September 2022

Abstract Natural Scenario Language Version 1.0

Florian Bock
CARIAD SE

Jens Lorenz
Luxoft GmbH

Abstract Natural Scenario Language Version 1.0

Dr. Florian Bock
CARIAD SE
florian.bock@cariad.technology
florian.inifau.bock@fau.de

Jens Lorenz
Luxoft GmbH
jlorenz3@dxc.com

September 19, 2022

Abstract

The development of modern driving assistant systems (assisted as well as automated) requires extensive testing and exact specification to ensure the quality of the developed systems. Therefore, scenarios are used throughout the whole process to act as accompanying artifact to assist within the design, implementation and testing procedures. Depending on the respective use case, different levels of abstraction, used natural languages and degrees of completeness are used for the scenarios. Due to the lack of an appropriate method for the specification of abstract scenarios that satisfies those needs for efficient usage, the language stiEF (acronym for "**s**cenario-accompanied, **t**ext-based, **i**terative **E**valuation of automated driving **F**unctions") was designed. This paper provides all details about the syntax and semantics of stiEF for the freeway domain. This enables the reader to read, understand, write and use stiEF for scenario descriptions.

Note: This document is the first version of the language standard stiEF. The content will likely be updated/modified in future versions, although we try to keep it as stable as possible. If you have any remarks, do not hesitate to contact us.

Chapter 1

Introduction

During the last years, the usage and development of driving assistance systems and automated driving functions gain more and more attention by the media and the public and thus also by potential car buyers. As a result, the rate of distribution of such functions regarding newly sold cars is rising. In parallel, those functions are getting more powerful and complex, and therefore are more and more able to relieve the driver by taking over the driving task for longer periods of time without the necessity for manual interventions. The SAE Institute (cf. http://www.sae.edu) has defined five levels of automation for those functions (taken from/based upon [1]):

1. Level 0 - No Driving Automation: The performance by the driver of the entire dynamic driving task (DDT), even when enhanced by active safety systems.
2. Level 1 - Driver Assistance: The sustained and operational design domain (ODD)-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.
3. Level 2 - Partial Driving Automation: The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the object and event detection, recognition, classification and response (OEDR)-subtask and supervises the driving automation system.
4. Level 3 - Conditional Driving Automation: The sustained and ODD-specific performance by an automated driving system (ADS) of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.
5. Level 4 - High Driving Automation: The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.
6. Level 5 - Full Driving Automation: The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.

Functions at level 1 and 2 are well-established and already available in many modern cars. Level 3 functions are currently in development or partially released (e.g., from Tesla[1] or AUDI[2]), whereas level 4 and 5 functions are more sophisticated and therefore will take more time to be delivered to the market.

The development of such functions is a complex and crucial task, that is mostly done by following a more or less modified version of the well-established V-model process (cf. Figure 1.1).
Testing and validating such complex driving functions is not feasible by solely using real test drives in realistic environments, instead simulation is getting more and more important in order to satisfy the requirements for extensive testing. Therefore, behavior descriptions of the system-to-develop have to be used throughout the complete

[1] https://www.tesla.com/de_DE/autopilot
[2] https://www.audi-technology-portal.de/de/elektrik-elektronik/fahrerassistenzsysteme/parkassistent

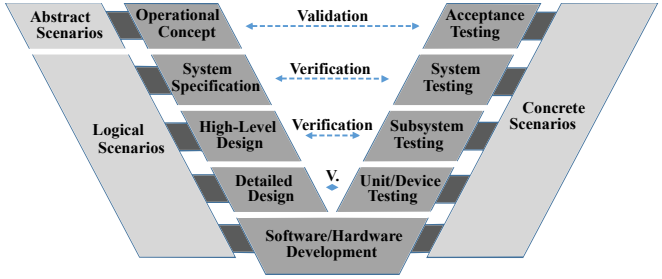


Figure 1.1: Scenarios accompanying the development process. [2]

development process, from the first specification steps (which still offer great potential for improvements according to [3]), through the design and implementation until the fining testing phase for legal approval. Complex behavior patterns are not describable by using previously used sensor-value-related describing techniques, instead an abstraction of the conditions surrounding the vehicle containing the system-under-test has to be utilized. They are called "scenarios" and incorporate all information about the environment and its conditions, as well as the vehicles/objects and their characteristics and kinematic behavior.

1.1 Terminology

1.1.1 Pegasus Terminology

The PEGASUS Project[3] was conducted by several car manufacturers, suppliers and research groups and concluded at the end of 2019. It has presented different approaches and results regarding the development of automated driving functions (cf. [4, 5]). For the content of this paper, especially the proposed taxonomies and terminologies are relevant. They are summarized in the following.

Abstraction Levels

The first terminology, that has a big influence on the definition of scenarios are the three described levels of abstraction:

- **Functional Scenarios**: "Functional scenarios contain natural language." [5]
- **Logical Scenarios**: "Logical scenarios describe parameter spaces in the state space." [5]
- **Concrete Scenarios**: "Concrete scenarios depict a concrete representative of a logical scenario." [5]

It is often assumed that there is a "1:m" relation between "abstract" and "logical" scenarios, as well as a "1:n" relation between "logical" and "concrete". For the sake of simplicity, we assume the first relation to be "1:1", i.e. each "abstract" scenario has a "logical" counterpart which differs in the way that "logical" scenarios contain value ranges for each parameter (e.g., the width of the lane) used in the "abstract" scenario.

Due to the extensive usage of the term "functional" with different meanings in the automotive domain, we introduced in previous publications the term "abstract scenarios" as synonym for "functional scenarios", because we believe that it is more suitable to reflect the abstraction-related nature of the terminology.

[3] https://www.pegasusprojekt.de/en/home

Content layers

Besides the definition of the abstraction levels of a scenario, the structuring of the content is an essential task to provide a well-defined scenario description. The PEGAUS project proposes a six-layer-model as basic scenario structure:

1. **Street level (L1)**: "Description of street layout and condition of the surface." [5]
2. **Infrastructure infrastructure (L2)**: "Traffic guidance infrastructure like signs, barriers, and markings." [5]
3. **Temporary modifications L1 und L2 (L3)**: "Temporary overlay of topology and geometry for temporal construction sites." [5]
4. **Objects (L4)**: "Description of traffic participants and objects including interactions based on maneuvers." [5]
5. **Environment conditions (L5)**: "Modeling of environment conditions like weather and daytime including influence on level 1 to 4." [5]
6. **Digital information(L6)**: "Digital Information (e.g.) V2X information, digital map." [4]

Note: The initial approach [5] consisted of five layers (L1-L5), but a sixth layer was added in the final report [4]. Additionally, layer 4 was renamed from "Movable objects" to "Objects" to also include static objects.

1.1.2 Problem Definition

As described before, scenarios are required throughout the complete development process. The main differentiation between the types of scenarios are the used level of abstraction and the used format.

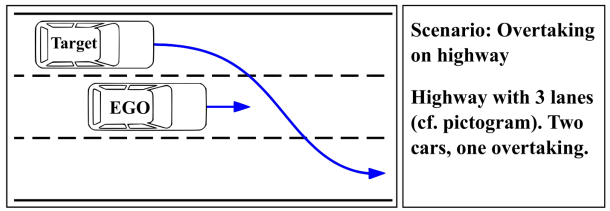
Regarding the format, different approaches are already available on the market or in the literature. The type of format is depending on the use case, e.g., a scenario that should be provided for stakeholder discussions or for the documentation of the system behavior for legal investigations should apply a natural-language notation (e.g., plain text) that is easy to read and limited in its level of detail (cf. Figure 1.2). Then again for simulation and testing, very detailed machine-readable formats (e.g., XML[4]) are required (cf. Figure 1.2). For the latter, existing standards such as OpenDRIVE [6] or OpenSCENARIO [6] are commonly applicable. For the former, popular document systems such as Microsoft Word[5] or Microsoft Excel[6] are typically used, i.e. engineers are writing scenario by hand as free text either without any guidance or by manually following written guidelines. The corresponding scenario visualizations are also drawn by hand. This leads to several problems:

- The text can be ambiguous because synonyms are used in different scenarios.
- No automatic spelling or grammar checks.
- No automatic translation, so either everybody uses the same language (e.g., English) which results in varying quality of the written text or manual translations are applied, which is expensive (time or costs).
- Inconsistencies between the text and the visualization are likely to be expected, as soon as one of them is changed. No automatic synchronization is ensured.

Therefore a potent solution to write natural-language scenario descriptions and simultaneously solve those issues is missing.

Regarding the levels of abstraction, obviously simulation scenarios will focus on the "concrete" level, whereas stakeholder discussions will be targeted at the "abstract" level. Although a certain mapping is possible, an automatic transformation between the different levels is missing, which would vastly increase the consistency throughout the development process. Also, the same scenario could be used in specification, in development, in testing and in the documentation.

[4] https://www.w3.org/XML/
[5] https://www.microsoft.com/de-de/microsoft-365/word
[6] https://www.microsoft.com/de-de/microsoft-365/excel



(a) Scenario as plain text with attached visualization. [7]

```
ROAD/GEOMETRY/LINE
Length = 10.000m
Lanes = RQ36 (Legal directive for lane widths and spacing)

ENTITIES
Entity/Name = CAR1
CAR1/VehicleModel/PKW = AUDI A3 2017
CAR1/Position/LaneID = 1
CAR1/Position/S = 100m (Relative lane position)
CAR1/Dynamics/Longitudinal/Speed = 28m/s

Entity/Name = CAR2
CAR2/VehicleModel/PKW = VW Golf VII 2017
CAR2/Position/LaneID = 1
CAR2/Position/S = 10m
CAR2/Dynamics/Longitudinal/Speed = 33m/s

MANEUVERS
Maneuver/Name = Decelerate
Maneuver/Owner = CAR1
Event/Type = Simulationtime
Simulationtime = 0s
Action/Type = Longitudinal/Speed
Longitudinal/Speed/Targetvalue = 20m/s
Longitudinal/Speed/Dynamics = linear
Longitudinal/Speed/Rate = -4m/s^2
```

(b) Scenarios in a technical format. [2]

Figure 1.2: Plain text or technical format.

As additional point, the degree of completeness of a scenario description will vary between the abstraction levels. “Abstract” scenarios tend to be more incomplete than “concrete” scenarios. “Concrete” scenarios have to be complete in order to be able to simulate, execute or test them. “Abstract” scenarios may contain less details, because:

1. One just does not know more details, therefore those details cannot be added yet.
2. One wants to leave the details out in order to allow variation of the scenarios (each “logical” scenario parameter range is varied in predefined steps to generate the “concrete” scenarios)

Existing approaches do not allow such an abstraction. The requirement therefore is to have a solution that allows scenario descriptions at different levels of abstraction, ideally without the necessity to manually transform them into oneanother.

Based on those problems and the derived requirements, stiEF was designed in order to provide a solution that has the following capabilities:

1. Provide the possibility to write natural-language scenarios at different natural languages (e.g., English and German).
2. Cover all three levels of abstraction with an automatic transformation.
3. Auto-generate the visualization out of the text in order to avoid inconsistencies.
4. Also allow “incomplete” descriptions.

stiEF itself consists of a language (syntax and semantics) as well as an implemented framework (cf. Figure 1.3). The language is part of this publication, the framework is currently closed source, but is planned to be released in the future to the public, either as Open-Source or as Freeware.

Note: The basic concepts of stiEF were already published before in [2], [7] and [8].

```
Layer 1 (Road Model):
  Segment #1 has a main roadway(🔒) of normal length and an entry.
    The main roadway has 2 driving lane(s) and a stop lane.
      Driving lane #1 has a narrow width.
    The entry has 1 driving lane(s) and a stop lane.
  Segment #2 has a main roadway(🔒) of long length.
    The main roadway has 3 driving lane(s) and a stop lane.
      Driving lane #3 has a narrowing in the middle.

Layer 2 (Infrastructure):
  Segment #1 contains following elements:
    There is at the beginning a mast #1 with a regulation sign of type speed limit with value "80".
    The road has guideposts and a guardrail on the median.
    The lateral vegetation consists of trees with 100 %(🔒) density.
  Segment #2 contains following elements:
    There is at the end a mast #2 with a regulation sign of type end of Speed Limit.
    The road leads under a bridge.

Layer 4 (Positioning and Velocity):
  The following Vehicle group #1 drives free on Segment #1:
    Car #1 drives with normal speed.
    Car #2 drives behind of the Car #1 with a challenging distance, on the left road mark.
  The following Column #2 drives on Segment #1:
    Truck #3 with Trailer drives right in front of the Car #1, close to the right road mark.
    Truck #4 drives behind of the Truck #3.
  On Segment #1, a stone #1(🔒) is at a critical distance in front of Car #1 and lies on the lane.

Layer 4 (Maneuvers):
  Phase #1 considers following maneuver sequence(s) :
    Car #2 follows the front vehicle and passes Truck #4.
    Truck #4 falls back from the front vehicle.
  Phase #2 considers following maneuver sequence(s) :
    Car #1 decelerates until at least a critical distance to stone #1 is reached and
      then Car #2 changes to right lane between Truck #3 and Truck #4.

Layer 5 (Environmental Conditions):
  The scenario takes place in autumn facing to North.
  On Segment #1 is moderate wind from the North-East and falling rain with normal precipitation.

  In Phase #2, the weather is changing and there is now a reduced visual range.
```

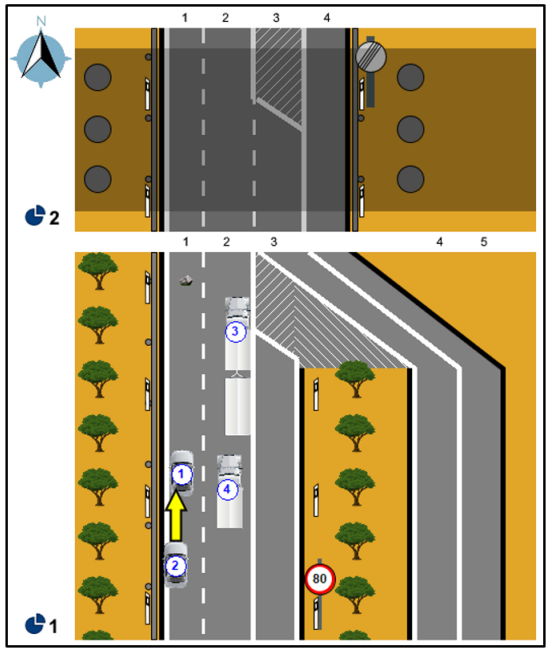


Figure 1.3: stiEF Framework. [7]

1.1.3 How-To Guide

Within the next chapters, the syntax and semantics of the language stiEF are described and explained in detail. They are following the PEGASUS content layer levels, so each chapter if focusing on one layer. To allow an efficient usage of the provided information, a short description of the general structure of such a chapter is given with additional information about the used notation and the proper usage.

Chapter 1 - Road Model

Short content description of this layer.

Section 1 - Use Cases

Description of underlying assumptions, modeling decisions and details about the involved content.

Section 2-X - Content Sections

Subsection 1 - Attributes

This subsection contains the definition of all used attributes for this grammar part. Therefore, each attribute name and a short description is given. If '#' is used, the attribute contains a unique ID (normally a running number as integer value). If '&' is used, the attribute is a reference to another attribute defined in another grammar part. Both '#' and '&' are combinable.

Example:

- **Segment#**: Segment identifier including a running number (unique within all segments of a road), for being referenceable by other layers.

Subsection 2 - Grammar

This subsection defines the grammar of this content part by using an Extended-Backus-Naur-Form-like style[7]. Both the English and the German grammar are given. 'NEWLINE' represents a new line, 'INDENT' an indent. '[...]' stands for optional elements, '(...)' is encapsulating data and '{...}' represents repeatable elements. Note that all elements on the right side of each grammar definition that are in '<...>' are taken out of the table in the transcription section (Subsection 4).

Example:

⟨*L1SegmentEng*⟩ ::= ⟨*Segment#*⟩ has a ⟨*Road*⟩ [of ⟨*Length*⟩ length] {[(, | and) [on the ⟨*Connection*⟩ side] ⟨*Feature*⟩]}. NEWLINE INDENT ⟨*L1RoadEng*⟩.

⟨*L1SegmentGer*⟩ ::= ⟨*Segment#*⟩ hat eine ⟨*Road*⟩ [von ⟨*Length*⟩ Länge] {[(, | und) [auf der ⟨*Connection*⟩ Seite] ⟨*Feature*⟩]}. NEWLINE IDENT ⟨*L1RoadGer*⟩.

Subsection 3 - Examples

This subsection contains simple examples of application for the grammar, often for all three abstraction levels (abstract, logical and concrete).

Example:

	A/L/C	**Examples**
1	A	Segment #1 has a main roadway.
2	L	Segment #1 has a main roadway of [500;1000]m length and an entry.
3	C	Segment #1 has a main roadway of 1000m length.

Subsection 4- Transcription

This subsection provides a table with all attributes from the grammar from Subsection 2, which are not already defined. There are attributes which only use textual enumeration values, they are marked in the corresponding 'enum' column with 'x' and do not provide logical or concrete values. If multiple values are available for an attribute, the default value is formatted bold.

Example:

TAG	**datatype**	**enum**	**Abstract values**		**Logical value**	**Default concrete value**	**unit**
			English	**German**			
<Segment#>	string/UUID#	x	'Segment #'	'Segment #'	-	-	-
<Length>	string/int	-	'short', '**normal**', 'long'	'kurzer', '**normaler**', 'langer'	[100;500[, **[500;1000[**, [1000;∞[	250, **700**, 1500	m

[7] https://en.wikipedia.org/wiki/Extended_Backus%E2%80%93Naur_form

Chapter 2

Layer 0 - Scenario

This chapter represents the top-element “scenario”. It contains all links to subsequent elements.

