Abstract:
Most safety studies come to the conclusion that human error is the main cause of accidents. Nevertheless, such a conclusion has not proved to be efficient in its capacity to offer adequate means to fight against this error. In a purpose of better qualifying accident causation in TRACE, so-called 'human error' is analyzed here from literature review and in-depth accident data with the aim of going further than such a simple statement. The present report is aimed at investigating the different types of 'errors' with the help of a classification model formalizing typical 'Human Functional Failures' (HFF) involved in road accidents. These failures are not seen as the causes of road accidents, but as the result of the driving system malfunctions which can be found in its components (user/road/vehicle) and their defective interactions (unfitness of an element with another). Such a view tries to extend 'accident causation' analysis toward understanding, not only the causes, but also the processes involved in the accident production. So the purpose is to go further than establishing the facts, toward making a diagnosis on their production process. The usefulness of this diagnosis is to help defining countermeasures suited to the malfunction processes in question.

This report D5.1, addressed to human functional failures, is in strong connection with Trace report D5.2 devoted to the factors (human and others) and situations of these failures. Trace deliverable D5.3 stresses the most recurrent typical scenarios in which the human functional failures are found. D5.4 is enlarging the questioning of 'human factors' from the side of sociological and cultural backgrounds determining accidental driving behaviour. All these reports are parts of WP5, whose main objective is to provide operational Work Packages of TRACE project with methodological support concerning 'human factors' aspects involved in road accidents.

Keyword list: Human error - Human factors - Accident study - Ergonomics - Cognitive Psychology
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1 Executive Summary

1.1 TRACE project: TRaffic Accident Causation in Europe

In spite of countless amounts of research and development, road safety is still one of the main societal concerns today. It is not only a matter of concern for the European Commission and National Governments but also for the vehicle industry, insurance companies, driving schools, non-governmental organisations and more generally for every single road user. Car manufacturers have made strong efforts and have dramatically improved passive (and also active) safety of their vehicle for the past 15 years. However, current road safety research has shown that an asymptote is about to be reached on this aspect in most countries and many experts agree that preventive (prevention of accidents) and active safety (recovery of an emergency situation) should now, particularly, be brought forward.

The TRACE project has 2 major objectives:

The first one addresses the determination and the continuous up-dating of the aetiology (i.e. analysis of the causes) of road accidents and injuries, and the definition of the real needs of the road users as they are deduced from accident and driver behaviour analyses.

The second one aims at identifying and assessing, among possible technology-based safety functions, the most promising solutions that can assist the driver or any other road users in a normal road situation or in an emergency situation.

So the purpose is first to bring a comprehensive and understandable definition of accident causation which goes further and deeper than the usual statements. It is also to provide the scientific community, the stakeholders, the suppliers, the vehicle industry and the other Integrated Safety program participants with a global overview of the road accident causation issues in Europe and promising solutions based on technology.

1.2 WP5 'Human Factors'

In order to gain new knowledge on accident causation, several methodological Work Packages (WP) have been defined in the structure of TRACE in order to give a support to the analyses conducted into the operational Work Packages of the project.

As such, WP5 'Human Factors' has been defined to improve the multidisciplinary methodologies that allow the analysis of the role of 'human factors' in road accident production. In brief, WP5 is oriented toward the diagnosis of the difficulties met by road users which lead them to an accident, toward the identification of the contexts in which they take place, and toward the definition of the origins of these difficulties whether they are human in nature otherwise.

The methods aim to standardise accident analysis in order to bring validated and comparable results from one study to the other, without losing the scientific and academic background required for a comprehensive research work.

Four tasks compose this Work Package. The first three are oriented toward the elaboration of an operational model permitting a comprehensive analysis and classification of 'human error' generating processes. The fourth one is devoted to a further and wider view on the influence of the social and societal context on accident occurrence.

- Task 5.1 A model for human functional failure analysis

The objective of this task is to define and characterize the different types of human errors, violations and difficulties which are involved in the accident generating process. Such modelling work is based both on scientific literature dealing with human error analysis, and on truly in-depth accident data. The purpose is to build an operational grid for human functional failures, consistent with ergonomics concepts and specifically adapted to the driving task.
Task 5.2 A comprehensive grid of factors and situations for human functional failure

Human failures are explained by factors characterizing the state of system, i.e. the defects of its components (human and other) and of their interactions. These factors are then considered as the explanatory elements of the road users' incapacity to adapt to the situation in hand. A grid of all the relevant elements contributing to human failures has been compiled, and differentiates those factors coming from the 'human' part of the system, from those coming from the layout, the traffic interaction and the vehicle.

Task 5.3 Typical failure-generating scenarios

The purpose of this third task is to combine the results from T5.1 and T5.2 in order to build a methodological frame allowing the aggregation of accident data under the form of generic accidental processes, viewed as an integration of the parameters characterizing the accident generation: which situation and context, which human failure, which explicative elements, which consequence, etc. They will allow putting forward the typical specificities of the difficulties encounters by different types of road users, in different types of situations.

Task 5.4 Social and cultural aspects of human factors

The purpose of this task is more prospective. It is to analyze the socio-economic/socio-cultural dimension of human activity, its interaction with the driving system, to build a framework of analysis aimed at completing the accident analysis framework proposed in T5.3 by putting forward broader 'upstream' factors of its production process.

Analyzing 'human functional failures' in road accidents: summary of TRACE report D5.1

So called 'human error' may be analysed in many different ways, depending on how it is viewed. As stated by Hollnagel and Amalberti (2001), it is an elusive concept which is both used in the frame of everyday life and in safety research, which leads to the tendency to take it in its common sense use. Such a tendency gives rise to an oversimplified conception of how events occur, relying on a binary model promoting the searching of a root cause either in the error of an operator or in the breakdown of a technical device. Such a view neglects the complexity of the accident phenomena which are the result of a combination of factors. This raises the question of the necessity to base every analysis upon a truly defined model which will guide not only the conception of the event, but also the way to manage it.

In a legal context, for instance, an error will be analysed as a ‘fault’. And the solution for it will be a punishment. In the present study directed towards ergonomics, ‘error’ is not considered as a fault to blame, but as a symptom of a problem characterizing the driving system. This symptom will be analysed as the undesirable result of interaction between an operator and a task, arising from interaction between internal and external determinants. And the solution will be searched in an adaptation of the system in line with the functioning of its users, in order to counteract the malfunctions originating such symptoms.

In order to avoid any semantic confusion, 'human error' will be studied here under the label of Human Functional Failure (HFF), described such as following.

What is a HFF? To be able to adapt successfully to the variability, complexity, and eventually malfunctions of the driving system, drivers put forward some combinations of perceptive, cognitive and active functions. We tend to forget that the use of these functions enables these drivers to overcome most of the problems they meet on the road. By so, the driver could be considered most of the time as a factor of safety. But it happens that these difficulties, coming from the driving system, are too strong for human capacities. In this case, these same functions may be overwhelmed and fail in attending their adaptive objectives. Seen from this ergonomic angle, human 'error' will be considered as the failure of the operator's attempt and/or capacity to adjust his activity, i.e. a human functional failure in terms of being able to successfully adapt to the difficulties encountered in task performance conditions.
Is HFF an accident factor? HFF have factors, human and others. In line with a system perspective approach (Dekker, 2002), the study of these HFF in roads accidents is not limited to the analysis of human determinants only (i.e. human factors of errors). The purpose of approaching error in that way is to show how malfunctions in interactions within the User-Vehicle-Environment system are revealed in the functions engaged by the person in charge of regulating and directly controlling this system: the driver seen as a regulator. As stated above, the emphasis of this work no longer focuses on blaming the human component of this system, but on revealing the explanatory mechanisms that lead to specific failures, in relation to the situational context in which they are found.

Why HFF instead of human error? There are different ways through which road users contribute to accident production and grouping them in an overall label of 'error' is not productive. As part of these 'unsafe acts', there are errors, strictly speaking, but there are also 'violations', and there are 'losses in capacities' which should not be treated the same. The work presented in this report is intended at integrating these different types of human failures in a comprehensive classification model. The interest of a precise differentiation of the various types of failures of human functions is twofold. First, it allows a better understanding of the real problems in hand. So will it be applied within operation Work Packages (1, 2, and 3) of TRACE. Secondly, it permits the search for better suited solutions in order to help the driver in performing his task. These solutions can be found through the definition of drivers' needs in help which are revealed by HFF, this help being potentially satisfied by many means (e.g. appropriate training, education, road design, driving aid, etc.). In order to reflect the real driver difficulties, such needs have to be clearly defined from in-depth research work based on suited data, such as accident data collected on the scene by a research team in that purpose. Such an analysis of drivers needs is conducted in Trace WP4.

This TRACE report D5.1 is divided in two main sections. The first section questions the role of the 'human' in the driving system. It reminds that, as far as driving activity, accidents are the results of complex interaction processes which must be studied thoroughly with the help of an explicit theory in order not to be misled by apparent evidence about 'human factors'. The second section presents a frame of analysis allowing the classification of the different types of human functional failures found in accidents, as a result of a combination of factors, human and others. This framework is presented both conceptually and operationally and its use is exemplified with two accident case analysis.
2 Introduction

TRACE project has the objective to promote a comprehensive view of accident causation in order to find the most promising solution able at helping road users to perform their task securely.

In line with this objective, Work Package 5 is dedicated to a transversal work aimed at providing operational models and methodological support to the other Work Packages of TRACE, concerning 'human factors' aspects involved in road accidents.

As part of this WP5, the present report addresses the question of 'human error' in road accidents, this so-called 'error' being analyzed as a failure of a human function: a Human Functional Failure (HFF).

2.1 TRACE project: TRaffic Accident Causation in Europe

In spite of countless amounts of research and development, road safety is still one of the main societal concerns today. It is not only a matter of concern for the European Commission and National Governments but also for the vehicle industry, insurance companies, driving schools, non-governmental organisations and more generally for every single road user. Car manufacturers have made strong efforts and have dramatically improved passive (and also active) safety of their vehicle for the past 15 years. However, current road safety research has shown that an asymptote is about to be reached on this aspect in most countries and many experts agree that preventive (prevention of accidents) and active safety (recovery of an emergency situation) should now, particularly, be brought forward.

