Prototypical scenarios, a means for describing traffic accident phenomena in road safety research and diagnostic studies.

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Abstract.

The concept of an accident 'scenario' (in France 'scénario' or 'scénario type') has been used since the late 80s in French research into road safety. An accident scenario can be defined as a prototypical accident process corresponding to a series of accidents which are similar in terms of the chain of facts and causal relationships found throughout the various accident stages. This concept provides a means of combining and generalizing the knowledge obtained from accident case studies, based on in-depth investigation methods or on detailed analyses of police reports. Applications of this concept are developed in both the field of traffic accident research and safety studies (diagnoses) in preparation for engineering measures or local safety policies. This paper presents the accident scenario concept, its theoretical background, the way it is used for safety research and studies, and the research work on this concept conducted by INRETS in co-operation with several Universities.

1 Scientific context

One of the research approaches used in the field of road safety is the accident in-depth investigation (Baker *et al.*, 1960; Moseley *et al.*, 1963; OECD, 1988). The principle of this approach is the detailed analysis of accident cases, based on an elaborate collection of data (see for example Baker and Fricke, 1986), and aimed at understanding the factual sequence of events and causal relations for each case studied. When such studies are based on a conceptual framework and explicit research objectives (OECD, 1984, 1988), they can produce notable results concerning in particular : the *a priori* evaluation of new technical measures, the evaluation of preliminary assumptions or the emergence of new assumptions concerning the production of accidents and the possibilities of prevention. In France, programmes of accident detailed investigations, using such a method, have been implemented since 1980 (Ferrandez *et al.*, 1986; Girard, 1993; Ferrandez *et al.*, 1995), following a more limited programme carried out between 1965 and 1969 (Veil *et al.*, 1970). Although the means used for such studies were often considered to be excessive compared

to the results obtained (Grayson and Hakkert, 1987), they seem, in the past few years, to be the subject of renewed interest, in particular among car manufacturers, and are finding new applications, for example in the *a priori* evaluation of driving aid technologies (Van Elslande and Nachtergaële, 1994, 1993b).

In this type of research, it is especially important to be able to progress from a series of case studies with findings specific to the cases, towards more general conclusions relating to sets of cases (see for example Midtland *et al.*, 1995). In many studies, the general results are expressed in the form of the frequency of involvement of the various causal factors identified (see the review of Saad, 1985). However, taking into account the heterogeneity and the complexity of the phenomena studied, it is useful to keep less disaggregated information, accounting for the bonds between the causal aspects and the sequences of events in which they are at work. Therefore, the need to perform aggregations or classifications of accident case analyses was also felt (see for example: Snyder and Knoblauch, 1971; Saad, 1985). Other research work, not based on in-depth investigations but on case analyses carried out from police reports, are also confronted with this need for aggregation or classification of such analyses (for example: Bernhoft *et al.*, 1989; Bernhoft, 1993; Yerpez, 1996; let us note that, in these studies, the theoretical framework results, in general, from former in-depth investigation programmes). The objective of such classifications is generally to obtain groups of accidents which are homogeneous from the point of view of the phenomena and processes at work, and thus also homogeneous from the point of view of prevention possibilities.

These classifications obviously vary : they can depend on very specific orientations of research (for example the analysis of the functional failures intervening in a precise phase of the accident: Malaterre, 1990; Nachtergaële and Van Elslande, 1994) or deal with a particular aspect of the accident process, corresponding to a narrowly delimited prospect for prevention (for example the supervision of young pedestrians by another person: Wills *et al.*, 1997). In other cases, classifications seem more directly founded on the phenomena, on the accident process, even if the reference to a prevention point of view is ever present (Schofer *et al.*, 1995; Bernhoft, 1993; Snyder and Knoblauch, 1971).

All of these taxonomies are based on accident case analyses, which are carried out by researchers and refer to a general prevention point of view. They thus differ from more conventional typologies derived from the treatment of accident data files usually available.

In some research work, aggregations of case analyses do not have for main objective the constitution of accident classes with precisely delimited boundaries, but rather aim at building and describing accident process prototypes, then constituting a backup for the study of preventive measures (see for example: Fleury *et al.*, 1987; Mercier, 1993; Dansereau and Lupien, 1994; Yerpez, 1996; Brenac and Yerpez, 1997). The cases aggregated around a prototype do not necessarily present a process identical to prototypical process, but there is a more or less large similarity between each one of these cases and the prototype. The accident process concept is not employed in the restrictive sense of a purely factual and dynamic sequence (route, events, manoeuvres, kinematics, collisions, etc.): a prototypical process can also include, for example, certain causal relations, or sometimes certain circumstances regularly noted in the cases studied. In the research work just quoted, these prototypes of accident process are named 'accident scenario' or 'prototypical scenario'. This concept is defined more precisely in the next part of this text, and illustrated

by various examples. In other research work, similar concepts have been used : for example, Bernhoft (1993) describes results concerning sets of accident cases in the form of 'common accident situations'.