2.1 Scenario

2.1.1 Attributes

- **L1SegmentEng/L1SegmentGer**: Segment definition including road and lane information (cf. Chapter 3).
- **L2InfrastructureEng/L2InfrastructureGer**: Infrastructure details such as bridges and lane equipment (cf. Chapter 4).
- **L2TrafficRegulationEng/L2TrafficRegulationGer**: Traffic signs, both static and variable ones, as well as traffic lights (cf. Chapter 4).
- **L2VegetationEng/L2VegetationGer**: Vegetation details with density values (cf. Chapter 4).
- **L3RoadImpactEng/L3RoadImpactGer**: Roadworks definition (cf. Chapter 5).
- **L3LaneImpactEng/L3LaneImpactGer**: Impact of the roadworks to the lane definition (cf. Chapter 5).
- **L3InfrastructureImpactEng/L3InfrastructureImpactGer**: Impact of the roadworks to the traffic infrastructure definition (cf. Chapter 5).
- **L4PGroupEng/L4PGroupGer**: Vehicle/pedestrian/animal definition and positioning (cf. Chapter 6).
- **L4PObstacleDefinitionEng/L4PObstacleDefinitionGer**: Obstacle definition and positioning (cf. Chapter 6).
- **L4MManeuverStoryEng/L4MManeuverStoryGer**: Maneuver specification for the objects (cf. Chapter 7).
- **L5GenericConditionEng/L5GenericConditionGer**: Generic environment conditions such as time/season and temperature (cf. Chapter 8).
- **L5SegmentConditionEng/L5SegmentConditionGer**: Segment-related environment conditions (cf. Chapter 8).
- **L5ManeuverConditionEng/L5ManeuverConditionGer**: Maneuver-related environment conditions (cf. Chapter 8).

2.1.2 Grammar

⟨*ScenarioEng*⟩ ::= ⟨*Layer1Eng*⟩ NEWLINE NEWLINE ⟨*Layer2Eng*⟩ NEWLINE NEWLINE ⟨*Layer3Eng*⟩ NEWLINE NEWLINE ⟨*Layer4PEng*⟩ NEWLINE NEWLINE ⟨*Layer4MEng*⟩ NEWLINE NEWLINE ⟨*Layer5*⟩ NEWLINE

⟨*Layer1Eng*⟩ ::= Layer1(Road Model): NEWLINE INDENT ⟨*L1SegmentEng*⟩

⟨*Layer2Eng*⟩ ::= Layer2(Infrastructure): NEWLINE INDENT [{⟨*L2InfrastructureEng*⟩}] NEWLINE INDENT [{⟨*L2TrafficRegulationEng*⟩}] NEWLINE INDENT [⟨*L2VegetationEng*⟩]

⟨*Layer3Eng*⟩ ::= Layer3(Temporary Modifications): NEWLINE INDENT [⟨*L3RoadImpactEng*⟩] NEWLINE INDENT [{⟨*L3LaneImpactEng*⟩}] NEWLINE INDENT [{⟨*L3InfrastructureImpactEng*⟩}]

⟨*Layer4PEng*⟩ ::= Layer4(Positioning and Velocity): NEWLINE INDENT [⟨*L4PGroupEng*⟩] NEWLINE INDENT [{⟨*L4PObstacleDefinitionEng*⟩}]

⟨*Layer4MEng*⟩ ::= Layer4(Maneuvers): NEWLINE INDENT [{⟨*PhaseEng*⟩}]

⟨*Layer5*⟩ ::= Layer5(Environmental Conditions): NEWLINE INDENT [⟨*L5GenericConditionEng*⟩] NEWLINE INDENT [{⟨*L5SegmentConditionEng*⟩}] NEWLINE INDENT [{⟨*L5ManeuverConditionEng*⟩}]

⟨*PhaseEng*⟩ ::= ⟨*Phase#*⟩ considers following maneuver sequence(s): NEWLINE INDENT [{⟨*L4MManeuverStoryEng*⟩}]

⟨*ScenarioGer*⟩ ::= ⟨*Layer1Ger*⟩ NEWLINE NEWLINE ⟨*Layer2Ger*⟩ NEWLINE NEWLINE ⟨*Layer3Ger*⟩ NEWLINE NEWLINE ⟨*Layer4PGer*⟩ NEWLINE NEWLINE ⟨*Layer4MGer*⟩ NEWLINE NEWLINE ⟨*Layer5*⟩ NEWLINE

⟨*Layer1Ger*⟩ ::= Schicht1(Straßenebene): NEWLINE INDENT ⟨*L1SegmentGer*⟩

⟨*Layer2Ger*⟩ ::= Schicht2(Straßenausstattung): NEWLINE INDENT [{⟨*L2InfrastructureGer*⟩}] NEWLINE INDENT [{⟨*L2TrafficRegulationGer*⟩}] NEWLINE INDENT [⟨*L2VegetationGer*⟩]

⟨*Layer3Ger*⟩ ::= Schicht3(Temporäre Beeinflussung): NEWLINE INDENT [⟨*L3RoadImpactGer*⟩] NEWLINE INDENT [{⟨*L3LaneImpactGer*⟩}] NEWLINE INDENT [{⟨*L3InfrastructureImpactGer*⟩}]

⟨*Layer4PGer*⟩ ::= Schicht4(Positionierung und Geschwindigkeit): NEWLINE INDENT [⟨*L4PGroupGer*⟩] NEWLINE INDENT [{⟨*L4PObstacleDefinitionGer*⟩}]

⟨*Layer4MGer*⟩ ::= Schicht4(Manöver): NEWLINE INDENT [{⟨*PhaseGer*⟩}]

⟨*Layer5*⟩ ::= Schicht5(Umweltbedingungen): NEWLINE INDENT [⟨*L5GenericConditionGer*⟩] NEWLINE INDENT [{⟨*L5SegmentConditionGer*⟩}] NEWLINE INDENT [{⟨*L5ManeuverConditionGer*⟩}]

⟨*PhaseGer*⟩ ::= ⟨*Phase#*⟩ berücksichtigt folgende Manöversequenz(en): NEWLINE INDENT [{⟨*L4MManeuverStoryGer*⟩}]

2.1.3 Examples

A simple example that includes different information from different layers could look like the following one:
Layer1(Road Model):
Segment #1 has a main roadway.

The Main roadway has a straight geometry which has 2 driving lane(s).
Driving lane #1 has a normal width and deep ruts.

Layer2(Infrastructure):
The Main roadway has guideposts.

Layer3(Temporary Modifications):
On the main roadway is a short term construction site.

Layer4(Positioning and Velocity):
Following Vehicle Group #1 drives on Segment #1:
Vehicle #1 is located on the Driving lane #1 and drives.
Vehicle #2 drives right in front of the Vehicle #1.

Layer4(Maneuvers):
Phase #1 considers following maneuver sequence(s):
Vehicle #1 accelerates strongly.

Layer5(Environmental Conditions):
The scenario takes place in summer and under clear conditions.

2.1.4 Transcription

All attributes used in the grammar are explained in the following chapters, so no transcription table is necessary here.

Chapter 3

Layer 1 - Road Model

This content section deals with the road topology, i.e. the description of the road level with segments, lanes, etc. To unambiguously describe the road, the content is based on the official *RAA specification for German freeways* [9] and the OpenDRIVE standards [6]. Additionally, already existing scenario descriptions were used as reference.

3.1 Use Cases

The review of various sources for scenario descriptions and the available standards led to some findings that are the base for the follow-up definition of layer 1 of *stiEF* and worth to be mentioned. Those findings are mainly described for German highways, although some of them can be transferred to other countries:

- The **regular cross-section** is a standard in the *RAA* used to define the lateral width of the entire road. Two examples for that are the definition for city freeways (cf. Figure 3.1) and city freeways in a tunnel (cf. Figure 3.2).

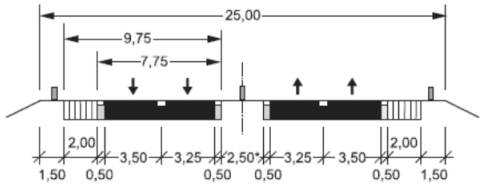


Figure 3.1: City freeway road width (taken from [9]).

- **Freeway entries** and **exits** have a great impact on the road model of the scenario description. There are nine types of entries and exits defined in the RAA[9] and they differ vastly in their geometrical structure. One important differentiation value is the structure of the ramp that leads to the entry or away from the exit: It can be direct, indirect or half-direct[1].

3.1.1 Summary

The unambiguous modeling of the road model is especially difficult if the road topology changes. Whereas the lateral subdivision of the road is quite easy (dividing into drivable and non-drivable lanes), the longitudinal is more challenging, because it normally has no predefined ending. Therefore, we chose to divide a road into

[1] https://de.wikipedia.org/wiki/Verbindungsrampe

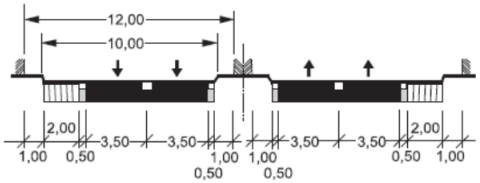


Figure 3.2: Road width in a tunnel (taken from [9]).

sub-elements, so called *segments*. As clear condition to start a new segment, a significant change in the topology is used. Such changes can for example be (incomplete list):

- Switching from a straight to a curved road
- Start of a freeway entry or exit
- Change of the number of lanes
- Start of a tunnel

Changes that would not count as "significant" are, e.g., a change of the curve radius or the start of an emergency bay.

To add significant changes to a road, a new segment has to be appended to the already existing one. Because all subsequent content layers derive information from the road layer, it must be ensured, that the description contains all relevant data. Therefore, the following information have to be included here:

- Segment definition
- Road attributes
- Number of lanes
- Entries and exists
- Connection of segments

3.2 Segment Definition

This section includes generic parameters of the segment for layer 1, such as the length or the features of the road.

3.2.1 Attributes

- **Segment#**: Segment identifier including a running number (unique within all segments of a road), for being referenceable by other layers.
- **Road**: Road type of the segment, e.g., "a main roadway". The road type preselects the attribute for the generic road attribute section, e.g., the type(s) one segment consists of. The provided types depend on the preselected location (e.g., freeway, federal road, etc.). For freeways, it is currently limited to "a main roadway", although for other domains, new elements such as "a roundabout" will be added in the future.
- **Length**: Length of the segment, either as abstract value (e.g., "short"), or in meters (interval or concrete value).

- **Connection**: Connection position of the features (e.g., the freeway entry). Examples for an exit: “from the left”, “to the right”, etc. This is specifically important for left-side or right-side traffic.
- **Feature**: Specific road features, which also preselects attributes for the generic road attribute section. Currently, “an entry” and “an exit” are available. This will be also extended for other domains.

3.2.2 Grammar

⟨*L1SegmentEng*⟩ ::= ⟨*Segment#*⟩ has a ⟨*Road*⟩ [of ⟨*Length*⟩ length] {[(, | and) [on the ⟨*Connection*⟩ side] ⟨*Feature*⟩]}. NEWLINE INDENT ⟨*L1RoadEng*⟩.

⟨*L1SegmentGer*⟩ ::= ⟨*Segment#*⟩ hat eine ⟨*Road*⟩ [von ⟨*Length*⟩ Länge] {[(, | und) [auf der ⟨*Connection*⟩ Seite] ⟨*Feature*⟩]}. NEWLINE IDENT ⟨*L1RoadGer*⟩.

3.2.3 Examples

	A/L/C	Examples
1	A	Segment #1 has a main roadway.
2	A	Segment #1 has a main roadway of long length and on the right side an entry.
3	L	Segment #1 has a main roadway of [500;1000]m length and an entry.
4	C	Segment #1 has a main roadway of 1000m length.

3.2.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Segment#>	string/UUID#	x	’Segment #’	’Segment #’	-	-	-
<Road>	string/UUID	x	’main roadway’	’Hauptstraße’	-	-	-
<Length>	string/int	-	’very short’, ’short’, ’**normal**’, ’long’, ’very long’	’sehr kurzer’, ’kurzer’, ’**normaler**’, ’langer’, ’sehr langer’	[0;100[, [100;500[, **[500;1000[**, [1000;2000[, [2000;∞[	50, 250, **700**, 1500, 2000	m
<Connection>	string	x	’**left**’, ’right’	’**linken**’, ’rechten’	-	-	-
<Feature>	string/UUID	x	’**an entry**’, ’an exit’	’**eine Auffahrt**’, ’eine Ausfahrt’	-	-	-

3.3 Road Attributes

The road of a segment can be detailed further by adding information about its geometric shape or the lanes (including special lanes such as stop lanes), which is described in this section.

3.3.1 Attributes

- **Road&**: The reference to the road defined in the segment section above.
- **Geometry**: Course of the segment, either “straight” or “curved”.
- **Radius**: Curvature radius, either as abstract value (e.g., “small”) or in meters (interval or concrete value).

- **Slope**: Slope of the road, either as abstract value (e.g., “steep”) or as percentage (interval or concrete value).
- **SlopeProfile**: Specification, whether the slope is “uphill” or “downhill”.
- **NumLanes**: Number of driving lanes of a road segment.
- **Tilt**: The lateral tilt of the road. The question, whether the value is positive or negative depends on the curved geometry. Positive is assumed to be right- and negative left-curved. Definition as abstract value (e.g., “with a slight”) or as percentage (interval or concrete value).
- **HOVLane#**: Information, whether the road (in the US or in China) has a high-occupancy-vehicle (HOV) lane close to the edge of the road.
- **FarSide**: Side, where the HOV lane is located (“right-most” or “left-most”).
- **StopLane#**: Information, whether the road has a stop lane.
- **EmergencyBay#**: Information, whether the road has an emergency bay (alias breakdown bay).
- **DividingLane#**: Information, whether the road has a dividing lane, which is used to specify non-drivable spaces (e.g., with vegetation).
- **Lane&#**: Reference to an already defined lane that is right/left of the dividing lane.

3.3.2 Grammar

⟨*L1RoadEng*⟩ ::= The ⟨*Road&*⟩ has ⟨*Geometry*⟩ geometry [with ⟨*Radius*⟩ radius] [(| and) (a ⟨*Slope*⟩ slope ⟨*SlopeProfile*⟩)] which has ⟨*NumLanes*⟩ driving lane(s) [(| with) ⟨*Tilt*⟩ lateral tilt] [(| , | and) ⟨*HOVLane #*⟩ [⟨*FarSide*⟩] [(| with) ⟨*Tilt*⟩ lateral tilt]] [(| , | and) ⟨*StopLane #*⟩ [(| with) ⟨*Tilt*⟩ lateral tilt]] [(| , | and) ⟨*EmergencyBay #*⟩] [(| and) (right | left) of ⟨*Lane&#*⟩ ⟨*DividingLane #*⟩]. NEWLINE INDENT ⟨*L1LaneEng*⟩.

⟨*L1RoadGer*⟩ ::= Eine ⟨*Road&*⟩ hat ⟨*Geometry*⟩ Geometrie [mit ⟨*Radius*⟩ Radius] [(| und) (eine ⟨*Slope*⟩ Steigung ⟨*SlopeProfile*⟩)], welche ⟨*NumLanes*⟩ Fahrstreifen [(| mit) ⟨*Tilt*⟩ Querneigung] [(| , | und) [⟨*FarSide*⟩] ⟨*HOVLane #*⟩ [(| mit) ⟨*Tilt*⟩ Querneigung]] [(| , | und) ⟨*StopLane #*⟩ [(| mit) ⟨*Tilt*⟩ Querneigung]] [(| , | und) ⟨*EmergencyBay #*⟩] [(| und) (rechts | links) von ⟨*Lane&#*⟩ ⟨*DividingLane #*⟩] besitzt. NEWLINE INDENT ⟨*L1LaneGer*⟩.

3.3.3 Examples

	A/L/C	Examples
1	A	The main roadway has 3 driving lanes.
2	A	The main roadway has a straight geometry and 2 driving lanes.
3	A	The main roadway has a curved geometry.
4	A	The main roadway has a left-curved geometry.
5	C	The entry has a left-curved geometry with 2500m radius.
6	A	The entry has a strong left-curved geometry.
7	L	The main roadway has a [10; 15]% slope uphill.
8	A	The exit has 1 driving lane and a steep slope downhill.
9	A	The main roadway has a left-curved geometry with small radius and a steep slope downhill, 4 driving lanes, a stop lane #5 and an emergency bay #6.

3.3.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Road&>	string/UUID&	-	-	-	-	-	-
<Geometry>	string	x	**'a straight'**, 'a left-curved', 'a right-curved'	**'eine gerade'**, 'eine links gerichtete', 'eine rechts gerichtete'	-	-	-
<Radius>	string/int	-	'small', 'middle', **'big'**	'einem schmalen', 'einem mittleren', **'einem großen'**	[1;500[, [500;1500[, **[1500;∞[**	250, 1000, **1500**	m
<Slope>	string/int	-	**'slight'**, 'middle', 'steep'	**'leichte'**, 'mittlere', 'starke'	**[0;5[**, [5;10[, [10;15[	**2**, 5, 10	%
<SlopeProfile>	string	x	**'downhill'**, 'uphill'	**'bergab'**, 'bergauf'	-	-	-
<NumLanes>	int	-	-	-	-	-	-
<Tilt>	string/float	-	'without a', **'with a slight'**, 'with a middle', 'with a steep'	'ohne', **'mit leichter'**, 'mit mittlerer', 'mit starker'	[0;2.5[, **[2.5;3.5[**, [3.5;5.0[, [5.0;7.0[	1.0, **3.0**, 4.0, 6.0	%
<HOVLane#>	string/UUID#	x	'an HOV lane #'	'einen Fahrgemeinschaftsstreifen #'	-	-	-
<FarSide>	string	x	**'left-most'**, 'right-most'	**'ganz links'**, 'ganz rechts'	-	-	-
<StopLane#>	string/UUID#	x	'a stop lane #'	'einen Standstreifen #'	-	-	-
<EmergencyBay#>	string/UUID#	x	'an emergency bay #'	'eine Nothaltebucht #'	-	-	-
<DividingLane#>	string/UUID#	x	'a dividing lane #'	'einen Trennstreifen #'	-	-	-
<Lane&#>	string/UUID&#	-	-	-	-	-	-

Note: For tilt, the value range starts from 0 till max 7.0% see RAA, Page 38 - Figure 23 [9].

