FAST-zero '23

# Comparison of German and Japanese Urban Intersection Data for Internationally Harmonized Test Procedures

**Silvia Thal [1)], Philip Wallis [1)], Roman Henze [1)], Ryo Hasegawa [2)], Shoichiro Teranishi [2)], Hiroki Nakamura [2)], Sou Kitajima [2)], Genya Abe [2)]**

*1) Institute of Automotive Engineering, Technische Universität Braunschweig*
*Hans-Sommer-Straße 4, 38106 Braunschweig, Germany (E-mail: s.thal@tu-braunschweig.de)*
*2) Japan Automobile Research Institute*
*2530 Karima, Tsukuba, Ibaraki 305-0832, Japan*

**ABSTRACT**: The worldwide introduction of automated driving systems (ADS) of SAE-level 4 and 5 requires standardized safety assessment methods. Despite recently published international regulations and standards, the question of their transferability across countries remains. In this paper, a naturalistic driving data comparison between Germany and Japan for vehicles crossing straight ahead on urban intersections, as part of the unprotected left turn scenario, was conducted. We quantified differences in the univariate parameter distributions as well as compared the dependencies in the two-dimensional parameter space. Despite different data sources (instrumented vehicle vs. infrastructure sensors) remarkable similarities in terms of safety understanding, distribution functions and behavior patterns could be found. Accordingly, the potential to harmonize modelling functions or human driver models exist. Since the found differences might result from different environmental conditions, further research on validating datasets and analyzing external influences on driving behavior is required.

**KEY WORDS**: Safety Assessment, International Harmonization, Data Comparison, Naturalistic Driving Data

## 1. Introduction

International harmonization and standardization of safety assessment methods for automated driving systems (ADS) is crucial for the global introduction of automated vehicles on public roads. Within research projects as VVMethoden, SUNRISE or SAKURA and standardization activitives, industry and academia developed the scenario-based testing methodology for ADS safety validation [1, 2] . It requires at first the abstraction of the Operational Design Domain (ODD) of the ADS into functional scenarios that verbally describe the occurring interaction. In the logical scenario definition, each functional scenario is abstracted by modelling parameters and their value ranges. Thereafter, concrete parameter combinations, referred as test cases, are determined for each logical scenario, which can prove the safety of a Vehicle under Test (VuT). [1, 3]

For logical scenario definition and test case generation, criteria as representativeness, realism and safety criticality apply[2], requesting the use and analysis of naturalistic driving data (NDD). However, most studies collect and analyze data only from one country and neclegt the intention for internationally harmonized test procedures to ensure a market-wide introduction. In this paper, we compare naturalistic driving data from urban intersections in Germany and Japan and derive implications on the transferability for safety assessment methods.

In the past, actions to collect and harmonize cross-country naturalistic driving data were initiated. euroFOT was one of the first intiatives for the large-scale and European-wide collection of NDD [4]. In the SafetyPool database, standardized scenario data are publicly available from all over the world [5]. IGLAD is the first internationally standardized database for accidents with almost 10,000 entries from five continents [6]. However, due to the limited access to cross-country NDD, the number of publications that systematically analyze country-specific traffic behavior is still small. So far, driving behaviour comparisons were conducted with the goal to either derive implications for harmonized test procedures [7–9], to analyze the use and adaptions of assistance systems [10] or to optimize traffic flow [11]. Further, the majority of publications focus on highway scenarios, with most research on the car following scenario [9, 10, 12].

*Liu and Selpi* analyzed the use of different safety indicators for the car following scenario and assessed differences between China and Sweden on highways. However, they underline that the detected smaller time headways in Sweden can either result from the nationality or the environmental conditions. [10] *Sato et al.* drew the same conclusion when comparing the car following behavior between UK and Japan on urban, rural and high-speed roads [12]. *Zlocki et al.* opposed the behavior in cut-in and deceleration in front scenarios between Germany and Japan and found despite the different data souces significant overlap in both scenarios [9]. Only one study analyzed and compared driving behavior on urban intersections but concentrates on the road utilization between China and the Netherlands [11]. To our best knowledge, no publication exists that compares the driving behavior on urban intersections in the context of harmonizing test procedures.

In this paper, we compare data of vehicles *going straight ahead across an intersection*. This is relevant for testing the unprotected left turn scenario, i.e. right turn in Japan, which is one of the most difficult scenarios as the VuT has to determine an appropriate time gap between objects in oncoming traffic. After presenting the German and Japanese datasets, the relevant parameters for comparison and the metrics for quantitative comparison in section 2, the univariate parameter distributions are opposed in section 3. Section 4 covers the comparison of dependencies in the 2-dimensional parameter space, followed by the implications and limitations of both comparisons in section 5.

