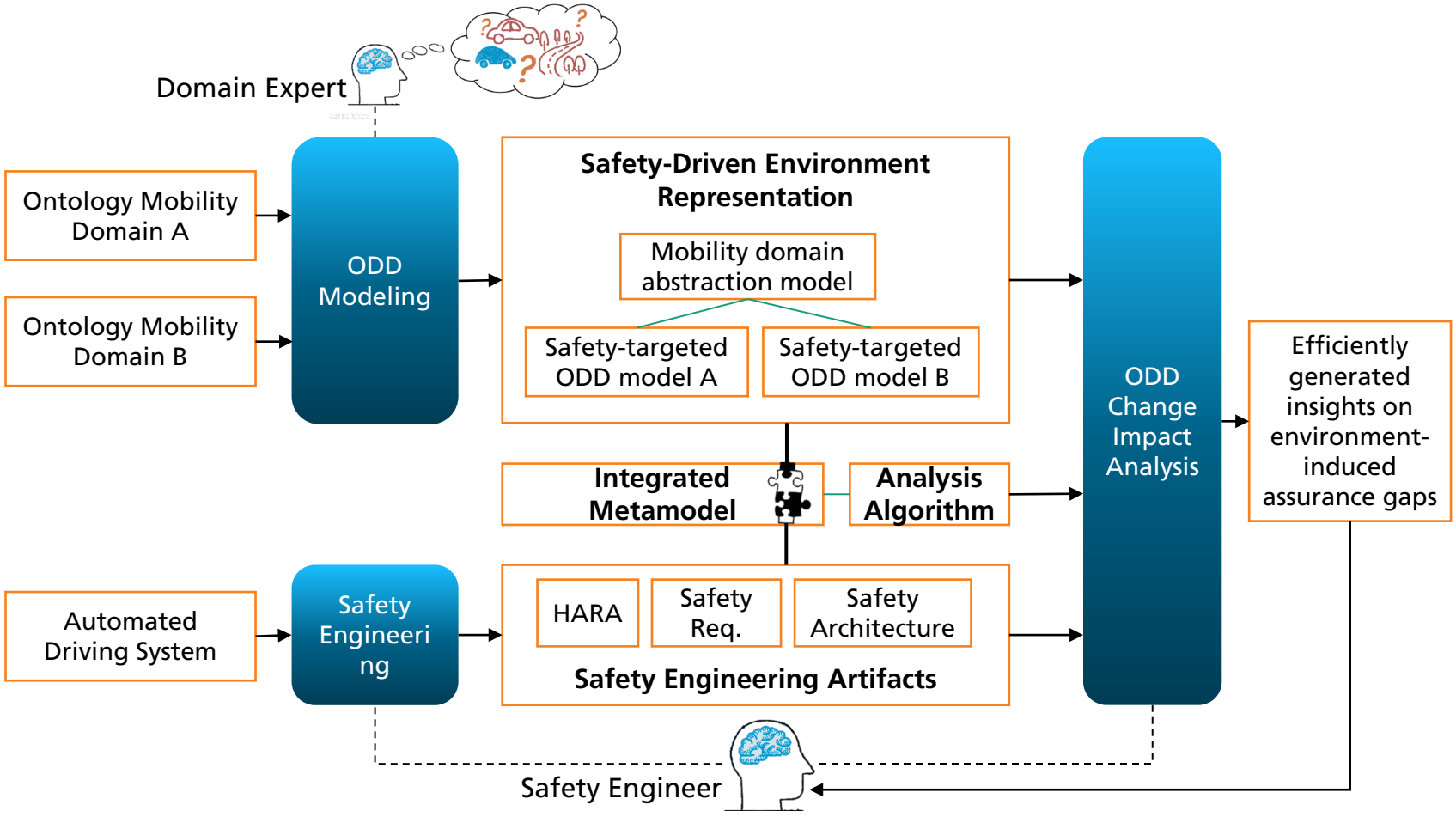
Safety-aware context engineering

Methodological Overview



Safety-aware context engineering

