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FAT-SCHRIFTENREIHE

FAT 280

PCM from iGLAD database

VDA Verband der Automobilindustrie

PCM from iGLAD database

Forschungsstelle:

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I. Symbols

Small letters

Symbol	Description
a	acceleration
s	distance
t	time
v	velocity

Indices

Symbol	Description
0	Initial point
k	Collision point

Abbreviations

Symbol	Description
ACEA	European Automobile Manufacturers Association
ADAS	Advanced driver assistance system
AEB	Autonomous Emergency Braking
BASt	Federal Highway Research Institute (Germany)
CAD	Computer-Aided-Design
CDC	Collision deformation classification
CoG	Center of gravity
FAT	The Research Association of Automotive Technology (Germany)
FIA	Fédération Internationale de l’Automobile
GIDAS	German In-Depth Accident Study
iGLAD	Initiative for the Global Harmonization of Accident Data
IRF	Injury-risk function
P1	Participant 1
P2	Participant 2
PCM	Pre-crash-matrices
PTW	Powered two/three wheeler
TTC	Time to collision
VDA	German Association of the Automotive Industry
VUFO	Traffic Accident Research Institute at University of Technology Dresden
WHO	World Health Organization

II. Structure

III. Abstract

Efforts in the field of vehicle safety have substantially reduced the number of seriously and fatally injured persons in the most European countries. Beside retrospective evaluations of safety systems prospective estimations become more and more important for further improvements of road safety. In the field of passive safety this is commonly done through standardized and reproducible crash tests leading to high costs and a limited number of test scenarios. In the field of active safety there are nearly no standardized test procedures existent at all. In contrast, the real traffic provides an infinite variety of scenarios. Thus, there is a strong need and a high potential for further developments based on simulation. Therefore, the actual vehicle behavior in real traffic accidents has to be simulated for prospective benefit estimations of active safety systems. This can be done with the help of so-called pre-crash matrices (PCM), which describe the vehicle dynamics in a defined time before the collision.

Due to the globalized development of vehicles and advanced driver assistance systems (ADAS) in combination with the large variety of traffic situations all over the world, there is an increasing need of evaluating the efficiency of ADAS on the basis of in international data. On the other hand side there is a lack of sufficient global accident data. Therefore, the "Initiative for the Global Harmonization of Accident Data" (iGLAD) was launched in 2011, in which currently ten traffic accident researches from Europe, North America, Australia and Asia take part in. The aim is to merge high-quality data from different national in-depth investigations.

The main goal of this study was the analysis of the iGLAD phase 1 data with regard to the creation of pre-crash simulations. The future aim is the evaluation of the safety potential of ADAS within the variety of road traffic accidents from around the world. The main focus will be on the methodology to derive PCM from this international database. This also includes the definition of minimum requirements to enable the simulation of the vehicle behavior in the pre-crash phase. Furthermore, methods were developed how to deal with unknown data with regard to the different data quality and quantity. For accidents with a non-compliance of the defined requirements appropriate compensation methods were developed. In addition it was analyzed which influence certain assumptions have on the accuracy and reliability of simulations. Finally the study shows the possibility to analyze active safety systems from a global point of view by implementing and assessing an exemplary ADAS for different global traffic accident scenarios.

With the work done within the study, especially with the catalogue of requirements and the developed methods, it is possible to create pre-crash simulations not only for upcoming iGLAD releases but also for other international accident databases.

0. Important remark

Just before finalizing this study, a decision about renaming the case numbers has been made from the "Technical working group" of the iGLAD consortium. It was decided to include the year of membership of the data providers instead of the year of release. All case numbers of iGLAD phase I accidents have officially changed their nomenclature from 14XX0000 to 13XX0000. Nevertheless all case numbers within this report were not changed and are still named as 14XX0000.

1. Introduction

For the development of advanced driver assistance systems (ADAS) information of the pre-crash phase are required. Therefore so-called pre-crash-matrices (PCM) can be used, as shown in [2]. They describe the motion of participants of the accident just before collision. Additionally, current or future ADAS can be implemented in the pre-crash phase and thus an evaluation of their efficiency, as described in [4], is possible.

Applying that methodology to the data of the German In-Depth Accident Study (GIDAS) already produced significant results, but only for German traffic accident scenario. However, international traffic scenario is also important for the development of vehicles and their ADAS. After the first publication of the "Initiative for the Global Harmonization of Accident Data" (iGLAD), see [1], it would be possible to prospectively analyze the safety potential of ADAS within the variety of road traffic accidents from around the world for the first time. Due to a smaller data volume of the iGLAD database compared with the GIDAS database, missing data is expected and the formulation of minimum requirements and the development of compensation methods seem to be necessary.

In the framework of this study a methodology for the creation of pre-crash simulations out of international accident databases is developed. The depth of information of the iGLAD data (phase I – 1.550 accidents) shall be determined and a PCM shall be created. The efficiency of an exemplarily ADAS in the field of global accident scenarios will be simulated and analyzed.

2. Pre-crash simulation

2.1. Benefit of pre-crash simulation

Traffic accidents are sudden, unexpected, involuntary and exogenous events for at least one person in the context of road traffic, leading to personal and/or material damage. The chronological sequence of accidents is shown in Figure 2.1. The unexpected event corresponds to the critical situation which unavoidably passes over into the pre-crash phase and the actual collision(s).

Beside accidents there are also a lot of critical scenes in real traffic which do not lead to a collision. There the critical situation leads more exactly to a pre-incident-phase instead of a pre-crash-phase and the collision is avoided by driver's reaction, advanced driver assistance systems (ADAS), opponent's reaction and/or other circumstances.

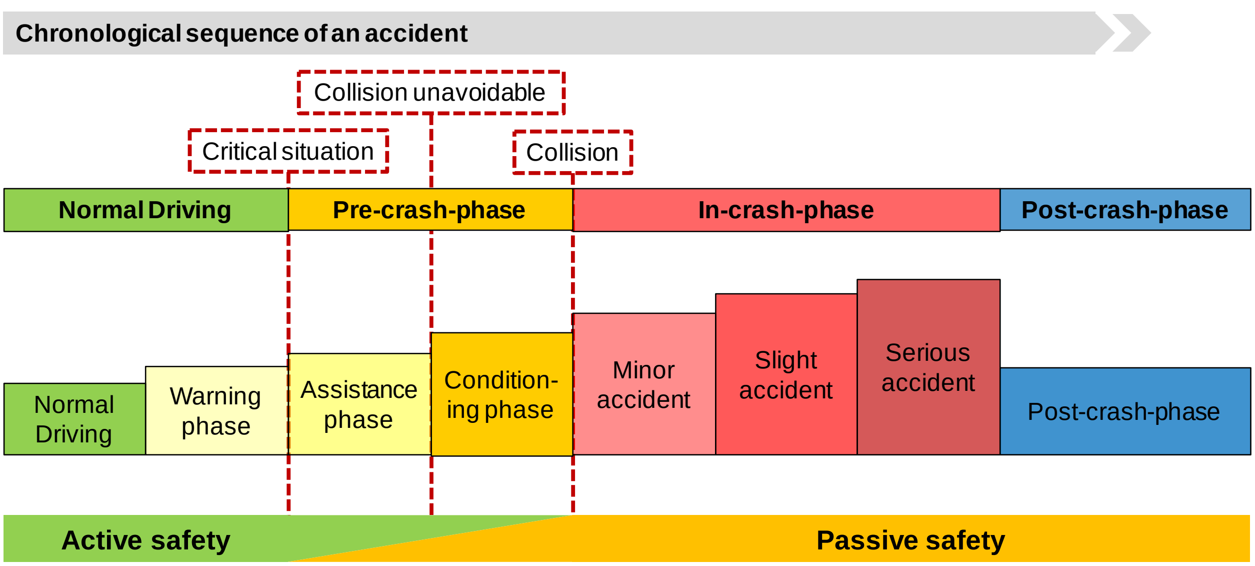


Figure 2.1 – Chronological sequence of an accident

ADAS are systems which assist the driver in the driving process to improve vehicle safety. This is accomplished by warnings to the driver to prevent a critical situation or by interventions into the vehicle behavior to avoid or at least mitigate a collision. Most of them have substantially reduced or will reduce the number of seriously and fatally injured persons. Therefore further development and improvement is important to support this progress.

To prospectively determine the effect of an ADAS it is possible to estimate the benefit by contrasting the original scenario (no ADAS implemented) with the virtual situation with an implemented system and to compare significant parameters (see Figure 2.2). Benefit estimations based on actual (crash) tests are limited due to small number of test scenarios and very high costs.

Contrary to that simulations of accident scenarios give the possibility to estimate the benefit in a nearly infinite variety of scenarios representative for the real traffic accident scenario. Therefore, the actual vehicle behavior in real traffic accidents has to be simulated and information about the pre-crash-phase is necessarily needed.

In-depth accident databases mostly contain much information about the in-crash and post-crash phases. Based on reconstruction of accident's chronological sequence it is possible to simulate the pre-crash-phase and to create so called Pre-Crash-Matrices (PCM). PCM contains information about vehicle dynamics of all participants for discrete time steps in a defined time before crash. Additionally information about surroundings, view obstacles and road markings can be contained. This data source can be then used to virtually implement ADAS and to simulate into one or many accident scenarios and to simulate the influence on driver and/or vehicle behavior. Afterwards, the simulation results can be used for further analyses, e.g. for benefit estimations using Injury Risk Functions (IRF).

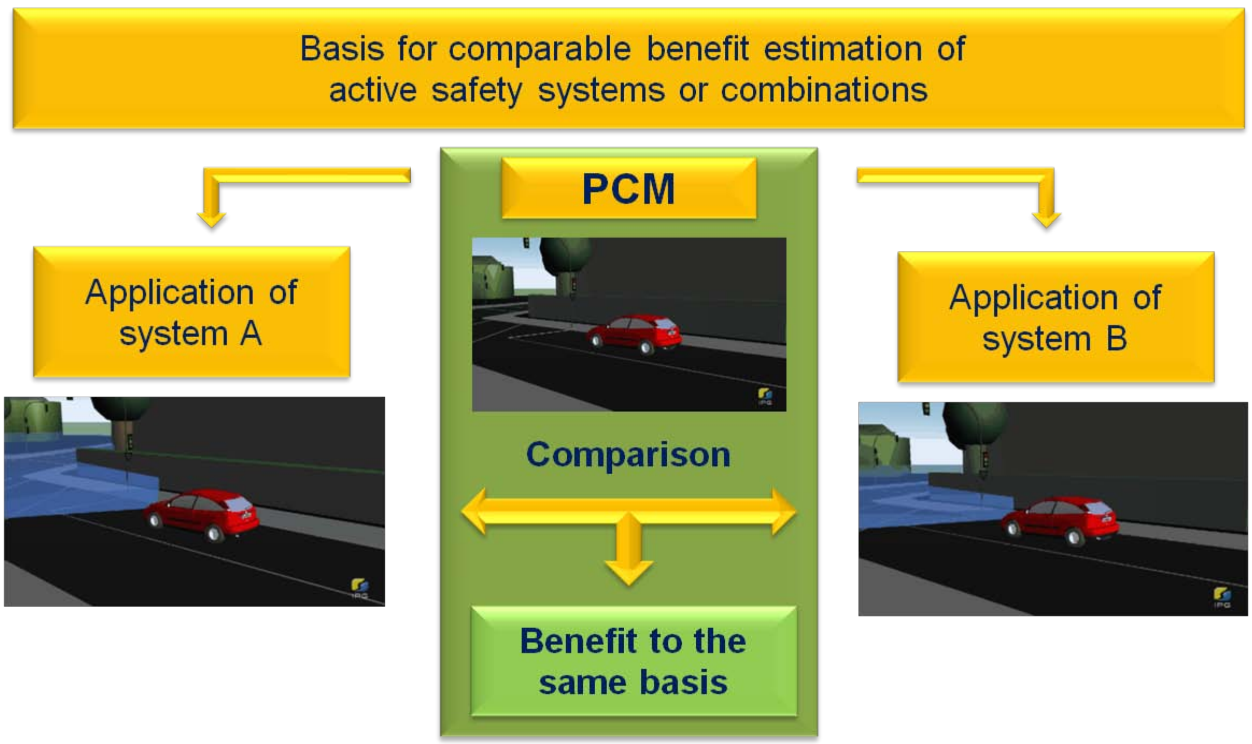


Figure 2.2 – Comparable benefit estimation of active safety systems

Basically, in-depth accident data is essential to do pre-crash simulations and create PCM. The first PCM was created in 2011 on the basis of GIDAS data. In the meanwhile this PCM is well established in the field of vehicle safety (at least in Germany) and widely used for benefit estimations of ADAS. Thus, the GIDAS based PCM could be seen as "current standard" for pre-crash simulations and thus, is used as reference within this study. Therefore the GIDAS project and the GIDAS based PCM will be shortly described in the following sections. Afterwards, the Initiative for the Global Harmonization of Accident Data (iGLAD) that was initiated to merge international accident data from several countries is described in section 3.

2.2. German In-Depth Accident Study (GIDAS)

GIDAS is a collaborative project of the Federal Highway Research Institute (BASt) of Germany and The Research Association of Automotive Technology (FAT) of Germany (Figure 2.3). It started in 1999 including data of research areas Dresden and Hanover. In these areas about 2,000 accidents per year are investigated and recorded to the GIDAS database. Each case is encoded with about 3,400 variables. Following the documentation, each accident is reconstructed by an experienced engineer.

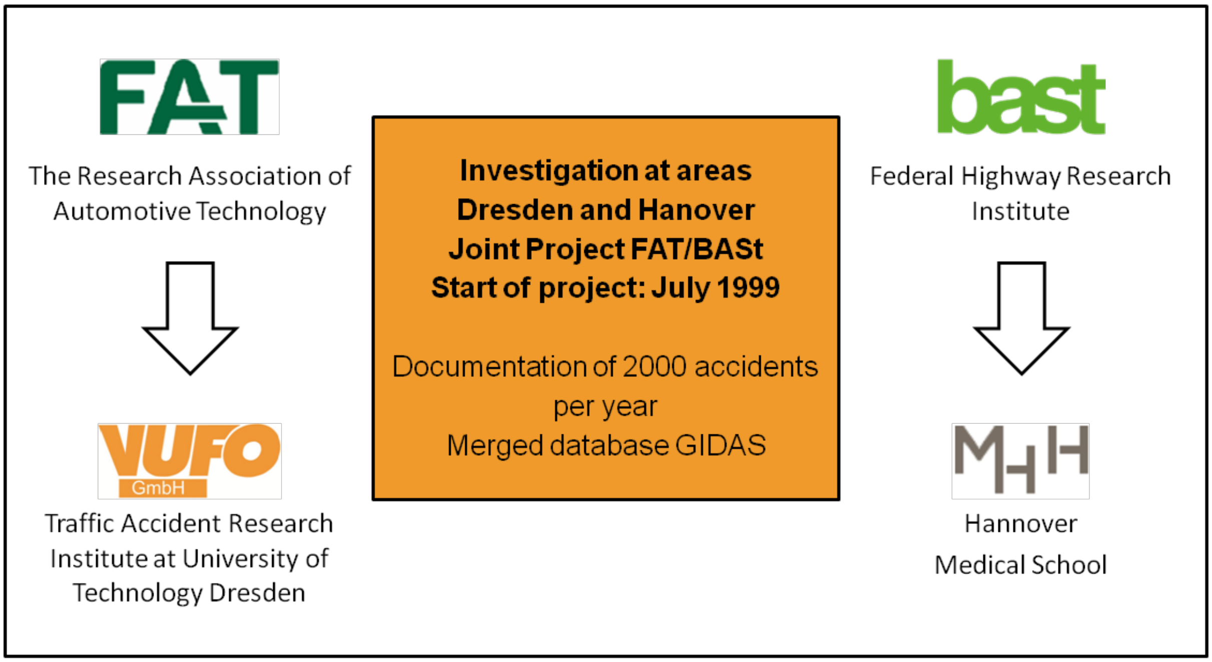


Figure 2.3 – Structure of the GIDAS project

The GIDAS database can be used for representative statements for the German traffic accident scenario due to the high number of recorded accidents, the fact that research areas represent topographically the German average and investigation follows a statistical sampling plan. For further details see [7].

2.3. GIDAS based pre-crash matrices (PCM)

The creation of the GIDAS based PCM was developed by the Traffic Accident Research Institute at University of Technology Dresden (VUFO) and is constantly further developed in coordination with the FAT members. Figure 2.4 describes the process how the GIDAS based PCM is created and Figure 2.5 the creation of GIDAS based PCM.

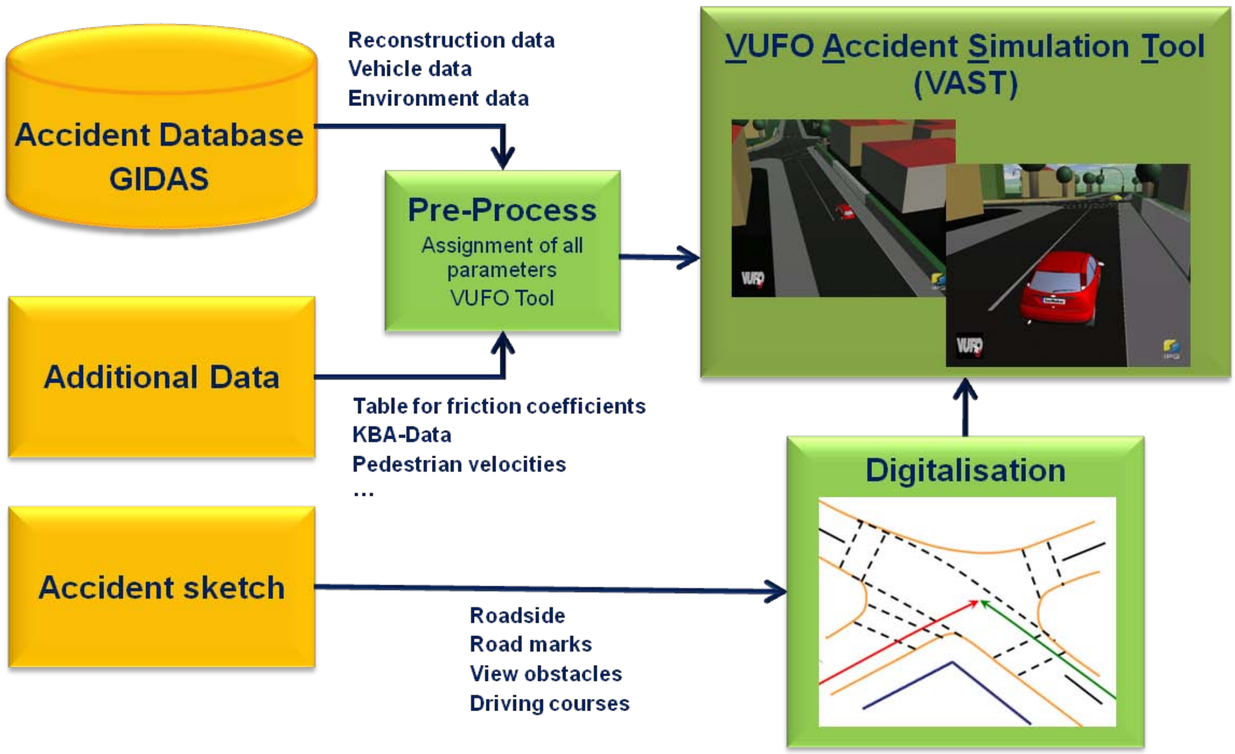


Figure 2.4 – Process of PCM creation on the basis of GIDAS

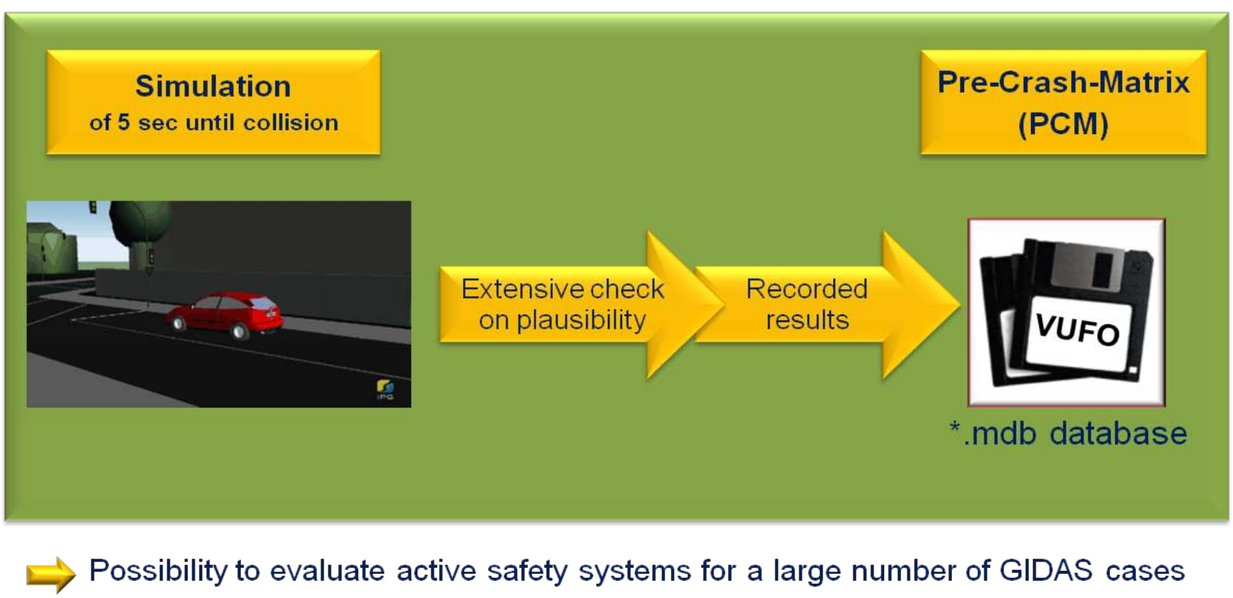


Figure 2.5 – Creation of GIDAS based PCM

For a high efficiency and useful results of the project the existing knowledge about the creation of PCM is used to transfer the methodology on the international database of iGLAD.

The current version of the PCM (Effective 2014-1) is an MS Access database containing several data tables like shown in Figure 2.6. There are several levels/categories of information:

- Global data (once per accident)
- Surroundings (once per accident)
- Participant data (once per participant)
- Dynamics (motion of participants in 10ms steps).

The table “global data” contains general information like the case number, the number of involved participants etc. The surroundings data are stored in several tables for the roadside geometry, road/lane markings and view obstacles. The table “participant’ data” contains information like the vehicle’s dimensions and center of gravity, moments of inertia and so on. The table “dynamics” contains information about the participant’s position, velocity, acceleration, yaw angle but also the participant’s reaction like braking or other. The dynamics are described in certain time steps (e.g. each 10 ms).

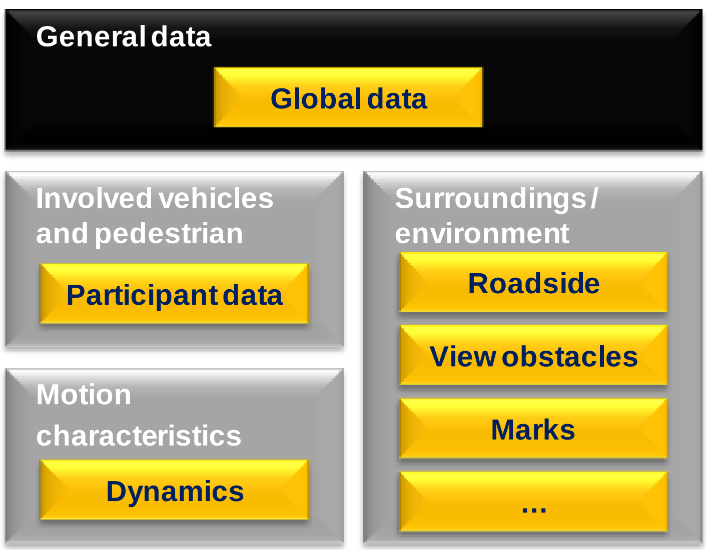


Figure 2.6 – Information in the GIDAS based PCM

The PCM database derived from pre-crash simulations in addition with the GIDAS database can be used to estimate the benefit of an ADAS like described in section 2.1. This serves as basis for all following considerations for creating PCM from iGLAD database.

