Comparison of Parametrization Approaches for Scenario-Based Testing

Christoph Glasmacher[a], Marcel Sonntag[b] and Lutz Eckstein

Institute for Automotive Engineering, RWTH Aachen University, Steinbachstraße 7, Aachen, Germany

Keywords: Scenario, Testing, Parametrization, Simulation, Automated Driving.

Abstract: Scenario-based testing is a promising approach to assess and assure the safety of automated and connected driving functions. In this approach, test scenarios are often described in an abstract way. Norms sometimes even provide certain parameter values for, e.g., approaching maneuvers in lane-keeping situations. However, the type of parametrization is often not fully specified - neither in databases nor in regulations. This paper assesses differences in possible types of parametrizations for test scenarios and gives guidance about the importance to choose a suitable parametrization for individual use cases. For this, different parametrization types are categorized. The effects on the outcome of tests are investigated in a comprehensive study simulating 435,456 test cases in the CARLA simulator. Thereby, 8 different systems under test are investigated to observe the outcome on different parametrizations on intersections. The results show a high influence of the parametrizations for different systems under test on the test outcomes leading to the need for carefully selecting a suitable parametrization approach.

1 INTRODUCTION

Due to technological advancements in machine learning and sensor systems, the development of automated driving systems (ADSs) sped up and first applications are introduced to the market (Mercedes-Benz AG, 2024; Waymo LLC, 2024). For the introduction and extension of them, it is required by regulatory bodies to assess the safety of ADSs before market introduction (UNECE, 2021). To cope with the complexity of today's traffic, scenario-based approaches such as (PEGASUS Project Consortium, 2019) or (Galbas et al., 2022) have emerged in recent years to facilitate those safety analyzes. Scenario-based approaches also made it into standardization (International Organization for Standardization, 2022a) and legislation (UNECE, 2021). Within scenario-based testing, one goal is to derive the suitable scenarios to represent the related operational design domain (ODD) for a given use case or application (e.g., motorway chauffeur) as realistically and completely as possible. Based on those scenarios, ADSs are to be tested in simulation as well as in real-world conditions.

Substantial research has been performed on identifying and systematizing these scenarios (or scenario categories) to represent the ODD (Weber et al., 2023a; de Gelder et al., 2022). Using these scenarios for testing purposes requires defining models representing them. Usually, these models consist of parameters defining characteristics, such as the starting conditions of actors involved. To generate concrete or logical scenarios, parameter values or ranges are assigned to these models. Research has also been performed on parameter value assignment (Glasmacher et al., 2023b). However, there is no common ground on how to define the models representing the scenarios, e.g., in simulations to achieve meaningful outcomes. In other words, there is no common ground in which way and with which parameters (not the values of them) should define the scenarios for testing to allow deriving valid conclusions for the specified test case. This task is called scenario parametrization. Standards like OpenSCENRIO XML (ASAM e.V., 2024) define a common language for scenario modelling for simulations, but no guidance is given on how to do the parametrization, i.e., how to define the scenario elements in detail to, e.g., define dynamic objects in the surrounding of the system under test (SuT). One recent study (de Gelder and Camp, 2024) provides first analyzes on this topic, considering different levels of detail of scenario parametrization of those objects. This is analyzed for scenarios in longitudinal traffic. However, different degrees of reactiv-

[a] https://orcid.org/0000-0003-4826-9706
[b] https://orcid.org/0009-0003-1247-1782

Glasmacher, C., Sonntag, M. and Eckstein, L.
Comparison of Parametrization Approaches for Scenario-Based Testing.
DOI: 10.5220/0013282200003941

In *Proceedings of the 11th International Conference on Vehicle Technology and Intelligent Transport Systems (VEHITS 2025)*, pages 439-447
ISBN: 978-989-758-745-0; ISSN: 2184-495X

ity of those objects or the general availability to react are not analyzed. The dynamic objects could be defined, e.g., using fixed trajectories or arbitrarily complex driver models. The influence of these types of parametrizations remains unclear in simulation outcomes.

In this work, we systematically define and categorize relevant terms and representations for scenario parametrization (see Section 3). Based on this categorization, three different scenario parametrizations of the same scenario are set up for testing in simulation, considering different degrees of reactivity of the dynamic objects in the surrounding of the SuT (see Section 4). Those parametrizations are analyzed by conducting an extensive experiment. The three different parametrizations combined with four different implementations of an SuT behavior as well as parameter values sampled from defined parameter ranges result in more than 400,000 simulated cases. This allows an extensive analysis of the influence of the parametrizations on simulation outcomes under varying conditions. The results (see Section 5) show that the choice of the scenario parametrization has significant influence on the test results with respect to the number and characteristics of the resulting collisions. Based on this, guidance is given on how to select a suitable scenario parametrization for the intended use (see Section 6).

