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Determination of accident scenarios via freely available accident databases

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Abstract: The derivation of real accident scenarios from accident databases represents an important task within vehicle safety research. Simulations are increasingly used for this purpose. Depending on the research interest, a wide range of accident databases exists worldwide, which differ mainly in the number of recorded data per accident and availability. This work aims to identify critical vehicle-to-vehicle accidents based on freely available accident databases to derive concrete scenarios for a subsequent simulation. For this purpose, the method of the pre-crash matrix is applied using the example of the freely available Crash Investigation Sampling System database of the National Highway Traffic Safety Administration. An analysis of existing databases worldwide shows that this is the most detailed, freely available database. The derivation of scenarios succeeds here by a new method, whereby a center of gravity calculation is carried out based on the damages of the vehicles according to Collision Deformation Classification nomenclature. In addition, the determination of other necessary parameters, as well as the limits of the database, is shown in order to derive a scenario that can be simulated. As a result, the constellations of the five most frequent vehicle-to-vehicle accident scenarios according to the Crash Investigation Sampling System database are presented. In particular,

other institutions should follow National Highway Traffic Safety Administration's example and make data freely available for accident research.

Keywords: accident databases, accident scenarios, vehicle-to-vehicle accidents, Pre-Crash-Matrix, Crash Investigation Sampling System

1 Introduction

In the field of vehicle safety, research institutes, vehicle manufacturers, suppliers, and service providers are concerned with questions relating to the improvement of safety in road traffic. Common to all involved is the question of weaknesses in current safety measures, both on the active and the passive side of vehicle safety. To identify these, research teams worldwide work together on an interdisciplinary basis to collect, reconstruct, and analyze real accident data. Data on the vehicle, the environment, and the people involved are collected and stored in aggregated form in accident databases [1].

The quality and depth of data in the various databases vary greatly, and different objectives are also pursued. For example, state-run databases, such as those of the German Federal Statistical Office, contain all accidents reported by the police in a country [2]. This is suitable for evaluating trend analyses and the effectiveness of measures such as the general obligation to wear seat belts or ESP. Still, their data depth is insufficient to analyze the crash constellation and its causes in detail [3]. Due to the large effort of an in-depth analysis of traffic accidents and the associated costs, the data are only freely accessible to participating institutions, exemplified by the German In-Depth Accident Study (GIDAS) database [4].

Therefore, this article aims to derive concrete accident scenarios using freely available databases, which can be simulated and analyzed. For this purpose, first, the minimum requirements for the information kept within the database for a subsequent simulation are given.

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In the second step, an overview of databases is provided to identify databases of interest for the analysis. Finally, the freely available American Crash Investigation Sampling System (CISS) database is used to demonstrate the possibility of creating concrete accident scenarios. Here, the focus is on vehicle-to-vehicle accidents with injured occupants.

2 Minimum requirements for accident databases for the determination and simulation of accident scenarios

To determine an accident scenario, the solution area must be limited in advance. A common approach here is the targeted consideration of accident types according to the accident type catalog of the German Insurance Association (GDV, dt. Gesamtverband der Deutschen Versicherungswirtschaft) [5].

If the database allows the desired delimitation of the solution space, the Pre-Crash-Matrix (PCM) developed by the German *Traffic Accident Research Institute of TU Dresden* (VUFO GmbH, dt. Verkehrsunfallforschung) should be used for the determination of accident scenarios and their subsequent simulation, which contains the minimum necessary parameters for the simulation of a crash scenario [6].

Table 1 shows the parameters of the PCM. As can be seen, the parameters are divided into dynamics, participants, and sketch categories. Dynamics refers to the speed and the deceleration until the first contact.

The initial speed represents the speeds of the participants before the critical event occurred. If the speed is not specified in the database, the permitted speed at the accident location can be assumed as an alternative. More important than the initial speed is the collision speed of the accident participants since this directly affects the crash mechanics. If the collision speed v_{col} is not given,

it can be calculated from the initial speed v_0 and the deceleration a_D [7].

$$v_{\text{col}} = v_0 + \int_t a_D \cdot dt. \quad (1)$$

If the deceleration is also not given, no deceleration or a full deceleration can be assumed. The deceleration path s_D is then to be determined by the following equation [6]:

$$s_D = s_0 + \int_t (v_0 + a_D \cdot t) dt. \quad (2)$$

The more assumptions, the higher the uncertainty within the scenario [6]. To confirm the correctness of the assumptions, sketches can be used that depict the accident sequence but also contain trajectories, end positions as well as other important environmental features. If a scenario can be reconstructed in such a way that the sketched end positions and deformations result from the dynamic parameters and the collision position, a plausible estimate of the dynamic parameters has been made [8]. To determine the coefficient of friction between tire and road, the road conditions in the form of pavement and weather conditions (dry, wet, and snow-covered) are also necessary for the database [6].

Significant for the reconstruction is a correct collision position, which is described by the location of the impact and the angle between the crash partners. Ideally, the location of the impact is a point in the X-Y plane of the global vehicle coordinate system according to SAE J670 [9]. However, this is usually not the case outside of in-depth databases. Therefore, a method for determining the most frequent point of impact is presented in Section IV to solve the problem.

Finally, data on the vehicles involved are necessary for the accident scenarios. If these are not available, it is possible to define a reference vehicle as an alternative.

