Development of an In-depth European Accident Causation Database and the Driving Reliability and Error Analysis Method, DREAM 3.0

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Abstract - The SafetyNet project was formulated in part to address the need for safety oriented European road accident data. One of the main tasks included within the project was the development of a methodology for better understanding of accident causation together with the development of an associated database involving data obtained from on-scene or "nearly on-scene" accident investigations. Information from these investigations was complemented by data from follow-up interviews with crash participants to determine critical events and contributory factors to the accident occurrence. A method for classification of accident contributing factors, known as DREAM 3.0, was developed and tested in conjunction with the SafetyNet activities. Collection of data and case analysis for some 1 000 individual crashes have recently been completed and inserted into the database and therefore aggregation analyses of the data are now being undertaken. This paper describes the methodology development, an overview of the database and the initial aggregation analyses.

INTRODUCTION

The SafetyNet project is an Integrated Project (IP) which was developed as part of the European Commission's 6th Framework programme. SafetyNet has built the foundations of a European Road Safety Observatory (ERSO) which can be used by the European Commission for the purposes of policy review and development. The SafetyNet project is divided into seven main Work Packages each of which deal with specific aspects of road safety research [1]. This paper describes the second task of Work Package 5 of SafetyNet which involves the development of a method for assessment of contributing factors and an accident causation database including some 1 000 individual cases. The accidents were investigated using an analysis approach known as the SafetyNet Accident Causation System (SNACS) [2] to classify the contributing factors that lead to the crash, SNACS is a slight modification of Driving Reliability and Error Analysis Method (DREAM 2.1) [3].

A persistent lack of data pertaining to accident causation is a major obstacle in the development and refinement of in-vehicle technological systems aimed at accident mitigation but also in the understanding of driver behaviour in different road environments. Data are needed to both assess the performance of existing systems and furthermore the development of systems of the future. Therefore, a harmonised, prospective "on-scene" method for recording the critical events and the contributing factors of road crashes was developed. Where appropriate, this includes interviewing road users in collaboration with more routine accident investigation techniques. The database enables multi-disciplinary information on the circumstances of crashes to be interpreted to provide information on the contributing factors. The development of the data-recording method is now described.

DEVELOPMENT OF DREAM 3.0

Since the middle of the 20th century the number of human-machine-systems has grown enormously. Unfortunately, these systems sometimes fail, resulting in more or less severe consequences. To prevent future failures it is important to understand why human-machine systems have failed in the past. A tool which was developed for analysis of past accidents as well as prediction of future ones within the process control domain (i.e. nuclear power plants, train operation, etc) is the Cognitive

Reliability and Error Analysis Method (CREAM) [4]. CREAM was later adapted to suit the road traffic domain and the resulting tools were called the Driving Reliability and Error Analysis Method (DREAM) [5] and the SafetyNet Accident Causation System (SNACS) [2]. The DREAM and SNACS methods have a Human-Technology-Organisation perspective. Their basic philosophy is that accidents happen when the dynamic interactions between people, technologies and organisations fail to meet the demands of the current situation in one way or another and that such failures are due to a combination of contributing factors which together generate the accident.

Methodology development process

DREAM 2.1 [3] was first used in the Swedish project Factors Influencing the Causation of Accidents and Incidents (FICA) [6]. When it was established that DREAM 2.1 would be used in work package 5 of the European co-operation road safety project SafetyNet [1], DREAM 2.1 was translated into English and adapted to suit the traffic environment in the participating countries. The adapted version was called SNACS [2]. It uses the same method, accident model and main structure of the classification system as DREAM 2.1, but some individual contributing factors and their links have been altered.

Both DREAM 2.1 [3] and SNACS 1.2 [2] have been successfully used as tools for accident analysis in Sweden and other European countries, including extensive application throughout the SafetyNet WP5 accident investigations. During this practical work some suggestions for improvements have been put forward. Both DREAM 2.1 and SNACS 1.2 were therefore revised by a reference group including researchers in psychology, human factors, accident analysis and driver behaviour.

The revision resulted in DREAM 3.0 [7] which is modified to meet the needs of practitioners all over Europe (DREAM 3.0 can of course also be used in other parts of the world but due to country specific differences further adjustments might be needed). DREAM 3.0 uses the same accident model as the earlier versions while the classification scheme and the method have been somewhat adjusted.