3.4 Lane Details

Lanes that were added to the segment can be refined by introducing more details in this section. For that, the main mandatory field is a unique identifier, containing a lane number, starting with 1. This lane number can be used to position and reference a lane if necessary. By default and unless otherwise specified, each n-th lane of a segment is connected with the n-th lane of the previous segment.

3.4.1 Attributes

- **Lane#**: Lane identifier including a running number (unique within all lanes of a road).
- **Width**: Width of the lane, either as abstract value (e.g., "narrow") or in meters (interval or concrete value).
- **Transition**: Used to specify a "widening" or a "narrowing".
- **Direction**: Direction of the narrowing ("to the right" or "to the left").

- **Position**: Longitudinal position of the transition on the segment either as abstract value (e.g., “at the beginning”) or as position (interval or concrete value).
- **Ruts**: Definition of existing ruts on the lane.
- **Marking**: Definition of the road markings.
- **Visibility**: Visibility of the road markings, either as abstract value (e.g., “fully visible”) or as percentage (interval or concrete value).
- **Lane&#**: Reference to an already defined lane for the connection.
- **Segment&#**: Reference to the segment of the lane for the connection.

3.4.2 Grammar

⟨*L1LaneEng*⟩ ::= ⟨*Lane#*⟩ [has] [a ⟨*Width*⟩ width] [(| , | and) a ⟨*Transition*⟩ [to ⟨*Direction*⟩ lane] [(| after) ⟨*Position*⟩]] [(| , | and) ⟨*Ruts*⟩ ruts] [(| , | and) a [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ visible] lane marking on the left] [(| , | and) a [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ visible] lane marking on the right] [(| and) (is connected to [⟨*Lane&#*⟩] [of segment ⟨*Segment&#*⟩] | no further segment connections)].

⟨*L1LaneGer*⟩ ::= ⟨*Lane#*⟩ [hat] [eine ⟨*Width*⟩ Breite] [(| , | und) [(| nach) ⟨*Position*⟩] eine ⟨*Transition*⟩ [zum ⟨*Direction*⟩ Fahrstreifen]] [(| , | und) ⟨*Ruts*⟩ Spurrillen] [(| , | und) links eine [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ sichtbare] Fahrstreifenmarkierung] [(| , | und) rechts eine [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ sichtbare] Fahrstreifenmarkierung] [(| und) (ist mit [⟨*Lane&#*⟩] [von Segment ⟨*Segment&#*⟩] verbunden | keine weiteren Segmentverbindungen)].

3.4.3 Examples

	A/L/C	Examples
1	A	Driving lane #1 has a narrow width.
2	C	Driving lane #2 has a 3,5 m width.
3	A	Driving lane #1 has deep ruts.
4	L	Stop lane #4 has badly visible lane markings on the left.
5	A	Driving lane #3 has a wide width, deep ruts, partially visible lane markings on the right and is connected to entry lane #3 of segment #2.

3.4.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Lane#>	string/UUID#	x	’**Driving lane #**’, ’Stop lane #’, ’Dividing lane #’, ’HOV lane #’	’**Fahrstreifen #**’, ’Standstreifen #’, ’Trennstreifen #’, ’Fahrgemeinschaftsstreifen #’	-	-	-
<Width>	string/float	-	’narrow’, ’**normal**’, ’wide’	’schmale’, ’**normale**’, ’weite’	[3.00;3.24[, **[3.25;3.49[**, [3.50;3.75[	3.20, **3.40**, 3.60	m
<Transition>	string	x	’**narrowing**’, ’widening’	’**Zusammenführung**’, ’Gabelung’	-	-	-
<Direction>	string	x	’**left**’, ’right’	’**linken**’, ’rechten’	-	-	-
<Position>	string/int	-	’**at the beginning**’, ’in the middle’, ’at the end’	’**am Anfang**’, ’in der Mitte’, ’am Ende’	**[0;25[**, [25;50[, [50;∞[	**10**, 30, 50	m

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Ruts>	string	x	'**no**', 'shallow', 'deep'	'**keine**', 'flache', 'tiefe'	-	-	-
<Marking>	string	x	'continuous', '**interrupted**', 'wide, continuous', 'wide, interrupted'	'durchgehende', '**unterbrochene**', 'breite, durchgehende', 'breite, unterbrochene'	-	-	-
<Visibility>	string/int	-	'not', 'poorly', 'partially', '**well**', 'perfectly'	'nicht', 'schlecht', 'teilweise', '**gut**', 'perfekt'	[0;10[, [10;40[, [40;60[, **[60;80[**, [80;100]	5, 30, 50, **70**, 90	%
<Lane&#>	string/UUID&#	-	-	-	-	-	-
<Segment&#>	string/UUID&#	-	-	-	-	-	-

Chapter 4

Layer 2 - Infrastructure

The second context section (Layer 2) includes definitions of the traffic infrastructure, traffic regulation elements and vegetation. As an abstraction, those elements are expected to be available along the complete street segment, therefore they are partly specified by using density values (e.g., for existing bushes/trees).

4.1 Infrastructure Details

The properties for the road infrastructure are defined in this section.

4.1.1 Attributes

- **Road&**: Reference to the road, where the traffic infrastructure elements should be positioned.
- **Structure**: A structure is defined as objects which surround/overtop the road (e.g., a bridge or a tunnel).
- **Clearance**: Clearance of the structure, either as abstract value (e.g., “very low”) or in meters (interval or concrete value).
- **Guideposts**: The presence of guideposts along the roadside of the segment.
- **Directory**: Distance between the guideposts, defined as abstract value (e.g., “small”) or as value in meters (interval or concrete value).
- **HOVEq**: Barrier between driving lane and HOV lane.
- **Equipment**: All types of equipment of the segment besides the road, even for structure elements such as bridges (e.g., “pillars”).
- **Shoulder**: Limiting guideposts or types of equipment to one of the shoulders of the road.
- **Height**: Height of the equipment in cm.
- **Houses**: Buildings alongside the road segment.
- **Density**: Density of houses as frequency occurrence ratio, either as abstract value (e.g., “low”) or as percentage (interval or concrete value).

4.1.2 Grammar

⟨*L2InfrastructureEng*⟩ ::= The ⟨*Road&*⟩ [leads ⟨*Structure*⟩ [with a (⟨*Clearance*⟩ clearance height | clearance height of ⟨*Clearance*⟩)]] [[and] has] [⟨*Guideposts*⟩ [on ⟨*Shoulder*⟩] [with (a |) ⟨*Directory*⟩ distance]] [⟨*HOVEq*⟩ which delineates the HOV-lane] [{(| , | and) ⟨*Equipment*⟩ [on ⟨*Shoulder*⟩] [of ⟨*Height*⟩cm height]}] [(| and) ⟨*Houses*⟩ [with ⟨*Density*⟩ density]].

⟨*L2InfrastructureGer*⟩ ::= Die ⟨*Road&*⟩ [führt ⟨*Structure*⟩ [mit einer (⟨*Clearance*⟩ Durchfahrtshöhe | Durchfahrtshöhe von ⟨*Clearance*⟩)]] [[und] hat] [⟨*Guideposts*⟩ [auf ⟨*Shoulder*⟩] [mit (einem |) ⟨*Directory*⟩ Abstand]] [⟨*HOVEq*⟩ welcher den Fahrgemeinschaftsstreifen abgrenzt] [{(| , | und) ⟨*Equipment*⟩ [auf ⟨*Shoulder*⟩] [von ⟨*Height*⟩cm Höhe]}] [(| und) ⟨*Houses*⟩ [mit ⟨*Density*⟩ Dichte]].

4.1.3 Examples

	A/L/C	Examples
1	A	The main roadway has a guardrail.
2	A	The main roadway has a noise barrier.
3	A	The main roadway has guideposts.
4	C	The main roadway has guideposts with a 50m distance.
5	A	The main roadway has houses with high density.
6	A	The main roadway leads under a bridge and has a continuous wall on the right shoulder and a guardrail on the median.
7	L	The main roadway has a noise barrier on the right shoulder of 180cm height and a concrete step barrier on the median lane of 120cm height.

4.1.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Road&>	string/UUID&	-	-	-	-	-	-
<Structure>	string	x	'**under a bridge**', 'through a tunnel', 'through a trough (u-shaped tunnel)'	'**unter einer Brücke hindurch**', 'durch einen Tunnel', 'durch einen Trog (u-förmiger Tunnel)'	-	-	-
<Clearance>	string/float	-	'very low', 'low', '**normal**', 'high', 'very high'	'sehr geringe', 'geringe', '**normale**', 'hohe', 'sehr hohe'	[0.0;1.0[, [1.0;2.2[, **[2.2;3.0[**, [3.0;5.0[, [5.0;∞[	0.5, 1.5, **2.2**, 4.0, 5.0	m
<Guideposts>	string	x	'guideposts'	'Leitpfosten'	-	-	-
<Shoulder>	string	x	'the median', 'the right shoulder', '**the median and the right shoulder**'	'dem Mittelstreifen', 'dem rechten Bankett', '**dem Mittelstreifen/dem rechten Bankett**'	-	-	-
<Directory>	string/int	-	'very small', 'small', '**normal**'	'sehr kleinem', 'kleinem', '**normalem**'	[0;10[, [11;40[, **[41;∞[**	5, 35, **50**	m
<HOVEq>	string	x	'**a guardrail**', 'concrete step barrier'	'**eine Leitplanke**', 'ein Betonrückhaltesystem'	-	-	-

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Equipment>	string	x	**'a guardrail'**, 'a noise barrier', 'a concrete step barrier', 'pillars', 'an interrupted wall', 'a continuous wall'	**'eine Leitplanke'**, 'eine Lärmschutzwand', 'ein Betonrückhaltesystem', 'Pfeiler', 'eine unterbrochene Wand', 'eine durchgehende Wand'	-	-	-
<Height>	int	-	-	-	-	-	-
<Houses>	string	x	'houses'	'Häuser'	-	-	-
<Density>	string/int	-	'very low', **'low'**, 'normal', 'high', 'very high'	'sehr niedrigen', **'niedrigen'**, 'normalen', 'hohen', 'sehr hohen'	[0;20[, **[20;40[**, [40;60[, [60;80[, [80;100]	10, **30**, 50, 70, 100	%

4.2 Traffic Regulating Elements

This section considers traffic signs or traffic regulating elements. This includes, e.g., groups of road signs or traffic lights on a mast, the visibility of elements due to aging or environmental conditions and element positions on a road segment.

4.2.1 Attributes

- **Position**: Position of the group of traffic signs in relation to the segment, either as abstract value (e.g., "at the beginning") or in meters (interval or concrete value). There can be several groups at the same position.
- **GroupType#**: Type of sign group, e.g., "mast", "bridge", etc. including a number.
- **Clearance**: Clearance of a traffic sign bridge, either as abstract value (e.g., "very low") or in meters (interval or concrete value).
- **Visibility**: Visibility of the road signs (due to dirt, aging, etc.), either as abstract value (e.g., "perfectly visible") or as percentage (interval or concrete value).
- **Aspects**: Configuration of the amount of aspects of a traffic light.
- **Light**: Current state of the blinking/static traffic light.
- **SignClass**: Class of a traffic sign (e.g., "informational" or "regulation" sign).
- **Name**: Designator of the traffic sign in natural language (e.g., "speed limit" or "overtaking forbidden").
- **SignNr**: Identifier of the traffic sign as number based on the current German catalog[1]. It is a string build by <number> and <sub-number>, e.g. "274-60" for "max speed 100 km/h" (specific for Germany).
- **Value**: Traffic signs may be attributed with an additional value, e.g., a city name or a speed limit value.
- **Height**: Height of the traffic sign, either as abstract value (e.g., "low") or in meters (interval or concrete value).
- **Lane&#**: Lane to which the traffic sign should be assigned.

[1] https://www.verkehrszeichen-online.org/

4.2.2 Grammar

⟨*L2TrafficRegulationEng*⟩ ::= (| After) ⟨*Position*⟩, {(there is | and) ⟨*GroupType#*⟩ [with [a (⟨*Clearance*⟩ clearance height | clearance height of ⟨*float*⟩m)] {(| , | and) a [⟨*Visibility*⟩ visible] [,] (a ⟨*Aspects*⟩ traffic light [(illuminating | flashing) ⟨*Light*⟩] | variable traffic sign [, which shows a ⟨*SignClass*⟩ sign [(⟨*SignNr*⟩ | of type ⟨*Name*⟩ [with value ⟨*Value*⟩])]] | ⟨*SignClass*⟩ sign (⟨*SignNr*⟩ | [of type ⟨*Name*⟩] [with value ⟨*Value*⟩])) [at (⟨*Height*⟩ height | height of ⟨*Height*⟩)] [(over | on) ⟨*Lane&#*⟩]}]}.

⟨*L2TrafficRegulationGer*⟩ ::= (| Nach) ⟨*Position*⟩ {(ist | und) ⟨*GroupType#*⟩ [mit [einer (⟨*Clearance*⟩ Durchfahrtshöhe | Durchfahrtshöhe von ⟨*Clearance*⟩)] {(| , | und) (einer | einem) [⟨*Visibility*⟩ sichtbaren] [,] (⟨*Aspects*⟩ Lichtzeichenanlage [, die ⟨*Light*⟩ (leuchtet | blinkt)] | variablen Verkehrszeichen [, welches ein ⟨*SignClass*⟩ [(⟨*SignNr*⟩ | des Typs ⟨*Name*⟩ [mit dem Wert ⟨*Value*⟩]] zeigt)]) | ⟨*SignClass*⟩ (⟨*SignNr*⟩ | des Typs (⟨*Name*⟩ | ⟨*SignNr*⟩) [mit dem Wert ⟨*Value*⟩])) [in einer (⟨*Height*⟩ Höhe | Höhe von ⟨*Height*⟩)] [(über | auf) ⟨*Lane&#*⟩]}]}.

4.2.3 Examples

	A/L/C	Examples
1	C	After 5m, there is a mast#1 with a danger sign #101.
2	A	At the beginning, there is a mast #3 with a partially visible regulation sign of type end of all speed limits.
3	A	In the middle, there is a bridge #1 with a variable traffic sign, which shows a regulation sign of type overtaking forbidden for trucks.

4.2.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Position>	string/int	-	'**At the beginning**', 'In the middle', 'At the end'	'**Am Anfang**', 'In der Mitte', 'Am Ende'	**[0;25[**, [25;50[, [50;∞[	**10**, 30, 50	m
<GroupType#>	string/UUID#	x	'**a sign group #**', 'a mast #', 'a bridge #', 'road markings #'	'**eine Schildergruppe #**', 'ein Mast #', 'eine Brücke #', 'Straßenmarkierungen #'	-	-	-
<Clearance>	string/float	-	'very low', 'low', '**normal**', 'high', 'very high'	'sehr geringe', 'geringe', '**normale**', 'hohe', 'sehr hohe'	[0.0;1.0[, [1.0;2.2[, **[2.2;3.0[**, [3.0;5.0[, [5.0;∞[	0.5, 1.5, **2.2**, 4.0, 5.0	m
<Visibility>	string/int	-	'not', 'poorly', 'partially', '**well**', 'perfectly'	'nicht', 'schlecht', 'teilweise', '**gut**', 'perfekt'	[0;10[, [10;40[, [40;60[, **[60;80[**, [80;100]	5, 30, 50, **70**, 90	%
<Aspects>	string	x	'single-aspects', '**dual-aspects**', 'three-aspects'	'einfarbigen', '**zweifarbigen**', 'dreifarbigen'	-	-	-
<Light>	string	x	'**green**', 'yellow', 'red'	'**grün**', 'gelb', 'rot'	-	-	-

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<SignClass>	string	x	'**regulation**', 'informational', 'danger', 'supplementary'	'**Vorschriftszeichen**', 'Richtzeichen', 'Gefahrenzeichen', 'Zusatzzeichen'	-	-	-
<Name>	string	x	'**speed limit**', 'end of all speed limits', 'local plaque ', 'overtaking forbidden'	'**Geschwindigkeitsbegrenzung**', 'Aufhebung Geschwindigkeits-/Überholverbote', 'Ortstafel', 'Überholen Verboten'	-	-	-
<SignNr>	int	-	-	-	-	-	-
<Value>	string	-	-	-	-	-	-
<Height>	string/int	-	'very low', 'low', '**normal**', 'high', 'very high'	'sehr geringe', 'geringe', '**normale**', 'hohe', 'sehr hohe'	[0.5;1.5[, [1.5;2.0[, **[2.0;2.3[**, [2.3;3.0[, [3.0;∞[	1.25, 1.5, **2.15**, 2.3, 3.0	m
<Lane&#>	UUID&#	-	-	-	-	-	-

Note: For <Name> some examples are given, additional traffic signs can be added to the collection based on the traffic domain.

4.3 Vegetation Details

This section contains information about existing vegetation alongside the road.

4.3.1 Attributes

- **Plant**: Specifies trees or bushes alongside the road.
- **Placement**: Placement of plants on the right shoulder and/or the median.
- **Height**: Height of the plants in cm.
- **Density**: Density of the vegetation as abstract value (e.g., "low") or as percentage (interval or concrete value).

4.3.2 Grammar

⟨*L2VegetationEng*⟩ ::= The lateral vegetation consists of [{(, | and) ⟨*Plant*⟩ [on ⟨*Placement*⟩] [of ⟨*Height*⟩cm height] [with ⟨*Density*⟩ density]}].

⟨*L2VegetationGer*⟩ ::= Die seitliche Vegetation besteht aus [{(, | und) ⟨*Plant*⟩ [auf ⟨*Placement*⟩] [von ⟨*Height*⟩cm Höhe,] [mit ⟨*Density*⟩ Dichte]}].

