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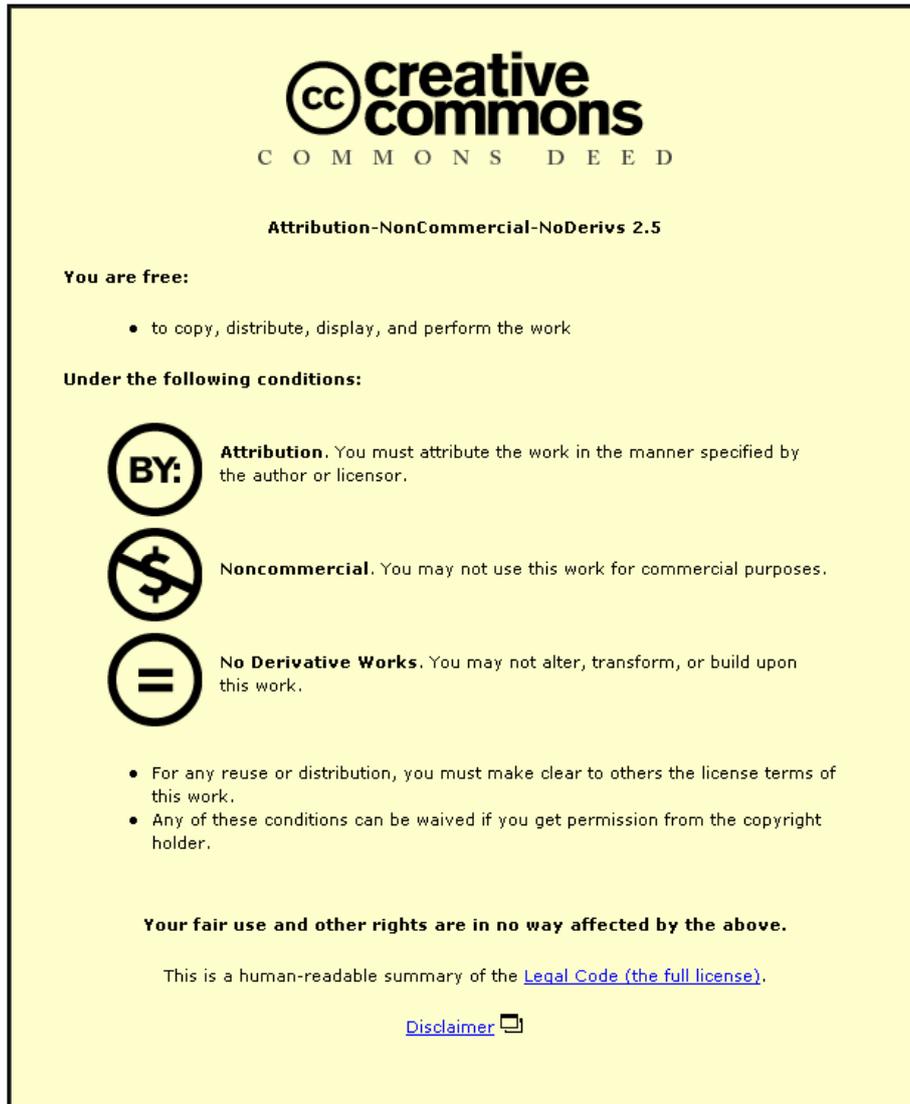
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The Development of a Multidisciplinary System to Understand Causal Factors in Road Crashes