2 STATE OF THE ART

In recent years, several publications on scenario-based testing have been made, applying the developed concepts to different use cases for scenarios. In order to structure this first, an overview of some of these various use cases is provided. Based on this, a detailed look is taken at their parametrization and the differences are elaborated.

2.1 Scenario-Based Testing and Applications

Due to the high complexity of today's traffic, regular testing approaches solely based on on-road testing are not applicable for testing ADSs, as the required mileage to be able to derive valid conclusions is within an unreasonable order of magnitude (Winner et al., 2018). Thus, scenario based approaches were introduced to enable a more systematic way for testing relevant situations (PEGASUS Project Consortium, 2019). A scenario, as defined in ISO 34501 (International Organization for Standardization, 2022b), is a sequence of scenes usually including the automated driving system(s) / subject vehicle(s), and its/their interactions in the process of performing the dynamic driving task (DDT).

While the term scenario is rather well-defined, the process of parametrization of scenarios is not defined precisely, leading to inconsistent use. Some use the term for the process of selecting specific parameter values from given ranges to come to concrete scenarios (Bach et al., 2016). Others are using the term for the process of identifying parameters that represent the desired scenarios in a meaningful way (de Gelder and Camp, 2024).

2.2 Different Parametrizations

When defining scenarios for simulation, models for the actors involved are to be defined to model their individual behavior. These models can have varying complexity, leading to different parameters that are to be defined. This is an important part of the scenario parametrization.

The most common standard for defining scenarios for simulations is the ASAM OpenSCENARIO XML standard (ASAM e.V., 2024). It allows different ways for the representation of the actors' behavior. First, fixed trajectories can be used defining dynamic states of the actors at consecutive positions over time. Second, behavior can be defined using predefined actions and triggers, allowing actors to react to defined circumstances and interactions. Third, custom controllers can be specified to model further interactions. Those different possibilities lead to the need for selecting an appropriate approach for the desired use, which might require different models for defining the actors' behaviors.

Within the V4SAFETY project, for the purpose of prospective safety impact assessment, different categories of models based on the actors' reactivity have been defined (Fahrenkrog et al., 2024). Within the defined baseline generation approaches, one can either use pre-simulation or in-simulation approaches. For the former, the characteristics of the object's trajectory are defined before the simulation is started. For the latter, the trajectories are defined during the simulation based on the actual interactions. Triggers and actions might define this behavior. This implies that different approaches require different parametrizations of scenarios, leading to the need of defining different parameters.

In addition, different levels of detail of modelling objects' behavior can be considered. Within the study of (de Gelder and Camp, 2024), the influence of this on simulation results is analyzed for the scenarios defined in the regulation UN ECE R157 (UNECE, 2021) focussing on longitudinal traffic. This includes, e.g., different ways of parametrizing lane changes within cut-in scenarios. A substantial influence of the different parametrization approaches on the test outcomes is shown. Though, the general influence of different parametrizations, e.g., considering objects' reactivity, is not discussed in current research.

This stresses the need of further investigating the influence of different scenario parametrizations to give guidance on how to select appropriate approaches.

3 DEFINITION AND CATEGORIZATION OF PARAMETRIZATIONS

Section 2.2 shows that scenarios are often described in different ways. In order to systematize different types, definitions are first discussed. Based on these, different categories of scenario parametrization are used to describe them.

3.1 Definitions

Although terms such as "parameter" or abstraction levels for scenarios are frequently used in ISO documents (International Organization for Standardization, 2022b), the level of detail leaves space for misinterpretation in the following methodology. To avoid this, definitions are set up for the task of parametrization in the same manner as for the distinction of types of logical scenarios as in (Glasmacher et al., 2023a):

- **Scenario Parameter:** Scenario parameters are elements of a logical or concrete scenario which quantify its characteristics (incl. involved actors).
- **Scenario Parametrization:** Process of modeling a logical scenario with a set of parameters without assigning concrete values, ranges or distributions.
- **Scenario Parameter Value Assignment:** Parameter value assignment describes the assignment of values, ranges or distributions to predefined scenario parameters.

Using an analogy with mathematics, parametrization opens up the vector space that may be designed to represent the real world. The assignment of the values or ranges then only sets a point or a body in the (high-dimensional) spanned space, which then represents a concrete or logical scenario.