## 2. Methodology

### 2.1. Available Datasets

We recorded NDD in urban area in Germany with our experimental vehicle TEASY 3 (Fig. 1, left) in 2019-2020. With no assistance activated, 15 different drivers acquired 6489 km or 246 h in the medium to large cities Braunschweig, Hannover and Hamburg. A highly precise lidar sensor set-up consisting of 4x IBEO LUX 4L and 2x IBEO LUX 8L records object trajectory data in a 360 degree surrounding view. Moreover, a GeneSys ADMA-Speed ensures exact positioning data of the vehicle. Further, the vehicle is equipped with a serial camera and and a mid-range radar sensor. All signals, including all CAN signals as well as additional webcam data for verfication purposes, are synchronisely recorded. [13]

From the raw dataset, all ego as well as object trajectories that are going straight ahead across an intersection are extracted [13]. Only intersections with traffic light existent, a speed limit of 50 km/h and two to three lanes going straight head are included to ensure a comparability to the Japanese dataset. Parameters as ID, timestamp, position, speed and acceleration are stored for each vehicle over time in the scenario database. At the end, the German dataset has a total of 2844 crossing straight maneuvers from 261 different intersections.

Infrastructure data of the Senkaku-mae intersection in Tokyo, Japan, are available from the SAKURA project [14] sponsored by the Japanese Ministry of Economy, Trade and Industriy (METI). Seven fixed cameras, including five wide-angle cameras installed on high-rise buildings at the roadside and two cameras with zoom lenses on the sidewalk record traffic up to 160 m into the intersection arms. From the available image material of 50 minutes, recorded on on 28.10.2020 from 11:00-11:50 a.m., a total of 1993 trajectories of vehicles crossing straight are available for the comparison. Fig. 1 right shows the intersection geometry and the positioning of the cameras for data recording.

Table 1 compares the scenario databases from Japan and Germany of vehicles going straight ahead.

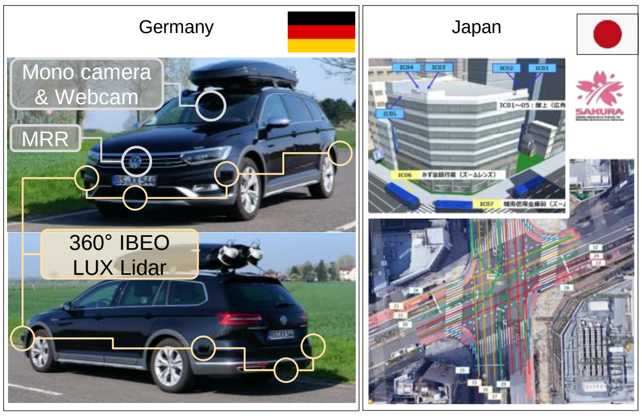


Fig. 1 Left: Test vehicle TEASY 3 to record NDD in Germany, Right: Intersection in Japan recorded with infrastructure sensors

Table 1 Comparison of the German and Japanese dataset

| | Germany | Japan |
|---|---|---|
| No of intersections | 261 | 1 |
| Traffic light existent | Yes | Yes |
| No. of lanes straight | 2-3 | 2-3 |
| Speed limit | 50 km/h → [0;1] | 60 km/h → [0;1] |
| Construction existent | No | No |
| Object types | Cars | Cars |
| Weather conditions | Sun, clouds, wind | Sun, clouds, wind |
| No. of Vehicles | 2844 | 2071 |
| No. of Vehicles [$\Delta v_x > 0$ during approach] | 544 | 504 |

For comparability of the speeds, they are normalized to the prescribed limit of 50 km/h and 60 km/h, respectively. Other factors such as the environmental conditions are consistent in both data sets. For extracting the parameters of each data set, the same reference points, coordinate systems, and outlier and filter mechanisms are applied to ensure comparability. In addition, only the values in the range of the 1st and 99th percentiles are used for each parameter in both data sets to reduce the influence of outliers. The comparison focuses on vehicles that *accelerate during their approach* towards the intersection to avoid different signs for the acceleration. The approach is defined as 80 m before the intersection midpoint to midpoint. Finally, 504 samples from the Japanese data and 544 from the German data set are available for the data comparison.