3 Compilation and description of databases

This section lists and describes German and other national and transnational accident databases. Figure 1 shows a selection of known accident databases, classified according to the scope of data collection per year as well as the processing effort and the depth of information per accident. The in-depth databases have a considerable depth of information, combined with a large processing effort per

Table 1: PCM [6]

Dynamics	Participants	Sketch
Initial speed	Vehicle make	Trajectories and final positions
Collision speed	Vehicle model	Collision position
Deceleration	Registration year	Road conditions
Deceleration distance	Vehicle mass	Scale figure

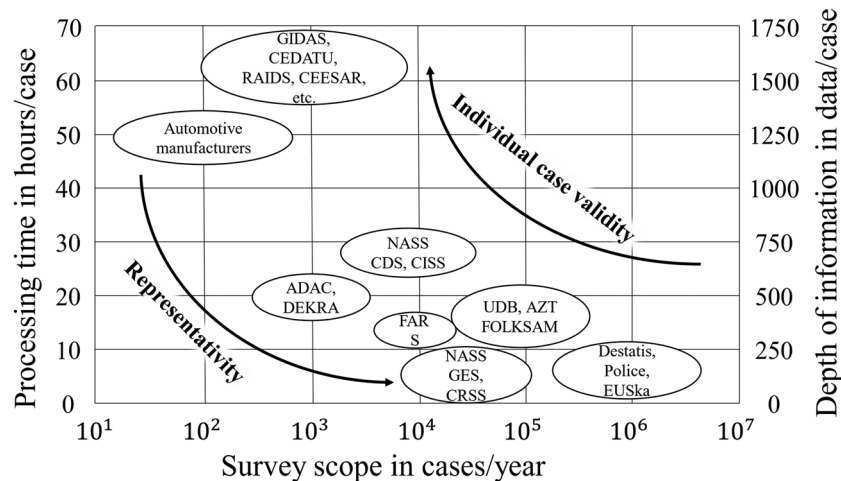


Figure 1: Scope of data collection, processing effort, and depth of information in accident surveys [1].

individual accident. This is in contrast to the national accident statistics, which usually list all accidents recorded by the police and evaluate them on the basis of a few criteria. In addition, accident data reported to the insurance companies are in the midfield [1].

3.1 German Databases

Various agencies in Germany collect data on traffic accidents and use them to create databases. These are described below.

3.1.1 DESTATIS – Federal Statistical Office

Since 1990, the German Federal Statistical Office has been publishing monthly traffic accidents under the title “Fachserie 8 Reihe 7” (eng. Reference Series 8 Line 7) [10], with some of the data going back to the 1970s. The federal statistics includes all traffic accidents in which people were killed, injured, or property was damaged due to driving on public roads and squares. The only accidents recorded are those for which the police were called in. These amounted to almost 2.7 million accidents in 2019 [10].

When recording, a distinction is traditionally made between the four basic terms accidents, participants, victims, and causes of accidents. In addition, the severity of the accident is subdivided into personal injury, severe property damage, other influences (e.g. alcohol and drugs), and further property damage, whereby the most severe accident consequence is always decisive. The category “persons involved” includes all persons directly involved in the accident; passengers involved in the accident are not included.

On the other hand, the term casualties include all persons involved in the accident, whereby a distinction is made between killed, seriously injured, and slightly injured. Finally, an accident is assigned to one of eight causes [10].

The “Fachserie 8 Reihe 7” of the German Federal Statistical Office provides free and public access to a large number of accident data, but these have only limited informative value on a case-by-case basis. This database is therefore not sufficient concerning the filling of the PCM.

3.1.2 GIDAS

Since 1999, the most extensive accident data collection with approx. 2,000 traffic accidents with personal injury per year has been carried out within the framework of the GIDAS project [11]. The project is supported by the German Federal Highway Research Institute (BAST, dt. Bundesanstalt für Straßenwesen) and the Research Association of Automotive Technology (FAT, dt. Forschungsvereinigung Automobiltechnik). The accident data collection and reconstruction are carried out by the traffic accident research of the TU Dresden (VUFO) and the accident research of the Hannover Medical University (MHH, dt. Medizinische Hochschule Hannover).

GIDAS is an in-depth data bank in which the two research teams (VUFO and MHH) collect data directly at the respective accident site with regard to accident traces. Ideally, the investigation teams are interdisciplinary to record the accident’s technical, medical, and psychological aspects. The collected data serves as a knowledge base for various interest groups, as well as for the improvement of traffic and vehicle safety, and is stored and evaluated in the GIDAS database for this purpose [1].

The data are not publicly accessible, but contacts are named on the website [12]. In most cases, access is provided via research projects or by companies.

3.1.3 Databases of German automotive manufacturers

Many German car manufacturers and others worldwide have their own accident research to document individual accidents – approx. 50–120 accidents per year – with their vehicle models. For new models, this is used to determine the effectiveness of safety modules. Data from accidents recorded by the police, automatic emergency call systems, media reports, sales centers, workshops, employees, and other internal and external sources are used [1].

Access to these data is not public, as the data are usually only used internally.

3.1.4 UDB – Insurers' Accident Database

For more than 60 years, the Accident Research of Insurers (UDV, dt. Unfallforschung der Versicherer) in the General Association of the German Insurance Industry (GDV, dt. Gesamtverband der Deutschen Versicherungswirtschaft) has been providing advice and research to improve road safety and accident avoidance. An interdisciplinary approach is followed to consider the roads, the transport infrastructure, and all vehicles and people of all age groups. This makes the UDV one of Germany's largest clients for road safety research [13].

For the accident database (UDB, dt. Unfalldatenbank der Versicherer) approx. 700–1,000 [14] real accidents with personal injury or damage costs of at least 15,000 € are recorded, analyzed, entered into the system [15], and published in research reports [16]. In conjunction with suitable extrapolation factors, the random sample obtained makes it possible to represent the loss event for German insurers [17]. A detailed recording is carried out with the help of traffic accident reports, accident reconstruction reports, damage reports, medical reports, witness statements, legal correspondence, and imagery [1].

The information depth of the UDB is comparable to that of GIDAS. However, the informative value of some features is limited because no analysis is carried out at the scene of the accident. The UDB database is also not publicly accessible [14].

3.1.5 EUSKa – electronic accident type card

Before the electronic accident type plug-in card system EUSKa (dt. Elektronische Unfalltypensteckkarte) was developed, the

individual traffic departments of the police used colored pins, which they pinned to large road maps. The electronic program EUSKa has been taking on these and other graphic functions since 2006 [18].

The software was developed in close cooperation with the interior ministries of the federal states, the police, and under the leadership of the Transport Technology Institute of German Insurers (ISK, dt. Institut für Straßenverkehr). The system contains the interface for the data entry of the accidents recorded by the police and the transfer to the state statistical offices. With the aid of the sketch editor, an accident sketch can be made quickly and easily for every accident. Further data such as time, day, season, vehicle participation, driver impairment, infrastructure conditions, and correlating combinations, etc., can also be specified. If more accidents occur in a certain period and area, connections can be analyzed [19].