The TRACE project has 2 major objectives:

The first one addresses the determination and the continuous up-dating of the aetiology (i.e. analysis of the causes) of road accidents and injuries, and the definition of the real needs of the road users as they are deduced from accident and driver behaviour analyses.

The second one aims at identifying and assessing, among possible technology-based safety functions, the most promising solutions that can assist the driver or any other road users in a normal road situation or in an emergency situation.

So the purpose is first to bring a comprehensive and understandable definition of accident causation which goes further and deeper than the usual statements. It is also to provide the scientific community, the stakeholders, the suppliers, the vehicle industry and the other Integrated Safety program participants with a global overview of the road accident causation issues in Europe and promising solutions based on technology.

2.2 WP5 'Human Factors'

In order to gain new knowledge on accident causation, several methodological Work Packages (WP) have been defined in the structure of TRACE in order to give a support to the analyses conducted into the operational Work Packages of the project.

As such, WP5 'Human Factors' has been defined to improve the multidisciplinary methodologies that allow the analysis of the role of 'human factors' in road accident production. In brief, WP5 is oriented toward the diagnosis of the difficulties met by road users which lead them to an accident, toward the identification of the contexts in which they take place, and toward the definition of the origins of these difficulties whether they are human in nature otherwise.

The methods aim to standardise accident analysis in order to bring validated and comparable results from one study to the other, without loosing the scientific and academic background required for a comprehensive research work.

Four tasks compose this Work Package. The first three are oriented toward the elaboration of an operational model permitting a comprehensive analysis and classification of 'human error' generating processes. The fourth one is devoted to a further and wider view on the influence of the social and societal context on accident occurrence.
- Task 5.1 A model for human functional failure analysis

The objective of this task is to define and characterize the different types of human errors, violations and difficulties which are involved in the accident generating process. Such modelling work is based both on scientific literature dealing with human error analysis, and on truly in-depth accident data. The purpose is to build an operational grid for human functional failures, consistent with ergonomics concepts and specifically adapted to the driving task.

- Task 5.2 A comprehensive grid of factors and situations for human functional failure

Human failures are explained by factors characterizing the state of system, i.e. the defects of its components (human and other) and of their interactions. These factors are then considered as the explanatory elements of the road users' incapacity to adapt to the situation in hand. A grid of all the relevant elements contributing to human failures has been compiled, and differentiates those factors coming from the 'human' part of the system, from those coming from the layout, the traffic interaction and the vehicle.

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The purpose of this third task is to combine the results from T5.1 and T5.2 in order to build a methodological frame allowing the aggregation of accident data under the form of generic accidental processes, viewed as an integration of the parameters characterizing the accident generation: which situation and context, which human failure, which explicative elements, which consequence, etc. They will allow putting forward the typical specificities of the difficulties encounters by different types of road users, in different types of situations.

- Task 5.4 Social and cultural aspects of human factors

The purpose of this task is more prospective. It is to analyze the socio-economic/socio-cultural dimension of human activity, its interaction with the driving system, to build a framework of analysis aimed at completing the accident analysis framework proposed in T5.3 by putting forward broader 'upstream' factors of its production process.

2.3 Analyzing 'human functional failures' in road accidents

The first task of this WP5, to which the present report is devoted, deals with the question of 'human error'. Its objective is to define and precisely characterize the different types of human difficulties which are involved in the accident generating process. Its final end is to build a methodological model allowing a systematic classification of the functional failures resulting from these difficulties, whether they take the form of errors, violations or capacities exceeding.

Such 'failures' are not viewed as accident factors. They qualify the weak aspects of the human procedures engaged by road users. These failures occur whereas the driver is trying to cope with the difficulties he encounters when he is faced to the different driving situations and to the different driving contexts drawbacks (including human, environmental and vehicular accident factors).

The interest behind such a view on 'human errors' is that it makes it possible to rely on them, not only as an overall statement, but as a precise diagnosis of driver's needs in help.

In fact, in the field of road safety research, most accident analyses tend to conclude by considering 'human error' as the main cause of accidents. And that's it. The problem behind such a statement is that it leads to very few chances of positive amelioration as far as human is difficult to change and also to discard from the driving system. So, the objective of this report is to go further in such an analysis by precisely characterizing these 'human errors' and by considering them not as primary causes of accidents but as an intermediate step in the driving system malfunctions; these malfunctions being potentially corrected by ameliorating the ergonomics of the system in accordance with human capacities and taking into account his weaknesses.

The present report is divided in two main sections. The first section questions the role of the 'human' in the driving system. It reminds that, as for driving activity as a whole, accidents are the results of complex interaction processes which must be studied thoroughly with the help of an explicit theory in order not to be misled by apparent evidence. The second section presents a frame of analysis allowing
the classification of the different types of Human Functional Failures which are found in accidents, these failures being the result of a combination of factors, human and others. This framework is presented both conceptually and operationally and its use is exemplified with an accident case analysis.

1 The classification grid for these factors is presented in Trace report D5.2 (Naing et al., 2007).
3 The human in the driving system

The specific place and role of human factors inside the driving system has to be stressed in order to go further than the (non efficient) usual view about the human as a factor of accidents. The approach which is developed here considers the road user in a double status; first, as an actor of displacement who is sometimes subject to a certain functional failing due to their own adaptation limits when confronting a critical situation; second, also as an 'heir' of the dysfunctions of the road system which contribute to the emergence of these failings.

From in-depth accident data, the general question which is investigated in this study is not 'to whom the fault?', and even less 'who are the reckless drivers?', but 'which are the combinations and interactions of elements which allow us to explain accidentalness'? This will be done with the intention, not to put the blame on anyone, but to define appropriate ways to avoid this accidentalness. It is indeed important, from a scientific point of view and in an operational purpose, to diverge from a common sense approach which tends to find into the 'human factor' the unique and unambiguous cause of the problems. Of course, in each accident, the road user plays an important role as far as he is active in the situation. But we should not omit that he acts in a certain context of which he does not master all the parameters. This 'environment of displacement', which is spatial, dynamic and social, is constituted by interactions with a car design, a road design, and with the surrounding traffic. And this context takes a determining weight in the genesis of drivers' behaviours and their possible maladjustments to the characteristics of the situation that these drivers try to master. So, human behaviour can be seen - at least, partly- as the result of the interactions between the different driving system components.

3.1 Driving and accidents as the result of interaction processes

It is so obvious that it becomes confusing. Everybody agrees to say that driving activity is the result of an interaction process and that accidents result from an interaction of factors. But most people - not excluding specialists of road safety - quickly add that much progress has been made concerning the road and the vehicles, in such a way that road users are finally the main remaining sources of the problem encountered inside this interaction. This comes to the conclusion than the 'human' remains the most frequent accident factor… and so, it is no more a problem of interaction.

By so doing, most people tend to forget that the driving system has been elaborated by humans and for humans. And they tend to forget that when a user encounters a problem when interacting with a device put at his disposal, the first conclusion to draw is that this device doesn't fit with this user. And the second is that there is an upstream problem of conception, ergonomics, organization, etc., of this device.

It is of human nature to err. This aphorism is too often heard in its only pejorative meaning of a word. By 'nature', indeed, the capacity of adaptation of human beings to a complex, variable, evolutionary and uncertain environment, notably bases on their capacity to resort to cognitive heuristics when an algorithmic functioning is not possible any more. By definition, heuristics are fast, economic and most of the time effective procedures, but which do not lead to the optimal result with certainty. It is consequently the same processes which allow the drivers to adapt themselves to the difficulties of the environment and which sometimes lead them to the error. It is this conception which underlies the definition of human as 'fallible agent of reliability' professed by Ergonomic Psychology.

By conception, the traffic system led the road users to progress in a complex, variable, evolutionary and uncertain environment, for which the appeal to heuristics is an inescapable procedure. This system exploits the capacities of adaptation of the human being, and it is in a certain way this capacity to make errors and to correct mostly the most important that allows the man to drive. A body which couldn't act without making any mistake could not drive a car, at least in the conditions of complexity and variability which define the current traffic system. By such, it seems difficult to swamp the characteristics of the human functioning, while it is these same characteristics which make the road

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2 With the meaning of 'everything dealing with the road user'.
system work in spite of all its difficulties, unpredictability and imperfections (Van Elslande & Alberton, 1999).

From an ergonomic point of view, the question is to understand the difficulties (in the broadest sense of the term) met by the users of a system in order to adapt this system so as to reduce these difficulties.

3.2 An accident production theory: the systemic approach

There is a great deal to be said about accidents. We know more or less how they are distributed in time and space and their severity. We also know more or less the populations prone to risk, in terms of category of user, vehicle or location involved. Statistical analyses of national reports reveal factors linked to accident risks or their severity. But, in fact, we know very little about how they are initiated, their progress and what should be done to prevent them. Although improvement has been made in the field of prevention, it is still insufficient, and we no longer know how to improve on this.

Every study needs a theory as a frame to interpret data and transform them into 'results'. To understand accident data, we need to elaborate on an accident production theory. The most fruitful - and shared among the community of safety researchers- approach would seem to be the systemic approach. This theory assumes different embedded levels of interactions as being the skeleton of any system functioning. So it is for the components that comprise the transport system. At its micro-level, the driving system is composed of the users, the transport tools and the infrastructures used for the journeys. These components operate by interacting with one another and the smooth running of the system implies that all three components have been adjusted correctly.

As shown in figure 1, several dynamic processes can be seen in the regular functioning of the driving system, even at the micro level of a single road user.

**Figure 1: Interactions within the elementary Human-Vehicle-Environment system**

- There is a guidance dynamic process which is based on interaction between a road user (Human) and a means of transport (Vehicle). The road user acts on his vehicle by the use of the commands, and the vehicle feeds him back with information dispatched on the displays (plus kinaesthetic sensations).
- The information acquisition dynamic process is based on an interaction between the road user and the infrastructure on which he evolves (Environment). It works with an active information search from the part of the Human on the Environment. But in return it also depends on the availability and salience of information given by the environment to the road user.
- A third dynamic process characterizes the vehicle-road interaction which works on an action/reaction basis, from the solicitations and demands imposed by one component on the other.
A last but not least dynamic process composing the elementary driving system functioning describes information processing. It works on an interaction between human and himself, putting in correspondence information gained from the vehicle and the environment components with information retrieved from experience through memory.