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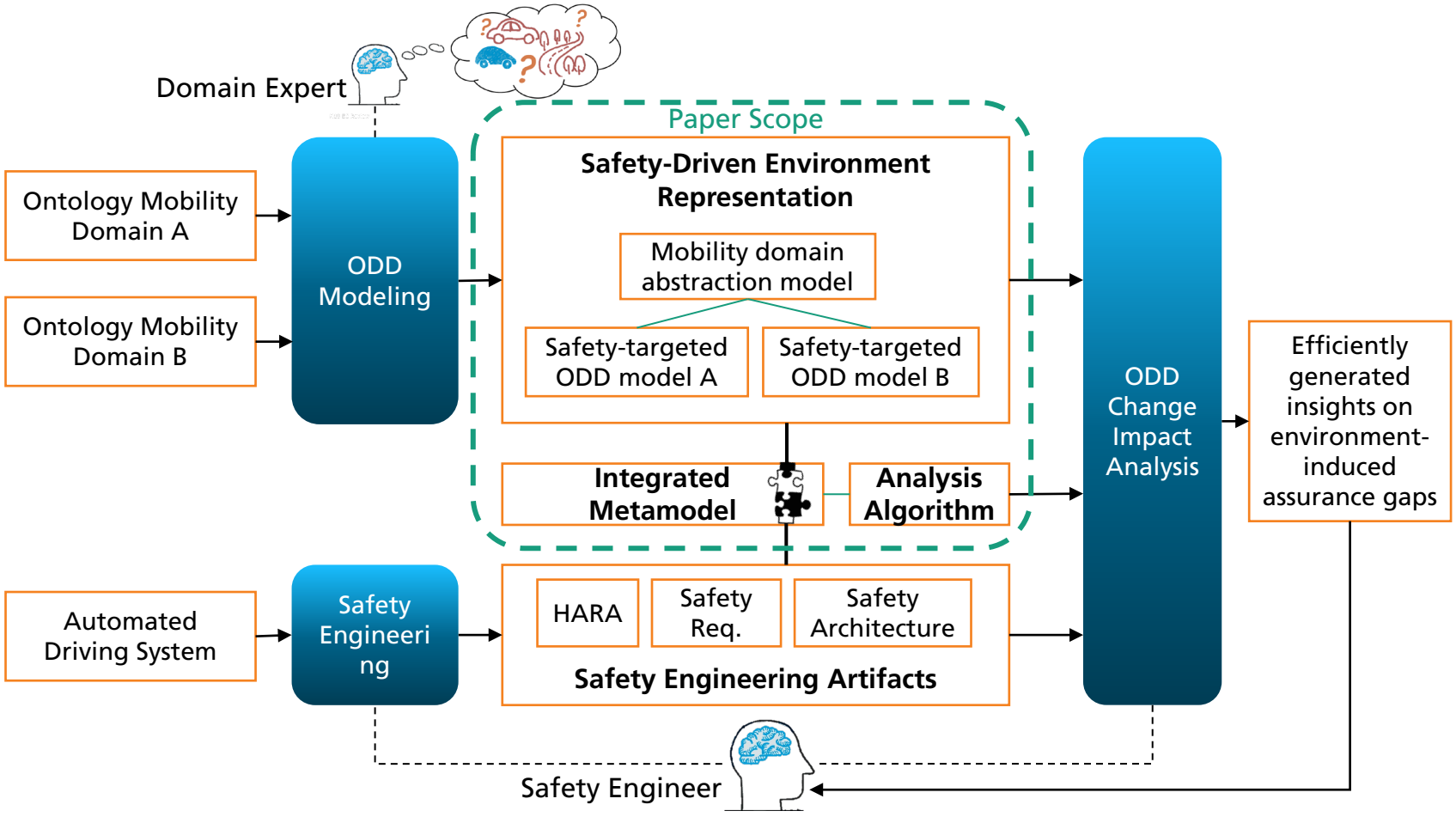
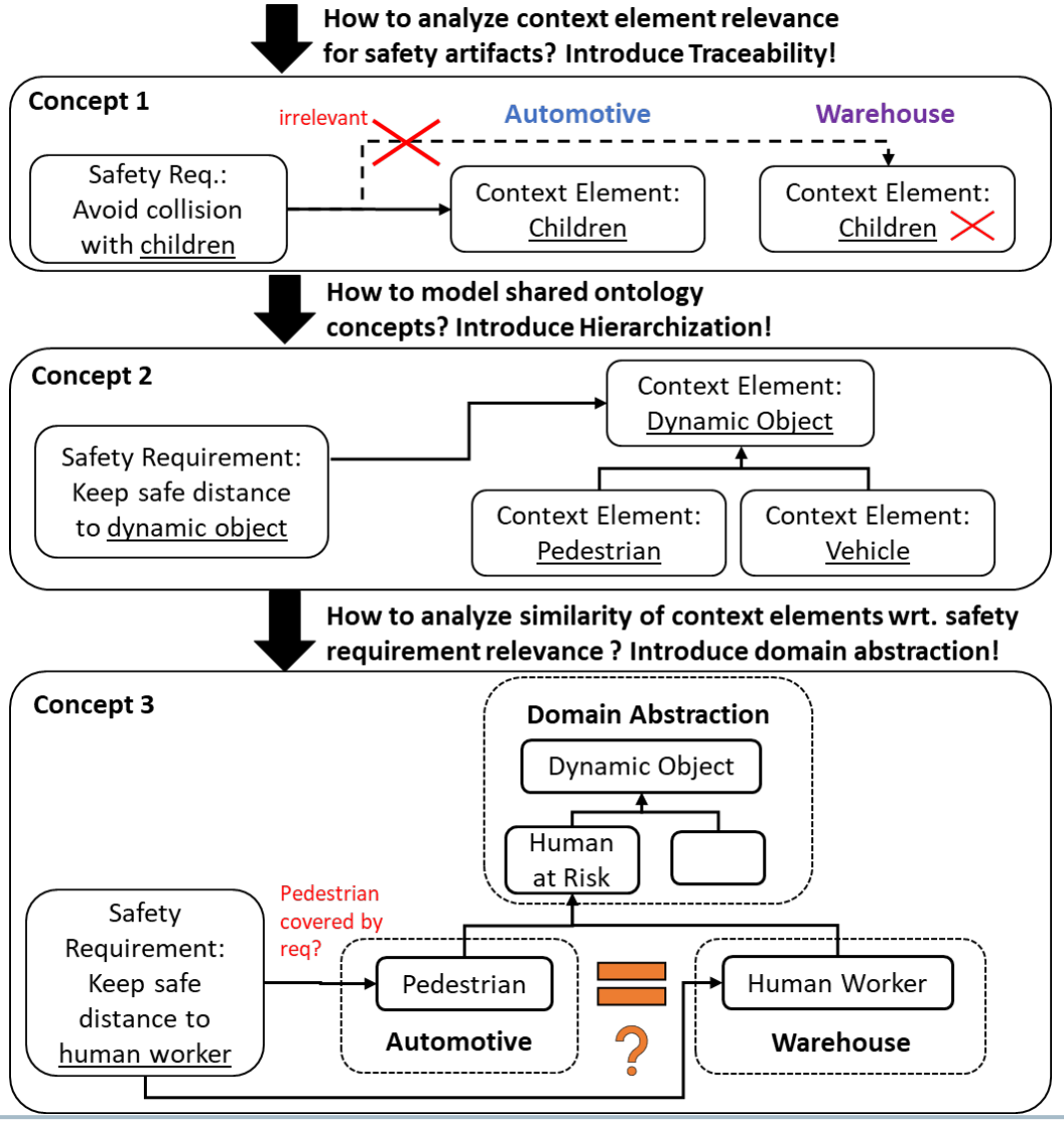