4.3.3 Examples

	A/L/C	Examples
1	A	The lateral vegetation consists of trees.
2	A	The lateral vegetation consists of bushes with high density.
3	C	The lateral vegetation consists of trees on the right shoulder with 70% density and bushes of 40cm height with 20% density.

4.3.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Plant>	string	x	'**trees**', 'bushes'	'**Bäumen**', 'Büschen'	-	-	-
<Placement>	string	x	'**the median**', 'the right shoulder', 'the median and the right shoulder'	'**dem Mittelstreifen**', 'dem rechten Bankett', 'dem Mittelstreifen und dem rechten Bankett'	-	-	-
<Height>	int	-	-	-	-	-	-
<Density>	string/int	-	'very low', '**low**', 'normal', 'high', 'very high'	'sehr niedrigen', '**niedrigen**', 'normalen', 'hohen', 'sehr hohen'	[0;20[, **[20;40[**, [40;60[, [60;80[, [80;100]	10, **30**, 50, 70, 100	%

Chapter 5

Layer 3 - Temporary Modifications

This section contains the temporary modifications for layer 1 and 2. This includes roadworks as well as changes of traffic signs (e.g., crossing a traffic sign out).

5.1 Use Cases

As for the other layers, different use cases can be incorporated here. There are mainly two classifications for roadworks: Long- and short-term construction sites. They inherit examples for a closure of an exit lane, construction sites with blocked lanes and those where lanes are directed to the opposite side road.

5.1.1 Long-Term Construction Sites

On Exit Lane For exit lanes, the placement of traffic signs has to be considered. Although – in general – no special impact to the road model scenario layer 1 is present, an exit could be blocked, which has to be possible.

On Stop Lane Stop lanes can also be blocked, which may lead to a narrowed situation. The first noticeable impact are the warning lights on the barks. They are optional according to the RSA [9].

On Entire Road If the entire road is blocked, it might be necessary to redirect the traffic to opposite lanes, which requires the definition of makeshift lanes. The barrier on the median has to be removed for that purpose.

5.1.2 Short-Term Construction Sites

On Lane A short-term construction site in difference to the long-term construction site does not contain makeshift lanes with new road markings, instead it is using traffic signs and barks to redirect the traffic.

5.2 Impact to Road Details

To describe the temporary modifications, the description format from layer 1 and 2 can be adapted. However, specific elements have to be added (e.g., “makeshift lanes”) to be able to reflect all types of modifications appropriately.

5.2.1 Attributes

- **Segment&#**: Reference to the segment defined in layer 1.
- **Road&**: Reference to the road from layer 1 that should be modified.
- **Feature&**: Reference to the feature from layer 1 that should be modified.
- **Reason**: Reason for the modifications, either “short term construction site” or “long term construction site”.
- **NumMakeshift**: Number of the makeshift lanes on top of the underlying road segment.
- **NumMakeshiftOpp**: Additional amount of makeshift lanes used on the opposite road side.
- **hasMakeshiftBay**: Information, whether the road has an emergency bay as makeshift solution.

5.2.2 Grammar

⟨*L3RoadImpactEng*⟩ ::= (On the | The) (⟨*Road&*⟩ | ⟨*Feature&*⟩) of ⟨*Segment&#*⟩ [is ⟨*Reason*⟩ [and it]] [has ⟨*NumMakeshift*⟩ makeshift lane(s) [(, | and) ⟨*NumMakeshiftOpp*⟩ lane(s) on the opposite side] [and ⟨*hasMakeshiftBay*⟩]].

⟨*L3RoadImpactGer*⟩ ::= (Auf der | Die) (⟨*Road&*⟩ | ⟨*Feature&*⟩) von ⟨*Segment&#*⟩ [ist ⟨*Reason*⟩ [und diese]] [hat ⟨*NumMakeshift*⟩ Behelfsspur(en) [(, | und) ⟨*NumMakeshiftOpp*⟩ Spuren auf der Gegenfahrbahn] [und ⟨*hasMakeshiftBay*⟩]].

5.2.3 Examples

	A/L/C	Examples
1	A	On the main roadway of Segment #1 is a short term construction site.
2	A	On the exit of Segment #1 is a long term construction site and it has 2 makeshift lane(s) and an emergency bay.

5.2.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Segment&#>	string/UUID&#	-	-	-	-	-	-
<Road&>	string/UUID&	-	-	-	-	-	-
<Feature&>	string/UUID&	-	-	-	-	-	-
<Reason>	string	x	**'a short term construction site'**, 'a long term construction site'	**'eine kurzfristige Baustelle'**, 'eine langfristige Baustelle'	-	-	-
<NumMakeshift>	int	-	-	-	-	-	-
<NumMakeshiftOpp>	int	-	-	-	-	-	-
<hasMakeshiftBay>	string	x	'an emergency bay'	'eine Nothaltebucht'	-	-	-

5.3 Impact to Lanes Details

Lanes on the road are mainly defined by road markings. In case of construction sites, additional temporal road markings (with a different color) are drawn over the regular markings. The specific colors vary depending on the country.
Besides construction sites, additional reasons for a lane blocking can exist, e.g., barriers, prohibition due to traffic signs, accidents, etc.

5.3.1 Attributes

- **Lane&#**: Reference to layer 1 lane. Subsequent segment lane references can link to makeshift lanes only.
- **Road&**: Reference to the road of the referenced segment.
- **Feature&**: Reference to the feature of the referenced segment.
- **Segment&#**: Reference to the segment of the referenced lane.
- **Blocked**: Specifies if the lane is blocked, either completely or on the left/right side.
- **Makeshift#**: Temporal makeshift lane.
- **LaneLink1&#**: Reference to lane from layer 1.
- **LaneLink2&#**: Reference to lane from layer 1.
- **Width**: Width of the lane. If different from layer 1, new makeshift lane markings are necessary.
- **Transition**: Definition, whether the lane "is narrowing (to left/right)" or "is widening (to left/right)" lane, e.g. for a freeway exit or entry.
- **Direction**: Parameter to specify the direction of the widening/narrowing, either "left" or "right".
- **Position**: Position of the transition on the segment, either as abstract value (e.g., "at the beginning") or in meters (interval or concrete value).
- **Marking**: Definition of the marking (left and right).
- **Visibility**: Visibility of the makeshift lane markings, either as abstract value (e.g., "well") or as percentage (interval or concrete value).

5.3.2 Grammar

⟨*L3LaneImpactEng*⟩ ::= (⟨*Lane&#*⟩ on (⟨*Road&*⟩ | ⟨*Feature&*⟩) of ⟨*Segment&#*⟩ [is ⟨*Blocked*⟩] | [⟨*Makeshift#*⟩ (redirects ⟨*LaneLink1&#*⟩ to ⟨*LaneLink2&#*⟩ | replaces ⟨*LaneLink1&#*⟩)] [(| , | and)] has [⟨*Width*⟩ width] [(| , | and) a ⟨*Transition*⟩ [to ⟨*Direction*⟩ lane] [(⟨*Position*⟩ | after ⟨*int*⟩m)]] [(| , | and) a [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ visible] lane marking on the left] [(| and) a [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ visible] lane marking on the right].

⟨*L3LaneImpactGer*⟩ ::= (⟨*Lane&#*⟩ auf (⟨*Road&*⟩ | ⟨*Feature&*⟩) von ⟨*Segment&#*⟩ [ist ⟨*Blocked*⟩] | [⟨*Makeshift#*⟩ (leitet den ⟨*LaneLink1&#*⟩ zum ⟨*LaneLink2&#*⟩ um | ersetzt ⟨*LaneLink1&#*⟩)] [(| , | und)] hat [⟨*Width*⟩ Breite] [(| , | und) [(⟨*Position*⟩ | nach ⟨*int*⟩m)] einer ⟨*Transition*⟩ [zum ⟨*Direction*⟩ Fahrsteifen]] [(| , | und) links eine [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ sichtbare] Fahrstreifenmarkierung] [(| und) rechts eine [⟨*Marking*⟩] [,] [⟨*Visibility*⟩ sichtbare] Fahrstreifenmarkierung].

5.3.3 Examples

	A/L/C	Examples
1	A	Driving lane #1 is blocked.
2	A	Stop lane #1 is blocked on right and has a narrow width.
3	L	Makeshift lane #1 replaces Driving lane #1 and has [3.20;3.50] width.
4	C	Driving lane #1 is blocked and has a narrowing to right lane after 100m.
5	A	Makeshift lane #1 redirects Driving lane #-1 to Driving lane #1, has a narrow width and a poorly visible road marking on the left.

5.3.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Lane&#>	string/UUID&#	-	-	-	-	-	-
<Road&>	string/UUID&	-	-	-	-	-	-
<Feature&>	string/UUID&	-	-	-	-	-	-
<Segment&#>	string/UUID&#	-	-	-	-	-	-
<Blocked>	string	x	'**blocked**', 'blocked on right', 'blocked on left', 'blocked by variable sign', 'blocked by mobile barrier', 'blocked by an accident'	'**gesperrt**', 'rechts gesperrt', 'links gesperrt', 'durch ein variables Signal gesperrt', 'durch eine fahrbare Absperrtafel gesperrt', 'durch einen Unfall gesperrt'	-	-	-
<Makeshift#>	string/UUID#	x	'**Makeshift lane #**', 'Emergency bay #'	'**Behelfsstreifen #**', 'Nothaltebucht #'	-	-	-
<LaneLink1&#> <LaneLink2&#>	string/UUID&#	-	-	-	-	-	-
<Width>	string/float	-	'a narrow', '**a normal**', 'a wide'	'eine schmale', '**eine normale**', 'eine weite'	[3.00;3.24[, **[3.25;3.49[**, [3.50;3.75[	3.20, **3.40**, 3.60	m
<Transition>	string	x	'**narrowing**', 'widening'	'**Zusammenführung**', 'Gabelung'	-	-	-
<Direction>	string	x	'**left**', 'right'	'**linken**', 'rechten'	-	-	-
<Position>	string/int	-	'**at the beginning**', 'in the middle', 'at the end'	'**am Anfang**', 'in der Mitte', 'am Ende'	**[0;25[**, [25;50[, [50;∞[	**10**, 30, 50	m
<Marking>	string	x	'continuous', '**interrupted**', 'wide, continuous', 'wide, interrupted'	'durchgehende', '**unterbrochene**', 'breite, durchgehende', 'breite, unterbrochene'	-	-	-
<Visibility>	string/int	-	'not', 'poorly', 'partially', '**well**', 'perfectly'	'nicht', 'schlecht', 'teilweise', '**gut**', 'perfekt'	[0;10[, [10;40[, [40;60[, **[60;80[**, [80;100]	5, 30, 50, **70**, 90	%

5.4 Impact to Infrastructure

This layer specifies temporary road furniture and rules for a road segment similar to layer 2. As it covers only temporary elements, infrastructure and vegetation elements are not included here. The below notation and attributes are used to define the explicit replacement of invalided signs. If new signs have to be placed, the notation of layer 2 should be used.

5.4.1 Attributes

- **GroupType&#**: The traffic sign group type in case a new traffic sign needs to be placed. In case an existing sign will be replaced on layer 2, the reference to existing group type can be used.
- **Name&**: Either the existing name defined in layer 2 or the new traffic sign out of the generic sign catalog (see layer 2).
- **SignNr&** or **SignNr**: Either the existing number defined in layer 2 or the new traffic sign number.
- **Visibility**: Visibility of the road signs (due to dirt, aging, etc.), either as abstract value (e.g., “perfectly visible”) or as percentage (interval or concrete value).
- **SignClass**: Class of a traffic sign (e.g., “informational” or “regulation” sign).
- **Value**: Traffic signs may be attributed with an additional value, e.g. a city name.
- **Clearance**: Clearance of a traffic sign bridge, either as abstract value (e.g., “very low”) or in meters (interval or concrete value).

5.4.2 Grammar

⟨*L3InfrastructureImpactEng*⟩ ::= At ⟨*GroupType&#*⟩, {(|, | and) the (sign (⟨*Name&*⟩ | ⟨*SignNr&*⟩) | traffic light) is (crossed-out | replaced with a [⟨*Visibility*⟩ visible] ⟨*SignClass*⟩ sign [(⟨*Name*⟩|⟨*SignNr*⟩) [with value ⟨*Value*⟩]] [with ⟨*Clearance*⟩ clearance height])}.

⟨*L3InfrastructureImpactGer*⟩ ::= An ⟨*GroupType&#*⟩ ist {(|, | und) (das Schild (⟨*Name&*⟩ | ⟨*SignNr&*⟩) | die Lichtzeichenanlage) ist (ausgekreuzt | ersetzt durch ein [⟨*Visibility*⟩ sichtbares] ⟨*SignClass*⟩ [(⟨*Name*⟩ | ⟨*SignNr*⟩) [mit dem Wert ⟨*Value*⟩]] [mit ⟨*Clearance*⟩ Durchfahrtshöhe])}.

5.4.3 Examples

	A/L/C	Examples
1	A	At the Mast 1, the sign speed limit is replaced with a regulation sign speed limit with value 60 km/h.
2	C	At the Mast 2, the sign 274-60 is replaced with a well visible regulation sign 274-56.
3	A	At the Bridge 1, the sign end of all speed limits is crossed-out.

5.4.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<GroupType&#>	string/UUID&#	-	-	-	-	-	-
<Name&>	string/UUID&	-	-	-	-	-	-
<SignNr& / SignNr>	UUID/UUID&	-	-	-	-	-	-
<Visibility>	string/int	-	’not’, ’poorly’, ’partially’, ’**well**’, ’perfectly’	’nicht’, ’schlecht’, ’teilweise’, ’**gut**’, ’perfekt’	[0;10[, [10;40[, [40;60[, **[60;80[**, [80;100]	5, 30, 50, **70**, 90	%

TAG	**datatype**	**enum**	**Abstract values**		**Logical value**	**Default concrete value**	**unit**
			English	**German**			
<SignClass>	string	x	'**regulation**', 'informational', 'danger', 'supplementary'	'**Vorschriftszeichen**', 'Richtzeichen', 'Gefahrenzeichen', 'Zusatzzeichen'	-	-	-
<Value>	string	-	-	-	-	-	-
<Clearance>	string/float	-	'very low', 'low', '**normal**', 'high', 'very high'	'sehr geringe', 'geringe', '**normale**', 'hohe', 'sehr hohe'	[0.0;1.0[, [1.0;2.2[, **[2.2;3.0**[, [3.0;5.0[, [5.0;∞[	0.5, 1.5, **2.2**, 4.0, 5.0	m

Chapter 6

Layer 4 - Positioning and Velocity

This section contains information about objects (vehicles and obstacles) and their positions on the road. For the description of their maneuvers, refer to the next chapter. Parts of the used information is based on the OpenSCENARIO standard [10].

6.1 Basic Information

Object Types

The types of objects are divided in two groups: "Vehicles" and "Obstacles". "Vehicles" includes, e.g., cars, trucks and motorcycles at different abstraction levels (e.g., "vehicle" ↔ "car" ↔ "station wagon" ↔ "Brand Sportscar 3 3.5D"). "Obstacles" contains animate (e.g., "person" or "animal") and inanimate objects (e.g., "stone" or "plastic bag").

Positioning

The positioning of vehicles/objects can be relative or absolute. The relative positioning schema is based on the relation between two objects, where the position of, e.g., *CarX* is defined relative to *CarY* by using the 8 directions: *CarX* drives left of/left in front of/in front of/right in front of/right of/right behind of/behind of/left behind of *CarY*.

When using absolute definitions, the object will be placed on the segment/lane by either defining its concrete position (x/y/z coordinates) or by using the abstract terms "at the beginning", "in the middle" or "at the end" of the segment (with its corresponding meter values as interval or concrete value).

In both cases, additional distance definitions can be included:

1. CarX drives in front of the CarY with a very small distance.
2. CarX drives right in front of the CarY with a small distance.
3. CarX drives right of the CarY with a long distance.
4. CarX drives left behind of the CarY with a very long distance.

Last but not least, the lateral refinement can be added in relation to the road markings:

1. CarX drives left of the CarY close to the right mark.
2. CarX drives right of the CarY on the left mark.

Velocity and Acceleration

Velocities and accelerations can be described in the same way by using abstract terms as well as value intervals and concrete values.

6.2 Group Definition

This section included information about vehicle group or column definitions and the corresponding parameters.

6.2.1 Attributes

- **isEgo**: Used to define the whole group as ego, primarily to test/define swarming functions. Either the group is marked as 'ego' or an individual vehicle.
- **Group#**: A unique identifier for the group (either "vehicle group" or "column").
- **TrafficFlowA|TrafficFlowB**: This defines the flow model of the vehicle group in a commonly know traffic situation, like traffic jam.
- **RelFlowSpeed**: The relative speed of the group with regards to the traffic situation as abstract value (e.g., "low") or in km/h or m/s (interval or concrete value).
- **Lane&#**: The lane reference of the road segment defined in layer 1.
- **Segment&#**: The segment reference.
- **Limit**: Allows weaker conditional definitions for speed, distance or time (e.g., "at least").
- **Density**: Traffic density value for columns, either as abstract value (e.g., "normal") or as percentage (interval or concrete value).
- **Action**: Acceleration action.
- **RelAcc**: Strength of the acceleration/deceleration.