With regards to the classification scheme in DREAM 3.0 [7], the majority of contributing factors are left in their original form. Where needed, definitions have been improved to resolve potential ambiguities. A few new contributing factors have been added and some have also been removed due to merging or exclusion. In conjunction with the revision a literature review [8] was conducted in order to investigate empirical support for the links between contributing factors in the classification system. A reliability test was also conducted to examine the intercoder agreement for DREAM 3.0 [9]. Both studies are briefly described later in this paper.

Theoretical Background

DREAM 3.0 [7] includes three main elements: an accident model, a classification scheme and a method.

The accident model

The accident model uses the human-technology-organisation (HTO) triad as a reference - represented by the driver (human), the vehicle and traffic environment (technology) and the organisation (see Table 1).

A key assumption is that driving can be viewed as a control task which involves the continuous adaptation to a changing environment, in a way which promotes goal fulfilment. The Contextual

Control Model (COCOM) [4, 10] is used to describe the nature of the basic cognitive processes which support drivers' control. COCOM recognises that cognition includes processing observations and producing reactions, as well as continuously revising goals and intentions which creates a "loop" on the level of interpretation and planning. This is assumed to occur in parallel with ongoing events, at the same time as it is also being determined by those events. In later work, COCOM has been extended into the Extended Control Model (ECOM) [10]. ECOM offers a control theoretic account for how goals on different levels interact dynamically, recognising that control includes working towards multiple parallel goals on different time scales, so in reality a number of parallel control processes are at play. Cognition in the context of human-machine system performance should therefore not be described as a sequence of steps, and classification schemes based on this model must represent a network rather than a hierarchy. This theoretical standpoint is reflected in how the contributing factors in the classification scheme are defined as well as related to each other.

The accident model of DREAM 3.0 [7] combines the driving-as-control concept with the wide HTO perspective on where contributing factors can be found. Figure 1 illustrates the model, showing how accidents are seen as a loss of control due to an unsuccessful interplay between driver, vehicle and traffic environment, as well as the organisation(s) responsible for shaping the conditions under which driving takes place. Failures at the sharp end as well as at the blunt end are taken into consideration. Sharp end failures happen in close proximity to the accident (e.g. the driver fails to see a red traffic light which contributes to two cars colliding), while blunt end failures occur at other times and/or at other locations (e.g. a mechanic fails to maintain the brakes properly which later contributes to two cars colliding).

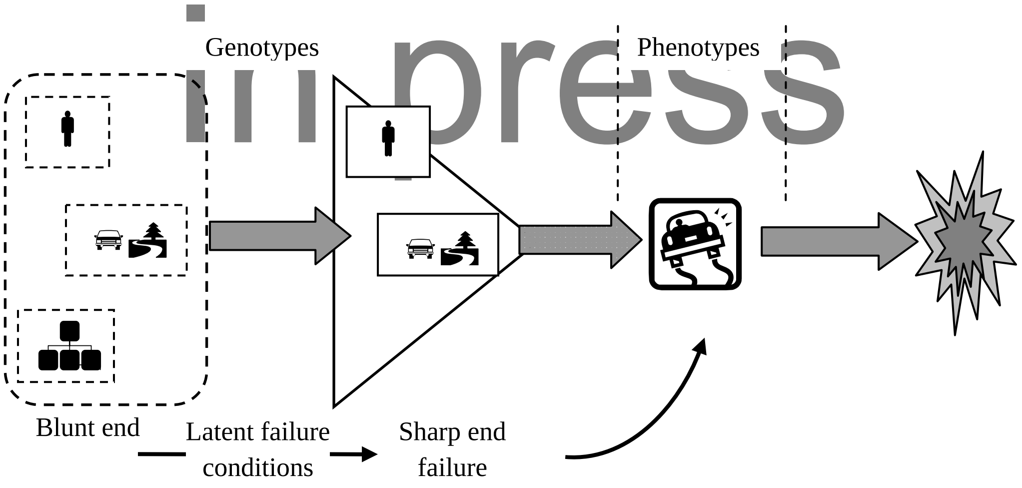


Figure 1. Blunt end and sharp end failures (after [5])