3.2 Categorization of Parametrization Approaches

Scenarios are described differently in the literature depending on the use case. In the context of this paper, categories for the parametrization of scenarios that contain parameters are of particular interest. We distinguish among three categories for scenario parametrization: level of abstraction, degree of reactivity, and type of description language.

The category of abstraction levels is traditionally used frequently and encompasses the level of detail. Common levels are functional, abstract, logical and concrete. As the level of detail increases with lower abstraction level, information must be added to make the description complete.

We define reactivity as the interactivity of the scenario elements to actions of the system under test. If a scenario consists exclusively of predefined elements, there is no reactivity of the scenario elements and the control loop of action and reaction of the scenario elements is not closed in the simulation. Thus, it is e.g. a direct replay of a recorded scenario. On the other side of the spectrum, all scenario elements would react to actions of the ego over the entire time span of the scenario. This is the case for road users, for example, if they continuously adjust to the ego's behavior and adapt their own behavior. Further gradations are possible between these two extremes.

The last category is the description language. Based on the selected parameters, the reactivity and the resulting level of abstraction, this can be selected to allow an (machine readable) interpretation of the scenario. Scenario description languages such as ASAM OpenScenario XML/ DSL or proprietary descriptions define those languages.

4 EXPERIMENT

The influence of different parametrization approaches on a simulation result is assessed within an experiment to investigate whether there is a relevant influence on the outcome of a potential assessment of a SuT focussing on the aspect of reactivity. In the experiment, a total of 435,456 scenarios are generated, simulated and evaluated to evaluate the influence of a wide range of combinations within and between different parametrization approaches. Within those scenarios, aspects with potentially high influence on the simulation result as the parametrization approach, underlying parameters and the system under test are varied for a comprehensive assessment. After setting up the scenarios (Section 4.1) and SuTs (Section 4.2),

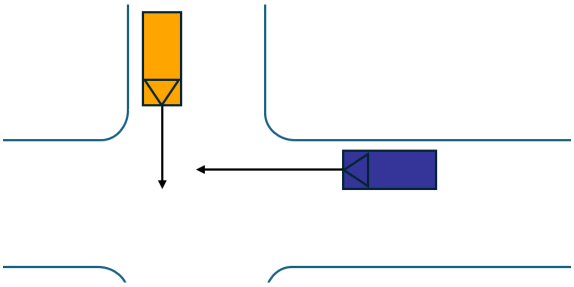

Figure 1: Constellation of ego road user (blue) and conflicting road user (orange).

each system under test is confronted with the scenarios using the simulation platform CARLOS (Geller et al., 2024) which is based on the CARLA simulator. They are assessed based on crashes and impact speeds since those are some of the most common metrics for assessing safety.

4.1 Scenario Parametrization and Parameter Value Assignment

Assessing a scenario with multiple characteristics can become a high dimensional problem. This increases even more if multiple parametrization approaches and different SuTs should be assessed. To limit this complexity, one specific abstract scenario is chosen. We decided to assess the scenario *ego passing straight with intersecting object from right passing straight* according to (Weber et al., 2023b) due to the high relevance in recent assessments. It is designed with vehicles for both road users, but since the models don't account for this difference, conclusions should be equally valid for other road user types such as VRUs or other situations (e.g. including occlusions). The scenario is applied to the four-arm intersection *Frankenburg* of the inD dataset (Bock et al., 2020). The constellation is shown in Figure 1.

According to Section 3.2 numerous possible parametrizations exist. The focus of this experiment is to investigate the influence of different reactivities within the defined scenario. Thus, three different parametrizations for the conflicting road user (*object*) in the same abstract scenario are set up according to the reactivity. The focus of this experiment is on the object's velocity (-profile) while keeping the same path:

- **Constant Velocity:** As a representative of the *fixed trajectory* approach, the object is modeled with a constant velocity not reacting to the behavior of the ego vehicle.
- **Synchronization:** For this approach, the behavior can be subdivided into two phases: before and after a locally fixed synchronization point for the object. Before this point, the object tries to provoke a collision ($PL = 0$) with the ego by accelerating or decelerating. After synchronization, the velocity does not change anymore. Thus, reactivity of the object is given to a certain point.
- **Adaptive Function:** This approach is comparable to the *synchronization* approach, but always tries to create a collision under given acceleration constraints without stopping this synchronization at a certain point. This reflects the highest degree of reactivity.