3. Initiative for the Global Harmonization of Accident Data (iGLAD)

3.1. Motivation of the initiative

While fatalities due to traffic accidents are slightly decreasing in high-income countries they are strongly increasing in middle-income and low-income countries, see Figure 3.2. Even with pessimistic predictions the worldwide number of traffic fatalities will tremendously increase in the next decade(s). That’s why traffic safety becomes more and more important from a global point of view. The publication of the World Health Organization (WHO) “World report on road traffic injury prevention” of 2004 estimated the annually number of fatalities up to 1.3 million and around 20-50 million injured people [8]. A newer report of 2009 tells over 1.2 million dies each year on the road and between 20 and 50 million suffer non-fatal injuries [10]. The latest statistical publication of 2013 of the WHO shows that worldwide about 1.24 million deaths occur annually and another 20 to 50 million sustain non-fatal injuries as a result of road traffic crashes [11]. Eighty-eight countries have reduced the number of deaths on their roads, but the total number of road traffic deaths remains unacceptably high at 1.24 million per year [11]. This clarifies fatalities within traffic scenario remains high. Current trends suggest that by 2030 road traffic deaths will become the fifth leading cause of death unless urgent action is taken [9]. But it can also be seen that road traffic deaths relative to population is much higher in middle-income and low-income countries than in high-income countries, see Figure 3.1. Therefore the need for action in this field and by association for an international in-depth database and its further improvement process is very high and even increasing.

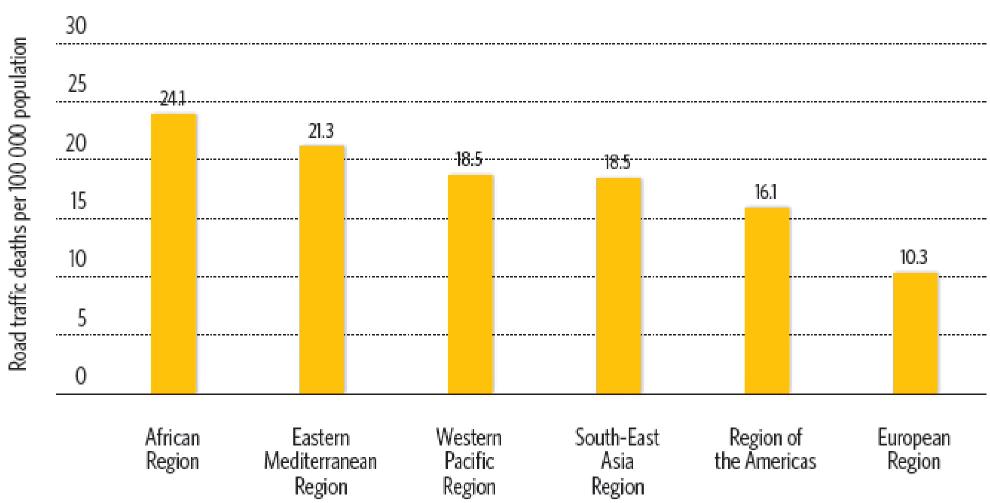


Figure 3.1 – Road traffic fatalities per 100,000 population [11]

This shows that actions in the fields of vehicle safety, infrastructure, and driver behavior / education should be taken.

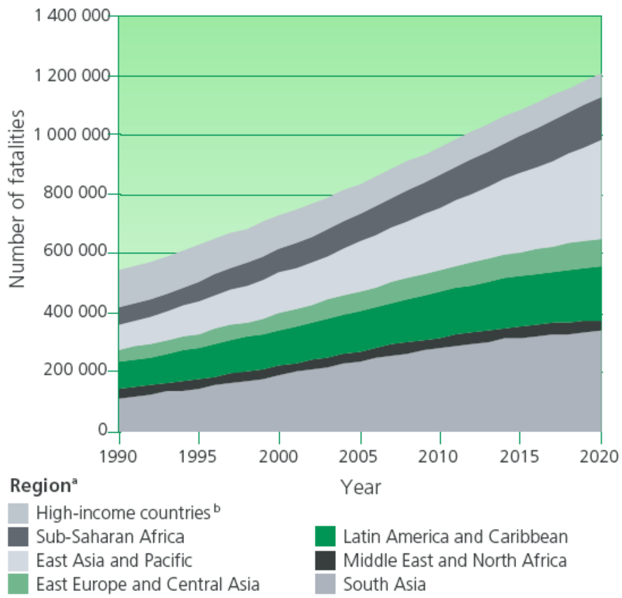


Figure 3.2 – Road traffic fatalities, adjusted for underreporting, 1990–2020 [8]

This is commonly done with the help of so called in-depth accident data like GIDAS in Germany or IFSTTAR in France. However, there is a lack of sufficient global accident data. "The harmonization of accident data on a multinational level has always been a promising but ambitious target which has not been achieved to date." [1]

Therefore the "Initiative for the Global Harmonization of Accident Data" (iGLAD) was launched in 2011 as a collaborative project of the European Automobile Manufacturers Association (ACEA) and the Fédération Internationale de l'Automobile (FIA). Currently ten traffic accident research institutes from Europe, North America, Australia and Asia take part in the project (see Figure 3.3). The aim is to merge high-quality data from different national in-depth investigations.

3.2. Content of the iGLAD database

The big challenge of a harmonized accident database is the different data content of the single in-depth investigation projects. Therefore, an appropriate selection of well defined parameters is necessary to ensure a certain quality standard on the one hand side and to enable useful comparisons and evaluations of the efficiency of ADAS on several markets on the other hand side [6].

The iGLAD project members currently finished phase I and phase II is under preparation (see section 3.3 Coming phases). The database of phase I contains 1550 cases from 10 countries, like shown in Figure 3.3, and is the database this study refers to. The inquiry period was 2007 to 2012 and each case includes information on 75 variables regarding accident, road, participants (information about vehicles and pedestrians), occupants and safety systems. The hierarchy of the data can be seen in Figure 3.4.

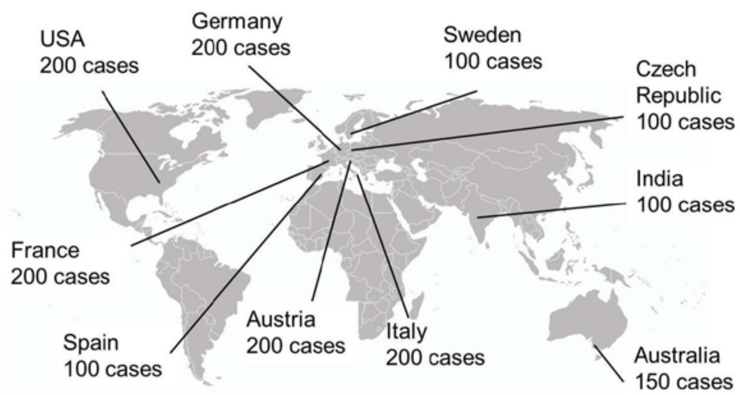


Figure 3.3 – Data providers of iGLAD phase I (2007 – 2012 data) [3]

One big benefit of the iGLAD database is the fact that reconstruction data (like initial speed, braking deceleration, collision speed, and delta-v) are available. Additionally the participating members are committed to provide accident sketches. Pictures of the accidents were not mandatory for Phase I cases.

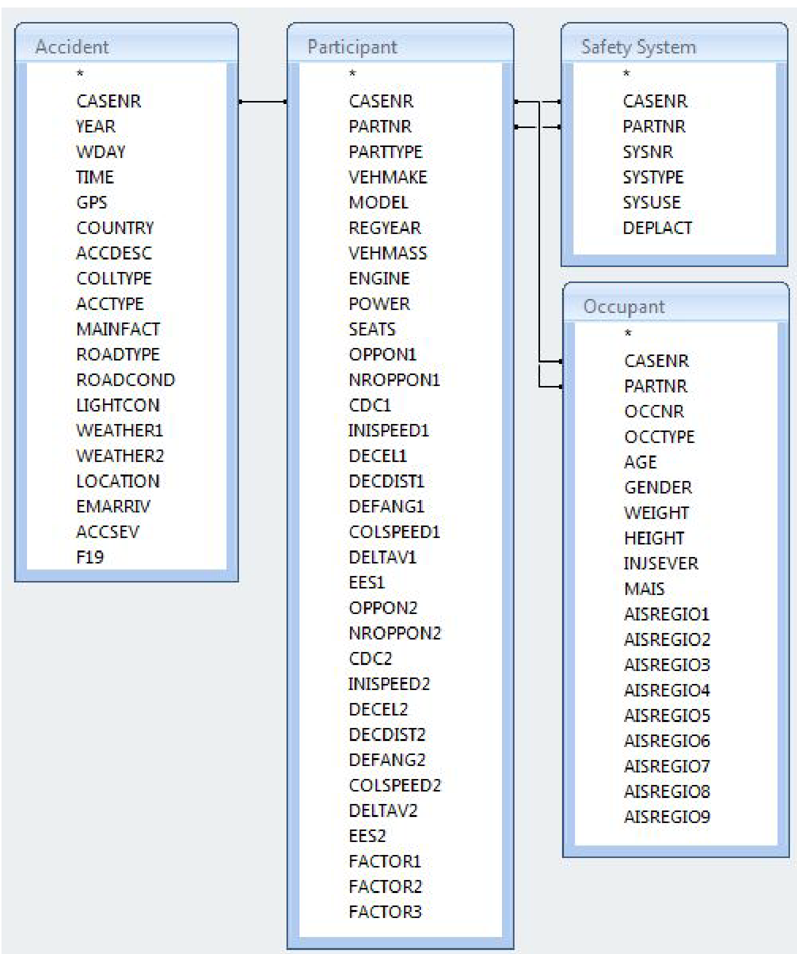


Figure 3.4 – Hierarchy of the iGLAD database

3.3. Coming phases

Due to the increasing need of a high quality global in-depth database iGLAD is a continuously advancing project. Several groups (the technical working group, the steering committee, the data administration team) work together at further improvements. This means the database has no finished format and will improve with every period. Many improvements will result from this study, especially in terms of data quality, plausibility checks and requirements on sketches and reconstruction.

The phase II will be finished within 2015, containing accidents from 2012 to 2013 and already containing further improvements like:

- a maximum of 20% unknown variables within one case
- new variables like type of road surface or assignment A and B to accident's type
- introduced plausibility checks
- sketches with a defined minimum content
- sketches in vectorized format

Pictures of accidents will not be mandatory for phase II, but are planned for coming releases. The following dataset should contain cases with inquiry period of 2014 and is planned to be finished and released within 2016.

4. Pre-crash matrices (PCM) from iGLAD database

4.1. Procedure

Object of this study is the creation of PCM from iGLAD database to make detailed information about the pre-crash phase available and to enable simulation and evaluation of efficiency of various ADAS in global traffic accident scenarios. As written in 2.3 the creation of the GIDAS based PCM has already been established and produced significant results, but only for German traffic scenario. However existing knowledge can perfectly be used for creation of PCM from iGLAD database. Nevertheless it is known, that depth of information in the iGLAD database is not as high as the GIDAS database can provide. To compare both, iGLAD contains 71 variables within 4 records (see Figure 3.4), whereas GIDAS contains around 2,600 variables within 31 records. This is no statement about included information quality, but gives an indication that within iGLAD not all necessary information is available. It is expected that the iGLAD database will not be able to reach the standard of GIDAS based PCM and compensation methods as well as assumptions may be necessary.

To take advantage of existing knowledge it is necessary to analyze required information for a creation of PCM referring to the GIDAS based PCM standard. Due to the expectation of unavailable information minimum requirements, characterizing the necessary information which has at least to be available, are defined. It is described in section 4.2. The findings are resulting in a catalogue of requirements (see appendix A). According to these requirements analyzing the released iGLAD phase I data is useful and described in section 4.3. It was planned to create a PCM for the whole iGLAD database in case of complied minimum requirements. 4.3 shows up a non-fulfillment, so pre-crash simulation cannot be performed completely for all cases of all data providers. Therefore it is necessary to take a look on dealing with missing data and to develop compensation methods, described in 4.4. To have an idea of the influence of such compensation methods to the accuracy of pre-crash simulation a sensitivity study regarding to vehicle data is done, see 4.5.

Building up on these results a PCM is created methodically for the “best” five cases per data provider; see 4.6. For cases with a non-fulfillment the compensation methods and estimations were applied. Thereby the effort and accuracy for creating a PCM per case is evaluated for each data provider. Finally in 4.7 two exemplarily ADAS (pedestrian AEB system and forward collision AEB system) are implemented and their effectivity is shown to demonstrate the benefit of PCM from iGLAD database for the development of global road traffic safety.

4.2. Definition of minimum requirements

For the definition of minimum requirements for creating a PCM from a (in-depth accident) database, existing expertise of the GIDAS based PCM standard is used. Thus it is analyzed, described in the following section and a catalogue of requirements is created.

The GIDAS based PCM contains various tables with all relevant data (see Figure 4.1) to reproduce the pre-crash phase of traffic accidents from the GIDAS database until 5 seconds before collision. It results from the simulation of traffic accidents coded in GIDAS by a simulation model of the Traffic Accident Research Institute at University of Technology Dresden (VUFO). If the time period of the reconstruction is less than 5 seconds the course of the vehicles are computed by linear backward calculation. Thus the reliability of the PCM dynamic values is only given for the time period of the reconstruction. Only the two participants of the first collision of the accident are modeled.

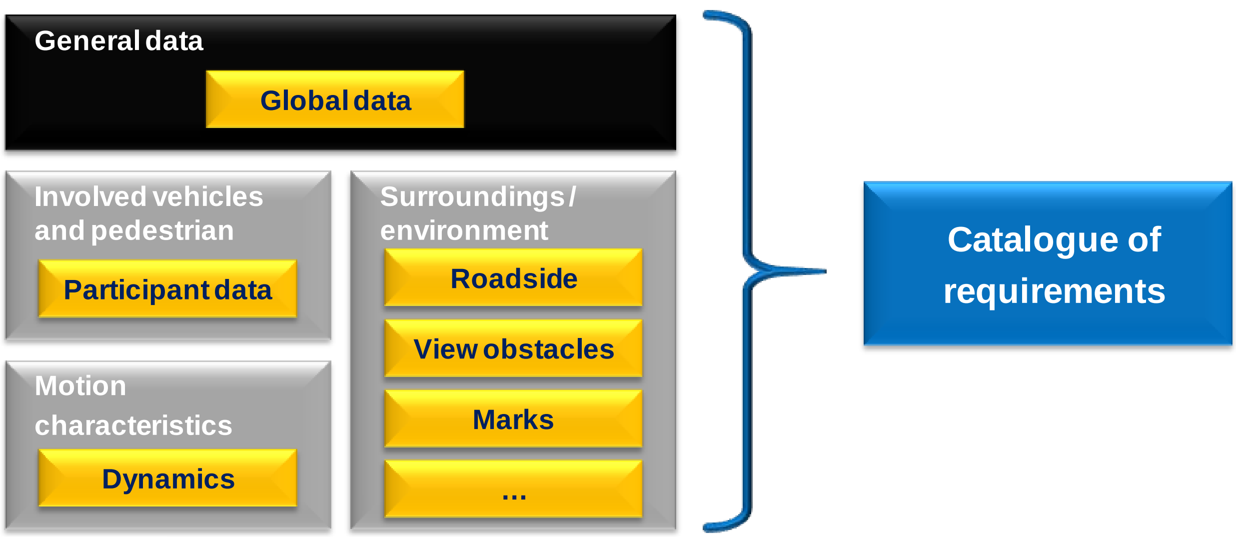


Figure 4.1 – Hierarchy of GIDAS based PCM

The *global data* gives some general information of the accident. First of all it names the case number, which is necessary to identify the accident bijective. It further contains information to categorize the accident like number of involved participants, combination of collision (meaning the part types of participants), number of collisions, collision type, accident type and its assignment to A and B. Also correction factors for positioning the digital accident sketch to a defined position are included. Though a coordinate transformation of the original accident sketch is made so that the end of the trajectory of participant 1 is always moved to the point of origin, the original orientation of the accident sketch remains the same, see Figure 4.2.

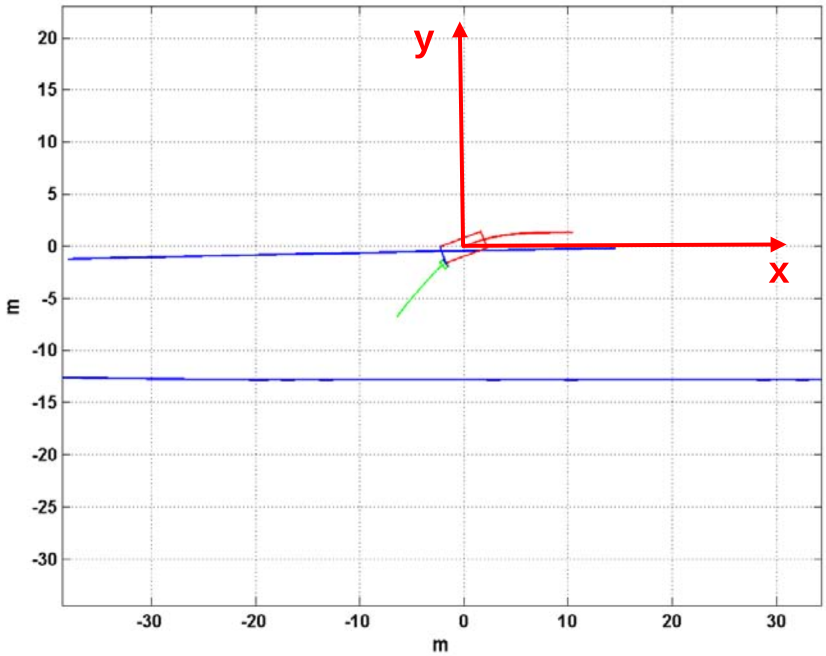


Figure 4.2 – Global coordinate system of PCM

The current GIDAS based PCM standard has a limitation to certain road users. So far the current PCM (status September 2014) only includes accidents where at least one passenger car was involved. The possible collision partners are listed below in Figure 4.3. All other combinations, e.g. with bus/truck, train, et cetera and single-vehicle accidents are excluded at the moment. An extension to trucks takes place in 2015.

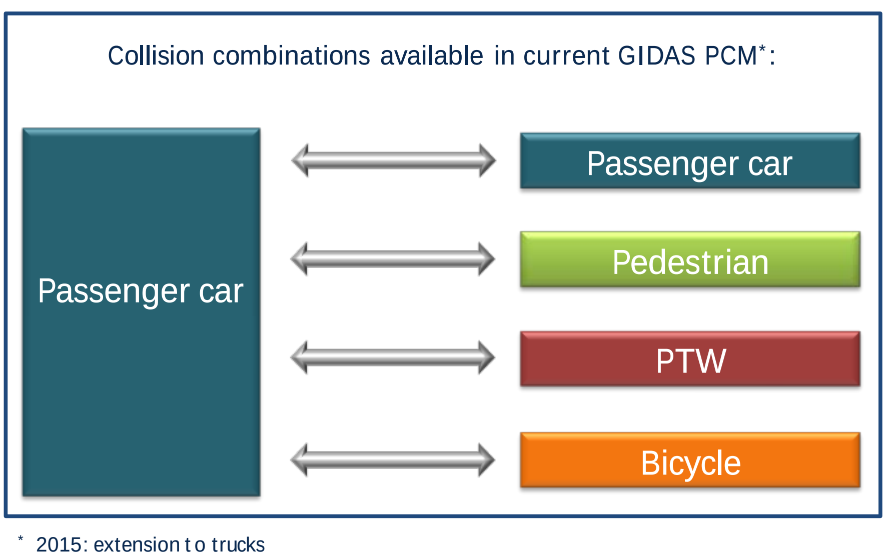


Figure 4.3 – Available collision combinations in current GIDAS PCM

The *participant data* contains all relevant variables to parameterize the vehicles. Beside the numbers of the participants which had the first collision of the accident, the geometry and further attributes of the participants are stored. For pedestrians default values are set. These default values are simulative values, for the realistic pedestrian characterization the original database has to be considered.

The table *dynamics* gives the motion characteristics of each participant to each time step of the simulation, whereby the coordinate system shown in Figure 4.4 is used. It contains global position, velocity, acceleration and global yaw angle of the vehicles. Time step 0 represents the beginning of the pre-crash phase. Furthermore the steering angle of the left and right front wheel is specified for each time step. Another variable defines, if the brake is actuated by the driver at the given time step, so the point of reaction is specified.

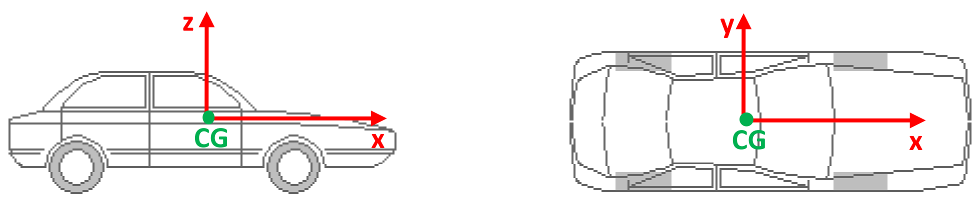


Figure 4.4 – Local coordinate system of GIDAS based PCM

The section *surroundings/environments* contains all information about the surroundings like view obstacles, road geometry or marks.

The table *roadside* defines the relevant boundaries of the road as lines, the table *view obstacles* describes relevant line-of-sight obstructions as lines and the table *marks* defines the relevant continuous, long interrupted and short interrupted road markings as lines.

The accident *sketch* plays an important role for the automated simulation as it defines surroundings and trajectories and their visualization. It should be available like shown most simply in Figure 4.2. It should at least include the following information:

- Traffic area
  - (Road geometry, all road markings, slope information)
- Environment and view obstacles
  - (Collision objects, traffic control devices, roadside profile, view obstacles)
- Accident marks and traces
  - (Final positions, marks, collision area, collision point)
- Driving lines (trajectories)
- Descriptions

Beside necessary information listed above, there are needs for an automated simulation regarding format as follows:

- Digitalized
- Vectorized
- Scaled, north arrow
- Layered

In detail the requirements respectively a guideline for digital accident sketch are summarized in appendix B.

All this information is contained in the GIDAS based PCM database. It is analyzed regarding all necessary information, resulting in a formulation of the minimum requirements, summarized in the catalogue of requirements, given in the appendix A. It finally contains all necessary information for a pre-crash simulation and furthermore contains additional information for an extended pre-crash simulation and evaluation of vehicle safety systems.

4.3. Analyses of the iGLAD database

The hierarchy of the iGLAD database differs from the GIDAS based PCM standard (comparison of Figure 3.4 and Figure 4.1). So as second step the iGLAD database phase I is analyzed regarding to the created catalogue of requirements. The order orientates on the hierarchy of the GIDAS based PCM standard (Figure 4.1).

4.3.1. Global data

First the global data is analyzed. This general information gives an overview about the accident. In general, all tables are linked by the unique case number (CASENR), which has the format: [yy][XX][0000]. The term [yy] is the last 2 digits of the year of data release. Phase I data was released in 2014, so there is a 14 for all cases. [XX] means the ISO 3166 code of the country of origin and [0000] means a consecutive accident number beginning with “0001”. An example is “14AT0001”, the first accident of Austria data of the iGLAD 2014 release. This number is essential for allocation of the data. It can’t be compensated but is also the basis of each case and therefore fundamental condition for all cases.