The classification scheme

The classification scheme of DREAM 3.0 [7] comprises a number of observable effects in the form of human actions and system events called critical events, or phenotypes. It also contains a number of possible contributing factors which may have brought about these observable effects. The contributing factors are called genotypes and are organised according to the driver-vehicle/traffic environment-organisation triad mentioned above. The driver category contains genotypes related to possible cognitive function problems such as observation, interpretation and planning failures (in accordance with COCOM [4, 10]). It also includes more general driver states of temporary and permanent person related character that can contribute to an accident (e.g. distraction, fatigue, etc). The vehicle/traffic environment category consists of vehicle and traffic environment related genotypes, while the organisation category consists of genotypes related to organisation, maintenance and design. See Table 1 for a schematic presentation of different categories. Besides the phenotypes and genotypes mentioned above, the classification scheme in DREAM 3.0 [7] also includes links between phenotypes and genotypes, as well as between different genotypes.

Table 1. Overall grouping of the genotypes and phenotypes in DREAM 3.0 [7]

GENOTYPES				PHENOTYPES
HUMAN		TECHNOLOGY	ORGANISATION	
Driver		**Vehicle**	**Organisation**	
Observation	} in accordance with COCOM	Temporary HMI problems	Organisation	Timing
Interpretation		Permanent HMI problems	Maintenance	Speed
Planning		Vehicle equipment failure	Vehicle design	Distance
Temporary Personal Factors			Road design	Direction
Permanent Personal Factors		**Traffic environment**		Force
		Weather conditions		Object
		Obstruction of view due to object		
		State of road		
		Communication		

The method

The method in DREAM3.0 [7] is fully bi-directional which means that the same principles can be used for analysing past accidents as for predicting future ones. However, with regards to DREAM 3.0, the focus is on retrospective analysis of accidents that have already occurred. The classification scheme is therefore organised to make this as easy as possible. Furthermore, the method contains several stop rules, e.g. well defined conditions that determine when the analysis should come to an end. These stop rules are necessary as the classification scheme represents a network (rather than a hierarchy) and the analysis or prediction could continue without end. Otherwise there is the risk that an analysis is terminated by subjective rather than objective criteria in the absence of these rules.

JUSTIFICATION OF THE CLASSIFICATION SCHEME

Literature review

The human-technology-organisation in CREAM [4] as well as the driver-vehicle/traffic environment-organisation triad in DREAM [3, 5] and SNACS [2] are used as frames of reference for the main categories of genotypes and COCOM [4, 10] to organise human cognition. For the links between the genotypes there are, however, no documented references to literature. The aim of the literature review was therefore to investigate the empirical support for the links between the genotypes in DREAM 3.0 [7]. It is however important to remember that, for the individual accident, even links with documented references in literature represents possible rather than necessary connections. The use of a link always has to be justified by available empirical data.

The literature review was based on the genotypes in DREAM 3.0 [7]. The databases used were PsychInfo and Science Direct. Depending on the number of hits, the genotypes were combined with other words (e.g. genotype, genotype + driv*, genotype + driv* performance, genotype + accident*, genotype + traffic*).

A first selection of texts was based on titles while a second selection was based on abstracts. This resulted in approximately 185 texts which were more thoroughly read and among them 76 texts could be referred to one or more links between the genotypes in DREAM 3.0. Most of the remaining texts could be referred to links between genotypes and accident involvement. Only texts relevant for links between genotypes are presented in the literature review report [8].

Reliability test – the intercoder agreement

Many different classification schemes have been used in the analysis of road traffic accidents but the agreement between coders using a scheme is rarely tested and/or reported. As a high intercoder agreement is a prerequisite for a study's validity, this is a serious shortcoming. The aim of the present study was, therefore, to test the intercoder agreement of the DREAM 3.0 [7] by letting seven coders from different European countries analyse and classify the contributing factors of the same four accident scenarios. The results showed that the intercoder agreement for genotypes (contributing factors) range from 68% to 94% with an average of 84%, while for phenotypes (observable effects) it ranges from 57% to 100% with an average of 78%. This high level of agreement between coders from different countries shows that the DREAM 3.0 classification scheme is clear and explicit enough to be used all over Europe. The results also showed that testing intercoder agreement can play an important role in identifying weaknesses in the classification scheme, in the training of coders as well as in how accident information is presented. The result of the study will be published in a paper submitted for publication [9]

SAFETYNET ACCIDENT CAUSATION DATABASE

The aim of the SafetyNet work package 5, task 2 was to develop an in-depth European accident causation database to identify the risk factors that contributes to road accident occurrence. The main outcome was to investigate some 1 000 accidents from six EU member states (including; Germany, Italy, The Netherlands, Finland, Sweden and the United Kingdom) according to a harmonised methodology. Three tools were developed to guide the investigation teams in the data collection process and in the individual case analysis.