These approaches are detailed by defining parameters and assigning parameter values. For the parameter value assignment, initial conditions are set equally for the different approaches in a realistic range for intersections. Besides these, specific parameters are set for the individual approaches if necessary (Table 1). To enable a simple sampling approach while still generating crashes easily and allowing comparisons, whenever possible, parameters are set in a way that the actors reach the conflict after a defined time. This means, for example, that the initial position is calculated based on the sampled initial velocity in the way, that the actor reaches the conflict area after a defined timespan, taking the sampled priority level into account.

The desired conflict is described with a predicted priority level (PrPL). According to (Hu and Li, 2017) this is defined in the interval $[-1, 1]$. However, to describe also near misses, this is extended to $[-1.5, 1.5]$.

Using a uniform sampling, 6,804 concrete scenarios are created for the constant velocity approach, 20,412 for the synchronization approach and 27,216 for the adaptive approach. This sampling approach ensures a good comparability between approaches and does not include bias due to the parameter value assignment.

4.2 Systems Under Test

The experiment is conducted with different SuTs, as different characteristics of a SuT might lead to different effects of parametrization approaches:

- **No reaction** (NR)**:** As a baseline, this system under test does not react on the object.
- **Autonomous Emergency Braking System** (AEB)**:** An AEB system is defined with a time-to-collision (TTC) threshold ($TTC < 1s$) and a distance headway (DHW) threshold ($DHW < 3m$). Once one condition is reached, an emergency breaking maneuver is performed.

Table 1: Parameter ranges for experimental setup.

Parameter	Unit	Constant velocity	Synchronization	Adaptive Function
Predicted pre-crash time	[s]	[0.3, 5.0]		
$v_{ego,init}$	[m/s]	[3.0, 20.0]		
$v_{object,init}$	[m/s]	[3.0, 20.0]		
Predicted Priority Level	[-]	[-1.5, 1.5]		
Max. acceleration	[m/s^2]	-	[9.81]	[1.0, 9.81]
Synchronization time to conflict	[s]	-	[0, 2.0]	-

Table 2: Logic system under tests.

SuT	Logic	Acc.
AEB	$TTC<1.0s \vee DHW<1.5m$	-9.81 m/s^2
Assist	$PrPET<1.0 \wedge PrPL>1.1$	2 m/s^2
	$PrPET<1.0 \wedge PrPL<1.1$	-2 m/s^2

- **Intersection Assist** (As)**:** An intersection assist (Assist) does not only break, but accelerates and decelerates based on the predicted post-encroachment-time (PrPET) and a predicted priority level (PrPL, (Hu and Li, 2017)) with a smaller acceleration/ deceleration to avoid a conflict (see Table 2).
- **AEB and Assist** (A-As)**:** Both AEB and Assist are used in combination. Once the AEB is activated, it overrides the Assist function.

For each SuT, two variants are set up to acknowledge different approaching maneuvers for intersections. This is done by defining a target speed to which the system under test decelerates when approaching the intersection. Such a behavior can reflect approaching an intersection on a minor or priority road. The approaching target speed is either set to *const* meaning that it does not intent to reduce the speed or to $3m/s$ for a more cautious approaching maneuver when the SuT might need to yield. Taking the number of different scenarios and the different SuTs into account, 435,456 test cases are set up and simulated in the CARLOS simulation environment.

5 RESULTS

According to the experiment description in Section 4, the test cases created are evaluated a posteriori using various metrics. Whereas mainly results based on accidents are shown in this section, analysis of various TTX metrics such as TTC, THW, PET, but also metrics with predictions such as PrPET and PrPL are incorporated in the conclusion. However, due to the limited space and similar statements, the focus within the results is on collisions. For this purpose, the crash ratio and collision speeds are primarily taken into account.

The influence of individual parameter values are not analyzed below, but rather the influence of the parametrization on the outcome of the scenario. Accordingly, the respective scenarios are not considered individually, but the results are aggregated. The results are clustered in two sections: the influence of the parametrization approach itself, and the influence of certain parameters in combination with the approach.

5.1 Influence of Parametrization

The comparison of the different parametrizations shows differences in the output of a simulation depending on the parametrization approach and the SuT used. These differences are not linear in each case, they partly counteract each other and depend on individual parameters (see Figure 2).