Safety-driven environment representation

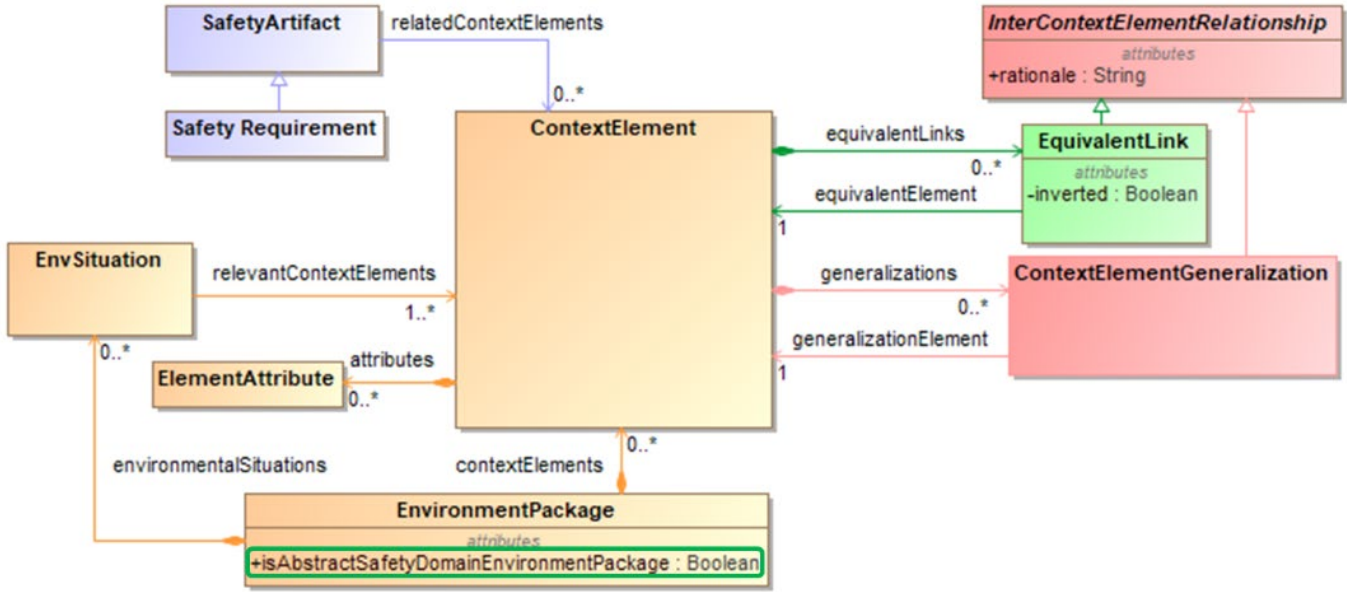
Concepts

- **Concept 1:** Linking safety engineering artifacts to context elements they refer to is the basis to analyze the safety impact of a changing ODD
- **Concept 2:** Hierarchization enables representing shared ontological concepts.
- **Concept 3:** Shared domain abstraction enables similarity specification.



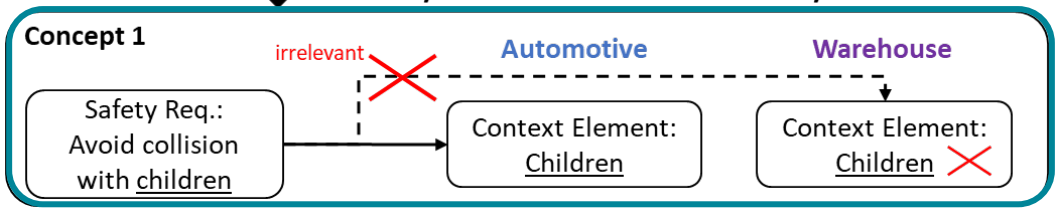
Concept Formalization

Metamodel



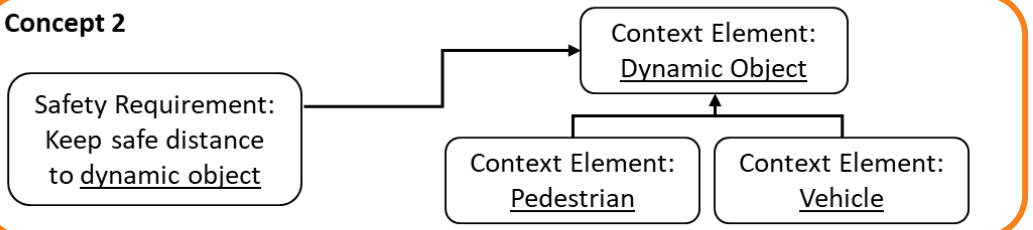
How to analyze context element relevance for safety artifacts? Introduce Traceability!

Concept 1



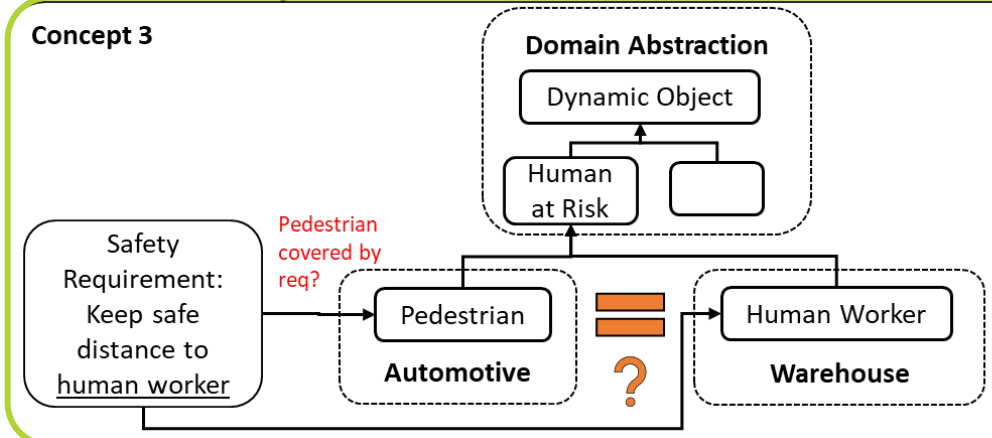
How to model shared ontology concepts? Introduce Hierarchization!

Concept 2



How to analyze similarity of context elements wrt. safety requirement relevance ? Introduce domain abstraction!

Concept 3

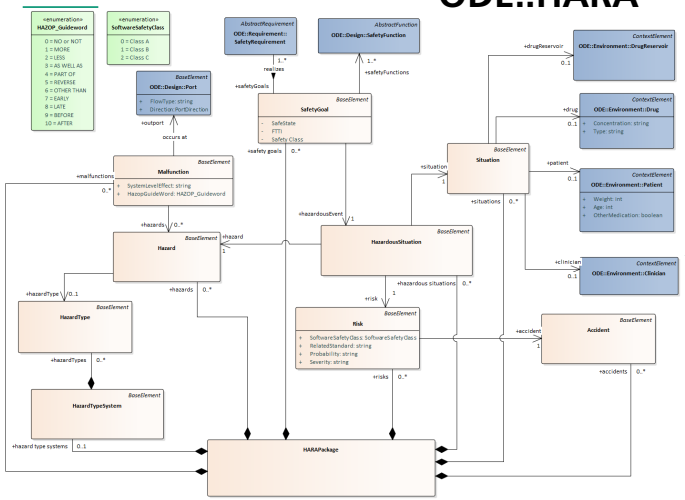


  Public

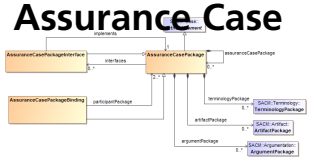
ODE::Environment Metamodel integration into the DDI