Seen from this point of view, an accident is the result of an incorrectly adjusted interaction between system components. So the cause of accident should not be attributed to one or another of these components taken separately. But the purpose of safety research is to try to understand the reasons for this defective inter-component interaction.

In accident studies, we usually know how to describe and identify the status of each of the components at the time of the accident. These descriptions are found in standard reports. We find more difficulties, however, in knowing how these characteristics can affect one another. To do so, we need to have detailed knowledge of how one event in the accident sequence led to another, and to explain this sequence. In-depth accident investigation provides a suitable tool with which to answer this type of question.

### 3.3 Human 'error': cause or consequence?

As it is well stated by Simon et al. (2005) in a very complete literature review, there are two theoretical approaches to human error: 1) the 'person approach' which focus upon the last step of system operation and by so treats human error as the cause of most of accidents; and 2) the 'safe system approach' which looks further in the accident process, as stated above, considering the role of the various organisational levels that contribute to the production of system outputs (rules, design, management, etc.) and looking for the 'holes' or 'weaknesses' in the various defence layers which are supposed to constitute a safe system, well adapted to its users.

From now on, most safety studies have been based upon a person approach and stress the role of human error in the production of 75 to 90 per cent of accidents. But it would be wrong to regard this 'error' as the primary cause of accidents. A safe system approach will rather consider it as a consequence of malfunctions further upstream, so that human error is only a link in the chain of events leading up to an accident. And he is a necessary link as far the driving system is unable to function without drivers.

As shown by Reason (1995), operator 'unsafe acts' are inscribed in the process of a system functioning. They are the result of a certain number of factors coming from the organization, the context, and so on.

![Figure 2: The active and latent paths of unsafe acts in the system process (from Reason, 1995)](image-url)
- The 'active failure pathway', by facilitating the occurrence of errors and violations. Referring to road system, this active way of inducing human failures could be illustrated by the role of a too complex layout design which will bring misunderstanding and by so promote traffic conflicts.
- The 'latent failure pathway', by not protecting operators against their potential errors. For example, a non practicable shoulder along the road will not allow a driver to recuperate an error of trajectory.

If a person makes a mistake, it is very seldom because he searched for it. Most usually, it is because both the external and internal conditions in which he was performing his activity did not enable him at a given moment to cope with the demands of the task before him.

It is nevertheless essential to understand what these errors consist of and to identify the elements that explain their origin in order to devise counter-measures for preventing their commission.

3.4 Human factors - Human actors

It is important to stress the very specific role of the human element in the traffic system: it is both a component and the principal actor. The driver is the element that drives the system. It is his task to regulate his activity and adjust it to the problems arising from the interactions between the different components, including him. To negotiate those difficulties, he performs a number of functions, especially cognitive ones. And we shouldn't forget that most of the time the use of these functions allows road users to succeed in compensating from driving system drawbacks. So they are at the basis of the driving system functioning. But the very functions that usually enable the driver to regulate his activity may fail if he encounters major malfunctions within the system that prevent those functions from attaining their regulating objective. This results in a functional failure, commonly called 'human error' (figure 3).

![Diagram of Human-Vehicle-Environment system](image)

**Figure 3: Interactions within the elementary Human-Vehicle-Environment system**

While it may appear artificial, this distinction between human as component of the system and human as actor is nevertheless important insofar as it enables us to differentiate between what are factors by nature - attributable to the three components of the system comprising elements characterizing road users - and what corresponds to the resulting difficulties in the operator's activity. However much one tries to highlight factors of errors, one thus has to focus on man as a component of the system like any other, rather than on his role as an actor who attempts to adapt to the difficulties arising from those components.

So it is essential not to make the recurring common sense amalgam between 'human error' and 'human factor'. The 'error', and better said the non recovered error\(^3\), corresponds to a momentary failure of the one or other of these sensory, cognitive and driving functions that the man usually

\(^3\) The negative consequences of the non recovered errors are far from being turned out (Amalberti, 2001).
operates to fit his activity to the difficulties of his task, where he mostly has success. Such a functional failure is the negative consequence of an integrated set of causal elements, combining human factors (state, motivation, etc.), infrastructure, and vehicle parameters. It is consequently necessary to identify human errors to understand the specificity of the difficulties met by the users in their attempts of regulation. But it is also essential to analyze correctly the combinations of elements characterizing the users, the infrastructures and the vehicles involved in the genesis of these errors (and in their non recovery) to be able to define solutions of the identified problems.

The study of these accidentalness problems, as considered under a cognitive angle through the road accidents, is not obviously exhaustive in its explanatory perspective of the dysfunctions. Numerous parameters intervene upstream, in the conception of the traffic system and in the values it conveys, a more macroscopic approach being the only solution to update them (cf. for instance Task 5.4 report on cultural and social factors, Engel, 2007).

From a historic, social, economic and even political point of view, the road was more conceived to produce travelling than safety. This conception is not without consequence on the disasters which it produces more or less directly due to the behaviours it incites and the layout structures which are not compatible with those behaviours. Nowadays, the emergent philosophies aim at inverting this tendency, making of road safety a hobbyhorse of the road systems. So there are perspectives of ‘zero vision’ or ‘durable safety’ (Rumar and Wegman, 1999) which underline the notion of responsibility shared between the various actors of the insecurity: the road users certainly, but also the society that builds and maintains roads, amends the rules of traffic, as well as the industry that conceives and sells the means of transportation. It is notably reminded to these last two actors that they have to adapt to the behaviours, characteristics and to the limits of the human capacities that they do not have to overwhelm.

3.4.1 A driver operating model

Particular attention is to be paid to the role of the driver, once more with the necessity of a model to avoid wild analysis. In the present context, the driver is seen through the model of an information processing and acting system putting forward different functions (figure 4). Following such a classical model, he picks up information in his environment, processes it and produces behaviour that is, in principle, adapted to both his objectives and the situation in hand. This description covers an extremely complex sequence of operations (Hale, Quist & Stoop, 1988; Hale & Stoop, 1988; Michon, 1985).

As stated by numerous authors (e.g. Rensink, 2002), the world is far too rich in information for human perception capacities. In order to adapt efficiently to this complexity, information acquisition is determined by a series of filters (Rumar, 1985):

- The most apparent are the physical filters that act as obstacles that impede visibility, and make access to information impossible.

- The second filter is physiological. The characteristics of the human vision are such that light, contrast, distance and movement may, depending on the case, facilitate or prevent information acquisition.

- The final, least known but nevertheless important, is the cognitive filter which will facilitate or impede integration of information, elements depending on their status and the knowledge associated with them.

And problems will come in case of an exceeding discrepancy between perception, gained through these filters, and reality.

As driving environment is extremely complex, the drivers, through their senses, can only exploit a limited sample. He in fact selects what is significant for him, depending on his knowledge, on the situation and his objectives. In other words, the driver does not remain passive when faced with a vast amount of information, but does not receive all this information in the same way. Human being is made in such a way that the driver will detect and accept more easily the information he is looking for and which corresponds to what he expects than that which may warn him he is making a mistake.
In a second stage⁴, he will interpret the information he has perceived. This interpretation results in constraints to be adhered to and procedures to be applied to adapt to situational demands. It is essential to understand that it is these interpretations that will determine the behaviour the driver considers to be suitable. These interpretations are, however, based on the considerable amount of knowledge acquired through experience. At this level, driving consists of establishing a balance between assimilating the present situation to situations previously experienced, and using the knowledge already acquired to deal with new situations.

Finally, he will use the vehicle controls to produce manoeuvres adapted to the results obtained when processing the preceding information.

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⁴ These stages have to be considered theoretically: in activity, human information processing is not a linear chain.
all the necessary information was accessible. If so, the second question is to find out why it was not used effectively, and to identify what led to its incorrect interpretation.

A specific way for gaining information about system malfunction refers to accident analysis.

### 3.4.2 An accident analysis model

The first stage of analysis consists of drawing up the accident scenario in terms of the sequence of events and, in particular, describing the initial system status, identifying the triggering event and reconstructing the emergency manoeuvre. The second stage is to identify the mechanisms that contribute to the production of this sequence of events: these mechanisms are found in the system component interaction. To achieve this, the scenario is divided into four phases, connected one to the others (figure 5).

- **The driving phase**

  The driving situation can be described as the one in which the user is before a problem arises. It is the 'normal' situation, which is characterised for the driver by the performance of a specific task in a given context, with certain objectives, certain expectations, and so on. It is 'normal' because no unexpected demands are made upon him. The driver can adapt effectively, the events unfold in line with his predictions, expectations and anticipations. He is not overloaded with information. He controls his speed and course; he is 'master of his vehicle'. In more general terms, this means that there is a balance between the demands and ability of the system components to respond one to another: alignment, skid-resistance, sight distance, tyre wear and pressure, condition of shock absorbers, speed, degree of driver awareness, etc.

  It should be noted that 'normality' in this case refers to effectiveness, but not necessarily to compliance with traffic regulations.

  The advantage of the study of this situation is to reveal what the driver considers to be both desirable and feasible in a particular place, and in a particular context.

- **The rupture phase**

  The 'rupture' is an unexpected event that interrupts the driving situation by upsetting its balance and thus endangering the system. That event could be an unforeseen presence or manoeuvre by another user, the advent of an infrastructure configuration which takes the driver by surprise, or provokes a sudden high workload, and so on. The effect of the rupture situation is to switch the system components from a bearable level of demand to a suddenly excessive demand in terms of ability to respond.

  It should be noted that an 'unexpected event' does not necessarily mean 'unpredictable'. Which raises the question of to what extent it really was unpredictable, and if not, why it was unexpected. Information gained on the driving situation is of considerable use when seeking this explanation.

- **The emergency phase**

  It is the period during which the driver tries to return to the normal situation by carrying out an emergency manoeuvre. A particular feature of this stage is that the driver faces very severe constraints (both temporal and dynamic) as regards the options open to him.

  The emergency phase covers the space and time between rupture and impact. If the rupture situation gives a statement of the problem in hand, the emergency situation defines the space-time 'credit' available in which to solve it. This 'credit' is, by definition, extremely limited.