6.2.2 Grammar

⟨*L4PGroupEng*⟩ ::= (The | Following) [isEgo] ⟨*Group#*⟩ (⟨*TrafficFlowA*⟩ | ⟨*TrafficFlowB*⟩ [with ⟨*RelFlowSpeed*⟩ speed]) on [⟨*Lane&#*⟩ of] ⟨*Segment&#*⟩ [with [⟨*Limit*⟩] a (⟨*Density*⟩ traffic density | time interval between [⟨*int*⟩-⟨*int*⟩]s | time interval of ⟨*double*⟩s)] [and ⟨*Action*⟩ [(with |) ⟨*RelAcc*⟩]] (.|:) NEWLINE [⟨*L4PVehicleDefinitionEng*⟩]

⟨*L4PGroupGer*⟩ ::= (Die | Folgende) [isEgo] ⟨*Group#*⟩ (⟨*TrafficFlowA*⟩ | ⟨*TrafficFlowB*⟩ [mit ⟨*RelFlowSpeed*⟩ Geschwindigkeit]) auf [dem ⟨*Lane&#*⟩ im] ⟨*Segment&#*⟩ [mit [⟨*Limit*⟩] einer (⟨*Density*⟩ Verkehrsdichte | Zeitlücke zwischen [⟨*int*⟩-⟨*int*⟩]s | Zeitlücke von ⟨*double*⟩s))] [und ist [(mit |)⟨*RelAcc*⟩] am ⟨*Action*⟩] (.|:) [⟨*L4PVehicleDefinitionGer*⟩]

6.2.3 Examples

	A/L/C	Examples
1	A	Following Vehicle group #1 drives on Segment #1:
2	A	The Ego Column #1 stands in a traffic jam on Driving lane #4 of Segment #1.
3	L	The Column #1 drives in stop-and-go on Segment #1 with a traffic density of [40;60]% and accelerates slowly.
4	C	Following Column #1 drives with 100 km/h on Driving lane #1 of Segment #2:

6.2.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<isEgo>	string	x	'Ego'	'Ego'	-	-	-
<Group#>	string/UUID#	x	'**Vehicle group #**', 'Column #'	'**Fahrzeuggruppe #**', 'Fahrzeugkolonne #'	-	-	-
<TrafficFlowA>	string	x	'**stands**', 'stands in a traffic jam'	'**steht**', 'steht im Stau'	-	-	-
<TrafficFlowB>	string	x	'drives in stop-and-go', '**drives**', 'drives free'	'fährt im Stop-and-Go', '**fährt**', 'fährt frei'	-	-	-
<RelFlowSpeed>	string/int	-	'very slow', 'slow', '**normal**', 'high', 'very high'	'sehr langsamer', 'langsamer', '**normaler**', 'hoher', 'sehr hoher'	[0;20[, [20;40[, **[40;60[**, [60;80[, [80;100]	5, 30, **50**, 70, 90	km/h
<Lane&#>	string/UUID&#	-	-	-	-	-	-
<Segment&#>	string/UUID&#	-	-	-	-	-	-
<Limit>	string	x	'**at least**', 'at most'	'**mindestens**', 'höchstens'	-	-	-
<Density>	string/float	-	'very low', 'low', '**normal**', 'high', 'very high'	'sehr niedrigen', 'niedrigen', '**normalen**', 'hohen', 'sehr hohen'	[10.1;20.0[, [7.5;10.0[, **[5.1;7.5[**, [2.6;5.0[, [2.0;2.5[	15.0, 8.0, **5.1**, 3.0, 2.0	s
<Action>	string	x	'**accelerates**', 'decelerates'	'**beschleunigen**', 'bremsen'	-	-	-
<RelAcc>	string/float	-	'very slowly', 'slowly', '**normally**', 'strongly', 'very strongly'	'sehr langsam', 'langsam', '**normal**', 'stark'	[0.0;1.0[, [1.0;1.6[, **[1.6;2.0[**, [2.0;2.5[, [2.5;∞[	0.5, 1.0, **1.6**, 2.0, 2.5	m/s^2

6.3 Vehicle Definition

This section includes the definition and positioning of vehicles. The position can be relative or absolute, but at least one vehicle has to be placed by using an absolute position to unambiguously allow relative positioning.

6.3.1 Attributes

- **isEgo**: Defines, if the vehicle is the Ego of this group or column. If the ego is set, no other group or vehicle can be set as ego anymore.
- **Class**: Class of the vehicle, e.g., “car” or “bike”.
- **Type**: Type of the vehicle, e.g., “station wagon” or “cabrio”.
- **Model**: Model of the vehicle, e.g., “AUDI A6”.
- **Trailer**: Defines a trailer and its type.
- **Doors**: Number of doors.
- **Paint**: Overall paint of the vehicle, e.g., “red”.
- **Weight**: Weight of the vehicle, either as abstract value (e.g., “heavy”) or in kilograms (interval or concrete value).
- **DLength**: Length of the vehicle, either as abstract value (e.g., “long”) or in meter (interval or concrete value).
- **DWidth**: Width of the vehicle, either as abstract value (e.g., “long”) or in meter (interval or concrete value).
- **DHeight**: Height of the vehicle, either as abstract value (e.g., “long”) or in meter (interval or concrete value).
- **Position**: Position of the vehicle, either as abstract value (e.g., “at the end”) or in meter as distance from the segment beginning (interval or concrete value).
- **RefLane&#**: The lane reference of the road segment defined in layer 1.
- **State**: Generic movement state of the vehicle: “drives” or “stands”.
- **Control**: Type of control over the vehicle (e.g., “manual” or “automated”) to reflect automated driving functions capabilities.
- **RelHeading**: Heading behavior, e.g., “in wiggling lines” or “straight”.
- **RelFlowSpeed**: Speed of the vehicle relative to the vehicle group speed, either as abstract value (e.g., “fast”) or in km/h or m/s (interval or concrete value).
- **RefSafe**: Longitudinal distance to the vehicle ahead, from a safety perspective, either as abstract value (e.g., “safe”) or in meter (interval or concrete value).
- **RefLong**: Longitudinal distance to the vehicle ahead, either as abstract value (e.g., “low”) or in meter (interval or concrete value).
- **relativePos**: Position of the vehicle in relation to the referenced one, e.g., “behind of” or “in front of”.
- **RefVehicle&#**: Vehicle reference to one of the already defined vehicles in the group.
- **RefSide**: Refinement of the side (e.g., ’on the left’).

6.3.2 Grammar

⟨*L4PVehicleDefinitionEng*⟩ ::= [isEgo] ⟨*Vehicle(<Class*⟩ | ⟨*Type*⟩ | ⟨*Model*⟩)#> [with a (⟨*Trailer*⟩ | ⟨*Type*⟩)] ((| ,) | [has [[⟨*Doors*⟩ doors] [(| , | and) a ⟨*Paint*⟩ paint] [(| , | and) a (⟨*Weight*⟩ weight]] [[(| , | and) a (⟨*DLength*⟩ length)] [(| , | and) a (⟨*DWidth*⟩ width)] [(| , | and) a (⟨*DHeight*⟩ height)]])]). It [is located [⟨*Position*⟩ of the segment] [on the ⟨*RefLane&#*⟩]] [(| , | and)] (⟨*State*⟩ [⟨*Control*⟩] [⟨*RelHeading*⟩]) [with [⟨*RelFlowSpeed*⟩ speed] [(| and) (⟨*RefSafe*⟩ | ⟨*RefLong*⟩) distance]] [⟨*relativePos*⟩ of the ⟨*RefVehicle&#*⟩] [(| ,) (⟨*RefSide*⟩ | ⟨*int*⟩cm ⟨*RefSide*⟩) lane marking].

⟨*L4PVehicleDefinitionGer*⟩ ::= [isEgo] ⟨*Vehicle(<Class*⟩ | ⟨*Type*⟩ | ⟨*Model*⟩)#> [mit einem (⟨*Trailer*⟩ | ⟨*Type*⟩)] ((| ,) | [hat [[⟨*Doors*⟩ Türen] [(| , | und) eine ⟨*Paint*⟩ Lackierung] [(| , | und) ein (⟨*Weight*⟩ Gewicht]] [[(| , | und) eine (⟨*DLength*⟩ Länge)] [(| , | und) eine (⟨*DWidth*⟩ Breite)] [(| , | und) eine (⟨*DHeight*⟩ Höhe)]])]). Es [befindet sich [⟨*Position*⟩ des Segments] [auf dem ⟨*RefLane&#*⟩] ,] [(| , | und)] (⟨*State*⟩ [⟨*Control*⟩] [⟨*RelHeading*⟩]) [mit [⟨*RelFlowSpeed*⟩ Geschwindigkeit] [(| und) ((⟨*RefSafe*⟩ | ⟨*RefLong*⟩)) Abstand]] [⟨*relativePos*⟩ dem ⟨*RefVehicle&#*⟩] [(| ,) (⟨*RefSide*⟩ | ⟨*int*⟩cm ⟨*RefSide*⟩ von) der Fahrbahnmarkierung].

6.3.3 Examples

	A/L/C	Examples
1	A	Ego Car #1. It is located on the Driving Lane #2.
2	C	SUV #1. It is located on the Driving Lane #2 and drives.
3	A	Truck #2 with trailer. It drives behind of Car #1.
4	A	Motorcycle #1. It is located on the Driving Lane #1 and drives on the right lane marking.
5	A	Car #1. It drives behind of Truck #2 with small distance, close to the left lane marking.
6	L	Motorcycle #1. It is located on the Driving Lane #2 and drives behind of Car #1 with [10;50]m distance, on the right road mark.
7	C	SUV #1 with motorcycle trailer. It drives behind of Heavy Hauler #2 with 50m distance, 30cm to the left lane marking.
8	C	Sport motorcycle #2. It drives left behind of Car #1 with 58 m/s speed.

6.3.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<isEgo>	string	x	'Ego'	'Ego'	-	-	-
<Class>	string	x	'**Vehicle**', 'Car', 'Truck', 'Bus', 'Motorcycle', 'Emergency Vehicle'	'**Fahrzeug**', 'PKW', 'LKW', 'Bus', 'Motorrad', 'Einsatzfahrzeug'	-	-	-
<Type>	string	-	-	-	-	-	-
<Model>	string	-	-	-	-	-	-
<Trailer>	string	x	'boat trailer', 'bus trailer', 'caravan', 'dolly', 'full trailer', 'livestock trailer', 'motorcycle trailer', 'semi-trailer', '**trailer**'	'Bootsanhänger', 'Busanhänger', 'Wohnanhänger', 'Transportwagen', 'Deichselanhänger', 'Viehanhänger', 'Motorradanhänger', 'Sattelanhänger', '**Anhänger**'	-	-	-

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Doors>	int	-	-	-	-	-	-
<Paint>	string	x	'gray', 'silver', 'brown', 'beige', 'yellow', 'red', 'green', 'blue', 'black', 'white'	'graue', 'silberne', 'braune', 'beige', 'gelbe', 'rote', 'grüne', 'blaue', 'schwarze', 'weiße'	-	-	-
<Weight>	string/int	-	'light', 'regular', 'heavy'	'geringes', 'reguläres', 'hohes'	[1000; 1400[, **[1400; 2000[**, [2000; 3000[	1200, **1700**, 2500	kg
<DLength>	string/float	-	'short', 'normal', 'long'	'kurze', 'normale', 'lange'	[3.5; 4.0[, **[4.0; 4.5[**, [4.5; 4.8[	3.7, **4.2**, 4.6	m
<DWidth>	string/float	-	'narrow', 'normal', 'wide'	'schmale', 'normale', 'weite'	[1.0; 1.9[, **[1.9; 2.2[**, [2.2; 3.0]	1.5, **2.0**, 2.5	m
<DHeight>	string/float	-	'low', 'normal', 'high'	'geringe', 'normale', 'hohe'	[1.0; 1.6[, **[1.6; 2.1[**, [2.1; 2.5[	1.2, **1.8**, 2.3	m
<Position>	string/int	-	'at the beginning', 'in the middle', 'at the end'	'am Anfang', 'in der Mitte', 'am Ende'	**[0;25[**, [25;50[, [50;∞[	**10**, 30, 50	m
<RefLane&#>	string/UUID&#	-	-	-	-	-	-
<State>	string	x	'stands', 'drives'	'steht', 'fährt'	-	-	-
<Control>	string	x	'manually', 'automated', 'assisted'	'manuell', 'automatisch', 'unterstäzt'	-	-	-
<RelHeading>	string	x	'straight', 'backwards', 'straight-line', 'in wiggling lines', 'in opposite direction'	'geradeaus', 'räckwärts', 'schnurgeradeaus', 'in Schlangenlinien', 'in Gegenrichtung'	-	-	-
<RelFlowSpeed>	string/int	-	'a very slow', 'a slow', 'a normal', 'a high', 'a very high'	'einer sehr langsamen', 'einer langsamen', 'einer normalen', 'einer hohen', 'einer sehr hohen'	[40;53[, [53;66[, **[66;106[**, [106;133[, [133;160[	46, 60, **86**, 120, 146	km/h

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<RefSafe>	string/int	-	'a critical', 'a risky', 'a challenging', 'a nearly-safe', '**a safe**', 'a highly-safe', 'an extreme, highly-safe'	"einem kritischen', 'einem risikoreichen', 'einem herausfordernden', 'einem nahezu sicheren', '**einem sicheren**', 'einem hochsicheren', 'einem extrem hochsicheren'	[0; 2[, [2; 10[, [10; 25[, [25; 50[, **[50; 65[**, [65; 120[, [120; ∞[	1, 2, 10, 25, **50**, 100, 120	m
<RefLong>	string/int	-	'a very small', 'a small', '**a normal**', 'a large', 'a very large'	'einem sehr kleinen', 'einem kleinen', '**einem normalen**', 'einem großen', 'einem sehr großen'	[1; 2[, [2; 5[, **[5; 10[**, [10; 50[, [50; ∞[	1, 3, **5**, 30, 100	m
<relativePos>	string	x	'right', 'right, in front', '**in front**', 'left, in front', 'left', 'left, behind', 'behind', 'right, behind'	'rechts', 'rechts vor', '**vor**', 'links vor', 'links', 'links hinter', 'hinter', 'rechts hinter'	-	-	-
<RefVehicle&#>	string/UUID&#	-	-	-	-	-	-
<RefSide>	string	x	'**on the left**', 'close to the left', 'close to the right', 'on the right'	'**auf der linken**', 'nahe der linken', 'nahe der rechten', 'auf der rechten'	-	-	-

6.4 Obstacle Definition

Obstacles are objects that are positioned on any road segment and might interfere with vehicles and their maneuvers.

6.4.1 Attributes

- **Segment&#**: Reference to the segment, where the obstacle is placed.
- **ObstacleType#**: Type of obstacle, e.g., "a safety cone" or "a stone".
- **Material**: Material of the obstacle, e.g., "plastic" or "wood".
- **Color**: Overall color of the obstacle, e.g., "gray".
- **Weight**: Weight of the obstacle, either as abstract value (e.g., "heavy") or in kilograms (interval or concrete value).
- **DLength**: Length of the obstacle, either as abstract value (e.g., "long") or in meter (interval or concrete value).
- **DWidth**: Width of the obstacle, either as abstract value (e.g., "long") or in meter (interval or concrete value).

- **DHeight**: Height of the obstacle, either as abstract value (e.g., “long”) or in meter (interval or concrete value).
- **RefSafe**: Longitudinal distance from the obstacle to another object/vehicle, from a safety perspective, either as abstract value (e.g., “safe”) or in meter (interval or concrete value).
- **relativePos**: Position of the obstacle in relation to the referenced object/vehicle, e.g., “behind of” or “in front of”.
- **RefVehicle&#**: Reference to an already defined vehicle.
- **Blocking**: Blocking characteristics of the object regarding the lane, e.g., “block” or “lies on”.
- **RefLane&#**: Lane reference which is affected by the obstacle.
- **RefSide**: Side refinement for the obstacle blocking: “on the left” or “on the right”.

6.4.2 Grammar

⟨*L4PObstacleDefinitionEng*⟩ ::= On ⟨*Segment&#*⟩, (an obstacle|⟨*ObstacleType#*⟩)[[and has][[of ⟨*Material*⟩ and has][a ⟨*Color*⟩ color][(|,|and) a (⟨*Weight*⟩ weight)]][[(|,|and) a (⟨*DLength*⟩ length)][(|,|and) a (⟨*DWidth*⟩ width)][(|,|and) a (⟨*DHeight*⟩ height)]]. It][is [(at a (⟨*RefSafe*⟩ distance|⟨*int*⟩m)]⟨*relativePos*⟩ of (the Vehicle|⟨*RefVehicle&#*⟩) and]⟨*Blocking*⟩ (⟨*RefLane&#*⟩ [⟨*RefSide*⟩]).

⟨*L4PObstacleDefinitionGer*⟩ ::= Auf ⟨*Segment&#*⟩ befindet sich (ein Hindernis|⟨*ObstacleType#*⟩) [[und hat][[aus ⟨*Material*⟩ und hat][eine ⟨*Color*⟩ Farbe][(|,|und) ein (⟨*Weight*⟩ Gewicht)]][[(|,|und) eine (⟨*DLength*⟩ Länge)][(|,|und) eine (⟨*DWidth*⟩ Breite)][(|,|und) eine (⟨*DHeight*⟩ Höhe)]]. Es ist][[in (einem ⟨*RefSafe*⟩ Abstand|⟨*int*⟩m)]⟨*relativePos*⟩ (dem Fahrzeug|⟨*RefVehicle&#*⟩)]und ⟨*Blocking*⟩ (⟨*RefLane&#*⟩ [⟨*RefSide*⟩]).

6.4.3 Examples

	A/L/C	Examples
1	A	On Segment #1, an obstacle #3 is in front of Vehicle #1 and blocks Driving Lane #5.
2	A	On Segment #1, an obstacle #3 is behind of Vehicle #2 and protudes into Driving Lane #4 on the left.
3	C	On Segment #1, a stone has a green gray black color and 0.10m length.

