TRACE Project. Deliverable 4.1.5. Assessing drivers' needs and contextual constraints for safety functions: A human centred approach from in-depth accident analysis

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Assessing drivers' needs and contextual constraints for safety functions: A human centred approach from in-depth accident analysis

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Abstract:

This document is a contribution to the objective of the European TRACE project of assessing the effectiveness of safety functions in their capacity to compensate for the malfunctions in the driving system, which are revealed by accident analysis. It starts from an ergonomic basis with the purpose of integrating the human functioning modes in this assessment. From such a perspective, it is aimed at:

- Defining the drivers needs in safety, and especially the most crucial ones;
- Evaluating the capacity of underway safety functions to fulfil these needs (*ex ante* approach);
- Defining the contextual constraints that these functions should take into account in order to maximise their potential safety benefits.

It is based on an In-depth study of a wide sample of accident cases (involving 432 drivers) weighted as regard as European statistical data. This study makes use of WP5 ("Human Factors") methodological results to analyse the potential safety effectiveness of the most promising safety functions defined by WP6 of the TRACE project.

The results underline the relative capacity of the functions to compensate for the drivers' needs and contextual constraints found in accidents. They also show the weak points to tackle in order to improve the potential safety benefit offered by such functions.

Keyword list: Safety functions – Drivers' needs – Contextual constraints - Human Error – Accident factors – Safety benefit

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1 Executive Summary

1.1 TRACE project: TRaffic Accident Causation in Europe

The European 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 the most promising solutions based on technology.

These objectives are targeted by an integrative contribution of different "Work Packages" with complementary aims, both methodological and operational.

1.2 TRACE WP4 "Evaluation"

The aim of this Work Package is to investigate the impact of advanced safety functions on reducing several types of accidents involving passenger cars or restricting accident consequences. The research works conducted are oriented toward evaluating the effectiveness of several safety functions on different accident configurations. This evaluation is done on a list of safety functions defined by the WP6 as the most promising to address current and future accident types on European roads. The analysis takes benefit from WP1, WP2 and WP3 as a valuable input for focusing on the pilot accident scenes for which the functions effectiveness has to be studied.

The evaluation is performed from two different perspectives:

- Assessment of the proportion of accidents that could be potentially avoided and of the proportion of accidents whose severity could be potentially reduced, for each safety function on progress (this is the so-called *a priori effectiveness*) (Task 4.1).
- Assessment of the proportion of accidents that could be avoided and of the proportion of accidents whose severity could be reduced, for each existing safety function once the cars are equipped with (this is the so-called *a posteriori effectiveness*) (Task 4.2).

Such a determination of the effectiveness of selected safety functions is seen as able to provide valuable input to the assessment of the potential socioeconomic impact of advanced safety functions when examined macroscopically.

1.3 Assessing drivers' needs and contextual constraints for safety functions: summary of TRACE report D4.1.5

The report starts with reminding the intrinsic difficulty of the driving task attributed to the drivers, as it is attested by accidents. As a consequence, it stresses the necessity to develop a human-centred approach when conceiving a technical system devoted to human beings. It also calls attention on the necessity to integrate the contextual constraints of the activity, as far as such a system is aimed at functioning in the "real world".

From this statement, a first step of analysis qualitatively defines and quantitatively assesses the <u>Drivers' Needs</u> as they are expressed in accident situations. The analysis of these needs is based on the characterization of human functional failures (perceptive, cognitive or active) found in accidents, as they are stated in TRACE WP5 (deliverable D5.1). Most of accidents reveal a difficulty that the driver was not able to compensate for. These human difficulties reversely show, as a mirror, the needs of the drivers to be helped. Though, these needs are be defined from a diagnosis of the real problems that drivers met in accidents. (Example: a need in detecting the slowing down of a vehicle ahead).

A second step of analysis defines the characteristics of the safety functions examined in TRACE project and gives an assessment of the Adaptation of the safety functions to drivers' needs, i.e. their potential capacity to address the needs of the drivers stated in the previous step. This study consists in an '*a priori* (or *ex ante*) evaluation'. It means that it is aimed at estimating the potential efficiency of safety functions under the hypothesis they were equipping the vehicles. (Example: capacity of safety functions to detect the slowing down of a vehicle ahead).

A third step stresses the potential Contextual Limitations which could lessen the optimal functioning of the safety systems. These potential limitations are defined from the parameters characterizing the contexts in which real accident occurred, showing some essential constraints to take into account in order to optimize the adaptation of the systems to effective accident situations. These potential limitations encompass the whole characteristics of both the drivers (internal context) and his driving environment (external context). (Example: driver looking backward toward a passenger at the rear).

A fourth step looks at the Response Efficiency of the safety functions, i.e. their capacity to compensate for the Contextual Limitations diagnosed in the previous stage, and by so to tackle the potential limitative impact of these contextual parameters. Such an analysis allows defining lacks and weaknesses in each function, and consequently put forward the specifications on which to progress for optimal safety efficiency. (Example: capacity of safety functions to alarm a driver not looking ahead).

A last step of analysis gives a comprehensive result of all the previous ones. It stresses the Safety Effectiveness of the safety functions, i.e. their capacity to compensate for drivers' needs. This safety effectiveness is defined as the combination of the adaptation of the safety functions to the needs and their response efficiency in compensating for the contextual limitations found in accident situations. The results allow defining which functions are the most promising in a safety purpose but also which drivers' needs are more or less compensated.

The report concludes on the originality of the method which allows not only to define a range of potential efficiency for the introduction of safety functions in the driving world, but also to indicate the conditions for improving these functions in the perspective of optimal adequacy to drivers needs and accident situations contexts..

2 Introduction

The European TRACE project addresses two main issues of road safety: to develop a comprehensive Accident Causation Analysis and to perform an Evaluation of the effectiveness of safety functions as a remedy to these accidents.

The second issue is notably covered in the context of Work Package 4 "Evaluation" of this project. More specifically, Task 4.1 of this WP is dealing with the evaluation of the expected effectiveness of on going safety functions, so called *a priori* (or *ex ante*)evaluation; while Task 4.2 is dealing with the observed effectiveness of existing safety functions, so called *a posteriori* (or *ex post*) evaluation.

In order to cover the objectives of the Task 4.1, the following steps have to be done:

- Step 1: Review the most critical safety functions and their relevance to accidents (contents of TRACE deliverable D4.1.1, done in cooperation with WP6).
- Step 2: Look for the best way to classify the accidents as well as to review the most critical accident configurations or scenarios (contents of D4.1.2)
- Step 3: Review and select the most promising and suitable methodologies for the a-priori evaluation of the TRACE selected safety functions (contents of D4.1.3).
- Step 4: Perform the evaluation and report the results (contents of D4.1.4 & D4.1.5).

2.1 Aims of the report

This D4.1.5 deliverable corresponds to the Step 4 of Task 4.1.The analysis put forward in this deliverable is specifically devoted to a human-centred approach on drivers' needs and contextual constraints diagnosed from accidents analysis. It will be complementary to the other evaluations realized in TRACE, more devoted to the technical aspects regarding safety functions benefit.
The report presents the results of this human centred approach aimed at:

- Assessing drivers' needs in aid;
- Evaluating the capacity of underway safety functions to meet these needs;
- Defining the constraints linked to accident contexts and the consecutive potential limitations that these functions should take into account to maximise their potential efficiency.
- Assessing the potential safety effectiveness of the safety functions regarding accident production contexts, on the basis of both: their *relevance* (i.e. their capacity to meet these needs) and their response efficiency (i.e. their capacity to compensate for the needs)

This approach constitutes an innovation aspect of TRACE and WP4. Up to now, most evaluation results are focused on the estimation of the effectiveness of safety functions in terms of safety increment. In TRACE project, all the selected primary safety functions will be also evaluated regarding their effectiveness in the human/driver needs fulfilment. Additionally, potential limitations which could prevent the driver from taking advantage of added driving aid and which could lessen the effectiveness of a safety function, will be thoroughly examined by in-depth analysis. By taking into account the contexts in which the driver failures occur, the presented approach will enable to define the constraints the safety systems will have to cope with, in order to fulfil not only the needs of the drivers but also to compensate the characteristics of the situations in which these needs are met. This work is strongly related to WP5 results dealing with 'human factors' analysis.

A list of 23 selected safety functions are evaluated in TRACE. This list is a common product of WP6 and WP4 and it has been produced from a larger list of more than 160 safety systems after evaluated them with critical criteria relating to safety (these criteria are described in details in the WP6 deliverables). eIMPACT requirements have been taken into account during the selection (cf. TRACE deliverables D4.1.3 & D6.1).

21 safety functions (plus 5 variants in their operative mode) from this list are evaluated in the present report, focussing on primary safety. For some of these functions, alternatives or variants in their functioning will be considered.

2.2 Driver needs and safety functions

The present section summarizes the approach developed along the report, as a reminder of the method exposed in TRACE deliverable D4.1.3 (Karabatsou et al, 2007). It notably stresses: the (too often forgotten) intrinsic difficulty of the driving task; the necessity to develop a human-centred approach when conceiving a technical system devoted to human beings; and the necessity to integrate the contextual constraints of the activity as far as such a system is aimed at functioning in the "real world".

Driving as a complex task calling for aid

Despite the apparent simplicity of the partly automatic (skilled) way in which drivers operate, driving a car can be considered as a difficult activity which forms part of a complex system in which the driver regulating functions are sometimes over requested, so that their adaptation capacities are eventually pushed to their limits (Van Elslande, 2003). Accidents are the most evident symptoms of this capacity exceeding in compensating for driving system demands. As far as drivers are not willing to have them, every accident case is necessary going through a failure in one or another regulating function that usually able road users to compensate for the driving difficulties they meet at the wheel.. Consequently, one of the best ways of obtaining knowledge on the relevant mechanisms behind road unsafety is to analyse these human function failures, their factors and the characteristics of the context in which they occur. In this purpose, in-depth accident studies makes it possible to reveal these operating malfunctions, in relation to both the situational driving context (interaction with the vehicle, the road and with other users) and the internal driving context (status, intentions, motivations, etc.).

In view of the difficulties encountered by drivers and their repercussions in terms of safety, a question which is increasingly relevant is how to lessen these difficulties using suitable driving aids. These aids are aimed at offsetting certain driving deficiencies in certain situations, by transmitting information or by taking over, almost automatically, critical subtasks. For informative aids, the principle is to supply users with messages which, one would assume, would facilitate their task and help them to solve the problems they encounter. Drivers must, however, be able to assimilate these messages and be willing to comply with them. For automatic aids, the principle is to take over the driver regulation in situations where he is overwhelmed. Even if they would be automatic, they should be defined so as to be valid, effective and acceptable for their users. As a consequence, every technical system aimed at helping an operator has to be thought at the light of the real difficulties encountered by this operator.

A human-centred approach

If, from a driving task standpoint, these aids are to be operational, a number of questions have then to be raised. These questions go beyond the strictly technical aspects of the equipment involved and refer to the psycho-ergonomic analysis of man-machine-environment interactions. Such an analysis is necessary to pinpoint possible matches and mismatches between the functioning mode of the operator, and the tool to be made available to him.

Literature dealing with ergonomics provides information on the considerable way man's adaptive behaviour may vary, particularly with regards to his sensorial, cognitive and motor capacities. This intra- and inter-individual variability in human operators reveals the difficulty in designing work aids which are sufficiently operative to adapt to fluctuations in human behaviour. This adaptability is nevertheless vital if the aids are to be used to the full and do not, as could sometimes be the case, conflict with the driver's task. As the purpose of an aid is to help the operator to deal with a difficulty, it would be self-contradictory to design systems which create additional difficulties. So, when planning to introduce a new component into an already complex task, an effort must therefore be made at least to remain within the limits of the perceptive and cognitive load acceptable to the driver (Hancock and Parasuraman, 1992). As it is impossible to provide an unlimited number of messages, and considering the fact that drivers will still have to process information from the road scene, it is important to know which information is really relevant and is needed by the operator to perform his task with greater safety. And to maximise the impact of the information provided, it is also important to determine what factors could interfere with the driver's assimilation of this added information. It is also important to know how new information interferes with or complements the driver's assimilation of information from the road scene. Connected to this last point, other essential questions are also to investigate, referring notably to Human Machine Interface to promote so as to optimize the positive effects of the systems while minimizing their potential negative effects, notably in line with the European Statement of Principles on human machine interface (ESoP, 2006).

Those last questions refer to a specific field of Research and involve research works using naturalistic driving and experimental studies. So they are beyond the scope of the present study which is dedicated to the diagnosis of the difficulties met by drivers and the constraints of the contexts in which they found these difficulties, as it can be established from in-depth accident studies. As a matter of fact a human-centred approach of safety functions is a far complex matter which appeals for a wide variety of studies with different types of data along the different levels in the ergonomic evaluation of safety functions.

Lacks to compensate for and constraints to cope with

As a contribution to WP4 of TRACE project, the present study is concentrated on 2 aspects: the first stage deals with the definition of actual driver's needs in driving aid, reflecting the lacks in safety of the driving system; the second step refers to identification of the specific constraints shown in accident production contexts, that should be taken into account by these driving aids.

Drivers' needs can be deduced from different methods (e.g. naturalistic driving: Klauer et , 2006), but the interest of in-depth analysis of accident cases is that it allows determining the difficulties encountered by drivers that are undoubtedly connected with real safety problems. These difficulties, as they are revealed by "human functional failures" (cf. TRACE deliverable D5.1), will be seen as a result of lacks in the operating of the driving system, and as a consequence of weaknesses in its defences. Once identified through accidents, these needs can be compared with safety functions in order to draw up an evaluation of the degree to which these functions are relevant, i.e. really addressing the true needs of the drivers. Such a procedure allows determining the adaptation of the safety functions to the difficulties met by drivers on the road.

But this analysis still have to be completed with a second stage of work aimed at taking into consideration the contextual constraints in which such safety functions will operate and the potential difficulties drivers may encounter when using them. As a matter of fact, providing an aid, even if this aid corresponds to a safety need correctly diagnosed, is in no way a guarantee that this aid will be used to the full by a user faced with an actual situation. In line with ergonomics trend, it appears necessary to define to what extent a driver, already involved in performing a given task which includes objectives to be reached and a certain workload will be able to make full use of the potential theoretically offered by the systems. Such parameters could act as limitations of the system efficiency. So they can be considered as *constraints* that safety functions must integrate in order to fit with the real contexts of accident producing and to be more efficient in counteracting accidents. As stated above, the overall definition of such constraints related to human functioning appeals for a wide variety of research works, using a wide variety of data (field studies, experiments, observations, interviews, etc.). The present study will consist in a contribution to this trend by taking advantage of in-depth accident data so as to make more apparent the specificities of accident contexts which have to be integrated as part of these constraints.

2.3 Scope of analysis

The analysis of the *drivers' needs* and *contextual constraints* presented in the present report is based on the study of a sample of 432 car drivers involved in a road accident. This sample was randomly extracted from INRETS in-depth accident study database (EDA). In order to be more representative, this sample has been weighted as regard as European statistical facts.

The needs and constraints diagnosed from accidents are confronted with 21 primary safety functions (plus 5 variants in their functioning) defined, in TRACE WP6 ("Safety Functions") deliverables, as the most connected to safety, in order to examine the ability of these functions to compensate for the driver's difficulties.

The analysis presented in this report is presented as follows:

- Chapter 3 qualitatively defines and quantitatively assesses the Drivers Needs as they are expressed in accident situations. The analysis starts from the characterization of the human functional failures (whereas perceptive, cognitive or active) found in accidents, as they are stated in TRACE WP5 (cf. deliverable D5.1). Most of accidents reveal a difficulty that the driver was not able to compensate for. The needs can be considered as the mirror of these human difficulties. By so, they can be defined from a diagnosis of the real problems that drivers met in accidents. To be more operational, they are neither inferred from drivers' wishes nor engineers' assumptions, but from expertise in accident producing analysis.

- Chapter 4 stresses the characteristics of the safety functions examined in TRACE project and gives an assessment of the Adaptation of the safety functions to driver needs, i.e. their potential capacity to address driver needs as they are stated in Chapter 3.

- Chapter 5 put forward the potential Contextual Constraints found in accident, which could lessen the optimal functioning of the safety systems if they are not truly taken into account. So called "potential limitations" are defined from the parameters characterizing the contexts in which accident occurred, showing some essential parameters to consider in order to optimize the adaptation of the systems to accident situations.

- Chapter 6 looks at the Response Efficiency of the safety functions, i.e. their capacity to compensate for the accident contextual limitations diagnosed in Chapter 5.

- Chapter 7 gives a comprehensive result of all the previous ones. It stresses the Safety Effectiveness of the safety functions, i.e. their capacity to fulfil drivers' needs. This safety effectiveness is defined as the combination of the adaptation of the safety functions to the needs and their response efficiency in compensating for the contextual limitations found in accident situations.

3 Drivers' Needs

This section describes the first step of this study dedicated to the use of in-depth accident studies as an added value to develop a human centred analysis of the efficiency of safety system. It first recalls the theoretical context behind the definition of "drivers' needs" and the method used to put them forward. Then it presents an estimation of the needs which have been diagnosed from In-depth accident data.

3.1 From functional human failure to drivers' needs: Theoretical context and Method

This study is directly connected to TRACE WP5 ("Human Factors"), both theoretically and methodologically. It makes use of a large sample of In-depth accident data in order to develop a comprehensive analysis of the difficulties encountered by drivers when trying to cope with the complexity of their tasks. The target of such an analysis inside this report will be the assessment of the potential technical means to compensate for these difficulties, starting from an ergonomic point of view.

In a first section is presented, as a reminder of TRACE deliverable D5.1, the conception behind the analysis of 'human error' in the purpose of defining operative solutions for helping human beings in their activity. In a second section will be presented the method used to define drivers' needs, the capacity of technical safety functions to meet these needs, and the constraints they should integrated to fulfil them.

3.1.1 Theoretical context

So called 'human error' may be analysed in many different ways, depending on how it is viewed, and the background system of belief.

In a juridical frame of analysis, an accident will be investigated through the level of responsibility of the people involved. Each diagnosable 'human error' will be then undertaken as a fault, and the solution for it will be defining a level of punishment. The problem is that this 'canonical' view tends to be widespread in every accidentological prospect, even not juridical, which impedes the search for more efficient solutions, at least better fitted with human difficulties.

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 (the drivers being of course part of it). 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' as they are studied from this ergonomic point of view, will be labelled 'Human Functional Failure' (cf. TRACE D5.1), defined as following. 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.

So, Human Functional 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. 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 analysis starts from the characterization of the human functional failures (whereas perceptive, cognitive or active) found in accidents, as they are stated in TRACE WP5. As far as an accident is not intentional, it reveals a difficulty that the driver was not able to compensate for. This difficulty -which led the driver to the accident, is regarded as a symptom of a driving system malfunction. This symptom reveals a safety need which has not been fulfilled. So the drivers' needs can be considered as the mirror of driving system malfunction, often hidden behind human failures.

An accident is a process, a story in which several stages can be defined (Figure 1). In this sequence, there is a crucial stage which marks the transition between a situation which is still under control (even if some drawbacks are part of it) and an impaired situation where the driver has suddenly to put forward an emergency manoeuvre in the purpose of coming back to a controlled driving stage. This crucial stage accounts for the rupture phase of the accident process and is materialized by a specific function failure, i.e. the failure of one of the perceptive, cognitive of active functions which usually allow the drivers to adapt to the difficulties encountered in normal driving. A special attention will be paid to this specific pivotal functional failure as far as it reveals the crucial need of the accidented driver.

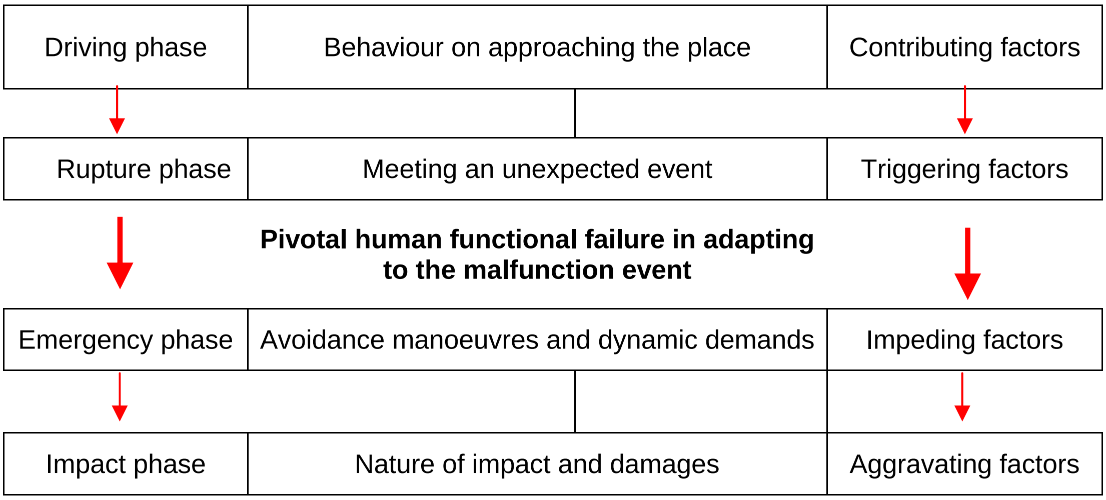


Figure 1 – Sequential accident process (adapted from Van Elslande & Fouquet, 2007)

To conclude, needs must be defined from a diagnosis of the real problems that drivers met in accidents. The assumption made is that if these needs were compensated for (by any means), the functional failure wouldn't occur, and the accident wouldn't happen.

3.1.2 Definition of a "need"

As already stressed in TRACE report D4.1.3, a need is not such a simple concept to define, as can be seen from the wide variety of definitions to be found in every dictionary. For our purposes, it will be globally defined as: "something essential to safety". Only this safety aspect of the problem will be taken into account in the frame of this study. Needs with regard to comfort, trouble-free driving, smooth running, however justifiable they may be, can be considered as only a secondary aspect of accident research (Malaterre *et al.* 1992), not mentioning the fact that sometimes comfort goes against safety. Road users' needs must also be clearly distinguished from eventual *wishes* that can be expressed by these users (through questionnaires, etc.). They have to be defined from an analysis by an expert of the difficulties manifested by the operators while attempting to adapt to the task which is devolved to him.

From a systemic conception, a driver's need implies and refers to something lacking inside the driving system functioning, in its defences and/or in its protections. Accidents are the most evident symptoms of these lacks. And human functional failures are a more precise sign of what was lacking to the driver in order to compensate for difficulties he met on the road.

That is why a driver's need can be considered as the "negative" (the mirror) of a functional failure experienced by a driver when being unable to compensate for a difficulty met at the wheel. The need represents what would have avoided the failure if it had been fulfilled. So it has to be diagnosed in order to allow helping the driver when meeting accident-generating situations.

3.1.3 Method

Such an analysis was conducted one the in-depth analysis of a sample of 432 drivers of passenger cars involved in 361 accidents.

What is the interest of accident data for determining drivers' needs? Analyses of the driving task through observation or experimentation are of course necessary for many purposes, but present the drawback to tend to stress the difficulties expressed by drivers rather than definite safety problems. The advantage of relying on accident data is that these are indubitably referring to safety. And the needs inferred from them are consequently truly safety needs.

What is the interest of In-depth accident data? The disadvantage of accident data gained from police procedures is a lack of detail with regard to information on the psychological procedures used by drivers during the event sequences which result in an accident. This is why use will be made of data from the INRETS in-depth survey (Ferrandez et al., 1986). The way data is collected (on the spot, in real time) and the depth of analyses (cinematic reconstruction; detailed interviews by psychologists, cognitive models) makes it possible to list what are termed accident mechanisms. This term applies to modes in which situations, actions and factors can combine in such a way as to result in an accident.

How determining needs? Safety needs are inferred from the difficulties that the drivers were confronted to during the accident process. As stated in TRACE WP5 "Human factors", the driver is the main regulating factor in the system. Consequently, it is usually possible to identify "errors" or "failures" in the driver's processing and acting functions[1]. A wide variety of models have been built in the literature as regard to human errors. The specificity of the classification model of human functional failures put forward in TRACE D5.1 is that it specifically addresses the difficulties that drivers met in real accident situation and in-depth studied, while benefiting from classical models found in the literature (Rasmussen, Reason, Wickens, etc.). According to this model, human failures can be dispatched along different stages of human functions impaired during the accident process, delineated along the detection level, the information processing level (diagnosis, prognosis), the decision level (when engaging a manoeuvre), the operating level (motor skills), or involving an overall decrement in driving capacity (Figure 2).

Another advantage of this model is that it allows well differentiating the failures from the factors (human and external) that produces them (for example, inattention can provoke different kind of failures, so inattention is considered as a factor and the result of it in the human processing and acting delineation will define the human function failure). The definition of the drivers' needs can be done in line with the delineation put forward in this model, so that these needs could well reflect the precise functional failures met by drivers (Figure 3).

Simply speaking, a detection failure will reveal a driver's need to be helped at the detection process level. A failure in evaluating time and space reveals a driver's need to be helped at the evaluation process level. And so on.

To take a more complex example: a driver who is surprised by the overtaking manoeuvre of another car in front of him which he couldn't detect before will manifest a perceptive failure at the rupture phase: the *Failure to detect linked to lack of visibility* (cf. Figure 2). He can also manifest a failure at the emergency phase, by acting to hard on his steering wheel, i.e. *Guidance defect*. Such a driver will consequently show a need in perception: *Detecting earlier an oncoming user in his lane*, in order to avoid the surprise effect at the rupture phase. He will also show a need in vehicle handling at the emergency phase: *Avoiding in a softer way*.

So, if a driver is subject to several failures, it probably means that he has several needs (even if one need being compensated, the other one could be able to disappear). There can be a more or less important influence of such or such failure as regard as the accident generating process, and the corresponding needs have also to be estimated as a consequence of this relative safety importance.