Independently of the research work on accident phenomena, generally carried out on specific themes (i.e. dealing with certain categories of accidents), which has just been mentioned, the need for instruments to aggregate or classify accident case analyses has appeared in the field of safety diagnoses methods. By safety diagnosis we mean the safety studies preliminary to the definition of engineering safety measures or local safety policies. These diagnoses must aim at a sufficient understanding of the phenomena, thus making it possible to define appropriate measures. This generally implies the use of relatively detailed analyses of the police reports. This type of study was initially applied to the treatment of 'black spots'. But diagnostic studies are today also applied to wider areas — road section, street, district, and even a whole road network (of a city, for example) — to prepare more general safety measures, or a local safety policy. It is then important to be able to gather accidents which, even if dispersed over a network or road section, present similarities in their process, and can lead to similar preventive measures : these accidents can then be aggregated around a prototypical scenario, as in the research previously quoted. The use of prototypical scenarios in diagnostic studies has been the object of several research (Fleury *et al.*, 1990, 1991; Brenac and Megherbi, 1996; Brenac *et al.*, 1996). The works of Dansereau and Lupien (1994), already referred to above, had other aims, but the authors, however, also insist on their methodological contribution to the safety studies carried out in practical contexts.

2 Concepts and methods

This deals with the accident scenario concept and the relevant methods, as used in the French research.

2.1 The accident scenario concept

An accident scenario can be defined as a prototypical process corresponding to a series of accidents which present overall similarities regarding the chain of facts and causal relationships throughout the various accident stages (see examples figures 1 and 2).

As mentioned above, the term 'process' is used here not only to indicate a purely factual and dynamic sequence (route, events, manoeuvres, kinematic, collision, etc.), even if this is essential. Depending on the case, certain malfunctions (e.g. : failing to notice a motorcycle) or certain causal relationships (e.g. : parked vehicles => hidden young pedestrian), often found in the accidents grouped together, are also included in the prototypical process.

We use the term 'prototype', referring to cognitive psychology, to emphasise the fact that the accident scenario is an abstract construction, illustrating the main features of a series of similar accidents, and not the specific, concrete process of any one of these. As previously stated, the processes of the accidents in this series are not, in general, identical to the prototypical process, but are to some extent similar[1].

Accident cases are usually aggregated on the basis of overall similarities referring to the various stages prior to collision[2]. This means that the similarity is based not only on an aspect of the accident process, for example the manoeuvre performed immediately before the accident, but also on other facts or mechanisms which occurred prior to this (route taken, approach speed, etc.) or subsequently (possible emergency manoeuvre, pattern of impact). This assumes having access to sufficiently detailed analyses of the accident cases in question : for this we use sequential methods of accident analysis which are dealt with briefly in the following paragraph.

2.2 Accident analysis method

Research carried out on accident phenomena, particularly in the context of in-depth investigations, has shown the complexity, dynamic character and the significance of the temporal dimension in accident production. They have led to structure accident analysis by identifying various phases in their process and, more particularly, within the pre-collision stage (Baker, 1960 ; OECD, 1984). More general theoretical considerations on the preventive strategies for injuries and accidents, which show the multiplicity of the possible

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[1] Christoffel et al. (1996) use the term scenario in a different way. For these authors, it is the actual case process, even if the scenario defined for each accident case is then used to form taxonomies, based on the grouping of cases considered to be identical - regarding certain necessarily limited aspects of the accident process.

[2] This principle provides a way of obtaining accident scenarios of which the significance, in terms of prevention, remains sufficiently extensive. In some research, with more limited objectives, this principle is not used, the similarity referring more to a causal or functional sequence leading to a specific event in the accident process (Nachtergaële & Van Elslande, 1994).

levels of preventive action, also lead to the introduction of a temporal segmentation in accident analysis (Andersson & Menckel, 1995 ; Haddon, 1980).

The sequential accident analysis method we have used (Fleury, 1985 ; Ferrandez *et al.*, 1986 ; Brenac, 1997) has been developed for in-depth investigations but has also been adapted to the study of police reports and the context of safety diagnoses. It favours accident prevention and therefore focuses on the pre-crash stage. It is based on a segmentation of the factual accident sequence into various phases :

- the situation prior to driving (should sufficient information be available),
- the driving situation, which describes the conditions and driving activity on the route and the section of route leading to the accident site,
- the accident situation or discontinuity situation : instantaneous, distinguished by an event (e.g. : a manoeuvre at an intersection) or kinematic conditions (e.g. : a high speed on approaching a difficult bend) indicating a shifting over to a critical situation (the emergency situation described below) ;
- the emergency situation, where only extreme manoeuvres could still, in some cases, prevent collision ;
- the collision situation, which includes the collision itself and its consequences

Initially, the various facts or events are situated and described within the various phases. This work of course includes some interpretation, particularly when the data under review (e.g. : police reports) give limited informations.

The investigation is then focused, phase by phase, on the functional processes and the causal factors that have determined these facts or events. This work is based on different theoretical assumptions (e.g. : a model in which the human operator is seen as an information processing system).

2.3 Method used to develop accident scenarios

In most of the French research work mentioned above (Fleury *et al.*, 1987 ; Fleury *et al.*, 1990, 1991 ; Mercier, 1993 ; Brenac & Megherbi, 1996 ; Brenac *et al.*, 1996 ; Yerpez, 1996 ; Brenac & Yerpez, 1997), the method used is an inductive approach, based on an examination of each case, grouping together similar cases and building a prototypical scenario using this case grouping.