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ABSTRACT

The persistent lack of crash causation data to help inform and monitor road and vehicle safety policy is a major obstacle. Data are needed to assess the performance of road and vehicle safety stakeholders and is needed to support the development of further actions. A recent analysis conducted by the European Transport Safety Council identified that there was no single system in place that could meet all of the needs and that there were major gaps including in-depth crash causation information. This paper describes the process of developing a data collection and analysis system designed to fill these gaps. A project team with members from 7 countries was set up to devise appropriate variable lists to collect crash causation information under the following topic levels: accident, road environment, vehicle, and road user, using two quite different sets of resources: retrospective detailed police reports (n=1300) and prospective, independent, on-scene accident research investigations (n=1000). Data categorisation and human factors analysis methods based on Cognitive Reliability and Error Analysis Method (Hollnagel, 1998) were developed to enable the causal factors to be recorded, linked and understood. A harmonised, prospective "on-scene" method for recording the root causes and critical events of road crashes was developed. Where appropriate, this includes interviewing road users in collaboration with more routine accident investigation techniques. The typical level of detail recorded is a minimum of 150 variables for each accident. The project will enable multidisciplinary information on the circumstances of crashes to be interpreted to provide information on the causal factors. This has major applications in the areas of active safety systems, infrastructure and road safety, as well as for tailoring behavioural interventions. There is no direct model available internationally that uses such a systems based approach.

1. INTRODUCTION

Each year within the European Union (EU-15), there are approximately 40,000 people killed on the roads and over 1.7 million people injured (European Commission, 2005a). Such incidents cost the Community over 180 billion Euros annually, equal to 2% of the EU's Gross National Product (GNP). With the growth in the number of EU member states (to EU-25), the European road death toll is set to increase to even more dramatic heights. To put these figures into perspective, "road crashes are the second most serious cause of death and hospital admission for EU citizens, preceded by cancer and followed by coronary heart disease" and for Europeans under 45 years of age, road crashes are the largest single cause of death (ETSC, 1999).

The number of people killed and injured on the roads started to decrease considerably from 2002 onwards (European Commission, 2005b), with improvements year on year for 2003 and 2004. However, there has not been such steep decline in the overall number of crashes. Incidents are still occurring frequently, although improvements in vehicle design and trauma management have helped to reduce the severity of injuries to the people involved in accidents, although the number of slight injuries has not decreased. Despite these improvements in injury outcomes, it is estimated that 97% of all socioeconomic costs for transport crashes within the EU are as a result of those on the roads, and that 97% of the transport related fatalities occur in the road sector (ETSC, 1997).

1.1 The perspective of one European country

This section is used to set the scene for a 'good practice' European country. The existing accident statistics and processes for collecting and examining data from crashes are described so that the reader can fully understand the implications of the multidisciplinary project that is presented in this paper.

Accident statistics. Britain has had –relatively speaking– remarkable success in reducing road casualties, despite the vast growth in traffic since the beginning of the last century. In 1930 there were only 2.3 million motor vehicles in Great Britain, but over 7,000 people were killed in road crashes. Today, there are over 27 million vehicles on the roads but far fewer road deaths. In 1987 a target was set to reduce road casualties by one-third by 2000 compared with the average for 1981-85. Britain has more than achieved this target for reducing deaths and serious injuries. Road deaths have fallen by 39% and serious injuries by 45% and the UK is now one of the safest countries in Europe (and indeed the world). The British government launched a new 10-year target for road safety in 2000 to help focus on achieving a further substantial improvement in road safety over the next decade.

Routine practice. When a road crash occurs, the police conduct investigations of varying levels of detail, dependent on the nature of the incident outcome. Upon notification of non-fatal road accidents, an investigation dependent on the concerns of the officers involved, the severity of the accident outcome, and the size of the incident, is conducted. Whenever they are informed of, or attend a road traffic accident in which a person is killed or injured, the police complete an accident record, and upon verification is transferred to a Stats19 form for input to the accident database of that police force. Data is used from Stats19 at a local level by engineers who look for indications of causation to design remedial measures, and nationally by policy-makers. The Department for Transport (DfT) compiles the national Stats19 data on personal injury road accidents, resulting casualties, and the vehicles involved. Personal injury road accidents statistics were first collected in 1909. This modern system of collecting information on injury accidents (Stats19) was introduced in 1949. The current system was established in 1979 following a wide ranging review. Subsequently the survey has been reviewed every 5 years to check that the data collected remain relevant. Following the 1997 Review of Collection of Road Accident Statistics a substantially revised data collection form was introduced in January 2005. This collects more detailed information indicating the precipitating and contributory factors which lead to a crash. The DfT make the national Stats19 data available by three main areas:

1. Accidents - including the severity of the accident, the number of vehicles and casualties involved, time and location, road class and number, speed limit, weather and road conditions, and carriageway hazards;
2. Vehicles - including type, location and manoeuvre at time of accident, and details of the driver (age, sex and breath test results);
3. Casualties - age, gender, injury severity and whether a driver, passenger or pedestrian.

Data are collected on a monthly basis from police forces throughout the year and are available for Great Britain and by country region and county. Unless there has been a fatality or a serious "threat to life", it is subjective as to what level of detail the police investigation goes into. It could be suggested that more attention is given to cases where children are involved due to the empathic nature of the situation.

For fatal road accidents, the guidelines elaborated in the Road Death Investigation Manual (Association for Chief Police Officers, 2004) are followed. These detail how to undertake the investigation and are a "set of criteria...to enable the police service to work to a consistent standard of professional investigation". A detailed report combining information from witnesses and the police investigation is produced on a routine basis for fatal road accidents. This report is used within the judicial process for examining criminal offences.

The national road accident statistics are collected and published, partly to inform public debate and partly to provide the basis for determining and monitoring effective road safety policies. It should be noted that while relatively few fatal accidents do not become known to the police, there is evidence that a large proportion of non-fatal accidents do not get reported to the police and therefore, there may be wide-spread under-reporting (GRPS, 2006). Additionally, studies have also shown that the police tend to underestimate the severity of injury because of the difficulties in distinguishing severity at the

scene of the accident, and that reporting rates are lower for the more vulnerable road users groups (Nakahara and Wakai, 2001).

1.2 Effective development of countermeasures

The EU target of a 50% reduction in fatalities on the roads by 2010 (European Commission 2005a) will only be achieved by the introduction of the most effective countermeasures. It relies on the existence of basic knowledge of crashes and their causation and the availability of road safety data to monitor and assess performance. Reduction of road casualties through vehicle design is typically achieved by taking an 'Active' or 'Passive' safety approach. Passive safety normally involves the implementation of safety technology within the vehicle which is specifically designed to reduce injuries in the event of a crash; airbags and advanced seat belt technology are prime examples of such devices. In more recent times, there has been much activity and research in the field of 'Active safety'. This approach is traditionally associated with technologies that are likely to result in crash avoidance and such technologies include Intelligent Speed Adaptation (ISA), Enhanced Stability Programmes (ESP) and Lane Departure Warnings (LDW). These technologies are implemented into the vehicle as information and control devices with the specific intention of ensuring that every measure is taken to prevent the crash from happening in the first place. Most modern vehicles are equipped with a suitable range of both Passive and Active safety devices such that if the Active safety measures are ineffective and a crash becomes inevitable, a level of protection of the occupants can be assured in the crash through deployment of the Passive safety systems.

Accompanying the development of Active safety systems is recognition of the need for good quality representative crash causation data within the European Union so that such technology can evolve with specific consideration to the nature, circumstances and causes of real-world crashes. However, not only are data required for technological development they are also seen as essential for the purposes of the development of safety policy and monitoring of regulation within Europe. Data are needed to both assess the performance of road safety stakeholders and also to support the development of further actions. An analysis conducted by the European Transport Safety Council (ETSC, 2001) identified that no single crash database could meet all of the needs and that there were in fact still major gaps particularly in respect of both in-depth crash and injury causation. Specific policy questions at EU level include the role of infrastructure in crash causation, the monitoring of progress towards the 2010 casualty reduction targets and in particular, the role of vehicle and road design in crash and injury causation.