DDI Packages Overview

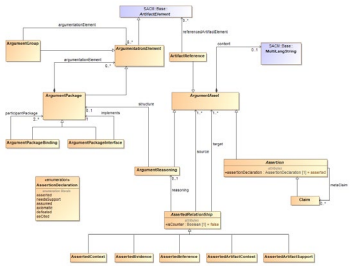
ODE::HARA



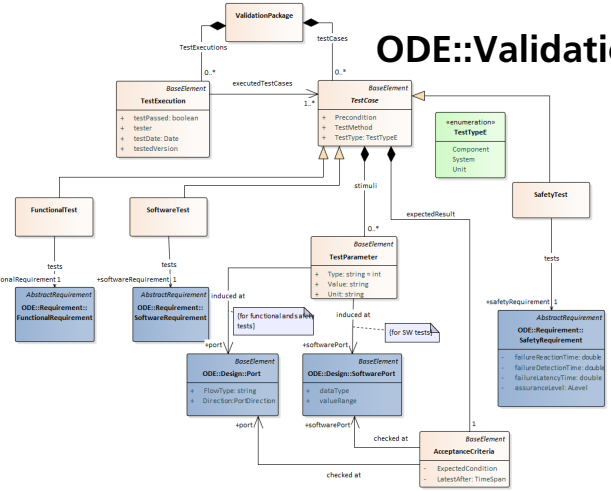
Assurance Case

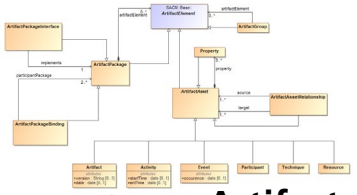


OMG SACM



ODE::Validation

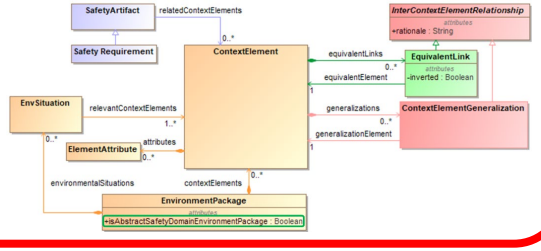




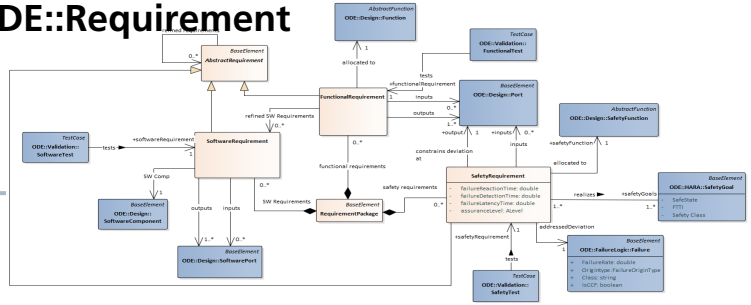
Artifact

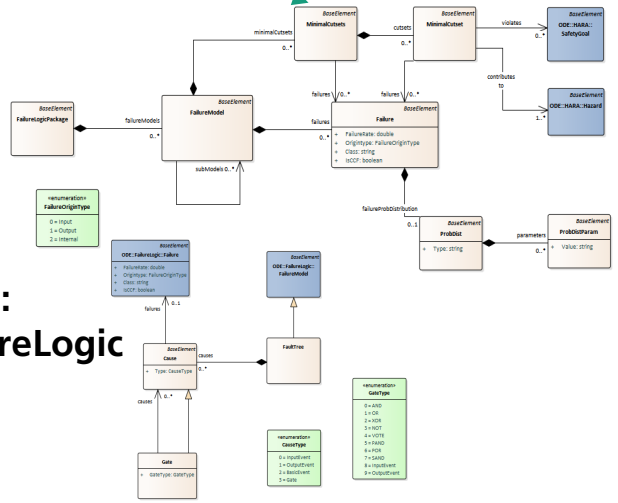
Argumentation

ODE::Environment



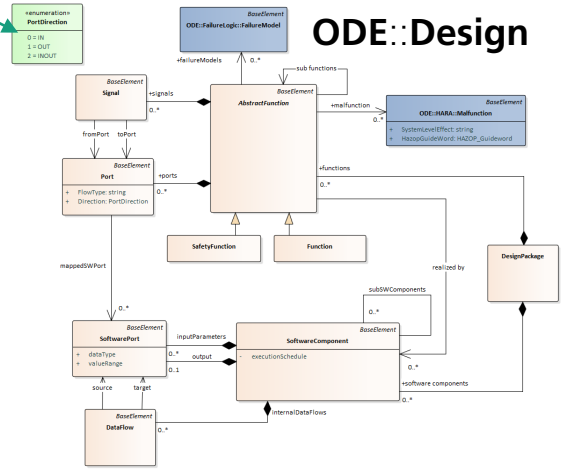
ODE::Requirement





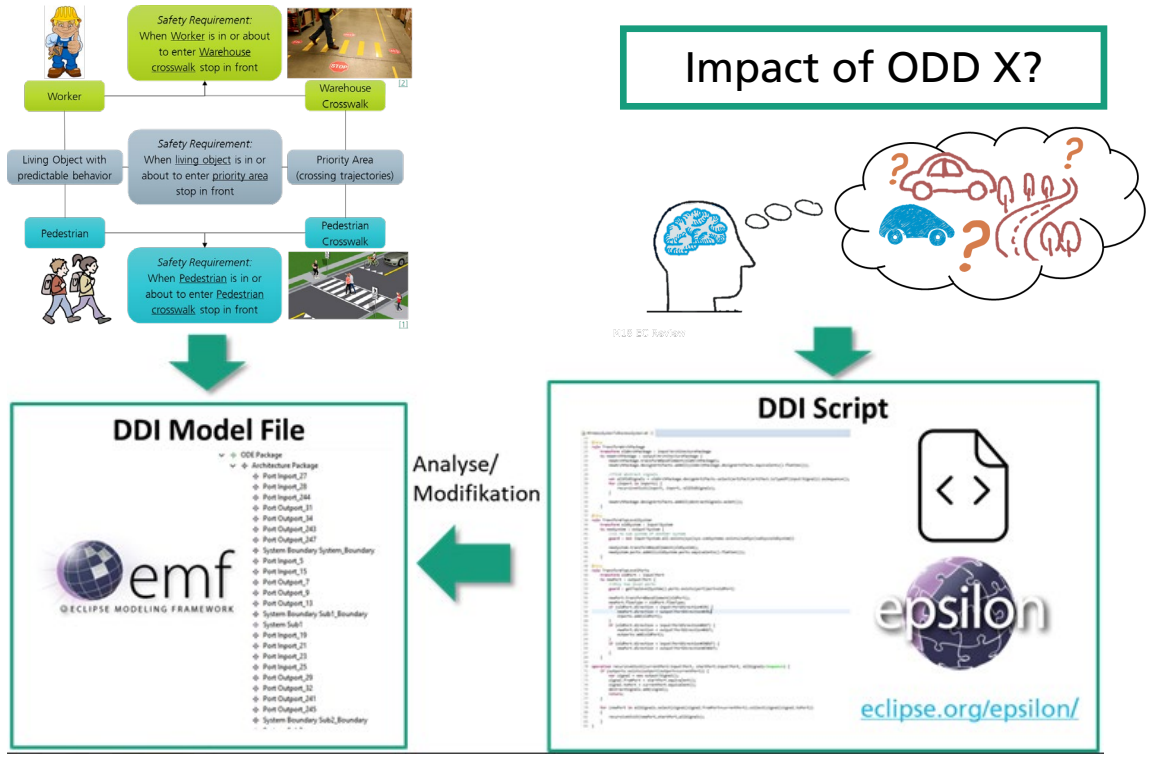
ODE:: FailureLogic

ODE::Design



Concept Formalization

Change Impact Analysis Algorithm




```
1  "Hierarchy of context elements".println();
2  "----------------------------".println();
3  "".println();
4
5
6  var highestAbstractionElements = ContextElement.
7                                       allInstances().
8                                       select(element | element.generalizations.isEmpty() or
9                                                        element.generalizations == null);
10
11 for (highestAbstractionElement : ContextElement in highestAbstractionElements) {
12     highestAbstractionElement.printHierarchyTreeRecursively("");
13     "".println();
14 }
15
16 operation ContextElement printHierarchyTreeRecursively(indentation : String) {
