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# Evaluation of a Vehicle-in-the-Loop Test Bench Setup – Insights into a Systematic Validation Configuration Evaluation Approach


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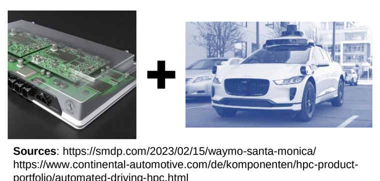
## Introduction

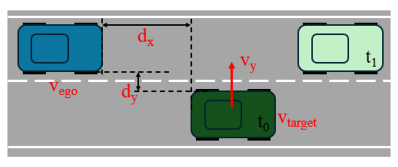
### Current Approaches in Automated Vehicle Validation

**Virtual Validation Methods**

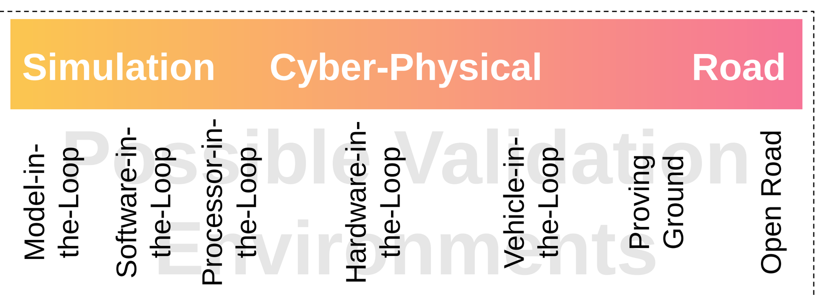



- Virtual validation methods are modeling aspects of the system under investigation, its connected systems and the environment. [1,2]
- Through this abstraction, tests can be (partly) virtualized, allowing earlier validation.

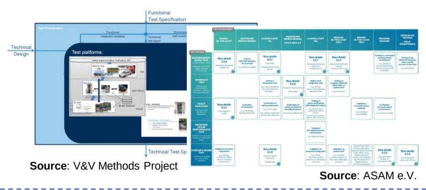
**Scenario-based Validation**



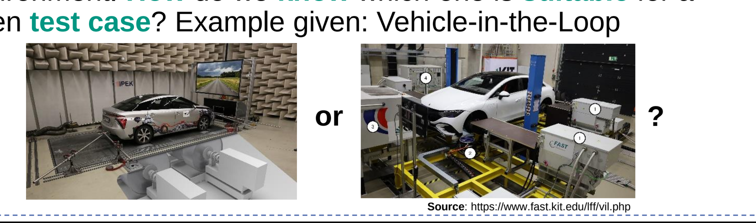
- Scenarios, based on the operational design domain, are generated to test and validate automated driving functions. [3]
- Thereby, the development of requirements and system designs can be supported in a resource-efficient way. [3]




There are existing research approaches dealing with the question: How to choose a validation environment for a given test case.




But …
There are many possible configurations within a validation environment. How do we know which one is suitable for a given test case? Example given: Vehicle-in-the-Loop




## Scope and Method

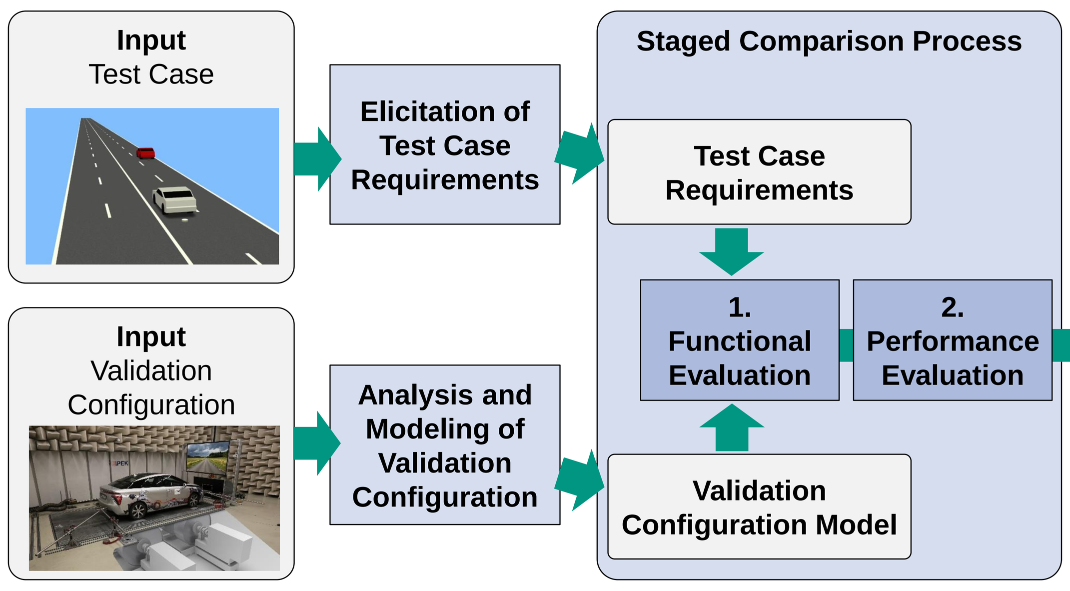
We need a **systematic evaluation method** to **choose** a **suitable validation configuration** for a given **test case**!

