Summary:

A methodological study of the Driving Reliability and Error Analysis Method (DREAM)

This study is part of a project about risk-related errors in transport, which has been carried out within the research programme "Risk and safety in the transport sector" (RISIT), organised by the Research Council of Norway. One purpose of the project is to develop tools for analysing dangerous incidents across transport modes, emphasising classification and explanation both of errors that could lead to accidents and of factors influencing the probability of such errors.

This report summarises our experience in the use of the Driving Reliability and Error Analysis Method (DREAM) for the secondary analysis of primary data from road accident investigations. These investigations were performed by the permanent accident investigation teams of the Norwegian Public Roads Administration (NPRA), and the material was made available for the DREAM analyses. DREAM is based on the same methodological and theoretical approach as the more generic method CREAM ("Cognitive Reliability and Error Analysis Method"), developed during the mid 1990's by Erik Hollnagel at the Institute of Energy Technology in Halden, Norway.

The use of DREAM on road accidents has shown that the method functions well for identifying factors that influence the course of events during the pre-crash phase of an accident, and that it adds to the results of primary investigations knowledge and hypotheses regarding causal mechanisms of accidents. Since the method involves classifying actions and causes according to predefined categories, it provides a basis for the aggregation of results from a large number of accidents. Such aggregated data can provide knowledge about the frequency of various risk factors and enable comparisons across different crash types, transport modes or sectors.

The study also resulted in suggestions for improvement of the analysis method.

Background

Although CREAM was originally developed to analyse safety-critical incidents in nuclear power plants, it is generic in the sense that it uses causal categories that are largely independent of the type of socio-technical system analysed. CREAM is based on an MTO perspective (Man-Technology-Organisation), and includes a taxonomy for causal categories covering the three elements M, T, and O, as well as a method for identifying relationships both among the categories and between causal factors and action categories ("error modes"). The method begins by characterising that action which is most directly connected to the critical event (a critical event here is an accident or a near-miss incident). This action characteristic is the "error mode" or, using a biological analogy, the *phenotype,* (which denotes the observable characteristics), as opposed to a *genotype*, which is the more or less covert cause of a phenotype. For a given incident, a general phenotype is selected from a list of nine different classes. This list is supposed to cover all possible physical relationships between objects, which may characterise an action: timing, duration, sequence, object, force, direction, speed, distance, volume. The error modes are further specifications of the general phenotypes, as e.g. "too short distance", "too high speed", or "wrong direction".

In the analysis, a given genotype is always an *antecedent* to a phenotype or to a different genotype. At the same time it may be a *consequent* of other genotypes. The taxonomy specifies the possible connections backward from a consequent to an antecedent, which in turn is the consequent of one or more other antecedents. In this way, and according to the rules for the analysis a network of (assumed) causal relationships is constructed.

Another important element in CREAM is the specification of "Common Performance Conditions (CPC)", which comprise the objective circumstances of the accident, such as work environment, time of day, work organisation or information, as well as an assessment of their possible favourable or unfavourable influence on the process in which the incident took place.

Other variants of CREAM have been developed for special applications or domains, where domain-specific causal categories have been added to the general categories (genotypes) of CREAM. DREAM is an example of such a modification for the road traffic domain, where some categories were added to cover factors related to vehicle and road system. Since CREAM is the core of all these approaches, the term "CREAM-based methods" will be used here when we are considering general aspects of the method.

Data basis

The data for this study are reports and documents from the in-depth analyses of fatal accidents, done by NPRA investigation teams. For the present study material from 15 accidents was selected. We chose accidents with a high level of complexity, i.e. where the chain of causal events was not clear, on the assumption that they would be more suitable for assessing the potential of DREAM to provide new knowledge. An additional selection criterion was driver age, so that most of the selected accidents involved young drivers. Those accidents were chosen because young drivers are over-involved in crashes, and it is therefore particularly important to get more knowledge about accident causation for this group.

Method

Because use of CREAM-based methods allows for some degree of subjectivity on part of the analyst, a small number of accidents were first analysed independently by two persons. The analyses were then compared and discussed, and some inconsistencies were identified and corrected, so that a common understanding was achieved. The remaining accidents were then analysed by only a single analyst.