17     self.printHierarchyEntry(indentation);
18
19     var directChildElements = self.getDirectChildElements();
20
21     if (not directChildElements.isEmpty()){
22         for (childElem : ContextElement in directChildElements) {
```

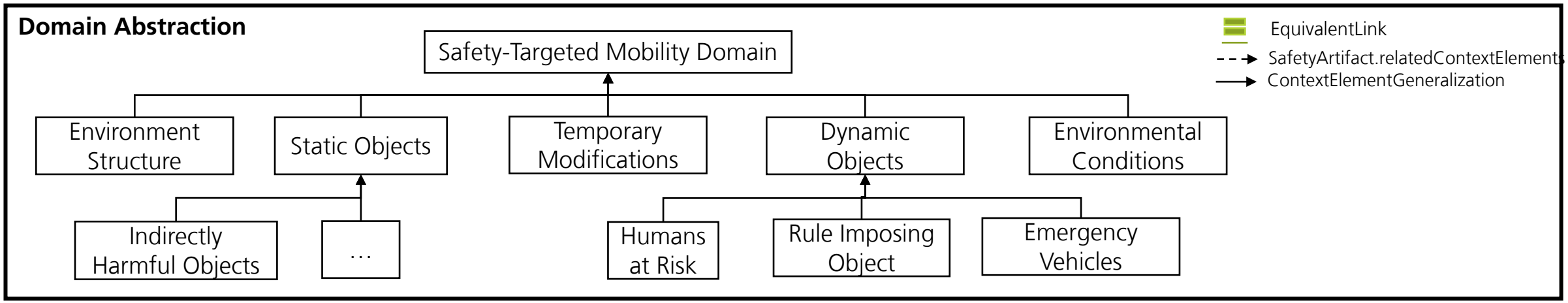
Problems | Javadoc | Declaration | Search | Console | Properties | Validation

Epsilon

```
Hierarchy of context elements
----------------------------

|-> Environment Structure (Safety-Targeted Mobility Domain)

|-> Static Objects (Safety-Targeted Mobility Domain)
       |-> Indirectly Harmful Objects (Safety-Targeted Mobility Domain)
              |-> Item Rack (Warehouse Domain)

|-> Temporary Modifications (Safety-Targeted Mobility Domain)

|-> Dynamic Objects (Safety-Targeted Mobility Domain)
       |-> Humans at Risk (Safety-Targeted Mobility Domain)
              |-> Human Worker (Warehouse Domain)
              |-> Police Officer (Automotive Domain)
       |-> Rule Imposing Object (Safety-Targeted Mobility Domain)
              |-> WH Leader (Warehouse Domain)
              |-> Police Officer (Automotive Domain)
       |-> Emergency Vehicles (Safety-Targeted Mobility Domain)
              |-> Fire truck (Automotive Domain)

|-> Environmental Conditions (Safety-Targeted Mobility Domain)
```