An independent accident investigation protocol (general variables) includes information from the accident site, the road environment, the vehicle(s) and the road user(s) involved. Since the investigations were focused at accident prevention rather that injury prevention the vehicle damages and the injury outcome were described in less detail.

A method to classify contributing factors was adapted to suit the traffic environment in the participating countries, known as SNACS [2] and DREAM 3.0 [7]. Where possible, interviews with drivers and other road users have been carried out according to an interview guide.

For input and storage of the data collected and the individual case analysis performed, a database was developed. The system was based on the general variables, the critical events and contributing factors in SNACS. It was especially suited to help the investigators in the SNACS analysis of each vehicle involved in an accident.

The database developed includes 1 006 accident cases, 1 833 vehicles and 2 428 road users. An on-scene approach for collecting the data has mainly been used where investigation teams has visit the accident scene shortly after occurrence.

Data analysis

The data analysis of the SafetyNet Accident Causation Database can be divided into two parts; analysis of individual cases and analysis of aggregated cases. The analysis of an individual case is performed on vehicle level (including pedestrians) and is based on the information collected from the accident scene and the interviews. The SafetyNet Accidents Causation System (SNACS 1.2) [2], which is one of the precursor methods to DREAM 3.0 [7], was used to analyse the individual cases stored in the database.

An example of an individual case analysis based on DREAM 3.0 is illustrated in Figure 2. The corresponding accident scenario is as follows: Driver A is driving above the 70 km/h speed limit on a road. When A enters a sharp curve, which is incorrectly cambered and the surface is covered in gravel, the vehicle starts skidding. A tries to control the skid but fails and the vehicle comes to rest upside down in a ditch. Driver A is a 19-year old man (has had a driving licence for 1 year), was not tired or distracted, was not under the influence of alcohol, drugs or medication. He drove an older Volvo in good condition.

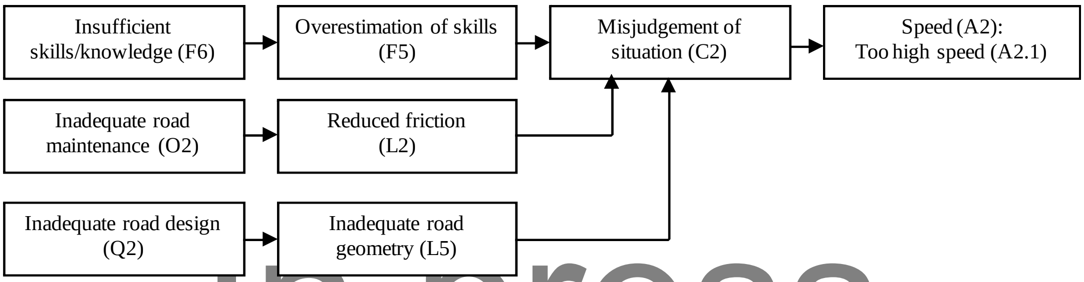


Figure 2. Example of an individual case analysis of a run off the road accident in a sharp curve (based on DREAM 3.0)

While the analysis of an individual case results in a chart of interlinked contributing factors, the analysis of aggregated cases is performed by superimposing individual charts in order to find common causation patterns for a selected group of cases. The selection of cases can be performed in a number of different ways depending on the research question. The analysis of aggregated cases in the SafetyNet Accident Causation Database is in progress and the initial data analysis is described below. An example of superimposing of cases (analysed with SNACS 1.2 [2]) from the analysis group vehicle-leaving-lane trajectories (further described below) is illustrated in Figure 3.