The first stage therefore consists of grouping together cases with overall similarities in the accident process. This comparison is both qualitative and holistic : the sequential analysis is not coded (as was the case with Clarke *et al.*, 1995) - there is therefore no formal case comparison -, and the similarity between cases is considered at a general level. There is, of course, a measure of interpretation in this regrouping[3]. A more formal approach

[3] To examine the variability of accident groupings in relation to those who developed them, we asked two students to each develop independently a series of prototypical scenarios using the same sample of 199 accidents representing accidents which occurred in 1995 in a given area of France. To illustrate the regroupings, a co-occurrence table was drawn up, defined by elements aij such as aij = 1, should accidents i and j be related to the same prototypical scenario, and aij = 0, if they are not related to the same prototypical scenario. The two tables of co-occurrence thus obtained, corresponding to the regroupings carried out by the first and second student, were compared using an Euclidean distance, ranging from 0 (perfect similarity) to 1 (perfect dissimilarity). The value obtained in this case was 0.26. Qualitatively, the difference between the series of prototypical scenarios (including 22 and 28 prototypical scenarios) seems to be often linked to differences in depth of detail ; the accidents related to a same scenario in the

would have led to an excessive reduction in the complexity and diversity of the phenomena and would probably only have replaced the interpretative dimension of the qualitative and holistic assessment by an arbitrary choice of coding and weighting of similarity criteria.

When the groupings are in place, it is then possible to build prototypical scenarios. In each group, the comparative examination of the various cases makes it possible to identify the main, most frequent, features of these accidents and to use this basis to construct a prototypical process. The representation of prototypical scenarios can take different forms (purely textual, formal, based on diagrams, combining several forms - Després, 1997 ; Rakotosaona, 1996) and be completed by various elements : information on cases used to construct the prototype, frequency of certain prototypical characteristics, causal factors identified, etc.

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first series of prototypical scenarios were, for example, grouped around two prototypical scenarios which were more detailed in the second series (Delcamp & Pelat, 1996).

3 Examples of the application of accident scenario concept

3.1 Applications for research into certain accident categories.

One of the first French research projects to make explicit use of the accident scenario concept dealt with accidents involving heavy goods vehicles and was based on 33 cases in the in-depth investigation programme at Salon-de-Provence (France) (Fleury *et al.*, 1987). Other research work on other themes (accidents when overtaking, loss of control on bends, etc) have since also used this concept. Among recent research, we can mention Mercier (1993) on traffic accidents in roadwork areas or Yerpez (Yerpez, 1996 ; Yerpez & Girard, 1996) on accidents involving elderly pedestrians in urban areas. In this work, the phenomena-related results are combined as a series of prototypical scenarios, which therefore provide a basis for considerations regarding preventive measures. Mercier, for example, obtained a series of 6 accident scenarios in roadwork areas, and suggested preventive measures in terms of signposting and the organisation of work sites, the management of traffic in these areas and the training of drivers and work-site personnel.

Prototypical scenario n°1 (23 cases)

General conditions and driving situation

In conditions of acute tiredness as a result of work or intensive activity, and/or after a long journey, a driver is travelling along a motorway.

Accident situation (discontinuity)

The driver goes to sleep at the wheel, the vehicle swerves and moves to the left or right, off the carriageway.

Emergency situation

The driver does not react.

Impact situation

Runs into obstacles, ditches, barriers along the side of the carriageway, or turns over.

Main causal factors : acute tiredness linked to a long journey, or linked to working conditions of long distance lorry drivers, or to private activities (e.g. : day spent skiing, etc.) ; lack of sleep linked to long night journey or to working conditions of long-distance lorry drivers.

Main preventive perspectives : checking and regulating working conditions for lorry drivers ; alarm systems (vehicle or infrastructure) to wake up a sleeping driver ; the design of hard shoulders on motorways ; communicating information for long-distance users.

Prototypical scenario n° 2a (7 cases)

General conditions and driving situation

A young, often inexperienced, driver residing locally, is driving along the motorway late at night or early in the morning, often after an evening spent with friends.

Accident situation (discontinuity))

The driver falls half asleep for a moment and his vehicles starts to swerve to the right or to the left.

Emergency situation

The driver jerks the wheel and loses control of his vehicle.

Impact situation

The vehicle usually runs into the protective barriers on the left or, less frequently, on the right of the carriageway, and comes to a halt in the other traffic lane or on the right hand hard shoulder.

Main causal factors : tiredness and lack of sleep due to an evening out or party spent with friends which went on to midnight or beyond ; late time in the night resulting in a need for sleep (circadian rhythm) ; lack of driving experience may lead to an over-abrupt reaction in any emergency situation.

Main preventive perspectives : co-driving or driving control systems in the event of excessive dynamic demands (in an emergency situation) ; driving instruction which includes vehicle behaviour under considerable dynamic demands ; informing young drivers.