### 2.2. Relevant Parameters for Comparison

Fig. 2 shows the abstracted turning scenario and the identified relevant parameters (Table 2) to model the behavior of objects crossing straight ahead the intersection that were also used in [15]. Accordingly, these parameters are extracted from both scenario databases. The longitudinal velocity at intersection midpoint refers to the time step when the vehicle center crosses the midpoint *P*. The minimal longitudinal velocity $v_{x,min}$ and the maximum step acceleration $a_{x,max,step}$ are determined only during the approach towards the intersection. $a_{x\ max,step}$ is the average acceleration during the period $\Delta t_{ax,max}$ in which the acceleration, starting from the maximum value, rises above 0.1 for the first time or falls below 0.1. At last, the time headway (THW) and distance headway DHW are extracted in the timestep that the preceding vehicle front bumper crosses *P*. This is to derive implications on the safety understanding of drivers in both countries.

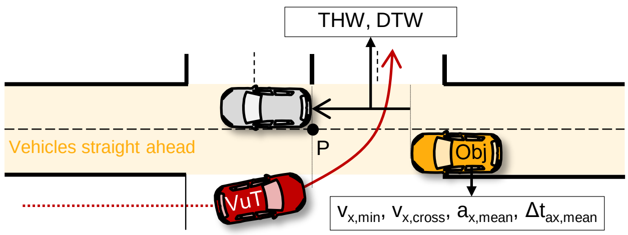


Fig 2 Visualization of the unprotected left turn scenario and the relevant parameters

Table 2 Description of the modelling parameter

| Symbol | Description | Unit |
|---|---|---|
| $v_{x,min}$ | Minimal long. velocity | - |
| $v_{x,cross}$ | Long. velocity at intersection midpoint | - |
| $a_{x,max,step}$ | Maximum long. step acceleration | m/s² |
| $\Delta t_{ax,max}$ | Duration of the maximum long. acceleration | s |
| THW | Time headway to preceding vehicle | s |
| DHW | Distance headway to preceding vehicle | m |

### 2.3. Estimation and comparison of the traffic density

The traffic density is both datasets is opposed to ensure that possible differences can be correctly interpreted. The traffic density *k* corresponds to the number of vehicles divided by the road length. Since in the German dataset only local distance information about the directly surrounding vehicles of the measurement vehicle is available, *k* is estimated in both datasets as follows. For each time step *t* during which a vehicle approaches the intersection, the sum of distances to its preceding and following vehicle are defined as the road length, on which three vehicles are located. If there is no vehicle in front or behind or one with a distance greater than 120 m, a distance of 120 m is assumed, which corresponds to the average maximum lidar distance measured. The traffic density $k$ of one vehicle during its approach is finally the mean value of $k_t$ over all $t$. **Fehler! Verweisquelle konnte nicht gefunden werden.** a) shows the applied calculation approach, while b) displays the distributions of the traffic densities in both data sets.

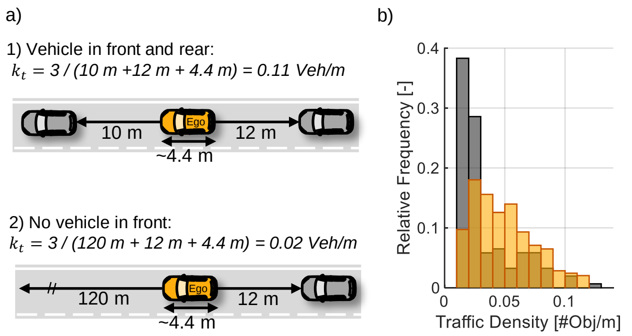


Fig. 3 a) Calculation of traffic density. b) Resulting traffic densities in the German and Japanese dataset

The comparison makes clear how different the existing traffic densities are in both datasets. While the traffic densities of the German database are predominantly smaller than 0.03, they are evenly distributed over the value range from 0.02 to 0.09 in the Japanese data set.

Moreover, in the Japanese data, there were consistently no surrounding vehicles of the ego vehicle in only 0.36 % of the trips, while this is the case in 29.83 % of the German data. These considerable differences in traffic density must be taken into account when interpreting the parameter distributions.

### 2.4. Metrics for comparison of univariate distributions

For the quantitative assessment of the similarity of the univariate parameter distributions, the Pearson correlation coefficient $r_{Corr}$ and the Jaccard coefficient $J$, also known as Intersection over Union (IoU), are used, building on the procedure in [9]. For calculation, the distributions are first modeled using probability density functions (pdf). The chi-squared test is used to test the suitability of the normal or generalized extreme value distribution (GEV), which are commonly used [16, 17]. If these do not show significance ($p < 0.05$), modeling is done using a kernel density function. $r_{Corr}$ indicates the linear positive or negative relationship between the respective parameter distributions of both countries. The Jaccard coefficient of two quantities A and B is calculated as:

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|} \qquad (1)$$

where A and B correspond to the respective areas under the distribution functions in this application. Consequently, this metric gives the overlap of the actual functions.