1.3 Developing a multidisciplinary system to understand causal factors in road crashes

The EC's 6th Framework project SafetyNet – Building the Road Safety Observatory (Thomas et al, 2005) was formulated in part to address the need for a range of in-depth crash data (including accident causation). SafetyNet broadly comprises 7 major elements (Work Packages) and one of these elements (Work Package 5) will produce two road crash data collection processes which deal specifically with the causation of crashes in the EU. It will also attempt to meet some requirements of the eSafety initiative (which has its own in-depth crash causation data needs) and to tie in with existing European projects where harmonies exist. Therefore, WP 5 of SafetyNet is divided into two main tasks: the development of a European fatal crash data collection process, and; the development of a European crash causation data collection process. The development and design of these two processes is discussed.

2. SYSTEM DEVELOPMENT

2.1 European Fatal Crash Data Collection Process and Data Resource - Examination of fatal crash causation using retrospective techniques

The main purpose of the task is to build an effective data gathering structure to ensure that specific data on fatal crashes can be gathered in a systematic and routine manner, with a bias towards understanding and recording crash causation to assist in the development of countermeasures. The data will be collected using completely compatible methods although there may be variations between teams according to differences in local infrastructure. This activity will develop a broad ranging intermediate level, fatal crash database by obtaining reports of police fatal crash investigations from a number of EU Member States (including France, Germany, Finland, The Netherlands, United

Kingdom, Italy and Sweden). The data itself will be of an intermediate level of detail but covering a representative sample of fatal crashes in each country. There will be no new investigations but research teams from each partner country will bring together available information from within the existing police and other emergency services structure. The information provided in the database will provide enhanced knowledge of the factors involved in fatal crashes at EU level and make good use of the detailed information collected in the police fatal investigations. The dataset is being systematically selected according to a defined sampling plan and the data is representative of the countries in which the data are collected. The main data collection period will investigate a representative sample of between 2% and 10% of the fatal crashes in each country covered, depending on the magnitude of the fatal crash population. In all, it is anticipated that 1300 fatal accident cases, involving at least 1 fatality per crash, will be collated and analysed. These data will describe the environmental factors, vehicle and driver factors to provide a description of the whole crash. Specific areas of data will describe the overall crash circumstances, driver and vehicle characteristics, specific road infrastructure features, and descriptions of other crash participants.

Establishing the needs of data users. Before any development work commenced, a workshop was held entitled Establishing Requirements for a New European In-Depth Crash Causation Information. The aim of this workshop was to provide the future users of crash data the opportunity to feed into the process of identifying general and specific research and policy questions which future crash data will be expected to address. A report was produced to summarise the workshop (SafetyNet, 2004) which focussed on the issues raised during the workshop session on the general and specific requirements for crash causation information and the subsequent feedback session on this topic. The feedback/research questions from the workshop were constantly referred to whilst developing the data variables to ensure consistency with user needs.

Data requirements were additionally sought from Road and Vehicle Safety National Experts in the EU25 Member States. Information and background on the project were presented to the National Experts and their feedback requested on data needs and requirements according to the nature of the project. All feedback was taken on board during the variable development process.