[1] Let's just remind that this concept does not necessarily involve the responsibility of the driver in the legal sense of the term, as far as one can find a functional failure for "non at fault" drivers. (cf. D5.1 and D5.5)

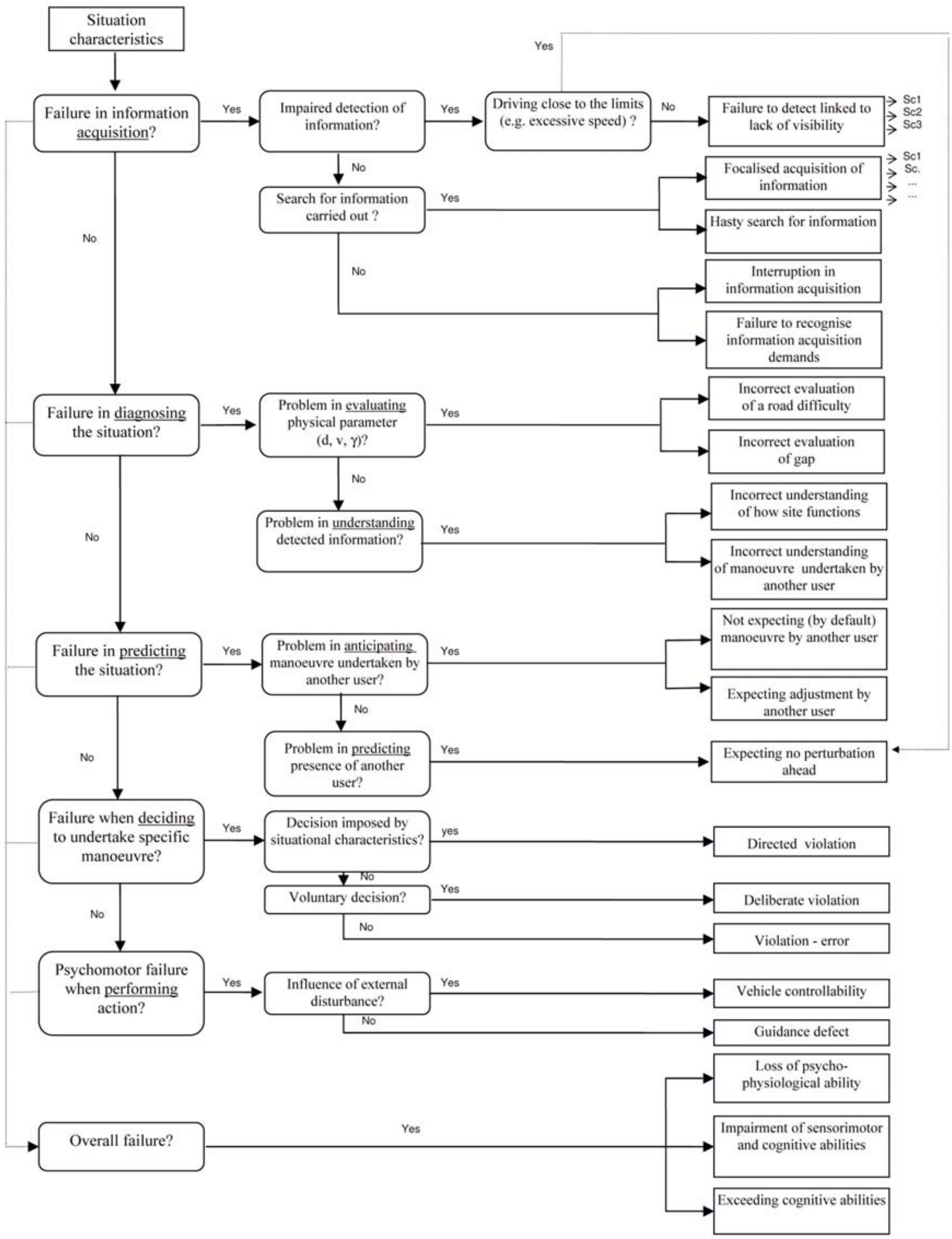


Figure 2: Model for Human Function Failures classification (from Van Elslande & Fouquet, 2008)

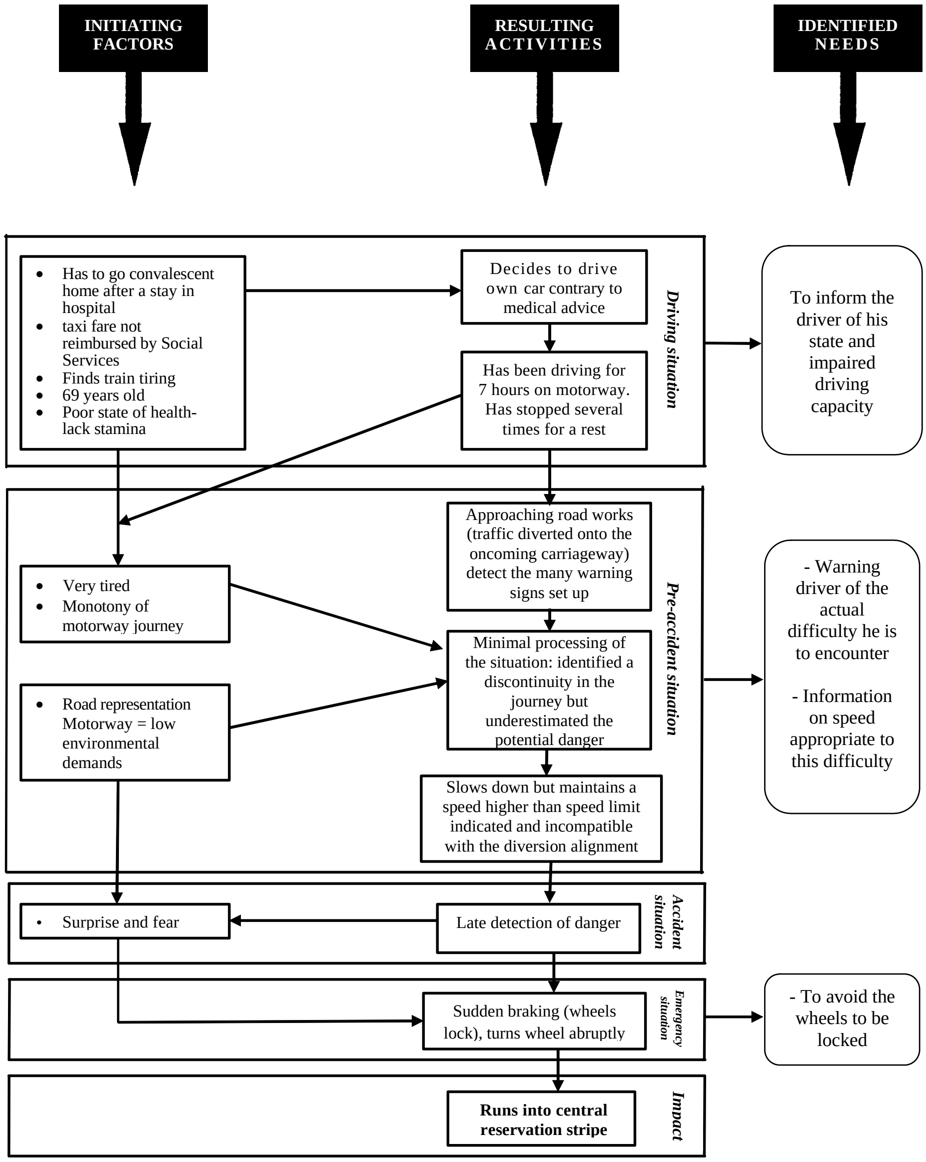


Figure 3: Determining needs from accident analysis (example)

A systematic grid for the classification of drivers' needs were elaborated for the present study, on the basis the model presented, making also use of a previous work on driver's needs (Van Elslande and Malaterre, 1987; Malaterre *et al.,* 1992), and by making use of the detailed information contained in a significant sample of In-depth accident studies including cinematic reconstruction and drivers' verbalizations collected by a psychologist from road users involved.

A list of 22 needs was thus put forward, reflecting the essential difficulties met by drivers in accident cases. This list of needs follows the different human functions involved in driving, which can be subject to failures. So they are defined in a way of operationally reflecting drivers' difficulties.

These 22 needs are spread into 5 categories: 1) Needs in internal diagnosis, 2) Needs in detection, 3) Needs in external diagnosis, 4) Needs in prevision, 5) Needs in control.

3.1.3.1 Needs in internal diagnosis

Needs in internal diagnosis refer to the driver's capacity to evaluate and understand information relative to its state and the one of his vehicle. These needs are so relating to the global question of the capacity of the driver and the vehicle to carry out a way.

- ***B01 Diagnosing driver condition***

The problem of 'driver condition' applies when driver performance is diminished by fatigue, alcohol, drugs or certain medicaments. The relevant need consists in being aware of one's own level of alertness and attention. It is coded each time a driver shows a strong decrement of this process.

- ***B02 Diagnosing vehicle condition***

The problem of 'vehicle condition' applies when a mechanical defect contributes to the accident production or to the ineffectiveness of the emergency manoeuvre (tyre pressure, condition of tyres, shock absorbers, braking system, etc.). The relevant need is an early failure diagnostic. There is 'no need' when the driver is aware of the defect in question.

3.1.3.2 Needs in detection

These needs relate to the perception of a difficulty or an obstacle to the progression.

- ***B03 Detecting an unexpected road difficulty***

This need applies for different difficulties linked with the road.

- Dangerous bend, particularly if it forms a discontinuity in the route.

- Intersection with no indication about right of way.

- Ice, fog patches, slippery road, roadwork, etc.

For this need to be coded, the driver must have encountered an unexpected difficulty. So it can also the case of roadside visibility problems (e.g. fog), and not only for "intrinsic" road problems.

- ***B04 Detecting a fixed obstacle on the road***

This need applies when any fixed obstacle that the driver has not seen, or have seen too late to avoid the accident. It must not to be confused with the question of understanding the manoeuvre of another road user, or anticipating his intentions. For this need to be coded, the obstacle (pedestrian, object, animal or vehicle) must be fixed in position on the road sufficiently in advance for drivers to be able to detect it, and so take this information into account.

- ***B05 Detecting a slowly moving obstacle on the road***

Next to the previous one, this need corresponds to the slowing down of vehicles ahead. For this need to be coded, the obstacle (pedestrian, object, animal or vehicle) must be in slow movement, in a position on the road sufficiently in advance for drivers to be able to detect it and so take this information into account.

- ***B06 Detecting an oncoming user in one's lane (moving)***

This applies to rear end collisions, frontal collisions, and to certain overtaking manoeuvres (excluding those due to poor evaluation of the time required to overtake). It may apply for vehicles obscured by a bend, a hump, another vehicle or poor visibility (fog, rain, ill-lit obstacle, sun glare, etc.). It can also correspond to drivers not paying enough attention to the driving scene.

- ***B07 Detecting a user on an intersecting course***

This need is coded only if sure that the other user (pedestrian, animal or vehicle) has been seen too late to avoid the accident (in cases of obscured visibility, particularly in built-up areas). This also applies to pedestrians who cross the road without seeing the approaching vehicle (need for pedestrian to detect vehicles).

- ***B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)***

This need emerges essentially when another vehicles behind or on the side is overtaking, changing lane, etc, which impede the manoeuvre in progress by the driver (changing direction, overtaking). This need typically follows an attentional failure.

- ***B09 Detecting a user in the forward field of vision (masked by an object)***

This need corresponds essentially to vehicles masked, by vegetation, a traffic panel, or by another vehicle (car, truck) which is overtaking, changing lane, etc, and which impede the manoeuvre in progress (change of direction, overtaking). This need directly comes from an external element which represents an obstacle to visibility.

- ***B10 Detecting deviation from the path***

This need applies when drivers do not detect their own vehicle course deviation (on the other way or the pavement), because of an attention problem or a drowsiness.

3.1.3.3 Needs in external diagnosis

Needs in external diagnosis refer to the driver's capacity to evaluate and understand information relating to the environment. These needs relate to the capacity of the driver to develop a behaviour adapted both to the road and to the other road-users.

- ***B11 Adapting speed to the road - 1: road geometry***

This need applies when speed is excessive regarding the road layout or skid resistance: in case of loosing control in bends or in straight sections (except when due to falling asleep). This need does not apply when speed is excessive only in relation with moving obstacles which cannot be avoided.

- ***B12 Adapting speed to road network - 2: legislation***

This need applied when speed is not in agreement with the traffic flows circulating, according to the type of road network (city, countryside, highway). It makes reference to the violations to the traffic rules.

- ***B13 Evaluating a catching up on a slower road user***

This need applies when the driver underestimates the speed of a vehicle ahead travelling slower than his/her own vehicle. This need applies in two cases:

- When, on a fast lane, the driver is suddenly faced with a vehicle travelling at a slower speed or who is just stopping, due in particular to traffic congestion.

- When, while moving in a traffic queue, a road user is surprised by the sudden braking of a vehicle ahead.

- ***B14 Estimating a collision course with another user***

This need applies at intersection, when a user badly assesses the relative movements between him and another user who is coming transversally to him. This does not apply when the other user is seen too late (otherwise it is a detection need).

- ***B15 Assessing gap when overtaking or changing lane***

This need only applies if the other users have been seen. It corresponds to cases where the relative movements or time required for the manoeuvre engaged have been badly assessed.

- ***B16 Assessing gaps when merging into or cutting across traffic***

This generally applies to users who do not have right of way and who must cut across or join a denser or faster-moving traffic flow. This often corresponds to moving off from a stop sign, or re-accelerating after changing direction at low speed.

3.1.3.4 Needs in prevision

Needs in prevision refer to the driver's capacity to predict:

- The behaviour adapted to layout functioning

- The other road users' behaviour.

- ***B17 Predicting that another user will pull out or fail to stop***

This applies mainly at intersections where driver who has right of way, thinks right up until the last moment that the other vehicle will let him through. This need is related to predicting the intentions of others.

➢ ***B18 Predicting that another user will slow down, stop or fail to disengage***

This applies mainly in linear sections where a driver on his way is surprised at the last moment when the other vehicle ahead of him suddenly brakes. This need is also related to predicting the intentions of others.

➢ ***B19 Predicting the manoeuvre of another user or pedestrian***

This need is similar to the previous case but is not related to right of way. It applies in cases where intentions of others are wrongly interpreted (a vehicle which overtakes, changes direction, a pedestrian who suddenly cross the road).

➢ ***B20 Predicting the appropriate manoeuvre for the functioning of the site***

This is a need in anticipation of the adequacy between an action and the infrastructure. The driver did detect the traffic signals, but interpreted them poorly. Or the driver did detect the presence of an intersection (often complex), but did not understand how to behave in it (problem of insufficient, erroneous or even suppressed road signals and markings).

3.1.3.5 Needs in control

The need in control refers to the driver's capacity of actions on his vehicle as regard to the traffic, the layout, or the dynamic solicitations of the vehicle.

➢ ***B21 Controlling one's vehicle***

There may be several causes at the origin of lack or loss of control of the car, in particular the non-perception of a difficulty. In the present frame, the need relates to the correct assessment of vehicle capabilities and the achievement of the appropriate skills, particularly concerning steering wheel movements.

3.1.3.6 Pivotal, Upstream and Emergency needs

It has been stressed above that an accident is a process which can be decomposed into sequences. This 'sequenciality' complicates the analysis of the problem behind accident generation and can lead to mistakes in the definition of solutions if it is not taken into account cautiously. Thus, we need to know which problem we are addressing and at which level of the accident we must put the counter action.

Operative human functions can fail to adapt as these different phases of the accident, showing successive needs in help. When a driver is confronted with several functional failures occurring in chain, the sequential analysis of the accident process allows defining which of these failures put the driver from a still controlled situation toward an uncontrolled one. As mentioned earlier, this failure is found at the rupture stage of the accident process. It is qualified as the 'pivotal failure', meaning its critical status as regard as the accident production: it figures out the "pivot" between a controlled situation and an impaired situation.

For each driver showing at least one failure, we can define at least one corresponding need at this rupture phase. This need will be considered as the 'pivotal need', meaning its critical status as regard as the possibility to prevent from the function failure, and by so to prevent from the accident occurring. Of course, this doesn't apply for drivers who are completely 'passive' in the accident production (for example being hurt when stopped). Having no failure, these drivers don't manifest any safety need[2].

But when several function failures are met -around the pivotal one-, several needs can be defined. In such a case, these failures and corresponding needs are dispatched along the accident process (Figure 2).

To go further in the analysis following this accident process, the drivers needs have been diagnosed in the frame of the present study at 3 moments:

- At the *driving stage*: These needs are diagnosed when a human failure beforehand has favoured the malfunction encountered at the rupture level. Needs at this stage will be qualified as 'Further Upstream Needs';

[2] For more precision, cf. TRACE deliverables D5.1 & D5.2.

- At the *rupture stage*: These needs correspond to the 'Pivotal Needs' described above;
- At the *emergency stage*: These needs are diagnosed when a function failure has hindered the driver from taking over the situation met at the rupture stage. Considering dynamic and temporal constraints, these 'Emergency Needs' only refer to the decision or execution processes (no 'cognitive' needs).
- This study specifically dealing with primary safety, no needs will be analysed in the present frame at the crash phase, as far as they do not refer to any human functional failure, but more to human body fragility. Nevertheless, such needs in protection can reflect 'aggravating factors' found in accident process (cf. Figure 1), showing a secondary safety potential of improving the driving system functioning.

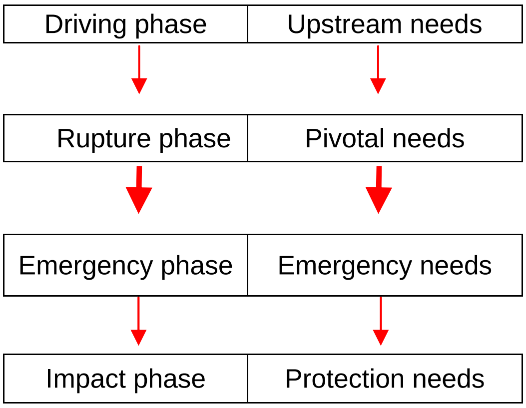


Figure 4 - Main phases within an accident process and corresponding needs

This delineation of these drivers' needs along the accident process allows putting forward a second level of analysis. This analysis consists in showing the chains of needs felt by the drivers, which have to be compensated by the safety functions in an integrated way.

3.2 Estimation of drivers' needs

Once the different types of needs have been operationally defined from in-depth accident material, still is to analyse their frequency of occurrence in order to get an estimation of the most important targets that safety functions will have to aim at in order to be effective.

3.2.1 Sample

The evaluation of needs has been done from a sample of 432 drivers of passenger cars[3] involved in an accident collected in the frame of the In-depth accident study (EDA) conducted at INRETS (France).

This sample comes from a larger sample studied (n=656) from which have been removed some road users involved:

- Those who were passive as regard as the acciden²t genesis, showing no function failure and so no direct need for them (n=86);

- Those for who the function failure staid undetermined, due to lack of enough confident information in the data collected (n=49);

- Those driving other vehicles than passenger cars : PTW, cycle, truck, bus, etc. (n=73); this choice has been made in line with the fact that only cars are supposed to be equipped with the safety functions selected in the frame of TRACE Work Package 6 (cf. Chapter 4, page 22).

[3] Includes car and vans (<3,5 tonnes)

- Pedestrians (n=16).

This sample of 432 people – involved in 361 accidents – has been weighted along European statistical data in order to be better illustrative, notably for the variables Age, Gender and Environment. The following results integrate this statistical correction.

3.2.2 Results: pivotal drivers needs

As stated above, pivotal needs are those relating to the failures felt by the drivers at the rupture stage of the accident process, i.e. at the moment when he met an unexpected difficulty which he could not manage, this failure precipitating him into an impaired situation. As a consequence, preventing this failure would allow him to avoid entering in an accidental sequence. This is why these pivotal needs will be considered in the foreground. Other needs may also be found further upstream, dealing with the suitability of the driving behaviour put forward before the difficulty is met. And more other needs can be diagnosed at the emergency situation, relating to drivers deficiencies in performing avoidance manoeuvres.

So the needs are defined from the characterisation of drivers' functional failures, in line with the methodological work performed in the frame of TRACE Work Package 5 (TRACE deliverable D5.1). Let us just remind that for operative purpose such failures shall not be taken as 'faults' but as reflecting the weaknesses in driving functions put forward by road users while trying to adapt to road system malfunctions. The characterisation of human failures allows defining the steps in the driver's functional chain which are the most 'breakable', and by so shows the most critical 'holes' in the driving system safety which could be fulfil by implementing adapted safety functions. To each of these failures will be affixed a corresponding need in help that such safety functions could address in order to improve the overall safety of the diving system. Then will be considered the capacity of these safety functions to effectively compensate for these needs.

Following the classification model presented in TRACE deliverable D5.1, human functional failures can be attributed to one of the 6 following categories:

- Failures at the information detection stage

This fist category accounts for accidents are which are directly attributable to the non-detection (or belated detection) of certain essential parameters of the situation, relating to the layout or to another road user on a potential collision course. These detection problems can involve difficulties linked with information conspicuity, with a deficient organisation of information acquisition, or even with a failure to search actively for information

- Failures at the diagnostic stage

This second functional stage involved in driving activity entails processing information acquired in the situations encountered. This processing activity should enable the driver: first, to evaluate the physical parameters (distance, speed, acceleration) determining the feasibility of planned manoeuvre; secondly, to understand the type of situation with which he is confronted.

- Failures at the prognosis stage

Given that driving is a dynamic activity, a next stage of information processing involves making a prognosis of the probable evolution of the present situation. Failures at this stage encompass problems linked with anticipation and prevision processes.

- Failures at the decision stage

Dealing with human functional failures, the problems considered at this stage relate to functional decisions made by the driver to undertake a specific manoeuvre. They do not account for the broader decisional factors related to the circumstances in which the journey is being made. Malfunctions revealed at this stage specifically relate to the notion of "violation" (Reason, 1993), would they be intentional or not.

- Execution failures

The last link in the functional chain involved in driving activity is the driver's manipulation of the controls of his vehicle to ensure keeping the 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, after the driver has successfully negotiated the other stages.

- Overall failures

The notion of overall failure refers to a deficiency of the whole driving functional chain. Malfunctions classified in this category put into question the psycho-physiological and cognitive state (linked to factors such as fatigue, alcohol, drugs, etc.) of the drivers as regard as the functional demands required by the general activity of driving.

As shown in Figure 5, the most frequent drivers' failures found in accident cases are perceptive failures (38.0%) and execution failures (15.6%), immediately followed by prognosis (anticipation) and global failures (showing an overall loss of driving capacity).

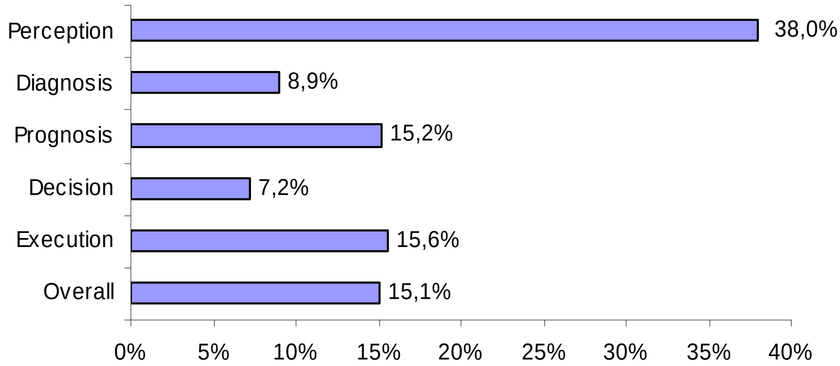


Figure 5. Overall drivers' functional failures distribution (n=432)

As shown on Figure 6 the most frequent pivotal drivers' needs diagnosed from functional failures deal with: Detecting another user on an intersecting course, Vehicle control, and Diagnosing driver condition. By themselves these 3 needs cover 38% of the needs diagnosed from the accident analysis of the 432 drivers of the population studied.

- B07 Detecting another user on an intersecting course (14,7%)

  This need is manifested essentially at intersection, but also when approaching pedestrian passage, at parking entrance and private path. It can be found by every type of road users.

  This need massively corresponds to one specific detection failure mainly, a late detection of a difficulty, due to a lack of visibility in approach. The driver involved is 'primary active' in the accident genesis in all cases.

  The parameters most often associated with this need are:

  . Driving on 'automatic mode' on well known or monotonous journey;

  . Operating a routine manoeuvre;

  . Being focalized on another critical parameter of the situation;

  . Showing a rigid attachment in right of way;

  . Meeting a visibility bounded by road layout (vegetation, building, signalisation)

  . Being confronted with the atypical manoeuvre from another user.

- B01 Diagnosing driver condition (alcohol, fatigue, health, attention, etc.) (11,8%)

  Passenger car vehicle drivers show a need to diagnose their physical conditions and state of awareness, mostly in case of alcohol consumption or an important state of fatigue leading them to falling asleep.

When this need is met, it is essentially based on an overall failure in driving capacities which systematically put the driver 'primary active' in the accident generating.

- B21 Controlling one's vehicle (11,7%)

  A need to be helped for Controlling one's vehicle emerges essentially in bends, in connexion with speed, or with poor road surface condition.

  This need reflects a failure at the execution level. This failure is most often at the origin of the accident occurrence (the driver is considered as 'primary active'). It has only a contributing role in one out of ten cases (the driver is 'secondary active')[4].

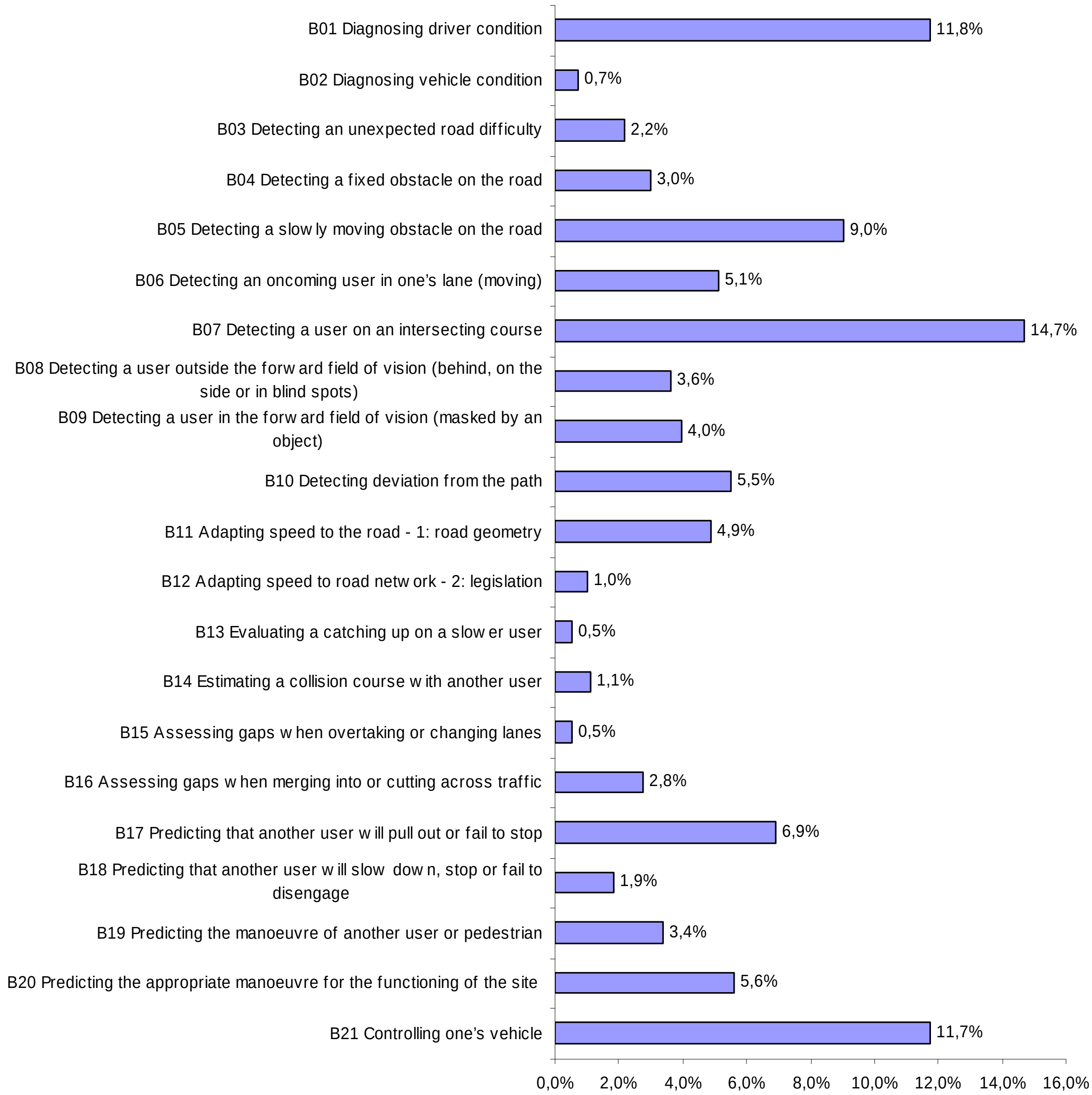


Figure 6 – Drivers' pivotal needs distribution (n=432)

3.2.3 Chains of needs

Needs diagnosed at the upstream driving situation and at the downstream emergency situation are presented at Figure and Figure in Annex 2. Each of these categories of needs will be analysed thoroughly in the next chapters in order to bring the complementary gain to expect from the safety functions.

[4] For more information, cf. TRACE deliverable D5.1.

The present section is intended at seeing which needs are the most often together, showing some links which are established between them, resulting for some in recurring chains of needs. The principle behind this analysis is to insist on the necessity, in certain cases, to take into account the integration of several linked difficulties when trying to help the drivers.

145 different chains of needs have been found at first try for the 432 drivers involved. In order to get more classifiable patterns, the needs showing strong proximities have been grouped as follows:

A category 'Detection on frontal vision without visibility constraints' reassembles the 3 needs:

- B04 Detecting a fixed obstacle on the road
- B05 Detecting a slowly moving obstacle on the road
- B06 Detecting an oncoming user in one's lane (moving)

A category: 'Detection on an intersecting course or outside the forward field of vision' reassembles the 2 needs:

- B07 Detecting a user on an intersecting course
- B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)

A category: 'Adapting speed' reassembles the 2 needs:

- B11 Adapting speed to the road - 1: road geometry
- B12 Adapting speed to road network - 2: legislation

A category: 'Assessing a gap' reassembles the 2 needs:

- B15 Assessing gaps when overtaking or changing lanes
- B16 Assessing gaps when merging into or cutting across traffic

The 12 others needs have been left by themselves, as too many aspects differentiate them.

This grouping allowed identifying 103 'chains' of need, among them 27 reflect 74.4% of the sample. The results presented below concern these 27 recurrent 'chains' of needs. They represent 10 singletons (39% of the drivers) and 17 chains composed of several needs (35.4% of the drivers).

The 10 most represented singletons are the following:

- Need category 'Detection on a transversal course out of frontal vision' (12.9% of the 432 drivers showing only one need)
- Need category 'Detection on frontal vision without visibility constraints' (7.8%)
- B01 Diagnosing driver condition (alcohol, fatigue, health, attention, etc.) (3.9%)
- B21 Controlling one's vehicle (3.5%)
- B17 Predicting that another user will pull out or fail to stop (2.7%)
- B09 Detecting a user in the forward field of vision (masked by an object) (2.4%)
- B20 Predicting the appropriate manoeuvre for the functioning of the site (1.7%)
- B10 Detecting deviation from the path (1.6%)
- Need category 'Assessing a gap' (1.3%)
- B19 Predicting the manoeuvre of another user or pedestrian (1.2%)

Among the (real) chains composed of several needs, the 8 most frequent (24%) are shown on Figure 7.