In order to assess the effects of different parametrizations more deeply, a baseline is used as the cases with the object road user with constant velocity parametrization and with a SuT with no reaction. Figure 2 shows for this baseline (two left blue bars) that all generated cases with $-1 < PL < 1$ reproduce a crash and according to the definition for $PL = -1.5$ and $PL = 1.5$ no crashes are detected. For $PL = -1$ and $PL = 1$, crashes are mostly detected but not always due to numerical inaccuracies, since this mathematical limiting case is extremely unstable. Already in the baseline, it can be seen that different SuTs show significantly different crash rates depending on the defined target speed (ts) for entering the intersection.

If we look at the changes caused by the influence of the other parametrization approach on this baseline, we can see significant differences depending on the behavior of the SuT. As expected, the synchronization approach produces more crashes compared to the baseline if no AEB is included since it reacts to the behavior of the SuT til a certain point to provoke the desired constellation - in this case a conflict situation. Less crashes are produced for the SuTs with AEB especially at $PL > 0$ since the object want to provoke a $PL = 0$ and so makes it easier for the AEB to

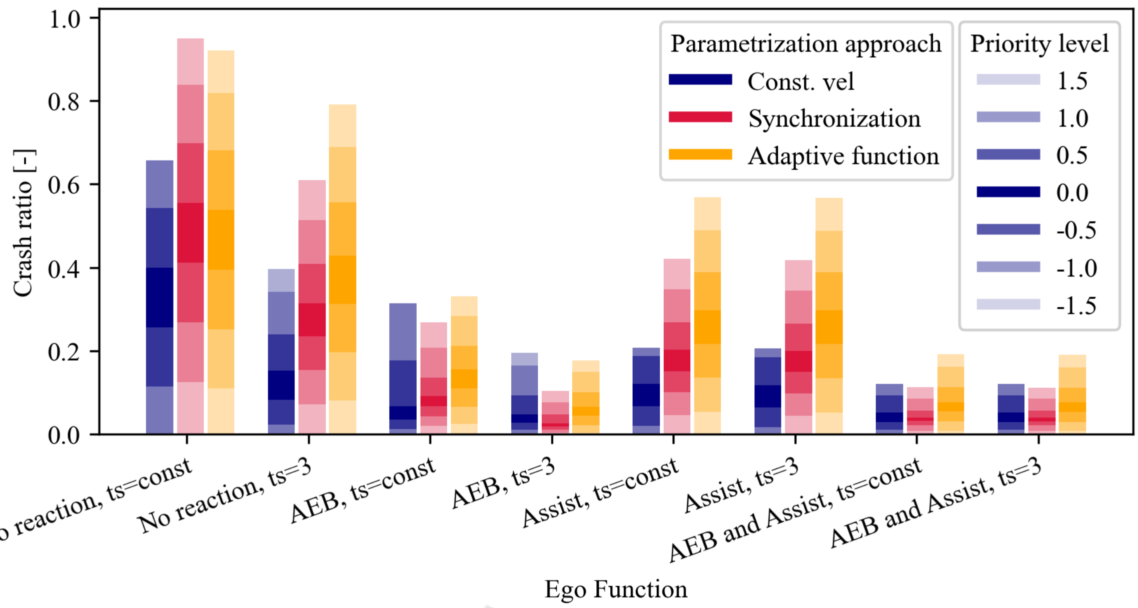

Figure 2: Influence of different parametrizations and SuTs on the case results.

prevent these cases. The adaptive approach produces generally even more collisions than the synchronization parametrization approaches. This is due to the fact that in this case a collision is provoked up to the conflict point and not only a prior point in time. In this case the SuT can only prevent a collision by stopping before entering the conflict area or if the initial conditions don't allow a conflict. This can be the case if the pre-crash time is relatively short and $PL \notin [-1,1]$ is selected. So, for a predefined SuT we can already see a significant influence of the parametrization approach on the simulation outcome.

When investigating the influence of the parametrization depending on different SuTs, a similar conclusion can be drawn. However, there is no clear correlation between the SuTs and parametrization approaches affecting the crash rates of the test cases. Although the synchronization produces fewer crashes for SuTs compared to the adaptive function, it is the opposite for the baseline SuT since the synchronization includes on average a higher acceleration intensity than the adaptive approach within the study. Furthermore, the synchronization approach produces even fewer crashes compared to the baseline in those cases, in which the synchronization is rather early and the change of the object propagate until the conflict area no matter how the SuT behaves. So, taking the influence of the SuT in comparison with the parametrization into account, the impact of the parametrization approach on the simulation outcome becomes less predictable between these SuTs.