In 4.2 the limitation to certain collision combinations through current GIDAS based PCM standard is described. As a consequence, the quantity of possible cases for a PCM from the iGLAD database is already reduced. Figure 4.5 shows the amounts of the main collision combinations. The types of the participants are categorized as follows:

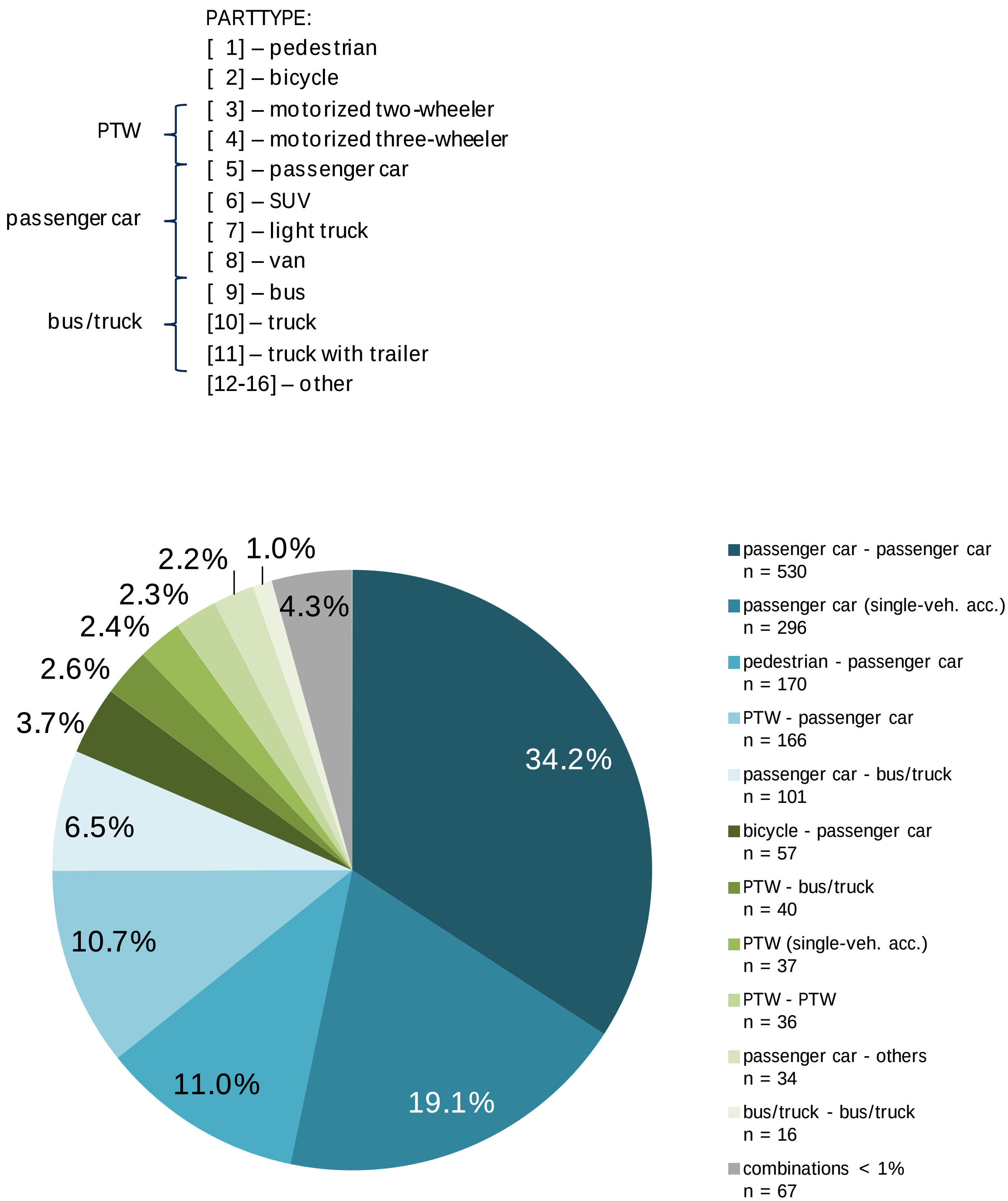


Figure 4.5 – Quantity of collision combinations in the iGLAD database

It can be seen that the majority are accidents with a passenger car. The possible combinations with the current GIDAS based PCM (see Figure 4.3) include:

Table 4.1 – Amount of iGLAD collision combinations provided by the current GDAS based PCM standard

Participant 1	Participant 2	Quantity of collision combinations	
		absolute	relative
Passenger car	Passenger car	530	34.2 %
Passenger car	Pedestrian	170	11.0 %
Passenger car	PTW	166	10.7 %
Passenger car	Bicycle	57	3.7 %

In total there are 923 accidents (59.5 % of all iGLAD cases) available for creation of PCM referring the combination of the collision. The biggest part of unavailable collision combinations are single vehicle accidents with 296 (19.1 % of all iGLAD cases) and “passenger car vs. bus/truck” accidents with 101 accidents (6.5 % of all iGLAD cases). Both categories are in process to be included in future PCM versions. The extension to trucks will take place in 2015, so there is a potential of further 6.5 % of iGLAD phase I cases. For a detailed list of all represented combinations see appendix C.

Section 4.2 respectively appendix A describes necessary information of global data. Table 4.2 shows their availability in the iGLAD phase I data. Column “Available” gives the number of cases, where the information is available and the column “Not available” gives the relative number of cases in percent, where the information is not available. The 1550 cases of iGLAD phase I data are the base. The column “Alternative source” shows the possibility of an indirect available variable in the database. It is not meant as compensation methods which are specified in section 4.4.

Table 4.2 – Analyses of global data

Necessary data	**iGLAD variable**	**Available [Qty.]** ✔	**Not available** ✘	**Alternative source**
Case number	CASENR	1,550	0.0 %	–
Combination of collision	OPPON1 PARTTYPE	1,534	1.3 %	– (ACCDESC)
Accident type	ACCTYPE	1,550	0.0 %	– (ACCDESC)
Assignment A/B	✘	✘	✘	– (ACCDESC)
Collision type	COLLTYPE	1,550	0.0 %	– (ACCDESC)
Road condition	ROADCOND	1,547	0.2 %	– (ACCDESC)
Road type	ROADTYPE	1,329	14.3 %	– (ACCDESC)
Type of road surface	✘	✘	✘	– phase II: ROADSURF
No. of involved participants	Max of PARTNR	1,550	0.0 %	– (ACCDESC)
No. of collisions	OPPON1/2	1,374	11.4 %	– (ACCDESC)

Notes: For variable abbreviations see the iGLAD Codebook [5]. The assignment A and B to the accident type (ACCTYPE) and the type of the road surface are not available within the data of phase I, but will be included from next release on. The Variable ACCDESC describes the accident description as a text (string format). It cannot be analyzed automatically but is useful for single case analyses. This would mean a very high effort, so it's grayed out. The correction factors, mentioned in 4.2, are not considered due to the fact, that this information is included in the digitalized sketch.

It can be seen, that most of necessary global data is available for the majority of iGLAD phase I cases. The number of collisions and the road type are not available in 11.4 % respectively 14.3 %. iGLAD data just contains the first and the second collision. Higher collision numbers are not included anyway. The assignment A and B to the accident type (ACCTYPE) and the type of the road surface are completely not available. The accident type, the collision type and the road condition are available for almost all iGLAD phase I cases.

4.3.2. Participant data

Second step is to take a look at the participant data, proceeding in the same way as with global data. The participant data contains the vehicle or pedestrian data. Table 4.3 lists in the column "Necessary data" the minimum requirements according to the catalogue of requirements (appendix A). Basis are the 2,882 participants of the 1550 iGLAD phase I cases.

Table 4.3 – Analyses of participant data

Necessary data	**iGLAD variable**	**Available [Qty.] ✔**	**Not available ✘**	**Alternative source**
Participant number	PARTNR	2,881	0.0 %	–
Type of Participant	PARTTYPE	2,820	2,1 %	– (ACCDESC)
Vehicle width	✘	✘	✘	o VEHMAKE + MODEL + REGYEAR o External car databases o Approximation formula
Vehicle length	✘	✘	✘	
Vehicle height	✘	✘	✘	
Center of gravity	✘	✘	✘	
Inertia tensor $\underline{I}$ (I_{xx}, I_{yy}, I_{zz})	✘	✘	✘	
Track width	✘	✘	✘	
Wheelbase	✘	✘	✘	
Weight of vehicle	VEHMASS	≤ 2,414	≥ 6.5 %	
Vehicle engine power	POWER	≤ 2,267	≥ 21.3 %	
Coefficient of friction	✘	✘	✘	ROADCOND, WEATHER + Reconstruction

The weight of vehicle and the vehicle engine power have limited reliability, due to some implausible high and implausible low values. The type of the participant contains 2.1 % of not available or wrong data. The majority (around 50 participants; 1.7 %) of these mistakes base on the usage of an outdated codebook (passenger cars with PARTTYPE = 4). The part type is automatically proofed by the combination of collision in the global data check anyway.

The analysis shows that many necessary vehicle parameters are not included in the iGLAD phase I data. There is a need for alternative data sources and compensation methods. The most efficient method seems to be the use of the type of the participant, the vehicle make, the vehicle model, and the year of first registration in combination with external car databases or approximation formulas. Table 4.4 shows the availability of this information. The figures are based on all 2,541 participants which are relevant for an automated research, meaning all participants in iGLAD except pedestrians, bicycles, tractors, trains, agricultural tractors, and animal driven carriages. It shows an acceptable availability, but nevertheless there are two big issues for an automated research. The first one is the MODEL variable which is saved as text in string format. This leads to very varying entries even for the same vehicle model. The different car markets are another issue because there is no suitable global car database available. As a consequence the definition of default models seems to be necessary.

Table 4.4 – Analysis of vehicle details

Necessary data	iGLAD variable	Available [Qty.] ✔	Not available ✘	Alternative source
Manufacturer of the vehicle	VEHMAKE	2426	95 %	–
Model of the vehicle	MODEL	2076	83 %	– (ACCDESC)
Year of first registration	REGYEAR	2339	92 %	– (ACCDESC)

4.3.3. Dynamics

The table “dynamics” mainly contains the reconstruction data of the participants. So the basis are the 2,882 participants of the 1550 iGLAD phase I cases. Table 4.5 shows the minimum requirements and their availability. The values are related to empty, “unknown” or “not applicable” entries. A check of plausibility is treated in the following figures.

Table 4.5 – Analyses of dynamics

Necessary data	iGLAD variable	Available [Qty.] ✔	Not available ✘	Alternative source
Global position of the vehicle	✘	✘	✘	SKETCH
Contact point	CDC1	≤ 2,588	≥ 10 %	– (Reconstruction)
Initial speed	INISPEED1	≤ 1,995	≥ 30 %	{COLSPEED1, DECEL1, DECDIST1}
Collision speed	COLSPEED1	≤ 1,837	≥ 36 %	{INISPEED1, DECEL1, DECDIST1}
Acceleration	DECEL1	≤ 1,787	≥ 38 %	{INISPEED1, COLSPEED1, DECDIST1}
Acceleration distance	DECDIST1	≤ 1,679	≥ 42 %	{INISPEED1, COLSPEED1, DECEL1}
Global yaw angle	✘	✘	✘	– (Reconstruction)
Steering angle left/right front wheel	✘	✘	✘	– (Reconstruction)

It can be seen, that motion variables (initial speed / INISPEED1, collision speed / COLSPEED1, deceleration / DECEL1, deceleration distance / DECDIST1) generally exist as parameters but only available for around two third of all cases. Further information about global yaw angle and steering angles is not available. The global position of the vehicle has to be determined from the digitalized sketch.

With the idea that one missing value out of {INISPEED1, COLSPEED1, DECEL1, DECDIST1} (see later section 4.4.3) can be calculated, the availability of these four values per participant is considered. Figure 4.6 shows the chart of all cases divided by the country of origin. The subdivisions are explained in the following Table 4.6.

Table 4.6 – Subdivision for analysis of availability of reconstruction data

1	missing	All 4 reco-variables of at least one participant are missing
2	little known	3 reco-variables of at least one participant are missing
3	partial known	2 reco-variables of at least one participant are missing
4	calculable	1 reco-variable of at least one participant is missing
5	complete	All 4 reco-variables of both participants are known

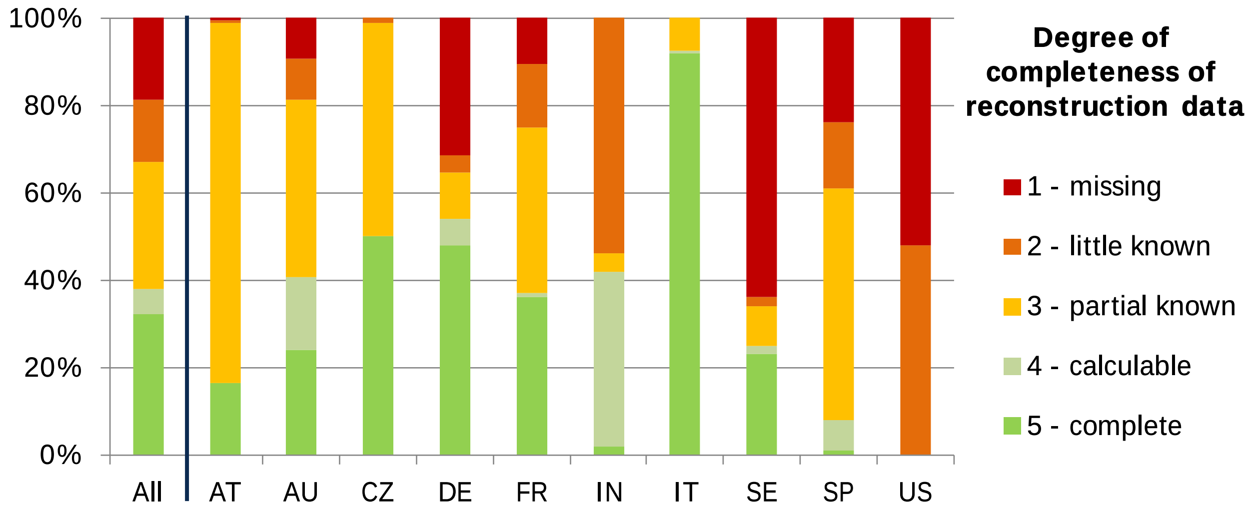


Figure 4.6 – Analysis of availability of reconstruction data

It can be seen that the availability is strongly varying. Cases from Italy show a high availability whereas cases from the United States do not provide complete reconstruction data at all. This is a main limitation for the creation of PCM.

However this is no statement about the reliability of the data, so its plausibility is checked in the next step. The chart of Figure 4.7 shows the results. The subdivision is as follows:

- "incomplete reco-data": min. 2 reco-variables per participant are missing
- "reco-data implausible": reco-variables known/can be calculated, but implausible
- "reco-data plausible": reco-variables known/can be calculated and plausible

Naturally the plausibility can just be checked for complete reconstruction data. It shows that implausible data exists in a relevant dimension. So the need for compensation methods is present.

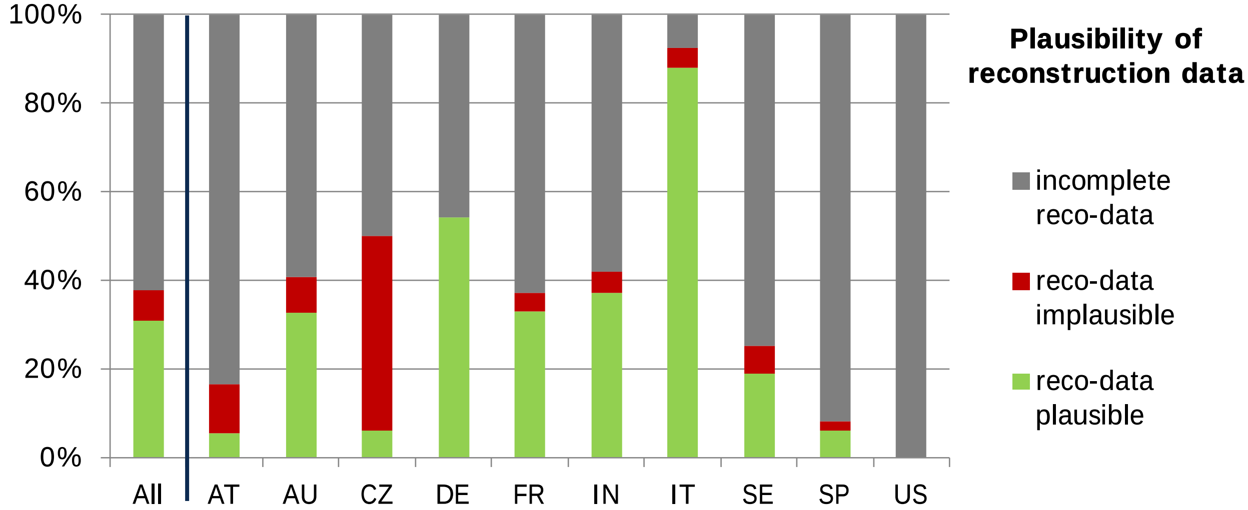


Figure 4.7 – Analysis of plausibility of reconstruction data

4.3.4. Surroundings/environments

The minimum requirements for surroundings and environmental data are not directly available as variables within the iGLAD database. Nevertheless they are mostly available in the sketch. So this section is focusing on the analysis of the content of provided sketches.

A digitalized sketch is necessarily needed for every accident for doing pre-crash simulations and following information must be contained:

- Trajectories
- Impact position (point of collision)
- Contact point
- Final position
- Roadside
- View obstacle
- Road markings

Requirements for contained information and format are described in appendix B in more detail. However, this was not an agreed requirement in the first iGLAD phase and thus is not always the case. Alternatively the sketch can be redrawn with the help of GPS data, map data and an expert reconstruction. Such possible method is better described in section 4.4.4.

Before analyzing the content, it is useful to check the availability. Table 4.7 shows the availability of sketches of all iGLAD cases subdivided into the country of origin. They are separated in categories as follows:

- "Not available" there was no sketch provided
- "Freehand" existing sketch as freehand sketch
- "Digitalized" digitalized format (jpg/pdf/dwg/…)

The category "digitalized" makes no difference between a pixel graphic and a vectorized graphic, because no vectorized sketches were provided except from the Italian data provider. It can be seen that availability and format varies between the several countries. The availability differs between 49 % and 100 % and digitalized availability between 0 % and 100 %, but has a good level for most of the cases. So the main limitation at this point is the low availability of sketches from single countries (e.g. Austria with 49 %) and the low rate of digitalized sketches from single countries (e.g. Czech Republic with 0 % or Sweden with 47 %). In general sketches are available for 90 % of all cases and 78 % are already digitalized. So for the majority of iGLAD cases in Phase 1 digitalized sketches are available.

Table 4.7 – Availability of sketches of all iGLAD cases

Country	Number of all cases		Not available		Freehand		Digitalized	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Austria	200	100 %	102	51 %	31	16 %	67	34 %
Australia	150	100 %	0	0 %	0	0 %	150	100 %
Czech Rep.	100	100 %	19	19 %	81	81%	0	0 %
Germany	200	100 %	1	1 %	12	6 %	187	94 %
France	200	100 %	0	0 %	16	8 %	184	92 %
India	100	100 %	0	0 %	0	0 %	100	100 %
Italy	200	100 %	13	7 %	9	5 %	178	89 %
Sweden	100	100 %	14	14 %	39	39 %	47	47 %
Spain	100	100 %	0	0 %	0	0 %	100	100 %
USA	200	100 %	0	0 %	0	0 %	200	100 %
SUM	1550	100 %	149	10 %	188	12 %	1213	78%

However this is no statement about the content of the sketches and therefore no reference for usability. All information that is not present has to be reworked manually (if possible) resulting in big efforts. To have an idea about usability and effort for rework of single case sketches it is important to know the content demanded above of each sketch. The result of this analysis is shown in Table 4.8, but only for potential cases regarding criteria named above (global data, participant data and dynamics data), due to high effort of analyzing the single case sketches. It can be seen that sketch content and quality varies strongly.

The bottom line is that 117 cases of basically three countries contain all necessary information. This does not satisfy the requirements for pre-crash simulation under the aspect of a global point of view. Compensation methods and the effort for rework of single case sketches will absolutely be necessary.

Table 4.8 – Content of potential sketches

Country	No. of pot. cases	Trajec-tory	Impact pos.	Contact point	Final pos.	Road-side	View obst.	Scale	Pot. sket-ches
Austria	16	9	6	1	9	10	0	10	0
Australia	28	28	28	28	28	28	7	28	28
Czech	0	0	0	0	0	0	0	0	0
Germany	59	56	52	47	54	59	38	59	43
France	44	15	22	18	18	36	6	33	10
India	0	0	0	0	0	0	0	0	0
Italy	141	55	111	100	112	118	23	80	35
Sweden	4	1	1	1	1	4	0	1	1
Spain	0	0	0	0	0	0	0	0	0
USA	0	0	0	0	0	0	0	0	0
SUM	292	164	220	195	213	255	74	211	**117**

4.3.5. Conclusion

Figure 4.8 summarizes all database checks described in chapter 4.3. Furthermore, the amount of available iGLAD phase I cases are shown step by step in Figure 4.9 (except analysis of the sketches). It can be seen that the available case number decreases substantially to 57% at the level of relevant accident constellations. Another strong decrease results from the requirement of known dynamics, meaning the available reconstruction variables, where only 33 % of the remaining cases meet the defined conditions. Steps of single countries with an extraordinary high reduction of the available case number are highlighted by red frames. By that the highest potentials for further improvements for coming iGLAD phases are marked. Details of the extraordinary high reductions due to the relevant accident constellation issue are shown in appendix D and details of dynamics data issues can be seen in appendix E.