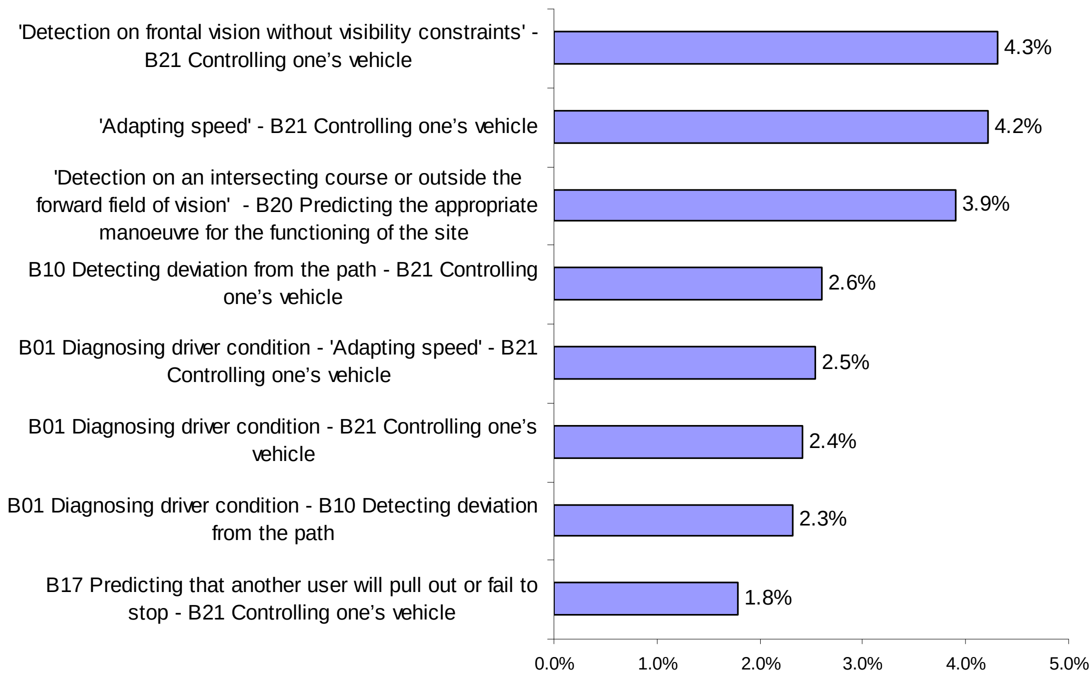


Figure 7. Main chains of needs (24% of 432 drivers)

What can first notice that, when drivers manifest several needs in chain, a need for vehicle controlling is most often part of them. When it is the case, this need generally appears at the end of the chain, at the emergency situation, i.e. when normal human capacities in manoeuvring are most often exceeded.

The two main chains of connected needs are referring to:

- 1) Detecting a vehicle ahead and 2) Controlling one's own vehicle. This pattern is related to 4.3% of the 432 drivers.
- 1) Evaluating one's speed, 2) Controlling one's own vehicle. This pattern stands for 4.2% of the 432 drivers.
- 1) Detecting an intersection course or outside the forward field of vision and 2) predicting the appropriate manoeuvre for the functioning of the site. This chain corresponds to, 3.9 % of the sample.

The other recurrent chains are those which involve a need dealing with Diagnosing driver condition, whereas linked to fatigue or to alcohol. This type of need is associated with:

- A need in adapting their proper driving speed (often for alcoholised state)
- A need in detecting a deviation from the path (often for falling asleep)
- Eventually a need in vehicle control.

3.3 Conclusion

Driver's needs have been defined from accidental research. They are not dealing with drivers' wishes, engineer's assumptions, or technological feasibility. They are diagnosed as a consequence of failures met by drivers while meeting critical driving situations. By so they are reflecting the true difficulties which lead drivers to accidents.

In the next chapter, these needs are confronted to the safety functions diagnosed as the most dedicated to safety in TRACE project WP6 (excluding "comfort" systems). This confrontation is intended at defining which needs are addressed by which safety functions and to what extent.

4 Adaptation of Safety Functions to Drivers Needs

This section presents the technical safety functions which are evaluated in this report. These functions are described below, before being evaluated in a second section as regard as their capacity to meet the drivers needs stressed above.

4.1 Safety functions functionalities

21 safety functions are studied, plus 5 variants in their operation modes. They represent the primary safety functions coming from the list of 23 functions selected in TRACE (WP6) as the most promising in their potential to reduce accidentalness. These functions and their potential variants (e.g. functioning. with an informative/automatic mode) will be analysed regarding their capacity to cope with real drivers needs (cf. 4.2) and to compensate for accident-generating conditions (cf. 5.2).

1. AAFS - Advanced Adaptive Front Light System
2. ACC - Advanced Adaptive Cruise Control

   We evaluated 4 ACC systems alternatives:

   - ACC1 – Information and Warning system
   - ACC2 – Communication-based Longitudinal Control System
   - ACC3 – Co-operative Assistance system
   - ACC+ - Communication and Braking-based Longitudinal Control System
3. AK - Alcolock Keys
4. BA - Brake Assist
5. BS - Blind Spot Detection
6. CA - Collision Avoidance
7. CBC - Cornering Brake Control
8. CW - Collision Warning
9. DDS - Drowsy Driver Detection System
10. DS - Dynamic Suspension
11. ESP - Electronic Stability Program
12. IC - Intersection Control
13. ISA - Intelligent Speed Adaptation

    We evaluated 3 ISA alternatives:

    - ISA1 - Advisory system (informative)
    - ISA2 - Voluntary system (driver activated or driver selected)
    - ISA3 - Mandatory system (compulsory)
14. LCA - Lane Changing Assistant
15. LKA - Lane Keeping Assistant
16. NV - Night Vision
17. PBA - Predictive Assist Braking
18. RLBF - Rear Light Brake Force Display
19. SAVE-U - Vulnerable Road Users Protection

20. TPMS - Tyre Pressure Monitoring and Warning
21. TSR - Traffic Sign Recognition

4.1.1 Information and assumptions about the safety functions

This study consists in an '*a priori* evaluation'. By 'a priori' it is not at all meant that this evaluation is based on an already made judgment. It means that it is aimed at estimating the potential efficiency of safety functions under the hypothesis they were equipping the vehicles. The interest of such a protocol is first to help putting the effort on the most promising aspects of the functions. Secondly it is aimed at diagnosing eventual drawbacks and lacks in the functions which could be counteracted in the future by a new implementation of these functions. In other words, this study consists in a prospective work following a purpose of 'Ergonomics of conception' for better safety effectiveness.

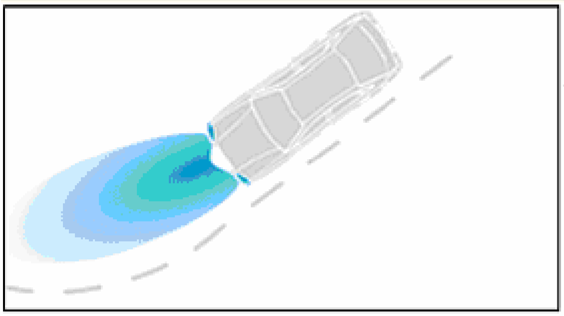
Dealing with (often) future systems, we must base the analysis on the information gettable about their functioning. This information was got from TRACE WP6 workers who compiled all the information gathered on the safety functions studied. But it has to be considered that all the safety functions are not ideally defined. In order not to favour the functions which are the less described – giving sometimes the implicit impression that they are able to tackle all the safety problems – we had to make clear statements about the systems specifications. These statements rely upon assumptions about the capacity and limits of the functions, which were defined, function by function, in collaboration with WP6.

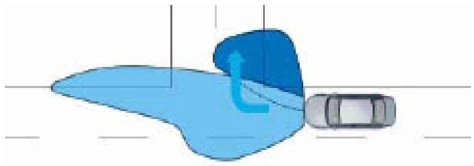
The details about the specifications considered (information got and assumptions made) can be found in Annex 3. The following page just gives an overview on the functions studied.

Moreover, in order to homogenise the analysis, we started from the postulate that all the vehicles in the traffic flow (even the vehicles surrounding) were equipped with the safety systems studied. Accordingly, the results will have to be taken 'à la baisse' if a period of transition is to be expected in the progressive introduction of the functions in the traffic.

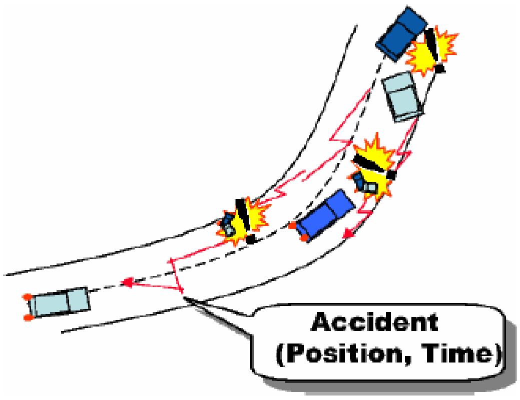
4.1.2 AAFS - Advanced Adaptive Front Light System

This function is considered as integrating the two following safety system: Advanced Front Light System and Adaptive light system.

Safety System – **ADVANCED FRONT LIGHT SYSTEM**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Visibility**	
Description: Concept of intelligent lighting, according to curves, weather and speed. At night, it lets you see around corners. It estimates where you will be in three seconds' time, using sensors that monitor your speed and the angle of your front wheels, and shines the car's headlights in that direction. The left and right headlamps swivel by different amounts depending on the way you are turning. So when you approach a corner, your lights follow the road ahead rather than simply illuminating the edge of the road.	

Safety System – **ADAPTIVE LIGHT**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Visibility**	
Description: The adaptive light system has an additional light unit located between the low-beam and main-beam bulbs of the xenon plus headlights. With the low-beam lights switched on and up to a speed of 70 km/h, this light unit is activated if the turn indicator is operated for some time or if the driver steers sharply. If the driver engages reverse gear, the additional headlights are automatically activated on both sides of the vehicle. This considerably improves visibility and orientation when reversing.	

4.1.3 ACC - Advanced Adaptive Cruise Control

Safety System – **ADVANCED ADAPTIVE CRUISE CONTROL**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: **1. Information and Warning system** A Vehicle will transmit a warning message when it detects a vehicle breakdown, high traffic density and congestion or dangerous road surface conditions **2. Communication-based Longitudinal Control System** Existing ACC only react to vehicles in front of them. By integrating communication, these systems may adapt longitudinal control to the traffic in front and can allow anticipating to an early braking manoeuvre when an invisible vehicle beyond the direct predecessor in front is braking. This leads to more natural following behaviour. **3. Co-operative Assistance system** A Typical scenario for co-operation is the highway entry and margining scenario. By exchanging information up to simple trajectory plans, critical situations can be foreseen and solved by the vehicles.	

We evaluated 4 ACC systems alternatives:

- ACC1 – Information and Warning system
- ACC2 – Communication-based Longitudinal Control System
- ACC3 – Co-operative Assistance system
- ACC+ - Communication and Braking-based Longitudinal Control System

4.1.4 AK - Alcolock Keys

Safety System – **ALCOLOCK KEYS (PREVENT DRUNK DRIVING)**

Classification: **Primary Safety**

Proposed for: **Cars, Heavy Vehicles**

Safety Function: **Drive Safe**

Description: Alcohol ignition interlocks (alcolocks) are devices that require the driver to take a breath test before starting the car. If the driver fails the test, the device locks the ignition so the engine will not start.
Alcolocks are most commonly used to prevent drink driving offenders from committing further violations. They are placed in vehicles of convicted drink drivers as part of a reinstatement requirement or a restricted driving license.
PHILADELPHIA - Breath-alcohol detectors installed in the cars of convicted drunken drivers prevented them from driving under the influence more than 10,000 times in the first year of Pennsylvania's Ignition Interlock Law, according to a study.

4.1.5 BA - Brake Assist

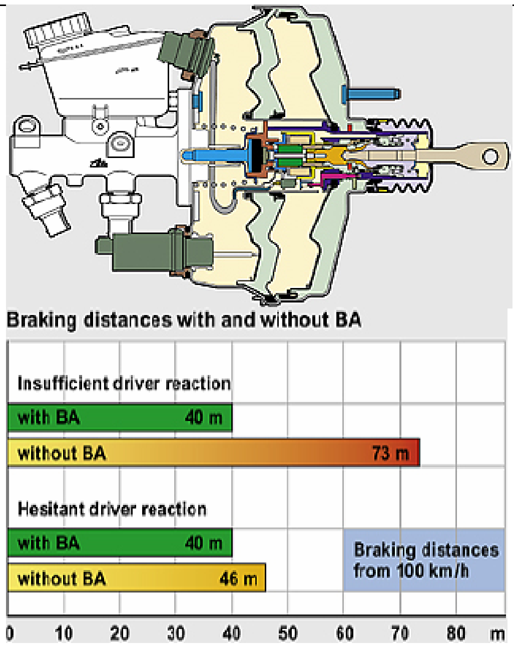
Safety System – **BRAKE ASSIST SYSTEM**

Classification: **Primary Safety**

Proposed for: **Cars,Heavy Vehicles**

Safety Function: **Braking Systems**

Description: Brake assist systems are an important aid in emergency braking situations - such as when the driver applies the brake fast, but not with sufficient pressure, which leads to dangerously long braking distances. The brake assist recognizes the brake application speed to detect this type of panic situation and activates the brake booster or the EBS hydraulic unit, so that even with moderate pedal forces maximum deceleration is achieved. There are several methods to implement these features. The Electronic BAS interacts with the vacuum brake booster, the ABS, the ESP and the ACC. The Mechanical BAS replaces the electronic system that detects pedal velocity by an inertial mechanism. The Hydraulic BAS bases directly in ESP components. The assist function is triggered through extension of the software routines.



4.1.6 BS - Blind Spot Detection

Safety System – **BLIND SPOT DETECTION**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: The camera-based monitoring system keeps watch for other vehicles travelling in the blind spot. When another vehicle enters the monitored zone, a warning light is illuminated near the exterior side mirror. Both sides of the vehicle are monitored in the same way. This visual warning gives the driver a clear indication that another vehicle is alongside. The system also alerts the driver both to vehicles approaching from behind and vehicles in front being overtaken.

4.1.7 CA - Collision Avoidance

Safety System – **COLLISION AVOIDANCE SYSTEM**

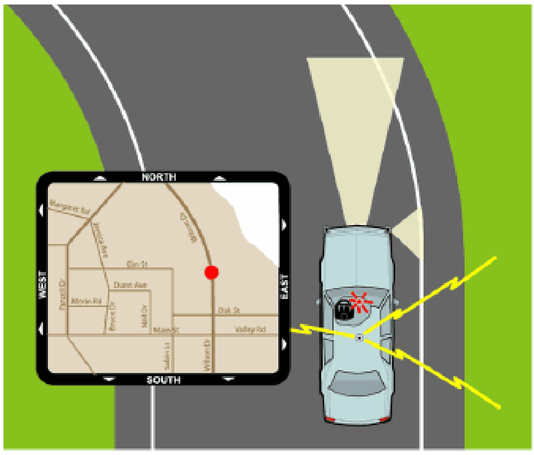
Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: The crash avoidance system is a relatively new technology. With the aid of a radar system, this system actively assesses the driving environment, with added alerts to the driver in any dangerous situations. The system also works in a similar way to prevent the driver from making any mistakes which could lead to or cause and accident.

Future developments of this system could provide recommendation to the driver on the appropriate actions to take in dangerous situations or possibly even assume partial control of the vehicle in order to avoid the prevention of an accident.



4.1.8 CBC - Cornering Brake Control

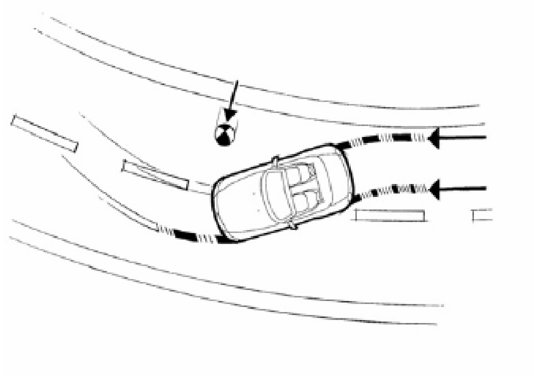
Safety System – CORNERING BRAKE CONTROL

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Braking Systems**

Description: The cornering brake control system works together with traditional anti-lock braking systems to overcome any over-steer which results from attempting a corner too quickly. The braking for each wheel also works independently such as in the Sensotronic Brake Control system.



4.1.9 CW - Collision Warning

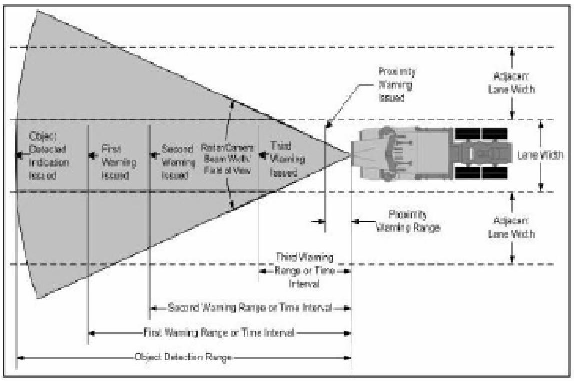
Safety System – COLLISION WARNING SYSTEM

Classification: **Primary Safety**

Proposed for: **Cars, Heavy Vehicles**

Safety Function: **Drive Safe**

Description: The crash warning system works in a similar way to the crash avoidance systems. A radar system is used in order to detect any particular hazards which may present themselves in the course of driving, such as another vehicle intercepting the path of this. The system is particularly useful in bad driving conditions, such as heavy rain or snow as well as at night when visibility is limited. An alarm will sound to warn the driver with progressively louder signals as the vehicle closes in on the hazard.



4.1.10 DDS - Drowsy Driver Detection System

Safety System – **DRIVER DROWSINESS DETECTION**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: Driver drowsiness is an important cause of truck crashes. There are some ways of detecting drowsiness, but they are based in eyes closure. One way is a video system that detects the eyes of the driver and measures directly the eye closure. Another way is a neural network model used to estimate the eye closure using measures associated with lane keeping, steering wheel movements and lateral acceleration of the vehicle. The warnings can begin as the driver becomes fatigued and intensify as the system detects increasing drowsiness, providing the driver with the opportunity for countermeasures such as taking a nap or getting a cup of coffee before they endanger themselves and/or others.

4.1.11 DS - Dynamic Suspension

Safety System - **DYNAMIC SUSPENSION SYSTEM**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Handling/Kinematic Assist**

Description: This system enhances on- and off-road handling, by varying the amount of torsional stiffness in the front and rear stabilizer bars. When the driver is travelling at high speeds on paved roads, the stabilizer bars have maximum stiffness, to keep the vehicle flat during cornering. However, if the driver goes off-road, the bars disengage. This allows the wheels to articulate according to need. The result is better traction on uneven trails, and a more comfortable ride.

4.1.12 ESP - Electronic Stability Program

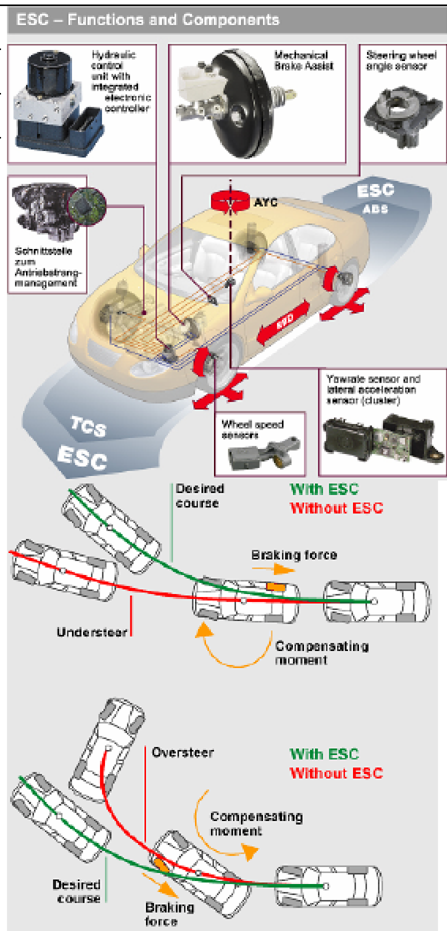
Safety System – ELECTRONIC STABILITY PROGRAM

Classification: **Primary Safety**

Proposed for: **Cars/Heavy Vehicles**

Safety Function: **Handling/Kinematic Assist**

Description: Electronic Stability Program (ESP) is an active safety system that recognizes unstable driving conditions at the very outset and applies automatic, corrective action. Utilizing the active build-up of direction-stabilizing brake forces, ESP helps the driver overcome critical situations and keep his vehicle safely under control.
ESP continuously evaluates the measured data from numerous sensors and compares the driver's input with the actual behaviour of the vehicle. If an unstable condition develops - such as a sudden evasive manoeuvre - within a fraction of a second, ESP intervenes via engine electronics and the brake system to help stabilize the vehicle.
If the front wheels of an under-steered vehicle drift outwards, braking applied to the rear wheel on the inside of the curve develops a compensating yaw moment which returns the vehicle to the desired course again.
If the vehicle threatens to over-steer with the rear of the car breaking away, braking is applied to the front wheel on the outside of the curve. The compensating moment operating in a clockwise direction turns the vehicle into the desired direction again.



4.1.13 IC - Intersection Control

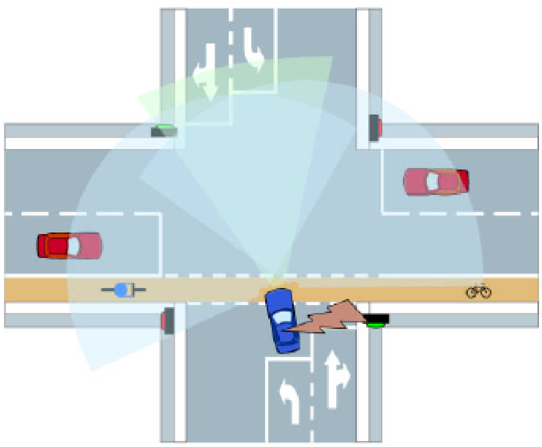
Safety System – INTERSECTION CONTROL (INTERSAFE)

Classification: **Primary Safety**

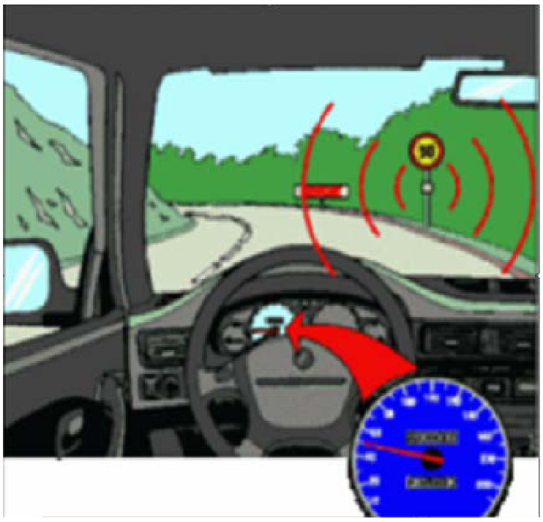
Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: A driver warning function based on communication with traffic lights and path prediction of all objects using the intersection.



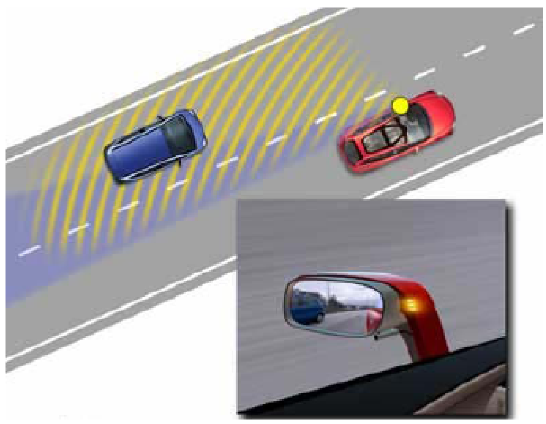
4.1.14 ISA - Intelligent Speed Adaptation

<table>
<tr><td colspan="2">Safety System – INTELLIGENT SPEED ADAPTATION</td></tr>
<tr><td><u>Classification</u>: Primary Safety</td><td rowspan="4"></td></tr>
<tr><td><u>Proposed for</u>: Cars</td></tr>
<tr><td><u>Safety Function</u>: Drive Safe</td></tr>
<tr><td><u>Description:</u> Research and development on the concept of Intelligent Speed Adaptation is going on both regarding speed limits and dynamically changing limits due to the prevailing conditions (e.g. adverse road-, or weather conditions). Some systems are based on the Active accelerator pedal. The Active accelerator pedal provides a counter-force whenever the driver tries to depress it beyond a pre-set speed limit. The performance of the vehicle is not affected at speed levels below the pre-set maximal speed. The Active accelerator pedal also restricts the engine's fuel injection when the vehicle reaches the actual speed limit.</td></tr>
</table>

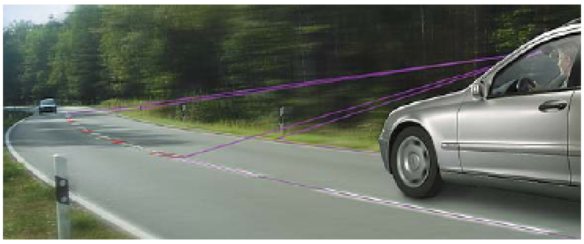
We evaluated 3 ISA alternatives:

- ISA1 - Advisory system (informative)
- ISA2 - Voluntary system (driver activated or driver selected)
- ISA3 - Mandatory system (compulsory)

4.1.15 LCA - Lane Changing Assistant

<table>
<tr><td colspan="2">Safety System – LANE CHANGING ASSISTANCE</td></tr>
<tr><td><u>Classification</u>: Primary Safety</td><td rowspan="4"></td></tr>
<tr><td><u>Proposed for</u>: Cars</td></tr>
<tr><td><u>Safety Function</u>: Drive Safe</td></tr>
<tr><td><u>Description:</u> The system monitors traffic approaching from behind or in the driver's blind spot, will warn the driver if they are about to make a potentially unsafe change lanes or turn. The same radar sensors also provide information for a safe door-opening function, warning the driver of any cyclists, people on rollerblades or vehicles approaching from behind before opening the door.</td></tr>
</table>

4.1.16 LKA - Lane Keeping Assistant

Safety System – **LANE KEEPING ASSISTANCE**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: Lane Departure Warning System (LDW) will warn the driver if he or she is on the verge of inadvertently drifting out of the lane. Using a CMOS Camera and an image processing algorithm, this driver assistance system registers the course of the lane in relation to the vehicle. The system "sees", as it were, the course of the road and where the car is going. If the warning algorithm detects an imminent leaving of the current driving lane, the system warns the driver with haptic, kine-static, or acoustical feedback. Possible warning alerts can be a trembling in the steering wheel, a vibrating seat or a virtual washboard sound (a noise people recognize as generated by driving over a lane marker at highway construction sites). Lane Keeping System (LKS), as a next step, becomes an active lane keeping assistant, through an intervention in the steering. Just like LDW, the LKS measures the vehicle position relative to the lane, but offers active support in keeping the vehicle to the lane. However, the driver always retains the driving initiative, meaning that although he can feel the recommended steering reaction as a gentle movement of the steering wheel, his own decision takes priority at all times.	

4.1.17 NV - Night Vision

Safety System – **NIGHT VISION/ (HEADS UP DISPLAY)**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Visibility**	
Description: This system provides a display of the dashboard instruments on the inside of your windshield and will make you feel like a jet fighter pilot. The luxury version option available on some cars incorporates night-vision technology that allows the driver to see further down the road than the headlights illuminate.	