### Research Approach

Focus on the development of hypotheses for further research activities.
➔Exploratory research method: Case Study [4]

- Start with a basic idea of the systematic evaluation approach.
- Application within a case study to generate insights.
- Improvement of the initial basic idea and development of a method.

### The Basic Idea



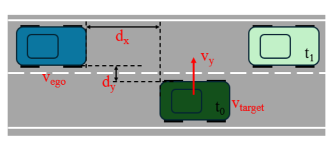

## Case Study

### Test Case

A test case contains the information about What and How to test. [5]

**What to test?**

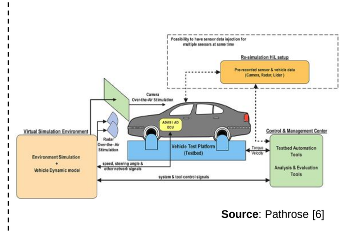
| System under Investigation & Operational Design Domain | Validation Objective & Desired Outcome | Scenarios & Parametrization |
|---|---|---|
| **Automated Lane Keeping System (ALKS)**<br>▪ SAE Level 3 System<br>▪ Highway only up to 60km/h max<br>▪ Class M vehicles | **ALKS performance evaluation**<br>Evaluation of an ALKS with its integration into the vehicle. Key index is the minimal distance between ego and target vehicle during the scenario. | **Cut-In scenario defined by UNECE R157 [10]** |



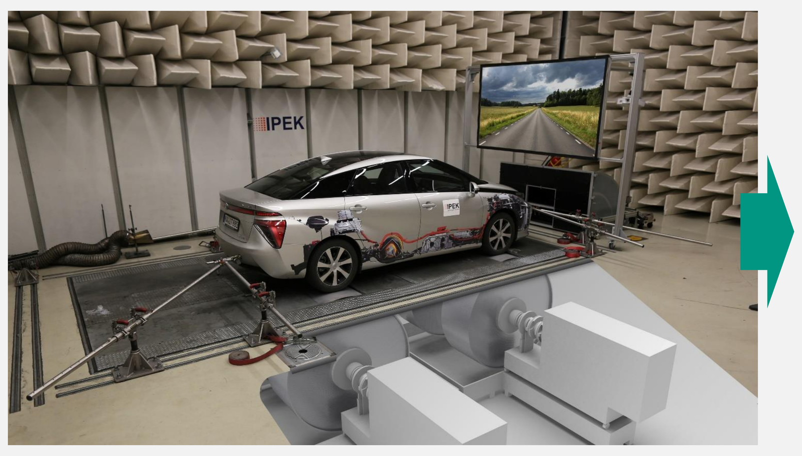

**How to test?**

Validation Environment

**Vehicle-in-the-Loop**




### Validation Configuration



- Existing 4x2 roller test bench, used for NVH investigations. There have been already first Advanced Driver Assistance System (ADAS) tests on this test bench, using camera, radar and ultrasonic simulation.

- Roll diameter: 1,910 mm
- Power per roller: 232 kW (264 kW Overload)
- Maximum speed: 254 km/h
- Maximum axle load: 3,000 kg