Figure 1. Two prototypical accident scenarios on non-urban motorway (adapted from research by Megherbi, 1997)

In recent research into accidents on non-urban motorways (Megherbi, 1997), 290 cases of accidents which occurred on the motorway network in the south of France were analysed using police reports. Twenty six prototypical scenarios were developed. Two of them are summarised in figure 1. They are presented in more detail in the reference quoted.

3.2 Applications for safety studies (diagnoses)

A number of research projects dealing with diagnostic methods have shown the advantages of the prototypical scenario concept in studies used to prepare safety network improvements or local safety policies (Fleury *et al*, ; 1990, 1991 ; Brenac & Megherbi, 1996 ; Brenac *et al.*, 1996). Within such a context, an analysis of unsafety phenomena can be approached from three complementary angles (Fleury *et al.*, 1990, 1991) : the statistical analysis of commonly available accident files, accident cartography and finally a detailed analysis of accident cases using, in general, police reports, with the possible addition of on-site observations. This case analysis approach is essential to understand the phenomena and define action adapted to the local context. The prototypical scenario concept is a way of combining the results of these case analyses. The prototypical scenarios obtained in this manner provide a basis on which to consider the action to be taken, but also concrete backup for the provision of accident information for information campaigns or training.

An example of a prototypical scenario is summarised in figure 2. It is the result of work conducted by Brenac *et al.* (1996). Four hundred and twenty accidents selected at random from the 7200 injury accidents that occurred in the French *département* of the Bouches du Rhône in 1995 were studied. Forty one prototypical scenarios were obtained. This approach forms part of studies conducted in preparation for a road safety plan in this *département*.

Prototypical scenario n° 12a (12 cases)

GC and DS	*AS*	*ES*	*IS*
- Vehicle travelling on urban road. Usually no pedestrian crossing. - Young pedestrian (3-10) usually accompanied.	The young pedestrian, usually hidden by a parked vehicle, runs across the carriageway, his attention often focused on an objective on the other side of the road (6 cases, in 4 of these cases, this objective is the child's mother).	The driver brakes too late. In some cases, he does not have time to react.	The vehicle knocks down the pedestrian

Figure 2. Prototypical accident scenario involving young pedestrian (adapted from Brenac et al., 1996)

This scenario is presented in greater detail, with a list of the causal factors identified for the cases as a whole, in the reference quoted (cf. also : Brenac & Yerpez, 1997). It can be seen that this prototypical scenario may suggest possible measures at several different levels, within the framework of a local safety policy : in terms of general network organisation (e.g., consideration could be given to adapting pedestrian crossings to the needs and usual routes taken by these pedestrians), technical measures (breaking up lines of parked vehicles by extending the sidewalk in places and therefore improving visibility), providing information for both children and parents in schools and associations (paying

particular attention to the behaviour of adults accompanying children). For this type of measure the accident scenario itself provides information that is useful and relatively easy to pass on as it is similar to actual accident phenomena.

4 The development of research into the accident scenario concept.

The concept of an accident scenario, as has just been defined in terms of both the generic characteristics of the accident process and in relation to a prevention-oriented study context, can, if seen from a cognitive science standpoint, be considered as knowledge : a specific accident is not a scenario and a scenario is the result of a combination of information leading to a cognitive construction. This raises several questions that we are unable to deal with here, concerning the status of this knowledge and its relationship to phenomena and action. These questions can be related to research into cognitive psychology regarding mental representations and categorisations (cf., Dubois, 1986, 1991).

We will mention only that accident scenarios can be considered as mental representations that include a certain degree of generalisation and a close relationship with the action. A comparison could be attempted - but with caution - with illness, which could allow us to speak of 'road traffic pathologies'. A metaphor such as this emphasises the logic of the progression of the phenomena (and therefore the mechanisms), the prevention aspect, but also suggests the related concept of symptom, a manifestation linked to malfunctions and which is above all more easily identifiable and possibly measurable. Considered in this way, accident scenarios provide a useful tool for the diagnosis of safety by way of their general nature (synthesis), their constitutive link with preventive action and the possibility of identifying them by way of certain characteristics that could be considered as symptoms.

Other questions can also be examined to envisage using this knowledge within the framework of preventive action :

- what is the consistency and soundness of this knowledge ?
- how can one recognise scenarios already established among significant accident populations for which only limited information is available ?
- what are the conditions for the practical use of this knowledge and, in particular, how can it be integrated into computerised systems for diagnostic purposes ?

4.1 Research into scenario consistency

The usual practice of developing scenarios using an accident sample is a bottom-up type approach which requires checking soundness and generalisation in several ways, by examining :

- the independence of these representations in terms of expert knowledge, in other words, checking that several analysts will construct results that concur;
- the independence of scenarios in terms of the sample of accidents being studied, which consists of checking that they are indeed general 'pathologies' and not specific to a particular site ; to achieve this it is possible to compare the scenarios obtained on similar road networks ;
- finally, the possibility of differentiating the scenarios at different levels ; these descriptions may be very general or very detailed regarding the accident process,

forming therefore a description organised in scenarios and sub-scenarios (knowledge organisation model).