4.1.18 PBA - Predictive Brake Assist

Safety System – **PREDICTIVE BRAKE ASSIST**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Braking Systems**	
Description: The Predictive Brake Assist (PBA) is the first safety system that in advance processes the relevant information from the vehicle's surroundings and reacts before the impending accident actually takes place. Using the data from the Adaptive Cruise Control's radar sensor, PBA detects situations which could be dangerous enough to develop into an accident, and in which it is more than likely that emergency braking will be needed. If such a dangerous situation does occur, PBA prepares the brake system in advance for panic braking. Pilot pressure is applied to the brake system so that the required brake pressure can be generated more quickly, and the brakes are applied very gently so that the driver doesn't notice. In addition PBA lowers the triggering threshold for the hydraulic brake-assist system in three stages. Studies have proven the effectiveness of these measures. Even in critical situations, only about a third of the drivers reacts appropriately and hit the brakes hard enough. Most drivers are hesitant, and don't apply enough pressure with the result that the hydraulic brake-assist system is not triggered. As soon as the driver reacts and hits the brakes, the full braking effect becomes available milliseconds earlier thanks to the measures that have already been initiated in advance. Valuable milliseconds that can decide between life and death. Here, the total braking distance can be reduced considerably due to the interaction between the driver's reactions and the driver-assist system.	

4.1.19 RLBF - Rear Light Brake Force Display

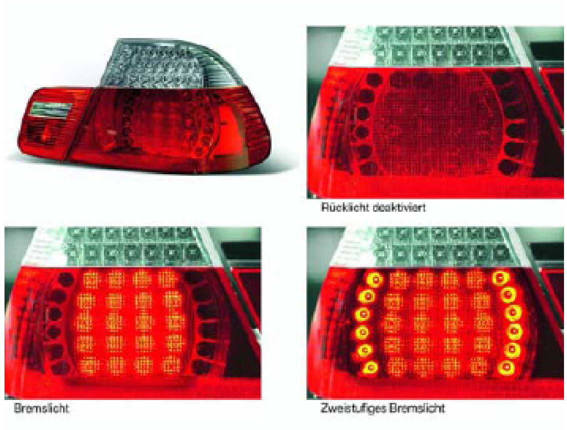
Safety System – **REAR LIGHT BRAKE FORCE DISPLAY**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Visibility**

Description: Rear Light Brake Force Display works by increasing the intensity of the brake lights in the rear lamp clusters by expanding the number of illuminated LEDs when heavy braking is detected. The extra lighting is triggered after the brake sensors detect a certain rate of deceleration, e.g. in excess of 5 m/s^2. The Rear Light Brake Force Display is not triggered by pedal pressure in order to avoid unnecessary illumination.
The system reacts within a few tenths of a second to increase the intensity of the stoplight illumination, projecting a highly visible warning beacon to following traffic.



4.1.20 SAVE-U - Vulnerable Road Users Protection

Safety System – **VULNERABLE ROAD USERS PROTECTION (SAVE-U)**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: The system calculates in a matter of seconds the movement of pedestrians within the `capture zone' which can be up to 30meters away from the vehicle. The camera tracks the pedestrian movement and the information is correlated with the data received from the radar network (speed of and distance to object). SAVE-U can consequently identify any pedestrian or cyclist coming within the trajectory of the vehicle and after analysing the situation, warn the driver or apply automatic braking if there is a risk of collision.

4.1.21 TPMS - Tyre Pressure Monitoring and Warning

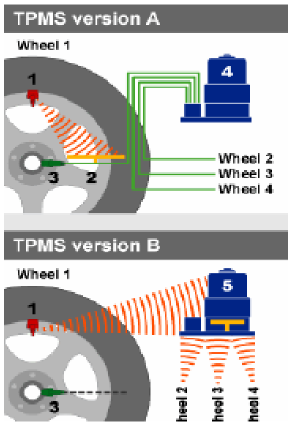
Safety System – **TYRE PRESSURE MONITORING**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: The system for tyre pressure monitoring detects small pressure fluctuations, locates the affected tires and informs the driver with warnings of varying urgency. A co-rotating wheel module with an integrated valve measures tyre pressure and temperature and transmits these data as an HF radio signal. In a system with 4 wheel modules, 4 antennas with HF coupler, the receiving antennas are located on the connecting cables for the wheel speed sensors. They send the data to the EBS-ECU, which then analyzes them in an intelligent warning strategy unit.



4.1.22 TSR - Traffic Sign Recognition

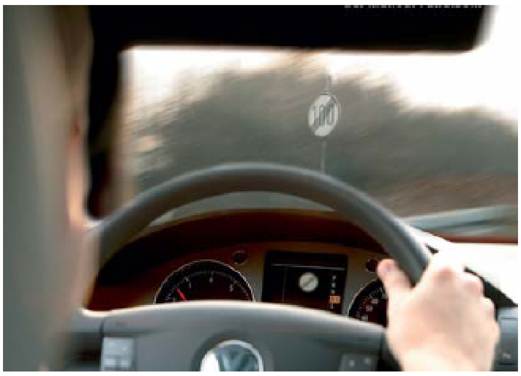
Safety System – **TRAFFIC SIGN RECOGNITION**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: The system incorporates a digital display which informs the driver of all the respectively applicable road signs along the motorway. The image processing system is most effective in areas where traffic signs or traffic lights have only been installed or are in operation temporarily - for example, at construction sites or on highway bridges equipped with electronic signs that change according to the traffic situation.



4.2 Which needs are met by the safety functions?

This first part of analysis is aimed at verifying that the safety functions studied are well turned toward the real difficulties encountered by drivers on the road. It presents an estimation of the proportion of drivers' needs which would be addressed by the introduction of the functions considered.

An overall result (Table 1) suggest that for 85% of the 432 car drivers of the sample studied, the pivotal need they manifest in the in-depth accident file would be met, at least by one of the functions. This seems at first sight very optimistic for the potential progress in safety to expect from the implementation of these functions in cars. But still will be have to consider the contextual constraints characterizing accidental reality (cf. Chapter 4).

Table 1: Pivotal needs met by the functions (n=432)

	No function applying	At least one function	Total of needs	
Needs	**%**	**%**	**%**	**(n)**
B01 Diagnosing driver condition	0,0%	11,8%	11,8%	(51)
B02 Diagnosing vehicle condition	0,4%	0,4%	0,8%	(3)
B03 Detecting an unexpected road difficulty	0,7%	1,5%	2,2%	(9)
B04 Detecting a fixed obstacle on the road	0,0%	3,0%	3,0%	(13)
B05 Detecting a slowly moving obstacle on the road	0,2%	8,8%	9,0%	(39)
B06 Detecting an oncoming user in one’s lane (moving)	0,4%	4,8%	5,2%	(22)
B07 Detecting a user on an intersecting course	0,7%	14,0%	14,7%	(63)
B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)	0,0%	3,6%	3,6%	(16)
B09 Detecting a user in the forward field of vision (masked by an object)	1,2%	2,8%	4,0%	(17)
B10 Detecting deviation from the path	1,4%	4,1%	5,5%	(24)
B11 Adapting speed to the road – 1: road geometry	1,6%	3,2%	4,8%	(21)
B12 Adapting speed to road network - 2: legislation	0,3%	0,7%	1,0%	(5)
B13 Evaluating a catching up on a slower user	0,0%	0,5%	0,5%	(2)
B14 Estimating a collision course with another user	0,1%	1,0%	1,1%	(5)
B15 Assessing gaps when overtaking or changing lanes	0,5%	0,0%	0,5%	(2)
B16 Assessing gaps when merging into or cutting across traffic	0,0%	2,8%	2,8%	(12)
B17 Predicting that another user will pull out or fail to stop	0,2%	6,7%	6,9%	(30)
B18 Predicting that another user will slow down, stop or fail to disengage	0,5%	1,4%	1,9%	(8)
B19 Predicting the manoeuvre of another user or pedestrian	2,1%	1,3%	3,4%	(15)
B20 Predicting the appropriate manoeuvre for the functioning of the site	2,5%	3,1%	5,6%	(24)
B21 Controlling one’s vehicle	2,4%	9,3%	11,7%	(51)
Total	15,2%	84,8%	100,0%	(432)

In 15% of the case, we found no function able to meet the need of the drivers, as it was diagnosed from accident studies. The pivotal needs the most difficult to fulfil with the functions studied are the following.

No safety functions apply for the pivotal need:

- B15 Assessing gaps when overtaking or changing lanes

More than half of the times, when the following pivotal needs emerge, they do not meet a safety-function:

- B19 Predicting the manoeuvre of another user or pedestrian

- B02 Diagnosing vehicle condition

Between a quarter and a third of the times, when the following pivotal needs emerge, they do not meet a safety-function

- B03 Detecting an unexpected road difficulty
- B12 Adapting speed to road network - 2: legislation
- B09 Detecting a user in the forward field of vision (masked by an object)
- B18 Predicting that another user will slow down, stop or fail to disengage
- B11 Adapting speed to the road - 1: road geometry
- B10 Detecting deviation from the path

Moreover, in the 85% of the cases where the functions studied were relevant, it appeared that several functions could address the same need. So there is a potential overlap between the functions in their safety effectiveness. The 21 safety functions studied were globally considered as able to address 1.6 times the pivotal needs. In 43.5% of the cases, only one safety-function meets the needs (Table 2). In 41.5% of cases, at least 2 functions are able to meet the needs.

Table 2: Capacity of safety functions to meet the needs

	Pivotal needs	
	n	%
No safety-function	66	15,2%
1 safety-function	188	43,5%
2 safety-functions	86	19,8%
3 safety-functions	61	14,3%
4 safety-functions	23	5,4%
5 safety-functions	8	1,8%
Total	432	100,0%

Some pivotal needs are always met by at least one function. So, in our sample there are potentially addressed in 100% of the cases when they appear (Table 3):

- **B01 Diagnosing driver condition (alcohol, fatigue, health, attention, etc.)**

  When the drivers need a help in diagnosing their state, at least one function (DDS, AK, or LKA) is potentially able to meet this need.

- **B04 Detecting a fixed obstacle on the road**

  This need is also addressed in 100% of the cases by one function at least, whereas: ACC+, ACC1, ACC2, CA, CW, NV, SAVE-U, or RLBF.

- **B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)**

  Either BS, CA, IC, LCA, or LKA are able to meet this need in every accident case studied.

- **B13 Catching up on a slower road user**

  When the drivers need a help in evaluating their catching up on a slower road user, this need is addressed either by ACC+, ACC2, CW, CA, or RLBF.

- **B16 Assessing gaps when merging into or cutting across traffic**

  This need is fulfilled by IC, LCA, BS, or CW.

Table 3: Need coverage by the safety functions

Needs	No function applying %	At least one function %	Total of needs
B01 Diagnosing driver condition	0,0%	100,0%	51
B02 Diagnosing vehicle condition	50,0%	50,0%	3
B03 Detecting an unexpected road difficulty	31,2%	68,8%	9
B04 Detecting a fixed obstacle on the road	0,0%	100,0%	13
B05 Detecting a slowly moving obstacle on the road	2,3%	97,7%	39
B06 Detecting an oncoming user in one’s lane (moving)	7,7%	92,3%	22
B07 Detecting a user on an intersecting course	4,6%	95,4%	63
B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)	0,0%	100,0%	16
B09 Detecting a user in the forward field of vision (masked by an object)	30,8%	69,2%	17
B10 Detecting deviation from the path	25,1%	74,9%	24
B11 Adapting speed to the road - 1: road geometry	33,3%	66,7%	21
B12 Adapting speed to road network - 2: legislation	27,3%	72,7%	5
B13 Evaluating a catching up on a slower user	0,0%	100,0%	2
B14 Estimating a collision course with another user	12,2%	87,8%	5
B15 Assessing gaps when overtaking or changing lanes	100,0%	0,0%	2
B16 Assessing gaps when merging into or cutting across traffic	0,0%	100,0%	12
B17 Predicting that another user will pull out or fail to stop	2,7%	97,3%	30
B18 Predicting that another user will slow down, stop or fail to disengage	26,3%	73,8%	8
B19 Predicting the manoeuvre of another user or pedestrian	60,5%	39,5%	15
B20 Predicting the appropriate manoeuvre for the functioning of the site	45,3%	54,7%	24
B21 Controlling one’s vehicle	20,9%	79,1%	51

Among the functions, some were more effective than others in their capacity to address the pivotal needs (for more details, cf. Table 9 in Annex 2):

Three functions potentially cover by themselves more than 75% of the drivers' pivotal needs:

- CA - Collision Avoidance (covers 31.6% of the pivotal needs)
- IC - Intersection Control (29.0%)
- CW - Collision Warning (26.4%)

Other systems are less effective, but are still able to meet between 2 et 10% of the pivotal needs:

- ESP - Electronic Stability Program (8.3%)
- DDS - Drowsy Driver Detection System (6.6%)
- SAVE-U - Vulnerable Road Users Protection (6.6%)
- AK - Alcolock Keys (5.7%)
- LKA - Lane Keeping Assistant (4.9%)
- ACC+ - Advanced Adaptive Cruise Control: Communication and braking-based longitudinal Control System (4.8%)

- NV - Night Vision (4.6%)
- BS - Blind Spot Detection (4.3%)
- LCA - Lane Changing Assistant (4.2%)
- ISA3 - Intelligent Speed Adaption “Mandatory System” (4.2%)
- ISA2 - Intelligent Speed Adaption “Voluntary System” (3.5%)
- ACC2 - Advanced Adaptive Cruise Control: Communication-based longitudinal Control System (3.4%)

The other functions were considered as being able to meet the pivotal need in less than 2 % of the cases. But it has to be stressed that some of the functions considered are more adressing the phase before or the phase after the 'rupture phase' in the accident process. This means that some of them are sometimes more able to act either at the driving phase (acting on some of the parameters condictionning the human failure), or at the emergency phase, once the human failure has become effective. It is notably the case for the following functions (cf. Table 10 and Table 11, in Annex 2):

- ISA1 – Intelligent Speed Adaption “Advisory System” (able to meet 1.9% of pivotal needs)
  - ISA1 is also able to meet 12.8% of further upstream needs. Thought it seems to be a function more adapted to help the drivers for current driving than for accidental difficulties.
- ACC1 – Advanced Adaptative Cruise control: Information and warning system (1.9%)
  - ACC1 is able to meet 1.1% of further upstream needs
- RLBF - Rear Light Brake Force Display (1.5%)
  - RLBF is able to meet neither further upstream needs nor emergency needs
- CBC – Cornering brake control (1.3%)
  - CBC is able to meet 4.6% of emergency needs
- PBA – Predictive Assist Braking (0.6%)
  - PBA is able to meet 16.6% of emergency needs
- DS - Dynamic Suspension (0.5%)
  - DS is able to meet neither further upstream needs nor emergency needs
- BA – Brake Assist (0.5%)
  - BA is able to meet 32.5% of emergency needs. Such a system seems largely devoted to the emergency situation as far as it assists the driver in engaging an emergency manoeuver. So it doen't help in preventing acidental situations but far more in correcting them.
- TPMS - Tyre Pressure Monitoring and Warning (0.4%)
  - TMPS is able to meet 3.7% of emergency needs
- AAFS - Advanced Adaptive Front Light System (0.0%)
  - AAFS is able to meet 0.9% of further upstream needs
- ACC3 – Co-operative Assistance System (0.0%)
  - ACC3 is able to meet neither further upstream needs nor emergency needs
- TSR - Traffic Sign Recognition (0.0%)
  - TRS is able to meet 2.5% of further upstream needs.

4.3 Conclusion

Confronting the safety functions to driver's needs gives a quite optimistic feeling as regard as the capacity of these functions to address the real difficulties encountered by drivers on the road. Though, 85 % of their pivotal needs appear as theoretically covered. But still will have these safety functions to be able to compensate efficiently the needs. In that purpose they will have to face the contextual constraints characterizing the accidents situations in which these needs are met. As a matter of fact, a lot of parameters, internal and external to the driver, describing the context in which the accidents occur are liable to limit the potential effect of the safety functions. Those potential limitations are examined in the following chapter.

5 Contextual Constraints for safety functions

In Chapter 3 ("Drivers Needs") have been delineated the safety needs of the drivers, as they are expressed by the human failures found in accidents.

In Chapter 4 ("Adaptation of Safety Functions to Drivers Needs") has been defined the ability of the safety functions -studied in the frame of TRACE project- to meet these needs (i.e. their potential capacity to address the difficulties encountered by drivers).

Once a need is diagnosed, once a function is evaluated as able at fulfilling this need, still have to be considered the every contextual element that could impede the potential effectiveness of the aid. These potential impeding elements define the constraints that safety functions have to integrate in order to really constitute "safety devices" able at counteracting the driving system malfunction. A wide variety of such parameters are to be studied, coming from physics to ergonomics. Some of these constraints have been identified in the literature, referring both to ergonomic, psychological and social acceptance. The potential limitative effects of such parameters should be thoroughly studied for each device with the help of the methods developed inside each of these disciplines. But in order to get a precise knowledge of the difficulties possibly met in a real operating context, it is necessary to consider all the parameters found in the accident situations which could prevent the driver from taking advantage of information added to his task, and which could weaken the efficiency of an assistance function. The present Chapter 5 ("Contextual Constraints") constitutes contribution to this purpose, dealing with the constraints to integrate in order to make a safety function efficient in the context of its real accident contexts. As a matter of fact, even if well addressing a need, if a system doesn't comply with the situations in which this need is met, it wouldn't get its full efficiency.

As stated in TRACE report D4.1.3, a basic requirement for every safety function is that it must not come into conflict with the driver's task, nor impose additional difficulties on him. Otherwise it isn't anymore really an aid. We will first present a reminder of the general parameters which are to consider when implementing any device devoted to human use. Then will be presented the added value that can be gained from the parameters which can be further found in the analysis of accident contexts. Such parameters require to be taken into account as far as they had an effective negative effect in the accident process, and they could in the same way impede such or such aspect of the safety function efficiency. These elements will be used in Chapter 6 ("Response efficiency") to assess the capacity of the function to tackle the potential lessening impact of accident production context parameters.

5.1 General parameters to consider

A huge amount of literature is addressing the ergonomic, psychological and sociological aspects to consider when implementing a disposal in an integrated task. As a matter of fact, a lot of criteria must be examined in the process of conception of any device addressed to a human use. The most essential are summarized hereafter.

In fact, there are many and various factors that, at a general level, can influence system efficiency: e.g. usability of systems; driver state (workload, distraction, fatigue, etc); behavioural adaptation (positive or negative); level of awareness of system capabilities and limits; over-reliance on systems; changes in patterns of exposure to risk when using systems; driver acceptance of systems; individual characteristics (e.g., age, gender, education, vision, driver behaviour, etc.). Other factors that can mediate the impact of a system acceptance and effectiveness include (Regan et al, 2006):

- Driving experience, travel patterns, and driving record (licence status, length of licence, business versus private, time of travel, mileage rate, areas of travel, passengers, speeding fines, etc.)
- Vehicle purchase preferences (price, model and make, type, colour, age, size, CCs, power, look, fuel economy, reliability, gadgets, etc)
- Experience with technology (ADAS, email, internet, telephone banking, etc.)
- Awareness of road safety issues (e.g. knowledge of road laws, awareness of relative risks)

- Attitudes towards driving behaviours (e.g. "I am comfortable driving close behind another car; speeding is always wrong; speed limits are too low"; etc)
- Attitudes towards ITS technologies ("I would like a car that … warns me if driving too fast; too close; etc.)
- Attitudes towards road safety measures (how effective are considered: speed cameras, speed humps, speed signs, etc.)
- Appropriateness of Human Machine Interface. This is one of the crucial questions for any system devoted to human use. So it is for ADAS. This question has to be precisely addressed once the drivers needs are diagnosed and the contextual constraints are identified. For such an important question, it is not sufficient to simply rely upon a catalogue of standards such as those proposed in the European Statement of Principles on human machine interface (ESoP, 2006).for useful such a catalogue can be, it must be each time considered that each HMI has to be adapted to the users of the device (and their heterogeneity and weaknesses), and to the specificities of the task in which it is integrated.

All these variables are to be considered, but all can neither be apprehended with the same means nor in the same study. Some of them will appeal for field operational tests, other for psycho-sociological surveys, experimental works, etc. The present study is a contribution to this line of works, using in-depth accident data in order to rise out the influence of parameters coming from accident contexts, showing the difficulties that the safety functions will meet in their real context of operating. In order to evaluate the ability of the safety functions to cope with accident parameters, we also took into account -when appropriate- among the following variables, some of ergonomic criteria found in the literature (e.g. Scapin & Bastien, 1993), and also the output of previous research works dealing with driving aid (Malaterre, Fontaine & Van Elslande, 1991; Malaterre & Saad, 1984, 1986 ; Van Elslande & Nachtergaele, 1992 ; Van Elslande & Nachtergaele, 1993), that are summarized below.

Mental workload

- The relevant elements must always emerge, in spite of the addition of information to process.
- The assistance devices must:
    - Reduce the perceptive and mnemonic load. The items of information presented must be short. The load must be evaluated for sets of elements and not only for single items.
    - Diagnose the actual problems and filter the other ones. If not, there is a risk of informative overload and loss of credibility. The difficulty is that the problems are not the same for everyone (notably according to the expertise of the drivers).
    - Alert explicitly the user so that he adapts efficiently, even by forsaking another task.
    - Provide information before the malfunction occurring, when the driver collects information to build his representation of the problem.
    - Present with certainty the interfering character of the encountering of another road user.

Distraction

- Introducing informative safety function in the driving task requires determining the potential disturbances being able at obstructing the detection and the data processing by the driver.

Inattention

- The information delivered must be able to compensate for potential "inattention" of the driver, (e.g. attention mobilization on other sources of information).

Significance of the codes

- According to Scapin and Bastien (1993), a strong semantic relationship must exist between the information provided by the system and the referent object in the world.

Conspicuity of information

- Information transmitted shall be clearly detectable. This involves a good ergonomic design. For example a better detection of information will require several channels to be used (not only visual, but also audio). A flash is more detectable than a coloured signal, because the conspicuity of the flash is less sensitive to the workload and tiredness (Thackray and Touchstone, 1991). An item of information must not be hidden by another.

For instance, the Lane Changing Assistance function informs the driver of the presence of another user by a flickering on the left external rear view mirror. But drivers needing LCA are typically drivers who look poorly on the side where they engage, so the flickering on the rear view mirror is likely not to be perceived. Or it can be confused with the indicator which is more and more equipping the external mirrors.

Information integration and processing

- For an optimal integration of information during the task, the messages must be delivered at a proper time, in order to optimize the response time, but also to form an integral part of the elements used by the operator to work out his diagnosis. Because once the diagnosis is elaborated, it is very difficult for the drivers to give it up. The use of kinematics reconstitutions of accidents can determine, in the temporal course of the accident, the favourable moment for the diffusion of information.

Competition

- Introducing several safety functions can involve a competition, and even a contradiction between several safety functions. In that case, a set of priorities will have to be defined between the functions.

Feasibility

- For old vehicles, it will be difficult to set up these safety functions.
- If new vehicles are equipped only optionally, it leads to the risk that people who pay (expensively) such safety functions want to benefit from it (example of ABS, Biehl, Aschenbrenner & Wurm, 1987).
- It would thus be useful to target the objectives corresponding to the strongest needs (state of the driver, detection), with the simplest and cheapest safety functions (to cover the widest range of the traffic flow (Malaterre, Fontaine & Van Elslande, 1991).

Heterogeneity of behaviours

- The increase in differences between vehicles 'equipped' and 'no equipped' can lead to different driving behaviours. It would also increase the variation for the vulnerable users (pedestrians, cyclists).

Motivation, social acceptance and resistance to changes

Some parameters referring to the Psychology of motivations are also to be taken into account, as them can influence drivers reactions to a new device added to their activity.

- A paradox shown by Malaterre & Saad (1984) can affect the use of information given: If the safety function brings redundant information with what the driver perceives, he will tend to consider the safety function useless; and if the safety function brings divergent information, the drivers will tend to privilege their own judgement.
- Rumar (1987) insists on the fact that drivers favoured safety functions providing them more information: hazards and obstacles detectors, navigation assistance, etc. But drivers may be far more reticent with systems supervising or intervening directly on the commands of the vehicle (cf. "coercive assistance" below).
- Among others, the question of the cost of the system should not be forgotten losses. It is for instance problematic for accidents cases involving a loss of control, as far as this type of accident often involves drivers with limited financial resources (young people), whereas the installation of the equipment is still expensive.
- It is necessary to consider the importance of drivers' motivations to use these safety functions, as well as advert which will be made around these safety functions. Advertisement can be alternatively directed towards technological consumption and performances or towards the search for increased safety, with different effects on drivers motivation to use the functions.

Transparency

According to Scapin and Bastien (1993), the actions of a system must be transparent for its user.

- Concerning the automatic assistances, a study from Van Elslande & Nachtergaele (1993) has shown that drivers dread loosing the control of their driving activity (responsibility for the acts, judgement of the situations and pleasure), in such a way that there is a great preference for informative assistance. From this study, 4/5 of the interviewed drivers would accept the intervention of an automatic safety function, but under several conditions:
  - The driver must have the choice to use it or not;
  - This type of assistance must work only for emergency;
  - The driver must be informed by a message of the assistance release to avoid surprise effect
  - Automatic assistances can have a perverse effect toward a less personal implication in monitoring tasks or in speed management tasks.

Behaviour adaptation, risk compensation

- For any individual, there are regulating mechanisms of incurred risks (Wilde, 1990) coming from an individual adjustment of the behaviour according to the perception of the risk taken while putting forward this behaviour. This adaptation process is often efficient. But it becomes problematic when it gives the drivers a false feeling of safety.
- Another problem comes from the preference given by certain drivers to their objectives than to safety consideration. For instance, if a driver increases its speed because of a strong temporal constraint, he will not take into account a safety function that doesn't match with its motivations, unless the system is "convincing" enough (Van Elslande & Nachtergaele, 1993). For another instance, when overtaking, if the driver's strategy is to approach quickly and close to the preceding vehicle, the driver will not take into account a safety function telling him that he is too close (ibid.). This is notably interesting for Collision Warning and Collision Avoidance functions.

Confidence

- A driver will tend to give prevalence on his own analysis. For instance, when driving on a very familiar route, information given about road characteristics could be neglected by the driver (Van Elslande & Nachtergaele, 1993).
- Confidence is also an important factor in the automation acceptability. It will be necessary to study the drivers' perception of automation performances.
- A lack of confidence can decrease the driver's cognitive and perceptive resources. If the driver calls into question the criteria of danger which led the safety function to emit alarm, he might be inattentive on his driving task, when supervising or motoring the system.
- On the other hand, absolute confidence can generate carelessness, dependence to the machine which can involve incapacity to react in critical situation, or whenever the machine fails (Moessinger, 2003).

5.2 Parameters related to accident production contexts

Considering all the parameters stressed above, the added value of the present study is to search for the limitations which could come from real accident contexts. For each case analysed, we searched for the parameters characterizing the conditions in which the accident occurred, that could have a lessening effect in the capacity of an added function to help the driver. These contextual limitations must be taken into account by the safety functions as constraints to cope with for being more effective in the context of accidents.

Thus, the question examined in the present work is not to imagine what could be the action of the driver if he had at his disposal such or such system[5]. It is to define in the effective accident context which elements could lessen the efficiency of a safety system. In brief: this study doesn't try to guess the

[5] This is more the matter of the European eImpact project.

potential impact of systems at more or less long term, but to define under which conditions these systems could be more efficient because more adapted to the real context of accident production.

Each given safety function may meet several limitations corresponding to several accident context parameters which could lessen its effectiveness. These potential limitations of safety functions effectiveness were searched for, case by case, in the accident context each time a safety function was addressing a driver's need. During the in-depth analysis, we took into account when necessary the useful parameters from kinematics reconstruction (speed, adherence, stopping distance, etc). This accident reconstruction put forward in EDA INRETS methodology consists in a scenario reproducing the pre-collision, the collision and the post-collision phases. The impact and initial velocities are calculated for each case, giving a simulation of the real crash with respect to energy, vehicle trajectory, road marks and vehicle deformations. These calculations are primarily based on the conservation of momentum and of kinetic energy. Reconstructions are made with ANAC software developed at INRETS (Lechner, Malaterre & Fleury, 1986). In order to analyse the safety functions effectiveness, we made use of these cinematic reconstitutions to evaluate parameters such as the braking effectiveness[6]. And more globally, every information referring to the context of the accident occurring was considered, and ergonomic criteria were taken into account insofar as they dealt with the parameters found in accident.

The overall approach is based on the following reasoning: accident-producing mechanisms often reveal one or several functional user failures (perceptive, interpretative, etc.). Prior to this malfunction, a certain number of precursory factors which help to produce the malfunction can be identified. The detection or processing of information and action by the driver in the effective situation was, in fact, influenced by these accident-initiating factors. It could therefore be assumed that they would intervene in the same way with regard to information provided by a driving aid if it is not designed to take into account the actual way in which human operators function and their limits. By identifying accident initiating factors which are likely to limit drivers' assimilation of added information, it is thought to define constraints that safety functions have to integrate. Thus, the principle of the method is to find out one or several initiating factors in the accident production which could impede optimal use of an information aid, and by so, constitute a potential limitation to the integration of this aid in the driving task as far as they could lessen the expected effectiveness of the safety function (Figure 8).