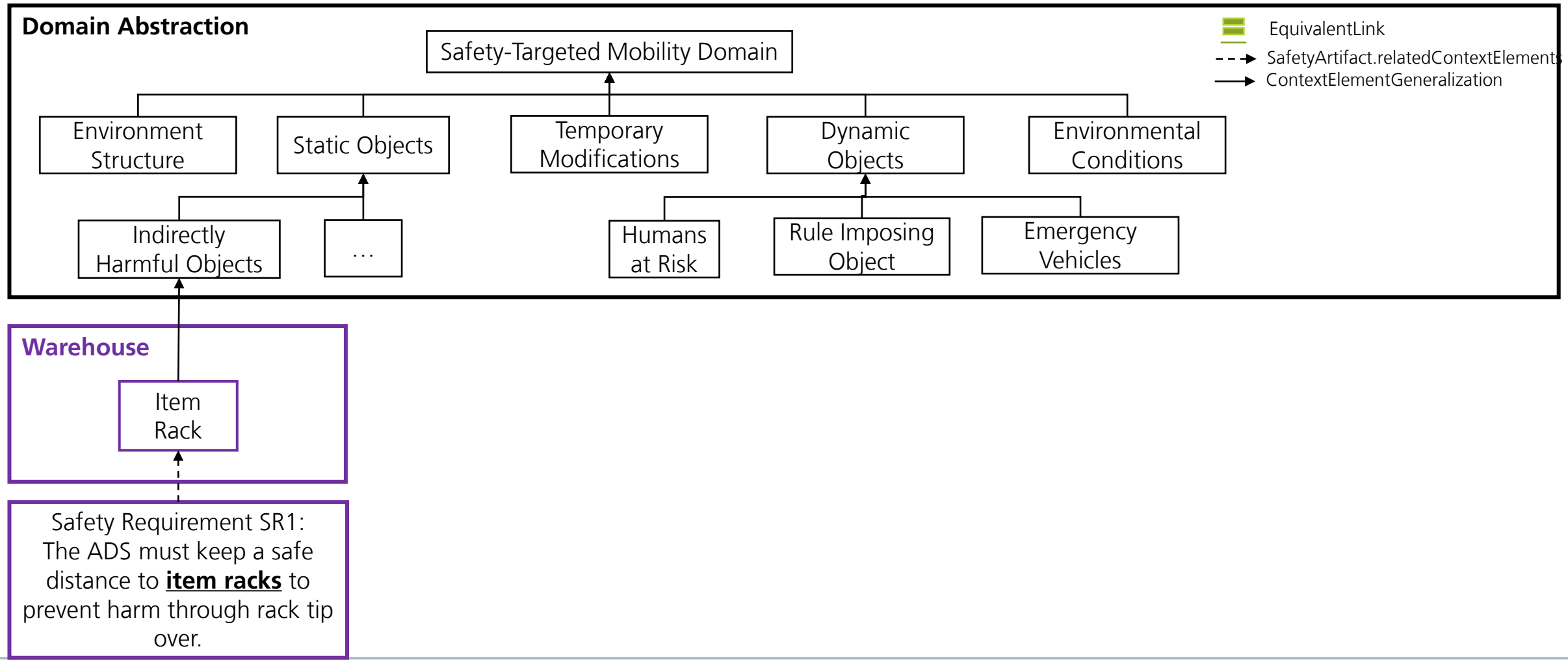
Initializing the metamodel

Example Model Instance



Initializing the metamodel

Example Model Instance



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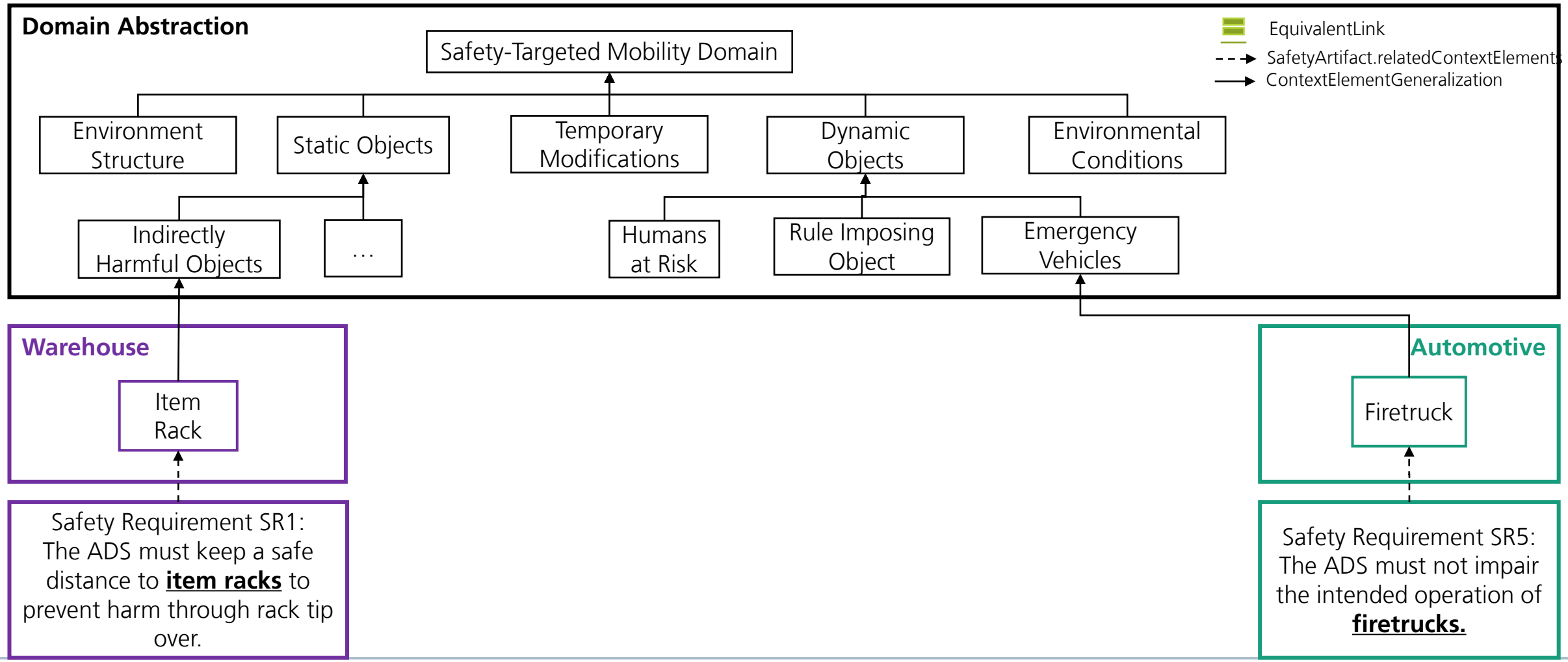

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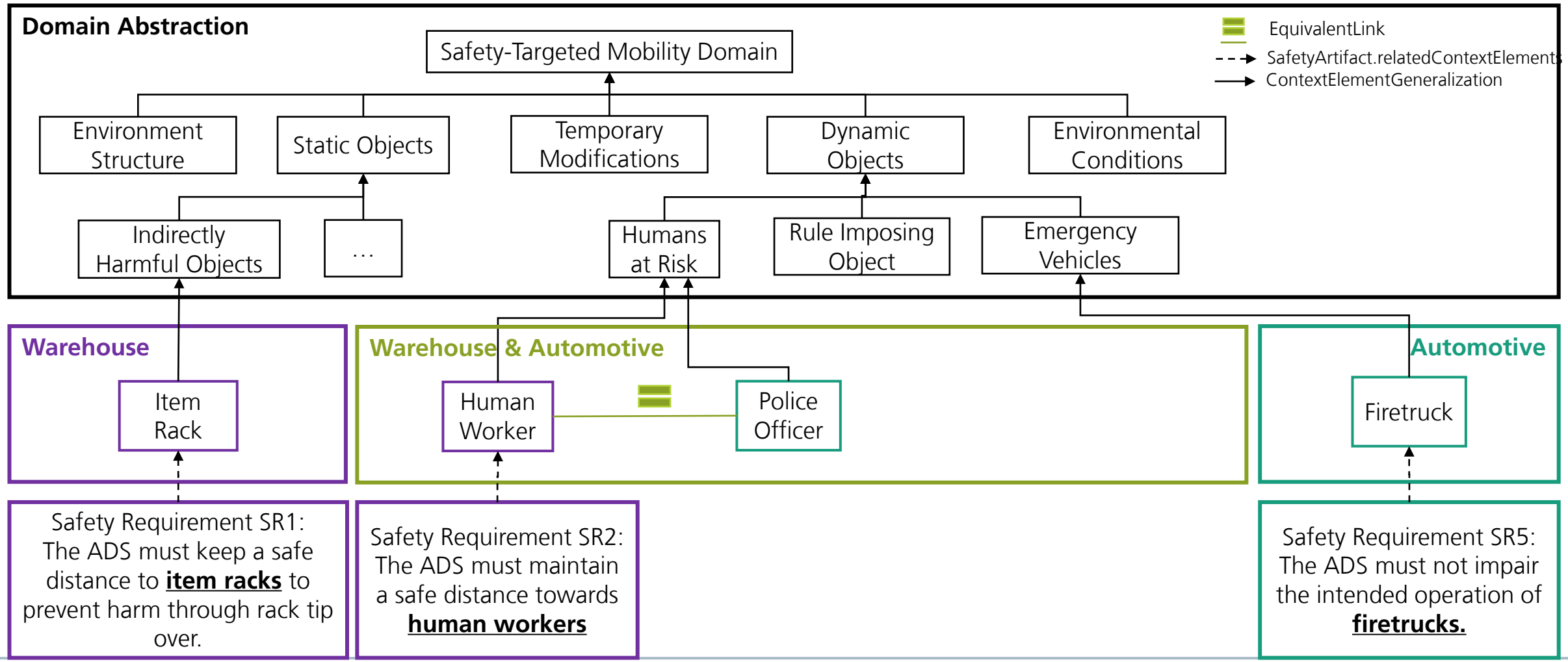