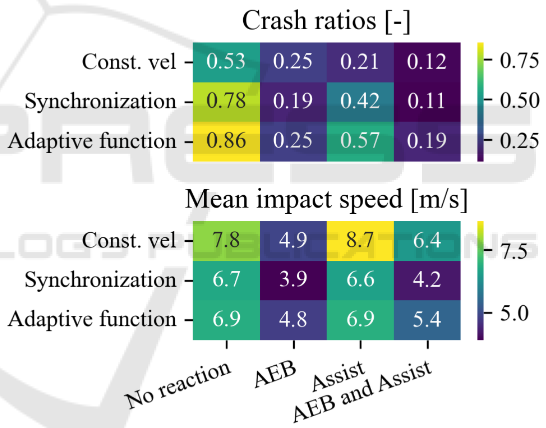

Figure 3: Impact speed distributions of object in comparison to crash ratios.

These differences can be seen not only in the number of collisions, but also in the object road user's impact speed (see Figure 3). Thereby, it is not distinguished between different target velocities. This shows that collisions not only occur at different frequencies, but that the severity of a collision does not change proportionally. Rather, a more differentiated picture must be drawn. Although the highest collision speeds of the object road user are recorded for the constant velocity, values for synchronization and adaptive function are similar for the assist function but significantly different for the AEB. This can be explained partly by the different intensities of the acceleration of the object within different parametriza-

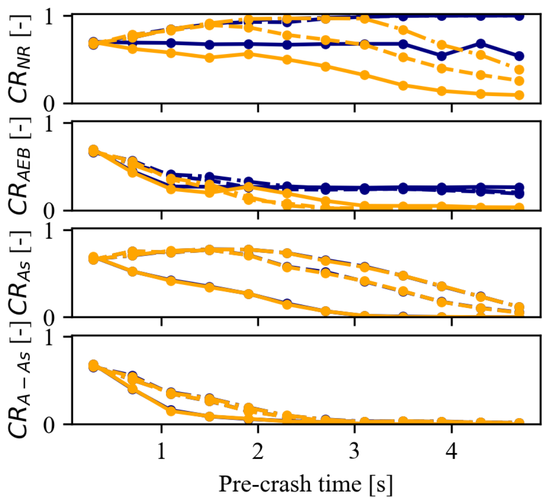

Figure 4: Pre-crash time influence for crash rates (CR) for SuTs with different target speeds const (blue) and 3 m/s (yellow) as well as constant velocity (solid), synchronization (dashed) and adaptive (dotted dashed) averaged over all investigated PLs.

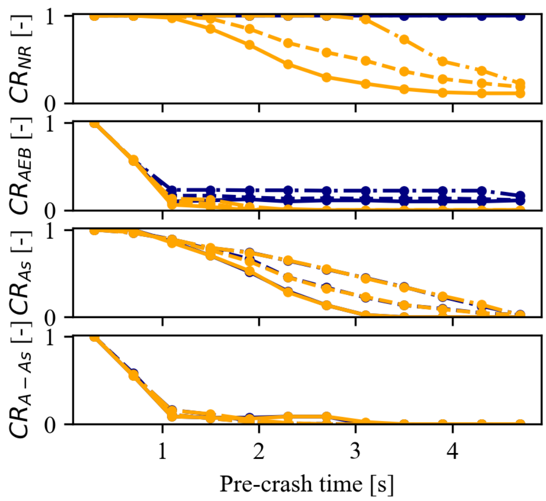

Figure 5: Pre-crash time influence for $PL = 0$ distinguishing target speed const (blue) and 3 m/s (yellow) as well as constant velocity (solid), synchronization (dashed) and adaptive (dotted dashed).

tions. Furthermore, a shift can be explained by the later reaction of an AEB which may be more often after the synchronization point. This shows that the quantitative influence of different parametrizations on the evaluation of a scenario can be significant and difficult to estimate a priori, as various factors usually have to be taken into account.

5.2 Implications on Parameter Value Assignment

In addition to the aggregated influence of the parametrization approach on a simulation outcome itself, we investigated how that effect varies depending on the actual parameter values assignment. This influence is investigated by varying the pre-crash time and PL. According to Figure 4, the number of crashes with regard to the influence of the pre-crash time and its dependency with parametrization approach and the SuT can be significant. The figure shows that the different characteristics of a parametrization and an SuT change based on the pre-crash time. While a similar outcome can be observed for a pre-crash time close to zero seconds, this changes with increasing time and converges in some cases. With regard to the effects of the SuT, it can be observed that shorter reaction times of SuTs such implemented in the AEB lead to faster convergence, while the assist function takes longer. We show that different effects work against each other, especially with the more adaptive parametrizations. For scenarios without a designed collision, the state of conflict must first be reached, resulting in more crashes (orange dotted dashed line curve). Especially with long pre-crash times, however, the early influence of the delay towards the intersection takes over the larger part, so that the curves decrease again with longer lead times of scenarios.