  The emergency situation can be determined in relation to the driving situation by the sudden excessive demand level imposed on the system components. The driver must solve, within a given time, a problem that is, in principle, entirely new to him. The range of solutions depends on the environment in terms of hostile obstacles or the space available for evasive action. The capacity of the vehicle to perform the required manoeuvre depends not only on its design and state of repair but also, when referring to vehicle-ground liaison, on the state of the infrastructure. The emergency situation reveals the insufficiencies or defects in one or another of the system components, weaknesses that remain tolerable when faced with normally moderate driving situation demands.
The emergency manoeuvre is an attempt to find a solution to a problem. It sometimes succeeds, but in accident databases this manoeuvre has failed. So the emergency situation is followed by the crash phase.

- The crash phase

The crash phase comprises the crash and its consequences. It determines the severity of the accident in terms of material damage and bodily injury. Once again, the situational circumstances depend on what has occurred previously and the interaction between the three components: thus an elderly person is more vulnerable to injury, modern vehicles are better designed to crashworthiness, a protection rail prevents impact with a hostile obstacle, etc.

From a safe-system model point of view, each of these phases should be considered specifically with the purpose of not generating hazards for the driver. So the driving system shouldn't generate ruptures, should be forgiving (i.e. giving the possibility to recuperate) in emergency phase, and protecting in impact phase.

<table>
<thead>
<tr>
<th>Driving phase</th>
<th>Rupture phase</th>
<th>Emergency phase</th>
<th>Impact phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviour on approaching the place</td>
<td>Meeting an unexpected event</td>
<td>Avoidance manoeuvres and dynamic demands</td>
<td>Nature of impact</td>
</tr>
</tbody>
</table>

Figure 5: Major steps to consider in a sequential analysis of accidents

The identification of these phases (or 'situations') enables the different sequential stages of the accident to be reconstituted in a homogeneous manner, which makes it possible not only to analyse each case from the viewpoint of the process that engenders it, but also to set up horizontal studies of several accidents by comparing the successive stages in their development.

We are particularly interested in the analysis that follows in the so-called 'accident' situation, which is a key stage that pitches the driver from a normal driving situation into an impaired one. That transitional phase is a good place for comparing accidents, to the extent that it marks the start of a malfunction process. In the sequence of failures that follows the accidental impact, we thus sought to identify those which characterise this moment of rupture and explain the fact that the driver suddenly finds himself in a critical situation.
4 Toward a classification model for Human Functional Failures in road accidents

The aim of a classification model for human functional failures is to allow a systematic sorting out of the different orders of malfunction phenomena which intervene in the genesis of this complex event that is an accident. It will be considered essential for any fruitful accident analysis apprehending human factors. In the absence of a well defined model of reference, analyses of accidents indeed tend to produce typologies which mix up very disjoined phenomena, putting for example on the same level: manoeuvres, processes, consequences, types of collision, etc.

The following analysis is first based on the most 'up to date' models developed regarding human error as a whole. The knowledge gained from these models is then viewed at the light of (ultra) in-depth accident data to build an operational classification model precisely devoted to the analysis of human functional failures found in road accidents.

4.1 From literature to road accidents

Driving is a complex, dynamic, and interactive activity calling for a variety of mechanisms: sensorimotor, cognitive, and so on. It was necessary to establish a framework enabling us to catalogue the failures liable to occur during it. We positioned this framework essentially in the cognitive field of information processing, although we knew that such a framework does not enable one to take account of all the human aspects involved in this activity. That is why some emotional and motivational aspects of behaviour are treated as explanatory elements of failures identified at the cognitive level.

The functional hierarchy model developed by Rasmussen (1986, 1990) was very useful for guiding our qualitative analysis of functional failures. It defines a certain number of stages in a person's functioning, at each of which errors can occur and have to be identified (figure 6). The model is flexible enough for a large variety of processes to be taken into account. It is a good basis for comparing the different levels of demands involved in the driving task, the functional origin of an error, and the level of human information processing that enables it to be negotiated. These characteristics make it a suitable model for studying the diversity of accident processes and the functional stages involved. But as Hoc and Amalberti (1994) suggested, we integrated a prognostic stage in that breakdown to take account of the processes of anticipation and prediction which drivers perform in order to negotiate the dynamics of the situations with which they are confronted.

We also borrowed from Reason (1990) the distinction he makes between 'error', which covers cases where a planned sequence of mental or physical activities does not achieve its desired ends, and 'violation', which is defined as a more or less deliberate deviation from the practices socially considered necessary for ensuring the safe functioning in a potentially dangerous system (figure 7). It seemed important to us to make that distinction, especially to take account of the particular nature of the failures identified at the level of the decision-making processes preceding the execution of a specific manoeuvre. But it has to be clearly distinguished from any judgment of 'responsibility', the question being to define 'what' before searching for 'why'.

By combining an analysis based on these models with an analysis of the specific tasks giving rise to the errors studied, we sought to avoid two pitfalls, namely: 1) classifications that are too particular to the field studied (e.g. valuable only for a specific industrial sector) and thus not applicable generally; and 2) classifications that are too generic and thus not sufficiently operational (e.g. differentiating only general traits of 'error' such as the classical perception-decision-action categorisation).

4.2 Definition of Human Functional Failure

As stated in introduction, and in the lineage of recent literature works (e.g. Reason, 1995, 2000; Leplat, 1999, Simon et al., 2005), 'human error' will not be analyzed as the first cause of the degradation of the

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5 The so-called "ultra" in-depth data are extracted from accident survey performed by INRETS (France) and are based not only on the reconstruction of physical parameters, but also on detailed interviews performed by a psychologist to apprehend the precise difficulties met by the drivers.
situations, but as the symptom and the vector of the system malfunctions (Van Elslande, 2003). We will report it mostly afterward with the label of 'functional failure'. That is for three reasons. At first, to distance itself from ambiguities of the notion of error in its common sense, often synonymic of the word 'fault'. Then, to target the analysis at the non retrieved errors, which are by definition those studied from accidents data. Finally, to include in this analysis the phenomena connected to capacities, notably physiological, of the individuals. In other words, this notion of function failure features the impairment of one (at least) of the cognitive, sensori-motor or psycho-physiological functions that usually allow the operator to adapt to the difficulties he meets when fulfilling his task. The notion of functional failure is thus useful to report the many levels of human dysfunctions: the error, the violation, the inaptitude.

'Error' is by definition not deliberated. We do not make a mistake on purpose or it is not really an error anymore. This question of intentionality led Reason (1990) to distinguish what concerns error and what corresponds to deliberate unsafe acts. There would be an error only when the subject does not reach the purpose aimed during the execution of a strategic sequence of mental or physical activities, and when these failures cannot be attributed to the intervention of fate only. The notion of error does not thus cover all the forms of contribution of the human beings to the accidents. Unsafe acts, which are deliberately operated, are identified by this author as 'violations'.

'Violation' is defined as the deliberated infringement (but not necessarily hostile, nor inevitably reprehensible from a legal point of view) of an established behaviour code or socially admitted to assure the safe functioning of a potentially dangerous system (Parker and al., 1995). In this explanatory system, it is also a question for extremes -even if they are rarer- of deliberately criminal behaviours and those which have the will to damage: they are qualified as 'sabotages' by these authors. They match on the road those acts named delinquent, and which are different from the more 'classic' road insecurity: car chases, search for vengeance, etc., which characterize certain atypical accidents.

The notion of failure also allows to integrate more diffuse problems which are connected to the more or less durable inaptitude of the individual to realize his task: falling asleep, an illness, an impairment or an exceeding of the sensori-motor and cognitive capacities.

4.3 Delineation of human functional failure

The following work is based on an in-depth analysis of detailed accident data including registered interviews of the drivers, made by a psychologist in the purpose of making them precisely explain their perceptions of the facts, their decisions, actions, the difficulties they encountered, etc.

To make things easier, failures found in accident cases are delineated below following a sequential theoretical chain of human functions involved in information gathering, processing, decision and action (figure 6). It doesn't imply at all that drivers function in a linear way. In the common functioning of the individual, there are numerous feedbacks between the various modules, and the data processing is strongly looped. But involving accidents as in the analysis which follows, we stop this functional buckle in the stage of rupture in the progress of the driver, as he is confronted with an unexpected difficulty which is going to lead him to lose the control of the situation which was more or less suitably regulated so far. It is thus a grid of analysis of the dysfunctions and not a model of functioning or dysfunction of the operator.

Each functional stage is associated with a certain number of potential failures, ending up with a malfunction chain.

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**Figure 6: Global stages of human malfunction chain potentially involved in accidents**
By examining in detail In-depth data collected on accident scenes, the following types of functional failures can be defined with each of these categories (figure 7). These failures are described, stage by stage, in the following pages.

![Figure 7: Delineation of functional failures found in In-depth accident data](image)

### 4.3.1 Failures at the information detection stage

The safe performance of a task in a given driving situation depends in the first place on early detection of all the relevant data required for that task to be performed. If not attending its perceptive ends, this first human function will interrupt the good process of the entire human functional chain. For drivers in that situation, accidents are directly attributable to the non-detection (or belated detection) of certain essential parameters of the situation, such as a change in the way the site functions or the presence of another user on a potential collision course. These detection failures can occur following different types of mechanisms which go far further than strictly sensorial mechanisms. They can refer to:

- Problems relating to information conspicuity,
- A deficient organisation of information acquisition,
- A failure to search actively for information.

- **P1 failure - Non-detection in visibility constraints conditions**

This first set of detection failure deals with a problem of access to some potential useful items of information. Environmental constraints linked to the layout of the road, to the presence of other vehicles, or luminosity problems, made it difficult to detect an important element in the situation when the drivers would have needed it.
Failures of P1 type seem *a priori* obvious to explain\(^6\), and even tautological as far as drivers didn't see because it was difficult for them to see. They nevertheless are based upon some more or less complex mechanisms, according to the situations in which they intervene and to the elements which explain them. And we will keep in mind that the purpose of the analysis is not to 'blame or not to blame' the driver, but to find out his perceptive needs through his detection difficulties.