### 2.5. Method to analyze of dependencies in the 2D parameter space

In [15] a methodlogy to assess dependencies in the two-dimensional parameter space was introduced. The consideration of dependencies is relevant for realistic test case design. The procedure is shortly described. Two-dimensional dependencies can usually not be found with a normal regression analysis due to the high variance in driving behavior. However, they often are qualitatively visible towards the parameter limit values. Accordingly, a regression analysis is to be conducted in the boundary area of the two-dimensional parameter space. The procedure for analyzing dependencies in the boundary area between two parameters $x^i$ and $x^{ii}$ is shown schematically in figure 3. In the first step, the parameter on the x-axis (here $x^i$) is divided into equidistant classes. Further, the representative value of each class as the mean value of the class interval is determined. In 2), for each class of $x^i$, the critical percentiles (here the 5th and 95th percentiles) of the values of $x^{ii}$ that lie within each class are calculated. Finally, in 3) the regression analysis between the class representative values and the 5th and 95th percentile values is performed, examining whether there is a linear, a 2nd degree polynomial or an exponential dependence. A significant dependency is defined with $r^2 > 0.85$. If more than one model shows significance, the one with the lowest complexity is chosen to prevent overfitting.

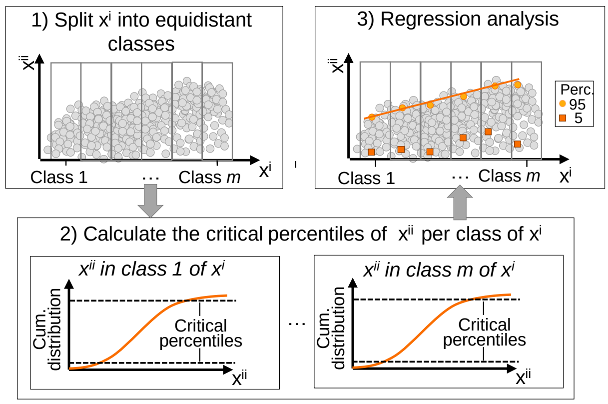


Fig 4 Procedure to evaluate dependencies in the boundary areas of two parameters

## 3. Implementation and Results

### 3.1. Comparison of univariate parameter distributions

The results are displayed in fig. 4. In general, the distributions exhibit qualitatively and quantitatively similar trends for all parameters in both countries. Four out of six parameters show a significant correlation with $r_{Corr} > 0.8$ , and three out of the six comparison parameters have an overlap greater than 0.8. Overall, high values are observed with an $r_{Corr}$ of 1.00 and a $J$ of 0.93, considering all parameters.

For the minimum longitudinal velocity $v_{x,min}$ in a), the highest accumulation of values is observed at 0.7, with a stronger presence in the Japanese data. The significant peak results in the inability to model the Japanese distribution as a Generalized Extreme Value (GEV) distribution, unlike the German distribution. Nevertheless, both distributions exhibit similar trends, as evidenced by the high $r_{Corr}$ value of 0.87. Additionally, in both countries, the allowed speed limit is exceeded to a comparable extent, with 6% for German drivers and 4% for Japanese drivers.

In b), the velocity at intersection midpoint $v_{x,cross}$, both countries show qualitatively similar distribution function patterns. However, the functions exhibit a shift of approximately 0.1 towards higher velocities in the German data. This shift is likely attributed to the higher traffic density in Japan, which automatically leads to lower average velocities. It is also noteworthy that in both countries, no vehicle crosses the intersection at less than half the allowed speed limit. Furthermore, the occurrence of speed violations becomes