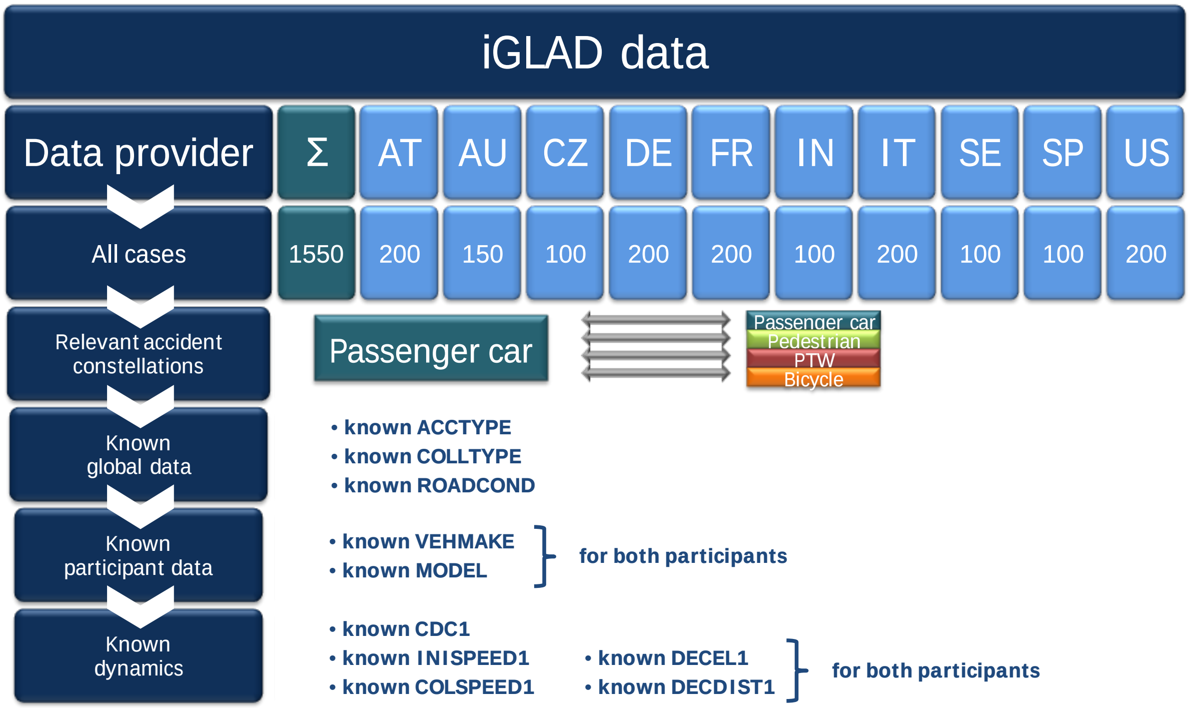


Figure 4.8 – Summary of necessary data

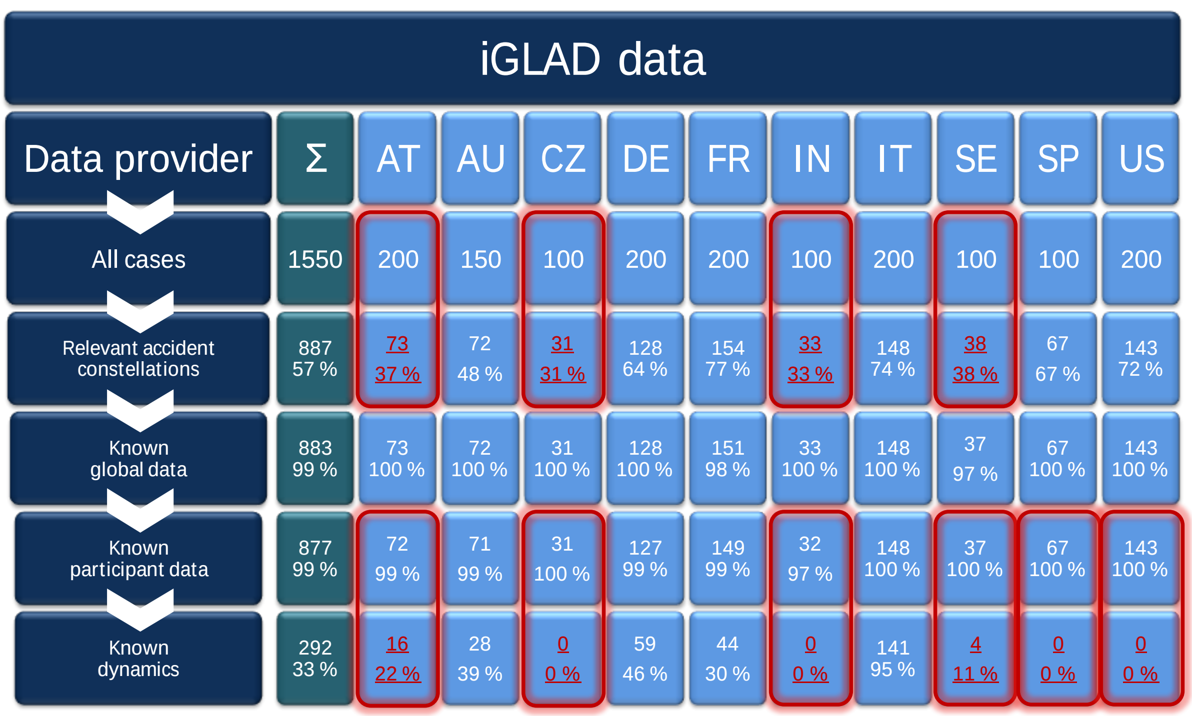


Figure 4.9 – Available case numbers per country

Like already mentioned Figure 4.9 does not contain any review of the surroundings. So there is an additional reduction of the available cases due to missing sketch content, like mentioned in 4.3.4 and Table 4.8. Figure 4.10 shows this reduction of available cases for the creation of PCM for the whole iGLAD phase I database. It can be seen that there are only 117 cases that contain all relevant information (40 % of all cases with known dynamics). . For the whole database this is less than 8 % of all cases. Due to the fact that no cases were provided with vectorized sketches a PCM cannot be created automatically for any accident at all. Thus, manual vectorization is necessary.

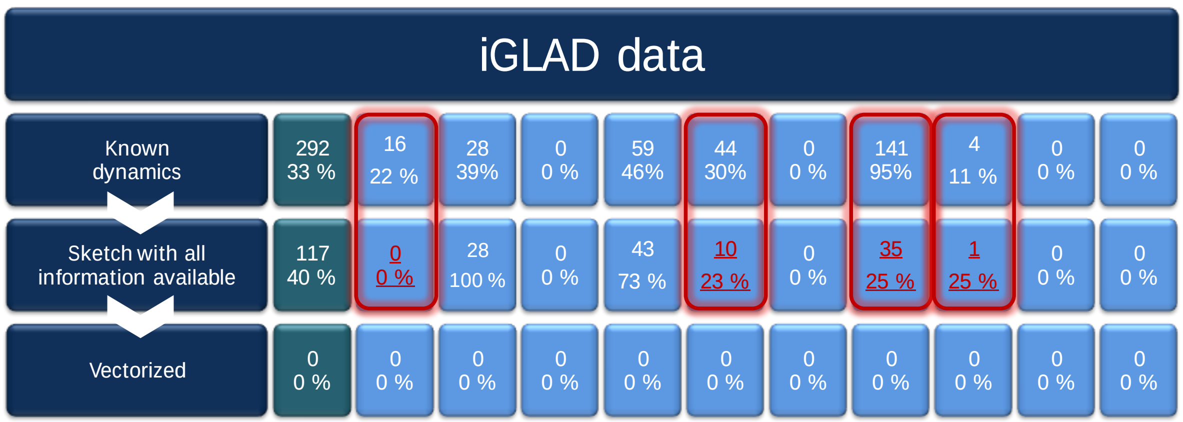


Figure 4.10 – Available case numbers due to sketch content

This is true for all iGLAD cases when only the provided database and sketches are used. However, 63 iGLAD cases (34 from the investigation team in Dresden and 29 from Hanover) are already included in the current GIDAS PCM (2014-2). For these cases an automated PCM creation is possible when additional GIDAS data is used.

All above mentioned points show that dealing with missing data and the development of compensation methods are absolutely essential to enable pre-crash simulation for global accidents out of the iGLAD database. Without such methods there are only 117 cases (less than 8 % of the whole iGLAD database) from mainly three data providers available for simulation. And without additional effort for vectorization of their sketches there are no cases available at all.

Some results of the present study have been directly used as input for the work of the “Technical working group” of the iGLAD consortium which is responsible for the improvement of both the codebook and data quality of further iGLAD phases. The following requirements have been defined based on this project:

- at least 80% filled and known variables
- Sketches: scaled, with English descriptions is mandatory
- Use of UNIDATO is mandatory → check of plausibility, ranges, input logics
- No photos will be provided for phase 2 (question of phase 3)

4.4. Dealing with missing data and development of compensation methods

Due to non-fulfillment of the minimum requirements of the majority of the iGLAD cases like shown in the section above, a defined procedure for dealing with missing data and the development of compensation methods are necessary to enable pre-crash simulations. This section deals with the developed methods and again orientates on the same order as in section 4.3:

- Compensation methods of missing **global data**
- Compensation methods of missing **participant data**
- Compensation methods of missing **dynamics**
- Compensation methods of missing **surroundings**
  (Information within **sketches**)

4.4.1. Global data

As seen in section 4.3.1 global data is existent for a high number of iGLAD cases. So generalized compensation methods are not necessary for such data. For missing information a single-case analysis is sufficient, if needed. The main limitation at this point results from the available collision combinations, meaning the participant types, which is not an issue of the data but of the simulation model.

4.4.2. Participant data

In contrast participant data, which is mainly vehicle data, has a lack of information within the database as shown in section 4.3.2, so alternative sources have to be found. The iGLAD database contains information about the participant's type (*PARTYPE*), vehicle make (*MAKE*), vehicle model (*MODEL*), year of registration (*REGYEAR*), vehicle mass (*VEHMASS*), engine power (*POWER*). Further information like the vehicle dimensions, the inertia tensor, the Center of Gravity (CoG) etcetera are not available in the iGLAD database. For this information compensation methods were developed. Possible alternative sources are:

- external databases (similar to KBA-list)
- manual research
- defining a default model

With the help of the exact vehicle make and model external databases provide very high data quality and quantity. But due to the already named issues of using the vehicle model and make (see Table 4.4 and text above) other compensation methods are necessarily required. A manual research also results in good data quality and quantity, but is connected with an enormous effort. So it is not a useful method for the compensation of the missing vehicle data for all iGLAD cases. An appropriate method is the definition of standardized vehicle models that only depend on the type of participant. By this method the accuracy of the data for the vehicle model decreases but makes data available for a very high number of cases.

It turned out, that three types of default vehicle models seem to be useful for passenger cars (“mini model”, “compact model” and “maxi model”, see Table 4.9).

Table 4.9 – Default vehicle models

example	Mini	Compact	Maxi
length [m]	3.600	4.100	5.100
width [m]	1.500	1.710	1.900
height [m]	1.350	1.395	1.500
wheelbase [m]	2.350	2.600	3.200
track width [m]	1.245	1.419	1.577

For future improvements vehicle body dependent models and also market specific models (different vehicle fleets) would be conceivable. Because then more accurate vehicle models become possible and might improve the accuracy of simulation results. One proposal for future iGLAD phase is the introduction of a variable for the vehicle body because this information is not available in iGLAD yet.

4.4.3. Dynamics

The dynamics of the participants are essentially needed for the creation of PCM. If not available it is not possible to simulate the movement of participants without further effort (e.g. manual reconstruction). In general, the reconstruction data in the iGLAD project (meaning the motion values of all accident’s participants) orientate on a uniformly accelerated (/decelerated) motion, see equation (4.1).

$$\vec{a} = \frac{d\vec{v}(t)}{dt} = \frac{d^2\vec{s}(t)}{dt^2} \qquad (4.1)$$

Regarding to that, the iGLAD database contains four values defined as follows (see Table 4.10):

Table 4.10 – iGLAD motion variables

description	variable	mathematics	estimated range
initial speed	INISPEED1	$\vec{v}_0 = \vec{v}(t = 0)$	$0 \leq v_o \leq 250\, km/h$
collision speed	COLSPEED1	$\vec{v}_k = \vec{v}(t = t_k)$	$0 \leq v_k \leq 250\, km/h$
mean deceleration	DECEL1	$\vec{a}(t) = const.$	$-9\, m/s^2 \leq a \leq 9\, m/s^2$
deceleration distance	DECDIST1	$\vec{s}_k = \vec{s}(t = t_k)$	$0 \leq s_k \leq 200\, m$

As described above there are some cases within the iGLAD database having incomplete reconstruction data, for example like shown in appendix F.1 and F.2. Normally these cases are not available for doing pre-crash simulations unless the missing values can be compensated by

- reconstruction
- simple calculation
- estimation
- a default case.

However, such compensation methods increase the effort and/or decrease the accuracy. Therefore a careful handling is important.

Following equation (4.1) one missing value of the four reconstruction variables can be easily calculated if three other ones are known. This compensational method does not lead to a loss of accuracy. As a result, 36 further cases (in total 328 cases) now meet the conditions for creating a PCM from the dynamics point of view (see Figure 4.12).

Furthermore it is important to take a look if given motion values are plausible. Following equation (4.1) one motion value needs to be calculable out of the given three other ones. So if the calculated value equals the given one or at least is within a small tolerance the case seems to be plausible and its reconstruction variables can be seen as reliable. An example is given in appendix F.4 where all calculated values approximately equal to the given ones. But there are also some issues like shown in Table 4.11. Verifying each value leads to different results which do not suit to the other given values each. Depending on which value is seen as correct for participant 1 several results can be derived:

- 44 kph instead of 68 kph as initial speed or
- 66 kph instead of 41 kph as collision speed or
- 2.4 m/s^2 instead of 0.2 m/s^2 as deceleration or
- 481.2 m instead of 46.7 m as deceleration distance.

Further details can be seen in appendix F.3. Such reconstruction data is worthless and the case cannot be used because it cannot be decided which value is correct and which one is false. Also if the motion values are calculated like stated above, but being out of estimated range (see Table 4.10) they seem to be implausible and will be ejected. Due to such implausible content there are 32 cases ejected for a creation of PCM (in total 296 cases left - see Figure 4.12).

Table 4.11 – Example of reconstruction data issue

CASENR	PARTNR	PARTTYPE	INISPEED1 [km/h]	COLSPEED1 [km/h]	DECEL1 [m/s^2]	DECDIST1 [m]
14AT0078	1	11	68	41	0.2	46.7
14AT0078	2	5	71	50	0.3	47.6

For all cases with more missing information (for examples see appendix F.1 and F.2), it cannot be handled like this. Using equation (**4.1**) with more than one unknown leads to infinite possible solutions. And unless the values are out of estimated range no statement about their plausibility can be made.

The reconstruction data of the case shown in appendix F.1 suggest that there was (nearly) no acceleration/deceleration of any participant. Anyway the accident description says that participant 2 (B) stopped at the stop sign and afterwards accelerated to cross the road. This does not suit and it cannot be determined which option is the correct one. The reconstruction data of the other example (attached as appendix F.2) suggests that both participants braked until rest. If this had been true there would have been no collision what obviously was not the case. So such reconstruction values are not reliable.

Nevertheless to make such cases available for creation of PCM the next step is the generation of assumptions and the definition of default driver and vehicle behavior. Three possible assumptions are:

1) No deceleration/acceleration: $\vec{v}_0 = \vec{v}_k = const.$
2) Full braking: $\vec{a} = \vec{a}_{max} = f(road\ surface/condition)$
3) Default velocity: $\vec{v}_0 = f(road\ type,\ main\ fact)$

"1) No deceleration/acceleration" means that there might be no reaction of the driver and the initial speed equals the collision speed. If there is no information about any deceleration or driver reaction this is an easy assumption to compensate this missing information. Nevertheless it is clear this assumption decreases the accuracy of the real motion. "2) Full braking" means that an emergency braking of the driver is assumed and the deceleration is defined as a function of the road surface and its condition, which gives a hint for the maximum coefficient of friction (additionally an information about the road surface would be helpful and will be introduced at the iGLAD phase II). "3) Default velocity" will only be used when nearly no information about the dynamics data are existing. There a default initial speed as a function of the type of road and its existing speed limit in combination with possible accident's main contributing factor like excessive speeding will be assumed. This assumption would be the worst case and simulated vehicle behavior might be far away from real accidents motion characteristics. Anyway there is no more information available for such case and it should be handled carefully because it is close to a default accident scenario. With these assumptions further 581 cases (in total 877 cases) could be used for creating PCM (see Figure 4.12).

Figure 4.11 summarizes the described procedure for available and missing reconstruction data. Figure 4.12 sets this procedure into action and gives an overview about the affected case numbers (in total already named above) of the iGLAD phase I database per data provider and in total.

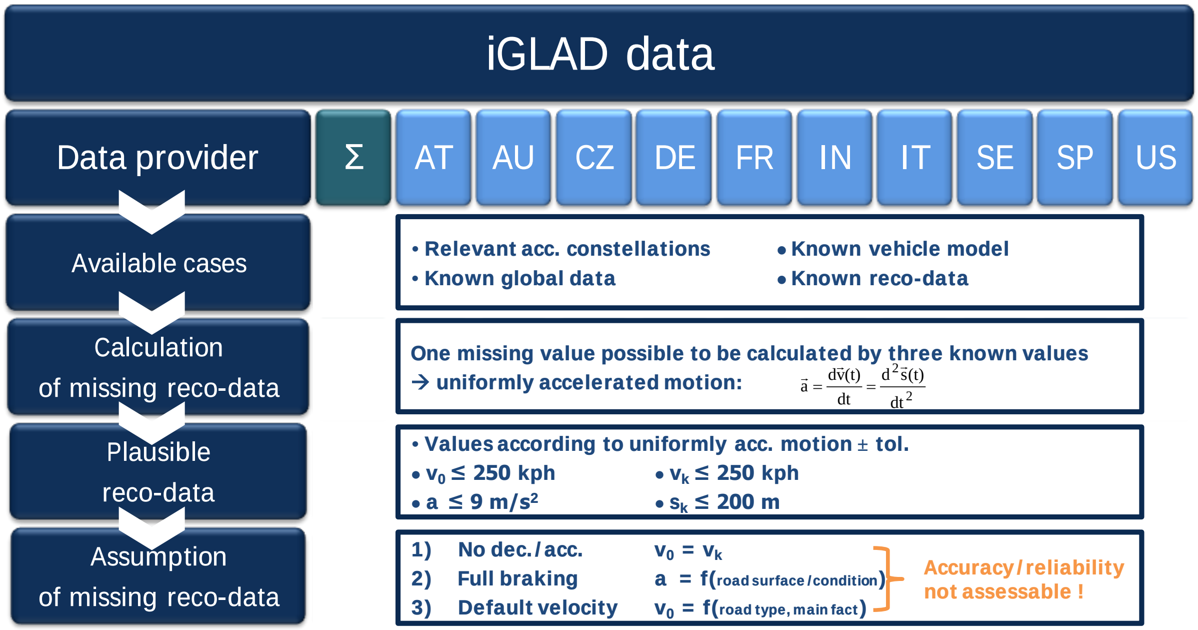


Figure 4.11 – Procedure for missing reconstruction data

iGLAD data	Σ	AT	AU	CZ	DE	FR	IN	IT	SE	SP	US
Data provider	Σ	AT	AU	CZ	DE	FR	IN	IT	SE	SP	US
Available cases	292	16	28	0	59	44	0	141	4	0	0
Calculation of missing reco-data	328	16	32	0	70	45	17	141	4	3	0
Plausible reco-data	296	6	25	0	70	40	14	135	3	3	0
Assumption of missing reco-data	877	72	71	31	127	149	32	148	37	67	143

Figure 4.12 – Available case numbers due to compensation of missing reconstruction data

4.4.4. Surroundings/environments

Necessary information for the surroundings and environment have been stated in chapter 4.2 and analyzed in chapter 4.3.4. They are included in the sketches of each case. Missing surrounding/environmental data can only be compensated by single case analyses causing additional efforts for re-drawing of sketches with the help of all other database information.

These are for example the accident description, global data, participant's data, dynamics data and other information. If there is not enough information available at all, it is not useful anymore to simulate such a low case quality. The main data sources are:

- GPS data with the help of maps data
- Accident description and accident type
- Collision deformation classification (CDC)

The effort to prepare a sketch for the creation of a PCM strongly depends on the format and content of the provided sketch. If the sketch contains all necessary information and is already vectorized, scaled, and layered, it can immediately be used to create a pre-crash simulation. In general, there is no sketch available in the iGLAD phase I data which meets these requirements due to other requirements within iGLAD. However, there are some sketches available which come close like the example in Appendix G.1. For these sketches the effort for rework is low. The majority of the sketches are digitalized but not vectorized (or at least were provided in non-vectorized pixel-format), like the example in Appendix G.2. In these cases the effort is much higher because the sketch has to be redrawn based on the provided one. How big the effort actually is strongly depends on the contained information. Appendix G.3 shows a sketch with sufficient information what leads to low effort, whereas the sketch in Appendix G.4 initially contains insufficient information resulting in a high effort for rework.

iGLAD also contains a certain number of freehand sketches (n=188, see section 4.3.4, Table 4.7), which leads to an enormous effort for redrawing. The accident scene has to be identified manually using the GPS coordinates and the scene has to be redrawn and scaled. Finally there are also cases without a sketch (n=149, see section 4.3.4, Table 4.7) like shown as aerial image of the scene in Appendix G.6. Then no compensation is possible at all.

The summarized procedure, sorted by increasing effort, is as follows:

1) vectorized sketch:
    - allocation of layers to all relevant lines
      → low effort

2) non-vectorized sketch:
    - redrawing of all relevant lines based on the provided sketch
      → high effort

3) freehand sketch:
    - manual identification of the accident scene using GPS coordinates
    - scaling of the sketch
    - redrawing of all relevant lines based on maps and accident description
      → very high effort

4) no sketch:
    - no compensation possible

With the sketches initially provided in iGLAD phase I an automated creation of PCM is not possible. For the majority of cases some effort is necessary to preprocess the sketches to enable pre-crash simulations.

4.4.5. Conclusion

Based on the iGLAD phase I data no accident is directly available for the creation of PCM. With low additional effort for redrawing sketches about 100 cases can be used for pre-crash simulations (see Figure 4.9 and Figure 4.10). However, this is neither a big percentage (around 7 % of the whole iGLAD database) nor significant for worldwide traffic accident scenario because these cases come from almost three data providers (AU, DE, IT). With the application of the introduced compensation methods and some additional effort for redrawing sketches, further 600 cases, meaning more than 35 % of the whole iGLAD phase I data, could be used for pre-crash simulation. On the other hand side it has to be kept in mind that the more compensation methods and assumptions need to be used, the less accurate the simulation of a case becomes. The quality of the data will not be increased with the help of such methods. Affected cases just become available for creation of PCM. After applying many compensation methods the accuracy and reliability is not assessable anymore and the simulation equals more standardized / generic accident scenario than real traffic scenario. So there has to be found a sensible grade of usage of the compensation methods.

4.5. Sensitivity study

Like mentioned in chapter 4.3.2 the iGLAD phase I database does not contain enough information for the creation of PCM regarding to participant data. There is only information available about the vehicle make, model, mass, engine type, engine power, number of seats, and registration year. Especially information about the vehicle’s dimensions is not available sufficiently although it is essential for pre-crash simulations. An automated research for such information by using the given vehicle make, model, and registration year can hardly be realized because of issues described in Table 4.4 and text above. To compensate this lack of information default vehicle models are introduced in section 4.4.2. The idea is to use a default vehicle model instead of the exact one. This enables simulation without the help of an external car database. However, this also affects the accuracy of the results. To get an idea about the magnitude of influence of such assumptions this sensitivity study is done.

To evaluate results it is useful to choose a case which is already available in the GIDAS PCM. The GIDAS database is much more detailed (2,550 GIDAS variables compared to 88 iGLAD variables) and there is also a lot of experience in creating PCMs. So the GIDAS case and its simulation can be used as benchmark. Figure 4.13 shows the sketch of the chosen accident (iGLAD case no.: 14DE0057, GIDAS case no.: 1090574) with its trajectories, collision position, and final position.

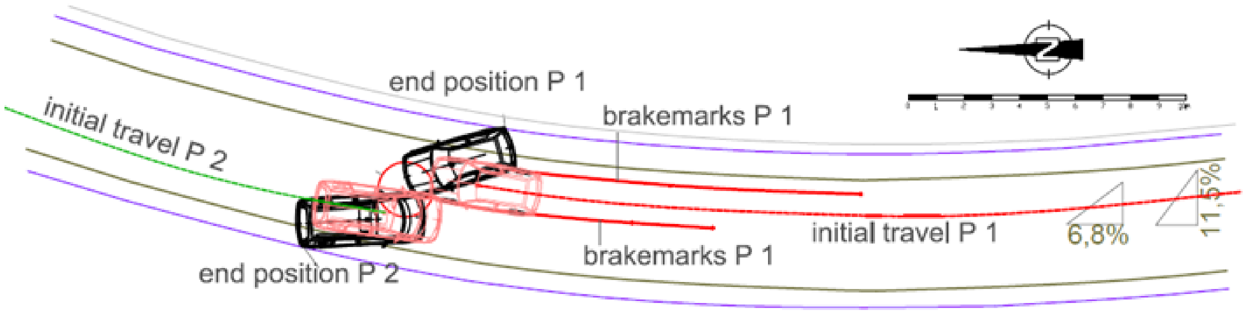


Figure 4.13 – Accident sketch (14DE0057)

It is a small overlap frontal crash where the influence of different vehicle dimensions could appear clearly. Especially the collision position (at time to collision (TTC) = 0 s) might differ. Table 4.12 shows corresponding reconstruction variables for both participants. The "initial speed", the "collision speed" and the "deceleration" are defined like already stated in 4.3.3 and 4.4.3. The "deformation location code" is represented by the third digit of the CDC which specifies the damaged area of the vehicle – either the front, right side, rear end, left side, top or underside of the vehicle. Finally the collision angle is measured between the vectorized velocities of both vehicles.