Variable development and protocols. An evaluation of the data gathering possibilities and the level of support from police, local and national administrations relating to access to current and recent fatal crashes was undertaken. Specific issues to be addressed locally e.g. legal, personal data, administrative and ethical considerations were identified. Specification of sampling region and criteria and specific data gathering methods were determined and a sampling methodology was implemented in each data collection region to ensure compatibility and linkage to national crash population (CARE). To start this process, a review of the existing procedures and protocols in EU Member States and the US was undertaken to ensure that the project would benefit from best practice. Existing procedures and protocols that were examined in detail included the UK Cooperative Crash Injury Study (CCIS), the UK On-the-Spot Project (OTS), the German In-Depth Accident Study (GIDAS), the US Fatal Accident Reporting System (FARS), and the Swedish Factors Influencing the Causation of Accidents and Incidents project (FICA). An initial data variable list was produced containing 1138 variables. This was reviewed and exclusions were made for variables that were outside the project objectives, e.g. injury related criteria. After close examination of the remaining 193 potential data variables, a provisional variable compilation list ensued. In order to determine which variables should be collected in the database, each variable was discussed in turn under the main headings of accident level, roadway level, vehicle level, and road user level. WP5 partners reviewed the provisional variable list during email circulation and at technical meetings. Each variable on the list was reviewed by each partner in collaboration with their infrastructure collaborators, against specific questions, including: Would collecting this data variable contribute usefully to the aims and objectives of the project and therefore is it deemed necessary to collect the data variable? Is the definition of each data variable suitable? Can the data variable be collected with respect to the determined definition? What is the expected reliability of the proposed data variable? What proportion of cases (per partner) could this data variable be gathered for? The decision was made that if the proportion of cases for a data variable was less than 30% for all partners in total, then the WP5 partners would consider removing the variable concerned. Additionally, if the number of positive partner responses for collecting the data variable was less than 50%, then careful deliberation needed to be given as to whether the variable was to be retained on the prospective list or not. Each 'potential' variable that had not already been agreed upon was discussed. This process included discussion for each variable's inclusion and definition, and partners' comments regarding possible problems with the collection of particular variables. The list received numerous iterations after lengthy and energetic discussions, with constant

revisiting of the objectives of the projects and the needs of the data users, as well as taking into account WP5 partners' comments regarding possible problems with the collection of particular variables. After preparation of the final variable list, the preparation of a glossary of terms and data storage system commenced.

Data and data levels. The data recorded describes the environmental (including road infrastructure, e.g. crash barriers, road signs etc.), vehicle and driver factors to provide a description of the whole crash. Approximately 150 variables are being collected in total for each case with approximately 500 pieces of information per case being obtained. The data is not being selected according to a "lowest common denominator" approach; instead partners have been challenged to gather a variety of information types. Additional interpretative information will also be required including a basic list of causation factors. It is anticipated that the data could be used by a multitude of stakeholders in the road transport system but specifically road infrastructure experts, highway engineers and vehicles designers. The data should be used to evaluate trends and to conduct inter-country comparisons where possible. There could be a link to national activities since most safety actions take place under subsidiary concerns.

Training. A training course was developed and presented for data gathering groups to ensure harmonised, compatible procedures for gathering of data. This was followed by a trial data gathering exercise used to examine the viability of each local system and to validate overall methodologies and procedures. This stage was conducted over a 2-month period and additionally used to determine the final costs per case and the total case numbers to be gathered. A thorough review of procedures was then undertaken and used to assess proposed data gathering practises, and make amendments to procedures.

Data collection and use. Data collection activity is currently in progress by all partners. It is anticipated that around 1300 sets of fatal crash data will be gathered over one year and entered onto a database. All data available to the public will be anonymous respecting the privacy laws of Member States. Upon complete data collection, data analysis and reporting will take place in accordance with the designated plan of action developed in line with EC priorities. The independent fatal crash database will primarily be directed to policy support in the areas of responsibility of the EC and there will be a dialogue to ensure that their needs are being addressed.

2.2 European Crash Causation Data Collection System and Data Resource - Examination of the causation of all severities of crashes using prospective techniques

Modern road traffic is a complex, rapidly changing and dynamic environment, which makes it a good example of a socio-technical system (Ljung, 2006). In this system, the task of the driver is gradually becoming more and more complicated, while at the same time the demands for a reduction in the number of crashes are increasing. This leads to certain requirements that need to be met by an accident model for modern road traffic:

- It needs to provide adequate means for recording the factors that can lead to a crash within the domain. Because of the interdependencies and the tight structural union between the elements of modern road traffic, the model also needs to describe how the causative factors interact with each other.
- The accident model needs to have a well defined capacity that covers the large variety of actors that form the road traffic system. This involves not only road users, but maintenance providers, designers, manufacturers, researchers, policy makers etc.
- The accident model needs to be able to cope with extended time spans. This is due to the fact that whenever an inappropriate action goes uncorrected, its consequences become a latent condition, and that condition can contribute to a later crash scenario.