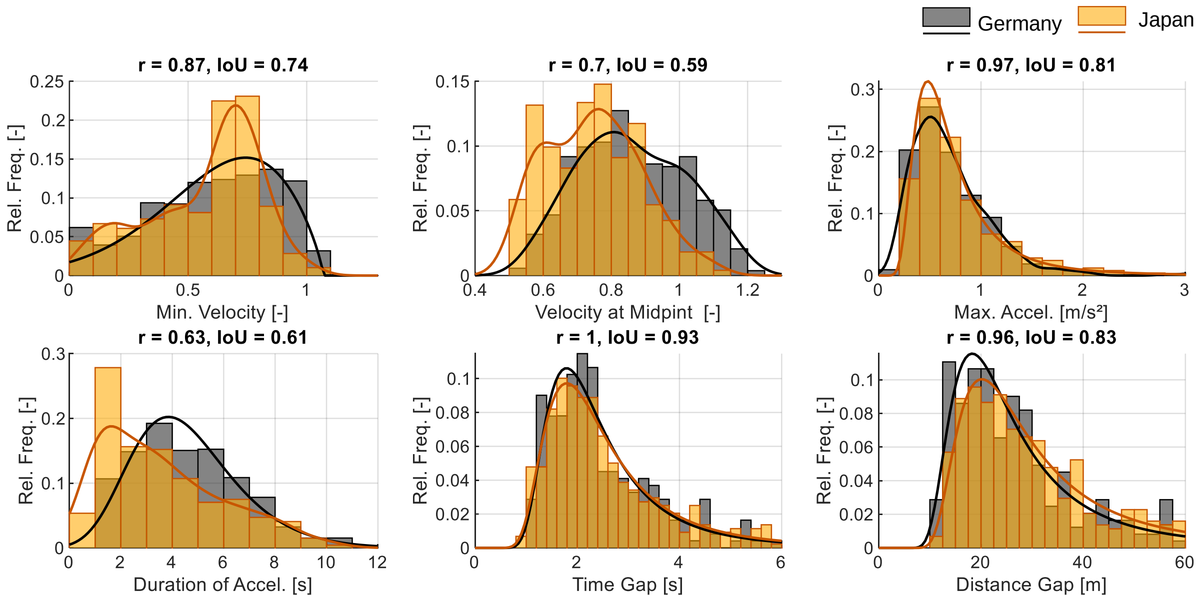


Fig. 5 Comparison of univariate parameter distributions between Germany and Japan

more pronounced in b), with a higher prevalence in the German dataset at 21% compared to 11% in the Japanese dataset.

The comparison of max acceleration $a_{x,max,step}$ in c) reveals a high similarity, with a high correlation coefficient of 0.97 and a substantial overlap of 0.81. Both distributions exhibit a noticeable decrease in frequencies towards higher accelerations, causing the 95th percentiles of the distributions to deviate significantly from the maximum values, with 1.39 m/s² for Germany and 1.75 m/s² for Japan. The notable differences in the maximum values of 3.30 m/s² and 2.89 m/s² are likely primarily due to individual data errors. Finally, it should be noted that the maximum accelerations occurring in the intersection area are generally moderate, with 95th percentiles smaller than 2 m/s².

In d), for the duration of maximum acceleration $\Delta tax,max$, a comparable pattern of the distribution functions is observed. However, a shift is also evident in this case, with the German data showing longer durations of approximately 2 seconds. The longer-lasting accelerations in the German data, combined with similar maximum accelerations in both countries, result in overall higher speed differences in the German data. These differences may arise either from the higher traffic density in the Japanese data, which prevents longer accelerations, or from an overall more dynamic driving behavior in Germany.

The calculated time and distance headways in e) and f) refer to the reference points of vehicle center to vehicle center and are computed to the following vehicle at the time of crossing the intersection. The distributions only include entries where a following vehicle was present. The distribution functions of both countries in e) and f) exhibit a high similarity, with the highest *J* values compared to the other parameters. While the distribution functions of time headways show almost complete overlap, a shift towards greater distances of approximately 3-5 m is observed in the Japanese data for distance headways. However, these larger distances are likely a result of higher speeds present at the Japanese intersection due to the higher speed limit of 60 km/h. The significantly high similarity in the velocity-normalized time headways indicates a similar understanding of safety in both countries.

3.2. Comparison of Parameter Dependencies

The methodology from section 2.5. was applied to both datasets. The four parameters that describe the vehicle's dynamic $v_{x,min}$, $v_{x,cross}$, $a_{x,max,step}$, $\Delta t_{ax,max}$ of the left-turn scenario were used for comparison. From these four parameters, 12 pairwise parameter combinations can be formed, resulting in a total of 24 boundary areas (each combination has an upper and lower boundary range) within which a dependence can be found. For the German scenario database, a significant dependence was found in 6 out of the 24 boundary areas. From the Japanese dataset, 8 out of 24 cases showed a dependence in the boundary ranges. In five of the 6 or 8 boundary areas the found dependencies were overlapping. Thus, one additional dependence was identified in the German dataset and three additional dependences were found in the Japanese dataset. If a dependence exists in the same boundary range in both countries, the same mathematical relationship, i.e., linear, polynomial, exponential was identified. Only one of the overlapping dependencies that were found in both datasets result from the nature of extraction. As only vehicles with a positive relative velocity are included, the combination of $v_{x,cross}$ and $v_{x,min}$ leads automatically to a strong linear dependence and is therefore excluded. Fig. 5 shows four exemplary parameter combinations out of the 12.