EUSKa is used by the police in some federal states of Germany. The Fraunhofer Institute for Transport and Infrastructure Systems (IVI) also uses these data [20]. However, there is no public access to the data [19,21].

3.1.6 AZT – Allianz Center for Technology

For 50 years, the AZT, dt. Allianz Zentrum für Technik has accompanied accident research with its own studies, committee work and safety campaigns [22]. This led to its own accident database in 2004. Accidents are detected and analyzed, ranging from minor property damage to severe accidents and major damage (>€ 1 million). In-depth analyses are used to assess accidents according to their structure, cause, the severity of damage, and avoidability [23].

With more than 15,000 accidents, the AZT database shows a representative sample used for motor vehicle liability and comprehensive damage claims reported to Allianz [17]. Information is obtained from the accident report forms of the insurance company, traffic accident reports, pictures of the accident site and the vehicles, accident sketches and reconstructions, lawyer and court correspondence, as well as (medical) reports. In contrast to the DESTATIS (dt. Statistisches Bundesamt) database, the ATZ contains fewer single accidents since, by definition, only third-party personal injuries are relevant in terms of insurance technology. Likewise, only around 75% of motor liability claims are reported to the police [23].

The data in the AZT accident database are also not openly accessible. Access is usually obtained through a joint research project with the Allianz Center for Technology.

3.1.7 ADAC and DEKRA

Since 2007, the ADAC (dt. Allgemeine Deutsche Automobil-Club e.V.) Foundation has supported initiatives and institutions in the field of accident research [24]. The department for accident research was founded at DEKRA (dt. Deutscher Kraftfahrzeug-Überwachungs-Verein e.V.) in the 1980s [25].

The ADAC has its own accident database with over 7,000 more deeply evaluated severe traffic accidents in Germany, for which the ADAC air rescue (helicopter) was called [17]. At DEKRA, on the other hand, the analysis of real accidents, accident reports, crash tests, and the creation of a comprehensive database plays an essential role. The area of accident research covers small collisions through to mass collisions, as well as the development and evaluation of their own and other accident databases. Since 1997, it has been possible to create a database of more than 1,000 accidents, in which each accident is described with over 400 individual parameters [25].

Both the ADAC and DEKRA accident databases are not publicly accessible [1].

3.2 National databases of other countries

There are other national accident databases around the world that are similar to the German one. Some of these are described below:

3.2.1 CEDATU – Central Database for In-Depth Accident Study

In 2004, the Graz University of Technology started the CEDATU (dt. Zentrale Datenbank tödlicher Unfälle in Österreich) project at the Austrian Road Safety Fund as a pilot project. The aim is to develop an accident database for in-depth analysis of traffic accidents. In the meantime, accidents with minor injuries as well as severe and fatal injuries are recorded and investigated [26].

CEDATU is an in-depth database in which the accidents are reconstructed and viewed in their entirety. The accidents are simulated three-dimensionally with the PC Crash accident reconstruction program, and the course of the accident is reconstructed. Various accident parameters are determined to analyze the course of the accident in depth [26].

Accident data are not publicly accessible at CEDATU either.

3.2.2 RAIDS – Road Accident In-Depth Studies

Since the 1960s, the Accident Research Group at the University of Birmingham (GB) has been recording accidents with specific types of accidents directly at the accident scene. In cooperation with the TLR (Transport Research Laboratory), the CCIS (Cooperative Crash Injury Study) was founded in 1983, up to 2010 evaluated approx. 1,200 accidents in detail every year. The evaluation was distorted in the direction of severe accidents with newer vehicles (<7 years.). The program has been continued under the name RAIDS (Road Accident In-Depth Studies) since 2012 [1].

Two types of data are now being determined: on the one hand, a crash scenario investigation directly after the accident, which focuses on the vehicle and the minor and uninjured road users. On the other hand, a backward-looking examination in severe accidents in which the occupants are hospitalized because of their injuries [27].

Thus, the RAIDS is an in-depth database with approx. 1,200 accidents per year. However, this is only available to researchers, who have a permit from the UK Department of Transport. Access is granted if there is an apparent reference to research that serves to improve road safety [27].

3.2.3 French databases BAAC, IFSTTAR, und CEESAR

In France, there are, among others, the three accident databases BAAC (fr. Bulletins d'Analyse des Accidents Corporels de la Circulation), CEESAR, and IFSTTAR MA. BAAC includes all accidents that are collected by the French law enforcement authorities. The other two, IFSTTAR MA (formerly INRETS) and CEESAR, are in-depth databases [1,28].

The French Institute for Science and Technology for Transport, Development and Networks, IFSTTAR MA (fr. Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux), is a public research organization founded in 2011, the result of the merger of the French National Institute for Transport and Safety Research (INRETS, fr. Institut National de Recherche rur les Transports et leur Sécurité) and the French Central Laboratory for Roads and Bridges (LCPC, fr. Laboratoire Central des Ponts et Chaussées) [29]. Data are collected in the south of France [1].

The second French in-depth accident database was founded in 1992 by the European Center for Safety Studies and Risk Analysis (CEESAR, fr. Centre Européen d'Etudes de Sécurité et d'Analyse des Risques) [30]. CEESAR mainly collects accident data near Paris, but for explicit questions, also from the whole national territory [1]. As part of this,

the VOIESUR project (Vehicle Occupant Infrastructure Studies for the Safety of Road Users, fr. Véhicule Occupant Infrastructure Études de la Sécurité des Usagers de la Route) was funded, which carried out detailed investigations at the scene of the accident in 2011 [31]. For this purpose, a database was compiled from almost all fatal accidents in 2011 (approx. 3,600), a representative random selection of personal accidents (approx. 2,700) and the accidents registered in the Rhône register (approx. 2,100) [32].