Comparing the results obtained by different specialists

This type of comparison has already been mentioned. To achieve this requires both producing a consensus between specialists and analysing the various frameworks suggested for the construction and representation of accident scenarios. Furthermore, some authors, who do not have extremely reliable information available, are more likely to base their descriptions on the symptoms and contexts within which the accidents occur whereas others, by basing themselves on in-depth investigation data, will focus more on the accident process. Such a formal diversity of results was subsequently used as a basis for *pathology - symptom - environment* relationships to be used in diagnoses.

Contextualisation of accident scenarios

When the independence of scenario construction in terms of specialists has been completed, to be able to speak of 'pathology' requires comparing the scenarios that occur in different types of locations. To achieve this we use two types of approach. The first consists of comparing and combining the results obtained for different populations of accidents that occurred either in urban areas, on country roads or on motorways. Different work already carried out is therefore reviewed to achieve a consensus between the results obtained (Després, 1977). A second approach entails using scenarios constructed from accidents that occurred on the local road network in the Eure et Loir *département* (Fleury *et al.*, 1990) and uses them again as a means of aggregating accidents which occurred on the same type of network in the Bouches du Rhône *département* (Garaud, 1994 ; de Reynies, 1995).

Classifying scenarios

Incorporating scenarios will tend to favour a level of scenario description apparent in previous examples. However, some of this work involves organising the results in groups of scenarios based on the relative similarity of accident processes for certain scenarios or on the similarity of malfunctions with similar origins (Reynier, 1992 ; Rakotosaona, 1996).

4.2 Recognising generic scenarios within an accident population

The mathematical problems involved in the recognition of accident scenarios

It is particularly difficult to compare knowledge obtained from relatively detailed data and data from statistical files which is succinct but which covers a larger number of accidents (Lee & Fell, 1988).

Considerable research work has been aimed at comparing scenarios already constructed to an accident population which, although extensive, comprises information which is superficial in terms of quality and quantity.

The general purpose is to recognise an accident process using descriptive variables that are considered to be more or less representative of certain symptoms[4]. The description of the succession of events in an accident file is, indeed, concise ; on the other hand, other variables may be of good quality. Systematic work to identify the contexts in which

[4] It is this approach that is implicitly followed when inferring a *loss of control* from characteristics of *single vehicle* and *wet road surface*.

accidents often occur, using work already carried out and which involves constructing scenarios, is useful when using these approaches.

In the same way, certain statistical techniques may provide a way of suggesting unrecognised accident groups and so offer specialists a way of constructing new scenarios by referring back to the information contained in the police reports for the corresponding accidents. Different approaches have been tested and have shown the importance of :

- Coding (standard, symbolic) but also weighting (in terms of probabilities or possibilities) representing the frequences of occurrence and also qualitative evaluations of specialists, assessments of the quality of the information, etc.
- The choice of classification methods. A number of solutions are possible and literature on the subject is abundant. Some methods involve case by case approach or a comparison of accident groups and scenarios.
- The similarity thresholds which are tested directly by examining, at different levels, the accident groups likely to be related to a scenario.
- Specialist validation of proposals for new scenarios and a possible scenario classification.

This research work is continued in co-operation with the Universities of Paris V and Paris IX (France).

4.3 Moving towards aid systems using the scenario concept

Accident analysis aid systems

When defining preventive measures likely to improve safety, the data collected by the police is only sufficient up to a certain point. It is sometimes necessary to use an ad hoc collection technique by investigating the scene of the accident either at the same time as the emergency services or later (one or two days after the accident). This type of collection is generally performed by a multi-disciplinary team, as various types of information need to be collected (interviews with those involved, technical data regarding the vehicle, route, etc.) (OECD, 1988). Such work is performed as part of the In-Depth Accident Study in Salon de Provence (France) (Ferrandez *et al.*, 1995).

A research project in collaboration with the Institut National de Recherche en Informatique et Automatique (INRIA) the University Paris V and INRETS (Dieng, 1995) is aimed at obtaining and modelling the knowledge used for accident analysis. Theoretically, road accident analysis requires the use of highly diverse knowledge, and therefore calls upon a number of specialist fields such as mathematics (kinematic), medicine, engineering, psychology, physiology, sociology, etc. Each of these fields provides a contribution that is both specific and complementary and helps to understand the development of such an event within - of course - the limits of the data which is accessible and collected. Collecting this varied expertise requires the use of methods such as KADS which initially provide a means of modelling this analytical work. The following schema suggests an architecture of an accident analysis aid system which should be developed in the years to come.