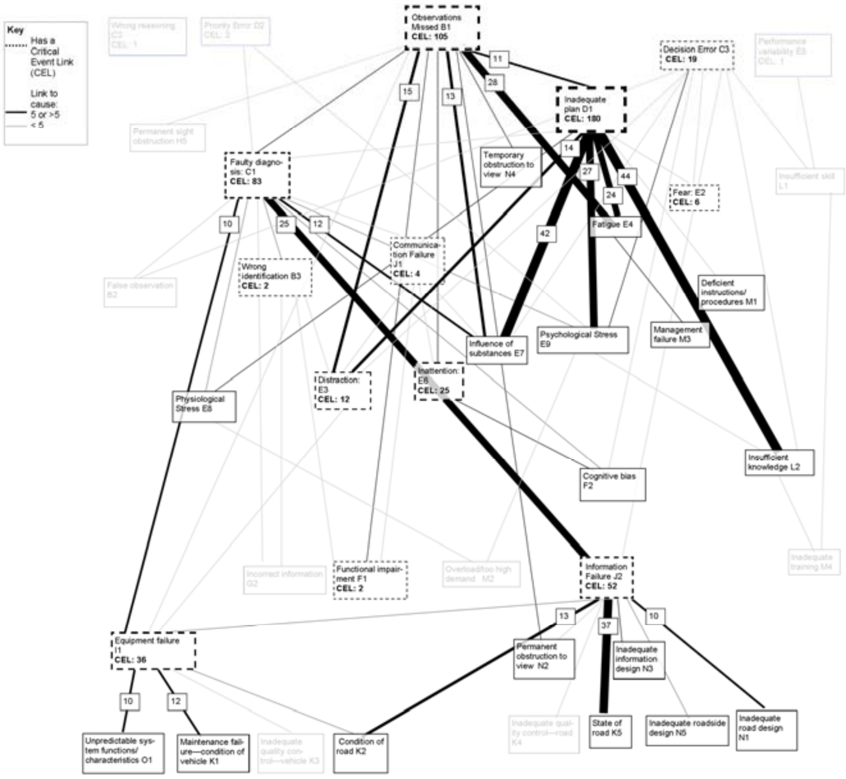


Figure 3. Example of a causation pattern for vehicle-leaving-lane trajectories (based on SNACS 1.2)

Initial data analysis - taxonomy

Since the analysis is causation focused rather than outcome focused, accident data was sorted into other groups than suggested by the traditional accident outcome based taxonomies. The main approach chosen was therefore to base the analysis on a combination of accident context and vehicle trajectory. Since an accident can contain more than one trajectory, (i.e. there will be one trajectory per involved vehicle), the sorting was performed on a vehicle level.

Prior to sorting the vehicles according to trajectory, all accidents involving Slower moving Vulnerable Road Users (SVRU), i.e. pedestrians and bicyclists, were sorted into a separate group because accidents involving SVRU is believed to have different causation patterns and characteristics, compared to single or multiple motorised vehicle crashes.

Except the SVRU group, the sorting resulted in three main accident context and vehicle trajectory based groups. Each main group was divided into subgroups relating to conflict scenario, participant or counterpart, for further analysis. The subgroups for each main group are described in more detail under each heading.

Vehicle leaving its lane

A vehicle-leaving-lane trajectory represents driving situations where the vehicle leaves its lane by crossing the lane boundary either to the left or the right. There are two subgroups, depending on whether the manoeuvre was intentional (e.g. driver actively changing lane or initiating an overtaking of another vehicle) or unintentional (driver drifting out of lane or losing control).

Figure 4 illustrates typical outcome scenarios initiated by vehicle-leaving-lane trajectories which can lead to a conflict with another vehicle or the vehicle running off the road. In scenario 1a the vehicle leaves its lane by crossing the median line intentionally (i.e. starts to overtake another vehicle) and collides with a vehicle travelling in the opposite direction. In scenario 1b the vehicle leaves its lane by intentionally crossing a lane marker (i.e. initiating a lane change manoeuvre) and collides with a vehicle travelling in the same direction. Lane departures where the initial crossing of a lane marker or median line is unintentional include the vehicle colliding with a vehicle travelling in the opposite direction (scenario 2a) and running off the road to the nearside or offside (scenarios 2b and 2c).