- **P2 failure - Information acquisition focused on a partial component of the situation**

This second group of detection problems refers to a question of information acquisition 'strategy'. It deals with drivers who encounter a particular problem during their journey and who focus their eyes and attention on that, which results in their not detecting another crucial element of the scene, such as an oncoming vehicle (or other hazard). Such a detection failure can be induced by elements such as task complexity, poor signalisation, multiplicity of potential events, profusion of stimuli, and every element which can induce a difficulty in the repartition of attentional resources.

- **P3 failure - Cursory or hurried information acquisition.**

Another type of poor organisation of information acquisition strategy will involve drivers who reduce to a minimum the time and attention they devote to the search for information, whether because of the routine nature of a manoeuvre or because they experience a situational pressure (with time constraint, workload, incitation from a third part, etc.).

- **P4 failure - Momentary interruption in information acquisition activity**

Here, the performance of a secondary task results in the driver momentarily diverting his eyes and attention from the road scene. This is the basic process of this failure. As for P1, such a failure is explained by itself: the non detection directly results from the engagement of an activity which competes with the information gathering in the driving scene. But a slight distinction can be done as regard to the nature of the annex activity put forward.

The difficulty can come from an outside 'attractor' (a stimulus such as an advertisement poster, an action such as regulating the mirror, the searching for a place to park) which will momentarily divert the eyes and attention from the driving scene. But the very same failure can also occur in a logic of a weak solicitation of resources by the ongoing task (e.g. monotony), which will drift the attention focus toward annex activity (such as looking at the surrounding, discussing with a passenger, etc.).

- **P5 failure - Neglecting the need to search for information**

In a situation of limited constraint, drivers’ attention becomes so diffused that they fail to identify an element of interference up to the moment it becomes an 'obstacle'. In these accident cases, we don't notice a real annex activity, apart from a strictly cognitive activity ('thinking'). This failure of information gathering function can involve different kinds of explicative elements. So, a strong knowledge of the journey, coupled with a time constraint can lead to a higher speed without stimulating a stronger attention. The same result can be induced by a feeling of right of way to the point of ignoring totally an opponent vehicle up to the moment when it becomes inevitable. To keep in mind, this failure seems to intervene principally when confronting with a non priority vehicle at intersection or when getting closer to a slower vehicle.

### 4.3.2 Failures at the diagnostic stage (information processing stage 1)

Following a sequential logic of analysis for malfunctions, once the detection stage is correctly performed, a second functional stage involved in driving entails processing information acquired in the situations encountered. This processing activity should essentially enable the driver to:

- On the one hand, *evaluate* the physical parameters (space, time, speed, acceleration, etc.) identified at the previous stage in order to assess the feasibility of undertaking his planned manoeuvre and,

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\(^6\) To the point that somebody looking at them from a strict 'causation' point of view would say they are not 'human failures'.
On the other hand, understand the information acquired concerning the type of situation with which he is confronted.

- **T1 failure - Erroneous evaluation of a passing road difficulty**

  The problems of evaluating an infrastructure-related difficulty mainly refer to difficult bends and a reduced adherence on a roadwork area. This problem has to be distinguished from the one of incorrectly manoeuvring (for example in a curve) even if they are often connected. One thing is to evaluate a difficulty (a cognitive matter); another is to control a trajectory (a sensori-motor matter). And if the result can be the same for the former and the latter (going out of the road), the aid to compensate for drivers needs can be different.

- **T2 failure - Erroneous evaluation of the size of a gap**

  We are still, here, at the function of estimating physical parameters, but relating to another vehicle path and speed. When they arrive at an intersection, drivers think they have time to cross when that is not the case, considering the speed and distance of approach of an opponent vehicle. It can also be the case when evaluating the approaching speed of a vehicle ahead. There can be numerous reasons, both internal and external to the driver, for this failure of evaluative judgement.

- **T3 failure - Mistaken understanding of how a site functions**

  We are entering, with T3 failures, in the domain of the more global interpreting process, that can lead to a poor understanding of an interaction, whether this interaction concerns road environment or another road user involved in the situation. The failing of this diagnosis function is usually the result of a combination of ignorance of the place and defects in layout (atypical, hard to read). It results in the driver not stopping in the right place at an intersection, acquiring information in an inappropriate order, or not expecting to encounter another vehicle.

- **T4 failure - Mistaken understanding of another user’s manoeuvre**

  This second type of understanding failure, specifically devoted to the behaviour of another road user can arise as a result of the other user not properly signalling his manoeuvre, or his giving of ambiguous signals, or of the driver making a cursory assessment of the interaction and going no further than identifying an impediment to his progress. Clarifying the situations of interaction by any means would be the main trend to follow in order to counteract such failures.

### 4.3.3 Failures at the prognostic stage (information processing stage 2)

Given that it is an activity with a dynamic component, a second stage in the processing of the information acquired involves making a prognosis of its probable evolution (Hoc, 1996). At this stage, the driver has two tasks: on the one hand ensuring he correctly anticipates the potential changes in the currently encountered situations and; on the other making a prevision on the possibilities of a not yet visible event potentially occurring in situation to come. We will remind that beyond its direct intervention in the accident mechanisms such as they are analysed here, the prognosis function has an over determining influence on other functions, and by so, conditions more or less implicitly the whole process involved in a dynamic activity such as driving. To support this idea, Hollnagel (1991) describes prognosis function as a 'genotype' of many problems which will express itself in at the end of the functional chain by many different 'phenotypes'.

Three types of prognosis failures can be identified within the realisation of driving activity in accidental situations. The two first deal with the anticipation process: the wrong expectation that another user won't move (T5), and the wrong expectation that another user will regulate the situation. The third failure refers to the prevision process: the wrong prediction that no 'obstacle' will be met.

- **T5 failure - Expecting another user not to perform a manoeuvre.**

  In the absence of cues to the contrary, drivers who have the priority at an intersection do not expect a non-priority user who is stationary to start moving forward and is surprised by this unexpected
manoeuvre. So this failure corresponds to 'pitfalls' situations for anticipation, just in the same way as P1 for detection. Such a 'failure' of anticipation function is easily explained by external elements (i.e. the very fact that the other user don't behave in an expectable way). But, as already stated the question is not to search for responsibility or not in driver's functioning but to find out where are the limits in the human capacities to predict event in order to help this function by any means. One point in question here is the status of formal versus informal rules that are differently followed by different drivers. This point can be referred to further upstream analysis, up to the social and cultural factors (cf. Task 5.4 reports).

- **T6 failure - Actively expecting another user to take regulating action.**

A second level of failure identifiable at this anticipated information processing stage deals with the expectancy of a regulation from the part of another user who the driver is in interaction with. On the basis of his erroneous expectations, based on what he is used to and has experienced, and despite observing disturbing signs, the driver rules out the possibility of a critical evolution of the interaction situation encountered and, as a result, does not execute a preventive driving strategy adapted to that predictable critical evolution.

- **T7 failure - Expecting no perturbation ahead.**

With this last failure dealing with expectancies, the mechanism of this predictive failure is unilaterally linked to the driver's adopting a mode of behaviour that does not integrate the possibility of his encountering an impediment to his progress, despite a lack of visibility. Instead of prompting him to take particular precautions, the driver's restricted visibility seems to encourage him to take the line that 'if I don't see anything, that means there isn't anything', and results in his moving into the space reserved for another user. So, 'expecting no perturbation ahead' failures accounts for the cases where drivers make use of their expectations so as to drive in a way that will make them inapt to adapt when meeting the difficulty, for example by going partly or totally on the path of another road user, sometimes just by speeding.

### 4.3.4 Failures at the stage of deciding on the execution of a specific manoeuvre

Still following sequentially the grid of analysis of human functional failures, the functional stage resulting from the detection and processing of the event encountered consists of the decision-making processes that come into play. Since the driver gathered the right information items, since he has correctly interpreted the situation and anticipated its short term evolution, he still has to 'select' amongst the driving strategies that are feasible in that situation the one that seems to him best suited to the event and its safety requirements. To the extent that the present analysis is focused on the problems that can pitch the driver into a situation of impeded progress, the failures outlined below relate to decisions to undertake a specific manoeuvre and not to the broader decisional factors related to the circumstances in which the journey is being made (alcohol intake, journey for recreational purposes, and so on), parameters which will be analysed as explicative elements for different types of failures.

Contrary to the failures analysed until now, the malfunctions revealed in this type of process have more to do with the notion of 'violation' (Reason, 1990) than the notion of 'error' in information processing terms. As already stated, 'violation' in this context doesn't refer to the law, but to the informal driving norms socially shared. Such 'violations' can be viewed as a deviation from the behaviours which could be expected from the majority of road users. Several types of failure in this decision-making function can be distinguished, according to the degree of intent involved in the violation committed:

- **D1 failure - Violation directed by the characteristics of the situation.**

The particularity of the drivers grouped in this category of failures, is to have been confronted with a situation in which they were directed to take a certain level of risk in order to attend their goals. This

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7 This point clearly differentiates this failure from detection pitfalls found in P1 failures.
'necessary risk taking' comes from layout deficiencies and traffic constraints which put the driver in difficulty, an even in a dilemma for the manoeuvre they want to perform.

These drawbacks concern the presence of visibility obstructions which force the drivers to move forward at an intersection in order to be able to take information about the feasibility of their manoeuvre (of crossing or merging). They also deal with progress obstructions which impose to swerve to the way allocated to the inverse traffic, as well as the organization of intersections unsuitable for the size of certain vehicles, making this crossing manoeuvre delicate whatever the adopted strategy is.

Because of these situational parameters, the drivers are confronted with a paradoxical situation which consists in having to adopt a strategy of safe behaviour on locations that do not really allow it. The explanatory elements that we shall find of such a decision-making failing are thus essentially related to the characteristics of situation. The limited visibility by the layout, the buildings, or the punctual visibility obstructions generated by vehicles, are the factors most frequently found.

- **D2 failure - Deliberate violation of a safety rule.**

This second decisional failure refers to the practices that are traditionally described as 'risk-taking' (Saad, 1988) in the performance of a manoeuvre. When taking their decision, dealing to the driving strategy to put forward in the situation, drivers momentarily relegate the safety aspects of their activity and let other motives take over, such as making up for being late, freeing themselves from an impediment to their progress, testing the performance of their vehicle, thrill of driving, making fun with friends, and so on.