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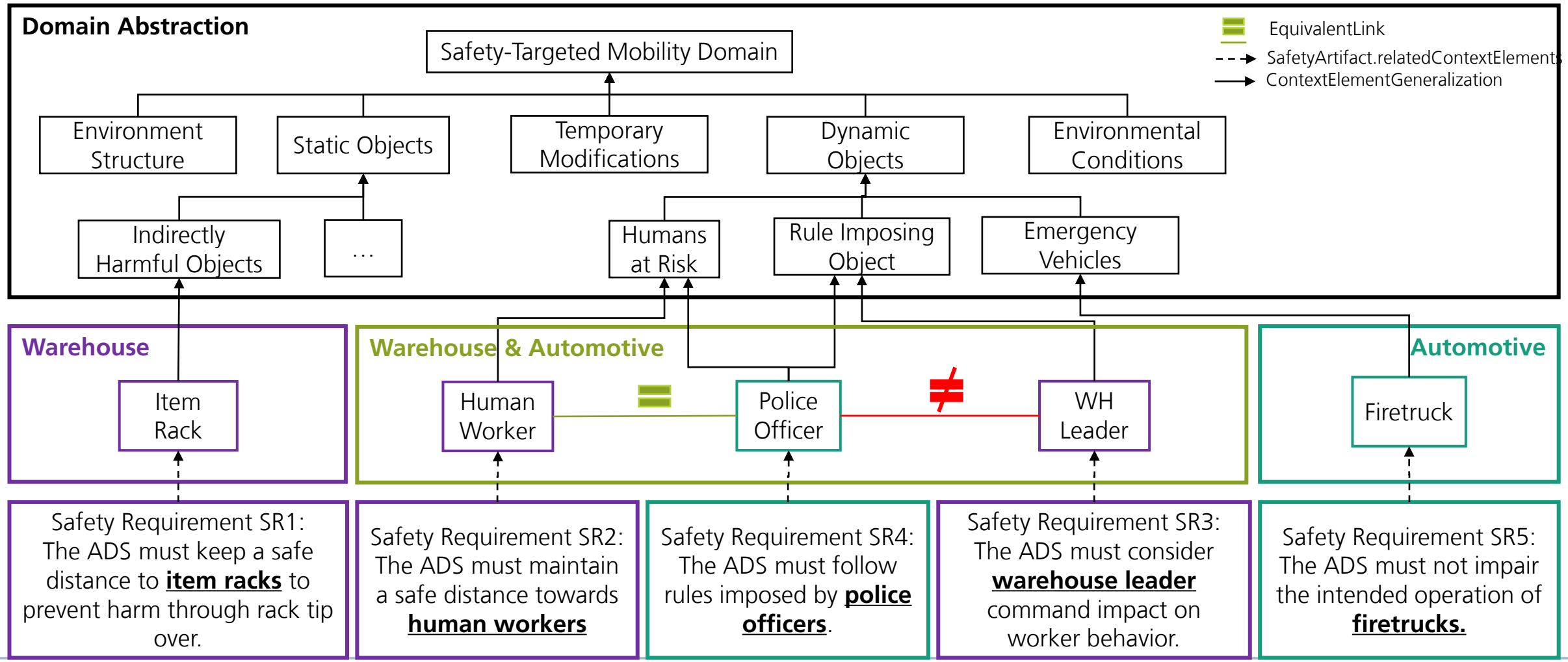
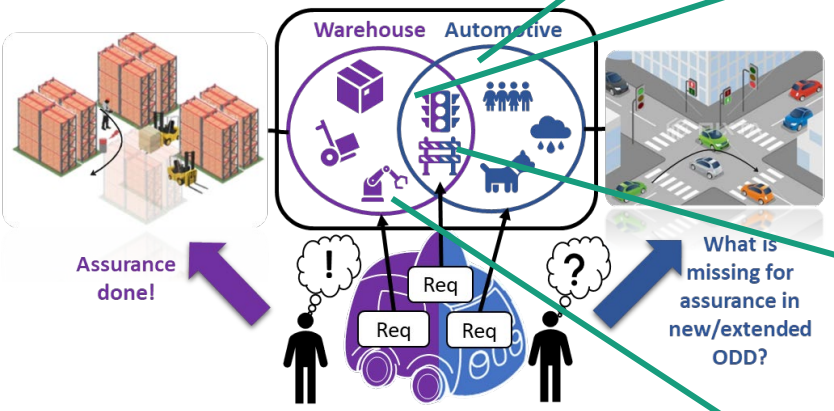