The BAAC database is similar to the German EUSka database in that the data are collected by the French law enforcement agencies [28]. CEESAR and IFST-TARMA, on the other hand, are comparable with the German in-depth accident databases of GIDAS in terms of data volume and data depth [1]. There is also no public access to the data.

3.2.4 American databases SCI, FARS, CISS, etc.

Figure 2 shows that six accident databases are maintained in the United States by the National Highway Traffic Safety Administration (NHTSA), which differ in their objectives and associated case numbers, level of detail, and availability.

NHTSA has been collecting in-depth accident data and storing it in the Special Crash Investigation (SCI) database since 1972. More than 100 detailed accidents with hundreds of parameters per case are added to the SCI each year. The selection of accidents is based on the current research interest of NHTSA [33].

To achieve a greater overview of accident occurrences in the United States, the National Automotive Sampling System (NASS) was established in 1988. This is divided into the Crashworthiness Data System (NASS CDS) and the General Estimates System (NASS GES) [34]. The former contains detailed data on randomly selected accidents involving at least one passenger car that has been towed from the scene of the accident. Every year,

approximately 5,000 accidents, each with up to one hundred recorded parameters, are investigated by accident analysts and added to the data bank. Thus, these data also offer the possibility to generate a detailed analysis of the accident that occurred in a representative way [35].

The goal of the NASS GES, on the other hand, is to show an overall picture of accidents involving motorized vehicles and to identify possible weak points within overall vehicle safety. For this purpose, more than 50,000 accidents in the USA are investigated annually and added to the database. The level of detail here is considerably lower than that of the NASS CDS [36].

In 2016, the NASS CDS was replaced by the Crash Investigation Sampling System (CISS), and the NASS GES was replaced by the Crash Report Sampling System (CRSS), although the principal data collection objectives and practices are the same. In addition, the number of parameters collected has increased within the new systems. For example, CISS data contain 39 data files with nearly 600 parameters [37,38]

In addition, NHTSA has maintained the Fatality Analysis Reporting System since 1975, which contains over 140 data on traffic crashes with at least one fatality [39]. Last, the Non-Traffic Surveillance and the Crash Injury Research & Engineering Network contain data on injuries not resulting from traffic crashes [40] and data on the causes of injuries during crashes, respectively [41].

The NHTSA is the only institution in the world to make all of its in-depth accident data publicly available [1].

3.3 Transnational databases

Since the annual number of road deaths reached 1.35 million in 2018, which is the most common cause of death among people aged 5–29 [42], road accidents are a global problem. Several international projects have been started to collect and evaluate cross-border databases to reduce this number. These are described below:

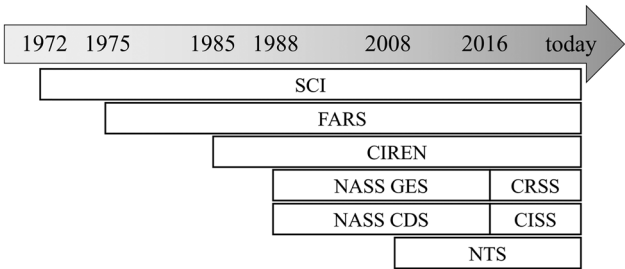


Figure 2: NHTSA accident databases and their collection period.

3.3.1 CARE – EU Road Accident Database

In 1993, the decision of the European Union to set up the EU database CARE on road traffic accidents came into force. This is a database where traffic accidents with injured or killed people are detected. With the decision (93/704/EG, OJ No. L329), all EU member states were obliged to provide annual data on traffic accidents [43].

The unique thing about CARE is the high breakdown of the statistically collected data. This includes extensive information on accidents, people, and vehicles used for accident analysis. The aim is to provide evidence for identifying and quantifying road traffic safety problems on the roads. It should also be possible to evaluate the efficiency of the measures, determine the relevance of the measures, and facilitate the exchange of experiences [43].

In addition to the CARE database, the European Road Safety Observatory (EROS) also collects road safety data in the European member states [44]. To support the member states in collecting data, the DaCoTa project (Road Safety Data Collection, Transfer, and Analysis) was launched to help them [45].

Primarily, member state officials have access to the CARE disaggregated data. There is no public access either to this or to the EROS data [43].

3.3.2 IGLAD – Initiative for the Global Harmonization of Accident Data

IGLAD was initiated in 2010 by Daimler AG, ACEA, and other research institutes and presented as a working group at the FIA Mobility Group. The aim is to create a common standardized accident data set for road safety. Today, the project consists of 23 international partners and is coordinated by SAFER [46–48].

In the course of a study, existing accident databases around the world were analyzed [49], and a data scheme was developed that, depending on the level of detail in the accident record, is located between an in-depth database and a police survey [50]. For this purpose, the accident data are not collected directly by specially trained teams but are made available by the member organizations. The aim is to combine the data from different sources and survey methods by providing 82 different evaluation categories to describe the accident [49].

The database currently includes around 7,000 accidents from 12 different countries; 800 to 1,000 new accidents occur every year. To finance the project, the members sell their own data to the other members and vice versa. There is no public and free access to the data here either [47,48].

3.3.3 IRTAD – International Road Traffic and Accident Database

The IRTAD was created in 1988. Today, more than 40 countries work together to collect international knowledge of traffic accident data. The data collected by IRTAD can

be found in the Road Safety Annual Report. Subscribers have online access to the complete IRTAD database via the Organisation for Economic Co-operation and Development statistics portal [51].

4 Evaluation of the CISS database

The previous section shows that the CISS database is the most detailed accident database freely available, as the SCI data can only be considered as individual cases in a case viewer. Therefore, the CISS is investigated using vehicle-to-vehicle crashes (V2V) concerning fulfilling the minimum requirements from Section 2. The General Vehicle (GV) data sets from 2017 to 2019 with 13,578 included crashes are used for the investigation. The goal is to identify specific crash scenarios that occur frequently and with particular severity for the occupants involved.