The accident context parameters taken into account for his study gather the whole characteristics of both the drivers (internal context) and environment (external context):

- The internal (endogenous) elements refer to the driver's psycho-physiological state, attention, motivations, risk taking, self confidence, and so on that contributed to the accident process. These elements can -in the same way as they did in the accident- lead to a weak integration of information provided by a safety function, whether because of an involuntary negligence or to a more or less voluntary refusal of an advice given.

- The external (exogenous) elements refer to everything which does not depend on the driver. It can be linked to the dynamic properties of the vehicle, to the road state, or to the characteristics of the traffic in interaction: every physical parameter found in the context of accident cases which could also limit the effective safety benefit of these functions.

Thus, 92 types of limitations were diagnosed from the accident context production for the 432 drivers of the sample studied. 39 are *endogenous*, corresponding to the internal context: i.e. parameters coming from the driver himself. 43 are *exogenous*, corresponding to external context: i.e. parameters coming from the driver's environment.

[6] The use of cinematic reconstitution data is presented more in detail in Annex 1, and is accompanied by an example of an accident reconstitution with or without assistance of Predictive Brake Assist (PBA) function.

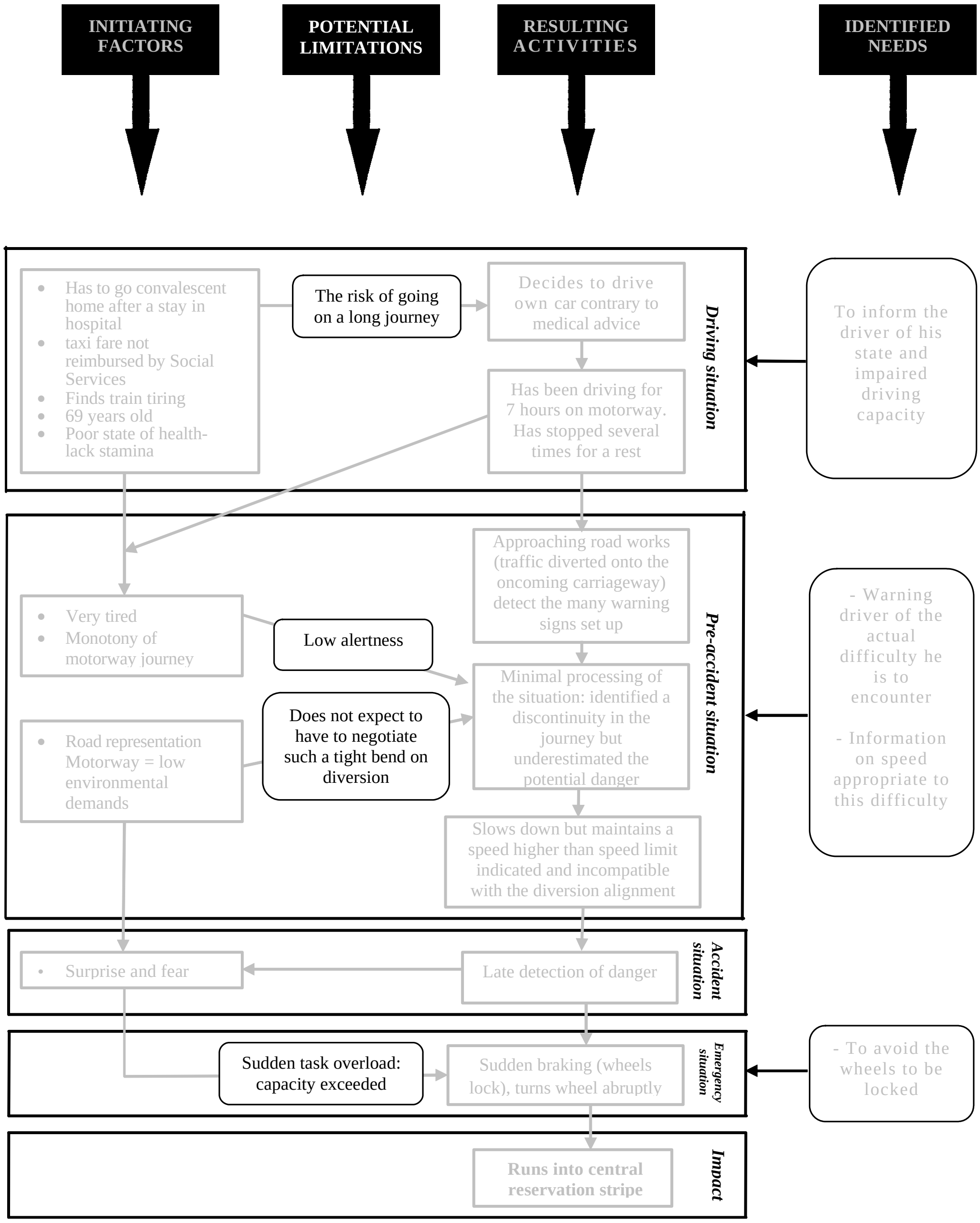


Figure 8 : Identifying potential limitations from accident analysis

5.2.1 Endogenous limitations linked to accident context

Variables potentially limiting the influence of a safety function referring to the driver himself can be dispatched in two categories according to their effect, whether they could lead to an unintentional disregard or an intentional reject of the aid by the driver.

Contextual variables which could lead to an unintentional disregard of the aid

An impaired psycho-physiological status or an attention-related problem can prevent the drivers from detecting integrating part of the information required to correctly manage the situation they were faced with. The factors corresponding to these malfunctions could hinder the assimilation of additional information in the same way, without this being intentional on the part of the driver. This is at least what we attempt to substantiate in the following paragraphs.

Driver state

The deterioration of the psycho-physiological state of the driver can be found at the level of reduced alertness and impaired driving ability. Diminished alertness is associated with fatigue, state of health and age, factors that are sometimes associated with a slight alcohol intake. This condition results in a minimal operating level, which may occasionally result in falling asleep. Impaired driving ability is associated with a substantial intake of psychotropic products (alcohol, medicaments, and illegal drugs) that put a disturbance in driving capacities. However it shall be noted that these two types of effects can combine. That is why these unintentional endogenous potential limitations are put together below:

- ***Hypovigilance: tiredness, drowsiness, falling asleep***

Hypovigilance at his different states is a variable able at more or less drastically preventing the driver from detecting and appropriately processing information provided.

- ***Faintness***

Even if not frequent faintness –as found at the origin of accidents- is a parameter radically limiting the potential of a safety function.

- ***Influence of alcohol / drug***

Any psychotropic drug, whether legal or not, is potentially diminishing the ability to integrate the benefit of an aid.

Attention-related problems

The concept of attention, defined as an instance of control and orientation of mental activity (Richard, 1980), refers in this context to the psychological resources the individual allocates to the task to be performed (cf. TRACE D3.4). A malfunction in the allocation of attentional resources can have an influence on processing added information. Different types of malfunctions can affect the attentional processes, some acting more as a deficit of resources, some as a derivation of these resources toward something else than driving, others as a too narrow focusing to a specific part of the road scene. The level of attention can also be degraded when being stressed or upset. All these elements have shown the decrement in information processing during the accident. So there are able to play the same role as regard as driving aids.

- ***Inattention***

Inattention refers to a global weak allocation of attentional resources to the driving task, notably in monotonous situations, leading the driver to be derived towards his thoughts and concerns.

- ***Passive distraction***

Distraction refers to a transfer of the attention required for the driving activity to a source of attraction outside this activity (discussion, supplementary task, etc). "Passive" distraction relates to a derive of attention during monotonous itinerary (e.g. reporting attention on the landscape).

- ***Active distraction***

This variable stresses a higher level of attentional derivation toward an external task (e.g. phone, chasing a wasp, etc.).

- ***Attentional focusing on right of way roads***

Focusing refers to the specific allocation of attention on a partial aspect of the driving task which the driver considers to be of prime importance. This hinders the assimilation of other parameters found in the situation where a hazard is coming from. It is specifically the case for roads with right of way.

- ***Attentional focusing on another potential hazard***

This element comes when driver's attention is already mobilized by an identified source of danger.

- ***Exceeding the cognitive capacities – novices, episodic drivers (e.g. elderly people)***

Drivers with low practice of driving activity are able to be overwhelmed when confronted with a too complex situation. This is a constraint that has to be taken into account for safety functions.

- ***Upset – Stressed***

When stressed or upset, the drivers proved to have their capacity of integrating information impaired. This could be acting for additional information.

Expectation-related problems

The concept of expectation refers to the fact that the driver, during his task, waits for some elements or some events to come, or on the contrary expect them not to come. These expectations are made from the experience and could lead to an unintentional disregard of the aid as far as people tend to believe more in what they think than in information given by a device (De Keyser, 1990). The following elements have been identified in the context of accident production, and could have a lessening effect in the driver taking into account a safety system.

- ***Expecting absence of interference***

E.g. when inserted in a line driver expected anything but the deceleration of the vehicle in front and reacted very late.

- ***"Dragging" effect***

It is often the case that the drivers delegate the decision and control to another driver, notably when inserted into a flow of vehicles. And relying on the other drivers' behaviour, he does not see the necessity to take other information on the situation.

- ***Unexpected road user***

Some road users (pedestrian, PTW, bicycle, etc.) are infrequent to encounter in certain places. In the accident process these road users have been proved to not be taken into account, even visible, as far the drivers were not expecting them on the place. This expectation can minimize the integration of information.

- ***Danger careless***

Certain drivers have manifested in their behaviour and declaration a very poor consciousness of any danger connected to driving, they coiuld consequently tend to neglect recommendations connected to safety.

- ***Poor interpretation of a signal***

This potential limitation come from the fact that drivers on well know road or situations tend to function at a low level, in an automatic way that did not allow them to be receptive to information from the road scene. So could it be for information from a safety function.

Action-related problems

- ***Spontaneous speeding***

This element refers to a tendency shown to accelerate or reaccelerate, even in spite of disposal inciting them to slow down.

- ***Slow reaction***

Some drivers manifest a strong tendency (because of age or lack of experience) to react very lately. Such an effect could have repercussion on the capacity to integrate the safety benefit of a function.

- ***Uncontrolled reaction due to surprise***

The surprise when detecting unexpected event can lead to react excessively.

- ***Freezing up***

The surprise can lead for some drivers to the incapacity to react.

Contextual variables which could lead to intentionally reject the aid

Driver state

- ***Fatigue assumed***

It is the case that the drivers already detected the problem they felt but refused to stop.

- ***Sign of faintness detected***

Idem.

- ***Chronic alcoholism***

This element account for the eventuality that a driver would find a way for not obeying an advice or try to get round a safety disposal

Attention-related problems

- ***Well-known itinerary***

When the driver feels they know perfectly well a situation, they are able to not trust any information contradictory to what they feel.

Expectation-related problems

- ***Expecting regulation from others***

When confronted with atypical situations, the drivers proved to be sure that it was the other driver to react, until it becomes too late.

- ***Feeling of right of way***

The right of way status tend to give the driver the impression that he is protected, whatever the event around.

Action-related problems

- ***Opposite action of the driver***

For example, the safety function could decelerate whereas the driver could insist on accelerating (if he has the capacity).

Motivation
Motivation can be so strong that it coul lead some drivers to completely neglect a safety function. This can relate to:

- ***Motive for the journey***
- ***Motive for speeding***
- ***Strong motive for the manoeuvre***
- ***Confidence in self judgment***
- ***Deliberate traffic violation***
- ***Risk of safety function disconnecting by the driver***

It can be notably the case for constraining devices: some in-depth accident studies bring to think that the driver could disconnect (if he can) the safety function in order to have fun on the road (e.g. ESP).

The most frequent endogenous accident context limitations are listed in the table below (Table 4). Their overall frequencies are presented in Annex 2 (Table 12)

Table 4: Delineation of the most frequent endogenous limitations and frequencies by safety functions occurrences

Expected absence of interference	184	27%
Inattention	82	12%
Feeling of right of way	75	11%
Attentional focus (on other potential hazards)	62	9%
Expected regulations from others	42	6%
"Active" distraction	41	6%
Poor interpretation of a signal	41	6%
Opposite action by the driver	39	6%
Upset – Stressed	38	6%
Motive for speeding	32	5%
Unexpected road user (powered two-wheeler)	32	5%
Unexpected road user (pedestrians)	28	4%
(...)[7]		

For these 675.5 occurrences of appropriateness of a function, we can notice that the endogenous limitation "Expected absence of interference" is far the most frequent limitation found in accident context production. It appeared 184.2 times, i.e. 27% of the cases (The most frequent endogenous accident context limitations are listed in the table below (Table 4). Their overall frequencies are presented in Annex 2 (Table 12)

Table 4). It means that in a quarter of the cases when the safety functions would be relevant to their need, the drivers would risk to minimize or even reject the information given because of their confidence in their expectations of having no trouble because of their trust in their own experience and processing of the situation. Expectation as a whole (including feeling of right of way, the regulations expected from others, etc.) proves to be an important parameter acting in drivers' processing of information found in the road scene, contributing to accident production. It might be acting in the same way as regard as information given by an added device, potentially mitigating its efficiency. Problems connected to driver's attention also appear crucial regarding accident production context and consequently on the potential benefit of a safety function: thus, inattention, attention focus and distraction play an important role as potentially mitigating the positive effect of safety functions added to the driving task. Other parameters, such as motivation, emotion interpretation also account for endogenous parameters the most able at mitigating the potential effect of safety functions.

The possible influence of these limitations on safety function effectiveness will be examined function after function in the section 5.3.

5.2.2 Exogenous limitations linked to accident context

Situational constraints

- - ***Reduced time / space conditions***
- - ***Strong dynamic constraints (speed, load, loss of control)***
- - ***Dense traffic (in city)***
- - ***Weather conditions (Rain, Wind, Snow)***
- - ***Reduced adherence (wet road, gravels, oil, ice)***

[7] The full list of endogenous limitations frequency in presented in Annex 2.

Visibility

- ***Limited conspicuity***

E.g. pedestrian in dark.

- ***Visibility impaired by a vehicle***
- ***Visibility limited by infrastructure, vegetation, curve, roundabout construction***
- ***Lighting conditions (diminished, night, dazzle)***
- ***Lighting defect in the zone***

Layout

- ***Poor signalisation***
- ***Inappropriate regulation (speed in bend, at intersection)***
- ***Atypical / complex intersection***
- ***Intersection configuration (roundabout, private road, car park, with central storage)***

Could not be taken into account by the system as an intersection

- ***Impracticable or missing verge***

Safety function characteristics

- ***Assistance trigger threshold***
- ***Insufficient alarm intensity (sound)***
- ***Inappropriate perceptive channel***
- ***Insufficient radar / camera width (in intersection, multi-lane road, opposite side of the road)***
- ***Insufficient radar / camera length***
- ***Poor localization of the source of information***

This refers to the fact that the driver could be looking at another direction or find hard to identify information no conspicuous enough. It refers to the ergonomics of the display.

Others

- ***Obstacle (infrastructure, non visible vehicle)***
- ***Tyre problem (under inflated)***
- ***Pedestrian outside the pedestrian crossing***
- ***Wrong way driving***

The most frequent exogenous limitations are listed in the tables below (Table 5). Their overall frequencies are presented in Annex 2 (Table 13).

Table 5: Delineation of the most frequent exogenous limitations and frequencies by safety functions occurrences

Reduced time/space conditions	282	42%
Strong dynamic constraints (speed)	50	7%
Insufficient radar/camera width (in intersection)	48	7%
Lighting conditions (night)	44	7%
Limited visibility (infrastructure-vegetation)	40	6%
Limited visibility (vehicle)	37	5%
Reduced adherence (wet road)	36	5%
Limited visibility (infrastructure-construction)	27	4%
Lighting conditions (dazzle)	21	3%
Poor pinpointing of the source of information	19	3%
Strong dynamic stress (loss of control)	19	3%
Road design defect (atypical intersection)	18	3%
Road design defect (signals)	17	3%
Limited visibility (infrastructure-curve)	15	2%
Tyre problems (under inflated)	14	2%
(…)		

We will notice that the exogenous limitation "Reduced time/space conditions" appear 282 times, i.e. in 42% of the cases when a safety function is relevant to a need (Table 5). This result, coming from the reconstruction of the accident cases, shows than even with the help of a safety function, the accident would have been avoided, due to the physical parameters into play. It means that in more than a third of the cases, the time between the detection of the hazard by the safety system and the possible action by the driver would be too long to allow avoiding the accident. This external contextual parameter appears as far the most represented when compared to others exogenous limitations.

5.3 Which contextual accident constraints for which safety functions?

We have seen in chapter 4 that in our sample of 432 drivers for whom a need has been identified, the 21 safety functions and variants evaluated appeared relevant 675 times to the needs, which can be viewed as an optimistic result regarding the capacity of these functions to well address drivers needs found in accident. But at the same time, 1038 endogenous limitations (56%) and 814 exogenous limitations (44%) have been identified in the accident production context as potentially lessening the effectiveness of these safety function.

The following sections present, aid by aid, the most frequent contextual limitations that have been estimated potentially mitigating the effectiveness of each of those systems.

5.3.1 ACC+

ACC+ has been considered (in section 4.2) as able to address 4.8% of all drivers' pivotal needs. This safety function matches the following needs:

- B05 Detecting an obstacle moving slowly (2.5% of drivers' pivotal needs)
- B04 Detecting a fixed obstacle (0.9%)
- B13 Evaluating a catching up on a slower road user (0.5%)
- B19 Predicting that another user will stop or slow down (0.4%)
- B17 Predicting that another user will move off or fail to stop (0.3% of drivers' pivotal needs)
- B18 Predicting that another user will stop or slow down (0.2%).

For these 4.8% of needs, endogenous and exogenous potential limitations have been diagnosed from the parameters characterising the accident cases in which these needs were found. These limitations are so considered as able to diminish the effectiveness of ACC+, if introduced in such accidental contexts.

- **Endogenous limitations**

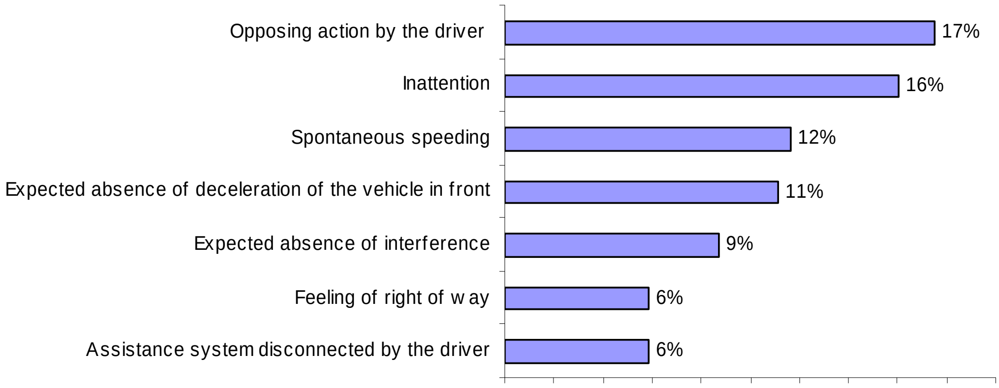


Figure 9 : Endogenous limitations for ACC+

The principal element putting the effectiveness of ACC+ in difficulty is that the drivers can have an opposing action to the action of deceleration of ACC+ (17%[8]): i.e. the drivers are likely to accelerate, not identifying the risk of interference. Moreover, in 16% of the cases when the driver would need ACC+, the driver is inattentive, which doesn't support a good analysis of the situation.

As for other variants of ACC presented below, an ergonomic solution would be to provide clear information to the driver about the nature and the localization of the hazard he is meeting.

- **Exogenous limitations**

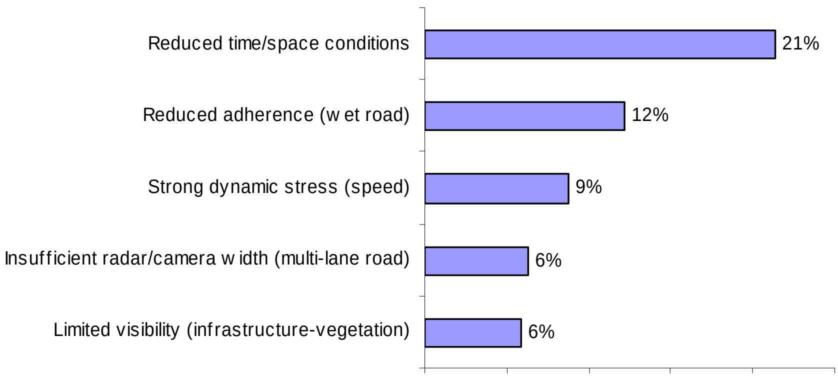


Figure 10: Exogenous limitations for ACC+

The effectiveness of ACC+ could be limited firstly by a reduced time/space condition (21%) between the moment the ACC+ radar collects the hazard and the moment of the impact. In 12% of the cases, the effectiveness of ACC+ could also be limited by reduced adherence on wet road.

5.3.2 ACC1 – Information and warning system

ACC1 has been able to fulfil 1.9% of drivers' pivotal needs identified in accidents. The ACC1 matches the following needs:

- B04 Detecting a fixed obstacle on the road (1.6% of drivers' pivotal needs)

[8] 17% of 4.8% of needs.

- B05 Detecting a slowly moving obstacle on the road (0.3%)

For this 1.9% of needs, endogenous and exogenous limitations could diminish the effectiveness of ACC1.

- **Endogenous limitations**

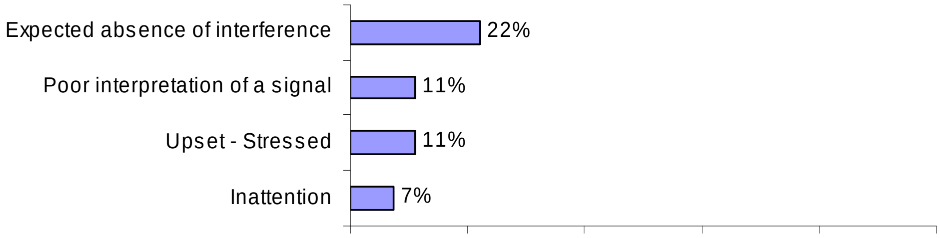


Figure 11: Endogenous limitations for ACC1

The principal limitation decreasing ACC1 effectiveness is that the drivers may expect an absence of interference with another road user (22% of the cases). As a consequence, they may not take into account the signal.

An ergonomic solution would be to provide clear information to the driver about the nature and the localization of the hazard.

- **Exogenous limitations**

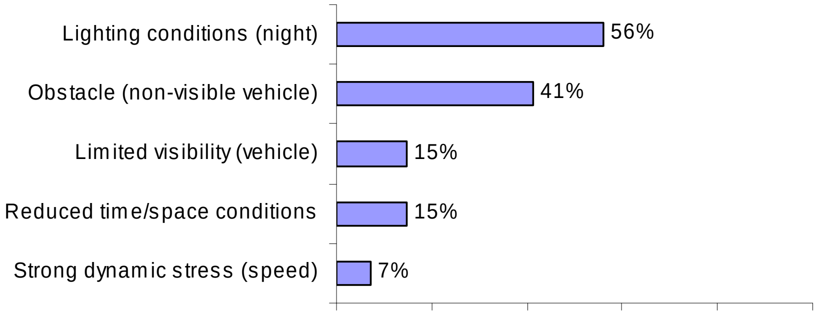


Figure 12: Exogenous limitations for ACC1

ACC1 efficiency could be limited in 56% of the cases (56% of 1.9% of needs) by bad lighting conditions during night time. As far as such a system asks for a strong reaction for the part of the driver, it could be often taken as a false alarm if no clear feed back in given on the source of the problem.

In 41% of the cases, the message would be transmitted by a vehicle-obstacle (broken, broken down) not visible in approach. It should be pointed out that the transmission shall no be obstructed by anything.

In 15% of the cases, the driver does not see the danger, because it is hidden behind another vehicle.

The effectiveness of the ACC1 can be limited in 15% of the cases because of reduced time/space between the moment when the ACC1 radar collects the hazard and the moment of the impact.

5.3.3 ACC2 – Communication-based Longitudinal Control System

ACC2 would be able to answer 3.4% of accidented drivers' pivotal needs. ACC2 fulfils the following needs:

- B05 Detecting an obstacle moving slowly (2.0% of drivers' pivotal needs)
- B04 Detecting a fixed obstacle (0.7%)
- B13 Evaluating a catching up on a slower road user (0.3%)

- B18 Predicting that another user will stop or slow down (0.2%)
- B19 Predicting that another user will stop or slow down (0.1%)

As for the other aid systems, effectiveness of ACC2 might be lessened by endogenous and exogenous limitations.

- **Endogenous limitations**

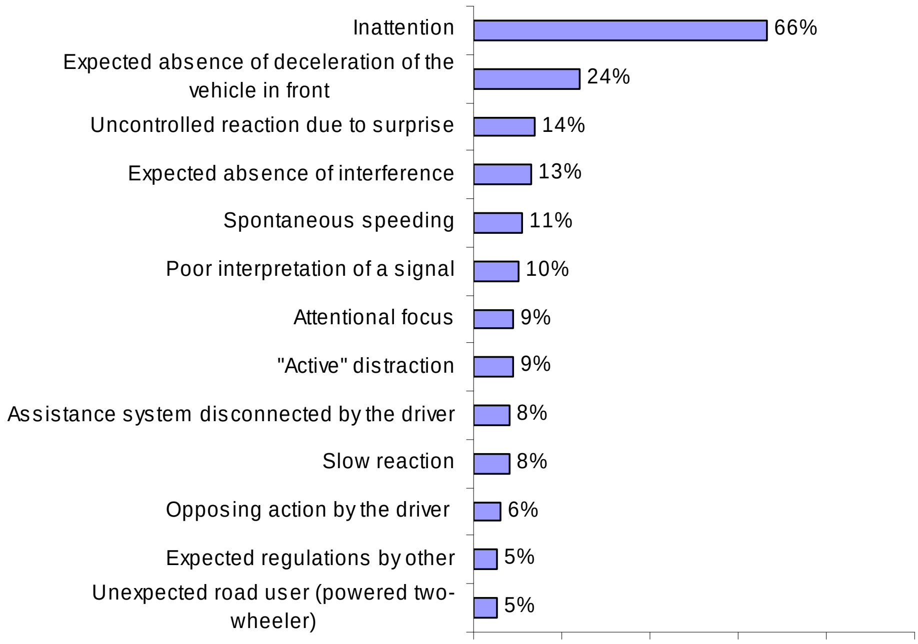


Figure 13: Endogenous limitations for ACC2

The principal element putting the effectiveness of ACC2 in difficulty is the inattention level of the drivers (66%).

In 24% of the cases, the drivers are likely to not identify the risk of deceleration of the vehicle in front, meaning that they can have an opposing action to the action of deceleration of ACC2: i.e. the drivers are likely to accelerate.

As mentioned above, an ergonomic solution would be to provide clear information to the driver about the nature and the localization of the hazard.

- **Exogenous limitations**

The effectiveness of ACC2 could be limited firstly by a reduced time/space condition (35%) between the moment the ACC2 radar collects the hazard and the moment of the impact. In 12% of the cases, the effectiveness of ACC2 could also be limited by strong dynamic stress (speed).

5.3.4 AK - Alcolock Keys

AK matches 5.7% of accidented drivers' pivotal needs which correspond to:

- B01 Diagnosing driver condition (alcohol, fatigue, health, attention, etc.) (5.5% of drivers' pivotal needs)

Only endogenous limitations have been observed as having an influence on the efficiency of this safety function.

- **Endogenous limitations**

The effectiveness of AK is likely to be restricted when the drivers are under the influence of a non detectable drug (10%) or alcohol in a legal proportion (10%) these elements are identified as accident factors but would not be taken into account by the function. People suffering from chronic alcoholism (21%) are likely to find a means to get round the safety function (e.g. making others to unlock the system).

5.3.5 BA - Brake Assist

BA matched 0.5% of drivers' pivotal needs. This aid fulfils the following needs:

- B20 Predicting the manoeuvre suited to the layout functioning (0.2%)
- B17 Predicting that another user will move off or fail to stop (0.3% of drivers' pivotal needs).

For this 0.5% of drivers, endogenous and exogenous limitations could lessen the BA effectiveness.

- **Endogenous limitations**

The late braking of the drivers is explained by endogenous limitations: drivers have an active distraction (40%) by a secondary activity (discussion with passenger, telephone, etc.) and/or they have little experience of accident situations so that their cognitive capacities are overwhelmed ("freezing", incomprehension of the manoeuvre, certainty that the other user will control: 40%).