The purpose of this study is to create an independent crash investigation protocol, categorisation and storage tool used to collect and examine in-depth road crash causation data so that the main risk factors leading to a crash can be identified. The independent in-depth crash causation data will have major applications in the areas of new technology development and active safety systems as well as the more traditional areas of infrastructure and road safety. Partners are from a number of EU Member States (including Germany, Finland, The Netherlands, United Kingdom, Italy and Sweden). This is a new crash investigation activity and the in-depth data will have significant applications for policy making and road safety practitioners, particularly for those working with infrastructure safety. The phenomenon of causality of real road crash can be difficult to study, and that one possible way of

studying them is investigating the crashes when they have taken place, rather than studying the behaviour of the driver in "controlled environments". One such well known approach involves the use of multidisciplinary crash investigation teams that travel to the site of crashes soon after they occur to collect data (Clarke et al, 2002). The data will contribute a major advance of the knowledge of crash causation factors at EU level, particularly with its use of on-scene data collection techniques and 'accident causal schema' (after Fell, 1976). By looking at what is generally available in current crash causation analysis it can be concluded that there is a need for new methodologies within the area (Sandin & Ljung, 2004). It can also be suggested that factors such as road and weather conditions and drug abuse are often used to describe crash causes, but when it comes to developing guidelines for active safety systems, they are not detailed enough. Therefore, it is important to obtain answers to the questions how and why accidents occur, to be able to develop active safety systems for crash prevention.

Establishing the needs of data users. The same workshop and survey approach were used as discussion in section 2.1 above and, again, feedback was taken on board during the development process.

Variable development and protocols. An evaluation of the existing accident causal schema used with on-scene data gathering protocols was undertaken. The systems evaluated included: the UK On-the-Spot Project (OTS), the German In-Depth Accident Study (GIDAS), the US Fatal Accident Reporting System (FARS), and the Swedish Factors Influencing the Causation of Accidents and Incidents project (FICA). The partners within the project had the opportunity to inform the rest of the group within the Work Package on the methods that each partner expects to use to collect data. From the partners' presentations of their field data it emerged that there was a strong emphasis on interviewing crash participants to gather data on causal factors in crashes, and it was determined that interviews will be used with the drivers/witnesses in association with collecting information on the more standardised accident/vehicle/roadway factors. It emerged that the variables collected within each group varied to some extent, and discussions within the group resulted in a list of variables that would be routinely collected. It was acknowledged that there is the opportunity to refine the data collection protocol and variable levels over time as more knowledge is obtained about the type of information that will be examined. Therefore, going out to the accident scene, there are two general types of data to be collected. The first type regards what we can observe by investigators at the scene, and the second type is the data that can be collected by interviewing the people involved in the incident. To facilitate the on-scene procedure and the interviewing, an on-scene checklist and an interview guide were prepared to help investigators in the on-scene work.

This study employs prospective, on-scene methods as there is a need for an in-depth crash investigation for each individual case. In most cases, this will involve a rapid-response team normally on stand-by who will travel under blue-light cover to the accident scene. The investigators consist of highly trained teams, usually comprising crash investigators, psychologists, engineers etc.

Data and data levels. A categorization of variables has been made and the variables are divided into different groups; general variables, critical event, road user, vehicle, infrastructure and organisation related contributing factors. There was a general consensus that critical events should be used as the strategy for this project. In order to determine crash causation, there has been a general consensus that identification of "critical events" should be used as the key strategy for this project. These "critical events" categorise the dysfunctional consequences of behaviour, i.e. the different ways in which the dysfunctional behaviour is observable in the dimensions of time, place and energy. For instance, the general critical event called "Timing" is split into three different specific critical events of which premature action is one. Two examples, for the general critical event "Timing" with the specific critical event "Premature action", would be: (1) Overtaking before there is good visibility. (2) Starting/stopping too early at traffic lights.