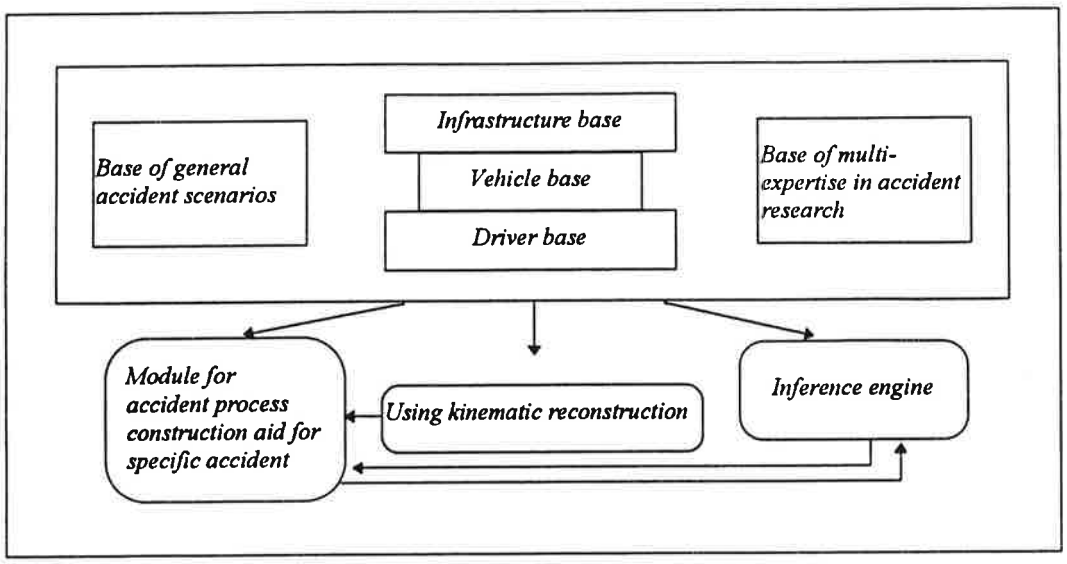

Figure 3. Architecture of road accident analysis aid system (Alpay et al., 1996)

Diagnosis aid system

In a more operational context, the use of the accident scenario concept as 'road traffic pathology' may produce a diagnosis aid to provide addition knowledge linked to the accident processes and relevant action and thus complete the data obtained from police accident files. This is where the metaphor acquires its full meaning as, in this type of file, information on the accident process is generally very sketchy, whereas factual elements can be used to recall specific symptoms. This type of approach continues on from previous work on scenario recognition and has been dealt with in two study projects, one on the design of an operational recognition tool for an existing population of accidents and the other on extending such work to include lexical[5], cartographic and numeric data.

[5] Certain municipal authorities and police services are starting to computerise the texts of accident reports (slightly changed in order to be anonymous).

5 Conclusion

The scenario concept used here is adapted to road safety. There are other applications in the field of research, when designing technical or risk prevention systems. The advantage of this type of analysis was recognised at an early stage - especially in the 70s - particularly with regard to industrial risks when justifying economic decisions made using rational models to weigh up the probability of certain accident scenarios occurring and their consequences in the light of the economic advantages to be gained by a company and the cost of prevention.

In brief, methods are based on experience feedback (accidents or incidents that actually occurred), on simulations that make it possible to calculate the probabilities of failure - including human failure -, or by using expert knowledge, should it be no longer possible to use the previous methods, especially for open-ended socio-technical system applications. In this way the methods can work back from the consequences to the causes (causal tree) or inversely, use graphs to analyse the consequences (failure analysis). This often provides a way of calculating occurrence probabilities. Other methods are based on expertise (interviews with those involved at a local level), analysing complex systems (e.g., a town) to reveal the initiating events, means of protection, means of prevention, severity-increasing phenomena, the consequences, and so construct risk/consequence scenarios to be used to display preventive measures (Theys & Rocker, 1986).

Road accident scenarios, which have been the subject of this paper, are based on the first type of method and constructed using a case by case model of the causal links revealed by analysis to have been at the origin of the accident. It is then possible to consider an a posteriori generic scenario or prototypical scenario (depending on the author) as a construction derived from a combination of several cases considered to be similar.

A completely different interpretation of the term scenario appears in the work of those who collect and reconstruct the accident sequence. This cognitive work refers not only to theoretical models but also to the known and recalled situations that can be identified as permanent scenarios or 'fragments of scenario' and which belong in full to analyst knowledge (Després, 1997). This refers to structures that can be considered to be static (Rakotosaona, 1996) as they previously existed, or dynamic as they recall cases already 'seen' and lead to both classification and analysis. This controversial theoretical question will not be dealt with here as it is discussed in the literature which specialises in cognitive psychology.

It is of course not easy to have direct access to knowledge regarding permanent scenarios. This is why the construction of a system that could be used for accident analysis and to reconstruct the relevant sequence by using a tested and validated a posteriori scenario data base, which will perform the same function as permanent scenarios, is seen as a possible solution for the improvement of analysis (Alpay *et al,* 1996). Such a system assumes prior conditions for the soundness of these a posteriori scenarios in relation to specialist knowledge, inter-road site differences, the mathematical methods used and the similarity tests (thresholds).

To conclude, the development of computer systems based on the scenario concept to assist in accident analysis or diagnostic studies would seem to be an avenue likely to provide

a step forward when considering safety at a local level, and justifies the orientation of our present-day research into road traffic accidents.

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References

Alpay, L., C. Amerge, O. Corby, R. Dieng, A. Giboin, S. Labidi, S. Lapalut, S. Després, F. Ferrandez, D. Fleury, Y. Girard, J.L. Jourdan, D. Lechner, E. Michel, and P. Van Elslande. - *Acquisition et modélisation des connaissances dans le cadre d'une coopération entre plusieurs experts : Application à un système d'aide à l'analyse de l'accident de la route*. Rapport final de recherche. Projet ACACIA (PREDIT/DRAST). INRIA, Sophia-Antipolis, 382p., 1996.