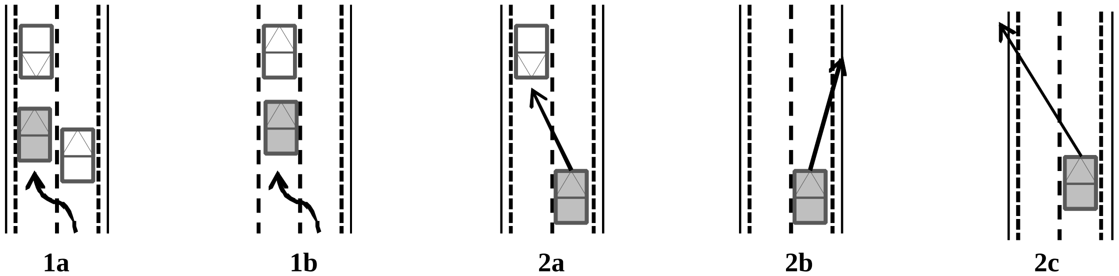


Figure 4. Typical outcomes scenarios following vehicle-leaving-lane trajectories. Conflicts between vehicles following an intentionally leaving lane trajectory either to overtake another vehicle (1a) or due to a lane change (1b). Conflict between vehicles (2a) or road departures (2b-2c) following an unintentionally leaving lane trajectory by drifting out of lane or loss of control, (subject vehicle is grey).

Vehicles are not included in vehicle-leaving-lane category if they first collide with a vehicle or an object in its own lane and then exit the lane – these vehicles will be included either in the ‘vehicle encountering something while remaining in its lane’ or ‘vehicle encountering another vehicle on crossing paths’ groups (see below).

Vehicle encountering something while remaining in its lane

This trajectory group represent vehicles encountering something in its own lane which typically result in a front or rear end collision for the subject vehicle. The main group is divided into four subgroups, depending on whether the conflict is with another vehicle, an animal or an object.

Figure 5 illustrates typical outcome scenarios following a trajectory where a vehicle encounters something in its own lane. In scenario 1 the subject vehicle is striking a lead vehicle, in scenario 2 the subject vehicle is rear ended by another vehicle. In Scenario 3 the subject vehicle is struck by a vehicle which has left its lane and in scenario 4a and 4b the subject vehicle is frontally striking object other than a vehicle.

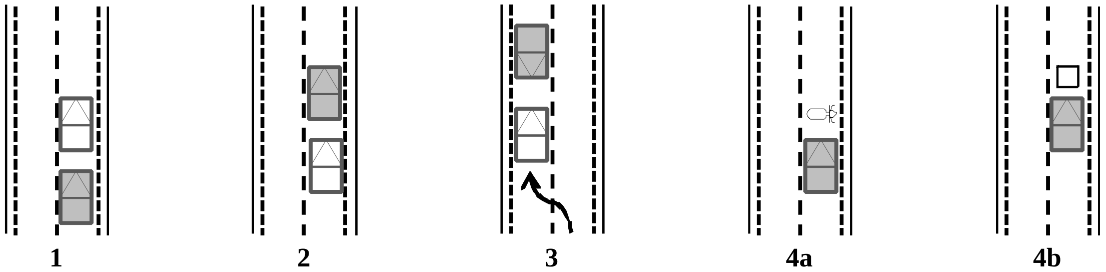
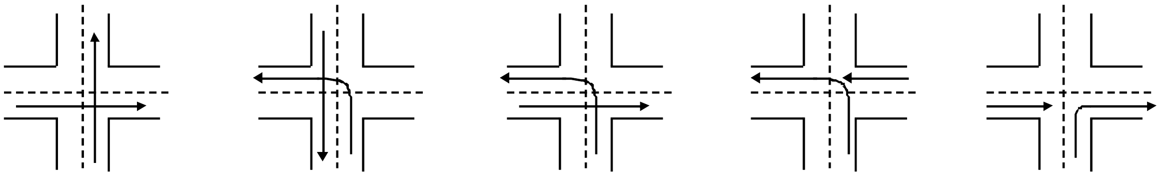


Figure 5. Typical outcome scenarios for vehicle encountering something while remaining in its lane. 1; striking lead vehicle, 2; being rear ended by another vehicle 3; being struck by a vehicle which has left its lane, 4a-4b; frontally striking object other than vehicle (subject vehicle is grey).

Vehicle encountering another vehicle on crossing paths

A crossing path crash is defined as a traffic conflict where one moving vehicle cuts across the path of another, when they were initially approaching from either lateral or opposite directions in such a way that they collided at or near a junction [11]. The typical outcome is an intersection crash, but reversing from a driveway type crashes are also included.