Taking the PL as another parameter in combination into account, the picture can be drawn slightly differently (see Figure 5). In this case, the effect of the rise is eliminated, as collisions already occur at the beginning and only the SuT can prevent them. However, the ability naturally goes hand in hand with the time available and the intensity of the SuT, as well as a counter movement of the parameterized object. Accordingly, the influence of the parametrization is shown. For example, the adaptive approach can ensure crashes for the longest pre-crash time, but falls off relatively faster. This shows that the influence of time also has a significant influence, which in turn depends on the parametrization and the SuT. However, it also shows that saturation effects occur with a sufficiently long pre-crash time, but these make the scenario less robust in relation to the originally desired constellation and therefore depending on the procedure harder to incorporate in a safety argumentation or assessment. So, it can be shown that even individual parameter value assignments itself may have relevant impacts varying depending on the parametrization.

6 DISCUSSION

The results show that not only the parameters itself, but also the approach of parametrization can have a significant influence on the simulation outcome. This implies that the comparability of two analyses cannot be described purely in terms of naming the outcome of abstract scenarios. Similarly, a relative comparison between a baseline and a SuT is not transferable as the influence is not independent of the parametrization. Rather, for a direct comparison of both absolute figures and relative evaluation a comparison of the parametrization type of a scenario is also necessary and should be presented transparently.

Furthermore, the analysis of the pre-crash time in a scenario shows that its influence can be significant. If it is too short, functions cannot react adequately. If it is too long, instabilities can play a role depending on the simulation model. Accordingly, this should be considered in advance for a valid result.

The results are based on the comprehensive analysis of one abstract scenario. However, a generalization of the discussed results is possible for several reasons: On the one hand, the scenario used represents a frequently occurring case. On the other hand, the models used to control road users are so general that no assumptions were made about the type of road user. Although there will be deviations for other road users due to the dimensions, there is no reason to assume that observed effects (possibly in a different form) will not also be found in other scenarios and may be even more significant depending on the complexity.

Based on the results, multiple findings can be summarized and recommendations can be derived:

- Different parametrizations produce fundamentally different results. Accordingly, the design should be closely coordinated with the purpose of the test.
- It is not advisable to compare outputs from scenarios directly with each other without detailed knowledge of their design, as these can differ.
- The longer the simulation, the less likely it is that even small changes will affect an outcome. Accordingly, the scenario should only be long enough to see the desired effects.
- The pre-crash time before the effect to be investigated should be long enough to allow a reaction within the scenario.
- For a good traceability and transparency, it is advisable to document key design decisions of the scenario parametrization.

As proposed in the first recommendation, the choice of scenario parametrization should depend on the use case, the purpose of the test, and the models used. Therefore, based on our findings, we propose questions which may guide in the selection of a proper approach.

- Can the SuT (or any other reactive in-simulation model) show any reaction because of the scenario component? If no reaction is to be expected within the scenario with regards to the scenario element, there is no need to generate a reactive scenario and actions can be predefined. In this case, further questions are not needed.
- Is the purpose of the scenario to challenge the SuT as much as possible to test conflict avoidance? If it should be used for a falsification of a SuT, the other road users should try to provoke an accident until the end. This leads to a high reacivity within the scenario.
- Should the behavior of the scenario components reflect usual/ realistic behavior? If that is the case, an interactivity leading to a falsification may be not suitable - neither may a purely trajectory following description be but a specific model may be needed.
- Is an *adequate* reaction model for scenario components available? If that is the case, it may make sense to go for a higher reactivity since the used model.

When answering these questions, limitations may arise due to missing information, trade-offs that have to be made, or missing models. These limitations should be made transparent to allow contextualization of test results.

7 CONCLUSION

Within the paper the authors assessed the influence of different parametrization approaches on the result of an assessment. Therefore, the difference between a parametrization approach and the actual parametrization is defined. Guidance is given which effects from parametrization approaches should be considered for different use cases. The influences of different approaches are shown in a large study assessing different SuTs and parameter values. As one aspect, the pre-crash time is shown as a relevant (meta) parameter affecting the outcome of a scenario. We show that the parametrization has a relevant effect on the outcome and should be chosen carefully. For this, recommendations are finally given to account for the capabilities of a SuT and the purpose of a test. It is essential to carefully choose and adequately document the parametrization approach to allow for a reliable statement within a safety assessment or safety assurance argumentation. These recommendations could be detailed for specific use cases.