Andersson, R., and E. Menckel - On the prevention of accidents and injuries, a comparative analysis of conceptual frameworks. *Accident Analysis and Prevention*, 27(6), 757-758, 1995.

Baker, J.S. - *Experimental case studies of traffic accidents : a general discussion of procedures and conclusions*. Northwestern University Traffic Institute, Evanston, Illinois, 1960.

Baker, J.S., and L.B. Fricke - *The traffic accident investigation manual. At-scene investigation and technical follow-up*. Northwestern University Traffic Institute, Evanston, Illinois, 1986.

Bernhoft, I.M. - Cyclist fatalities in Denmark. International conference *Strategic highway research program and traffic safety on two continents*, The Hague, The Netherlands, 22-24 sept. 1993.

Bernhoft, I.M., J. Christensen, H.J. Johansen, L. Larsen, and H. Lund - *Fatal accidents involving heavy freight vehicles in 1989*. Report, Danish Council of Road Safety Research, Copenhagen, 1990.

Brenac, T. - *L'analyse séquentielle de l'accident de la route (méthode INRETS), comment la mettre en pratique dans les diagnostics de sécurité routière ?* Rapport INRETS, Outils et Méthodes, n° 3, 79 p., 1997.

Brenac, T., and B. Megherbi - Diagnostic de sécurité routière sur une ville : intérêt de l'analyse fine de procédures d'accidents tirées aléatoirement. *Recherche Transports Sécurité*, n° 52, pp. 59-71, 1996.

Brenac, T., J. Delcamp, S. Pelat, and G. Teisseire - *Scénarios types d'accidents de la circulation dans le département des Bouches du Rhône*. Rapport MA 9611-2, 73 p., 1996.

Brenac, T. and J. Yerpez - Accidents impliquant des piétons : scénarios types obtenus à partir d'analyses fines de cas. *Actes du colloque européen sur les usagers vulnérables dans la circulation, Vulnerabilis 1997*, Lyon, 14-15 Jan. 1997.

Christoffel, K.K., J.L. Schofer *et al.* - Evaluation of a systematic approach for identifying injury scenarios. *Injury Prevention*, 2, 221-227, 1996.

Clarke, D.D., R. Forsyth and R. Wright - *The analysis of pre-accident sequences*. TRL Contractor report, n° 305, 63 p., 1995.

Dansereau, P., and C. Lupien - Scénarios d'accidents et conditions environnementales. *29ème Congrès annuel de l'AQTR*, pp. 65-79, 1994.

Delcamp, J. and S. Pelat - *Diagnostics locaux de sécurité, étude des méthodes d'analyse en scénarios types d'accident*. Ecole Nationale des Travaux Publics de l'Etat, unpublished, 86 p., 1996.

Després, S. - Personal communication (1997).

Dieng, R., A. Giboin, C. Amergé, O. Corby, S. Labidi, S. Lapalut, L. Alpay, S. Després, F. Ferrandez, D. Fleury, Y. Girard, J.L. Jourdan, D. Lechner, E. Michel, and Van Elslande P. - *Acquisition et modélisation des connaissances dans le cadre d'une coopération entre plusieurs experts : Application à un système d'aide à l'analyse de l'accident de la route*. Rapport d'avancement. Projet ACACIA (PREDIT/DRAST). INRIA, Sophia-Antipolis, 62p., 1995.

Dubois, D. - *La compréhension de phrases : représentation sémantique et processus*. Thèse de Doctorat d'Etat. Université de Paris VIII. 1986.

Dubois, D. (ed.) - *Sémantique et Cognition*, Ed. du CNRS, Paris, 1991.

Ferrandez, F., D. Fleury and G. Malaterre - L'étude détaillée d'accidents (EDA), une nouvelle orientation de la recherche en sécurité routière. *Recherche Transports Sécurité*, n° 9-10, pp. 17-20, 1986.

Ferrandez, F. *et al.* - *L'étude détaillée d'accidents orientée vers la sécurité primaire, méthodologie de recueil et de pré-analyse*. Presses de l'Ecole Nationale des Ponts et Chaussées, Paris, 244 p., 1995.

Fleury, D. - L'analyse de l'accident. *Actes de la journée spécialisée Genèse des accidents et perspectives de recherche en sécurité : étude pilote de Salon de Provence*, 1er octobre 1985, INRETS.

Fleury, D., C. Fline and J.F. Peytavin - Les accidents de poids lourds, analyse des dossiers de l'Etude Détaillée d'Accidents. *Recherche Transports Sécurité*, n° 14, pp. 31-39, 1987.

Fleury, D., C. Fline, J.F. Peytavin *et al.* - *Diagnostic de sécurité sur un département, application au cas de l'Eure et Loir*. Rapport INRETS, n° 125, 199 p., 1990.

Fleury, D., C. Fline and J.F. Peytavin - *Diagnostic local de sécurité, outils et méthodes*. INRETS, SETRA, 62 p., 1991.

Garraud, I. - Etude de la robustesse de scénarios d'accidents. Mémoire de DEA (under the supervision of M. Summa) Université Paris IX Dauphine, 1994.