If a significant dependence was found in the boundary area, the regression function is plotted in the scatter plot of the respective country. For the parameter combination of minimum velocity and velocity at intersection midpoint in a), both the German and Japanese datasets show a dependence in the lower boundary area. This dependence follows a polynomial pattern at lower minimum speeds and a linear pattern at higher values. The Japanese driving behavior also exhibits an upper linear boundary function, which is not visible in the German dataset due to the overall higher and more variable velocity differences. In the parameter combination of minimum velocity and maximum acceleration in b), both countries exhibit a polynomial dependence in the lower boundary range. Thus, lower minimum velocities require higher accelerations. In c), the combination of minimum speed and acceleration duration reveals a linear dependence in the upper boundary area for both the German and Japanese datasets. This indicates that as the starting speed increases, shorter acceleration durations are observed in both countries. In d), a similar relationship is observed for the

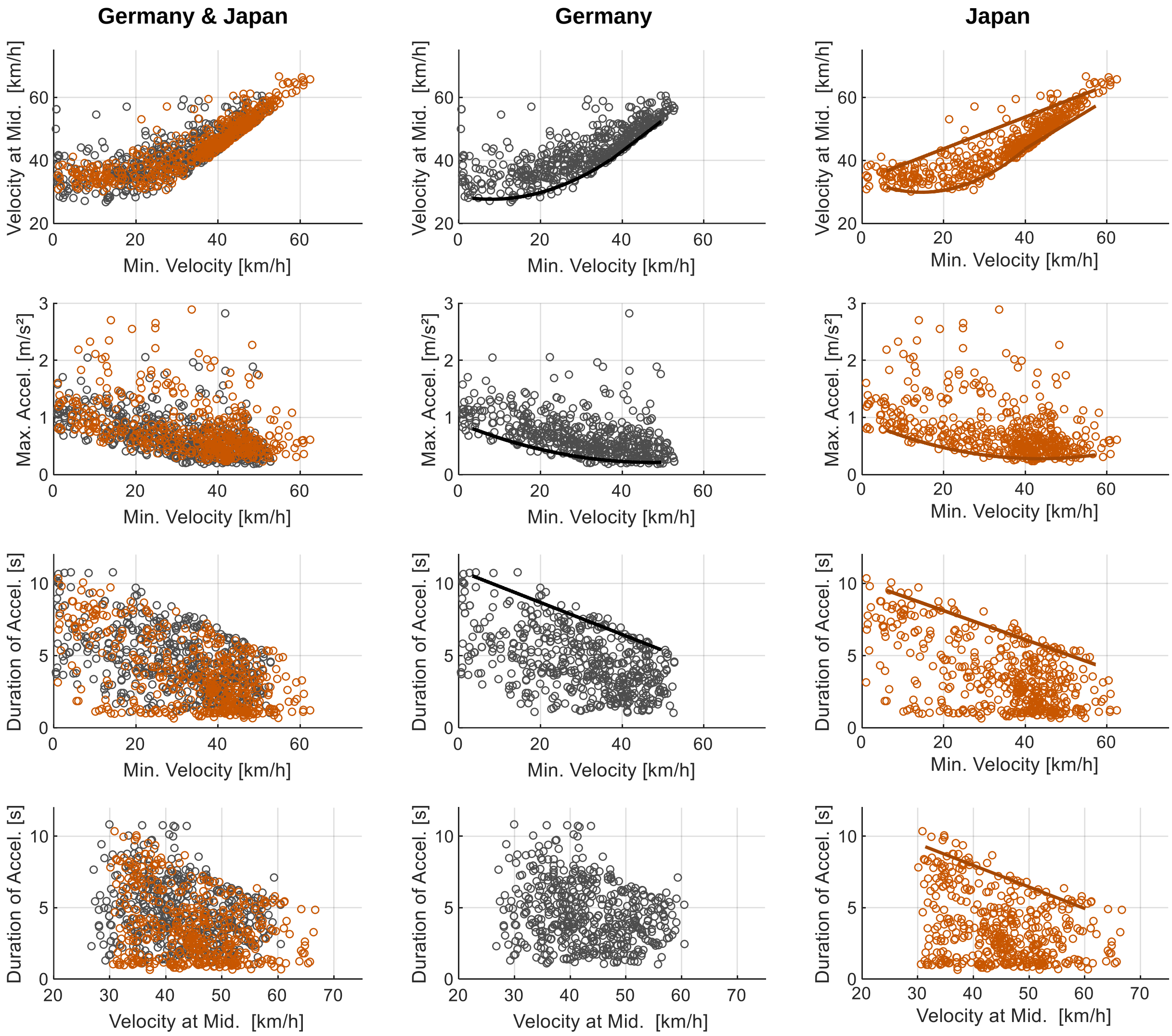


Fig 6 Comparison of four selected parameter combinations and their dependencies in the boundary areas. If a regression line is plotted a dependency was foundin that boundary area.

combination of velocity at intersection midpoint and duration in the Japanese dataset. However, this relationship is not visible in the German dataset due to a higher variance in acceleration durations, especially at lower intersection velocities.