6.4.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Segment&#>	string/UUID&#	-	-	-	-	-	-
<ObstacleType#>	string/UUID#	x	**'an obstacle #'**, 'a cube #', 'a broken vehicle #', 'a stone #', 'a delineator #', 'a safety cone #', 'an animal #', 'a tire #'	**'ein Hindernis #'**, 'ein Würfel #', 'ein defektes Fahrzeug #', 'ein Stein #', 'eine Bake #', 'ein Leitkegel #', 'ein Tier #', 'ein Rad #'	-	-	-

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Material>	string	x	'steel', 'plastic', 'concrete', '**stone**', 'foam', 'wood'	'Stahl', 'Plastik', 'Beton', '**Stein**', 'Schaumstoff', 'Holz'	-	-	-
<Color>	string	x	'**gray**', 'silver', 'brown', 'beige', 'yellow', 'red', 'green', 'blue', 'black', 'white'	'**graue**', 'silberne', 'braune', 'beige', 'gelbe', 'rote', 'grüne', 'blaue', 'schwarze', 'weiße'	-	-	-
<Weight>	string/int	-	'light', '**regular**', 'heavy'	'geringes', '**reguläres**', 'hohes'	[1; 20[, **[20; 50[**, [50; 500[	10, **40**, 250	kg
<DLength>	string/float	-	'short', '**normal**', 'long'	'kurze', '**normale**', 'lange'	[0.5; 1.0[, **[1.0; 1.5[**, [1.5; 3.0[	0.7, **1.2**, 2.5	m
<DWidth>	string/float	-	'narrow', '**normal**', 'wide'	'schmale', '**normale**', 'weite'	[0.5; 1.0[, **[1.0; 1.5[**, [1.5; 3.0[	0.7, **1.2**, 2.5	m
<DHeight>	string/float	-	'low', '**normal**', 'high'	'geringe', '**normale**', 'hohe'	[0.5; 1.0[, **[1.0; 1.5[**, [1.5; 3.0[	0.7, **1.2**, 2.5	m
<RefSafe>	string/int	-	'an extreme, highly-safe', 'a highly-safe', '**a safe**', 'a nearly-safe', 'a challenging', 'a risky', 'a critical'	'einem extrem hochsicheren', 'einem hochsicheren', '**einem sicheren**', 'einem nahezu sicheren', 'einem herausfordernden', 'einem risikoreichen', 'einem kritischen'	[120; ∞[, [65; 120[, **[50; 65[**, [25; 50[, [10; 25[, [2; 10[, [0; 2[	120, 100, **50**, 25, 10, 2, 1	m
<relativePos>	string	x	'right', 'right, in front', '**in front**', 'left, in front', 'left', 'left, behind', 'behind', 'right, behind'	'rechts', 'rechts vor', '**vor**', 'links vor', 'links', 'links hinter', 'hinter', 'rechts hinter'	-	-	-
<RefVehicle&#>	string/UUID&#	-	-	-	-	-	-

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Blocking>	string	x	'**blocks**', 'lies on', 'protrudes into'	'**blockiert den**', 'liegt auf dem', 'ragt in den'	-	-	-
<RefLane&#>	string/UUID&#	-	-	-	-	-	-
<RefSide>	string	x	'**on the left**', 'on the right'	'**auf der linken Seite**', 'auf der rechten Seite'	-	-	-

Chapter 7

Layer 4 - Maneuvers

This chapter focuses on the descriptions of longitudinal, lateral and passive maneuvers of the vehicles defined in the previous chapter.

7.1 Use Cases

To defined the appropriate maneuvers, one has to look at the different types of driver actions and the corresponding conditions in relation to the traffic and the environment. Those considerations also take into account the information from the OpenSCENARIO standard [10].

7.1.1 Driver Actions

Basic driver actions can be clustered into three aspects:

1. “Longitudinal actions” which can be controlled by the pedals (e.g., “accelerate”).
2. “Lateral actions” which can be controlled by the steering wheel (e.g., “change lane”).
3. “No actions”, i.e. no explicit action is performed by the user (e.g., “drive”).

Those actions can be described in “absolute” and “relative” manner. “Absolute” is considered as free trajectory whereas “relative” means that other participants or objects are along the trajectory and can therefore be referenced as part of the maneuver. Some examples are given in the following table.

Force	Free Trajectory	Trajectory with Relations
Passive	keep speed	follow the vehicle
Longitudinal	accelerate	close up to the front vehicle
	decelerate	fall back from the front vehicle
Lateral	change lane	change behind of vehicle
		dodge the front vehicle
		dodge an emergency vehicle

7.1.2 Conditions

A scenario describes a sequence of scenes, whereas an action describes the start of such a sequence but without termination. A phase on the other hand should be terminated by well defined conditions. Some exemplary conditions are given below.

Absolute condition	Relative condition
Distance reached	Passes by the vehicle (lateral and longitudinal)
Velocity reached	Passes by the infrastructure element
Lane reached	In parallel to other vehicle
Time reached	Into the time gap between vehicles

7.1.3 Maneuver Stories

A “maneuver” always belongs to a single vehicle. A collection of subsequent or parallel maneuvers belonging to the same vehicle is called “maneuver story”. Here also conditions are used to determine the end point of the different incorporated maneuvers. Example: “Car #1 accelerates until 100 km/h are reached and afterwards changes the lane to the left.”

7.1.4 Phases

A “phase” is a collection of maneuvers or maneuver stories with different assigned vehicles. They can occur in parallel or sequentially.

Example:

- Car #1 overtakes Car #2 on the left side.
- Car #2 decelerates strongly until standing.

7.2 Maneuver Story

This section defines the high-level stories reflecting maneuver sequences for one vehicle. The combination and concatenation of basic maneuvers allow to create more complex sequences such as overtaking maneuvers.

7.2.1 Attributes

- **Conjunction**: Conjunction words to be used to concatenate maneuvers within a maneuver story on a temporal basis.
- **Maneuver<Type>**: Class of maneuver that should be executed, either “Passive”, “Longitudinal” or “Lateral”.

7.2.2 Grammar

⟨*L4MManeuverStoryEng*⟩ ::= [(⟨*L4MPassiveManeuverEng*⟩ | ⟨*L4MLongitudinalManeuverEng*⟩ | ⟨*L4MLateralManeuverEng*⟩) (, | and) [⟨*Conjunction*⟩])].

⟨*L4MManeuverStoryGer*⟩ ::= [(⟨*L4MPassiveManeuverGer*⟩ | ⟨*L4MLongitudinalManeuverGer*⟩ | ⟨*L4MLateralManeuverGer*⟩) (, | und) [⟨*Conjunction*⟩])].

7.2.3 Examples

	A/L/C	Examples
1	A	Vehicle #1 drives.
2	L	Vehicle #1 drives for [100; 300]m, simultaneously changes to right lane.
3	C	Vehicle #1 follows the front vehicle for 10s, afterwards Vehicle #1 accelerates.

7.2.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	**German**			
<Conjunction>	string	x	'**afterwards**', 'simultaneously'	'**anschließend**', 'gleichzeitig'	-	-	-
<Maneuver>	<Type>	x	**Passive**, Longitudinal, Lateral	**Passiv**, Longitudinal, Lateral	-	-	-

7.3 Passive Maneuver

This section defines passive maneuvers that considers a longitudinal free trajectory without activity, i.e. that keeps speed and follows. Also included are corresponding end triggers.

7.3.1 Attributes

- **Vehicle&#**: Reference to the actor of the maneuver (vehicle).
- **State**: State of the vehicle, e.g., "stands" or "rolls".
- **RelHeading**: Heading behavior, e.g., "in wiggling lines" or "straight".
- **VehicleRef&#**: Reference to another vehicle as relative reference point for the following maneuver.
- **Lane&#**: Lane reference as relative reference point for the following maneuver.
- **Transition&**: Reference to a transition defined in layer 1, e.g. "narrowing".
- **GroupType&#**: Reference to a bridge or mast passing the trajectory (layer 2 or layer 3).
- **Pedestrian#**: Definition of a pedestrian.
- **Animal#**: Definition of an animal.
- **Direction**: Lateral side where the vehicle, pedestrian or animal is passed.
- **Limit**: Allows weaker conditional definitions for speed, distance or time (e.g., "at least").
- **RelSpeed**: The relative speed of the vehicle as abstract value (e.g., "low") or in km/h or m/s (interval or concrete value).
- **RelSafe**: Longitudinal distance to the vehicle ahead, from a safety perspective, either as abstract value (e.g., "safe") or in meter (interval or concrete value).
- **Duration**: Duration of the maneuver, either in seconds or meters.

7.3.2 Grammar

⟨*L4MPassiveManeuverEng*⟩ ::= [⟨*Vehicle&#*⟩] (⟨*State*⟩ [RelHeading] | ⟨*State="follows"*⟩ [⟨*RelHeading*⟩] the (front vehicle | ⟨*VehicleRef&#*⟩ | ⟨*Lane&#*⟩)) [(| and) passes (⟨*Transition&*⟩ | ⟨*GroupType&#*⟩ | ⟨*Pedestrian#*⟩ | ⟨*Animal#*⟩) [on the ⟨*Direction*⟩ side]] [with [⟨*Limit*⟩] (⟨*RelSpeed*⟩ speed)] [(with | and) [⟨*Limit*⟩] (⟨*RelSafe*⟩) distance] [for [⟨*Limit*⟩] (⟨*Duration*⟩ (meter | seconds))].

⟨*L4MPassiveManeuverGer*⟩ ::= [⟨*Vehicle&#*⟩] (⟨*State*⟩ [RelHeading] | ⟨*State="folgt"*⟩ [⟨*RelHeading*⟩] dem (vorderen Fahrzeug | ⟨*VehicleRef&#*⟩ | ⟨*Lane&#*⟩)) [(| und) passiert (⟨*Transition&*⟩ | ⟨*GroupType&#*⟩ | ⟨*Pedestrian#*⟩ | ⟨*Animal#*⟩) [auf der ⟨*Direction*⟩ Seite]] [mit [⟨*Limit*⟩] (⟨*RelSpeed*⟩ Geschwindigkeit)] [(mit | und) [⟨*Limit*⟩] (⟨*RelSafe*⟩) Abstand] [für [⟨*Limit*⟩] (⟨*Duration*⟩ (Meter | Sekunden))].

7.3.3 Examples

	A/L/C	Examples
1	A	Vehicle #1 drives with normal speed.
2	A	Vehicle #1 follows the front vehicle.
3	L	Vehicle #1 follows with [80; 120]km/h speed and [10; 30]m distance.
4	C	Vehicle #1 drives with 150km/h for at least 30 seconds.
5	A	Motorcycle #2 drives and passes the blocking with a safe distance on the right side.

7.3.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Vehicle&#>	string/UUID&#	-	-	-	-	-	-
<State>	string	x	'stands', '**drives**', 'rolls', 'follows'	'steht', '**fährt**', 'rollt', 'folgt'	-	-	-
<RelHeading>	string	x	'**straight**', 'backwards', 'straight-line', 'in wiggling lines', 'in opposite direction'	'**geradeaus**', 'rückwärts', 'schnurgeradeaus', 'in Schlangenlinien', 'in Gegenrichtung'	-	-	-
<VehicleRef&#>	string/UUID&#	-	-	-	-	-	-
<Lane&#>	string/UUID&#	-	-	-	-	-	-
<Transition&>	string/UUID&	-	-	-	-	-	-
<GroupType&#>	string/UUID&#	-	-	-	-	-	-
<Pedestrian#>	string/UUID#	x	'Pedestrian #'	'Fußgänger #'	-	-	-
<Animal#>	string/UUID#	x	'**an Animal #**', 'a Deer #', 'a Cow #', 'a Horse #', 'a Wild boar #', 'a Fox #', 'a Dog #'	'**ein Tier #**', 'ein Hirsch #', 'eine Kuh #', 'ein Pferd #', 'ein Wildschwein #', 'ein Hund #'	-	-	-

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Direction>	string	x	'**left**', 'right'	'**linken**', 'rechten'	-	-	-
<Limit>	string	x	'**at least**', 'at most'	'**mindestens**', 'höchstens'	-	-	-
<RelSpeed>	string/int	-	'very slow', 'slow', '**normal**', 'high', 'very high'	'sehr langsamer', 'langsamer', '**normaler**', 'hoher', 'sehr hoher'	[0;20[, [20;40[, **[40;60[**, [60;80[, [80;100[	5, 30, **50**, 70, 90	km/h
<RelSafe>	string/int	-	'a critical', 'a risky', 'a challenging', 'a nearly-safe', '**a safe**', 'a highly-safe', 'an extreme, highly-safe'	"einem kritischen', 'einem risikoreichen', 'einem herausfordernden', 'einem nahezu sicheren', **einem sicheren**', 'einem hochsicheren', 'einem extrem hochsicheren'	[0; 2[, [2; 10[, [10; 25[, [25; 50[, **[50; 65[**, [65; 120[, [120; ∞[	1, 2, 10, 25, **50**, 100, 120	m
<Duration>	int	-	-	-	-	-	-

7.4 Longitudinal Maneuver

This section handles maneuvers that have an impact on the velocity of the vehicle in longitudinal direction including end triggers.

7.4.1 Attributes

- **Vehicle&#**: Reference to the actor of the maneuver (vehicle).
- **AbsAcc**: Acceleration value, either as abstract value (e.g., "strongly") or in m/s^2.
- **RelHeading**: Heading behavior, e.g., "in wiggling lines" or "straight".
- **VehicleRef&#**: Reference to another vehicle as relative reference point for the longitudinal maneuver.
- **Limit**: Allows weaker conditional definitions for speed, distance or time (e.g., "at least").
- **RelSpeed**: The relative speed of the vehicle as abstract value (e.g., "low") or in km/h or m/s (interval or concrete value).
- **RelSafe**: Distance to the vehicle ahead, from a safety perspective, either as abstract value (e.g., "safe") or in meter (interval or concrete value).
- **Transition&**: Reference to a transition defined in layer 1, e.g. "narrowing".
- **ObstacleType&#**: Reference to an obstacle located on the road.
- **GroupType&#**: Reference to a bridge or mast.
- **VehicleRef2&#**: Second reference to another vehicle as relative reference point for the longitudinal maneuver.
- **Direction**: Lateral side where the vehicle, pedestrian or animal is passed.

7.4.2 Grammar

⟨*L4MLongitudinalManeuverEng*⟩ ::= [⟨*Vehicle&#*⟩] (accelerates [(with |) ⟨*AbsAcc*⟩] [and] [⟨*RelHeading*⟩] | decelerates [(with |) ⟨*AbsAcc*⟩] [and] [⟨*RelHeading*⟩] [until standing] | (closes up [⟨*RelHeading*⟩] to | falls back [⟨*RelHeading*⟩] from) (the front vehicle|⟨*VehicleRef&#*⟩)) [[until [Limit] (⟨*RelSpeed*⟩ speed)] [(until | or | and) [⟨*Limit*⟩] (⟨*RelSafe*⟩) distance [to (⟨*Transition&*⟩ | ⟨*ObstacleType&#*⟩ | ⟨*GroupType&#*⟩ | ⟨*VehicleRef2&#*⟩)]] (is reached | for [⟨*Limit*⟩] (⟨*int*⟩ meter|⟨*int*⟩ seconds))] [(until | or | and) (⟨*RefRoad*⟩ | ⟨*ObstacleType&#*⟩ | ⟨*GroupType&#*⟩ | ⟨*VehicleRef2&#*⟩) [on the ⟨*Direction*⟩ side] is passed].

⟨*L4MLongitudinalManeuverGer*⟩ ::= [⟨*Vehicle&#*⟩] (beschleunigt [(mit |) ⟨*AbsAcc*⟩] [and] [⟨*RelHeading*⟩] | bremst [(mit |)⟨*AbsAcc*⟩] [and] [⟨*RelHeading*⟩] [bis zum Stillstand] | (schließt [⟨*RelHeading*⟩] auf bis zum | fällt [⟨*RelHeading*⟩] zurück vom) (vorderen Fahrzeug | ⟨*VehicleRef&#*⟩)) [[bis [Limit] (⟨*RelSpeed*⟩ Geschwindigkeit)] [(oder | und) bis [⟨*Limit*⟩] (⟨*RelSafe*⟩) Abstand [(⟨*RefRoad*⟩ | ⟨*ObstacleType&#*⟩ | ⟨*GroupType&#*⟩ | ⟨*VehicleRef2&#*⟩)]] (erreicht ist | für [⟨*Limit*⟩] (⟨*int*⟩ Meter|⟨*int*⟩ Sekunden))] [(oder | und) bis (⟨*Transition&*⟩ | ⟨*ObstacleType&#*⟩ | ⟨*GroupType&#*⟩ | ⟨*VehicleRef2&#*⟩) [auf der ⟨*Direction*⟩ Seite] passiert ist].

7.4.3 Examples

	A/L/C	Examples
1	A	Vehicle #1 accelerates.
2	A	Vehicle #1 decelerates carefully until normal speed is reached.
3	L	Vehicle #1 closes up to front vehicle until [30;50]m distance is reached.
4	C	Vehicle #1 accelerates with 5m/s^2, until 80 km/h distance to Car #2 is reached.

7.4.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Vehicle&#>	string/UUID&#	-	-	-	-	-	-
<AbsAcc>	string/float	-	'very carefully', 'carefully', '**normal**', 'strongly', 'very strongly'	'sehr vorsichtig', 'vorsichtig', '**normal**', 'stark', 'sehr stark'	[0.0;1.0[, [1.0;1.6[, **[1.6;2.0[**, [2.0;3.0[, [3.0;∞[	0.5, 1.0, **1.6**, 2.0, 3.0	m/s^2
<RelHeading>	string	x	'**straight**', 'backwards', 'straight-line', 'in wiggling lines', 'in opposite direction'	'**geradeaus**', 'räckwärts', 'schnurgeradeaus', 'in Schlangenlinien', 'in Gegenrichtung'	-	-	-
<VehicleRef&#>	string/UUID&#	-	-	-	-	-	-
<Limit>	string	x	'**at least**', 'at most'	'**mindestens**', 'höchstens'	-	-	-
<RelSpeed>	string/int	-	'very slow', 'slow', '**normal**', 'high', 'very high'	'sehr langsamer', 'langsamer', '**normaler**', 'hoher', 'sehr hoher'	[0;20[, [20;40[, **[40;60[**, [60;80[, [80;100]	5, 30, **50**, 70, 90	km/h

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<RelSafe>	string/int	-	'a critical', 'a risky', 'a challenging', 'a nearly-safe', **'a safe'**, 'a highly-safe', 'an extreme, highly-safe'	"einem kritischen', 'einem risikoreichen', 'einem herausfordernden', 'einem nahezu sicheren', **einem sicheren'**, 'einem hochsicheren', 'einem extrem hochsicheren'	[0; 2[, [2; 10[, [10; 25[, [25; 50[, **[50; 65[**, [65; 120[, [120; ∞[	1, 2, 10, 25, **50**, 100, 120	m
<Transition&>	string/UUID&	-	-	-	-	-	-
<ObstacleType&#>	string/UUID&#	-	-	-	-	-	-
<GroupType&#>	string/UUID&#	-	-	-	-	-	-
<VehicleRef2&#>	string/UUID&#	-	-	-	-	-	-
<Direction>	string	x	**'left'**, 'right'	**'linken'**, 'rechten'	-	-	-

7.5 Lateral Maneuver

This section handles maneuvers that have an impact to lateral direction only, including end triggers.