Table 4.12 – Reconstruction data (14DE0057)

reconstruction data	initial speed [kph]	collision speed [kph]	decelera-tion [m/s²]	deformation location code (CDC)	collision angle [°]
P1 = VW Golf	58	29	6.5	front	177
P2 = Ford Galaxy	40	10	6.9	front	-177

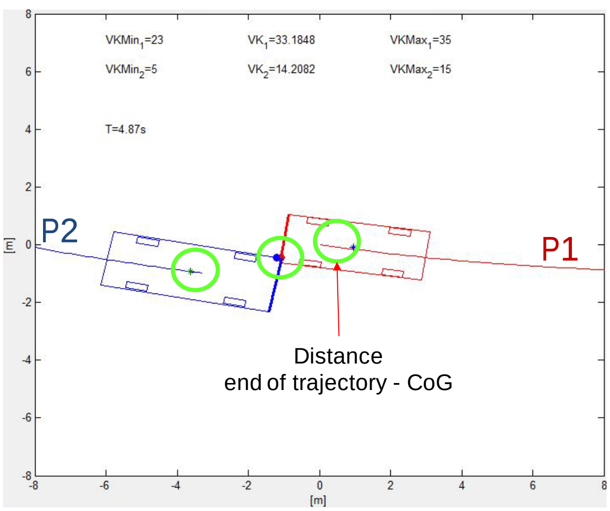
These five values are used to evaluate the results of simulations with varying vehicle dimensions (see Table 4.14). Additionally the cases are compared regarding the distance between the end of the drawn trajectory and the simulated collision position of the vehicle (collision position of vehicle's CoG of forward simulation). This distance arises out of the stated final point of the trajectory in the pre-process of the simulation and the resulting vehicle's collision position by solving. These points do not necessarily lie on top of each other. But the closer they are the more exact the simulation results are.

As first step the accident is simulated based on the exact vehicle dimensions, see Table 4.13. Afterwards its results are compared with simulation results based on the defined default vehicle models, see section 4.4.2, Table 4.9. Summarized the chosen case is calculated four times with varying vehicle dimensions and the results are compared regarding named parameters. Accident sketch's trajectories remained unchanged.

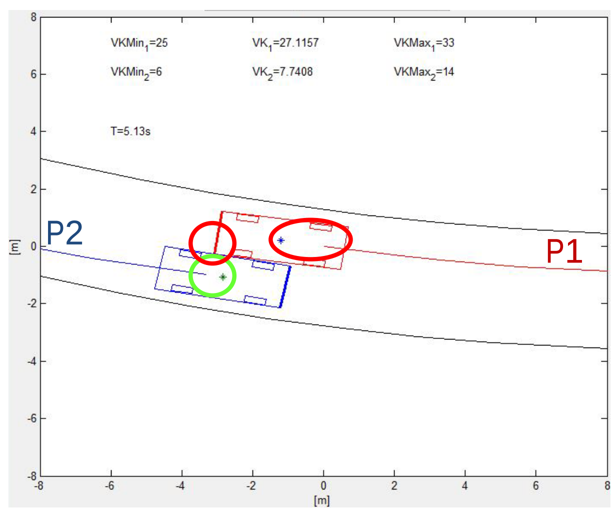
Table 4.13 – Vehicle dimensions (14DE0057)

real vehicle dimensions	length [m]	width [m]	height [m]	wheel base [m]	track width [m]
P1 = VW Golf	4.020	1.695	1.385	2.336	1.460
P2 = Ford Galaxy	4.820	1.884	1.765	2.800	1.600

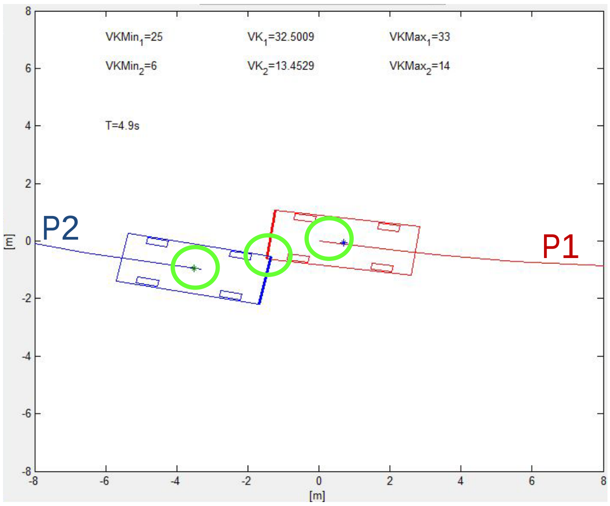
Figure 4.14 a) – d) show the simulated collision positions (at TTC = 0 s) through varying vehicle dimensions. The original case (exact vehicle dimensions) ended with a head-on collision whilst the simulation with the default model "mini" resulted in another collision type (front vs. left side). Furthermore there was a larger deviation of the end of the trajectory to the CoG. A theoretical vehicle model with an even smaller width would have completely missed the collision opponent. This clearly shows an inaccuracy in the use of such default models. It has to be stated that this large deviation especially appeared due to the combination of an actually wide vehicle (Ford Galaxy, width: 1.884 m), the use of the smallest default model ("mini", width: 1.5 m) in a very special collision constellation (small overlap). Figure 4.14 c) and d) show the same case with the medium default vehicle model ("compact") and the large one ("maxi"). The use of both vehicle models each lead to head-on collisions which are nearly comparable to the original case. However, the collision speed of participant 1 (VW Golf) does not match to the original accident. The reason is the large difference between the vehicle length of the actual and the default vehicle which makes up about 90 cm. As a consequence both participants collide earlier, their deceleration distance decreases and thus, their collision speeds are higher than in the original accident.



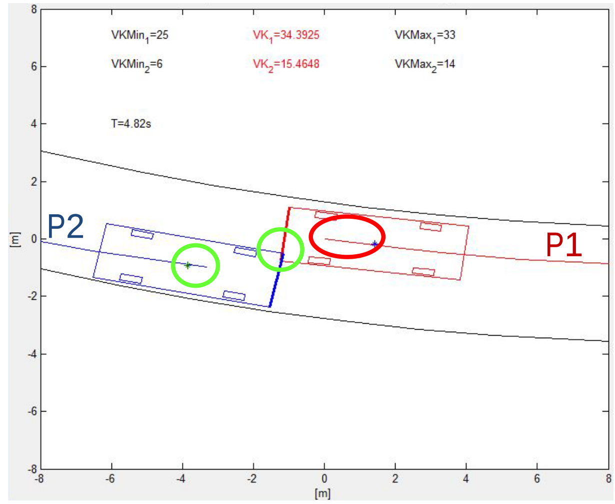
a) exact vehicle dimensions



b) default model "mini"



c) default model “compact”



d) default model “maxi”

Figure 4.14 – Simulated collision positions (at TTC = 0 s) through varying vehicle dimensions (14DE0057)

It can be seen that variations of vehicle dimensions directly influence the simulation results and thereby PCM as shown above. Even other collision constellations are possible (see Figure 4.13 and Figure 4.14 b).

Table 4.14 and

Table 4.15 show the results of both participants and all vehicle dimension variations. Red marked values in Table 4.14 stand for values that exceeded the predefined simulation tolerances compared to the original value in the iGLAD database.

Table 4.14 – Simulation results of participant 1 (VW Golf) (14DE0057)

	iGLAD database	exact vehicle data	default model		
			mini	compact	maxi
Initial speed [kph]	58	58	58	58	58
Collision speed [kph]	29	33	27	32	34
Deceleration [m/s²]	6.5	6.5	6.5	6.5	6.5
Deformation location code (CDC)	front	front	front	front	front
Distance [m]: end of trajectory - CoG	-	0.96	1.2	-0.68	-1.4
Collision angle [°]	177	177	178	177	176

Table 4.15 – Simulation results of participant 2 (Ford Galaxy) (14DE0057)

	iGLAD database	exact vehicle data	default model		
			mini	compact	maxi
Initial speed [kph]	40	40	40	40	40
Collision speed [kph]	10	14	8	13	16
Deceleration [m/s²]	6.9	6.9	6.9	6.9	6.9
Deformation location code (CDC)	front	front	left	front	front
Distance [m]: end of trajectory - CoG	-	-0.34	0.48	-0.21	-0.53
Collision angle [°]	-177	-177	-178	-177	-176

However in the majority of the iGLAD sketches no trajectories of the participants exist. Therefore they have to be redrawn manually using all other available information. This redrawing process influences the same parameters like the variation of the vehicle dimensions. That means that the influence of varied vehicle dimensions is not as high as it seems to be at first. For an overview of influencing factors see Table 4.16.

Table 4.16 – Influencing factors of the simulation regarding

	VEHICLE					SKETCH		
	length	width	height	wheel base	track width	trajectory	collision position	road side
Initial speed	-	-	-	-	-	-	-	-
Collision speed	I	I	-	-	-	I	I	-
Deceleration	-	-	-	-	-	-	-	-
Deformation location code (CDC 2)	I	I	-	-	-	I	I	-
Distance end of trajectory – CoG	I	I	-	-	-	I	I	-
Collision angle	I	I	-	-	-	I	I	-

I ... influence

\- ... no influence

Further studies regarding sensitivity of dynamic values or sketch accuracy are conceivable, but not included in the scope of this study.

4.6. Creation of pre-crash matrices

4.6.1. Preparation process and general challenges

Sections above describe that no creation of a PCM from the entire iGLAD database is possible. Figure 4.10 shows, that there is no case available to initially create a PCM. This is especially a result of the insufficient sketch quality within iGLAD phase I. So based on the point that sketches have at least to be vectorized anyway, there are 117 cases (see Figure 4.10) with sufficient data to create PCM. But a look into detail shows that these 117 cases come from three countries (Australia, Germany, Italy). This cannot be understood as a global PCM. Therefore it was decided to create a PCM including 5 cases per data provider and altogether 50 cases out of 10 countries. This decision caused more effort due to the necessary redrawing of sketches and compensation of missing information. Furthermore, it caused some loss of accuracy for accidents of some data providers. But it also leads to PCM containing cases from as many research areas as possible and develops a methodology to create a PCM out of the iGLAD database for arbitrary cases and coming iGLAD phases. Additionally it gives an estimation of necessary effort per data provider and points out issues for further improvements in coming iGLAD releases.

To keep the use of compensation methods and thereby the loss of accuracy as low as possible the “best” five cases per data provider regarding data quality are chosen. However accuracy is strongly varying through the cases. The following selection criteria were used to identify the “best” five cases:

1) Relevant accident constellations
2) Vehicle model known
3) Known and plausible vehicle dynamics (e.g. not possible for CZ and US cases)
4) Sketch with trajectory, collision position and roadside (e.g. not possible for CZ and IN cases)

Originally only sketches in pixel graphic format existed in the iGLAD phase I database (exceptions are Italian sketches). After choosing 50 cases for the methodical PCM data providers were contacted if they can provide relevant sketches in vectorized format (most of the jpg files suggest that also vectorized ones exist). The use of provided sketches reduced the effort for redrawing them. Appendix H shows the list of chosen methodical PCM cases including their available sketch format.

4.6.2. Creation process

At first the methodology to fulfill all necessary data has to be stated. This methodology is the basis to create a PCM out of the iGLAD database. Figure 4.15, Figure 4.16 and Figure 4.17 visualize the process schematically, divided to the dynamics data, participant data, and the information within sketches. Therein different possibilities for processing can be seen.

If information is sufficient the "✔"-path can be used. If information is not sufficient the "✘ - path" has to be followed and an alternative source has to be used. If there is too much missing data the case finally cannot be simulated and has to be excluded. If all necessary information is available and complete it is possible to create a pre-crash simulation for this case. Figure 4.18 gives the overview of creating PCM out of the required data. The developed methodology can be adapted not only to upcoming iGLAD releases but also to other international accident databases.

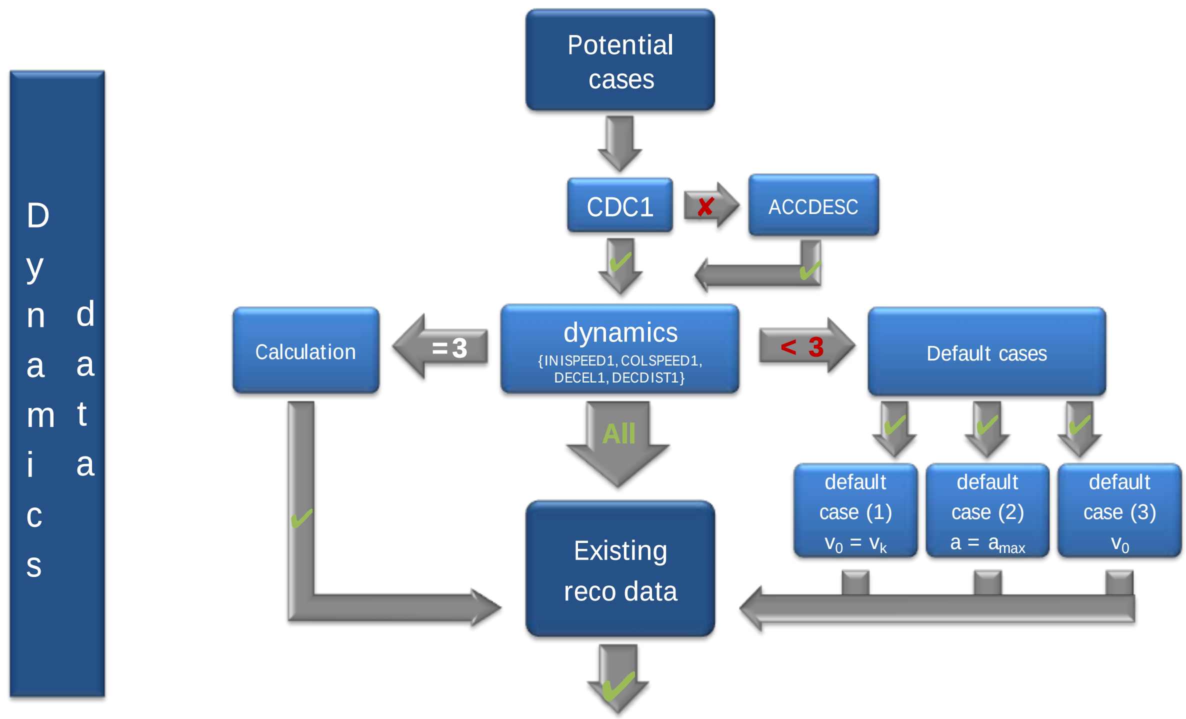


Figure 4.15 – Procedure to fulfill reconstruction (dynamics) data

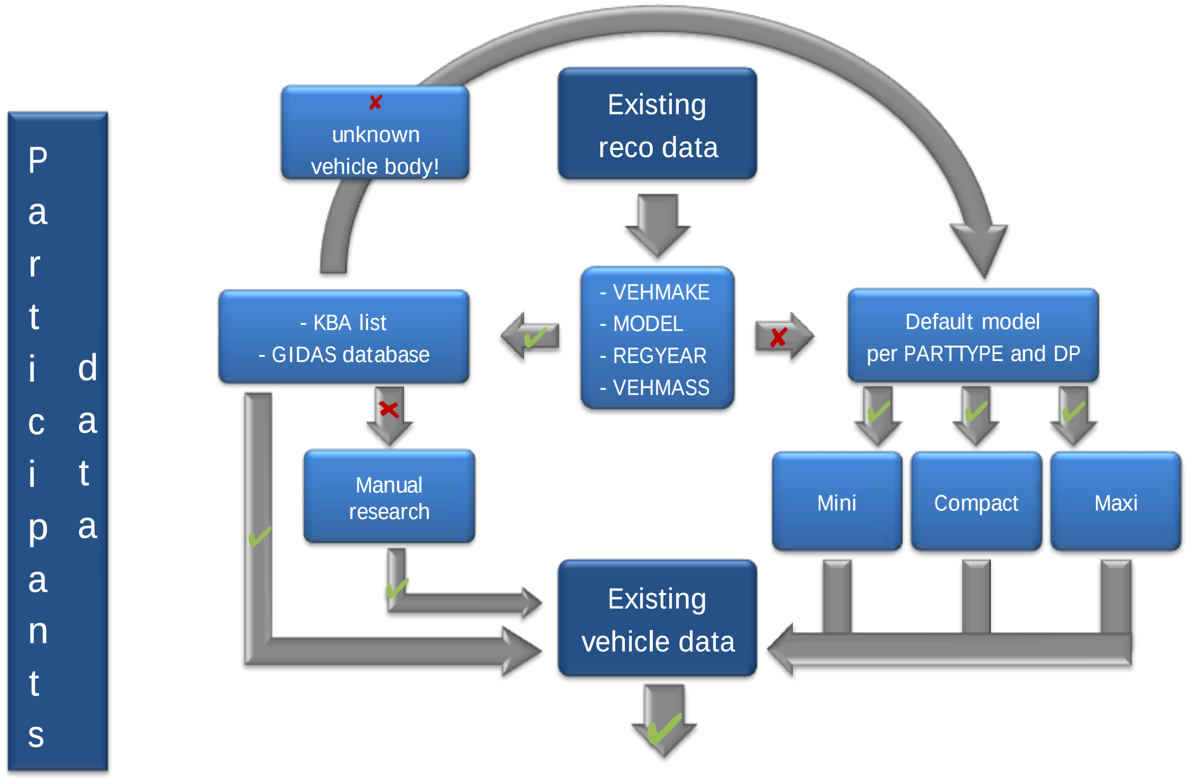


Figure 4.16 – Procedure to fulfill participant data

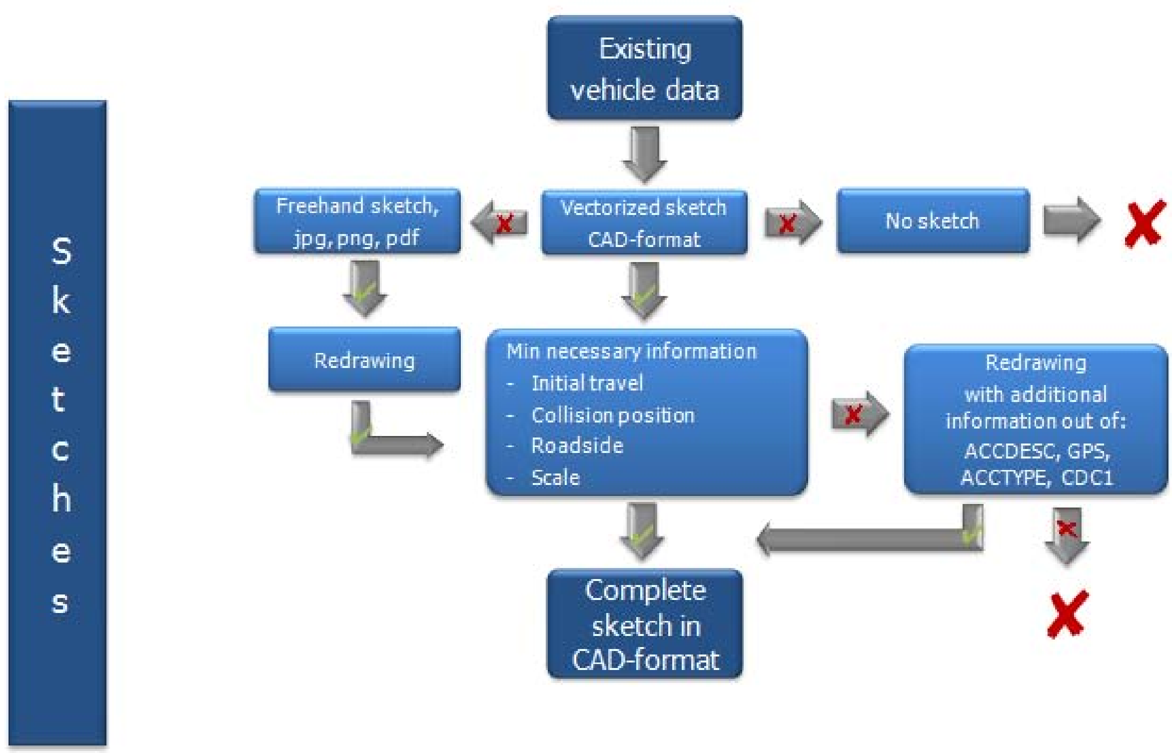


Figure 4.17 – Procedure to fulfill sketches

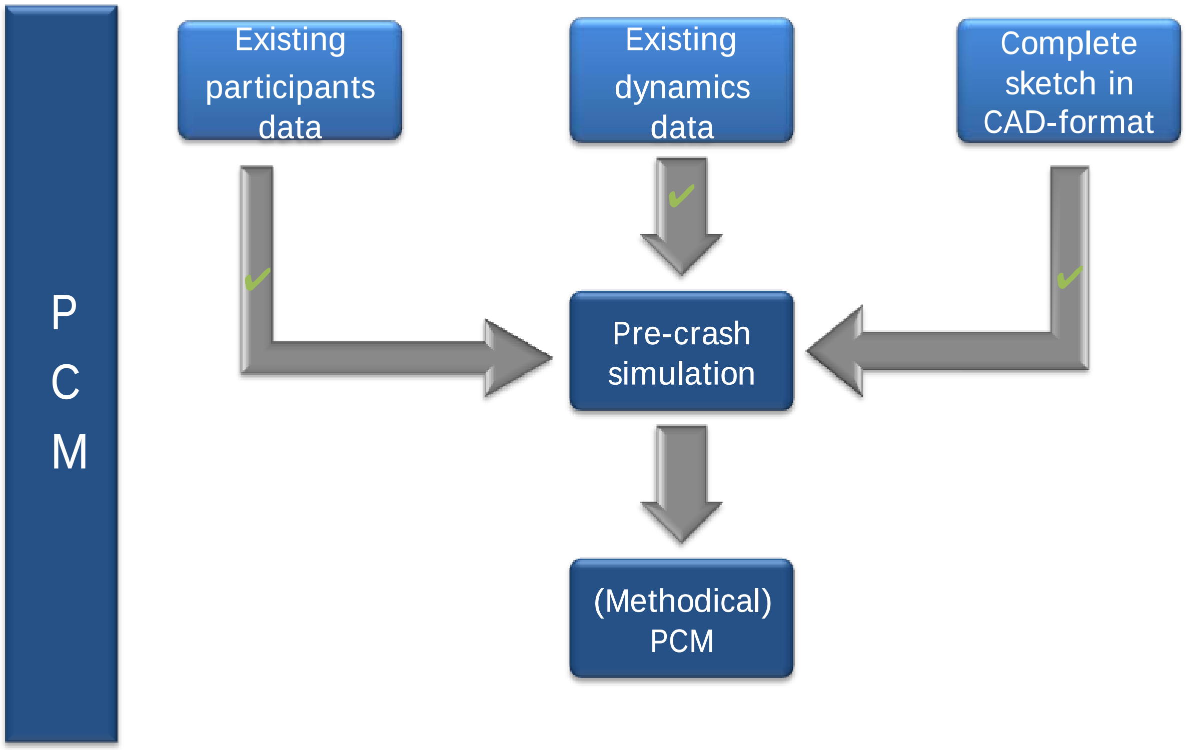


Figure 4.18 – Procedure to create PCM

Building up on the previous results pre-crash simulations are performed for the 50 chosen cases. For cases with non-fulfillment of the minimum requirements compensation methods and assumptions were applied.

Especially the input of reconstruction data is sensitive for the accuracy of the results in the PCM. The more information has to be compensated the less accurate the results will be. Therefore for the 50 PCM cases the applied method to get reconstruction data is shown in Figure 4.19. It can be seen that for the majority of the cases sufficient reconstruction data exists in the iGLAD database (for the best five cases per data provider). For remaining cases an appropriate compensation method is used. It was also necessary to complete the reconstruction data of three participants by single case reconstruction due to of implausible data.