- **Exogenous limitations**

The effectiveness of BA can be limited by the fact that the drivers initiate their braking too late because of poor luminosity related to night time (60%), or just because the time/space conditions are insufficient to prevent the accident, in 60% of the cases.

5.3.6 BS - Blind Spot Detection

4.3% of drivers' pivotal needs are covered by BS. This system matches the following needs:

- B08 Detecting a user outside the frontal field of vision (behind, on the sides, or in blind spot) (3.2% of drivers' pivotal needs)
- B16 Assessing gaps when joining or cutting across a traffic flow after changing direction at low speed (0.6%)
- B19 Predicting that another user will stop or slow down (0.2%)
- B20 Predicting the manoeuvre suited to the layout functioning (0.2%)
- B09 Detecting a user outside the frontal field of vision (masked by something) (0.1%)

- **Endogenous limitations**

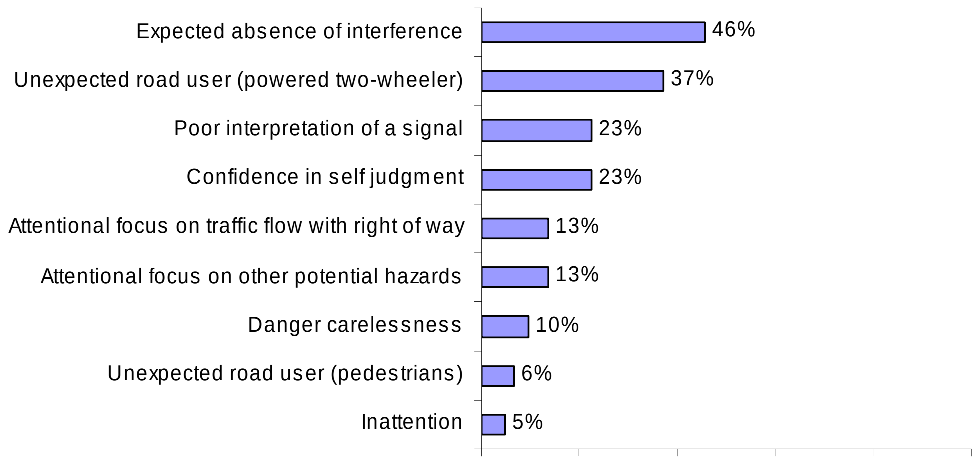


Figure 14: Endogenous limitations for BS

The essential endogenous limitations being able to restrict the effectiveness are expected absence of interference (46%), and more particularly when the interfering vehicle is a motorized two-wheeled vehicle because of their low expectiveness (37% of the cases).

- **Exogenous limitations**

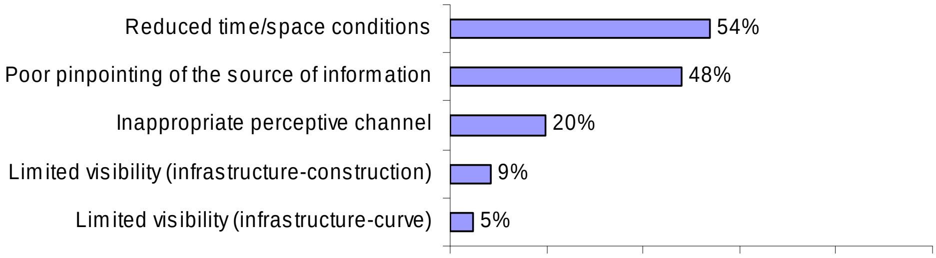


Figure 15: Exogenous limitations for BS

The reduced time/space condition is an essential limitation, as far as in 54% of the cases, when the driver changes lane, he collides the interfering user almost immediately.

For the same reasons as for LCA, the effectiveness of BS can be restricted, in 48% of the cases, because of the localization of the visual alarm (i.e. on the left external rear view mirror) and of inappropriate perceptive channel (visual mode), in 20% of the cases. Indeed, the drivers who have an accident while changing lane or overtaking are people who do not (or insufficiently) look at their rear view mirror. Even with a light on the rear view mirror, the opponent road user would not have been seen anyway. A coupling with an audible alarm when the driver begins his lane changing would be more appropriate to inform them efficiently.

5.3.7 CA - Collision Avoidance

CA has been identified as appropriate for 31.6% of the drivers' pivotal needs. This system matches the following wide variety of needs:

- B05 Detecting an obstacle moving slowly (8.4% of drivers' pivotal needs)
- B07 Detecting a user on an intersecting course (5.8%)
- B17 Predicting that another user will move off or fail to stop (4.6%)
- B06 Detecting an oncoming user (in movement) (4.0%)
- B04 Detecting a fixed obstacle (2.7%)
- B09Detecting a user outside the frontal field of vision (masked by something) (1.9%)
- B18 Predicting that another user will stop or slow down (0.9%)
- B19 Predicting that another user will stop or slow down (0.9%)
- B14 Estimating a collision course with another user (0.8%)
- B13 Evaluating a catching up on a slower road user (0.5%)
- B10 Detecting a course deviation (0.5%) [9]
- B21 Vehicle control (handling) (0.4%)
- B08 Detecting a user outside the frontal field of vision (behind, on the sides, or in blind spot) (0.2%)
- B03 Detecting a road-related difficulty (0.1%)

[9] Note that when this need appears, in 26% of cases (7 cases out of 26) no safety function is able to fulfil it.

For these 31.6% of drivers, here are the endogenous and exogenous limitations that could diminish the effectiveness of CA.

- **Endogenous limitations**

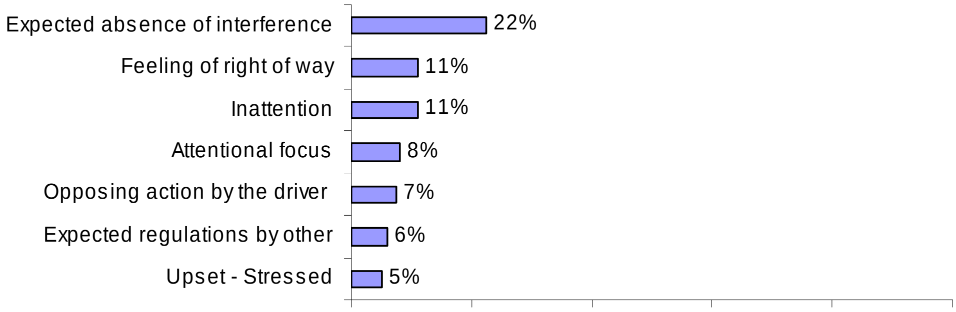


Figure 16: Endogenous limitations for CA

The effectiveness of CA can be restricted by the fact that the drivers do not expect to enter in interference (22%) with anything. Once more, the efforts will have to be developed to provide good-quality information about the nature of the hazard to the driver.

- **Exogenous limitations**

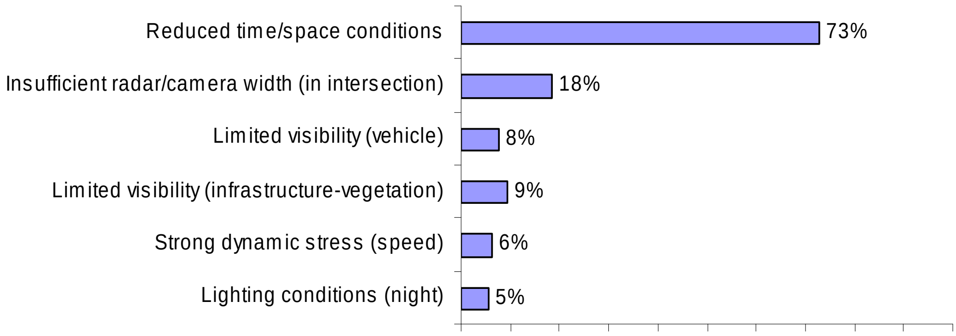


Figure 17: Exogenous limitations for CA

Exogenous limitations being able to decrease the Collision Avoidance effectiveness are similar to those of Collision Warning (below). The reduced time/space conditions are essential limitations of the efficiency of this aid. This limitation appears in 73% of the cases.

5.3.8 CBC - Cornering Brake Control

CBC corresponds to 1.3% of drivers' pivotal needs. Only one need is covered by this system:

- B21 Controlling one's vehicle (1.3% of drivers' pivotal needs)

For this 1.3% of drivers, the limitations lessening CBC effectiveness are presented below.

- **Endogenous limitations**

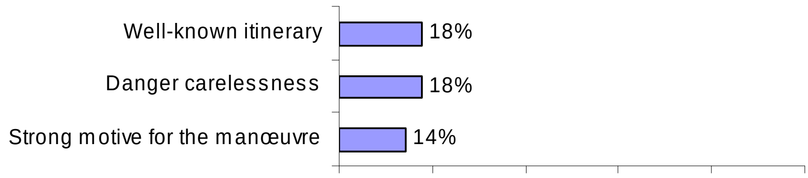


Figure 18: Endogenous limitations for CBC

The effectiveness of CBC can be restricted on well-known itinerary, when the driver is deliberately careless or when he is constrained to carry out a contrary action (maintaining the wheel and accentuating an over-steer).

- **Exogenous limitations**

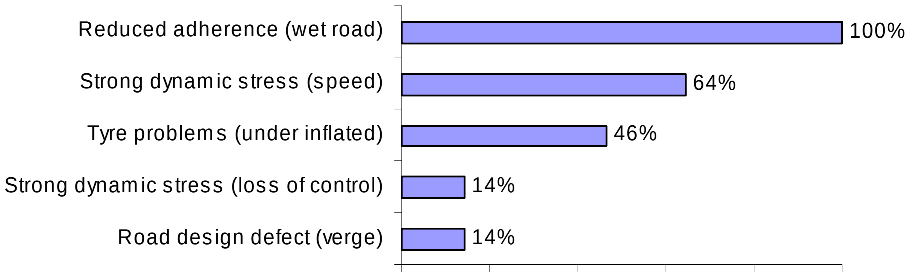


Figure 19: Exogenous limitations for CBC

For all of the 1.3% of the cases when CBC would be able to answer drivers pivotal need, (i.e. to control the vehicle, when the driver brakes while moving the wheel and when there is a risk of over-steering), adherence is reduced by the wet roadway, limiting the aid efficiency. It is interesting to see that risks of over-steer linked to braking take place on wet road. Although this result is to be taken with caution, because of the weak number of pivotal needs concerned with the CBC (1.3%).

The strong dynamic stress related to high speed is also a constraint that the CBC will have to take into account, because speed is present in 64% of the cases.

In 46% of the cases, a tyre problem (under inflation) was identified. A solution would be to envisage a coupling with the TPMS (Tyre Pressure Monitoring and Warning) which meets an upstream need of diagnosing a problem linked to the vehicle.

5.3.9 CW - Collision Warning

CW is suited to match a fourth (26.4%) of drivers' pivotal needs. CW meets the following needs:

- B05 Detecting an obstacle moving slowly (7.5%of drivers' pivotal needs)
- B07 Detecting a user on an intersecting course (3.8%)
- B17 Predicting that another user will move off or fail to stop (3.6%)
- B06 Detecting an oncoming user (in movement) (3.4%)
- B04 Detecting a fixed obstacle (2.7%)
- B18 Predicting that another user will stop or slow down (1.4%)
- B14 Estimating a collision course with another user (0.8%)
- B09 Detecting a user outside the frontal field of vision (masked by something) (0.7%)
- B13 Evaluating a catching up on a slower road user (0.7%)
- B10 Detecting a course deviation (0.5%)

- B16 Assessing gaps when joining or cutting across a traffic flow after changing direction at low speed(0.4%)
- B21 Vehicle control (handling) (0.4%)
- B03 Detecting a road-related difficulty (0.3%)
- B19 Predicting that another user will stop or slow down (0.3%)

The following endogenous and exogenous limitations to CW have been identified for these 26.4% of drivers.

- **Endogenous limitations**

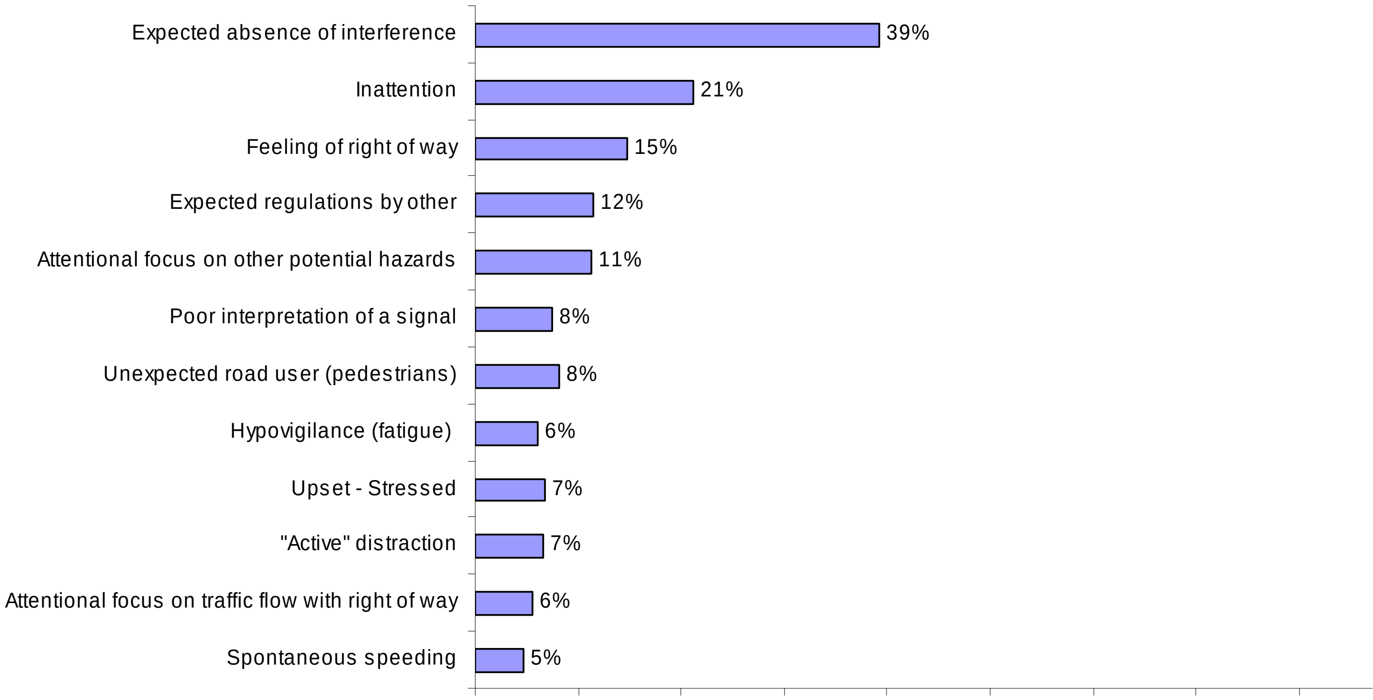


Figure 20: Endogenous limitations for CW

The principal limitations to CW effectiveness are overlapping. They relate to drivers whose attention is allotted to other object that the relevant one (inattention: 21% and attentional focalisation: 11%), or who do not expect an interference (39%). A Simple warning could lead to a problem of interpretation and drivers would not take into account the signal emitted by CW because of a feeling of priority (15%); an expected regulation by the other: 12%) or a poor interpretation of the signal (8%), with the feeling for example that the assistance radars are too sensitive.

- **Exogenous limitations**

As it was the case for Collision Avoidance function, the principal limit lowering the effectiveness of CW is a reduced time/space (62%) between the moment when the driver would have information on the potential hazard, would process these data and then initiate a braking or any other action of avoidance.

In 11% of the cases, the poor luminous conditions related to night time constitute a limit to the effectiveness of CW.

In 14% of the cases, the width of the radar is insufficient to detect the hazards at intersection.

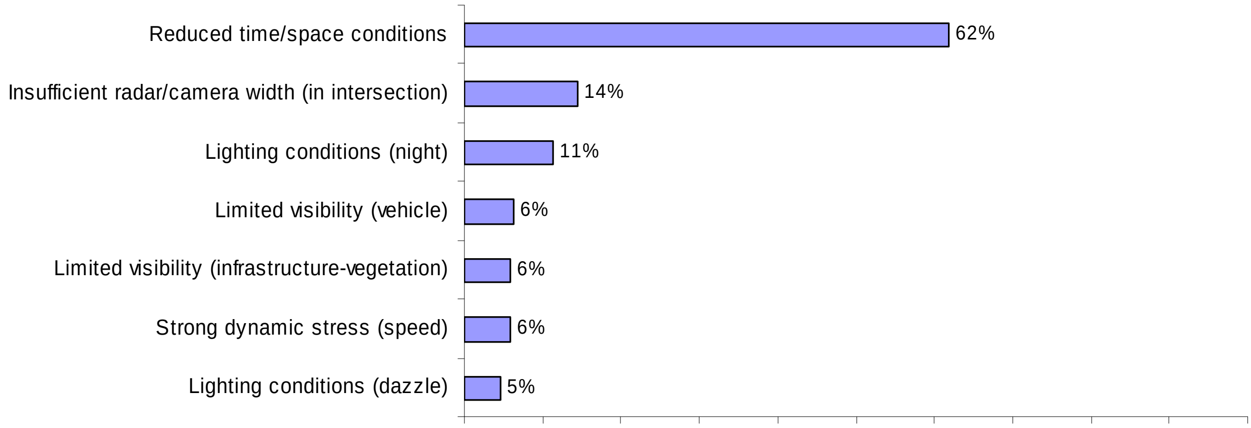


Figure 21: Exogenous limitations for CW

5.3.10 DDS - Drowsy Driver Detection System

DDS is able to support 6.6% of accidented drivers' pivotal needs. It fulfils the following needs:

- B01 Diagnosing driver state (alcohol, fatigue, health, attention, etc.) (6.4% of drivers' pivotal needs)
- B10 Detecting deviation from the path (0.2%)

For these 6.6% of drivers, the endogenous and exogenous limitations that could diminish the DDS effectiveness are listed below. As it could be expected, the efficiency of this system is far more affected by endogenous than exogenous limitations.

- **Endogenous limitations**

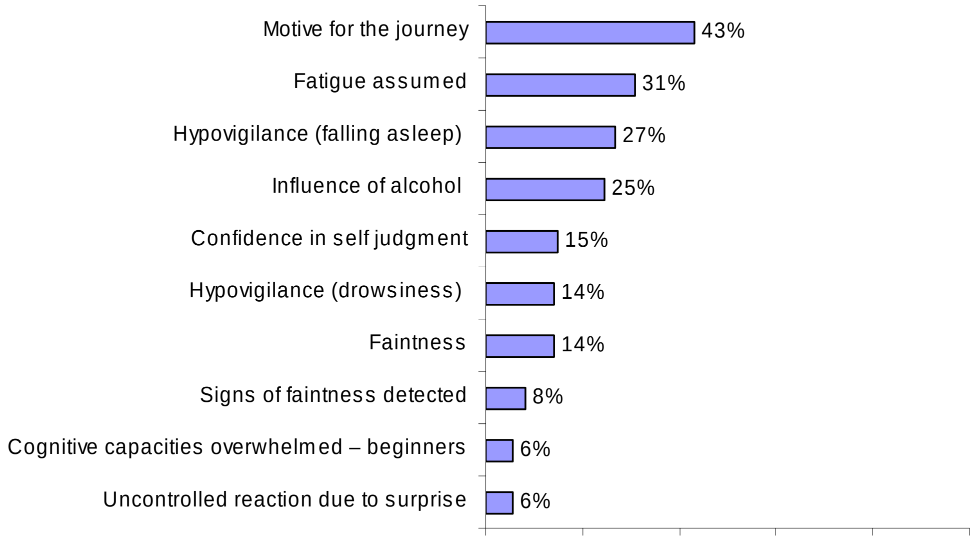


Figure 22: Endogenous limitations for DDS

In almost half of the cases (43%), the drivers have a motivation related to the journey (strong will to reach their destination) and are likely not to take into account DDS.

The effectiveness of DDS can also be decreased because 31% of the drivers know their state of fatigue and are likely to not take account the DDS signals.

The influence of alcohol (25%), which is often connected with drowsiness, is also a constraint which might lessen DDS efficiency in the degree of taking into account information.

The hypovigilance (falling asleep) concerns 27% of the drivers at the pivotal time of the accident. The DDS will have to intervene before, i.e. at the first signs of drowsiness.

- **Exogenous limitations**

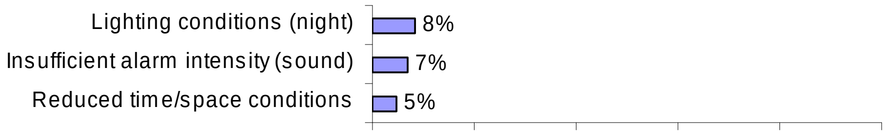


Figure 23: Exogenous limitations for DDS

In 8% of the accidents, the poor lighting conditions at night, mostly in rural areas, have been identified, i.e. if the face of the driver is absolutely not lighted, the cues related to the driver falling asleep would not be detectable. As drowsiness takes place in the majority by night on monotonous road in countryside, the effectiveness of the DDS is reduced if the camera does not catch driver's eyelid movements.

The second limit would be insufficient alarm intensity (7%) when the driver is strongly alcoholised, very tired and falling asleep.

5.3.11 DS - Dynamic Suspension

DS is only connected to 0.5% of drivers' pivotal needs. DS is concerned by the following need:

- B21 Vehicle control (handling) (0.5% of drivers' pivotal needs)

For this 0.5% of drivers, only one exogenous limitation have been identified for lessening the DS efficiency.

- **Exogenous limitations**

In 57% of the cases when DS would support a pivotal need for control of the vehicle, a problem of tire (under-inflation) was identified and could decrease the effectiveness of DS.

It is necessary to envisage a coupling with the TPMS (Tyre Pressure Monitoring and Warning) which fulfils a need to diagnose the vehicle upstream.

5.3.12 ESP - Electronic Stability Program

ESP fits with 8.3% of accidented drivers' pivotal needs:

- B21 Vehicle control (handling) (8.3% of drivers' pivotal needs)

For these 8.3% of drivers, endogenous and exogenous limitations have been identified as lowering the effectiveness of ESP.

- **Endogenous limitations**

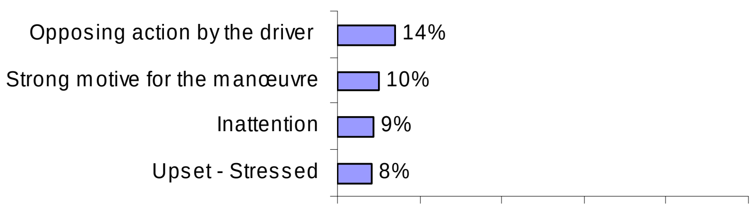


Figure 24: Endogenous limitations for ESP

In 14% of the cases, the driver has an action opposed to ESP and this could decrease its effectiveness. For example: when the driver maintains the wheel, accentuating the over-steer.

- **Exogenous limitations**

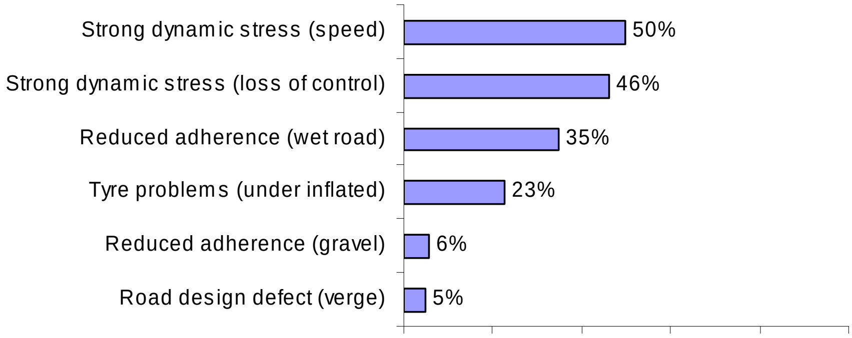


Figure 25: Exogenous limitations for ESP

A potential decrease in the ESP effectiveness has been diagnosed in a half of the cases because of a strong dynamic stress related to speed.

It is also true for strong dynamic stress linked to the loss of control (46% of the cases): the vehicle slips on the roadway or runs off the roadway, so as the driver couldn't recover the situation when truing to stabilize his vehicle on the roadway.

In 23% of the cases, a problem of tire (under-inflation) was identified and could decrease the effectiveness of ESP.

5.3.13 IC - Intersection Control

This aid covers 29.0% of drivers' pivotal needs. It matches the following needs:

- B07 Detecting a user on an intersecting course (12.8% of drivers' pivotal needs)
- B17 Predicting that another user will move off or fail to stop (5.7%)
- B20 Predicting the manoeuvre suited to the layout functioning (2.5%)
- B16 Assessing gaps when joining or cutting across a traffic flow after changing direction at low speed(2.0%)
- B06 Detecting an oncoming user (in movement) (1.9%)
- B05 Detecting an obstacle moving slowly (1.5%)
- B03 Detecting a road-related difficulty (1.2%)
- B09 Detecting a user outside the frontal field of vision (masked by something) (0.7%)
- B14 Estimating a collision course with another user (0.2%)
- B19 Predicting that another user will stop or slow down (0.2%)
- B08 Detecting a user outside the frontal field of vision (behind, on the sides, or in blind spot) (0.2%)

Below are listed, for these 29.0% of drivers, endogenous and exogenous limitations that could lessen the effectiveness of IC.

- **Endogenous limitations**

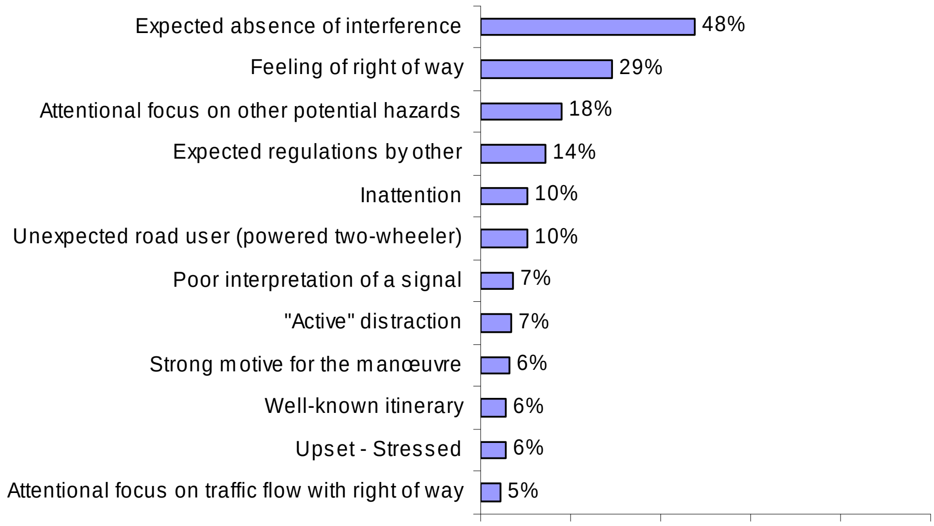


Figure 26: Endogenous limitations for IC

Expected absence of interference constitutes the principal limit to IC effectiveness (48%), leading the drivers not to take into account the safety function. Such a limitation is notably observed when the drivers have a strong feeling of right of way (29%) and/or think that the interfering vehicle will control the situation (14%).

- **Exogenous limitations**

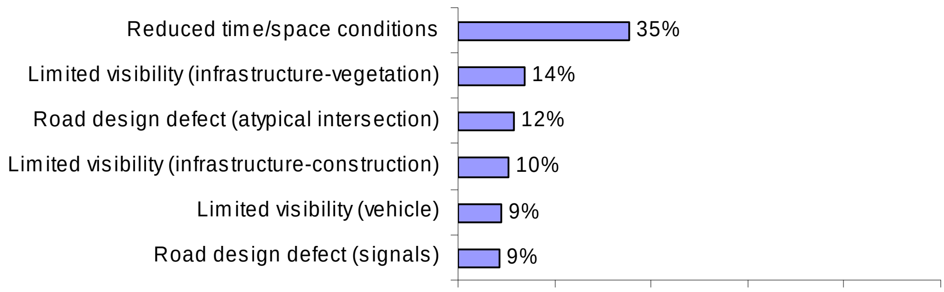


Figure 27: Exogenous limitations for IC

In 35% of the cases, the effectiveness of IC can be decreased by the reduced time/space condition between the moment when IC will detect the hazard and the moment of the impact.

The effectiveness of the IC can also be lessen by visibility limited by vegetation (14%) and /or related to buildings (10%), as far as the function is assumed as not being able to detect through physical objects.

The defects of road installations in particular the atypical nature of intersections can also constitute a limitation with the effectiveness of the IC, in 12% of the cases.