4.1 Boundary conditions

Filtering the data by V2V crashes is only possible indirectly due to a missing column for the accident type. By setting the columns BODYCAT = 1 and TREEPOLE = 0, only the accidents to passenger cars that did not crash into a pole or tree will be shown. This yields 6,708 accidents for the study. Considering the appropriate crash categories, which refer to accidents with other vehicles, it is possible to consider V2V crashes. The meaning of the variables, such as BODYCAT, and the possible settings can be found in the Analytical User's Manual [52].

The maximum abbreviated injury scale value (MAIS) of an accident listed in the CISS database is used to assess the severity of the accident (VAIS column). Since the number of samples is significantly reduced later in the evaluation, accidents with a MAIS of two or more are classified as severe accidents for the purposes of statistical significance.

4.2 Crash categories and configurations

Similar to the accident types of the German Insurance Association, the CISS classifies the accidents into crash categories (CRASHCAT) and crash configurations (CRASHCONF). The classification differs from the accident types known in Germany. The categories are superimposed on the configurations, as shown in Figure 3.

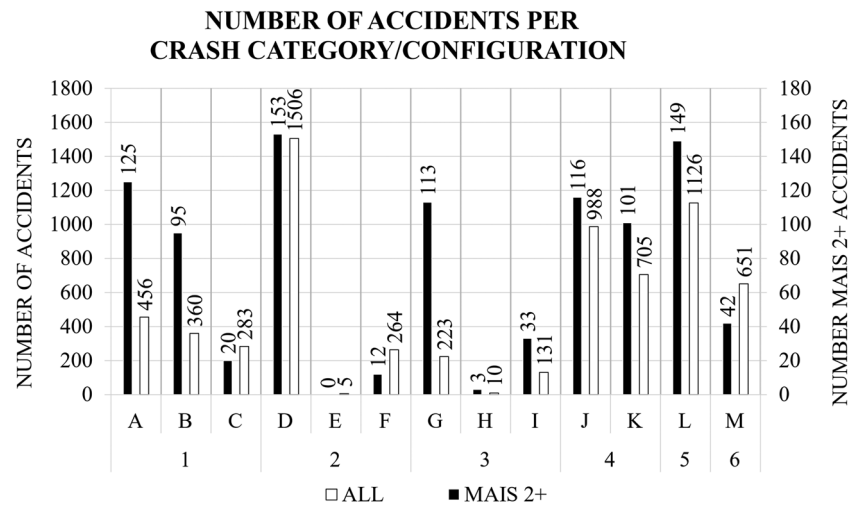


Figure 3: Frequency of all V2V crashes and crashes with MAIS 2+ injuries according to the analysis of the CISS database [53].

This analysis shows that five crash configurations from four categories are attractive for detailed analysis in terms of crash severity and frequency. Configuration D from category 2 (rear impact) is the most common crash type. Here, every tenth accident results in serious injury to the occupants. In the further course, the configurations L, K, and J follow, which describe an accident due to intersecting trajectories (turning or crossing) from different directions. The relative frequency of severe accident consequences increases by up to 4% compared to rear-end collisions. Finally, configuration G (frontal impact) has been chosen for further investigations because it leads to severe personal injuries in more than 50% of the accidents. This is explained by the high differential speed of the oncoming vehicles. Configurations A and B, which appear attractive at first glance due to the high relative frequency of MAIS 2+ accidents, are not considered because they describe a single vehicle involved in an accident.

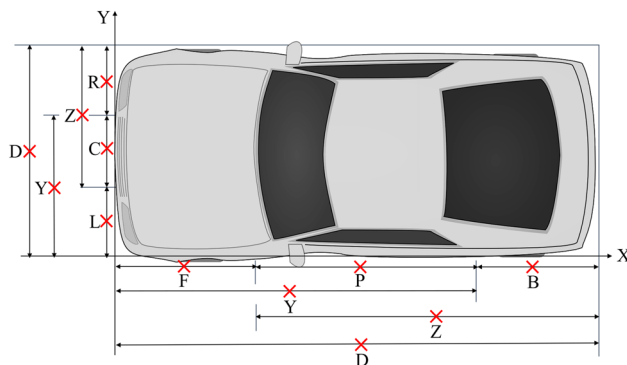


Figure 4: Marking and location of the focal points of the CDC areas (vehicle: image with a free license from pixabay.com).

4.3 Detailed evaluation and derivation of accident scenarios

In the following, a detailed evaluation is carried out using the example of crash configuration J: turning and crossing (Figure 5). The possibilities as well as the limits of the CISS database are shown, and finally, a concrete collision position is derived with the help of a center of gravity calculation. The analysis is based on the minimum requirements defined by the PCM.

4.3.1 Detailed evaluation of configuration J

Each crash configuration is further specified in the CISS database by a crash type (CRASHTYPE) [52]. Configuration J has seven crash types, with types 68 and 69 occurring in more than 90% of all accidents and in more than 95% of all accidents with severe personal injury. Crash types 68 and 69 represent a common crash scenario schematically represented by the black arrows in Figure 5. The absolute frequency and probability of sustaining a severe injury from this constellation is 3–5% higher for the turning and crossing vehicle 68 than for the arriving vehicle 69.

By looking at the crash type, it is thus possible to identify the basic constellation. However, this is not sufficient for a concrete derivation of a scenario since neither the dynamics, the exact collision position, nor the accident participants are evident from this.

4.3.2 Parameters for the identification of crash dynamics

With regard to the dynamic parameters, the CISS database reaches its limit. Neither deceleration, deceleration