Girard, Y. - In-depth investigation of accidents, the experience of INRETS at Salon de Provence. *ICTCT Congress 1993*, Salzbourg, 27-29 october 1993.

Grayson, G.B., and A.S. Hakkert - Accident analysis and conflict behaviour. In J. Rothengatter et R. de Bruin (Eds), *Road Users and Traffic Safety*, Van Gorcum, Assen, 1987.

Haddon, W. - The basic strategies for reducing damage from hazards of all kinds. *Hazard Prevention*, 16, 8-11, 1980.

Heurdier, S. - Analyse symbolique de scénarios d'accidents. Recherche et interprétation de leur extension à partir de données du BAAC (under the supervision of E. Diday). Université Paris IX Dauphine, 1991.

Lee S.N., and J.C. Fell - *An Historical Review of the National Highway Traffic Safety Administration's Field Accident Investigation Activities*. National Center for Statistics and Analysis - NHTSA Technical Report, Washington, 1988.

Malaterre, G. - Error analysis and in-depth accident studies. *Ergonomics*, 33, 1403-1421, 1990.

Megherbi, B. - *Classifications d'accidents, reconnaissance de l'appartenance d'accidents à des scénarios types : applications aux autoroutes interurbaines*. Rapport intermédiaire MA 9707-1, pour l'ASFA. INRETS, 71 p., 1997.

Mercier, A. - *Les accidents de la circulation au droit des chantiers routiers*. Rapport, INRETS, SPRIR, 80 p., 1993.

Midtland, K., R. Muskaug, F. Sagberg, and N.O. Jorgensen - *Evaluation of the in-depth investigations of the Swedish National Road Administration*. TØI report, 296/1995, Oslo, Norway, 153 p., 1995.

Moseley, A.L. *et al.* - *Research on fatal highway collisions*. Harvard Medical School, 257 p., 1963.

Nachtergaële, C. and P. Van Elslande - *Classification des défaillances des conducteurs selon leur implication fonctionnelle dans la genèse d'un accident*. Rapport, INRETS, 101 p., 1994.

OECD - *Programmes intégrés de sécurité routière*. Paris, 103 p., 1984.

OECD - *Accidents de la route, enquêtes sur le site*. Paris, 113 p., 1988.

Rakotosaona, H. (under the supervision of S. Després and D. Fleury) - *Représentation des scénarios et classifications des accidents de la route*. Université René Descartes, INRETS, unpublished, 1996.

Reynier, A. - Analyse symbolique de scénarios d'accidents. Mémoire de DEA (under the supervision of M. Summa , E. Diday and D. Fleury).Université Paris IX Dauphine, INRETS, 1992.

Reynies (de), A. - Etude méthodologique de la validation de scénarios d'accidents. Rapport de DESS, Université Paris IX Dauphine, 1995.

Saad, F. - L'étude détaillée d'accidents, revue bibliographique. *Actes de la journée spécialisée Genèse des accidents et perspectives de recherche en sécurité : étude pilote de Salon de Provence*, 1rst oct. 1985, INRETS.

Schofer, J.L., K.K. Christoffel, M. Donovan, J.V. Lavigne, R.R. Tanz and K.E. Wills - Child pedestrian injury taxonomy based on visibility and action. *Accident Analysis and Prevention*, 27 (3), 317-333, 1995.

Snyder, M.B. and R.L. Knoblauch - *Pedestrian safety : The identification of precipitating factors and possible countermeasures*. Vol. I. Operations Research Inc. for National Highway Traffic Safety Administration, 1971.

Theys, J., and O. Rocher - Etude de la sécurité d'une ville, Poitiers. In : Colloque international de recherche *Evaluer et maitriser les risques*, Chantilly, 20 - 22 Jan., 1986.

Van Elslande P., and C. Nachtergaële - *Evaluation des CED4 et CED5 de Prometheus : une analyse a priori sur dossiers détaillés d'accidents.* Rapport, INRETS, 1993 (a).

Van Elslande, P. and C. Nachtergaële (1993b) - A qualitative evaluation of RTI demonstrators using in-depth accident analysis and opinion investigation. *ICTCT Congress*, Salzbourg, 27-29 october 1993.

Veil, C. *et al.* - *Etude clinique d'accidents de la circulation routière, rapport final.* Cahiers d'études de l'ONSER, n° 25, 1970.

Wills, K.E., R.R. Tanz, K.K. Christoffel, J.L. Schofer, J.V. Lavigne, M. Donovan and K. Kalangis - Supervision in childhood injury cases : a reliable taxonomy. *Accident Analysis and Prevention*, 29 (1), 133-137, 1997.

Yerpez, J. - Piétons âgés en ville, typologie d'accidents de la circulation routière, le cas de deux villes françaises. *Actes du 3ème colloque national sur la sécurité routière du Maroc "Pour des routes et des rues plus sûres"*, Casablanca, 5-6 dec. 1996.

Yerpez, J. and Y. Girard - *Le piéton âgé en ville moyenne : insécurité subjective et accidents de la circulation.* Rapport INRETS-PIRVilles, 115 p., 1996.