Figure 6 illustrates the four subgroups which are divided into; Straight Crossing Paths (1. SCP), Left Turn Across Path-Opposite Direction (2. LTAP-OD), Left Turn Across Path-Lateral Direction (3. LTAP-LD) and Merge conflicts, (Left Turn Into Path (4a. LTIP) and Right Turn Into Path (4b. RTIP)).



1. SCP **2. LTAP-OD** **3. LTAP-LD** **4a. LTIP** **4b. RTIP**

Figure 6. Typical outcome scenarios for vehicle encountering another vehicle on crossing paths. Straight Crossing Paths (1. SCP), Left Turn Across Path-Opposite Direction (2. LTAP-OD), Left Turn Across Path-Lateral Direction (3. LTAP-LD), Merge conflicts, Left Turn Into Path (4a. LTIP) and Right Turn Into Path (4b. RTIP)

Initial data analysis - summary of vehicle grouping

Since the analysis of aggregated cases is in progress the causation patterns can not be presented for each group. According to the grouping of vehicles presented above the vehicles included in each group is distributed as shown in Table 2.

Table 2. Number of vehicles for each group selected for analysis of aggregated cases. *9 vehicles are excluded from the selection.

	SVRU	Leaving lane	Remaining in own lane	Crossing paths	Total
Agricultural vehicle	-	-	4	1	5
Bicycle	96	-	-	-	96
Bus / Minibus	11	4	10	10	35
Car / MPV	134	277	396	357	1164
Motorcycle / Moped	11	27	36	105	179
Other	2	2	8	6	18
Pedestrian	91	-	-	-	91
Train / Tram	2	-	-	8	10
Truck	11	37	59	28	135
Unknown	-	-	1	-	1
Van	11	14	43	22	90
Total	369	361	557	537	1824*

DISCUSSION

The aim of the SafetyNet work package 5.2 was to develop an in-depth European accident causation database to find the risk factors that contributes to road accident occurrence. The work performed was closely related to already existing accident investigation activities within the partnership including multidisciplinary teams with many years of experience within the field. The main outcome was to investigate some 1 000 accidents from six EU member states according to a harmonised methodology discussed previously.

Despite the high level of expertise within the investigation teams it was discovered that cultural differences and differences in the road traffic system and definitions resulted in some challenges. The general variables had to be clearly defined and revised several times to discard any confusions and differences in interpretations among the investigators. Concerning the analysis of individual cases with SNACS [2] several quality review meeting was conducted to ensure that the classification scheme was clear and explicit enough to be used all over Europe. During the work suggestions on clarifications and additions/removal of contributing factors were made resulting in an updated version of the method (SNACS 1.2) [2] that was used throughout the project. However, further development was needed and the final version DREAM 3.0 [7] has gone through an extensive literature review [8] and a reliability test [9].

Trying to understand the contributing factors to accident occurrence throughout Europe has shown being a complex task. The new way of thinking in accident prevention compared to injury prevention demand understanding of cognitive processes and driver behaviour. Nevertheless, it has been shown in the project that when sufficient training has been undertaken and the threshold for the understanding of the classification scheme is reached by the investigators the intercoder agreement can be considered acceptable.

The initial aggregation analysis is performed on a vehicle level rather than on accident level. The subgroups under each heading may not be completely intuitive, since they do not follow the traditional outcome based categorisation in passive safety. However, the taxonomy is hypothesised to present the clearest differences in causation patterns between each of its three main groups as well as their subgroups. Also, sorting on trajectories facilitates comparison with existing, outcome oriented crash databases, since they usually contain detailed vehicle trajectory information. It is believed that the aggregation of each analysis by describing the frequency of accident contributing factors and their relationship as shown on the example identifies the main determiners how and why accident occurs in sufficient detail to be used for further traffic safety development.

CONCLUSION

The data from the accident causation study are required for a variety of reasons. For example, the data are needed to provide policy-makers and regulators with data that can be used in decision making for road safety policy and regulation. It is intended that the data can also be used in the development of new in-vehicle technology e.g. accident avoidance systems and road design.

The next step in the development of DREAM 3.0 could be to use the method in a wider range of countries and eventually adjust the classification scheme to fit to non-European countries. Even when DREAM 3.0 is used within Europe it is important to remember that the classification scheme should not be seen as fixed or static. Instead it should be adjusted in order to fit the needs of different projects as well as the future needs required by the road traffic development.

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