On the basis of the experience with the analyses, some modifications of the taxonomy were made, and all the analyses were reviewed and revised in accordance with the modified taxonomy.

The results of the DREAM analyses were compared to the available causal analyses in the reports from the NPRA accident investigation teams. Pros and cons were compared between DREAM and the methods used by the investigation teams – primarily "Sequentially Timed and Events Plotting" (STEP) and "Why-Because-Analysis" (WBA).

Results and implications

Identified causal factors

In the 15 accidents analysed, the most frequent phenotype was "wrong direction", reflecting the fact that many of the accidents involved vehicles that ran off the road or moved into the opposite lane and collided with an oncoming vehicle. The most frequent immediate causal factors (genotypes) were "observation missed", "information failure", "false diagnosis", and "performance variability". The most frequent antecedents to these genotypes were (ranked by frequency of occurrence): sight obstruction, inattention, inadequate road design or maintenance, inadequate skill, influence by substance, psychological stress, error in mental model, fatigue, and distraction. The finding that inadequate skill is among the most frequent factors is clearly related to the high proportion of young drivers in the sample.

Assessment of DREAM

In most cases there was a reasonable correspondence between possible causal factors identified by DREAM and the primary analysis. There were, however, a few cases where the DREAM analysis resulted in new hypotheses about accident causes.

An important difference between DREAM and the primary analysis is that DREAM uses predefined causal categories, whereas both STEP and WBA describe events in terms of causal factors defined *ad hoc*. This means that results from DREAM analyses can be aggregated so that frequencies of causal factors can be compared, for instance, between different domains. Such aggregation is not possible when categories are specific for each incident. In other words, the use of specific categories enables a more detailed description of each incident, but it is uncertain whether this will result in more knowledge about accident causation in general.

One possible drawback of those causal analysis methods which, like DREAM, are based on single incidents, is that there is uncertainty associated with some of the identified factors. The results of the analysis may thus give the impression that all factors are equally important. A possible way to partly overcome this problem, is to include a qualification of each factor in terms of a simple probability statement, i.e. to try and differentiate between "possible", "probable", and "certain" factors. An important tool that can help make such judgements is the specification of "Common Performance Conditions" that is carried out in advance of the causal analysis.

A limitation of DREAM as a total approach to accident investigation, is that the method can be used to analyse the course of events only up to the point of loss of control; for road traffic accident this means only the pre-crash phase, while the other methods mentioned here also include description of the crash and post-crash phases.

Another limitation is that DREAM is not suitable for analysing the importance of preventative measures, or "barriers", that could have prevented the incident or reduced its consequences. On the other hand, the knowledge about causal factors obtained using DREAM may in turn have implications for barriers for reducing the risk of similar accidents.

Even though the present assessment is based on experience with DREAM, the similarity to CREAM is so close that the conclusions here can be assumed to be valid for CREAM-based methods in general.

Implications for analyses of road accidents

Against the background of the advantages and limitations discussed above, it is concluded that DREAM would be very useful as one out of three main elements in a total road accident analysis approach. The main function of DREAM would be to analyse the background factors contributing to the occurrence of dangerous situations. The second element should be a method for timeline plotting of all relevant actions and events occurring before, during and after an accident, that could have contributed either to the occurrence of the accident or to its consequences. STEP, which is commonly used by investigation teams, seems to be suitable for this purpose. The third element should be a method for identifying possible barriers that can be assumed to prevent similar accidents or reduce their consequences.

In many cases it was difficult to carry out the DREAM analysis as thoroughly as we would have liked, because information was either missing or of poor quality. This observation raises questions about the procedures that the NPRA investigation teams use to collect accident data. The use of a relatively structured approach like DREAM demands high quality data, and its use should lead to suggestions about the way data collected in the first place could be improved. To achieve a more comprehensive test of a DREAM-based approach to road accident investigation it would be useful to use DREAM as an integrated part of the primary data collection, in which the method of analysis could influence which data are collected.

Finally, a practical limitation to consider is that the CREAM-based methods require a good understanding of the underlying theoretical model(s) and cognitive concepts used in the taxonomy. On the other hand, clear definitions of the concepts, supported by good examples, should make it possible to use the methods without very comprehensive training beyond the basic knowledge of the domain of the particular analysis.