7.5.1 Attributes

- **Vehicle&#**: Reference to the actor of the maneuver (vehicle).
- **Limit**: Allows weaker conditional definitions for speed, distance or time (e.g., "at least").
- **Duration**: Duration of the maneuver in meters or seconds.
- **RelSafe**: Distance to the vehicle ahead, from a safety perspective, either as abstract value (e.g., "safe") or in meter (interval or concrete value).
- **Transition&**: Reference to a transition defined in layer 1, e.g. "narrowing".
- **ObstacleType&#**: Reference to an obstacle located on the road.
- **GroupType&#**: Reference to a bridge or mast.
- **VehicleRef&#**: Second reference to another vehicle as relative reference point for the lateral maneuver.
- **LatSpeed**: Lateral speed to the left or right lane, either as abstract value (e.g., "slowly") or in m/s (interval or concrete value).
- **Lane&#**: Reference to the lane where the actor will move to.
- **Direction**: Relative lateral lane direction of the vehicle.
- **DirectionDistance**: Direction distance in cm.
- **Gap**: Gap after, before or between vehicles.
- **RefLateral**: Refinement of the side (e.g., 'on the left').

7.5.2 Grammar

⟨*L4MLateralManeuverEng*⟩ ::= [⟨*Vehicle&#*⟩] (changes | dodges | overtakes) [after [⟨*Limit*⟩] (⟨*Duration*⟩ (meter | seconds))] [, with [⟨*Limit*⟩] (⟨*RelSafe*⟩) distance [(⟨*Transition&*⟩ | ⟨*ObstacleType&#*⟩ | ⟨*GroupType&#*⟩ | ⟨*VehicleRef&#*⟩)] ,] [LatSpeed] to (⟨*Lane&#*⟩ | ⟨*Direction*⟩ lane) [[into the time gap] ⟨*Gap*⟩ {[and] ⟨*VehicleRef&#*⟩}] [(⟨*RefLateral*⟩ | with ⟨*DirectionDistance*⟩cm distance ⟨*Direction*⟩) mark].

⟨*L4MLateralManeuverGer*⟩ ::= [⟨*Vehicle&#*⟩] (wechselt | weicht aus | überholt) [nach [⟨*Limit*⟩] (⟨*Duration*⟩ (Metern | Sekunden))] [, mit [⟨*Limit*⟩] (⟨*RelSafe*⟩) Abstand [(⟨*RefRoad*⟩ | zum ⟨*VehicleRef&#*⟩ | ⟨*ObstacleType&#*⟩ | ⟨*Transition&*⟩)] ,] [LatSpeed] zum (⟨*Lane&#*⟩ | ⟨*Direction*⟩ Fahrstreifen) [[in die Zeitlücke] ⟨*Gap*⟩ {[und] ⟨*VehicleRef&#*⟩}] [(⟨*RefLateral*⟩ | mit ⟨*DirectionDistance*⟩cm Abstand zur ⟨*Direction*⟩) Straßenmarkierung].

7.5.3 Examples

	A/L/C	Examples
1	A	Vehicle #1 changes to right lane.
2	A	Vehicle #1 changes with safe distance before the narrowing to right lane.
3	C	Vehicle #1 changes after 200m to the Driving Lane #3.
4	A	Vehicle #1 dodges with minimum safe distance to Car #2 to left lane close to the right mark.
5	L	Vehicle #1 changes to Driving Lane #3 with [50; 100]cm distance to the right mark.
6	A	Vehicle #1 changes into the time gap between Truck #2 and Truck #3.

7.5.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Vehicle&#>	string/UUID&#	-	-	-	-	-	-
<Limit>	string	x	'**at least**', 'at most'	'**mindestens**', 'höchstens'	-	-	-
<Duration>	int	-	-	-	-	-	-
<RelSafe>	string/int	-	'a critical', 'a risky', 'a challenging', 'a nearly-safe', '**a safe**', 'a highly-safe', 'an extreme, highly-safe'	"einem kritischen', 'einem risikoreichen', 'einem herausfordernden', 'einem nahezu sicheren', '**einem sicheren**', 'einem hochsicheren', 'einem extrem hochsicheren'	[0; 2[, [2; 10[, [10; 25[, [25; 50[, **[50; 65[**, [65; 120[, [120; ∞[	1, 2, 10, 25, **50**, 100, 120	m
<Transition&>	string/UUID&	-	-	-	-	-	-
<ObstacleType&#>	string/UUID&#	-	-	-	-	-	-
<GroupType&#>	string/UUID&#	-	-	-	-	-	-
<VehicleRef&#>	string/UUID&#	-	-	-	-	-	-
<RelSpeed>	string/int	-	'a very slow', 'a slow', '**a normal**', 'a high', 'a very high'	'einer sehr langsamen', 'einer langsamen', '**einer normalen**', 'einer hohen', 'einer sehr hohen'	[40;53[, [53;66[, **[66;106[**, [106;133[, [133;160[	46, 60, **86**, 120, 146	km/h

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Lane&#>	string/UUID&#	-	-	-	-	-	-
<Direction>	string	x	'to far left', 'to left', '**within current**', 'to right', 'to far right'	'zur äusserst linken', 'zur linken', '**innerhalb der**', 'zur rechten', 'zur äusserst rechten'	-	-	-
<DirectionDistance>	int	-	-	-	-	-	-
<Gap>	string	x	'after', '**between**', 'before'	'nach dem', '**zwischen**', 'vor dem'	-	-	-
<RefLateral>	string	x	'**on the left**', 'close to the left', 'close to the right', 'on the right'	'**auf der linken**', 'nahe der linken', 'nahe der rechten', 'auf der rechten'	-	-	-

Chapter 8

Layer 5 - Environmental Conditions

This chapter is focused on the environmental conditions for the scenario. This includes defining generic conditions such as time of day, season, temperature or scenario orientation, as well as specific weather conditions regarding the segments and the maneuvers (e.g., precipitation, visibility ranges, lightning, road coverage, etc.). Therefore, the section is divided into three parts: Generic conditions, segment conditions and conditions with impact to maneuvers.

8.1 Generic Conditions

This section contains information about the generic scenario conditions. Besides temporal parameters such as time of day or the current season, additional values with influence to the environmental circumstances are given, e.g., the temperature or the cloudiness.

8.1.1 Attributes

- **TimeOfDay**: Time of day, either as abstract value (e.g., “at noon”) or as time (interval or concrete value, e.g., “08:00 o’clock”).
- **Season**: Season of the year, either as abstract season value (e.g., “autumn”) or as month (interval or concrete value).
- **RelTemp**: Relative temperature of the scenario in comparison to the normal temperature based on the chosen season, either as abstract value (e.g., “very cold”) or in degree Celsius (interval or concrete value).
- **Clouds**: Cloudiness of the scenario, which impacts the brightness of the scenario, either as abstract value (e.g., “mainly cloudy”) or in percent (interval or concrete value).
- **Lightning**: Defines the type of local lightning events (e.g., “local thunderstorms”).
- **Heading**: The orientation of the scenario in form of a compass direction, either as abstract value (e.g., “North-West”) or in degrees relative to North (interval or concrete value).

8.1.2 Grammar

⟨*L5GenericConditionEng*⟩ ::= The scenario takes place [⟨*TimeOfDay*⟩] [(| , | and) in [(early | late)] ⟨*Season*⟩] [(| , | and) at ⟨*RelTemp*⟩ temperature] [(| , | and) under (⟨*Clouds*⟩ (conditions | cloud coverage)) [and ⟨*Lightning*⟩]] [facing ⟨*Heading*⟩].

⟨*L5GenericConditionGer*⟩ ::= Das Szenario findet [⟨*TimeOfDay*⟩] [(| , | und) im [(frühen | späten)] ⟨*Season*⟩] [(| , | und) bei einer ⟨*RelTemp*⟩ Temperatur] [(| , | und) unter (⟨*Clouds*⟩ (Bedingungen | Wolkenabdeckung)) [und ⟨*Lightning*⟩]] [in Richtung ⟨*Heading*⟩] statt.

8.1.3 Examples

	A/L/C	Examples
1	A	The scenario takes place in summer at noon.
2	A	The scenario takes place at midnight facing West.
3	L	The scenario takes place at [10:00; 13:00] o'clock and at [20.0; 25.0]°C temperature.
4	A	The scenario takes place at very cold temperature and under cloudy conditions.
5	C	The scenario takes place at 5:30 o'clock, in early July, under 90% cloud coverage and heat thunderstorms facing 10.0°GeN.

8.1.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<TimeOfDay>	string/time	-	"at midnight', 'after midnight', 'at night', 'in the early morning', 'at sunrise', 'in the morning', 'before noon', '**at noon**', 'at afternoon', 'in the evening', 'at sunset', 'before midnight'	'um Mitternacht', 'nach Mitternacht', 'Nachts', 'früh morgens', 'bei Sonnenaufgang', 'gegen Morgen', 'gegen Vormittag', '**um Mittag**', 'gegen Nachmittag', 'gegen Abend', 'bei Sonnenuntergang', 'vor Mitternacht'	[00:00; 01:00[, [01:00; 03:00[, [03:00; 05:00[, [05:00; 06:00[, [06:00; 06:30[, [06:30; 10:00[, [10:00; 12:00[, **[12:00; 13:00[**, [13:00; 16:00[, [16:00; 19:30[, [19:30; 20:00[, [20:00; 00:00[	00:00, 01:00, 03:00, 05:00, 06:00, 06:30, 10:00, **12:00**, 13:00, 16:00, 19:30, 21:00	o'clock/Uhr
<Season>	string	-	'**summer**', 'autumn', 'winter', 'spring'	'**Sommer**', 'Herbst', 'Winter', 'Frühling'	**[Jun; Aug]**, [Sep; Nov], [Dec; Feb], [Mar; May]	**Jul**, Oct, Jan, Apr	-
<RelTemp>	string/float	-	'very cold', 'freezing cold', 'cold', 'cool', '**normal**', 'mild', 'warm', 'hot', 'very hot'	'sehr kalten', 'frostig kalten', 'kalten', 'kühlen', '**normalen**', 'milden', 'warmen', 'heißen', 'sehr heißen'	[-30.0; -10.0[, [-10.0; -5.0[, [-5.0; 10.0[, [10.0; 20.0[, **[20.0; 25.0[**, [25.0; 30.0[, [30.0; 35.0[, [35.0; 40.0[, [40.0; ∞[	-20.0, -10.0, 0.0, 10.0, **20.0**, 25.0, 30.0, 35.0, 40.0	°C

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Clouds>	string/int	-	'clear', 'sunny', 'fair', 'scattered', 'mainly cloudy', 'cloudy', 'almost covered', 'covered', 'overcast'	'klaren', 'sonnigen', 'heiteren', 'aufgelockerten', 'wolkigen', 'bewölkten', 'stark bewölkten', 'fast bedeckten', 'bedeckten'	[0; 1[, [1; 10[, [10; 20[, [20; 40[, [40; 50[, [50; 60[, [60; 70[, [70; 80[, [80; 100]	0, 1, 10, 20, 40, 50, 60, 70, 80	%
<Lightning>	string	x	'heat thunderstorms', 'local thunderstorms', 'local earth lightnings', 'local cloud lightnings'	'Hitzegewittern', 'örtlichen Gewittern', 'örtlichen Erdblitzen', 'örtlichen Wolkenblitzen'	-	-	-
<Heading>	string/float	-	'North', 'North-East', 'East', 'South-East', 'South', 'South-West', 'West', 'North-West'	'Nord', 'Nord-Ost', 'Ost', 'Süd-Ost', 'Süd', 'Süd-West', 'West', 'Nord-West'	[-22.5; 22.5[, [22.5; 67.5[, [67.5; 112.5[, [112.5; 157.5[, [157.5; 202.5[, [202.5; 247.5[, [247.5; 292.5[, [292.5; 337.5[	10.0, 45.0, 90.0, 120.0, 180.0, 220.0, 280.0, 300.0	° GeN

8.2 Segment Conditions

This section is focused on the local properties of the segment, which are useful to model changing conditions. Examples for such conditions are, e.g., starting rain or appearing side wind after a bridge.

8.2.1 Attributes

- **Segment&#**: Reference to the segment on which the conditions apply.
- **Wind**: Wind speed, either as abstract value (e.g., “moderate wind”) or in m/s (interval or concrete value).
- **Direction**: Wind direction.
- **PrecipitationType**: Precipitation type, both for liquid (e.g., “rain”) and frozen precipitation (e.g., “snow”).
- **Precipitation**: Relative amount of precipitation, either as abstract value (e.g., “intense”) or in millimeter or liter per square-meter (interval or concrete value).
- **Visibility**: Visibility, i.e. the mean sight range, either as abstract value (e.g., “reduced”) or in meter (interval or concrete value).
- **Road&**: Reference to the road.
- **Feature&**: Reference to a feature.

- **Position**: Position of the condition on the segment either as abstract value (e.g., “at the beginning”) or as position (interval or concrete value).
- **Lane&#**: Reference to the lane where the conditions apply.
- **Illumination**: Level of illumination, either as abstract value (e.g., “very-darkly”) or in Lux (interval or concrete value).
- **Coverage**: Road surface coverage caused by snow- or rainfall, either as abstract value (e.g., “slightly”) or as percentage (interval or concrete value).
- **Cover**: Type of road coverage, e.g., snow or paddles.
- **Grip**: Grip value, either as abstract value (e.g., “good”) or in mu (interval or concrete value).

8.2.2 Grammar

⟨*L5SegmentConditionEng*⟩ ::= On ⟨*Segment&#*⟩, [⟨*Wind*⟩ blows [from the ⟨*Direction*⟩]] [(| and) ⟨*PrecipitationType*⟩ falls [with ⟨*Precipitation*⟩ precipitation]] [(the visual range is ⟨*Visibility*⟩ reduced]. [{Furthermore, the surface of (⟨*Road&*⟩ | ⟨*Feature&*⟩) is [⟨*Position*⟩] [of ⟨*Lane&#*⟩] [(mit |) ⟨*Illumination*⟩ illuminated] [(| and) is [⟨*Coverage*⟩] covered with ⟨*Cover*⟩] [resulting in (a |) ⟨*grip*⟩ friction].}]

⟨*L5SegmentConditionGer*⟩ ::= Auf ⟨*Segment&#*⟩ [weht ⟨*Wind*⟩ [aus ⟨*Direction*⟩]] [(| und es) fällt ⟨*PrecipitationType*⟩ [mit ⟨*Precipitation*⟩ Niederschlag]] [(ist | welcher) die Sichtweite ⟨*Visibility*⟩ beeinträchtigt]. [{Des Weiteren ist [Position] die Oberfläche von (⟨*Road&*⟩ | ⟨*Feature&*⟩) [des ⟨*Lane&#*⟩] [(mit |) ⟨*Illumination*⟩ ausgeleuchtet] [(| und) mit ⟨*Cover*⟩ [⟨*Coverage*⟩] bedeckt] [was zu (einer |) ⟨*grip*⟩ Haftreibung) führt].}]

8.2.3 Examples

	A/L/C	Examples
1	A	On Segment #1, a moderate wind blows.
2	A	On Segment #1, no wind blows and the visual range is reduced.
3	L	On Segment #1, [5.5; 7.9]m/s wind blows from the [-22.5; 22.5]°GeN. Furthermore, the surface of the main roadway is covered with puddles.
4	C	On Segment #1, the visual range is to 1000m reduced.
5	A	On Segment #1, a strong wind blows from the North-West and snow falls with moderate precipitation which barely reduces the visual range.