5.3.14 ISA1 - Intelligent Speed Adaptation: Advisory system

This first variant of ISA matches 1.9% of accidented drivers' pivotal needs and fulfils the following needs:

- B11 Adapting speed to road conditions - 1: road geometry (1.8% of drivers' pivotal needs)
- B20 Predicting the manoeuvre suited to the layout functioning (0.2%)

For these 1.9% of drivers, mostly endogenous limitations have been identified that could diminish the effectiveness of ISA1.

- **Endogenous limitations**

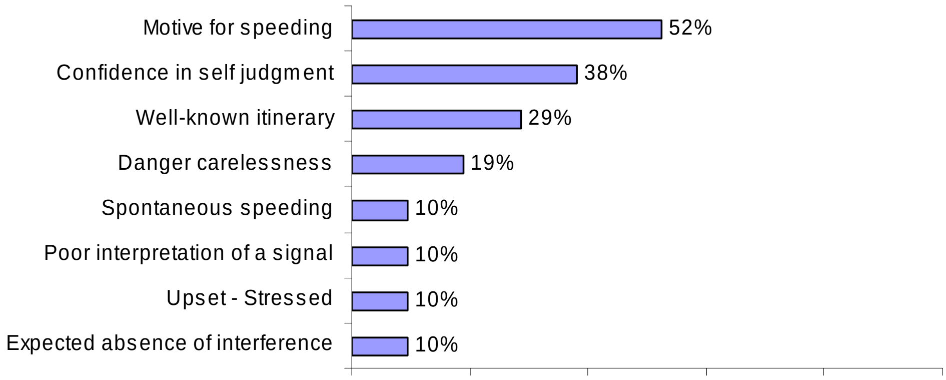


Figure 28: Endogenous limitations for ISA1

The main limitation potentially counteracting the efficiency of IAS1 is related to deliberate speed (52%): the driver would not take into account simple information provided by the system because of his strong motive for the adopted speed. Other aspects can lead the drivers to not process the message delivered by the safety function: when the itinerary is familiar (29%), when he neglects the notion of danger (19%), etc.

- **Exogenous limitations**

Only a few exogenous limitations have been identified for ISA1. They deal with are an inappropriate regulation (as for speed in bend) and a reduced adherence on wet road, in 19% for both. The others are related to strong dynamic stress (10% of the cases), or lighting deficiency (10% also)

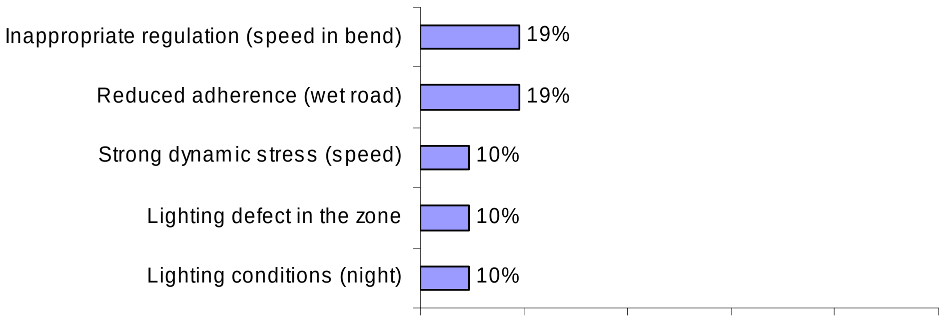


Figure 29: Exogenous limitations for ISA1

5.3.15 ISA2 - Intelligent Speed Adaptation: Voluntary system

This second version of ISA is found to be efficient in 3.5% of drivers' pivotal needs. ISA2 matches the following needs:

- B11 Adapting speed to road conditions - 1: road geometry (2.6% of drivers' pivotal needs)
- B12 Adapting speed to road conditions - 2: legislation (0.7%)
- B20 Predicting the manoeuvre suited to the layout functioning (0.2%)

For these 3.5% of drivers, the effectiveness of this system appears to be lowered by endogenous limitations mainly.

- **Endogenous limitations**

As for the first version this aid, the major endogenous limitation lessening ISA2 efficiency concerns the fact that the drivers may not process the information delivered by the safety function. This can be related to several reasons such as speed-related motive (in 68% of the cases), a well-known itinerary (34%), etc.

Additionally in this variant of ISA, the driver still has the possibility to disconnect the function, cancelling immediately the benefit of the safety system (it was considered as probable in 61% of the cases in relation with drivers' conditions).

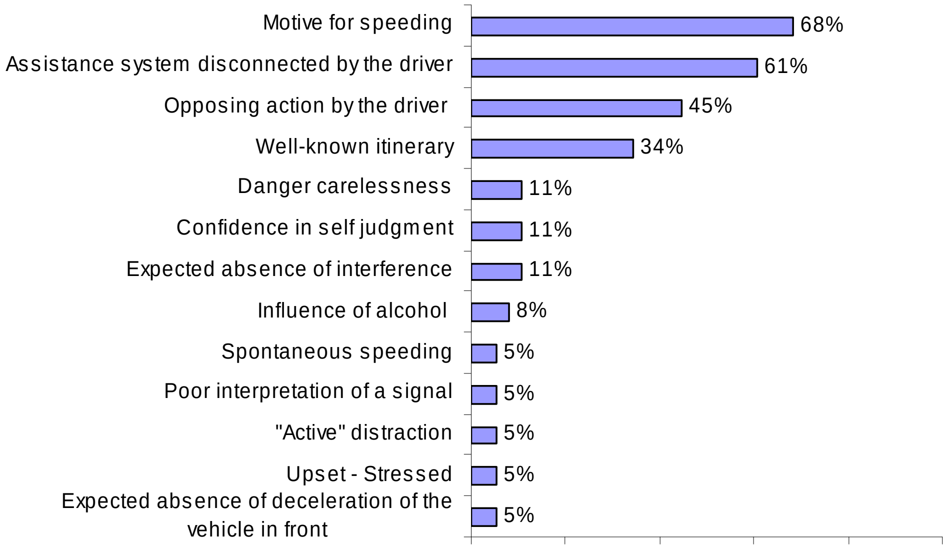


Figure 30: Endogenous limitations for ISA2

- **Exogenous limitations**

ISA2 is slightly concerned by exogenous limitations. There are similar to those acting on the effectiveness of ISA1 and are related to an inappropriate regulation in bend (11%), reduced adherence due to wet road (11%), lighting conditions, etc.

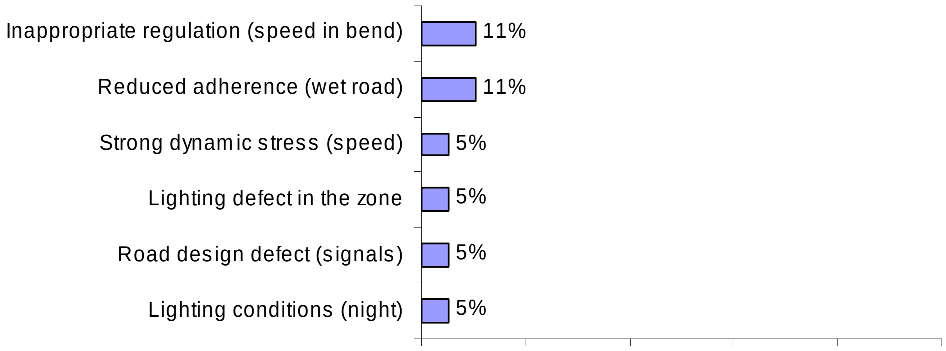


Figure 31: Exogenous limitations for ISA2

5.3.16 ISA3 - Intelligent Speed Adaptation: Mandatory system

ISA3 matches pivotal needs in 4.2% the cases. This aid supports the following needs:

- B11 Adapting speed to road conditions - 1: road geometry (3.2% of drivers' pivotal needs)
- B12 Adapting speed to road conditions - 2: legislation (0.7%)
- B20 Predicting the manoeuvre suited to the layout functioning (0.2%)

For these 4.2% of drivers, the limitations being likely to lower the effectiveness of ISA3 are mostly endogenous and are listed below.

- **Endogenous limitations**

The effectiveness of Mandatory ISA3 could be limited when the drivers are motivated to speed (64% of the cases), or when the itinerary is familiar to them (29%).

In 44% of the cases, the driver may have an opposing action to the deceleration produced by Mandotory ISA3. The drivers may also not take into account the recommendations of the assistance or, in the worst case, disconnect the system if it has an inopportune intervention on the speed of the vehicle.

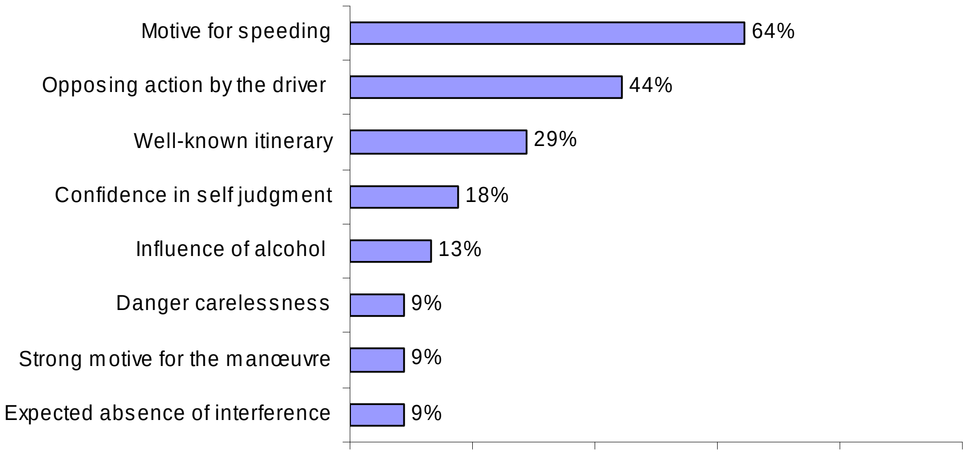


Figure 32: Endogenous limitations for ISA3

- **Exogenous limitations**

There are very few exogenous limitations being able to decrease the effectiveness of ISA3, as described in the figure above (Figure 33).

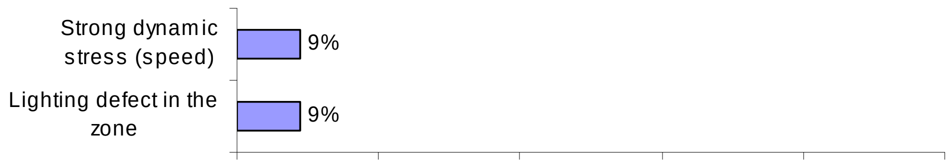


Figure 33: Exogenous limitations for ISA3.

5.3.17 LCA - Lane Changing Assistant

LCA matches 4.2% of accidented-drivers' pivotal needs. This safety function is adapted to support the following needs:

- B08 Detecting a user outside the frontal field of vision (behind, on the sides, or in blind spot) (2.6% of drivers' pivotal needs)
- B16 Assessing gaps when joining or cutting across a traffic flow after changing direction at low speed (0.6%)
- B09 Detecting a user outside the frontal field of vision (masked by an object) (0.4%)
- B10 Detecting a course deviation (0.4%)
- B20 Predicting the manoeuvre suited to the layout functioning (0.2%)

For these 4.2% of drivers, the effectiveness of LCA can be affected by endogenous and exogenous limitations.

- **Endogenous limitations**

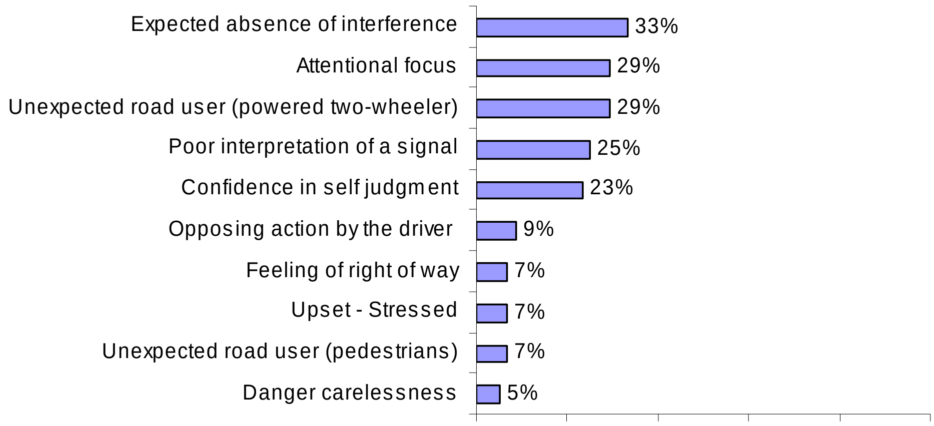


Figure 34: Endogenous limitations for LCA

Expected absence of interference can limit the effectiveness of LCA in 33% of cases (i.e. expecting that no user will interfere during the change of lane).

The weak expectancies developed as regard as PTW also acts against the effectiveness of the LCA (29% of the cases).

Another limitation may com from the fact that the driver is sometimes attentionally focused on another potential hazard (29% of the cases) and would not detect this system alarm better than he did detect the problem in the accident situation.

At last, the effectiveness of LCA can also be limited by not taking into account the signal because of a weak interpretation (25%), or because of a strong felling of right of way (7%).

- **Exogenous limitations**

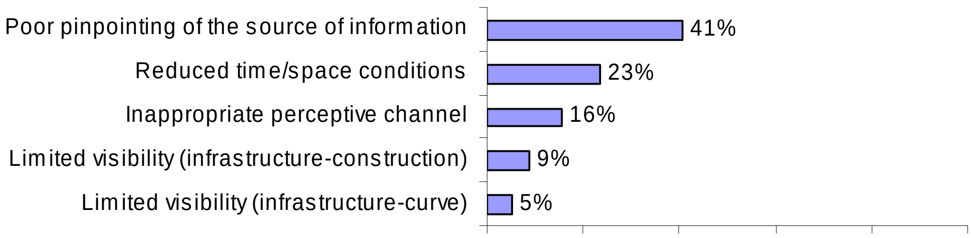


Figure 35: Exogenous limitations for LCA

The effectiveness of LCA can be restricted in 41% of the cases because of the localization of the visual alarm (i.e. on the left external rear view mirror). Indeed, the drivers turning left or overtaking who collide another road user when realizing their manoeuvre, are, in 41% of the cases, not (or insufficiently) looking at in their rear view mirror. A coupling with an audible alarm when the driver begins to change lane would be more effective to inform him.

5.3.18 LKA - Lane Keeping Assistant

LKA is relevant to 4.9% of accidented drivers' pivotal needs:

- B10 Detecting a course deviation (3.6% of drivers' pivotal needs)
- B21 Vehicle control (handling) (0.7%)
- B01 Diagnosing driver state (alcohol, fatigue, health, attention, etc.) (0.4%)

- B08 Detecting a user outside the frontal field of vision (behind, on the sides, or in blind spot) (0.3%)

- **Endogenous limitations**

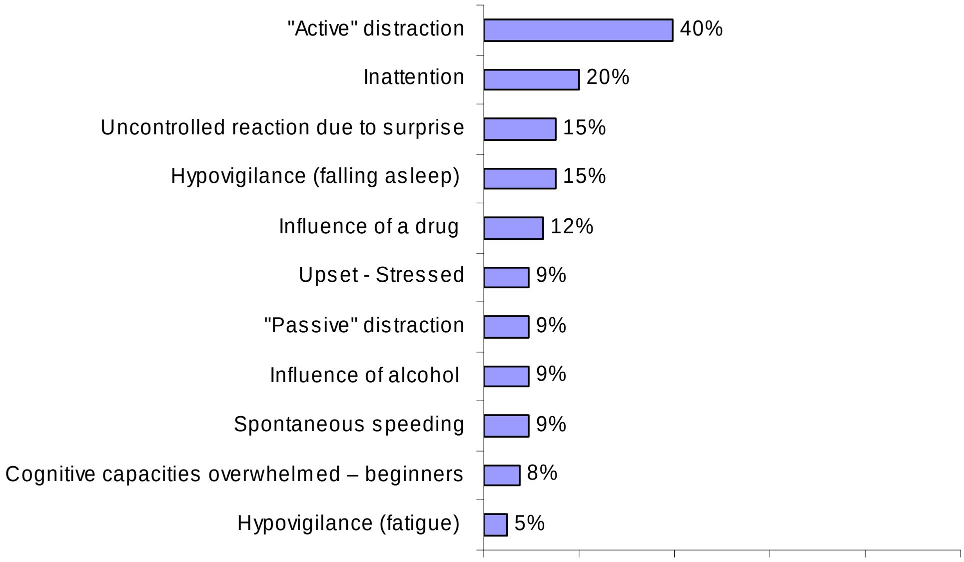


Figure 36: Endogenous limitations for LKA

The essential endogenous limits to LKA effectiveness are the defects in drivers' attention (active distractions: 40%, passive distraction: 9%; inattention: 20%) and hypo-vigilance (falling asleep: 15%; influence of drugs; 12%; or alcohol: 9%).

- **Exogenous limitations**

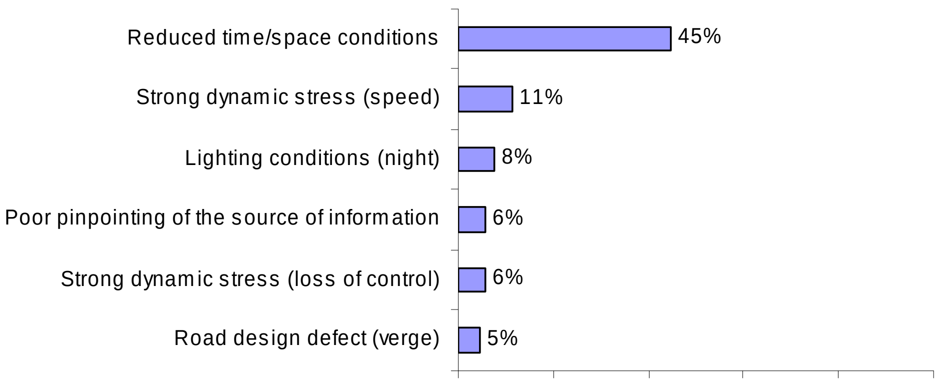


Figure 37: Exogenous limitations for LKA

The principal exogenous limit to LKA effectiveness is reduced time/space conditions (in 45% of the cases) between the drift of the vehicle out of the marking lines and a possible readjustment on the lane. The efficiency of LKA is also lessened when the drivers drive at high speed (leading to a too late readjustment) (11%), and by night (8%) where markings on the carriageway could not be well identified by LKA radar.

It has to be mentioned that even though this system has not been conceived in this purpose, one can assume that it would be useful for situations of low level of attention or vigilance (drowsiness, carelessness, etc.).

5.3.19 NV - Night Vision

NV is associated to 4.6% of drivers' pivotal needs:

- B05 Detecting an obstacle moving slowly (2.1% of drivers' pivotal needs)
- B04 Detecting a fixed obstacle (1.4%)
- B20 Predicting the manoeuvre suited to the layout functioning (0.6%)
- B06 Detecting an oncoming user (in movement) (0.3%)
- B17 Predicting that another user will move off or fail to stop (0.3%)

For these 4.6% of drivers, the endogenous and exogenous limitations lowering NV effectiveness are listed below.

- **Endogenous limitations**

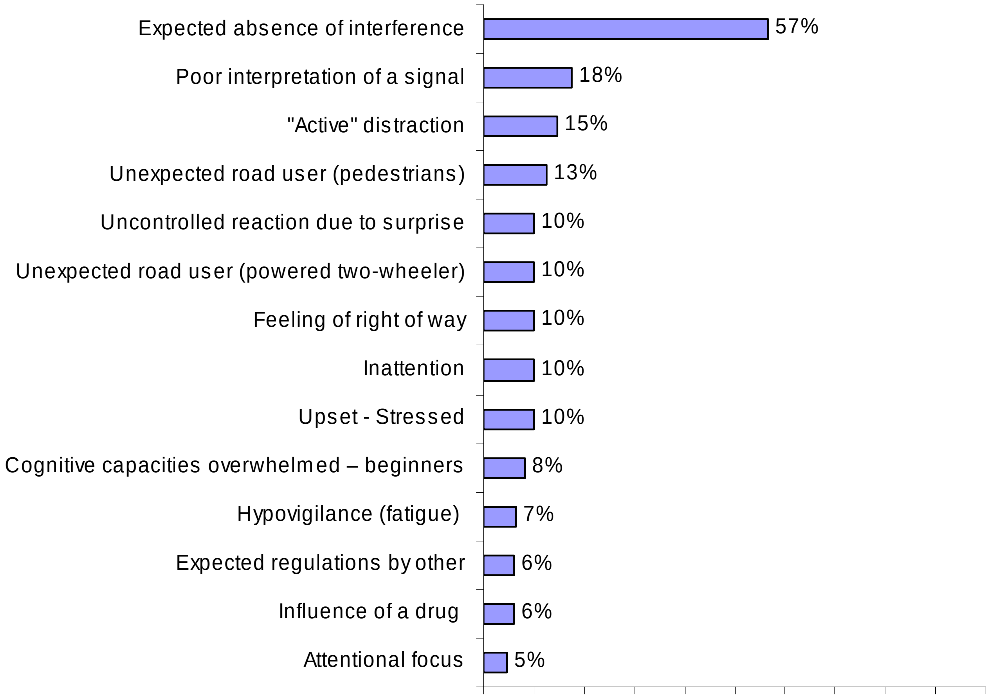


Figure 38: Endogenous limitations for NV

A high number of limitations has been identified for this system, but the most restrictive one (57% of the cases) is the expected absence of interference which would lead the driver to neglect a counter information.

Most of the other ones are related either to defects of attention ("active" distraction: 15%; inattention: 10%; attentional focus: 5%) or to hypovigilance (influence of alcohol, drug).

- **Exogenous limitations**

In 46% of the cases, the effectiveness of NV can be limited by reduced time/space conditions between the moment the system detects an obstacle and then displays it, and the moment the driver processes it and sets up a strategy of avoidance. This accounts for the main limitation, the others being identified in less than 11% of the cases.

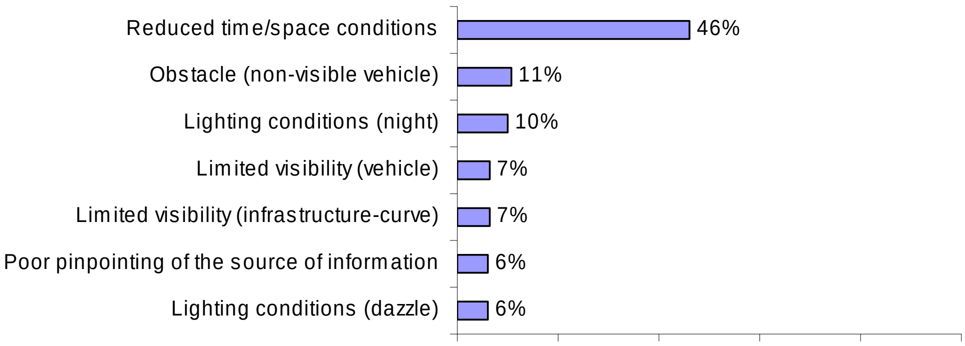


Figure 39: Exogenous limitations for NV

5.3.20 PBA - Predictive Assist Braking

PBA has been related to 0.6% of pivotal needs:

- B17 Predicting that another user will move off or fail to stop (0.6% of drivers' pivotal needs).

- **Endogenous limitations**

The effectiveness of PBA is likely to be restricted because 50% of drivers have a feeling of right of way. They may not consequently take into account the hazard and thus slow down too late to take advantage of the system.

- **Exogenous limitations**

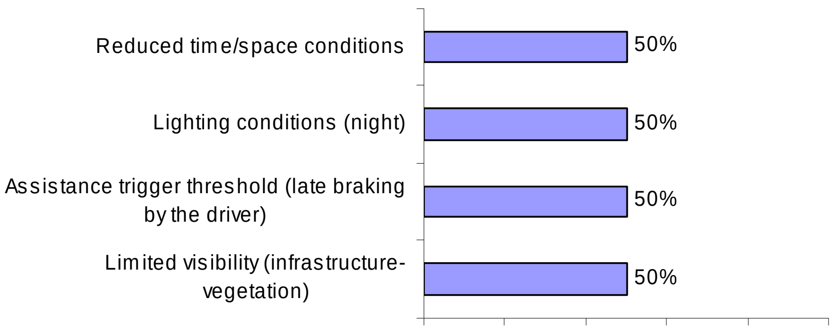


Figure 40: Exogenous limitations for PBA

In 50% of the cases, reduced time/space conditions and/or the lighting conditions related to night time can decrease the PBA effectiveness.

Limitations come also from the fact that PBA starts tardily consequently to a late braking initiated by the driver (50%). The system is also likely to be activated lately because of a limited visibility due to vegetation (50%) that often prevents the radar from detecting the hazard.

5.3.21 RLBF - Rear Light Brake Force Display

RLBF fulfils 1.5% of accidented drivers' pivotal needs and corresponds to the following needs:

- B05 Detecting an obstacle moving slowly (0.6% of drivers' pivotal needs)
- B04 Detecting a fixed obstacle (0.3%)
- B13 Evaluating a catching up on a slower road user (0.2%)

- B18 Predicting that another user will stop or slow down (0.2%)
- B19 Predicting that another user will stop or slow down (0.1%)
- B20 Predicting the manoeuvre suited to the layout functioning (0.1%)

- **Endogenous limitations**

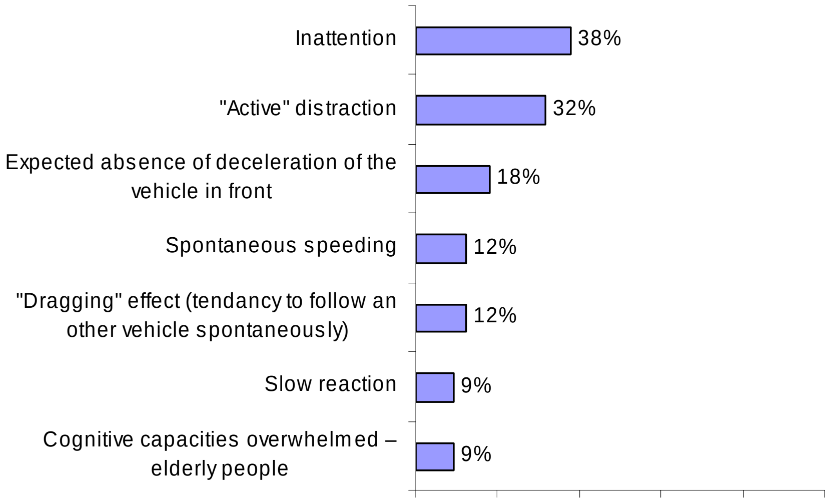


Figure 41: Endogenous limitations for RLBF

The main endogenous limitation to RLBF efficiency is inattention (38%) vis-à-vis the vehicle ahead.

In 32% of the cases, an "active" distraction has been identified for the driver, meaning that he has been executing a secondary activity not related to the driving task (discussion with a passenger, phoning, handling audio display…).

One of the other limits comes from a problem of expectation developed by the driver about the absence of deceleration of the vehicle ahead (18% of the cases).

- **Exogenous limitations**

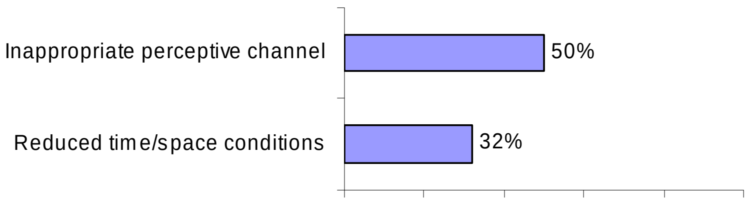


Figure 42: Exogenous limitations for RLBF

In half of the cases a use of inappropriate perceptive channel is likely to reduce RLBF effectiveness. In those cases the drivers would not detect the emergency braking of the vehicle preceding them because their attention was not oriented toward this object. This could be counteracted by a beep inside the vehicle.

The effectiveness of RLFB can be reduced by a low time/space rate (32%) between the moment when the RLBF switches on and the moment this alarm is identified by the driver and then starts braking. This will especially lower the efficiency of this aid if the inter-distance between the vehicles is short.

5.3.22 SAVE-U - Vulnerable Road Users Protection

SAVE-U matches 6.6% of pivotal needs which are described below:

- B05 Detecting an obstacle moving slowly (3.3% of drivers' pivotal needs)
- B07 Detecting a user on an intersecting course (1.7%)
- B09 Detecting a user outside the frontal field of vision (masked by something) (0.6%)
- B17 Predicting that another user will move off or fail to stop (0.4%)
- B04 Detecting a fixed obstacle (0.3%)
- B06 Detecting an oncoming user (in movement) (0.3%)

For these 6.6% of drivers, endogenous and exogenous limitations could lessen SAVE-U effectiveness.