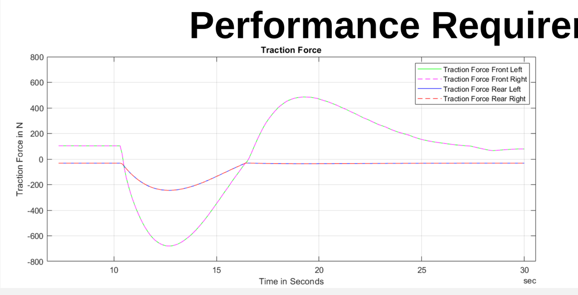
### Staged Comparison Process

#### Test Case Requirements

**Functional Requirements**

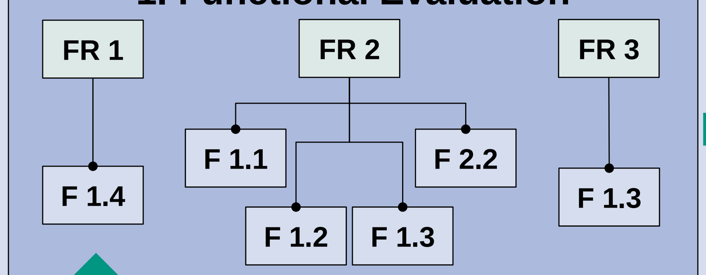
- **FR 1:** The validation configuration shall enable the rotation of the wheel and its connected drive system.
- **FR 2:** The validation configuration shall apply the road loads in longitudinal direction on the wheel and drivetrain.
- **FR 3:** There shall be no adjustment of the vehicle for a quick and easy setup.

**Performance Requirements**

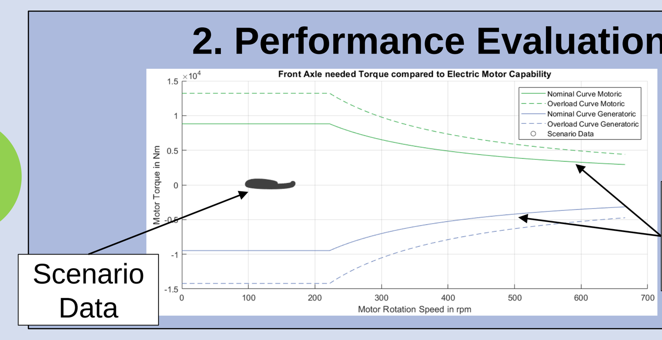


Needed traction force in drive direction for given scenario, calculated via simulation.

#### 1. Functional Evaluation




#### 2. Performance Evaluation



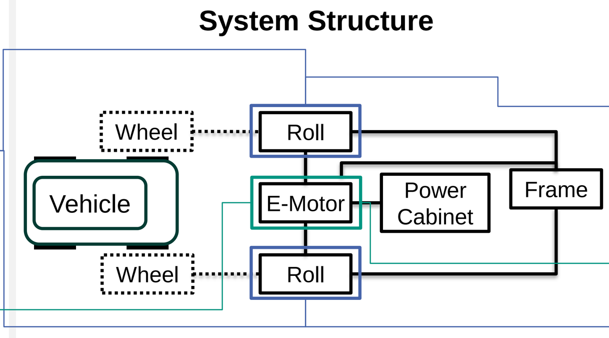

#### Validation Configuration Model

**Functional Structure**

Roll
**F1.1:** Transmission of electric motor torque to the tires.
**F1.2:** Generating a mass inertia moment.
**F1.3:** Applying traction force on wheel through tire-roll contact patch.
**F1.4:** Enabling rotational movement of the wheel.

Electric Motor
**F2.1:** Convert electric energy into rotational energy.
**F2.2:** Applying torque on connected rolls.

**System Structure**




**Technical Quality Features**

Roll

| | | |
|---|---|---|
| **Radius** | 955 | mm |
| **Inertia** | 2152.4 | kgm² |

Electric Motor

| | | | | | |
|---|---|---|---|---|---|
| **Rated Torque** | 8812.5 | Nm | **Field Weakening** | 3.15 | - |
| **Rated Speed** | 222 | rpm | **Rotor Base Inertia** | 45 | kg m² |

## Derived Systematic Evaluation Approach

### Test Case

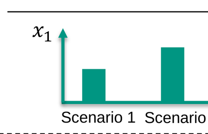
**What to test?**

System under Investigation & Operational Design Domain | Validation Objective & Desired Outcome | Scenarios

**How to test?**

Validation Environment: Simulation Cyber-Physical Road

Parameter Variations




### Test Case Requirements

**Functional Requirements**

- Functional requirements represent basic needs of the test case.

**Performance Requirements**

- Performance requirements represent the range of operation of the test case.

### Staged Comparison Process

**1. Functional Evaluation**

- Assessment of the functional feasibility. The fulfillment of functional requirements by the functional structure is checked.

**2. Performance Evaluation**

- Assessment of the suitability. It is checked if the technical quality features are within the range of operation.

### Validation Configuration Model

**Functional Structure**

- Functionalities of the validation configuration.

**System Structure**

- Overview of the validation configuration.

**Technical Quality Features**

- Performance of the validation configuration.

### Validation Configuration

- Mostly validation resources (test benches, measurement tools, models, simulation tools, …) that can be overtaken from earlier validation activities.


**References**

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