	Participant 1	Participant 2
Complete iGLAD reconstruction data	34	32
Assumption (1) $v_0=v_K$	8	14
Assumption (2) $a=a_{max}$	6	3
Assumption (3) $v_0=f(\text{ROADTYPE, MAINFACT})$	0	0
Single case reconstruction	2	1
Available reco data (for PCM)	50	50

Figure 4.19 – Applied compensation methods for dynamics data

4.6.3. Quality assessment

With the assignment of compensation methods any lack of information is settled and it cannot be separated between cases with high original data quality and cases with very low available information after creating PCM anymore. To have an idea of the accuracy of the resulting pre-crash simulation a look on the originally available data and the used compensation methods per case is taken. So the simulation quality can be assessed.

Figure 4.20 shows the quality classification of simulated cases, basing on the originally available data content and the used compensations methods and assumptions. Finally every simulated case has a quality number, which represents the lowest quality out of reconstruction quality, sketch quality and simulation quality.

Appendix I shows the overview of the five simulated cases per data provider. The quality number in the last column (final quality) gives the final input quality per case. With that quality criterion the input quality per case can be seen, without knowing the exactly used compensation methods or assumptions. This quality number is included in the PCM.

Points	**Quality reconstruction**
5	fulfill and plausible
4	1-2 value(s) missing but bijective
3	2 values missing
2	3 values missing or implausible
1	4 values missing

Points	**Quality sketch**
5	optimal (scaled, final position, collision position, trajectories)
4	scaled, final position, collision point
3	scaled, final position
2	freehand sketch, little information
1	no sketch

Points	**Quality simulation**
5	plausible
1	implausible (e.g. collision speed or lateral acceleration wrong)

Quality evaluation for simulated cases:

lowest quality points becomes the quality number of the simulated case

Figure 4.20 – Quality classification

Quality and time effort of the 50 cases was documented during processing and mean values per case are shown in Table 4.17.

It can be seen, that the mean time effort is strongly varying per data provider (between 21 and 113 min per case). For example the mean time effort for German cases (marked green) is very low. It results from already existing GIDAS based PCM, so sketches in correct format could be used and data satisfies all criteria and plausibility checks. An opposite example with a large time effort are Czech cases (marked red). All sketches are freehand ones, leading to very high effort of redrawing. Further there are no trajectories at all so they have to be assumed and adapted iteratively. This results in almost two hours for processing per CZ case. The summarized time effort for the entire creation of PCM for a mean iGLAD phase I case is 70 min.

Table 4.17 – Time effort for creation of the Methodical PCM

	Reconstruction		Sketch		Simulation	**Ø Required time for processing**
	Mean quality	Ø Effort of time for compensation	Mean quality	Ø Effort of time for redrawing	Ø Effort of time for Pre-Crash-Simulation*	
DP	value	[min/case]	value	[min/case]	[min/case]	[min/case]
AT	3,0	~10	3,2	~15	~30	**~55**
AU	4,2	~3	5,0	~13	~35	**~51**
CZ	2,4	~12	2,3	~41	~60	**~113**
DE	5,0	~1	5,0	~0	~20	**~21**
FR	4,4	~2	4,8	~16	~30	**~48**
IN	4,0	~5	2,8	~34	~40	**~79**
IT	4,4	~2	4,6	~15	~32	**~49**
SE	3,2	~11	3,6	~23	~50	**~84**
SP	3,0	~8	5,0	~14	~60	**~82**
US	2,0	~15	5,0	~19	~60	**~94**
Mean	***3,7***	***~7***	***4,1***	***~19***	***~45***	***~70***

* Simulation time could be further optimized by an automatic data transfer

4.6.4. Additional information for evaluation of ADAS

Beside the already analyzed necessary content (see 4.3) additional interesting information about surroundings are considered. They may be essential for the evaluation of effectiveness of ADAS. It is also considered for methodical PCM cases, even though it does not contain to the minimum requirements for the creation of PCM. The main information of interest and its availability is listed in Table 4.18. The basis are the 140 occupants of the 50 accidents included in the iGLAD PCM. It can be seen that most information is either available for the majority of the cases or not existent at all.

Table 4.18 – Additional information for evaluation of ADAS

Necessary data	iGLAD variable	Available [Qty.] ✔	Not available ✘	Alternative source
time of day	TIME	138	1 %	– (ACCDESC)
scene of accident within road network	✘	✘	✘	ACCTYPE MAINFACT GPS
Environment	✘	✘	✘	ROADTYPE (ACCDESC)
Precipitation	WEATHER1 WEATHER2	140	0 %	– (ACCDESC)
Cloud cover	✘	✘	✘	WEATHER1 WEATHER2
Visibility	✘	✘	✘	FACTOR1, FACTOR2, FACTOR3
Road condition	ROADCOND	140	0 %	FACTOR1, FACTOR2, FACTOR3
Occupant number	OCCNR	140	0 %	– (ACCDESC)
Age	AGE	115	18 %	– (ACCDESC)
Gender	GENDER	136	3 %	– (ACCDESC)
Psychiatric medication	✘	✘	✘	FACTOR1, FACTOR2, FACTOR3
Drugs/intoxicant	✘	✘	✘	FACTOR1, FACTOR2, FACTOR3
Alcohol	✘	✘	✘	FACTOR1, FACTOR2, FACTOR3
Physical disability	✘	✘	✘	FACTOR1, FACTOR2, FACTOR3
Injury severity	INJSEVER	129	8 %	– (ACCDESC)

4.7. Examples of application

By using the created pre-crash simulations it is now possible to evaluate an ADAS on the basis of single cases. Therefore two generic ADAS have been defined. The first two cases are simulated with and with-out an implemented Advanced Emergency Braking system (AEB). This demonstrates the benefit of pre-crash simulations from iGLAD database for the development of global road traffic safety. The implemented pedestrian-AEB system has the following characteristics (also see Figure 4.21):

- sensor range: 50 m
- sensor opening angle: 60 °
- sampling rate: 0.1 sec
- triggering AEB @ TTC ≤ 1.2 sec
- minimum object width: 0.5 m

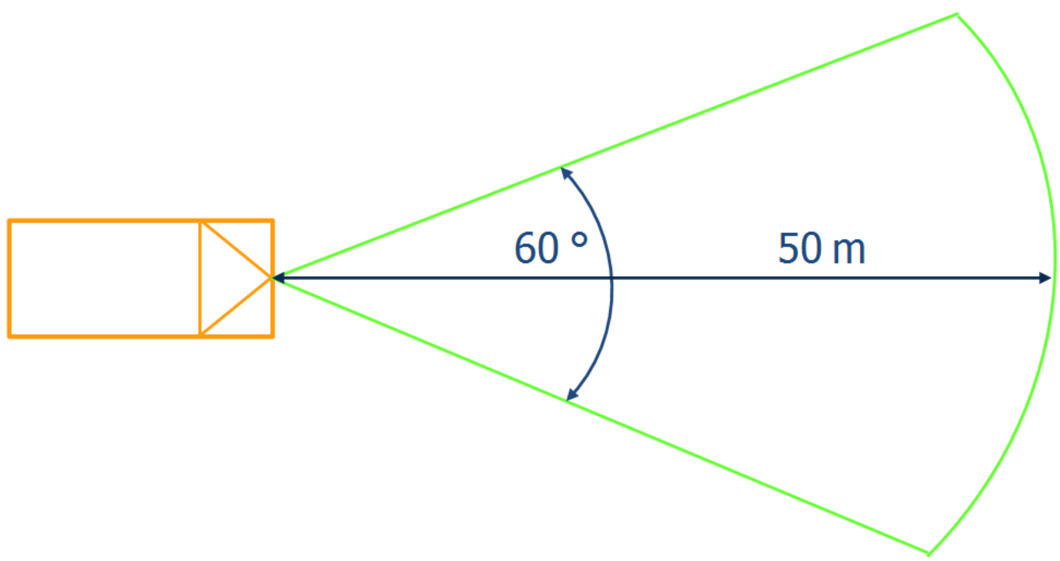


Figure 4.21 – Characteristics of implemented AEB

Figure 4.22 and Figure 4.23 show the collision position of both participants of a passenger car – pedestrian accident (country of origin: Italy). Green lines represent the sensor field of the AEB system. The original collision speed was 31 kph. With the virtually implemented AEB system, which brakes with more intensity, the speed was reduced to 24 kph. So the benefit in this example is a reduction of the collision speed of 7 kph. This information can be used as input parameter for an evaluation with the help of injury risk functions. Visually it can be seen that the accident could almost be avoided, because the pedestrian is hit by the left front corner of the vehicle.

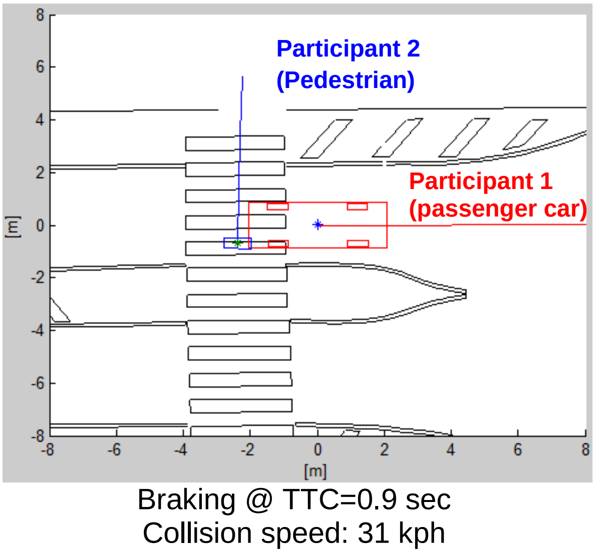


Figure 4.22 – Implemented ADAS – braking without AEB System (14IT0165)

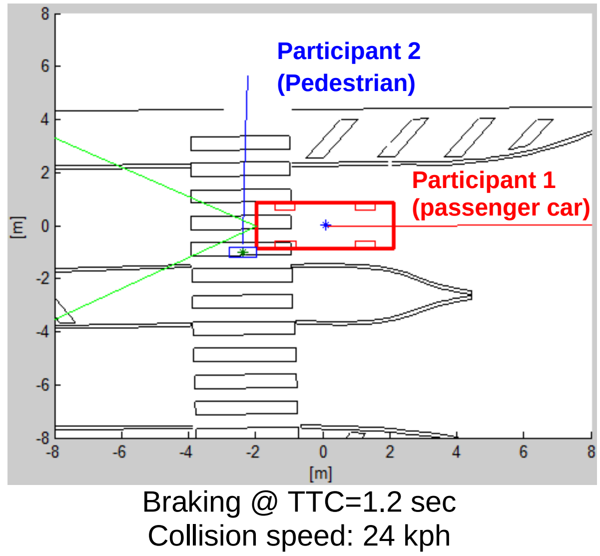


Figure 4.23 – Implemented ADAS – braking with AEB System (14IT0165)

Figure 4.24 and Figure 4.25 show the same implemented AEB for another passenger car – pedestrian accident (country of origin: France). In the original accident a passenger car collides with a pedestrian at a collision speed of 15 kph. With the implemented AEB system the collision could be avoided. So the benefit in this case is the complete avoidance of the collision.

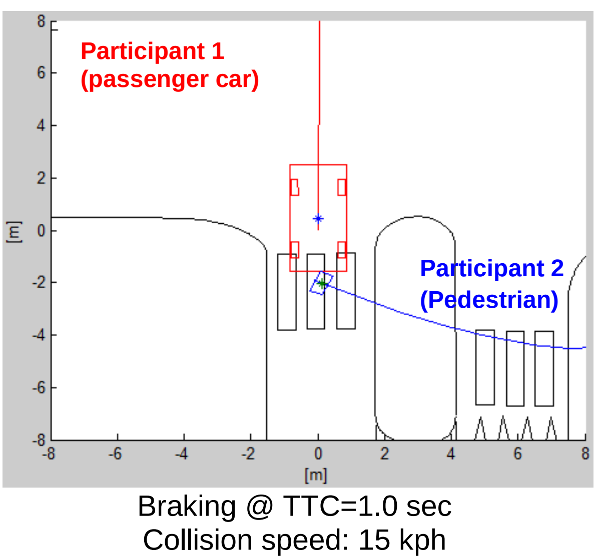


Figure 4.24 – Implemented ADAS – braking without AEB System (14FR0102)

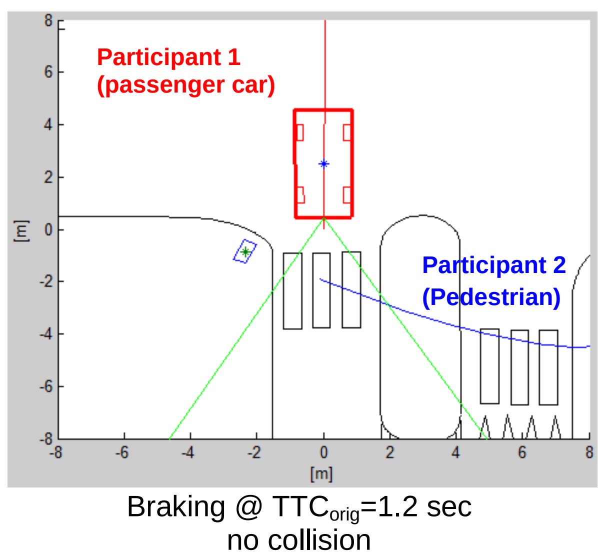
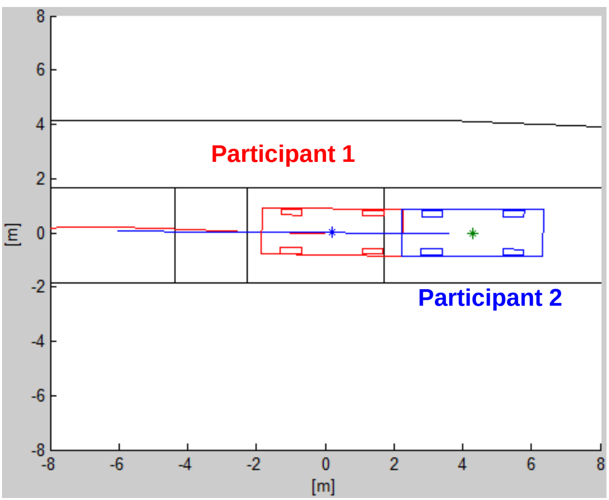


Figure 4.25 – Implemented ADAS – braking with AEB System (14FR0102)

The second application example is a forward collision assist. It is implemented and visualized at a German case (14DE0015). The implemented forward collision-AEB system has the following dataset:

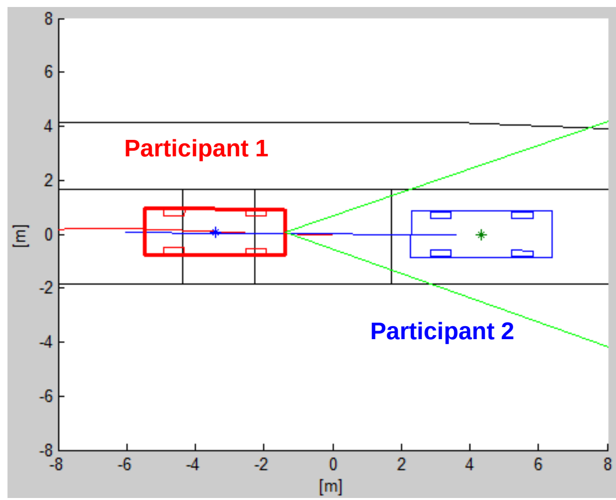
- sensor range: 50 m
- sensor opening angle: 50 °
- sampling rate: 0.35 sec
- triggering AEB @ TTC <= 1.8 sec

Figure 4.24 and Figure 4.25 visualize the original accident on the left hand side and the same critical situation with the implemented collision AEB-system on the right hand side. The active system detects the critical object (here: standing vehicle) and brakes 0.8 seconds earlier than the driver did in the original scene. This leads to an avoidance of the collision.



Braking @ TTC=1.0 sec
Collision speed: 16 kph

Figure 4.26 – Implemented ADAS – braking without AEB System (14DE0015)



Braking @ TTC_{orig}=1.8 sec
no collision

Figure 4.27 – Implemented ADAS – braking with AEB System (14DE0015)

5. Summary and outlook

Pre-crash simulation and evaluation of the effectiveness of several ADAS based on the German In-Depth Accident Study (GIDAS) has already been established and produced significant results, but only for German traffic accident scenario. After the publication of the first iGLAD dataset a study was done dealing with the creation of pre-crash simulations out of international accident databases. The main focus is on the methodology to create a Pre-Crash-Matrix (PCM) from this international database. This also includes the definition of minimum requirements to enable the simulation of vehicle behavior in the pre-crash phase.

Due to the increasing need of a high quality global in-depth database iGLAD is a continuously advancing project. Several groups (e.g. technical working group, steering committee, data administration team) work together for further improvements. This means the database has no finished format and will improve with every phase. Many improvements will result from this study, especially in terms of data quality, plausibility checks and requirements on sketches and reconstruction. The phase II will be finished within 2015, containing accidents from 2012 to 2013. Based on the results of this study some decisions were made by the iGLAD consortium to improve the data quality. Many of them are already included in the current phase II.

Nevertheless the iGLAD database is a reduced dataset compared with GIDAS. Compensation methods were developed how to deal with unknown data with regard to the different data quality and quantity. These are always at the expense of accuracy and reliability of the results. So the more data has to be compensated and assumed, the more the results are closer to standard cases. To address this inaccuracy a quality criterion was introduced. Pre-crash simulations for 50 cases, 5 per data provider, were created and are provided as PCM attached to this final report.

Finally the study shows the unique possibility to analyze active safety systems from a global point of view by implementing and assessing an exemplary ADAS for different global traffic accident scenarios. Thereby already existing ADAS and also systems which are in stage of development can be simulated and their expected benefit can be evaluated on global market.

With the work done within the study, especially with the definition of minimum requirements and the developed compensation methods, it is possible to create pre-crash simulations not only for upcoming iGLAD releases but also for other international accident databases. Thus for the first time the safety potential of ADAS can be evaluated retrospectively and prospectively in the wide variety of global traffic accident scenario.

6. List of literature

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[9] WORLD HEALTH ORGANIZATION: *The global burden of disease 2004 update.* Geneva, Switzerland : World Health Organization, 2008

[10] WORLD HEALTH ORGANIZATION: *Global status report on road safety - time for action*. Geneva : World Health Organization, 2009

[11] WORLD HEALTH ORGANIZATION: *Global status report on road safety 2013: supporting a decade of action.*, 2013

7. List of figures

8. List of tables

A. Catalogue of requirements

Necessary data	Description	Existing iGLAD variable
GLOBAL		
Accident number	Numbering of the accidents.	CASENR
Accident description	Description of the course of the accident.	ACCDESC
Collision type	Moving direction of the involved vehicles at the point of the first collision on the roadway.	COLLTYPE
Accident type	Describes the situation or the conflict that led to the accident.	ACCTYPE
Main contributing factor	The contributing factor that has the main (most critically) influence in triggering the accident.	MAINFACT
GPS coordinates	GPS coordinates where accident happened. Support in case of insufficient sketch	GPS

VEHICLE		
Participant number	Numbering of the participants	PARTNR
Participant type	The type of the participant of the accident. (e.g. pedestrian, bicylce, passenger car etc.)	PARTTYPE
Vehicle mass	The weight of the participant/vehicle at the time of the crash.	VEHMASS
Dimensions	The dimensions of the participant (vehicle body) (width; length; height).	-
Track width (front/rear)	The track width of the (front/rear) axle of the vehicle.	-
Wheelbase	The wheelbase of the vehicle.	-
Tire dimension	Nominal width of tire in millimeters ; Ratio of heigth to width; Rim diameter; Load index and speed symbol	-
COG [x; y; z]	Center of gravity of the participant in the x/y/z-direction.	-
Overhang front	The distance from the front-axle to the leading edge of the vehicle.	-
Inertia tensor [Ixx; Iyy; Izz]	The inertia tensor of the participant/vehicle (moment of inertia in direction of x/y/z-axis).	-
For detailed vehicle models:		
Vehicle make	The manufacturer of the vehicle.	VEHMAKE
Vehicle model	The model of the vehicle. Should be the official label given by the manufacturer.	MODELL
Vehicle engine power	The power of the vehicle's engine	POWER
Registration year	Year of first registration of the vehicle.	REGYEAR
Registration month	Month of the first registration.	N/A
Vehicle model key-number	The model of the vehicle ('Key number 3').	N/A
Type of body	Type of body of the vehicle.	N/A

Necessary data	Description	Existing iGLAD variable
RECONSTRUCTION		
Generally	Complete and plausible	
Participant number	Numbering of the participants	PARTNR
opponent	The opponent of the primary collision.	OPPON1
opponent collision	Number of the collision of the opponent (primary/secondary collision)	NROPPON1
CDC	Deformation characteristics of the vehicle caused by its primary collision	CDC1
Initial speed	Initial speed of the participants	INISPEED1
Collision speed	Collision speed of the participants	COLSPEED1
Tolerance	Tolerance of the value of collision speed.	N/A
Acceleration	Acceleration/deceleration (pos.=deceleration; neg.=acceleration)	DECEL1
Accelerated distance	Brake distance. From the begin of the deceleration/acceleration to the end of the event.	DECDIST1
Coefficient of friction	Coefficient of friction of the road surface.	-
Contact point	The point at the participant of the first contact with the opponent.	-
Roadcondition	The state of the road surface at the time of the accident. As assumption for the coefficient of friction	ROADCOND
Direction	The vehicle's direction of motion immediately prior to the primary collision.	N/A

SKETCH		
Participant number	Numbering of the participants	depending on DP
Trajectory	Course of center of gravity of the participants.	-
Impact position	The impact position of the participants.	depending on DP
Roadside	Includes the geometry of the roadside, out of the digitalized sketch.	depending on DP
For detailed sketch:		
Generally	digitalized, layered with consistent nomenclature, vectorized sketch (e.g. dxf), english descripitons	depending on DP
View obstacle	view-obstacles that affect the accident expiration.	depending on DP
Final position	The final positions of the participants.	depending on DP
Marks continuous	Geometry of the continuous marks of road.	depending on DP
Marks interupted long	Geometry of the interupted marks of road (long).	depending on DP
Marks interupted short	Geometry of the interupted marks of road(short).	depending on DP

B. Requirements/Guidelines for digital accident sketch

VUFO GmbH

TECHNISCHE UNIVERSITÄT DRESDEN

ein Unternehmen der TUDAG

Verkehrsunfallforschung an der TU Dresden GmbH

Guidelines for GIDAS accident sketches

The accident sketch is the basis for the reconstruction of traffic accidents. Furthermore, the accident sketch gives an overview about the accident initiation. All details that are necessary for the accident reconstruction should be included in the sketch.

According to the German standards of sketches a scale of 1:200 is used. The final product in the GIDAS project is a digital accident sketch in graphic format (jpg). Currently, accident sketches in the GIDAS project base on the following tools and methods:

1.) Tools

Traditional measuring instruments:
- Measuring tape
- measuring wheel (odometer)

(Accuracy within ± 5cm)

Electronic measuring equipment:
- Laser distometer
- Laser scanner
- Digital water-level

(theoretical accuracy in the cm range)

2.) Methods

At the accident site the following methods are used:
- the rectangle-(coordinate) measuring method
- the triangle measuring method
- the photogrammetric measuring method
- the measuring method for curves and
- the laserscan.

The application of a suitable method and the selection of the measuring instrument is decided by the investigator depending on the situation on the accident site. A fixed presetting is not possible/useful due to the different accident situations (traffic density, available time, light and weather conditions etc.).

If the creation of a sketch at the accident site is not feasible (e.g. due to high traffic, missing knowledge about the actual accident site) the accident sketch will be created in afterwork.

The sketch is later transferred into a CAD program (usually AutoCAD®). During that process the raw sketch (hand made) is processed to the digital accident sketch. To reproduce the appearance of the road layout aerial images can be used.

The following represents the necessary contents of an accident sketch according to the GIDAS agreements.