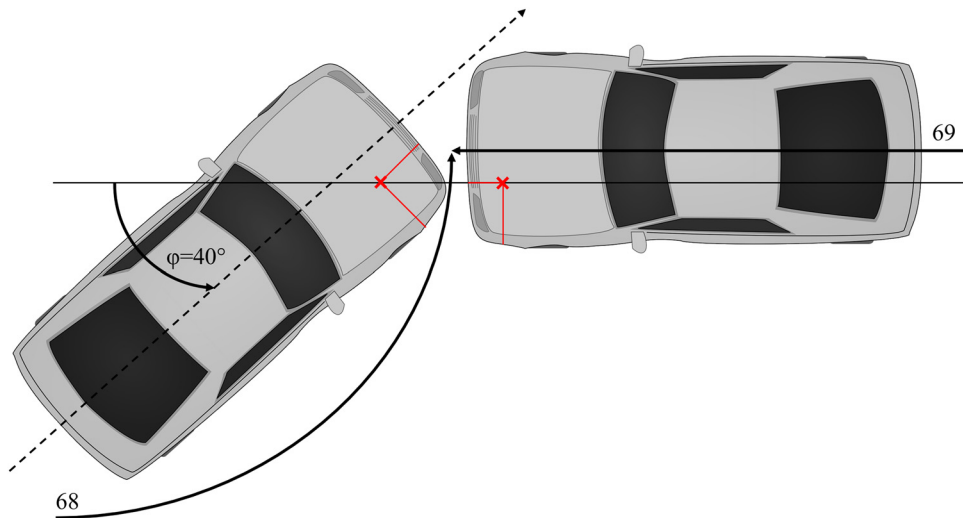


Figure 5: Scenario J – left-turning and crossing (68, 69); result of the accident constellation based on the focal point of impact.

distance, nor the initial velocity is documented. Only the collision speed can be taken from the column DVSPEED, which is determined retrospectively by the program WinSMASH [52]. The analysis showed that the variable was not documented in any of the accidents investigated. This is the greatest weakness in determining crash scenarios, especially with regard to simulation. Nevertheless, the CISS Crash Viewer provides a possibility to obtain concrete dynamic parameters. By entering the CASE-ID, it is possible to view each accident individually in detail. Since Event Data Recorders (EDR) are already widespread in the USA, speeds and delays before the crash are stored there and can be viewed in the Crash Viewer. As described in Section 2, it is possible to assign assumptions to the dynamic parameters. The variable SPEEDLIMIT shows the speed limit at the location of the crash. An alternative to the collision speed is the variable DVBS, which describes the Barrier Equivalent Speed. Thus, the plastic deformation work performed by the crash participants is assigned to a speed. This can be regarded as the minimum speed during the impact since elastic deformations and run-out speeds are not recorded, which leads to a higher collision speed.

4.3.2.1 Determination of the collision position

To determine a concrete crash scenario, the collision position plays an overriding role since the location and angle of the impact strongly influence the momentum and the resulting force fluxes, depending on the vehicle's structure. Even small deviations can change the outcome of a crash [1].

In the following, the collision angle is determined, which occurs most frequently among the crash types 68 + 69.

For this purpose, the variables DVANGTHIS and DVANGOTH can be used, which do not code the angle between the accident participants, but the angle of the driving direction with respect to the north vector. The angle increases in 5° steps in a mathematically negative direction starting from the north [52].

Thus, the following equation [3] must be considered to determine the collision angle, noting that the larger angle must be subtracted from the smaller angle to avoid obtaining multiples of 360°.

$$\varphi_{\text{Koll}} = |\text{DVANGTHIS} - \text{DVANGOTH} - 180|, \quad (3)$$

For crash types 68 + 69, this results in a collision angle of 40° between the vehicles, which most frequently leads to severe injuries to the occupants. There is also a wide dispersion of the angles, with 94% of the severe injuries occurring in the 30–90° angle range. The wide dispersion here is not surprising, as vehicle 68 is inside a turn, leading to the wide occurrence of different collision angles.

No parameters are coded within the GV data to determine the collision location. However, the CISS has further separate data sheets linked to each other by the CASE-ID. With this, it is possible to merge additional data from the other data sheets with the GV data. An exact point of impact is also not found there, but in the following, a method is shown to determine the most frequent point of impact. For this purpose, the Collision Deformation Classification (CDC.CSV) data is used and merged with the GV data. The CDC data contain the areas of the vehicle that the crash has most severely deformed. The data are collected following SAE standard J224 [54].

To determine the local center of gravity of the crash, the longitudinal deformation of the front and the lateral

deformation at the sides must be considered. Since the coded letters of the fourth column (CDCLONGLAT) are partially used for the front and the side, the third column (CDCPLANE) must also be used for identification.

Figure 4 shows the location, and Table 2 shows the center of gravity points in the X - Y plane. Since these are one-dimensional lines, the center of gravity is located in the middle of the respective CDC area. The division of the frontal CDC areas is regulated in J224. Thus, the areas L, C, and R are each distributed in thirds over the front. Y and Z are the sums of L + C and R + C, respectively. D extends over the entire width of the vehicle [54]. The centers of gravity shown at the bottom left of the figure are percentages of the vehicle width.

The same applies to the lateral position of the centers of gravity. Here, areas P, F, and B are vehicle specific. Since this cannot be considered individually in the evaluation, F and B are assigned 25% of the front and rear vehicle length for all vehicles.

To determine the crash center of gravity, assign the relative frequency of MAIS 2+ accidents to the CDC areas. The crash center of gravity can then be calculated using equation [4]:

$$\text{Crash_CoG}_{X,Y} = \frac{\sum \text{CoG}_{\text{CDC}} \cdot \text{Relative frequency}_{\text{CDC}}}{\sum \text{Relative frequency}_{\text{CDC}}} \quad (4)$$

For the case examined here, this results in a center of gravity of $X_{\text{CoG}} = 0.12l$ and $Y_{\text{CoG}} = 0.33b$ for the turning vehicle 68. For the approaching vehicle 69, this results in a center of gravity of $X_{\text{CoG}} = 0.08l$ and $Y_{\text{CoG}} = 0.33b$.

Figure 5 visualizes the collision position found using this method. The vehicles are aligned in such a way that the crash centers of gravity form a line. The line is to be interpreted as a vector of the maximum force direction during the impact.

4.3.2.2 Determination of the further PCM entries

For the simulation of a crash scenario, the other fields within the PCM must be filled in. Information about the crash participants is sufficiently available within the CISS database. Using the parameters MAKE, MODEL, CURBW-EIGHT, and MODELyr, it is possible to determine the vehicle make, the model, as well as its curb weight and year of manufacture. For concrete scenarios, this information is also documented in the CISS crash viewer for each recorded accident. In the statistical evaluation of these parameters within the crash type 68 + 69 with severe personal injuries, it can be seen that vehicles are predominantly from American or Asian manufacturers.