### 4. Implications and Discussion

Both comparisons yields the following implications for the international harmonization of testing procedures:

**Definition of Logical Scenarios:** Firstly, both countries show a tendency for speed violations, indicating that logical scenarios and their limits should not be solely based on current speed limits. Furthermore, differences in threshold values are observed for certain parameters such as minimum velocity, verlocity at intersection midpoint, or maximum acceleration. If internationally standardized parameter limits for logical scenarios are defined, it is recommended to adopt the more safety-critical values from each country (e.g., using the maximum intersection velocity from Germany).

**Standardization of Models:** In general, the distributions exhibit very similar trends across all parameters, as evidenced by the high average $r_{Corr}$. This indicates that the behavior of human drivers in both countries follows similar patterns. Consequently, it can be inferred that human driver models, which often serve as references in safety assessments, can be internationally standardized. Additionally, it can be concluded that the chosen probability density functions for modeling distributions can be standardized internationally. In this case, the use of the Generalized Extreme Value (GEV) distribution for parameters with natural limits (e.g., zero) has proven suitable for both countries. Finally, the high similarity in time headways indicates a shared understanding of safety in terms of distance and velocity in both countries. Therefore, safety metrics and their critical thresholds can be standardized internationally.

**Transferability of Methods:** It has been demonstrated that the methodology for analyzing dependencies in boundary areas published in [15] is transferable and applicable to other datasets. Therefore, a focus on the joint development of standardized methods for data analysis should continue in international harmonization efforts.

**Standardization of Dependences:** Despite the limited sample sizes of the German and Japanese data, relatively strong similarities and many shared relationships in the 2-dimensional parameter space were observed. This is evident from the high intersection of four identical boundary ranges that were characterized by equivalent mathematical relationships. Thus, it indicates the tendency that mathematical dependences between parameters can be uniformly defined. However, since the value ranges vary between countries, only the mathematical relationships should be uniformly applied, while the modeling of the functions should always be based on country-specific data.

**Consideration of Traffic Density:** The differences in the univariate distributions of the velocity-related parameters and the duration of acceleration, as indicated by the lower $J$ value due to the shift in distributions, can result from the differences in the traffic density of both datasets. Further, in the 2-dimensional space, the differences in the upper boundary functions in fig. 5 a) and d) might also be a result of the higher traffic density in the Japanese dataset, which allows for lower accelerations. To enable a valid comparison of parameters, the traffic densities of the datasets need to be harmonized. To derive country-specific parameter distributions and limits comprehensively, it is recommended to differentiate the overall dataset based on traffic density classes, such as free-flow or stop-and-go traffic, allowing for the analysis of distributions within each class.

The data comparison is subject to limitations. Although the available databases with a size of 544 and 504 samples can reveal tendencies regarding similarities and differences between Germany and Japan, larger scopes are necessary for validated statements. Furthermore, although the datasets were made as comparable as possible, intrinsic differences due to the different measurement principles (camera vs. lidar, instrumented vehicle vs. infrastructure sensors) and different environment (one intersection with high traffic density vs. several with rather low density) cannot be avoided. Consequently, it is not clear, if the differences oberserved result from the design of experiment or from the nationality. Future work should therefore address the harmonization and validation of data sets from different sources. Finally, an extension of the data comparison across further countries is aimed at.

## 4. Conclusion

In this study, a naturalistic driving data comparison between Germany and Japan for vehicles crossing straight ahead on urban intersections was conducted. Despite the different nature of the datasets, strong similarities with high correlation and intersection values between both datasets could be found. In particular, the distribution functions of the safety-related parameter *time gap* overlap almost completely showing the same understanding of safety. Further, the modelling functions as well as the found dependencies in the two-dimensional parameter space show strong similarities. The comparison implied for the international harmonization that modelling functions, human driver models and methodologies have to potential to be standardized across countries. However, the concrete settting of values or regression functions should be done on country-level. The differences found (e.g. shift in the distributions, more variate behavior in Germany with higher accelerations) can either result from the nationality or from the difference data sources. Therefore, future work is required that aim at the validation of datasets and comparability studies of datasets from different data sources.