1. Traffic Area

The accident sketch represents the traffic area around the accident scene. Therefore, the following requirements should be considered:

The sketch should cover the collision point and the surrounding traffic area within (at least) the "length" of the permitted speed assimilated in meter (Example: urban area, crossing accident, permitted speed = 50kph means that the sketch should cover the road of both involved parties up to 50m in both directions). On motorways at least 200m should be covered.

This length has to be seen as the minimum range. In general, the location of the critical (accident causing) situation has to be part of the accident sketch.

For example: If a vehicle collides on a straight road after driving through a curve, the passed curve is necessarily part of the accident sketch.

The sketch should include the following elements of the traffic area:

- *the road geometry*
(limited by the edge of the carriageway, curbs)

- *all road markings*
(in principle; i.e. a scaled illustration of the different lines is not required in almost all cases (e.g. the distance of the gaps of interrupted lines). To show the correct marking type the relevant layer should be used (see below "Layer"). By using the right marking types the carriageway will be represented (lanes, cyclepaths, etc.).
Furthermore, additional markings (e.g. arrows with permitted driving directions)) should be part of the sketch (again in principle).

- *Traffic control devices, traffic signs, traffic lights*

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- Slope information

The longitudinal and lateral slope has to be stated for each involved vehicle in their direction of travelling. If there are relevant changings in the slope this should be also considered in the accident sketch (dashed line, dotted line, etc.).
Usually roads have a lateral slope: Either the road has a one-sided slope or the highest point is in the mid of the road and there is a slope towards both edges of the road. In all cases each slope has to be measured.

2. Environment and view obstacles

The sketch should further contain all relevant elements in the environment that are necessary for the reconstruction of the accident:

Collision objects

Every collision object has to be in the sketch. Round collision objects (poles, pilars, trees, ...) require an indication of the diameter.
If there is an impact on planar objects (eg. guardrails), the contact area should be presented separately as collision area.
In order to follow the driving line of the vehicles in the roadway, it may be necessary to include further objects in the direct environment of the potential trajectory of the vehicle.

Traffic control devices

All elements which guide the vehicle (e.g. guard rails, posts, railings, ...) should be included in the sketch (similar to collision objects).

Roadside profile

The roadside profile is part of the accident sketch for collisions with objects beside the road and/or all accidents where a vehicle left the road. Then, the profil is provided in cross-sections for the point of road departure and/or object collision. In case of changing profiles different sections are necessery. To ensure a better readability of the profiles they are not drawn with a scale of 1:200. However, they have to be dimensioned in the sketch.

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View obstacles

View obstructions should be included in the sketch. This is often relevant for accidents involving two or more participants. Here, all (potential) view obstructions (parked or standing vehicles, walls, buildings, trees, fences, etc.) have to be specified in the sketch with their exact position. A distinction between permanent and non-permanent view obstacles is made.

Driving/Standing vehicles (not parked vehicles) as view obstacles have to be drawn in principle with their probable position. Their exact position can not be defined because this ic changing over time.

View obstructions can also be relevant in single vehicle accidents (resulting from the road design or the environment). Usually they can not be drawn directly into the sketch but should be described in an additional remark.

3. Accident marks and traces

All discovered marks have to be measured and provided in the accident sketch. If they cannot be measured accurately they should nevertheless be drawn described specifically (e.g. "end position, derived from police images").

Final positions

The vehicles have to be drawn in their final positions using realistic vehicle shapes. If the final position can not be identified exactly (e.g. final position of bicycles on the basis of witness statements) an area covering the probable final position should be marked in the sketch. The same applies for the final positions of persons.

Marks

If possible every mark should be allocated to the causing participant. Furthermore, the marks should be labelled as exact as possible, including the type of mark, e.g.:

- braking mark	- skidding mark
- drifting mark	- slipping mark
- scratch mark	- pitting marks
- liquids	- areas with (glass) splinters

- abrasion mark (e.g. from pedestrian's / cyclist's clothing

Areas in the roadside with thrown up earth should also be mentioned as collision area or mark of a participant.

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Collision areas, collision point
The identified collision point/area has to be marked in the sketch in principle. In addition to the basic accident sketch the reconstruction creates an accident reconstruction sketch in which the collision positions of the involved vehicles are given.

4. Driving lines (trajectories)

The driving lines of the involved participants have to be drawn in dependence of the direction of the vehicle up to the first collision. The trajectory ends at the center of gravity of the vehicle in the collision position. At first, the trajectory is roughly drawn by the investigator (creator of the sketch) and will later by precised by the reconstruction engineer. The correction is made in the reconstruction accident sketch (_ZUR).

Parking (also standing) vehicles also get a driving line. It is drawn in longitudinal direction of the vehicle and ends behind the outermost longitudinal extension of the vehicle.

For pedestrians an estimated walking/running line is drawn in the form of a driving line.

5. Descriptions

The following descriptions have to be given at least:

- involved vehicles and persons in their final position
- driving / walking lines of involved vehicles and persons
- Type of road usaer *(e.g. Participant 1: pedestrian, Part. 2: Mercedes Vito)*
- Street names
- Road directions
- Marks and traces
- Collision areas and collision objects
- other relevant/necessary comments (eg. "icy areas", "slope change", etc ...)

6. Layer

All drawings in the accident sketch should be made in the agreed layer system (see Appendix). The use of own (or new) layers is not allowed. They have to be transferred into the pre-defined and agreed layers.

7. Additional tools

To scale the sketch a measure scale must be used. Furthermore, a north arrow should be used to enable the orientation of the sketch to north. To provide further informationn (e.g. explanation of the accident initiation, details of the accident, accident time, etc.) an appropriate text field should be filled .

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Basic component of the digital accident sketch is a defined layer hierarchy. In addition to the defined objective requirements of an accident sketch (accident sequence, end positions, labels, etc.), the "Layering" of the sketch represents the increased scope of services. In the following the whole to be used layer hierarchy is presented and, if necessary, explained. In Document 2 "Notes on the use of layers in the digital sketch" special use principles are illustrated and explained.

Complete hierarchy of layers

Resting positions

ENDLAGEN	Resting positions of participants

Collision points and areas

KOLLBER	Collision points and areas
KOLLOBJ	Collision objects (e.g. trees, walls etc.)
KOLL1R	Position of the collision 1 (Reko), (Collision 1)
KOLL2R	Position of the collision 2 (Reko), (Collision 2)
KOLL3R	Position of the collision 3 (Reko), (Collision 3)
KOLL4R	Position of the collision 4 (Reko), (Collision 4)

Traces

SPBET1	Traces participant 1
SPBET2	Traces participant 2
SPBET3	Traces participant 3
SPBET4	Traces participant 4
SPBET5	Traces participant 5
SPBET6	Traces participant 6

Driving lines/trajectories

Are created as SPLINE directional in the direction of travel of the vehicle. The driving line ends in the center of gravity of the parties in conflict position. For pedestrians there is also a driving line, created analogous to the assumed walking line. Parked vehicles get out of simulation reasons also a driving line.

FLBET1	Driving line Participant 1
FLBET2	Driving line Participant 2
FLBET3	Driving line Participant 3
FLBET4	Driving line Participant 4
FLBET5	Driving line Participant 5
FLBET6	Driving line Participant 6

Traffic area

FBAHNRAND	Edge of the carriageway
FS-BEGRENZ	Mark of the roadway

The layer FS-LIMIT regulates the limitation of the roadway clear.
The edge of the road is a curb or end of the asphalt, etc..
In case of cutouts the edge of the roadway is situated behind the cutout. An additional mark (FS-BEGRENZ) represents the planar transition from road and parking bay.

DURCHGEZOG	Marking continious
UNTERLANG	Marking interrupted
UNTERKURZ	Marking interrupted short

BAHNGLEISE	tracks
ORIGINAL	Marking interrupted original (Layer for working purpose, e.g. to draw originally markings. Does not appear in the finally accident sketch!)
DICKELINIE	Fat Marking (e.g. markings on Autobahn, everytime longitudinal to the direction of the road)
STOPPLINIE	Marking Stopp (Stopp-mark on crossroads, Busstops, etc., …)

Roadway environment

RADWEG	Bicycle path
FUSSWEG	Pavement
VERKZEICH	Traffic sight
LEITPLANKE	Roadsidebarriers
SONST	Others
GELAENDE	Terrain

Additional tools

BESCHRIFT	Descriptions
HM_REFEREN	Reference layer
HM_A3_RAH	Frame A3
HILFSLINIE	Construktionline
HM_A4_RAH	Frame A4
HM_A2_RAH	Frame A2
NORDPFEIL	Northern arrow

View obstacles

SICHTHIND1	Permanent view obstacle (e.g. houses, walls, trees, etc., … For houses: visible edges has to be layered as "SICHTHIND1". Ensure that can not be looked "behind" through the houses.
SICHTHIND2	Not permanent view obstacle (parking cars: Has to be layered as "others" and then has to lay a rectangle of the layer "Sichthind2" around)
SICHTHIND3	Driving vehicles (view obstacling driving cars, also traffic jam)

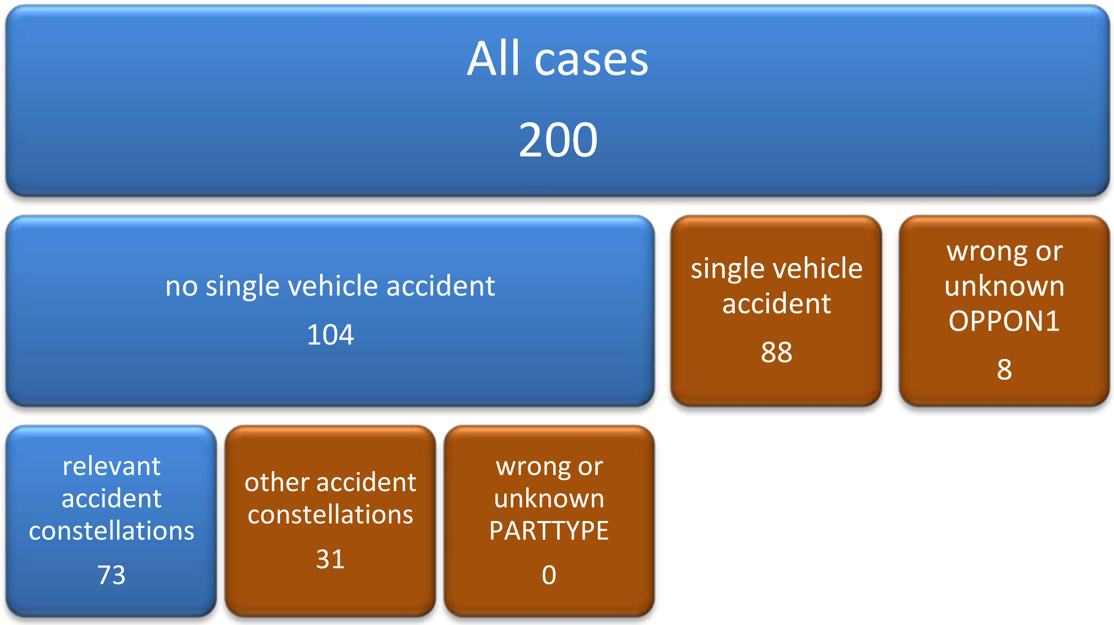
C. Detailed list of collision combinations in the iGLAD database

Participant 1	Participant 2	Quantity of collision combinations* absolut	relativ
	SUM	1550	100%
passenger car	passenger car	530	34,2%
passenger car		296	19,1%
pedestrian	passenger car	170	11,0%
PTW	passenger car	166	10,7%
passenger car	bus/truck	101	6,5%
bicycle	passenger car	57	3,7%
PTW	bus/truck	40	2,6%
PTW		37	2,4%
PTW	PTW	36	2,3%
passenger car	others	34	2,2%
bus/truck	bus/truck	16	1,0%
combinations < 1%		67	4,3%
bicycle		9	0,6%
pedestrian	bus/truck	9	0,6%
pedestrian	PTW	8	0,5%
bus/truck		7	0,5%
others		6	0,4%
bicycle	bicycle	5	0,3%
bicycle	PTW	5	0,3%
pedestrian	bicycle	4	0,3%
bus/truck	others	4	0,3%
unknown		4	0,3%
PTW	others	3	0,2%
pedestrian	others	1	0,1%
bicycle	bus/truck	1	0,1%
bicycle	others	1	0,1%
pedestrian		0	0,0%
pedestrian	pedestrian	0	0,0%
others	others	0	0,0%

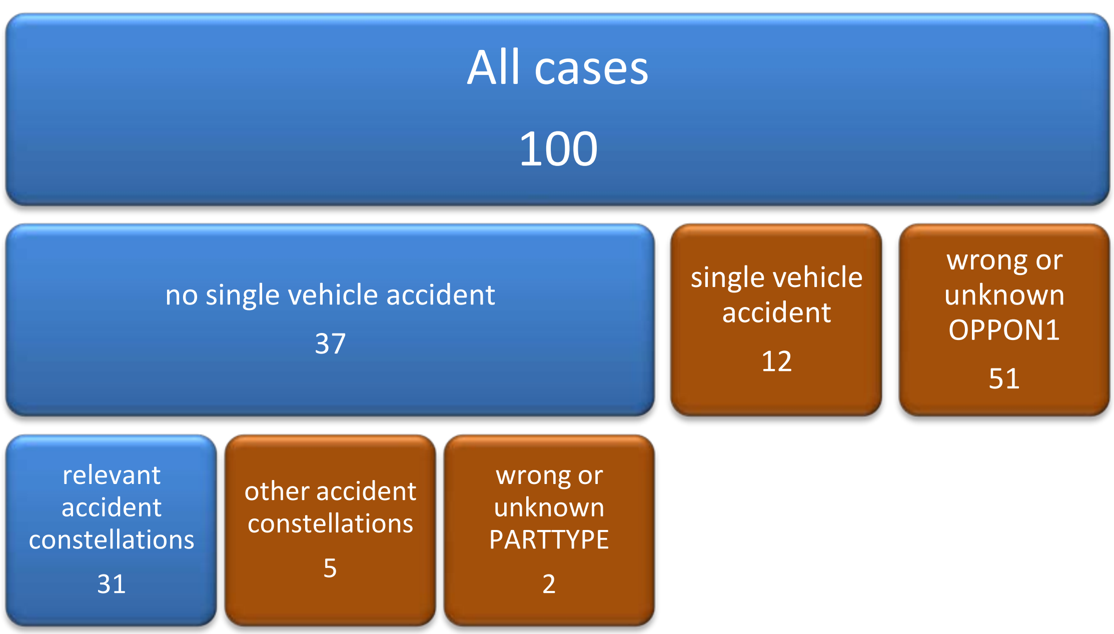
* no information available about causer and non-causer

D. Details of relevant accident constellation issues

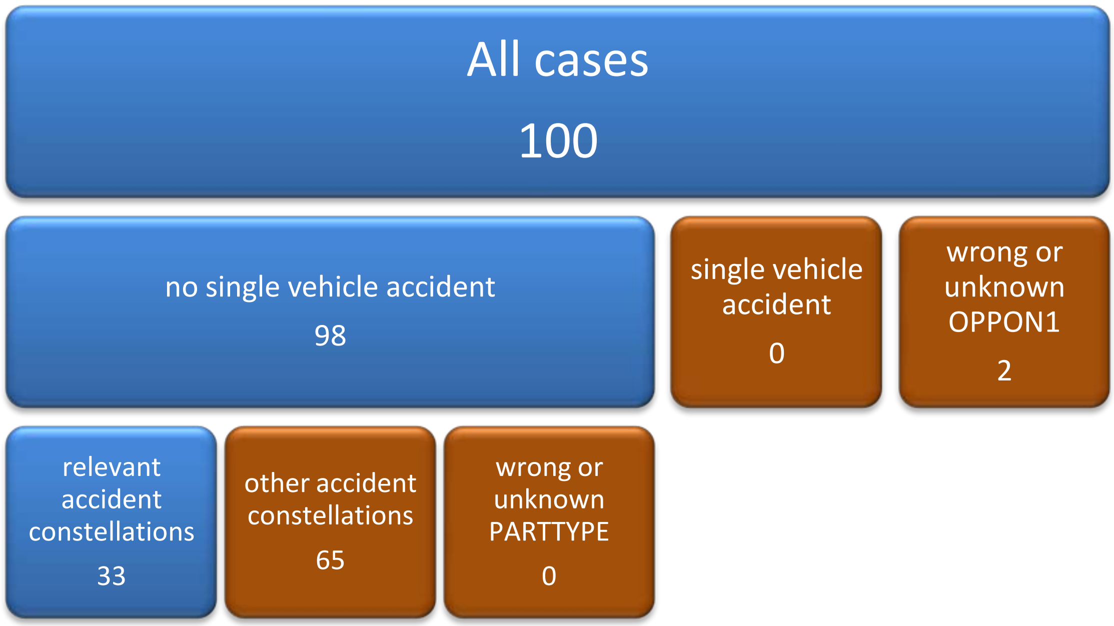
D.1 Austria



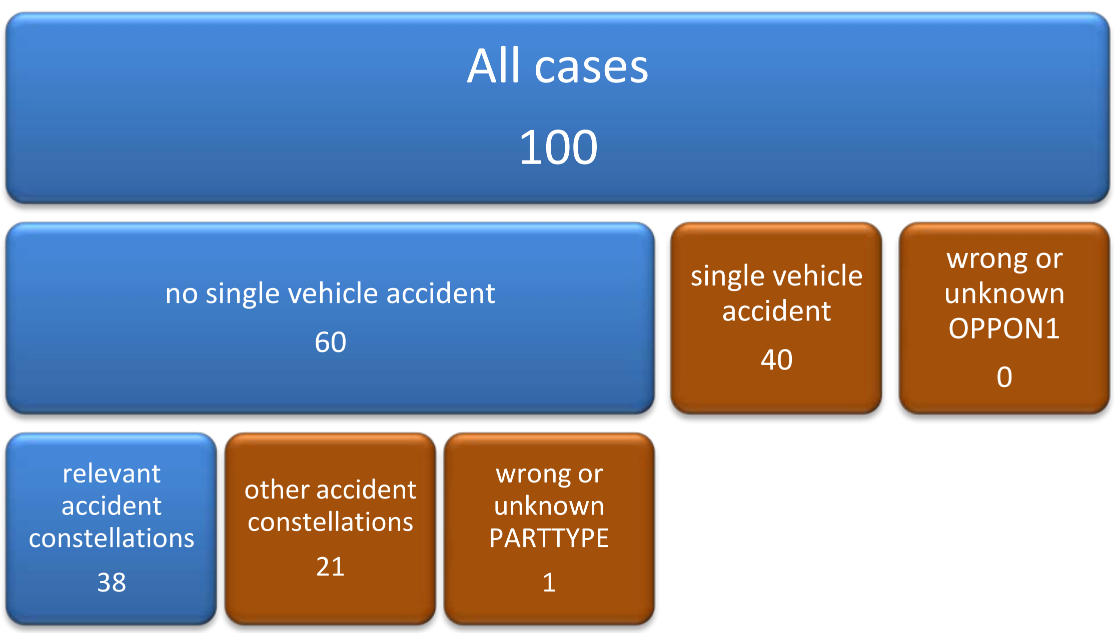
D.2 Czech Republic



D.3 India

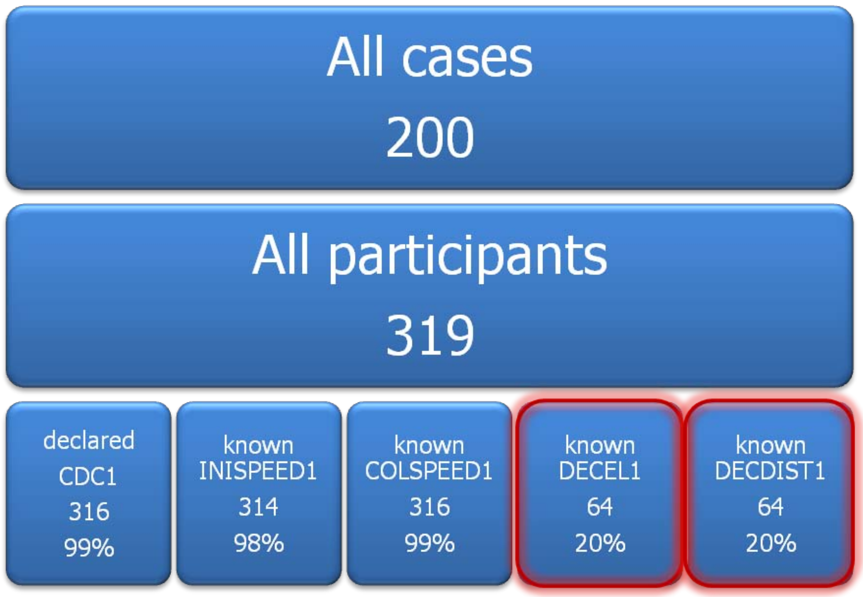


D.4 Sweden

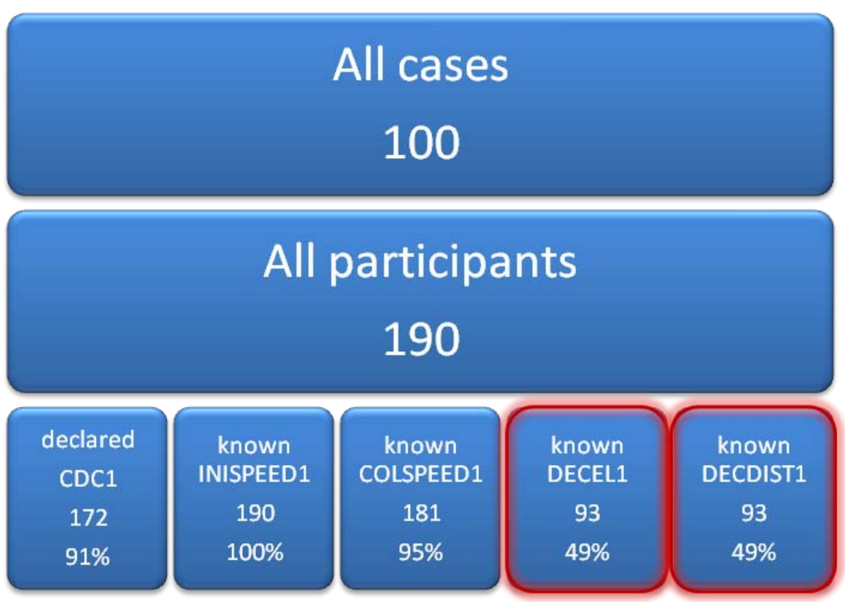


E. Details of dynamics data content issues

E.1 Austria



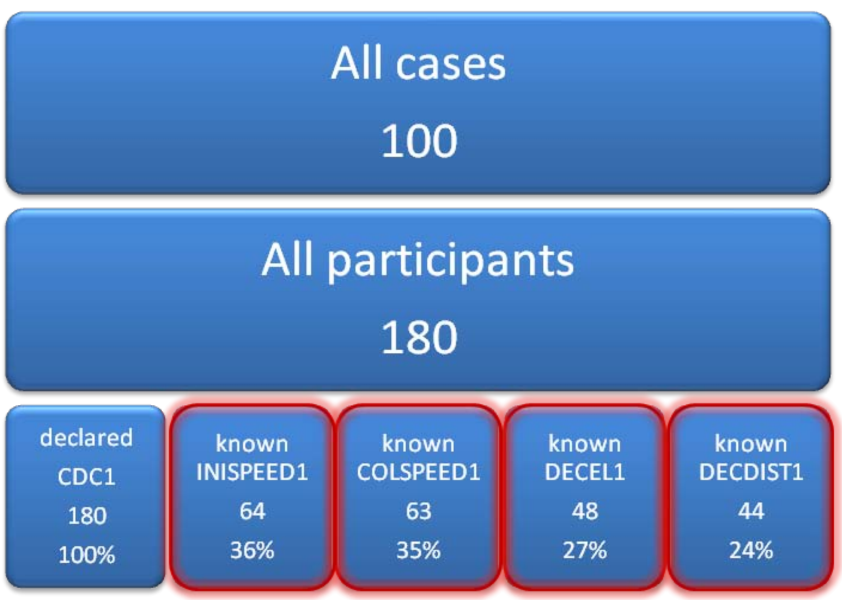
E.2 Czech Republic



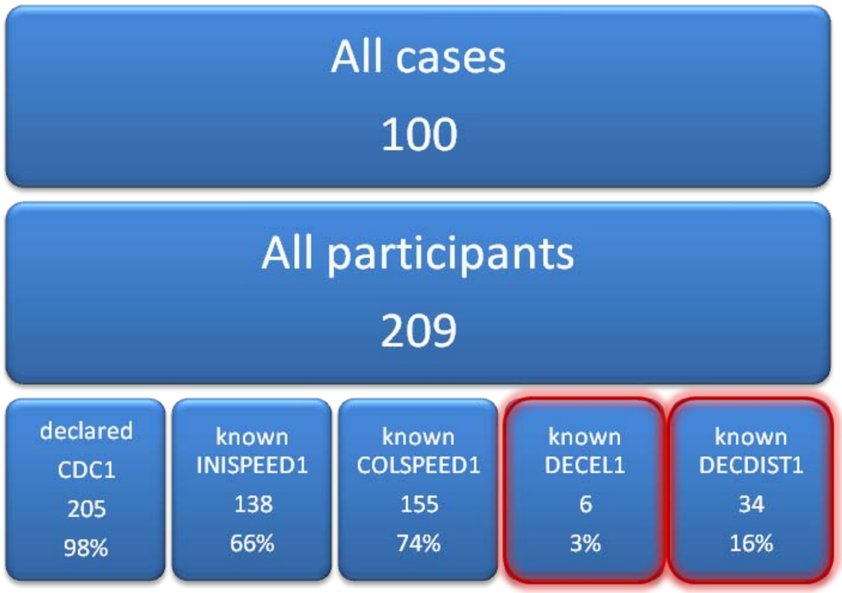
E.3 India

*93 participants with "known" DECEL1=0 m/s^2 and unknown {INISPEED1, COLSPEED1, DECDIST1}