Table 2: Relative position of the centers of gravity over the vehicle length X and width Y

Center of Gravity X			
In Y-direction		In X-direction	
D_{CoG}	0.5y	D_{CoG}	0.5x
Z_{CoG}	0.66y	Z_{CoG}	0.675x
Y_{CoG}	0.33y	Y_{CoG}	0.375x
L_{CoG}	0.165y	F_{CoG}	0.125x
C_{CoG}	0.5y	P_{CoG}	0.5x
R_{CoG}	0.835y	B_{CoG}	0.875x

German premium manufacturers, in particular, are not to be found here. Furthermore, a generalization and transfer of the results to the German market must be viewed critically due to the higher average vehicle mass of the involved accident vehicles. In contrast to the vehicles in the CISS database, with an average curb weight of 1,811 kg, this was only 1,463 kg in Germany over the last 15 years [55]. Thus, no general transfer of the results and scenarios to German traffic can be made but should be backed up with statistics.

Finally, the sketch data must be filled within the PCM. The collision position is already determined here. The road conditions are to be identified using the parameters SURFCOND and SURFTYPE. SURFCOND indicates the road condition (dry, wet, snow-covered, etc.) and SURFTYPE the road surface (concrete, asphalt, etc.). The evaluation shows that turning and crossing accidents occur on dry and asphalted roads.

Information on scale sketches of trajectories and end positions, as well as other accident data such as tire tracks, is provided by the TRAJDOC column within the GV data. This variable assigns the individual accidents with a sketched representation of the accident sequence between the accident participants. The sketches contain true-to-scale drawings of the vehicles, road, and surroundings overall crash phases (normal driving to post-crash) and are available via the CISS crash viewer.

4.3.3 Results of the other configurations

The procedure shown for configuration J (Figure 5) is illustrated in the appendix for all configurations of interest according to Figure 3. Implementing the center of gravity method for the other configurations leads to the shown center of gravity collision positions.

For the scenarios for the configurations, D rear-end collision (Figure A1), K left-turn same direction (Figure A2), and L

crossing trajectories (Figure A3), a possible offset within the collision position is additionally indicated. This results from considering the CDC areas, which also allows a statement about the deviation from the crash center of gravity.

As an example, this can be seen in scenario G frontal impact (Figure A4), which shows the offset toward a smaller overlap of the vehicles. When looking at the damaged areas, the left sub-area L is deformed more frequently than sub-area R. This leads to the conclusion that the shift in the collision position is toward smaller overlaps.

5 Discussion

The examination of the CISS database with regard to the applicability of PCM revealed both strengths and weaknesses. Strengths can be found mainly in the information about the participants and sketches. On the other hand, the dynamics is very poorly coded within the CISS database and can only be determined in more detail via specified speed limits or vehicle deformations. However, these approaches can have substantial deviations from the actual vehicle dynamics. The EDR data offer a solution to this in individual cases, but these must additionally be extracted from the CISS Case Viewer. This makes it particularly difficult to automatically generate simulations along the lines of the PCM.

In addition, no exact collision position can be extracted from the data, so the method shown was developed. In particular, it must be noted that the lateral areas F and B have been assigned a general 25%, which can, in reality, lead to deviations. In principle, it would be possible to determine the exact proportions for F and B using additional data sheets available on the internet for the respective vehicles involved. However, this also represents an enormous additional effort.

However, whether the accident scenarios found in this way also occur particularly frequently in Germany with serious accident consequences must be determined in further investigations. Furthermore, it should be noted that the scenarios arise from an intersection of many individual parameters, which is why the concrete scenario as such does not necessarily have to occur frequently in the database. Instead, they act as “focus scenarios” for the critical accident types and configurations.

6 Conclusion

The aim of this article is to derive simulation-capable accident scenarios using freely available databases. To

ensure the simulation capability, the principle of the PCM was applied. This requires parameters for the dynamics, the accident participants, and the environment, including true-scaled sketches.

When looking at accident databases available worldwide, it can be seen that there are many national and international databases that, with a few exceptions, are not freely accessible. The pioneer in this respect is NHTSA, which makes extensive data freely available. The CISS database turned out to be the most detailed, why it was examined more closely with regard to the requirements of the PCM.

During the investigation, the CISS showed its strengths, especially in the parameters concerning the accident participants and the environmental conditions. The most problematic aspect turned out to be the determination of dynamic parameters, which can only be filled by substitute values (speed limit) or assumptions. Using the CISS crash viewer makes it possible to determine EDR data for the accident and thus dynamic parameters for individual cases.

A further difficulty was determining the specific accident position since precise information is not given. The method developed in this thesis for the determination of a crash center of gravity to derive crash positions for concrete accident scenarios shows a possibility to determine a collision position despite non-existing in-depth data and thus enable the derivation of a concrete scenario.

This method made it possible to identify five “focus scenarios” for frequently occurring V2V crashes with severe accident consequences. The rear-end collision (scenario D) is the most frequently occurring accident, followed by scenarios L (crossing trajectories), J (left-turn and crossing), and K (left-turn and same direction). Scenario G, which represents a frontal collision and leads to severe injuries to the occupants in over 50% of the cases, was last considered based on this.

By using the CISS database, it is possible to create scenarios that can be simulated for different research interests. However, as a substitute for in-depth databases, the CISS is only partially sufficient due to the limitations of the database. In particular, there is a need for improvement in the specification of dynamic data, such as collision speed, run-in speed, and accelerations or decelerations shortly before the crash. Furthermore, the specification of a concrete collision point would be desirable to reduce the effort by the method shown here. Despite this, the CISS is the most detailed database freely available, driven by NHTSA’s goal to promote vehicle safety worldwide. Considering this goal and the globally anchored Vision Zero, it is desirable that other institutions follow this example and create free access to detailed accident data.

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Appendix

Results for the collision position of the further scenarios.