Script Output

Based on the Example Model Instance




```
New elements exclusive for domain: Automotive – New safety requirements must be derived:
Firetruck
…
=============================================================================================
New elements of domain: Automotive with equivalent elements in domain: Warehouse – Requirements can be
reused:
<abstract> Humans at Risk:
    Police Officer = Human Worker -> Rational: Both are vulnerable humans that are in danger
        |-> SR2 - The ADS must maintain a safe distance towards Human Worker
        |-> Proposal: SR2.1 – The ADS must maintain a safe distance towards Police Officer
…
=============================================================================================
New elements of domain: Automotive that are nonequivalent to elements in domain: Warehouse – Safety
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workers
        |-> SR3 - The ADS must consider warehouse leader command impact on worker behavior
…
=============================================================================================
Elements exclusive for domain: Warehouse – No action required:
Item Rack
        |-> The ADS must keep a safe distance to item racks to prevent harm through rack tip over
…
```
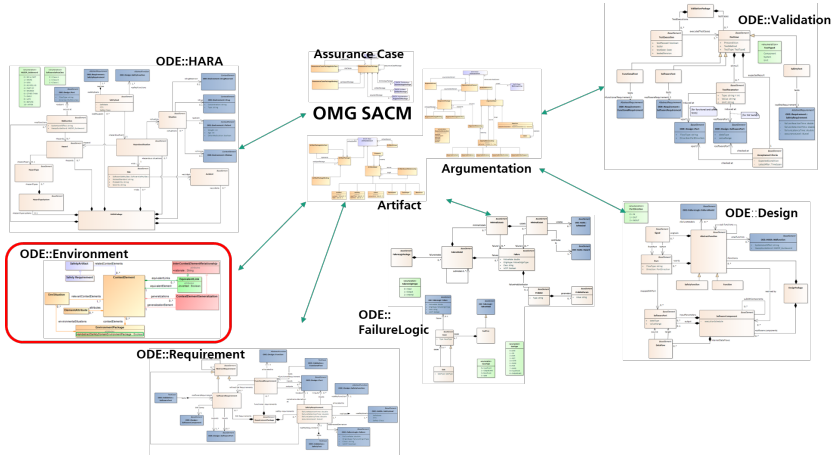
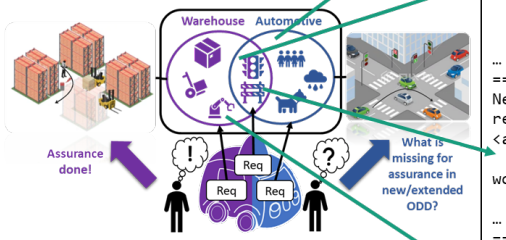

Summary & Conclusion

Recap

- Meta model to formalize the environment
- Integration into DDI to implement traceability between safety artifacts and environmental elements
- Scripts to support safety engineers with the change impact analysis



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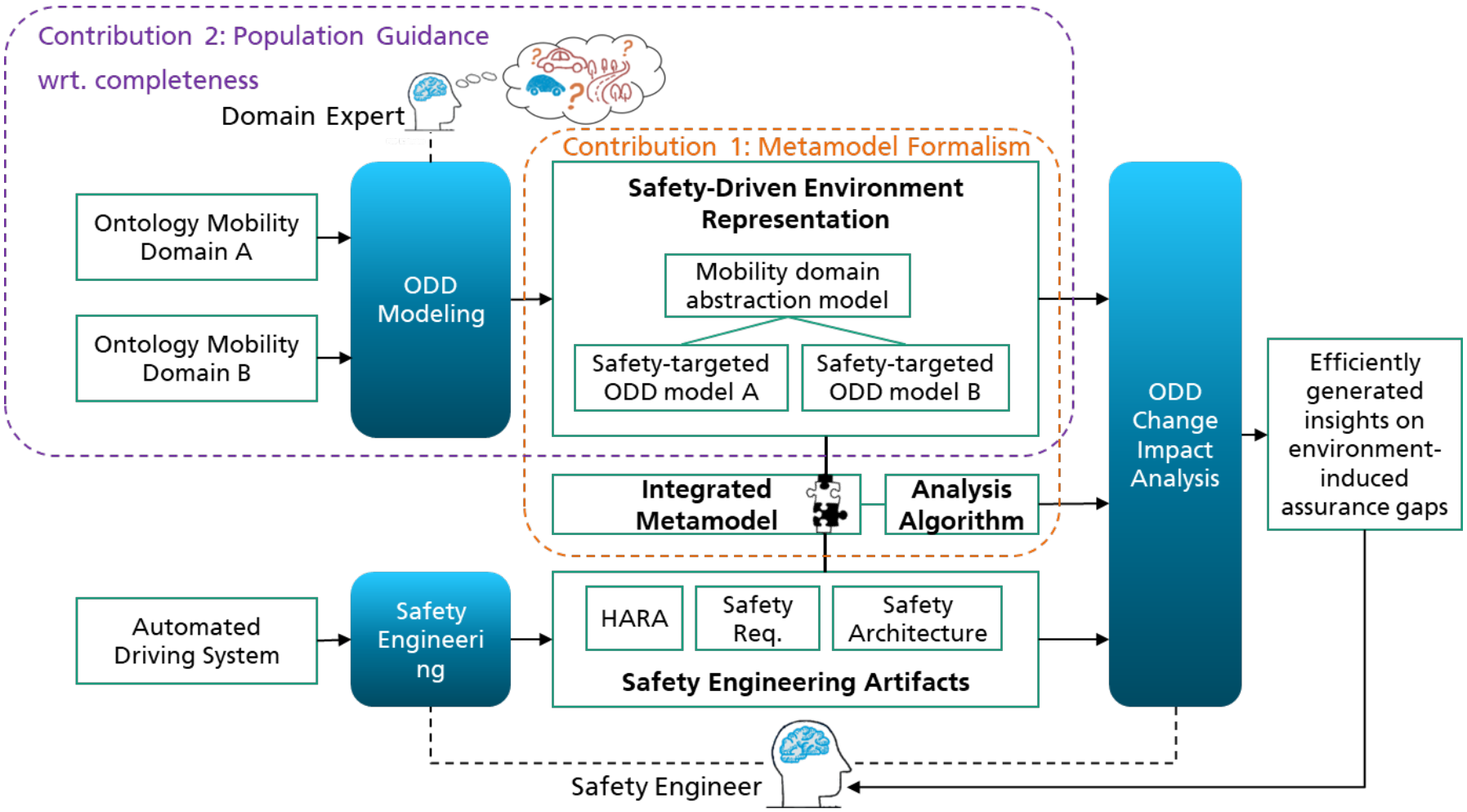
Outlook


Contribution 2: Population Guidance
wrt. completeness
Domain Expert
Contribution 1: Metamodel Formalism
Ontology Mobility Domain A
Ontology Mobility Domain B
ODD Modeling
Safety-Driven Environment Representation
Mobility domain abstraction model
Safety-targeted ODD model A
Safety-targeted ODD model B
Integrated Metamodel
Analysis Algorithm
ODD Change Impact Analysis
Efficiently generated insights on environment-induced assurance gaps
Automated Driving System
Safety Engineering
HARA
Safety Req.
Safety Architecture
Safety Engineering Artifacts
Safety Engineer

Thank you for your interest!

Contact

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Thank You!