Thus it can be noticed in the functioning mode of these users, either a certain form of 'will' for infringement of safety regulations, as these are imposed by the road signs or required by the evidence of the danger of the situation, or a more implicit 'denial' of the risks run in the situations.

Only in certain extreme cases, these violations can take the form of deliberate aggressive behaviour. In that case, Reason (1990) refers to them as 'sabotage'.

- **D3 failure - Violation-error.**

This 'violation-error' or 'unintentional violation' (Reason et al, 1990) refers to an intermediate mechanism between the notion of violation (as far as the drivers break certain number of elementary safety rules) and the notion of error (as far as this infringement is not really deliberate). It corresponds, in road accidents, to the initiation of a manoeuvre as a result of the impulsive release of an automatism. This occurs mostly in answer to a certain form of delegation to others of the processing of the situation (dragging effect) which is going to lead the driver to change direction or to enter an intersection without having taken previously the precautions necessary for the realization of such an operation.

The dragging effect, which is thus the most systematically explanatory element of such a failure, is provoked either by the departure of a previous vehicle that the user decides to follow 'in the stride' without getting more information, or by the command of a third (passenger or external user) which incites him to realize the manoeuvre without more cautiousness.

### 4.3.5 Failures at the psychomotor stage of taking action

The last link in the functional chain involved in driving activity is the driver's manipulation of the controls of his vehicle to ensure it continues along his chosen trajectory. This category only includes accidents in which a problem of vehicle control is the direct cause of the emergence of an accident situation, meaning that they occur after the driver has successfully negotiated the other stages. Note that these failures do not refer to the emergency stage but, as for other failures declined here, are analysed at the rupture stage.

Two types of problems distinguish as the handling failure features an external element which comes to perturb the controllability of the manoeuvre (E1), or only the conditions of attention allocated to the task of trajectory regulation (E2).
• **E1 failure - Poor control of an external disruption.**

In situations where he meets severe constraints, drivers are no longer able to control the trajectory of their vehicle. These problems of manoeuvre controllability arise either from an external disturbance (skid on wet or icy road, presence of a wasp in the passenger compartment), or from a sudden mechanical defect (defective brakes, breaking of a cable which comes to be stuck in the front wheel of a motorcycle, etc.).

And, as usual, even if the causes of the poor control performance can be defined as external, they nevertheless show a limit in the capacity of the human function of vehicle control to adapt to driving difficulties. And by so, they show a need for help in certain critical situations of regulation.

• **E2 failure - Guidance problem.**

Having momentarily neglected the task of regulating their trajectory to undertake a secondary activity (picking up fallen objects inside the vehicle, talking to a passenger in the rear, and so on), drivers realise too late that their vehicle has veered off course. These guidance problems are linked to vigilance or attentional deficits, as it was the case for P4 failures, but here the distraction has an effect on the control trajectory.

### 4.3.6 Overall failures

Until now we studied the failures corresponding to one or the other of the functional stages involved in the driving activity. However there are cases for which the problem does not settle anymore in terms of functions failure but in terms of capacities. It recovers the notion of 'global failure' which corresponds to a degradation of the whole functional chain, the outcome of which is a loss of control of the situation. These include those cases where the whole of the functions necessitate to drive seems to have been deficient in the mechanism leading to an accident.

It is thus at the level of the general capacity of the individual to manage the situation encountered, as much from the point of view of the information to be collected, treatments to be operated, decisions to set, actions to undertake, that the problem is situated. Hence, the problem is located at the key level of the individual’s general ability to handle the situations he encounters, as regards not only information acquisition and processing but also the decisions to be made and the action to be taken. The origin of this ‘global’ failure is to be found in the parameters (factors) indicating a psycho-physiological and cognitive state of the drivers scarcely compatible with the functional demands required by the general activity of driving. These factors can refer to different things such as fatigue, alcohol or other drugs intake, fitness to drive, and so on.

Three types of driving capacities degradation are listed in this category: the loss of psycho-physiological capacities (G1), the alteration of the sensori-motor and cognitive capacities (G2), the overstretching of the cognitive capacities (G3).

• **G1 failure - Loss of psycho-physiological capacities.**

The perturbation characterizing this failure refers to a loss of awareness by the driver as a result of being taken ill or falling asleep because of tiredness and/or a high blood-alcohol level, which occurs most frequently during a simple guidance task. This loss of awareness obviously causes an interruption in the driving activity as a whole, resulting in a loss of control of the vehicle.

• **G2 failure - Alteration of sensorimotor and cognitive capacities.**

Even if they didn't fall asleep as above, the drivers showing this capacity failure are not in a psychophysiological state for adequately controlling driving activity as a whole. They show a disorganisation of the activity which typically results from a high degree of intoxication, whether due to alcohol, drugs or psychotropic medicines. The consequences of this impairment in sensorimotor and cognitive capacities reveal themselves at the moment the user meets the slightest difficulty in his journey, which he seems unable to manage at any functional level.
• **G3 failure - Overstretching cognitive capacities.**

Linked to a general loss of skill in relation to driving activity (age, occasional driving), drivers find their abilities are overstretched the moment they encounter a difficulty in their progress, and they sometimes carry out absurd manoeuvres.

4.4 **Moment of the failure**

Every researcher in the field of road safety knows that an accident occurs along a temporal process and that it has to be analysed according to this sequentiality. But a lot of them tend to forget this when dealing with so-called 'human factors' (i.e. everything referring to the operator), quickly going up to a rigid analysis biased toward the human component contribution to the accident. Nevertheless, as for other parameters, the role of the human has to be traced along the different sequences characterizing an accident. It is the case for factors as it is for 'errors'.

Depending on the 'situation' we look at, we will see differently the role of the elements: at the 'driving situation' we will be able to identify initiating or facilitating factors, at the 'rupture situation' we will get triggering factors, aggravating factors for emergency and crash situations.

In the same vein, from the angle of the road user, the malfunction process can be viewed as a functional chain of failure producing. Each stage of the accident process can be characterized by a certain number of 'unsafe acts', different from one another. For instance we can find a 'violation to a safety rule' at the driving stage (e.g. speeding), which turns toward a 'poor information gathering' at the rupture stage (e.g. hasty search for information), and finish with a 'bad execution of manoeuvre' at the emergency stage (e.g. guidance problem). Each of these errors will result into conditions (i.e. factors) which will act upon the next stage considered. In the example given, the violation committed at the driving stage will act upon the error committed at the rupture stage through the speed factor which will impede a correct search for information. The problems begin when all these failures are considered at the same level and the pretended most important one is only chosen on the basis of an intuitive judgment, which is the case without any model on which to base the analysis. This explains why we can find so different conclusions according to the author. One analyst could focus on the legal aspects - as would do a policeman - and conclude to a violation of a safety rule as being the main human error; another will opt for a poor search for information; another one for a poor car control by the driver.

To counteract such judgement biases, we can once more rely upon the sequential and multicausal accident analysis model largely shared among road safety analysts. And considering human error along the road user activity, we will consider that there is an axis stage which will be considered as crucial in the chain of failures. This stage is the transient point between a normal course situation and an impaired course situation that is called the rupture or accident situation (figure 8). And it is at this stage that we will diagnose the pivotal human functional failure which could be counteracted so as to avoid the accident production.

![Figure 8: Transient moment between a controlled situation and an impaired](image-url)
4.5 Degree of involvement of the drivers

This variable defines the role played by the driver in the genesis of the accident. Close to the notion of 'responsibility', it differs from this latter by the reference not to a legal code but by the recourse to a strictly behavioural reference ('code'). In an ergonomic approach, we try only to clarify the respective degree of participation of the various users involved in the same accident, from the point of view of the degradation of the situations. Four modalities are so defined which show in a decreasing way the degree to which the driver participates by his behaviour to the fact that the critical situation turned to an accident:

- Primary active

This modality designates the drivers who 'provoke the disturbance'. They have a determining functional involvement in the genesis of the accident: they are directly at the origin of the destabilization of the situation. Following the functional failure, the drivers provoke for themselves or for the other interfering users in the system, a critical situation in which the accident situation is going to take place. Examples: a manoeuvre bringing the driver toward a trajectory of collision with the other, generating an unpredictable disturbance for the other users, provoking a loss of control, etc. In certain extreme situations, we can isolate two primary actives in the same accident, when they are both contributing to the destabilisation of the situation (for example: when two drivers decide to overtake face to face on the third way).

- Secondary active

These drivers are not at the origin of the disturbance which precipitates the conflict, but they are however part of the genesis of the accident by not trying to resolve this conflict. We cannot attribute them a direct functional implication in the destabilization of the situation but they participate in the non-resolution of the problem by a wrong anticipation of the events evolution. In situation of pre-accident, they did not envisage a possible degradation of the events, although this degradation was theoretically detectable according to more or less alarming indications that they had. Potentially able to anticipate whereas they do not, they so contribute to the genesis of the accident by the absence of adapted preventive strategies. Examples: absence of behavioural adaptation because they expect an adjustment from the other user, no anticipation of a possible conflicting pathway with others although alarming indications, etc.

- Non-active

These drivers are confronted with an atypical manoeuvre of others that is hardly predictable, whether it is or not in contradiction with the legislation. As a general rule, the human functional failure observed among these drivers doesn't feature any endogenous (human) explanatory element8. They are not considered as 'active' subjects because the information they had did not enable them to prevent the failure of others. They were not able to anticipate, for lack of information, the degradation of the situation, while the avoidance of the accident would have been possible in theory if this information had been supplied to them in time. But we differentiate them from 'passive' users in the strict sense, for whom no information would a priori have allowed to avoid the collision. Examples: drivers confronted with visibility constraints, drivers that must face an atypical manoeuvre of others and who do not have warning indications at disposal, etc.

- Passive

These drivers are not involved in the destabilization of the situation but they are nevertheless an integral part of the system. Their only role consists in being present and they cannot be considered as an engaging part in the disturbance. No measure may a priori be beneficial to them, except to act on the other driver. Examples: drivers who are collided when stopped at a traffic light or on a parking spot, drivers confronted with stone falls, etc.