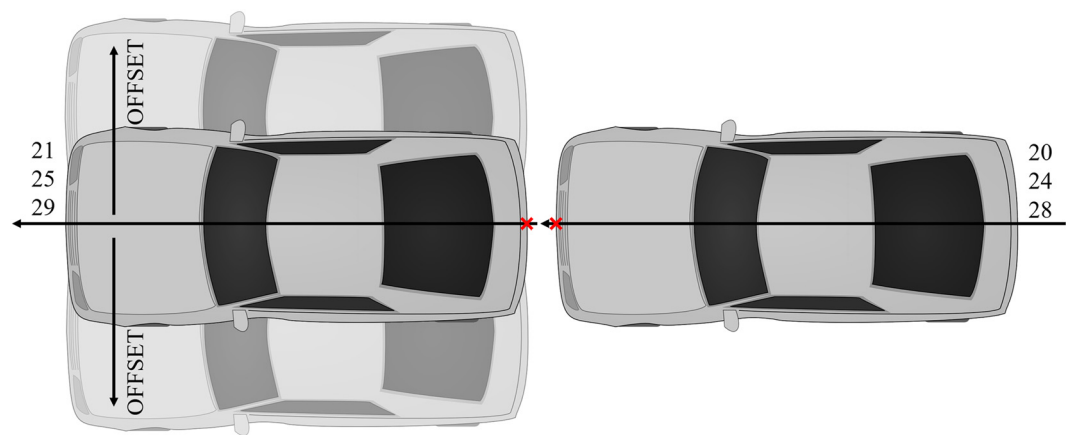


Figure A1: Collision position for scenario D – rear impacts 20, 21, 24, 25, 28, and 29.

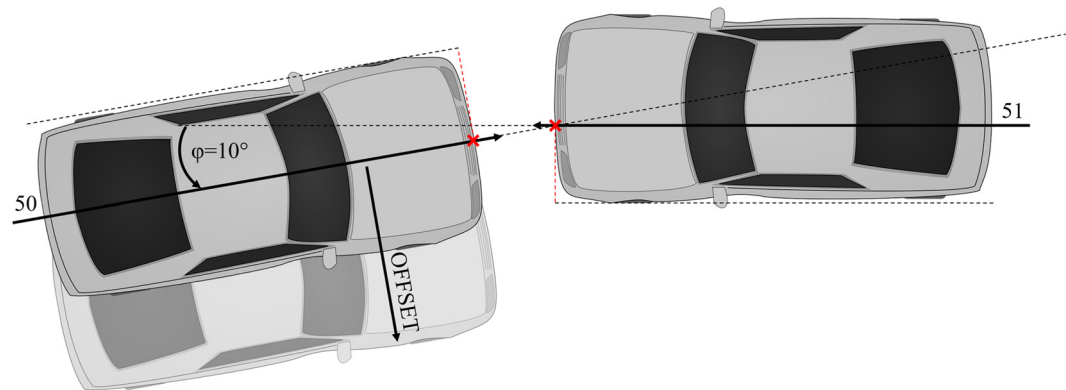


Figure A2: Collision position for scenario G – front impacts 50 and 51.

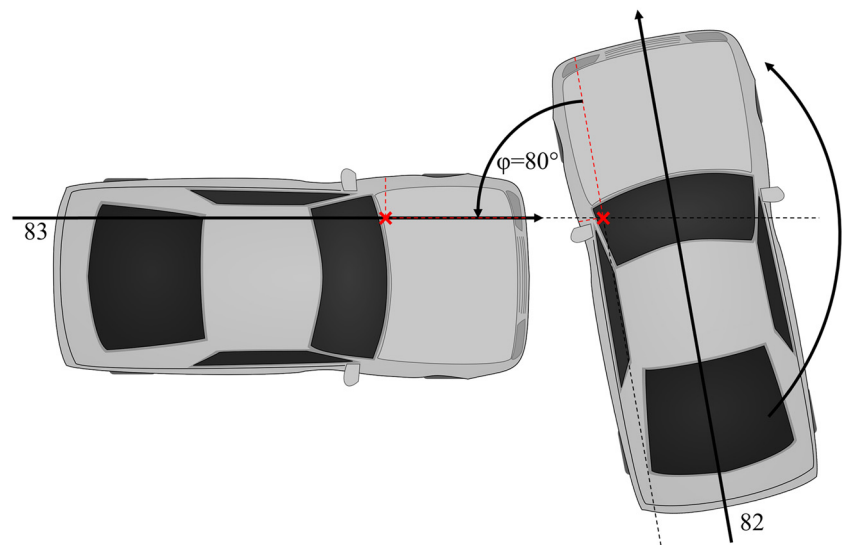


Figure A3: Collision position for scenario K – left turn in the same directions 82 and 83.

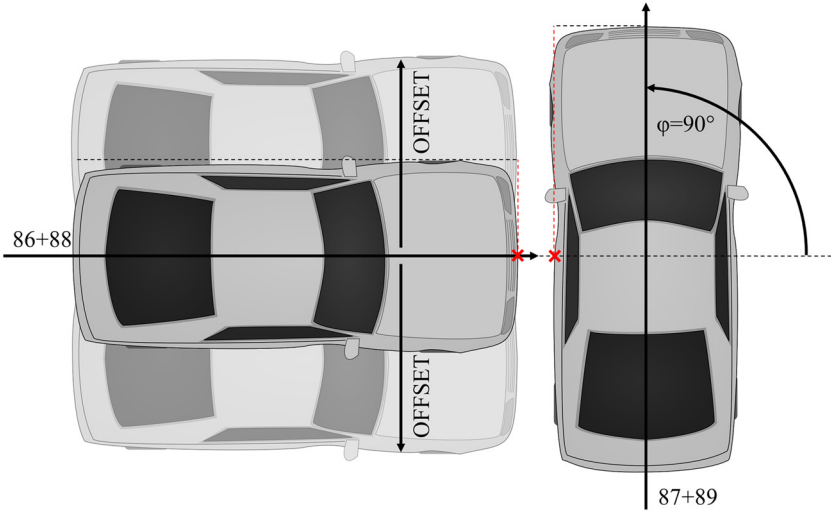


Figure A4: Collision position for scenario L – crossing trajectories 86, 87, 88, and 89.