This study has been supported by the Ministry of Economy, Trade and Industry of Japan through the SAKURA project.

## References


(1) T. Menzel, G. Bagschik, and M. Maurer, "Scenarios for Development, Test and Validation of Automated Vehicles," in *2018 IEEE Intelligent Vehicles Symposium (IV)*, Changshu, 2018, pp. 1821–1827.

(2) *ISO 34502: Road vehicles — Test scenarios for automated driving systems — Scenario based safety evaluation framework*, 2022.

(3) H. Hungar, "Scenario-Based Validation of Automated Driving Systems," in *Lecture Notes in Computer Science, Leveraging Applications of Formal Methods, Verification and Validation. Distributed Systems*, T. Margaria and B. Steffen, Eds., Cham: Springer International Publishing, 2018, pp. 449–460.

(4) C. Kessler *et al., Deliverable D11.3: Final report. euroFOT Consortium, Aachen Germany, Techn. Rep. D11.3.* [Online]. Available: https://research.chalmers.se/ (accessed: Aug. 17 2023).

(5) Deepen AI and University of Warwick, *Safety Pool Scenario Database.* [Online]. Available: https://www.safetypool.ai/ (accessed: Aug. 17 2023).

(6) IGLAD, *Initiative for the global hamonisation of accident data.* [Online]. Available: http://www.iglad.net/eb/page.aspx?sid=10771 (accessed: Aug. 17 2023).

(7) W. Hu *et al.,* "Mining and comparative analysis of typical pre-crash scenarios from IGLAD," *Accident; analysis and prevention*, vol. 145, p. 105699, 2020, doi: 10.1016/j.aap.2020.105699.

(8) S. Thal *et al.,* "Series Sensor Data Processing and International Data Comparison in Automated Driving Safety Assessment," in *6th International Symposium on Future Active Safety Technology Towards zero traffic accidents (FAST-zero)*, Kanazawa, Online Conference, 2021.

(9) A. Zlocki *et al.,* "Logical Scenarios Parameterization for Automated Vehicle Safety Assessment: Comparison of Deceleration and Cut-In Scenarios From Japanese and German Highways," *IEEE Access*, vol. 10, pp. 26817–26829, 2022, doi: 10.1109/ACCESS.2022.3154415.

(10) T. Liu and Selpi, "Comparison of Car-Following Behavior in Terms of Safety Indicators Between China and Sweden," *IEEE Transactions on Intelligent Transportation Systems*, vol. 21, no. 9, pp. 3696–3705, 2020, doi: 10.1109/TITS.2019.2931797.

(11) J. Li, H. J. van Zuylen, Y. Chen, and R. Lu, "Comparison of Driver Behavior and Saturation Flow between China and The Netherlands," *Proceedings of the 2nd Intern. Conference on Transportation Engineering, July 25 - 27, 2009, Chengdu, China*, pp. 3900–3905, 2009, doi: 10.1061/41039(345)643.

(12) T. Sato, M. Akamatsu, P. Zheng, and M. McDonald, "Comparison of car following behavior between UK and Japan," in *ICCAS-SICE 2009*, Fukuoka City, Japan, 2009, pp. 4155–4160.

(13) S. Thal *et al.,* "Generic Detection and Search-based Test Case Generation of Urban Scenarios based on Real Driving Data," in *2022 IEEE Intelligent Vehicles Symposium (IV)*, 2022.

(14) Ministry of Economy, Trade and Industry of Japan, *Project for accelerating the implementation of advanced MaaS (R&D project to build a safety assessment base for automated driving systems).* [Online]. Available: https://www.meti.go.jp /meti_lib/report/2021FY/000334.pdf (accessed: Mar. 29 2023).

(15) S. Thal *et al.,* "Towards Realistic, Safety-Critical and Complete Test Case Catalogs for Safe Automated Driving in Urban Scenarios. Manuscript submitted.," in *2023 IEEE Intelligent Vehicles Symposium (IV)*, Anchorage, Alaska, 2023.

(16) L. Stepien *et al.,* "Applying Heuristics to Generate Test Cases for Automated Driving Safety Evaluation," *Applied Sciences*, vol. 11, no. 21, p. 10166, 2021

(17) M. Khatun, G. B. Caldeira, R. Jung, and M. GlaB, "An Optimization and Validation Method to Detect the Collision Scenarios and Identifying the Safety Specification of Highly Automated Driving Vehicle," in *2021 21st Intern. Conference 2021*, pp. 1570–1575.