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8 For a presentation of the different types of elements explaining human functional failures, cf. TRACE report D5.2 (Naing et al., 2007)
4.6 Classification procedure

The procedure to identify human functional failure consists in:

- Searching in the data collected to see if there is enough trustful information concerning the conditions of accident outset (otherwise the result would be ‘unknown’).

- Define the rupture stage. It has to be precisely determined at the moment when the driver is confronted to an unexpected event that he was not able to manage. Remember that the effect of this phase is to switch the system components from a bearable level of demand to a suddenly excessive demand in terms of ability to respond. As a consequence, at the rupture time, the driver is, placed in a non retrievable situation.

- Define what critical category of function is involved in this transition from a controlled situation to an impaired situation. This will be facilitated if always keeping in mind that the question to answer is not ‘whose fault is it?’ but ‘what can be done in order to help the driver in performing securely his task?’

- Define which specific function, within the chain of failures that might have happened all along the accident phases, is the most explicative of this transition (with the same question in mind as above).

Some pitfalls must be avoided:

- To be misled by evidence. For instance, if a driver says 'I didn't see', it doesn't necessary imply a detection problem’. E.g. it can signify that he didn't 'see' the vehicle was too fast.

- Don't forget that there is nearly always a problem of perception at the beginning of a functional chain and a problem of action at the end. And depending on what we look at, we could say that every accident are due to perceptive problems, or to action problems. The question that has to be reminded each time is ‘at which point the driver didn't manage his own errors?’.

- Do not confuse P1 and T7. When driving close to the limits (too fast for the encountered situation for example), a road user may put himself in a situation where he cannot see the danger. This can be misleading as the analyst is tempted to attribute this user to a failure linked to lack of visibility (P1). It has to be reminded that the road user's way of driving (such as excessive speed) can be a clue: he is driving fast because he does not expect to meet any perturbation ahead. In that case the failure happens at the prognosis stage (T7) and not at the perceptive one.

- Remember that to commit a failure does not mean to commit a fault. When a road user sees a non priority vehicle coming toward him and thinks that he will yield the priority, he is not at fault. But he expects adjustment from the other and that makes a failure (T5).

The following model (figure 9) can help to progress step by step in this analysis. On the left hand side, it shows the generic functions that are generally recognized as pertinent in driver operating models. On the right hand side it shows the specificities of the HFF found in accident data.
Figure 9: Model for Human Functional Failures classification
4.7 Case studies

In order to illustrate what has been developed so far, two accident cases are analysed from the angle of human functional failure. In accordance with the accident characteristics, the failure, the explanatory elements, and the driving situation can be figured. The typical scenarios to which they belong are then deduced as well as the degree of participation of each driver.

4.7.1 Case example one

Summary

On September 2006, around noon, the driver of an Opel drives in a secondary axis of the city centre. The weather is clear and the road dry. He stops by an intersection regulated by stop sign. He has to make a left-turn on a boulevard but having no sufficient visibility on the left, so he moves his vehicle onto the stop line. He looks to the left, sees a Seat arriving from this direction on the boulevard Arnaud, then looks to the right, and finally crosses the intersection. While the Opel is completely engaged on the road, the driver suddenly notices that the Seat is close to him. He tempts an emergency manoeuvre but both vehicles collide in left front-side impact. Both drivers are slightly injured during this accident.

Map of the accident

Driver 1 (Opel): Useful accident parameters:
- 24 year-old man
- Lives in the town
- Congenital deafness
- Has his driving license for 5 years
- Has to drive to a job interview and is just living the town to get there

Driving phase: the driver is heading his appointment place (=145Km further) and has to drive through the town to get there. Reaching the intersection, he stops at the stop line. Although there are visibility constraints (trees, advertisement and road signs) on his left, he sees the car coming from the left with right of way.

Rupture phase: he thinks he has time to make a left turn and starts the manoeuvre.

Emergency phase: while he is turning left he realizes that the other car is coming fast. He tries to adapt, turning a little bit larger than he had planned.

Crash phase: the front of the car hurts his car on the left back side.

Driver 1 (Opel): Accident analysis
- Human Functional Failure: T2 - Erroneous evaluation of the size of a gap
- Explanatory elements (ref. TRACE report D5.2):
  - Visibility: Road side objects
  - Experienced: Over-experienced of the place
- Driving situation (ref. TRACE report D5.2): Turning across traffic at a 'stop' intersection
- Typical Failure Generating Scenario (ref. TRACE report D5.3.2): T2 B - Erroneous evaluation of a merging gap connected to the low attention paid to the manoeuvre
- Degree of participation: Primary active (the driver has generated the perturbation)

<table>
<thead>
<tr>
<th>HFF</th>
<th>Explanatory elements</th>
<th>Driving situation</th>
<th>Scenario</th>
<th>Degree of participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>Visibility impaired by road side objects</td>
<td>Over-experience of the environment</td>
<td>Turning across traffic at a 'stop' intersection</td>
<td>T2 B</td>
</tr>
</tbody>
</table>

Driver 2 (Seat): Useful accident parameters
- 30 year-old man
- Lives in the town
- Has his driving license for 10 years
- Drives a rent car and is used to this practice
- Comes back from work
- Started at 5am but declares that he is not tired

Driving phase: the driver comes back from work on his usual return journey. He had been working since 5am and has a physical activity but he declares he is not tired (practices boxing so professional activity fits with his expectations). He sees the non-priority car stopped at the intersection on the right.

Rupture phase: he knows he has the right of way and consider that the other driver will not start his manoeuvre.

Emergency phase: the non-priority car is turning left and he doesn’t have the time to stop as he was driving rather fast (60Km/h declared, 70-75Km/h reconstituted, 50Km/h limited).

Crash phase: the front of his car crashes into the back left side of the Opel.
Driver 2 (Seat): Accident analysis

- HFF: T6 - Actively expecting another user to take any appropriate regulating action
- Explanatory elements (cf. TRACE report D5.2):
  - Behaviour: Risk taking; Speed exceeding the practices and the rules
  - User state: Rigid attachment to the right-of-way status
- Driving situation (cf. TRACE report D5.2): Approaching intersection where road user has right-of-way
- Scenario (cf. TRACE report D5.3): T6 C - Erroneous expectation that the a non priority vehicle coming on the trajectory will stop)
- Degree of participation: Secondary active (the driver participates to the non-resolution of the problem by a wrong anticipation of the events evolution)

<table>
<thead>
<tr>
<th>HFF</th>
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<th>Scenario</th>
<th>Degree of participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6</td>
<td>Speed</td>
<td>Rigid attachment to the right-of-way status</td>
<td>Approaching intersection where road user has right-of-way</td>
<td>T6 C</td>
</tr>
</tbody>
</table>

4.7.2 Case example two

Summary

On November 2005, at about 04:40 am, at night with clear weather and wet road, the driver of a Renault Clio circulates on a major axis toward the city where he works. He drives at a speed close to 60 kph in a series of bends. He approaches a right curve when he realizes that his vehicle is going toward the left shoulder. Surprised, the driver turns the steering wheel to the right. The Clio spins then half a tour while going to the right shoulder. Its back collides a tree before it stops moving. The driver is slightly injured during the accident.

Map of the accident
Driver 1 (Renault Clio): Useful accident parameters

- 20 year-old man
- Has had his driving licence for 1 year and 3 months
- Has been working for a month
- Is 15 minutes late
- Wet road

Driving phase: the driver is going to work and is 15 minutes late. This situation is annoying him so he drives a little bit faster than usually. He enters a succession of several bends that he knows very well.

Rupture phase: he starts negotiating a right bend and feels that his vehicle is heading the left of the carriageway.

Emergency phase: he suddenly steers the wheel to the right to stay on his lane.

Crash phase: he loses the control of his vehicle which starts spinning and hits a tree on the right shoulder of the road.

Accident analysis: Driver 1 (Renault Clio)

- HFF: T1 - Erroneous evaluation of a road difficulty
- Explanatory elements (cf. Trace report D5.2):
  - Behaviour: Risk taking: Speed
  - Experience: Over-experienced: Route
  - User state: Psycho-physiological condition: In a hurry
  - Road geometry: Bend: Tight
  - Road condition: Contaminants: Wet
- Driving situation (cf. Trace report D5.2): Negotiating a right bend
- Scenario (cf. Trace report D5.3): T1 B - Under evaluation of the difficulty of a known bend
- Degree of participation: Primary active (the driver has generated the perturbation with his wrong evaluation)

Table 3 - Synthesis for Road User 1 in Case Example Two

<table>
<thead>
<tr>
<th>HFF</th>
<th>Explanatory elements</th>
<th>Driving situation</th>
<th>Scenario</th>
<th>Degree of participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Speed</td>
<td>In a hurry</td>
<td>Tight</td>
<td>Wet road</td>
</tr>
</tbody>
</table>

4.8 Link the failure with its context of production

The concept of error as 'functional failure' is thus central in the clinical analysis of the accidents cases. It will be the axis of the comparison of the problems encountered by road users in the various accidents configurations. But one must be reminded that the failure is only a link in the chain of events which leads to the accident. It is important to know the precise nature of the difficulties met by the operator, but the functional failure is strongly related to a context (i.e. a 'malfunction task') which is not trivial from the point of view of the failure production. And it should not be forgotten either that this functional failure is explained by a certain number of factors (i.e. 'explanatory elements'), that it is essential to put in evidence if we want to understand the origin and the process that conditions such an issue. Once identified, every 'error' is reintroduced within the appropriate scenario which notably
reports combinations of elements that explain it, connected to the driver and to the environment of his
task (in the sense of the various parameters that play role in its realization).

We shall remind that these failures are analyzed under a strict cognitive angle dealing with
information processing. But the search for their human causes also takes into account other
'psychological' parameters relative to:

- the motivations (e.g. catch up a delay, a playful route),
- the feelings (impatience, fear),
- the state of road users, both psychological (degree of attention) and physiological (level of vigilance).

And let us also remind ourselves that for the greater part, it is the combination of various factors
resulting from various sources that is mostly going to explain the fall of the driver from a normal
situation towards a degraded situation (Van Elslande, 2003).