Training. A training course was developed and presented alongside the training already described in section 2.1 above to ensure harmonised, compatible procedures for gathering of data. This was followed by a 2-month trial data gathering exercise used to examine the viability of each local system and to validate overall methodologies and procedures, and a thorough review.

Data collection and use. This method used for the identification of critical events and hence the 'accident causation' factors is entitled SNACS (SafetyNet Accident Causation System) which is based on an existing method called DREAM (Driving Reliability and Error Analysis Method). DREAM, in turn,

is an adaptation (for the area of vehicle traffic safety) of a model known as CREAM (Cognitive Reliability and Error Analysis Method, Hollnagel, 1998). The DREAM method has a Human-Technology-Organisation perspective, which implies that crashes happen when the dynamic interaction between people, technologies and organisations fails in one way or another and that there are a variety of interacting causes creating the crash (Ljung, 2002).

The SNACS analysis makes it possible to distinguish between different causes of crashes and eventually determine a number of key causation 'clusters', and takes more consideration of the human factors involved in an incident. This is a very useful method since the development of crash countermeasures needs to take into account the factors that are most evident in real-world events in order that such events might be prevented by technology.

Standard data are also recorded describing the environmental (including road infrastructure, e.g. crash barriers, road signs etc.), vehicle and driver factors to provide a description of the whole crash. It is possible to collect a total of more than 1,000 items of information for each case. The data from this study are required for a variety of reasons. First and foremost, the data are needed to provide the European Commission with data that can be used in decision making for road safety policy and regulation. It is anticipated that the data could be used by a multitude of stakeholders in the road transport system but specifically road infrastructure experts, highway engineers and vehicles designers. Thirdly, it is expected that the information will be used by the members of the EC's eSafety initiative (e-Safety, 2006) for the future development of active safety and crash avoidance systems.

3. DISCUSSION

In-depth crash databases contain the necessary post-crash information for analyses of causal factors in crashes. They often contain the detailed injury and vehicle crash data generally gathered by teams of medical and technical experts and police specialists soon after a severe incident. These combined details of road crashes are indispensable for input to road safety regulation.

This project demonstrates (i) the efficient use of existing high quality and under-utilised information resources and the use of such to understand crashes and develop effective countermeasures, and (ii) the development of a novel data capture and categorisation system with the use of existing infrastructure to collect high quality, multidisciplinary crash causation data. Crash causation databases traditionally contain the necessary details of the pre-crash data, where the other databases either contain hardly any data on the pre-crash phase of the incidents or only post-crash data. Self-evidently pre-crash data are indispensable for the analysis of effective countermeasures to prevent road crashes. Since the focus on the relevant pre-crash data generally differs for incidents of different road users, there are activities on crash causation data gathering for car crashes, for motorcycle crashes and pedestrian crashes; the latter two for obvious reasons also include data that are relevant for the causation of injuries. Some national crash causation studies have been carried out in several Member States, either in connection with the in-depth injury causation work (e.g. Medical University of Hannover) or by the police in routine recording of incidents and casualties in the national crash database system (e.g. Great Britain). Additionally, some previous studies have been conducted: The Association of European Car Manufacturers (ACEA) has conducted a European Accident Causation Survey on car crashes with financial support from the European Commission. The focus on research interests of the car manufacturers for this study on the pre-crash conditions of car crashes is quite understandable, since improvement of pre-crash conditions may focus more on road infrastructure as much as vehicle design. However, great care must be taken that any database is independent of the major stakeholders if it is to be used to inform public policy and evaluate the effectiveness of safety systems in an impartial way.

Future directions in pre-crash technology, including that undertaken by the eSafety group involve the development and implementation of many technologies that have the potential for casualty reduction and a representative research in-depth database is needed to ensure that strategic decisions over systems development are directed by estimates of casualty reduction under real-world conditions.

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