8.2.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Segment&#>	string/UUID&#	-	-	-	-	-	-
<Wind>	string/float	-	’**no wind**’, ’a weak wind’, ’a moderate wind’, ’a fresh wind’, ’a strong wind’, ’a storm’, ’a severe storm’, ’a hurricane-like storm’, ’a hurricane’	’kein Wind’, ’ein schwacher Wind’, ’ein mäßiger Wind’, ’ein frischer Wind’, ’ein starker Wind’, ’ein Sturm’, ’ein schwerer Sturm’, ’ein orkanartiger Sturm’, ’ein Orkan’	**[0.0; 0.3[**, [0.3, 5.5[, [5.5, 8.0[, [8.0; 10.8[, [10.8; 17.2[, [17.2; 24.5[, [24.5; 28.5[, [28.5; 32.7[, [32.7; ∞[	**0.1**, 3.5, 5.5, 9.0, 15.0, 20.0, 25.0, 30.0, 32.7	km/h

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Direction>	string/float	-	'**North**', 'North-East', 'East', 'South-East', 'South', 'South-West', 'West', 'North-West'	'**Nord**', 'Nord-Ost', 'Ost', 'Süd-Ost', 'Süd', 'Süd-West', 'West', 'Nord-West'	**[-22.5; 22.5[**, [22.5; 67.5[, [67.5; 112.5[, [112.5; 157.5[, [157.5; 202.5[, [202.5; 247.5[, [247.5; 292.5[, [292.5; 337.5[	**10.0**, 45.0, 90.0, 120.0, 180.0, 220.0, 280.0, 300.0	° GeN
<PrecipitationType>	string	x	'**rain**', 'freezing rain', 'ice rain', 'snow', 'sleet', 'hail', 'snow grain'	'**Regen**', 'gefrorener Regen', 'Eisregen', 'Schnee', 'Graupel', 'Hagel', 'Schneegriesel'	-	-	-
<Precipitation>	string/float	-	'**little**', 'moderate', 'strong', 'intense'	'**leichtem**', 'mäßigem', 'starkem', 'intensivem'	**[0.1; 0.5[**, [0.5; 2.0[, [2.0; 8.0[, [8.0; ∞[	**0.25**, 1.0, 4.0, 10.0	mm|l/m^2
<Visibility>	string/int	-	'very strongly', 'strongly', 'barely', '**not**'	'sehr stark', 'stark', 'wenig', '**nicht**'	[0; 50], [50; 100], [100; 200], **[200; ∞]**	30, 60, 150, **1000**	m
<Road&>	string/UUID&	-	-	-	-	-	-
<Feature&>	string/UUID&	-	-	-	-	-	-
<Position>	string/int	-	'**at the beginning**', 'in the middle', 'at the end'	'**am Anfang**', 'in der Mitte', 'am Ende'	**[0;25[**, [25;50[, [50;∞[	**10**, 30, 50	m
<Lane&#>	string/UUID&#	-	-	-	-	-	-
<Illumination>	string/float	-	'pitch black', 'very darkly', 'darkly', '**normally**', 'brightly', 'very brightly'	'stockfinster', 'sehr dunkel', 'dunkel', '**normal**', 'hell', 'sehr hell'	[0.0; 50.0[, [50.0; 150.0[, [150.0; 400.0[, **[400.0; 1000.0[**, [1000.0; 10000.0[, [10000.0; ∞[	20.0, 50.0, 150.0, **400.0**, 1000.0, 10000.0	Lux
<Coverage>	string/int	-	'barely', '**slightly**', 'heavily', 'completely'	'kaum', '**leicht**', 'stark', 'vollständig'	[0; 10[, **[10; 25[**, [25; 70[, [70; 100]	5, **20**, 70, 90	%

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Cover>	string	x	'**puddles**', 'snowmelt', 'snow', 'snow slush', 'ice', 'black ice', 'rime ice', 'snow and ice'	'**Pfützen**', 'Schneeschmelze', 'Schneedecke', 'Schneematsch', 'Eis', 'Glatteis', 'Raueis', 'Schnee und Eis'	-	-	-
<Grip>	string/float	-	'very low', 'low', '**normal**', 'good', 'very good'	'sehr geringen', 'geringen', '**normalen**', 'guten', 'sehr guten"	[0.0; 0.2[, [0.2; 0.5[, **[0.5; 1.0[**, [1.0; 2.0[, [2.0; ∞[	0.0, 0.3, **0.5**, 1.0, 2.0	mu

8.3 Impact to Maneuver

This section covers environmental changes based on maneuvers and maneuver phases.

8.3.1 Attributes

- **Phase&#** Reference to the phase defined in the maneuver section.
- **Segment&#** Reference to the segment, where the changes take place.
- **Limit**: Weaker conditional time event for the respective weather change.
- **Wind**: Wind speed, either as abstract value (e.g., "moderate wind") or in m/s (interval or concrete value).
- **Direction**: Wind direction.
- **PrecipitationType**: Precipitation type, both for liquid (e.g., "rain") and frozen precipitation (e.g., "snow").
- **Precipitation**: Relative amount of precipitation, either as abstract value (e.g., "intense") or in millimeter or liter per square-meter (interval or concrete value).
- **Visibility**: Visibility, i.e. the mean sight range, either as abstract value (e.g., "reduced") or in meter (interval or concrete value).
- **Proximity**: Distance to the flash light.
- **relativePos**: Longitudinal and lateral position of the flash light.
- **VehicleRef&#**: Vehicle reference, to which the flash light is positioned relatively.
- **Road&**: Reference to the road.
- **Feature&**: Reference to a feature.
- **Position**: Position of the condition on the segment either as abstract value (e.g., "at the beginning") or as position (interval or concrete value).

- **Lane&#**: Reference to the lane where the conditions apply.
- **Coverage**: Road surface coverage caused by snow- or rainfall, either as abstract value (e.g., “slightly”) or as percentage (interval or concrete value).
- **Cover**: Type of road coverage, e.g., snow or paddles.
- **Grip**: Grip value, either as abstract value (e.g., “good”) or in mu (interval or concrete value).

8.3.2 Grammar

⟨*L5ManeuverConditionEng*⟩ ::= In ⟨*Phase&#*⟩, the weather on ⟨*Segment&#*⟩ is changing and there is now [[after [⟨*Limit*⟩] ⟨*int*⟩ seconds] (⟨*Wind*⟩ (| wind)) [from the ⟨*Direction*⟩]] [(| and) [after [⟨*Limit*⟩] ⟨*int*⟩ seconds] [⟨*PrecipitationType*⟩ that falls [with ⟨*Precipitation*⟩ precipitation]] [the visual range is ⟨*Visibility*⟩ reduced] [. Suddenly, there is [after [⟨*Limit*⟩] ⟨*int*⟩ seconds] a flash light [in ⟨*Proximity*⟩] [⟨*relativePos*⟩ of the ⟨*VehicleRef&#*⟩]]. [{Moreover, the surface of (⟨*Road&*⟩ | ⟨*Feature&*⟩) is [⟨*Position*⟩] [of ⟨*Lane&#*⟩] is [after [⟨*Limit*⟩] ⟨*int*⟩ seconds] [⟨*Coverage*⟩] covered with ⟨*Cover*⟩] [resulting in (a |) ⟨*Grip*⟩ friction]}].

⟨*L5ManeuverConditionGer*⟩ ::= In ⟨*Phase&#*⟩ ändert sich auf ⟨*Segment&#*⟩ das Wetter und es gibt jetzt [[nach [⟨*Limit*⟩] ⟨*int*⟩ Sekunden] [(einen ⟨*Wind*⟩ (| Wind)) [aus ⟨*Direction*⟩]] [[nach [⟨*Limit*⟩] ⟨*int*⟩ Sekunden] fallenden ⟨*PrecipitationType*⟩ [mit ⟨*Precipitation*⟩ Niederschlag] [welcher die Sichtweite ⟨*Visibility*⟩ beeinträchtigt] [. Plötzlich gibt es [nach [⟨*Limit*⟩] ⟨*int*⟩ Sekunden] [in ⟨*Proximity*⟩] ein Blitzlicht [⟨*relativePos*⟩ dem ⟨*VehicleRef&#*⟩]]. [{Außerdem ist die Oberfläche von (⟨*Road&*⟩ | ⟨*Feature&*⟩) [von ⟨*Lane&#*⟩] [nach [⟨*Limit*⟩] ⟨*int*⟩ Sekunden] [⟨*Coverage*⟩] bedeckt mit ⟨*Cover*⟩] [(was zu (einer |) ⟨*Grip*⟩ Haftreibung führt]]}.

8.3.3 Examples

	A/L/C	Examples
1	A	In Phase #1, the weather is changing and there is now after 2 seconds a fresh wind from North-East.
2	A	In Phase #1, the weather is changing and there is now falling rain. Furthermore, the surface of the main roadway is covered with black ice.
3	C	In Phase #1, the weather is changing and there is now rain that falls with 40 mm precipitation which reduces the visual range to 1000m.

8.3.4 Transcription

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Phase&#>	string/UUID&#	-	-	-	-	-	-
<Segment&#>	string/UUID&#	-	-	-	-	-	-
<Limit>	string	x	’at least’, ’at most’	’mindestens’, ’höchstens’	-	-	-
<Wind>	string/float	-	**’no wind’**, ’a weak wind’, ’a moderate wind’, ’a fresh wind’, ’a strong wind’, ’a storm’, ’a severe storm’, ’a hurricane-like storm’, ’a hurricane’	**’kein Wind’**, ’ein schwacher Wind’, ’ein mäßiger Wind’, ’ein frischer Wind’, ’ein starker Wind’, ’ein Sturm’, ’ein schwerer Sturm’, ’ein orkanartiger Sturm’, ’ein Orkan’	**[0.0; 0.3[**, [0.3, 5.5[, [5.5, 8.0[, [8.0; 10.8[, [10.8; 17.2[, [17.2; 24.5[, [24.5; 28.5[, [28.5; 32.7[, [32.7; ∞[	**0.1**, 3.5, 5.5, 9.0, 15.0, 20.0, 25.0, 30.0, 32.7	km/h

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Direction>	string/float	-	'**North**', 'North-East', 'East', 'South-East', 'South', 'South-West', 'West', 'North-West'	'**Nord**', 'Nord-Ost', 'Ost', 'Süd-Ost', 'Süd', 'Süd-West', 'West', 'Nord-West'	**[-22.5; 22.5[**, [22.5; 67.5[, [67.5; 112.5[, [112.5; 157.5[, [157.5; 202.5[, [202.5; 247.5[, [247.5; 292.5[, [292.5; 337.5[	**10.0**, 45.0, 90.0, 120.0, 180.0, 220.0, 280.0, 300.0	° GeN
<PrecipitationType>	string	x	'**rain**', 'freezing rain', 'ice rain', 'snow', 'sleet', 'hail', 'snow grain'	'**Regen**', 'gefrorener Regen', 'Eisregen', 'Schnee', 'Graupel', 'Hagel', 'Schneegriesel'	-	-	-
<Precipitation>	string/float	-	'**little**', 'moderate', 'strong', 'intense'	'**leichtem**', 'mäßigem', 'starkem', 'intensivem'	**[0.1; 0.5[**, [0.5; 2.0[, [2.0; 8.0[, [8.0; ∞[	**0.25**, 1.0, 4.0, 10.0	mm|l/m^2
<Visibility>	string/int	-	'very strongly', 'strongly', 'barely', '**not**'	'sehr stark', 'stark', 'wenig', '**nicht**'	[0; 50], [50; 100], [100; 200], **[200; ∞]**	30, 60, 150, **1000**	m
<Proximity>	string	x	'**closeness**', 'afar'	'**der Nähe**', 'der Ferne'	-	-	-
<relativePos>	string	x	'right', 'left', '**in front**', 'behind', 'right, in front', 'right, behind', 'left, in front', 'left, behind'	'rechts von', 'links von', '**vor**', 'hinter', 'rechts vor', 'rechts hinter', 'links vor', 'links hinter'	-	-	-
<VehicleRef&#>	string/UUID&#	-	-	-	-	-	-
<Road&>	string/UUID&	-	-	-	-	-	-
<Feature&>	string/UUID&	-	-	-	-	-	-
<Position>	string/int	-	'**at the beginning**', 'in the middle', 'at the end'	'**am Anfang**', 'in der Mitte', 'am Ende'	**[0;25[**, [25;50[, [50;∞[	**10**, 30, 50	m
<Lane&#>	string/UUID&#	-	-	-	-	-	-
<Coverage>	string/int	-	'barely', '**slightly**', 'heavily', 'completely'	'kaum', '**leicht**', 'stark', 'vollständig'	[0; 10[, **[10; 25[**, [25; 70[, [70; 100]	5, **20**, 70, 90	%

TAG	datatype	enum	Abstract values		Logical value	Default concrete value	unit
			English	German			
<Cover>	string	x	'**puddles**', 'snowmelt', 'snow', 'snow slush', 'ice', 'black ice', 'rime ice', 'snow and ice'	'**Pfützen**', 'Schneeschmelze', 'Schneedecke', 'Schneematsch', 'Eis', 'Glatteis', 'Raueis', 'Schnee und Eis'	-	-	-
<Grip>	string/float	-	'very low', 'low', '**normal**', 'good', 'very good'	'sehr geringen', 'geringen', '**normalen**', 'guten', 'sehr guten"	[0.0; 0.2[, [0.2; 0.5[, **[0.5; 1.0[**, [1.0; 2.0[, [2.0; ∞[	0.0, 0.3, **0.5**, 1.0, 2.0	mu

Chapter 9

Outlook

The details presented in this paper allow the unambiguous textual definition of scenario descriptions in English and German for the freeway domain. The language itself is still in development, therefore extensions and minor modifications are likely to happen in the near future. Nevertheless, this document can be use as a solid base for the scenario definition, either by manually applying the rules and grammar on a document-basis or by implementing them into some kind of framework.

The presented version of the stiEF language is limited to the freeway domain and to English/German as natural language. Extensions for parking garages/areas and roundabouts have already been developed and will be released in an updated version of this document in the near future. This also applies to Chinese, which has already been added to the collection of languages. Finally, further extensions (rural, urban and city traffic, as well as additional languages) are planned and likely to be carried out.

The already existing implementation of stiEF as tool, which is based on the Open-Source-framework Jetbrains Meta-Programming System (MPS)[1], is currently closed source. However, there are plans to release it either as Open-Source or as Freeware.

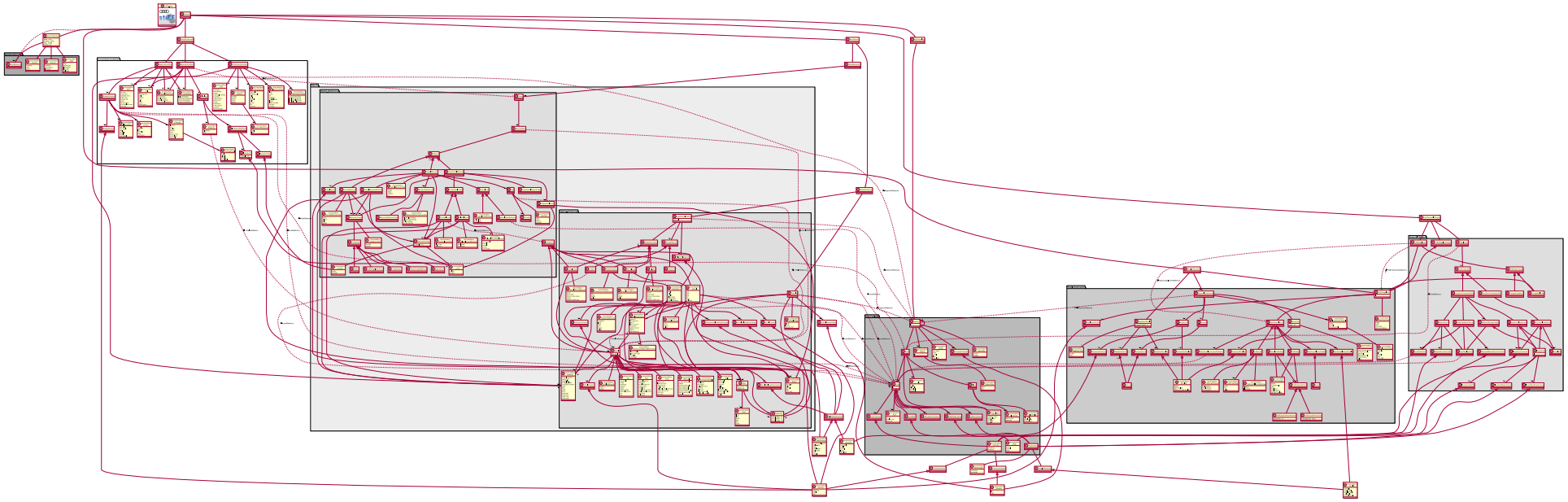
[1] https://www.jetbrains.com/mps/

Chapter 10

Appendix

Besides the syntax definition for the language given in the previous chapters, the underlying information model is relevant to understand which data can be stored in such scenario descriptions. The following diagram depicts this information model as UML[1] class diagram based on our exemplary implementation. This includes the elements, the appropriate selection possibilities and the cardinalities. Minor discrepancies to the content of the previous chapters are due to the implementation.

Remark: Use the digital version of this document to read the details on this page.



[1] https://www.uml.org/

Bibliography

[1] SAE International, "Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles," 2016. [Online]. Available: https://saemobilus.sae.org/content/j3016_201806

[2] F. Bock, C. Sippl, A. Heinz, C. Lauer, and R. German, "Advantageous Usage of Textual Domain-Specific Languages for Scenario-Driven Development of Automated Driving Functions," in *Proceedings of the 2019 Annual IEEE International Systems Conference (SysCon)*, 2019. [Online]. Available: https://ieeexplore.ieee.org/document/8836912

[3] F. Bock, R. German, and C. Sippl, "Fully automated vehicles: Challenges, expectations and methods," in *17. Internationales Stuttgarter Symposium.* Springer, 2017, pp. 1373–1387.

[4] PEGASUS Project Office, "Pegasus method an overview," German Aerospace Center, Tech. Rep., 2019. [Online]. Available: https://www.pegasusprojekt.de/files/tmpl/Pegasus-Abschlussveranstaltung/PEGASUS-Gesamtmethode.pdf

[5] ——, "Scenario description," German Aerospace Center, Tech. Rep., 2019. [Online]. Available: https://www.pegasusprojekt.de/files/tmpl/PDF-Symposium/04_Scenario-Description.pdf

[6] M. Dupuis and H. Grezlikowski, "OpenDRIVE®-an open standard for the description of roads in driving simulations," in *Proceedings of the Driving Simulation Conference*, 2006, pp. 25–36. [Online]. Available: http://www.opendrive.org/download.html

[7] F. Bock, A. Heinz, and J. Lorenz, "Efficient usage of abstract scenarios for the development of highly-automated driving functions," in *20. Internationales Stuttgarter Symposium.* Springer, 2020. [Online]. Available: https://www.springer.com/de/book/9783658299422

[8] F. Bock, "Beiträge zur szenarienbegleiteten Entwicklung von automatisierten Fahrfunktionen," Ph.D. dissertation, Friedrich-Alexander-University Erlangen-Nuremberg, 2021.

[9] F. FORSCHUNGSGESELLSCHAFT, "Straßen-und verkehrswesen (hrsg.): Richtlinie für die anlage von autobahnen (raa)," 2008.

[10] M. Dupois, "Openscenario - bringing content to the road," in *2nd OpenSCENARIO Meeting*, 2016. [Online]. Available: http://www.openscenario.org/docs/OSCUserMeeting20151015_VIRES.pdf