ACKNOWLEDGEMENTS

The work of this paper has been done in the context of the V4SAFETY project which is funded by the European Commission's Horizon Europe Research and Innovation Programme under grant agreement number 101075068. Views and opinions expressed, are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

REFERENCES

ASAM e.V. (2024). ASAM OpenSCENARIO® XML Version 1.3.0.

Bach, J., Otten, S., and Sax, E. (2016). Model based scenario specification for development and test of automated driving functions. In *2016 IEEE Intelligent Vehicles Symposium (IV)*, pages 1149–1155.

Bock, J., Krajewski, R., Moers, T., Runde, S., Vater, L., and Eckstein, L. (2020). The ind dataset: A drone dataset of naturalistic road user trajectories at german intersections. In *2020 IEEE Intelligent Vehicles Symposium (IV)*, pages 1929–1934.

de Gelder, E. and Camp, O. O. d. (2024). Scenario-based assessment of automated driving systems: How (not) to parameterize scenarios? *arXiv preprint arXiv:2409.01117*.

de Gelder, E., Paardekooper, J.-P., Saberi, A. K., Elrofai, H., Camp, O. O. d., Kraines, S., Ploeg, J., and De Schutter, B. (2022). Towards an ontology for scenario definition for the assessment of automated vehicles: An object-oriented framework. *IEEE Transactions on Intelligent Vehicles*, 7(2):300–314.

Fahrenkrog, F., Fries, A., Das, A., Kalisvaart, S., Charoniti, E., Op den Camp, O., et al. (2024). Draft prospective safety assessment framework - method. Milestone report MS10 of the Horizon Europe project V4SAFETY.

Galbas, R., Reich, J., Schittenhelm, H., and Wagener, N. (2022). Safeguarding methods for complex traffic scenarios for approval of automated driving functions. *ATZ worldwide*, 124(9):56–61.

Geller, C., Haas, B., Kloeker, A., Hermens, J., Lampe, B., Beemelmanns, T., and Eckstein, L. (2024). Carlos: An open, modular, and scalable simulation framework for the development and testing of software for c-its. In *2024 IEEE Intelligent Vehicles Symposium (IV)*, pages 3100–3106. IEEE.

Glasmacher, C., Schuldes, M., Topalakatti, P., Hristov, P., Weber, H., and Eckstein, L. (2023a). Scenario-based model of the odd through scenario databases.

Glasmacher, C., Weber, H., Schuldes, M., Wagener, N., and Eckstein., L. (2023b). Generation of concrete parameters from logical urban driving scenarios based on hybrid graphs. In *Proceedings of the 9th International Conference on Vehicle Technology and Intelligent Transport Systems - VEHITS*, pages 215–222. INSTICC, SciTePress.

Hu, M. and Li, Y. (2017). Drivers' avoidance patterns in near-collision intersection conflicts. In *2017 IEEE 20th International Conference on Intelligent Transportation Systems (ITSC)*, pages 1–6.

International Organization for Standardization (2022a). Road vehicles - safety of the intended functionality.

International Organization for Standardization (2022b). Road vehicles - test scenarios for automated driving systems - vocabulary.

Mercedes-Benz AG (2024). Drive pilot technology by mercedes-benz. Accessed: 2024-11-08.

PEGASUS Project Consortium (2019). Pegasus method - an overview. Technical report. Accessed: 2024-11-04.

UNECE (2021). UN Regulation No. 157 on Automated Lane-Keeping Systems (ALKS). Revision as of January 2023, adopted by UNECE's World Forum for Harmonization of Vehicle Regulations.

Waymo LLC (2024). Waymo driver. Accessed: 2024-11-08.

Weber, H., Glasmacher, C., Schuldes, M., Wagener, N., and Eckstein, L. (2023a). Holistic driving scenario concept for urban traffic. In *2023 IEEE Intelligent Vehicles Symposium (IV)*, pages 1–8.

Weber, H., Glasmacher, C., Schuldes, M., Wagener, N., and Eckstein, L. (2023b). Holistic driving scenario concept for urban traffic. pages 1–8.

Winner, H., Lemmer, K., Form, T., and Mazzega, J. (2018). PEGASUS—first steps for the safe introduction of automated driving. In *Lecture Notes in Mobility*, pages 185–195. Springer International Publishing.