Once a failure is truly identified, it will have to be put in relation with the following elements:

- The task that the function in question was intended to perform in the pre-accident situation (i.e. the
  outcome the driver wanted to attain). The list of these 'malfunction tasks' will be found in Task 5.2
  report (Naing et al., 2007).
- The combination of elements that explain the fact that the appropriate function failed in attaining the
  wanted outcome (i.e. 'factors' of HFF). The list of these explicative elements will be found in the same
  report as above (Naing et al, 2007). It shall be kept in mind that the selected elements must be related
  only to HFF and not to the whole accident. Simply said, such factors explain the human failure at the
  rupture stage, not all the accident. For instance, if the critical failure is P2 failure (Information
  acquisition focused on a partial component of the situation), the presence of icy road may have a role
  in the emergency phase but not in the rupture one. Such a factor will not then be kept as explicative of
  the human functional failure production, but only for the inability of its recuperation.
- The action resulting from the HFF. This parameter points out the event (manoeuvre) which the
  human functional failure led to (i.e. what did the driver do that he shouldn't, or didn't do that he
  should, as a consequence of this failure).
- The crash configuration. This last parameter figures out the type of collision resulting from the 'HFF
  resulting action'.

The integration of the HFF within all these parameters in a production process will define the 'human
functional failure-generating scenario' for this driver. And, as explained in Trace report D.5.3 (Van
Elslande & Fouquet, 2007), this will allow aggregating several similar individual scenarios into 'typical
scenarios', in the purpose of generalizing results gained from case by case analysis, in spite of the
specificity characterizing each accident case, furthermore when they are analysed in a comprehensive
way.
5 Conclusion

TRACE project is underlined by the ambition of putting forward a diagnosis of the main driving system malfunctions in Europe, as they are revealed by the symptom that accidents consist in. To do so, it needs to go further than the simple statement of the problems as they are often taken for granted, up to the comprehensive analysis of their backgrounds. In line with this objective, WP5 is devoted to the definition of a methodology allowing a more comprehensive analysis of ‘human factors’. As part of this scheme, the present report is focalized on Human Functional Failures (HFF) to which roads users are subjects in critical driving situations. These HFF have been precisely defined from knowledge gained from the literature and the detailed examination of in-depth accident data.

As a matter of fact, the present-day trend in road accident studies, particularly in Europe, refers back to work carried out in the 1970s regarding the mechanisms which control these accidents (e.g. Fell, 1976; Treat et al., 1979). So it calls for the realignment of the results in the light of advances in knowledge as to how drivers function. This requires the set up of a comprehensive reference grid for human functional failures by which traffic system malfunctions are revealed. Such a grid should help to refine the conclusions made with regard to the ‘human factor’ taken too globally, which is often incorrectly seen as only an ‘accident factor’ - forgetting that the human part is also the essential factor for successful driving through its adaptation capacities. This type of classification can be used to gain a better idea of the way traffic system malfunctions can result in the failure of one of the regulating functions which usually enable the drivers to negotiate the difficulties they encounter. A systemic analysis of the genesis of accidents thus leads one to regard human error as a consequence rather than the cause of the deterioration in situations.

The failure classification model presented here benefits from a wealth of detailed accident data and a re-examination of data in the light of contemporary theoretical models. In this model, HFF account for errors, as well as for ‘violations’ and loss in capacities, as far as these three different types of degradation of human functions contribute to accident production. They are delineated along the different stages of the human functional chain analysed from the standpoint of information processing procedures: detection, diagnosis, prognosis, decision, and action. They operationally characterize the difficulties found by drivers in critical driving situations. HFF are not considered as factors by themselves, but as a result of factors which are found in the state of the driving system components (human, vehicle, and environment) and in their interaction defects. These factors of failures are examined in the second report of TRACE WP5, D5.2 (Naing et al., 2007) which proposes an extensive classification grid for their analysis.

By promoting a greater homogeneity of results, another advantage to be gained from a detailed classification of the various types of difficulties that drivers may encounter, would be to favour comparative and cross analyses of different databases. In that regard, it should stimulate a greater standardisation of the analysis carried out within the framework of detailed accident studies focusing on the part played by the human factor in the multi-causal deterioration of road situations. This methodology is notably addressed to the operational Work Packages of TRACE project in which HFF will be examined under the different angles of the type of road users (WP1), the type of road situations (WP2), and the type of accident factors (WP3). The classification model proposed should be used in line with the ergonomic conception of ‘human error’ defended in this report, as not being the ultimate accident cause of accident to blame but the symptom of a driving system malfunction, the roots of which have to be defined in order to solve them in a suited way. Correctly applying this classification as it is described along this report and using enough detailed accident data will allow future researches to diagnose the specificity of such or such population of drivers (or situations, or factors) as compared with others, regarding the difficulties met by the human ‘actors’ of the system. The first developments of this method have proved to be efficient in several earlier studies (Van Elslande, 2002, 2003, 2005).

A last advantage of precisely defining the difficulties met by the drivers which led them to a HFF, is to operationally show the drivers’ underlying needs for help that their difficulties manifest. By analysing the failures found in the human functions, the utility of different technical safety functions compensating for road users difficulties can be defined. This methodology will notably be applied in
the frame of TRACE WP4 to evaluate the capacity of electronic devices to fulfil the drivers' needs in aid.

To conclude, it should be reminded that not all rupture or emergency situations lead to a crash, human functions showing most of the time the ability to overcome the difficulties encountered, notably as a result of experience gained by the road users through practice. To improve safety, the conception of the driving system as a whole should take these human adaptive functions as the element to help and assist by any means, one of them being electronic devices. Toward this objective, an essential role of safety research is to well understand and precisely characterize the conditions under which such or such human functions may fail and the combinations of factors which contribute to these failures. This knowledge will allow determining the road users' needs in safety devices, and the constraints that these devices should comply with in order to be well suited to real life human functioning. In other words, this knowledge is a basis upon which could be defined an Ergonomics of Safety. Such a frame would remind that the purpose of any system offered to a human use should be conceived and built in a way of not being dangerous for its users. So should be the driving system. The road user is the core of the system, and human performance the measure of its effectiveness. The research works conducted in the frame of the TRACE project will contribute to such a trend by promoting a comprehensive analysis of road users' difficulties and by assessing potential safety measures aimed at compensating for these difficulties.
References


Glossary

Active failure pathway. In Reason's model, the way that facilitates the occurrence of errors and violations in the system process.

Cognitive functions. Mental processes of perception, memory, judgment, and reasoning (in contrast With emotional and volitional processes) which enable the individual to understand and interact with his environment.

Crash phase. The crash phase comprises the crash and its consequences. It determines the severity of the accident in terms of material damage and bodily injury.

Decision stage. Once the driver gathered the right information items, has correctly interpreted the situation and anticipated its short termed evolution, he still has to 'select' amongst the driving strategies that are feasible in that situation the one that seems to him best suited to the event and its safety requirements. At this stage, the failures relate to decisions to undertake a specific manoeuvre and not to the broader decisional factors related to the circumstances in which the journey is being made (alcohol intake, journey for recreational purposes, and so on).

Detection / Acquisition stage. It deals with a specific moment of information processing when the subject is trying to collect all the relevant clues required for the task to perform. Detection failures can occur following different types of mechanisms which go far further than strictly sensorial mechanisms. They can refer to problems relating to information conspicuity, a deficient organisation of information acquisition, and a failure to search actively for information.

Diagnostic stage. At this stage of information processing the road user 1) evaluates the physical parameters (space, time, speed, acceleration, etc.) identified at the detection stage in order to assess the feasibility of undertaking his planned manoeuvre and 2) understands the information acquired concerning the type of situation with which he is confronted.

Driving phase. It is the situation in which the user is before a problem arises. It is the 'normal' situation, which is characterized for the driver by the performances of a specific task in a given context, with certain objectives, certain expectations and so on.

Emergency phase. IT is the period during which the driver tries to return to the normal situation by carrying out an emergency manoeuvre.

Error (for ergonomics). Undesirable result of interaction between an operator and a task, arising from an interaction between internal and external determinants

Error factor. It deals with the explanation of the human error and covers internal elements (vigilance, experience, distraction…) as well as external ones (traffic condition, layout parameter, vehicle defect…). It is essential to put them in evidence if we want to understand the origin and the process that conditions the error.

Handling stage. The stage involves the driver's manipulation of the controls of his vehicle to ensure it continues along his chosen trajectory. Failures classified in this category only include accidents in which a problem of vehicle control is the direct cause of the emergence of an accident situation. It implicitly means that they occur after the driver has successfully negotiated the other stages.

Heuristic. A rule of thumb, simplification, or educated guess that reduces or limits the search for solutions in domains that are difficult and poorly understood. Unlike algorithms, heuristics do not guarantee optimal, or even feasible, solutions and are often used with no theoretical guarantee.

Human error. Failure of the operator's attempt and/or capacity to adjust his activity, in terms of being able to successfully adapt to the difficulties encountered in task performance conditions

Human factor. Every parameter connected to human state and condition which has a role at one or another stage of the accident process.

Human Functional Failure (HFF). Define the failures of the human functions which usually allow the road user to adapt to the difficulties of the driving task. The HFF is described as the consequence of a
gap between the requirements of a task and the capacities of an operator to face it, this gap resulting from the combined influence, and mostly inseparable, of the internal conditions characterizing this operator and external conditions to which he is confronted in the realization of his activity.

**Latent failure pathway.** In Reason's model, the way of not protecting operators against their potential errors.

**Overall failure.** It covers the notion of 'global failure' which corresponds to a degradation of the whole functional chain, the outcome of which is a loss of control of the situation. These include those cases where the whole of the functions necessitate to drive seem to have been deficient in the mechanisms leading to an accident.

**Prognostic stage.** At this stage, the driver has two tasks: on the one hand ensuring he correctly anticipates the potential changes in the currently encountered situations and; on the other hand making a prevision on the possibilities of a not yet visible event potentially occurring in situation to come.

**Rupture phase.** The rupture is an unexpected (for the road user) event that interrupts the driving situation by upsetting its balance and thus endangering the system.

**Violation.** A more or less deliberate deviation from the practices socially considered necessary for ensuring the safe functioning of a potentially dangerous system (must not be confused with 'infringement, referring to a strictly legal norm, and are more police matter than researchers' ones).