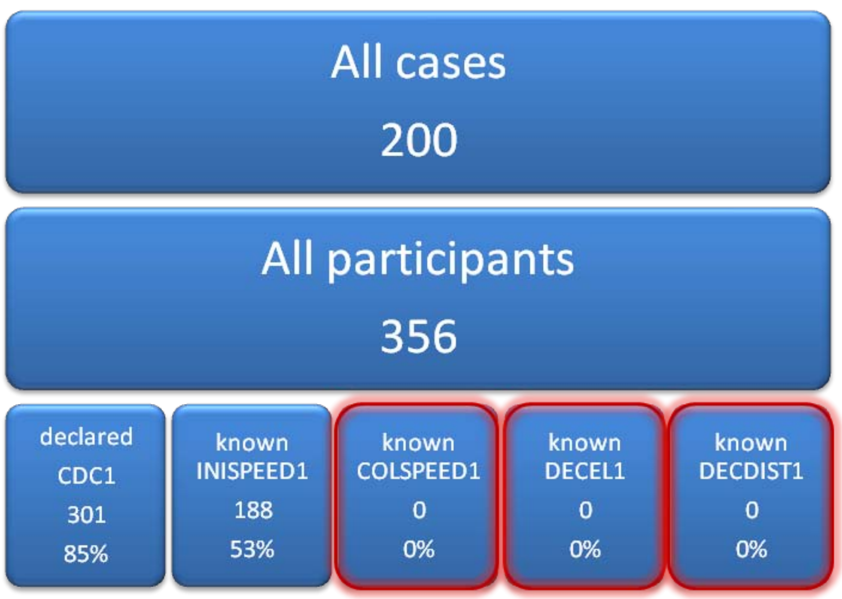
E.4 Sweden



E.5 Spain



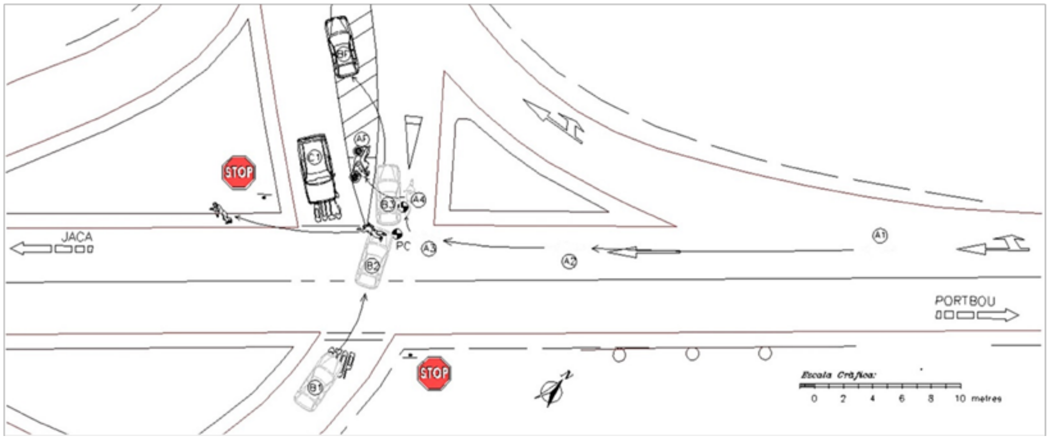
E.6 United States of America



F. Examples of reconstruction data issues

F.1 Incomplete reconstruction data (1)

CASENR	PARTNR	PARTTYPE	INISPEED1 [km/h]	COLSPEED1 [km/h]	DECEL1 [m/s²]	DECDIST1 [m]
14SP0092	1	3	53	53	9999.9	9999.9
14SP0092	2	5	24	25	9999.9	9999.9

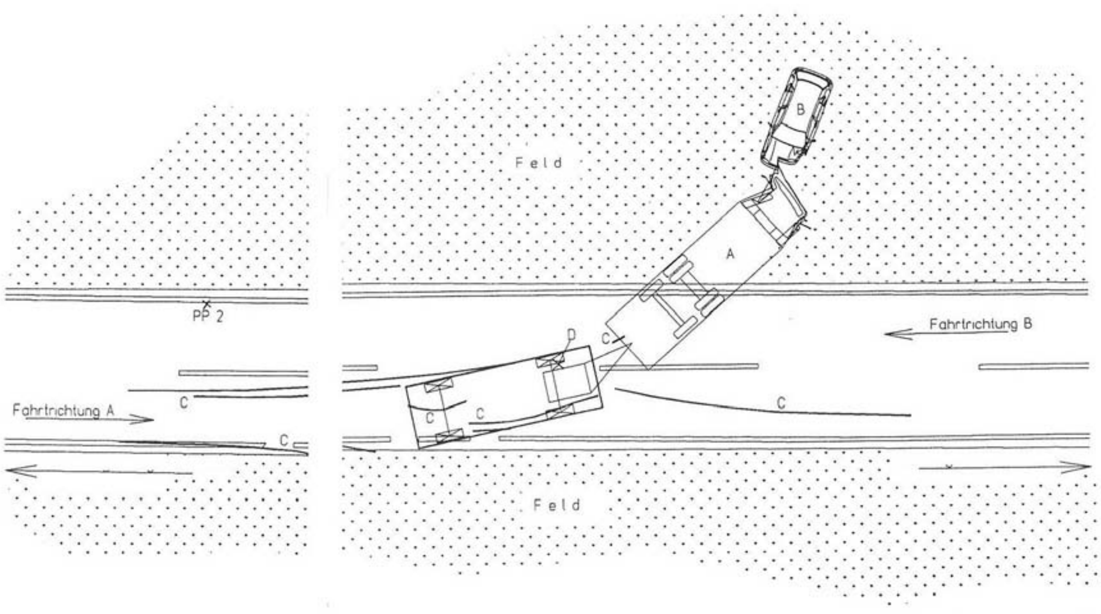


F.2 Incomplete reconstruction data (2)

CASENR	PARTNR	PARTTYPE	INISPEED1 [km/h]	COLSPEED1 [km/h]	DECEL1 [m/s²]	DECDIST1 [m]
14CZ0052	1	5	55	0	9999.9	9999.9
14CZ0052	2	5	50	0	9999.9	9999.9

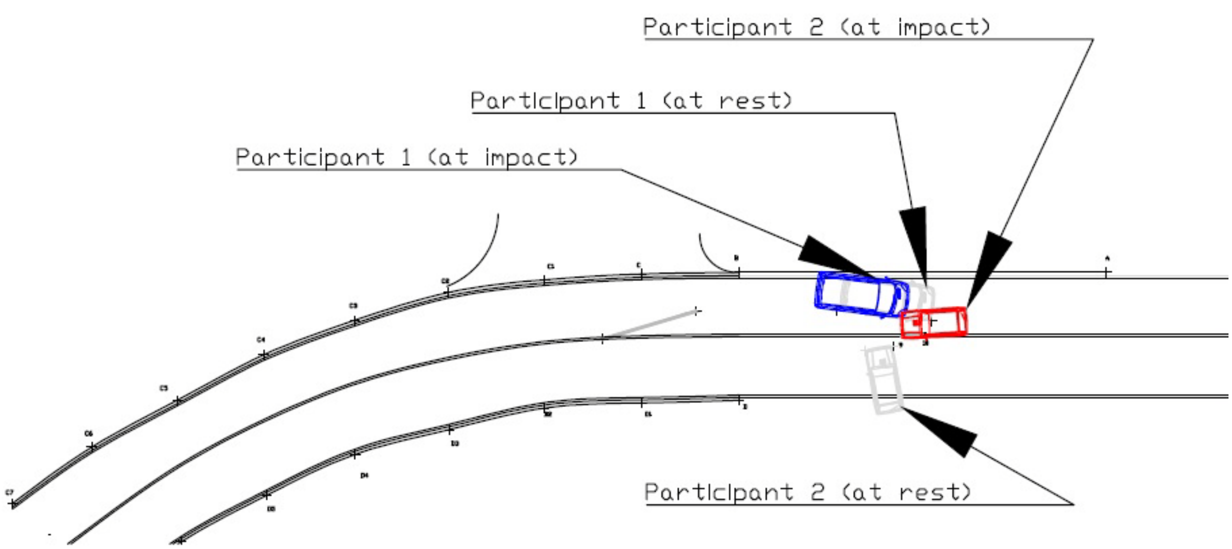
F.3 Implausible reconstruction data

CASENR	PARTNR	PARTTYPE	INISPEED1 [km/h]	COLSPEED1 [km/h]	DECEL1 [m/s²]	DECDIST1 [m]
14AT0078	1	11	68	41	0.2	46.7
14AT0078	2	5	71	50	0.3	47.6
Evaluated initial speed			**44.3**	41	0.2	46.7
			52.9	50	0.3	47.6
Evaluated collision speed			68	**65.9**	0.2	46.7
			71	**68.8**	0.3	47.6
Evaluated deceleration			68	41	**2.4**	46.7
			71	50	**2.1**	47.6
Evaluated deceleration distance			68	41	0.2	**481.2**
			71	50	0.3	**386.7**



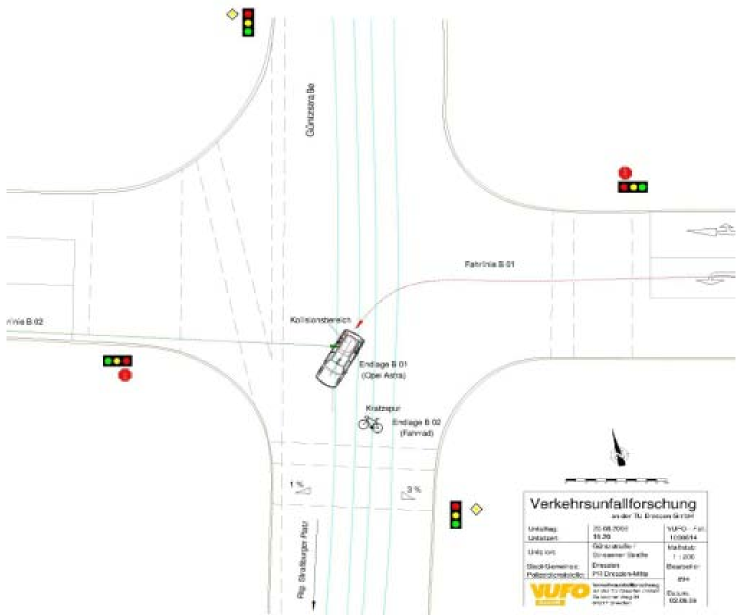
F.4 Plausible reconstruction data

CASENR	PARTNR	PARTTYPE	INISPEED1 [km/h]	COLSPEED1 [km/h]	DECEL1 [m/s²]	DECDIST1 [m]
14IT0114	1	5	109	94	5.9	21.2
14IT0114	2	5	65	65	0	0
Evaluated initial speed			**109.8**	94	5.9	21.2
			65	65	0	0
Evaluated collision speed			109	**92.9**	5.9	21.2
			65	**65**	0	0
Evaluated deceleration			109	94	**5.5**	21.2
			65	65	**0**	0
Evaluated deceleration distance			109	94	5.9	**19.9**
			65	65	0	**0**

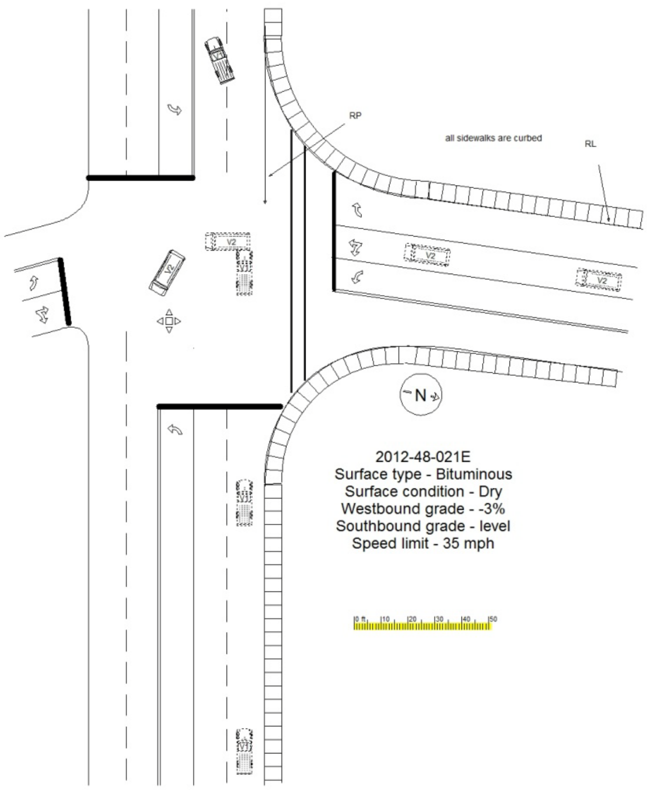


G. Examples of sketch issues

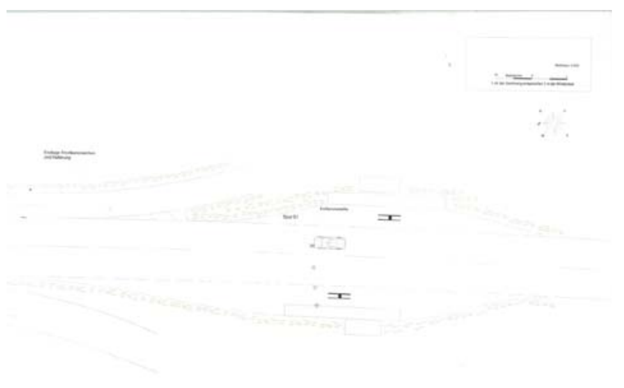
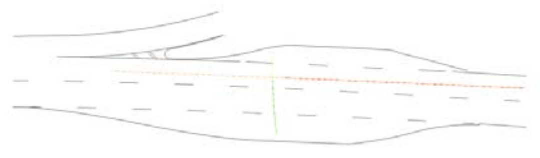
G.1 Vectorized sketch (14DE0059)



G.2 Non-vectorized sketch (14US0095)

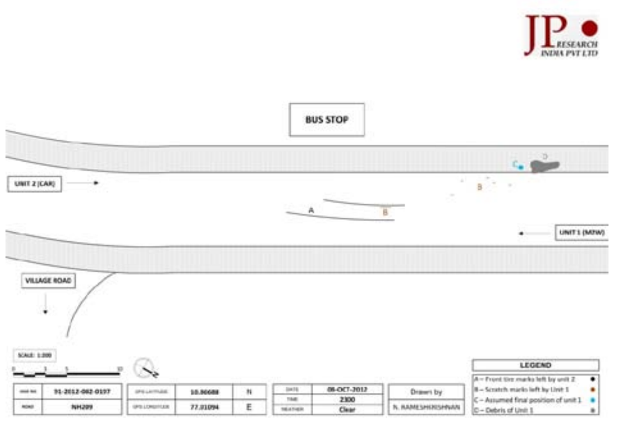


G.3 Sufficient sketch content (14AT0008)

provided sketch	redrawn sketch
	

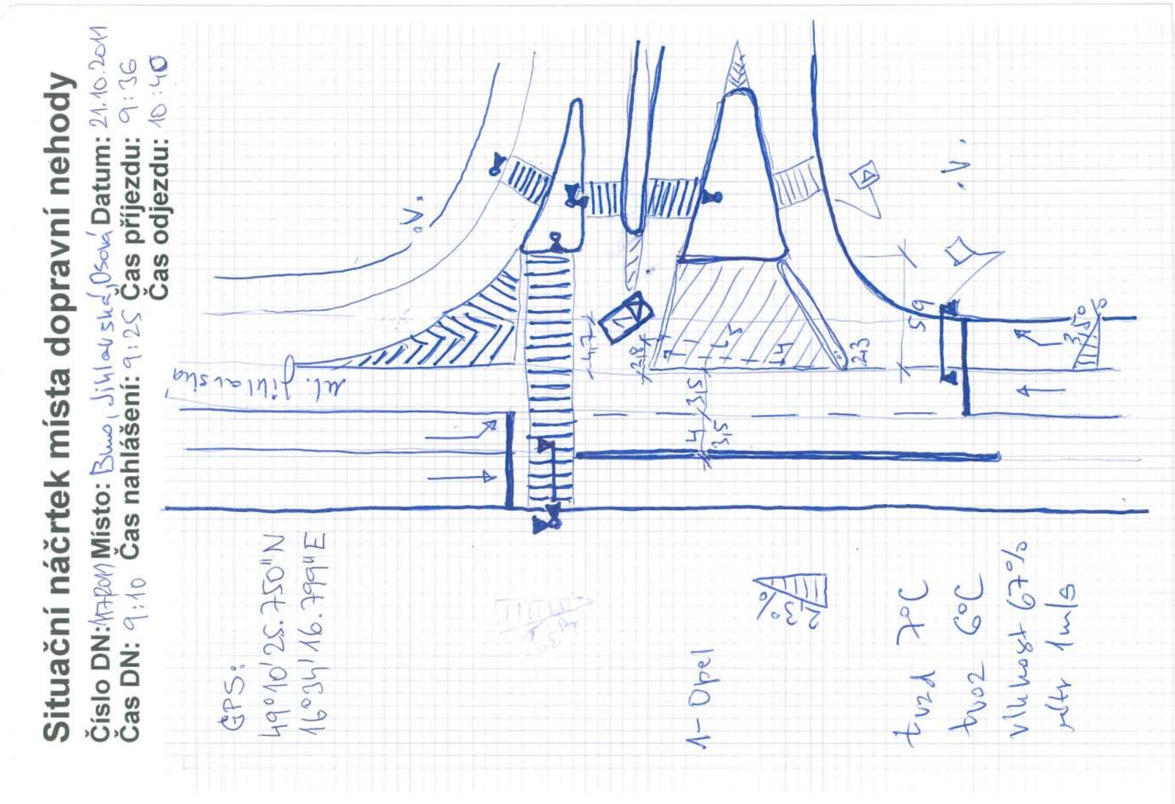
➔ low effort for redrawing (~15 min), because sketch contains all necessary information

G.4 Insufficient sketch content (14IN0074)

provided sketch	redrawn sketch
	

➔ high effort for redrawing (~45 min), because collision position and pre-crash-phase are unknown

G.5 Freehand sketch (14CZ0003)



G.6 No sketch available (14AT0001)

H. Methodical PCM cases

Country	Case no.	Sketch-format	Info	Country	Case no.	Sketch-format	Info
AT	14AT0008	jpg	no vector-graphics existing	IN	14IN0017	dwg	have been sent on request
AT	14AT0025			IN	14IN0064		
AT	14AT0032			IN	14IN0073		
AT	14AT0057			IN	14IN0074		
AT	14AT0081			IN	14IN0083		
AU	14AU0012	dwg	have been sent on request	IT	14IT0037	dxf	already provided in iGLAD phase I
AU	14AU0016			IT	14IT0045		
AU	14AU0022			IT	14IT0146		
AU	14AU0026			IT	14IT0165		
AU	14AU0045			IT	14IT0181		
CZ	14CZ0013	jpg	handsketch	SE	14SE0061	dxf	have been sent on request
CZ	14CZ0052			SE	14SE0068		
CZ	14CZ0060			SE	14SE0072		
CZ	14CZ0068			SE	14SE0082		
CZ	14CZ0073			SE	14SE0090		
DE	14DE0011	dxf	GIDAS	SP	14SP0021	dwg	have been sent on request
DE	14DE0015			SP	14SP0032		
DE	14DE0030			SP	14SP0092		
DE	14DE0118			SP	14SP0097		
DE	14DE0135			SP	14SP0100		
FR	14FR0005	dxf	have been sent on request	US	14US0064	wmf	"Easy street draw" (ESD)
FR	14FR0049			US	14US0068		
FR	14FR0064			US	14US0072		
FR	14FR0074			US	14US0084		
FR	14FR0102			US	14US0105		

I. Methodical PCM cases with quality evaluation

DP	case	Quality reconstruction	Quality sketch	Quality Simulation	Final quality
AT	14AT0008	4	4	5	4
AT	14AT0025	2	3	5	2
AT	14AT0032	3	3	5	3
AT	14AT0057	3	3	5	3
AT	14AT0081	3	3	5	3
AU	14AU0012	4	5	1	1
AU	14AU0016	5	5	5	5
AU	14AU0022	5	5	5	5
AU	14AU0026	2	5	1	1
AU	14AU0045	5	5	5	5
CZ	14CZ0013	2	2	5	2
CZ	14CZ0068	2	2	5	2
CZ	14CZ0052	2	4	5	2
CZ	14CZ0060	3	2	5	2
CZ	14CZ0073	3	2	5	2
DE	14DE0011	5	5	5	5
DE	14DE0015	5	5	5	5
DE	14DE0030	5	5	5	5
DE	14DE0118	5	5	5	5
DE	14DE0135	5	5	5	5
FR	14FR0005	5	4	5	4
FR	14FR0049	5	5	5	5
FR	14FR0064	2	5	5	2
FR	14FR0074	5	5	5	5
FR	14FR0102	5	5	5	5
IN	14IN0064	4	2	5	2
IN	14IN0073	4	3	5	4
IN	14IN0074	4	2	5	2
IN	14IN0083	4	3	5	3
IN	14IN0017	4	2	5	3
IT	14IT0037	5	5	5	5
IT	14IT0045	5	5	5	5
IT	14IT0146	5	4	5	4
IT	14IT0165	2	5	5	2
IT	14IT0181	5	4	5	4
SE	14SE0061	5	5	5	5
SE	14SE0068	1	3	5	1
SE	14SE0090	3	3	1	1
SE	14SE0072	4	3	1	1
SE	14SE0082	3	3	5	3
SP	14SP0021	4	5	1	1
SP	14SP0097	2	5	1	1
SP	14SP0100	4	5	5	4
SP	14SP0032	2	5	5	2
SP	14SP0092	3	5	5	3
US	14US0064	2	5	1	1
US	14US0068	2	5	5	2
US	14US0072	2	5	5	2
US	14US0084	2	5	5	2
US	14US0105	2	5	5	2

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