- **Endogenous limitations**

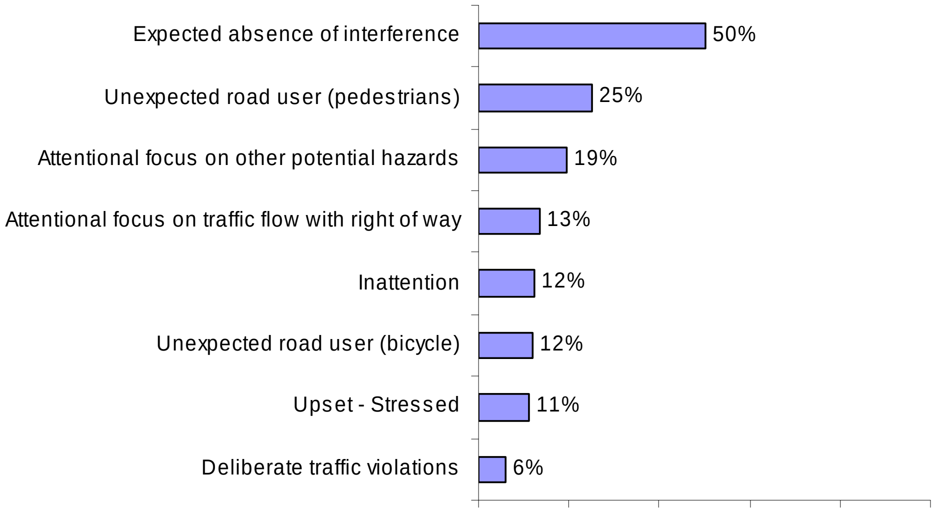


Figure 43: Endogenous limitations for SAVE-U

The effectiveness of the SAVE-U could mainly be restricted by the fact that the drivers do not expect to find a pedestrian or a bicycle at the specific location they happen to be (50%). Even if they look in their direction, they sometimes do not detect them (in 25% of the cases with pedestrians and 12% of the cases with bicycle).

A default of attention is also a source of limitation for this safety system (focus on other potential hazards: 19%; focus on traffic having right of way: 13%).

- **Exogenous limitations**

The effectiveness of SAVE-U can be limited, in 63% of the cases, by reduced time/space conditions between the moment the driver gets information on the presence of the pedestrian, processes these data, and the moment he initiates a braking or any other action of avoidance.

The radar/camera width is insufficient, in 14% of the cases, to allow detecting pedestrians located on the edge of the road and who initiated their crossing.

Few sources of limitations are related to visibility or lighting conditions (night: 12%; limited by infrastructure or vegetation: 10%; limited by the vehicle: 6%).

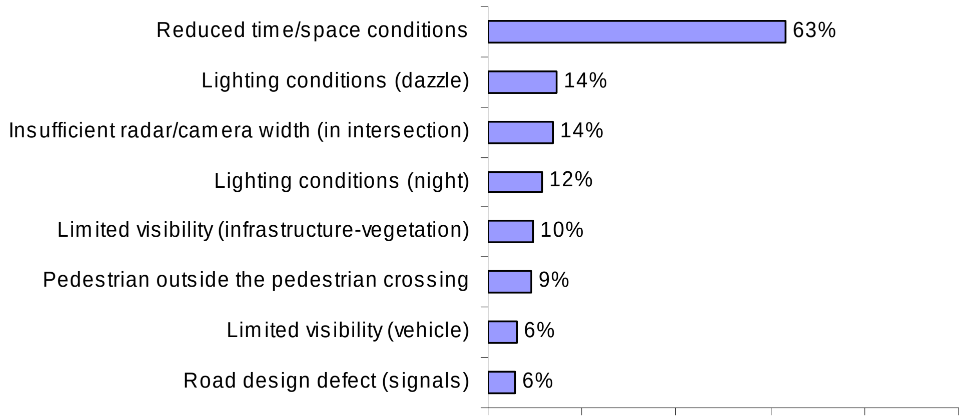


Figure 44: Exogenous limitations for SAVE-U

5.3.23 TPMS - Tyre Pressure Monitoring and Warning

TMPS is associated to 0.4% of accidented drivers' pivotal needs that happen to be:

- B02 Diagnosing vehicle state (mechanical) (0.4% of drivers' pivotal needs)

For this 0.4% of drivers, only endogenous limitations have been identified as lowering TPMS efficiency.

- **Endogenous limitations**

Two limitations are pointed out, both of them potentially preventing the system from any benefit at all. The first is related to motive for the journey and the other concerns the underestimation of danger. Both of them would lead the driver to not process the indication provided by the safety function.

5.4 Conclusion: potential limitations on safety functions optimality

This chapter is turned toward the critical aspects of driving reality which could impede the safety impact of safety functions. These critical aspects first take into account ergonomic consideration which should be integrated while conceiving any aid system devoted to human being. They secondly relate to the notion of "context" that gathers the whole driver (endogenous) and environment (exogenous) characteristics in which accident occur. Both of them can lead to potential limitations, and must be taken into account by the safety functions as constraints they should integrate if they are thought to be the most effective as possible.

Consequently a description of potential limitations is detailed. 92 types of limitations were distinguished for this study: 39 endogenous and 53 exogenous. It is interesting to notice that endogenous limitations are overrepresented in comparison to exogenous ones (i.e. the effectiveness of safety functions is more affected by driver's characteristics than by environment ones: 56% vs. 44%).

In the last part of this chapter, each of the 21 safety systems and their 5 variants is analysed with regard to these various limitations. For each aid, are given the endogenous and exogenous limitations that could lower the effectiveness of the considered system and is estimated the proportion to which they might lower it.

The next Chapter ('Response Efficiency") assesses the ability of the safety functions to cope with the limitations established in the present Chapter

6 Response efficiency of the safety functions to contextual limitations

In Chapter 3 ("Drivers Needs") have been delineated the needs of the drivers, as they are expressed by the human failures found in accidents.

In Chapter 4 ("Adaptation of Safety functions to drivers needs"), has been defined the ability of the safety functions studied in TRACE to address these needs (i.e. their potential capacity to answer the difficulties encountered by the drivers).

In Chapter 5 ("Limitations") have been outlined the different parameters found in the accident contexts which would need to be taken into account as far as they could impede such or such aspect of the safety function efficiency with regard to accidental reality.

The present chapter will analyse the consequences of these potential limitations on the function ability to tackle the problems.

6.1 Introduction

Therefore, two aspects are to be considered in the assessment of safety function effectiveness:

1- The fact that safety functions are more or less addressing such or such needs of the drivers; this aspect has been referred as the **adaptation of the safety function to drivers' needs** (cf. Chapter 4);

2- The fact that, each time a safety function has the potential to meet a need, this function is more or less able to compensate for it, considering both its functionalities and the potential limitations linked to accident context parameters. This second aspect of the assessment will be referred as to the **response efficiency of the safety functions.**

This second aspect is the focus of the present chapter. It analyses the influence of accident contextual parameters in their potentiality to lessen the effective capacity of the safety-function to compensate for drivers' needs. The next chapter will combine the two aspects mentioned above, so as to define the **safety functions effectiveness**, integrating their ability to meet the needs and their capacity to compensate for the limiting parameters of the context in which the needs are found.

6.2 Method to evaluate the "Response efficiency" of the safety-functions

For every safety function able to meet a need, we put forward a response efficiency cue (going from 10 % to 100%), taking into account the weight of the potential limitations defined in the previous chapter.

Precisely, when a need was identified in the accident cases, we looked among the 21 safety functions (and 5 variants envisaged) for which ones were able to meet this need. For each safety function that was adapted to the need we defined this response efficiency cue, taking into account the impact of the potential limitations according to the technical specifications of the function.

When the contextual parameters could not lessen the effective capacity of the safety function, we gave to the safety function a response efficiency cue of 100%; this means that the need will be totally fulfilled and the driver's failure would not emerge or be countered. Conversely, when the weight of the potential limitations was very important and liable to lessen the effective capacity of the safety function, we gave to the safety function a response efficiency cue of 10%. It means that the need will be very slightly answered and the driver's failure would certainly emerge, even with the help of the safety function.

This analysis took advantage of the cinematic reconstruction of the accident cases, together with the specifications of the safety functions.

For example, when the drivers manifest a need in "Diagnosing driver's condition" and when this need is met by the safety function AK (Alcolock Key), AK has a response efficiency of 98.5%. This means that the weight of the potential limitations is very slight in this case, and given the functionalities of AK the need "Diagnosing driver's condition" will be compensated in 98.5% of the accident cases when the function could apply.

It is important to notice that the safety-functions were evaluated independently the ones from the others. So, for one given need, two safety functions could be adapted; and if the first safety function had a response efficiency cue of 100%, the other one could also get a response efficiency cue of 100%.

Some safety functions won't have any response efficiency score because they would a priori never meet a pivotal need. It is the case for 3 of them (AAFS - Advanced Adaptive Front Light System, ACC3 – Co-operative Assistance System, TSR - Traffic Sign Recognition). But it has to be stressed that the functions can also meet some upstream needs (needs merging before the rupture situation) and /or some downstream needs (needs merging after the rupture situation). The scope of the present study is specifically addressing the drivers needs found at the pivotal moment of the accident (the rupture between a controlled situation and an uncontrolled situation). However, these upstream and downstream needs will be studied in a complementary analysis in chapter 7.

6.3 Response efficiencies of the safety functions

So the "response efficiency" is the estimated capacity of a function (given its specifications) to compensate for the potential limitations found in the accident contexts, as given in Chapter 5. Below are presented the responses efficiencies of each safety function studied in TRACE for the needs for which these functions are relevant[10]. The overall results of the evaluation of the response efficiencies of the safety functions when they able to meet the needs is presented in Annex (page 103).

- **ACC+ – Communication and brake -based Longitudinal Control System**

  With its capacity to inform the driver about a slowing down ahead, ACC+ has very good response efficiency when it meets needs in detection ahead :

  - 96.8% of response efficiency for the need "B04 Detecting a fixed obstacle on the road"
  - 88.8% for "B05 Detecting a slowly moving obstacle on the road".

  But this efficiency is a little bit lesser for needs in evaluation or prediction:

  - 61.8% of response efficiency for the need "B13 Evaluating a catching up on a slower road user"
  - 50.0% for "B18 Predicting that another user will slow down, stop or fail to disengage".

  This lower efficiency to meet needs in evaluation or prediction can be explained by the endogeneous limitations (such as "expected absence of deceleration of vehicle in front", "inattention", or "opposing action by the driver") which prevent the driver who do not identify directly the hazard, from understanding (or trust) the information given by the ACC+.

- **ACC1 – Information and warning system**

  Because of its capacity to inform the driver very early about a potential danger in a radius of 1000 meters, ACC1 has very good response efficiency when it meets needs in detection ahead:

  - 79.5% of response efficiency for the need "B04 Detecting a fixed obstacle on the road"
  - 100% for "B05 Detecting a slowly moving obstacle on the road".

- **ACC2 – Communication - based Longitudinal Control System**

  ACC2 meets the same needs as ACC+, but the response efficiency of ACC2 is lower than ACC+, because ACC2 only gives an information, whereas ACC+ is supposed to be able to brake.

  Because of its capacity to inform the driver about a slowing down in front, ACC2 has good response efficiency when it meets needs in detection ahead :

  - 71.4% of response efficiency for the need "B04 Detecting a fixed obstacle on the road"
  - 49.2% for "B05 Detecting a slowly moving obstacle on the road".

[10] Remind that the specifications of these functions (and variants in their functioning) can be found in Annex 3.

But, this efficiency is lesser for needs in evaluation or prediction:

- o 42.9% of response efficiency for the need "B13 Evaluating a catching up on a slower road user"
- o 40.0% for "B18 Predicting that another user will slow down, stop or fail to disengage".

This response efficiency of ACC2 (lower than ACC+, in general and particularly to meet needs in evaluation or prediction) can be explained by the potential limitation "Inattention" of the driver. This limitation could lessen the efficiency in 66% of cases when ACC2 were useful. This proportion is only of 16% for ACC+, as far as ACC+ braking can counteract the negative effect of inattention.

- **AK - Alcolock Keys**

As shown in the example quoted earlier, when drivers show a need in "Diagnosing driver's condition" and when this need is met by the safety function AK (Alcolock Key), AK has a response efficiency of 98.5%.

This response efficiency is one of the best of all the safety functions, but this result has to be moderated in case of potential misuse of the function. In fact we have assumed the person breathing in the system is the same than the one who is driving…

- **BA - Brake assist**

BA mainly meets the emergency need "B21 Controlling one's vehicle", with a response efficiency of 12.9%.

BA has poor response efficiency when it meets pivotal needs in prediction:

- o 10.0% of response efficiency for the need "B17 Predicting that another user will pull out or fail to stop"
- o 10.0% for the need "B20 Predicting the appropriate manoeuvre for the functionning of the site"

These weak response efficiencies are essentially due to the weight of endogenous and exogenous limitations: In 60% of cases when BA could meet these needs, the reduced time/space conditions might have impeded the capacity of BA to avoid the accident or to reduce accident consequences. In 40% of the cases, drivers brake lately because of an active distraction (look at the passenger, search something in the car, etc.) or because of their cognitive capacities being overwhelmed ("freezing reaction").

- **BS - Blind Spot Detection**

With the camera-based monitoring system detecting vehicle travelling in blind spot, BS has good response efficiency (50.0%) when it meets the need "B09 Detecting a user outside the frontal field of vision (masked by an object)".

BS has also good response efficiency when it meets need of predicting his/her own manoeuvre or the manoeuvre of an other user:

- o 50.0% of response efficiency to meet the need "B19 Predicting the manoeuvre of another user or pedestrian".
- o 50.0% of response efficiency to meet the need "B20 Predicting the appropriate manoeuvre for the functioning of the site".

This mitigation is essentially due to the weight of the following limitations:

As agreed with WP6, we assume the BS capture zone is up to 9.5 meters by 3.0 meters. This capture zone is not large enough for giving a warning every times, and in 54% of cases the time/space conditions are reduced between the moment of the warning and the moment of the collision.

Another limitation acting on the response efficiency of BS is the poor pinpointing of the source of the information : the side mirror is not looked by the driver in 48% of the cases, and a signal put on the mirror could be missed the same way.

BS response efficiency is also diminished by the expected absence of interference which impede the driver from looking for the relevant information, essentially for the powered two-wheelers which are even less expected.

- **CA - Collision Avoidance**

Thanks to its capacity to inform the driver about a obstacle in front, and eventually brake if necessary, CA has very good response efficiency when it meets a need in vehicle control :

  - 100.0% of response efficiency for the need "B21 Controlling one's vehicle", to avoid the vehicle ahead.

CA has good response efficiency when it meets needs in detection in front:

  - 76.3% of response efficiency for the need "B04 Detecting a fixed obstacle on the road"
  - 59.4%. for the need "B05 Detecting a slowly moving obstacle on the road"
  - 50.0% of the need "B03 Detecting an unexpected road difficulty"

CA has also good response efficiency when it meets a need in evaluation :

  - 61.8% of response efficiency for the need "B13 Evaluating a catching up on a slower road user", when the driver have seen the vehicle in front but do not have evaluated properly his or her catching up.

- **CBC - Cornering Brake Control**

When CBC has the capacity to meet the need "B21 Controlling one's vehicle" (the only need CBC meets), CBC has a response efficiency of 53.9%. This mitigated efficiency is essentially due to exogenous limitations found in accident cases such as: underflated tyre, strong dynamic stress (speed) and reduced friction coefficient (wet road).

- **CW - Collision Warning**

CW meets essentially the same need as those met by CA, but with lower efficiency because CW only informs the driver and cannot brake.

The best efficiency reached by CW is when it meets need in detection or evaluation of a danger ahead:

  - 55.2% of response efficiency for the need "B04 Detecting a fixed obstacle on the road"
  - 52.0% of response efficiency for the need "B13 Evaluating a catching up on a slower road user"

Response efficiency of CW is essentially reduced by the exogenous limitation "reduced time/space condition" (in 62% of cases) and the endogenous limitation "expected absence of interference" in 39% of cases.

- **DDS - Drowsy Driver Detection System**

Because of its detection of eyes closure, DDS has the capacity to meet the need «"B01 Diagnosing driver condition" (loss of vigilance due to alcohol, fatigue, health, attention, etc.). But DDS has a relative response efficiency of 42.7%. This weakness can be essentially explained by endogeneous limitations: in 43% of cases, the motive the journey is so important for the driver that the warning could be not accepted. Other endogenous limitations potentially impeding the response efficiency are "already recognised fatigue", "influence of alcohol" and when the drowsiness goes up to "falling asleep".

Eyes closure can also be accompagned with a deviation from path. So DDS has the capacity to meet the need "B10 Detecting deviation from the path", with a response efficiency of 50.0%, as far as such a failure is often connected with drowsiness.

In 8% of cases, weak lighting conditions of night could have impede the response efficiency of DDS, because the driver's face is not enlighted and eyes closure can be not detected. So, it is important that eyes closure detection is coupled with other devices for the detection of drowsiness, like lane keeping, steering wheel movements, and so on.

- **DS - Dynamic Suspension**

By varying the amount of torsional stiffness in the front and rear stablized bar, DS has sometimes the capacity to meet the need "B21 Controlling one's vehicle" (the only need DS meet), with a response efficiency of 27.1%.

This response efficiency could be lessen notably when the vehicule has also an important under inflated tyre problem.

- **ESP - Electronic Stability Program**

ESP has the capacity to meet only one pivotal need «"B21 Controlling one's vehicle" with a response efficiency of 54.0%. This efficiency to compensate for the driver's handling problem is essentially diminuished by strong dynamics stresses and reduced adherence.

- **IC - Intersection Control**

For all needs met by IC, the response efficiency is diminuished by the endogenous limitation "expected absence of interference" (in 48% of cases) and by exogeneous limitation "reduced time/space condition" (in 35% of cases).

IC has the capacity to meet the need in detection "B09 Detecting a user in the forward field of vision (masked by an object)", with a response efficiency of 58.0%. It is an encouraging sign because drivers who identify the mask would be able to get over their first judgment and proceed to a second information gathering.

Two other needs in detection can be met by IC, but with a lesser response efficiency, essentially because of endogeneous limitations "feeling of right of way" and "expected oncoming user's regulation" :

- o 44.2% of response efficiency for the need "B06 Detecting an oncoming user in one's lane (moving)",
- o 43.9% of response efficiency for the need "B07 Detecting a user on an intersecting course".

IC has also the capacity to meet the need for anticipation "B20 Predicting the appropriate manoeuvre for the functioning of the site", with an estimated response efficiency of 57.5%. This result is particularly useful for older drivers, drivers who do not know the intersection, and for complex intersections.

In addition, IC has the capacity to meet the need "B16 Assessing gaps when merging into or cutting across traffic", with a response efficiency of 46.4%. This result shows that IC is also relevant for inattentive or distracted drivers, and for beginners and old drivers who have difficulties in assessing gaps. But these driver's characteristics also involve potential limitations by themselves…

- **ISA1 - Intelligent Speed Adaption: Advisory System**

Results are rather disappointing about the response efficiency of adapting speed to the road conditions:

- o 23.7% of response efficiency for the need "B11 Adapting speed to the road - 1: road geometry"

- No capacity to compensate for the need "B12 Adapting speed to road network - 2: legislation".

This weak efficiency is essentially due to the advisory mode. The principal limitation to the efficiency are endogeneous: drivers could not proccess the advice, because they have speed-related motive (52% of cases), because they know well the itinary (in 29% of cases). But it must be reminded that such a function can also be operational beforehand. The response efficiency of Advisory ISA described above has been evaluated for drivers for whom the need to adapt their speed had directly cause their failure, and so the accident.

In 19% of cases, there are 2 exogenous limitations: unsufficient regulation in bend and reduced adherence linked to the wet road. This shows the limit of ISA (1, 2, and 3 in general), to give to the driver a relevant indication about the possible acceleration of the vehicule in curve or on varying road surfaces.

This result does not mean Advisory ISA is not usefull. But this usefullness is not directly operating at the accident situation. In fact, Advisory ISA has better response efficiency for further upstream needs (cf Table 15, page 104). As a consequence, such a function can be thougt as acting more preventively, in a sense of precaution rather than accident avoiding.

- **ISA2 - Intelligent Speed Adaption : Voluntary System**

Results are still rather disappointing about adapting speed to the road conditions, in the volontary variant of the function:

- 22.5% of response efficiency for the need "B11 Adapting speed to the road - 1: road geometry"
- 13.8% of response efficiency to tackle the need "B12 Adapting speed to road network - 2: legislation".

Voluntary ISA has also the capacity to compensate the need for anticipation "B20 Predicting the appropriate manoeuvre for the functioning of the site", with a response efficiency of 20.0%.

The weak response efficiency of Voluntary system of ISA can essentially be explained by the fact that in 61% of cases, accidented drivers would probably have disconnect the system because it didn't fit with their objective of going fast. And in 45%, they would certainly use the "kick down" function which enables the driver to temporary override the system by an action of acceleration.

- **ISA3 - Intelligent Speed Adaption : Mandatory System**

ISA3 meets the same needs as ISA2, but with a better response efficienc, directly due to the fact that it would operate more systematically:

- 40.9% of response efficiency for the need "B11 Adapting speed to the road - 1: road geometry"
- 32.5% of response efficiency to fulfil the need "B12 Adapting speed to road network - 2: legislation".
- 50.0% of response efficiency to fulfil the need "B20 Predicting the appropriate manoeuvre for the functioning of the site".
- This function would notably be very useful for predicting the appropriate speed when entering an agglomeration.

Among the 3 ISA systems, Mandatory system is the one having the best results, because ISA3 have the advantages of ISA2 (i.e. automatic restriction of the engine's fuel injection which directly decreases the speed) but not the inconvenient (the driver is not allowed to enable or disable control). It shall nevertheless be reminded that a compulsory mode is always more difficult to be accepted, even more when dealing with an activity for which "freedom" in the first motive…

- **LCA - Lane Changing Assistant**

With its monitoring of traffic approaching behind and in the driver's blind spot, LCA has the capacity to meet the need in detection: "B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)", but with a rather low response efficiency of 38.1%.

One observes a surprisingly weak result for the needs concerning the voluntary change of lane:

  - 35.6% of response efficiency for the need "B16 Assessing gaps when merging into or cutting across traffic"
  - LCA have not the capacity to fulfil the pivotal need "B15 Assessing gaps when overtaking or changing lanes".

This weak response efficiency is due to endogeneous and exogeneous limitations: limitations proper to LCA are the reduced time/space condition and the poor pinpointing of the warning: in 41% of cases: drivers who do not detect a hazard behind or in his or her blind spot, do not look into their exterior side miror.

This poor response efficiency of LCA can also be explianed by endogeneous limitations, such as expected absence of interference, attentional focus on another potential hazard, weak expectancies developped as regard as powered two-wheelers.

Results are better when drivers show an hesitation in the accident context: for the need "B20 Predicting the appropriate manoeuvre for the functioning of the site", LCA has response efficiency of 50.0%.

Surprisingly, LCA has a response efficiency of 50.0% when it has the capacity to meet the need "B10 Detecting deviation from the path". Whereas the purpose of LCA is not to detect deviation from path (LKA had been imaginated for that), when the deviation brings the driver to move dangerously close to other vehicules in blind spot, LCA has the capacity to inform the driver. But, response efficiency is still weak because of the same limitations as above.

- **LKA - Lane Keeping Assistant**

When LKA has the capacity to meet the need "B10 Detecting deviation from the path", LKA has a response efficiency of 48.7%. Response efficiency that could be lessened by active distraction or inattention of the driver who do not process the relevant informations from the road scene.

The unexpected result is that LKA has the capacity to meet the need "B01 Diagnosing driver condition (alcohol, fatigue, health, attention, etc.)", with a response efficiency of 40.0%. In addition of detecting the deviation from the path, LKA would allow the drivers to diagnose the reason of the deviation, making them aware of their condition.

- **NV - Night Vision**

Because of its head-up display, NV has the capacity to fulfil the need "B04 Detecting a fixed obstacle on the road", with a good response efficiency of 56.8%. Limitations which could impede the response efficiency are the reduced time/space conditions betwwen the moment the driver identifies the obstacle and the moment of the collision.

NV has also a good response efficiency of 60.0%, when it meets the need "B17 Predicting that another user will pull out or fail to stop", because in these cases, driver has identified the danger (i.e. another driver on an intersecting course) , NV will permit the driver to confirm his or her diagnosis.

NV has lesser response efficiency for more unexpected hazard:

  - 27.2%. of response efficiency for the need "B05 Detecting a slowly moving obstacle on the road"
  - 10.0% for the need "B06 Detecting an oncoming user in one's lane (moving)",

- 23.3% for the need"B20 Predicting the appropriate manoeuvre for the functioning of the site".

These poor response efficiencies can be explained by the expected absence of interference (in 57% of cases), by the poor interpretation of what will be displayed by NV, active distraction, and uncontrolled reaction due to surprise.

- **PBA - Predictive Brake Assist**

When PBA has the capacity to meet the need "B17 Predicting that another user will pull out or fail to stop", (the only need PBA meet), PBA has a response efficiency of 15.0%. This low efficiency is essentially due to its capacity of detection (i.e. the radar of ACC). The sensors may be affected by the poor lighting conditions of the night (50% of cases), or/and by vegetation. Moreover, the gain in braking of 0.2 second is often insufficient when the driver has a feeling of right of way and brakes too late.

- **RLBF - Rear Light Brake Force Display**

When RFBF has the capacity to meet the need "B18 Predicting that another user will slow down, stop or fail to disengage", RLBF has a response efficiency of 50.0%.

This result can be explained by endogenous limitations: when drivers show this need, they are sometimes inattentive (38% of cases) or have an "active distration" (32% of cases) and could not see the increased intensity of the brake light. This leeds to a limitation proper to the safety function: the inappropriate perceptive channel, in 50% of cases.

- **SAVE-U - Vulnerable Road Users Protection**

When SAVE-U has the capacity to meet the need «"B04 Detecting a fixed obstacle on the road", SAVE-U has a very satisfying response efficiency of 90.0%.

The response efficiency is lesser for the following needs:

- "B05 Detecting a slowly moving obstacle on the road", 55.5% of response efficiency,
- "B07 Detecting a user on an intersecting course", 41.3% of response efficiency.

This loss of efficiency could be explained by the insufficient radar/camera width in intersection, that may impede the system to detect pedestrian or bike at intersection. Lighting conditions like dazzle or night could also impede this efficiency. The main endogenous limitation is the expected absence of interference, particularly concerns poorly expected road users such as pedestrians or bicycles.

- **TPMS - Tyre Pressure Monitoring and Warning**

When TPMS has the capacity to meet the need "B02 Diagnosing vehicle condition (mechanical)", TPMS has a response efficiency of 50.0%.

This result is due to the fact that in every cases, driver could not process the information given by TPMS, because he or she has an itinary-related motive or is unaware of the danger related to pressure fluctuation.

But, this result does not mean TPMS is not usefull. The information given by TPMS is of course important at an upstream level (i.e. before the rupture situation).

6.4 Conclusion on the response efficiency of the safety functions

We can recall the top 5 safety functions in tem of their response efficiencies:

- **ACC+ – Communication and brake -based Longitudinal Control System:** when ACC+ has the capacity to meet the needs "B04 Detecting a fixed obstacle on the road" and "B05 Detecting a slowly moving obstacle on the road", ACC+ has a response efficiency of respectively 96.8% and 88.8%.

- **ACC1 – Information and warning system:** when ACC1 has the capacity to meet the needs "B04 Detecting a fixed obstacle on the road", and "B05 Detecting a slowly moving obstacle on the road", ACC1 has a response efficiency of respectivly 79.0% and 100.0%.

- **AK - Alcolock Keys:** when AK is able to meet the need "Diagnosing driver's condition" AK has a response efficiency of 98.5%.

- **CA - Collision Avoidance:** when CA has the capacity to meet the needs "B04 Detecting a fixed obstacle on the road" and "B21 Controlling one's vehicle", CA has a response efficiency of respectively 76.3% and 100.0%.

- **SAVE-U - Vulnerable Road Users Protection:** when SAVE-U has the capacity to meet the need «B04 Detecting a fixed obstacle on the road», SAVE-U has a response efficiency of 90.0%.

Some others will need improvements in their capacity to compensate for the conditions in which accidents are found, following the recommendations which are expressed in detail in this chapter.

Nevertheless, the response efficiency has to be put in relation with the frequency of the cases when the functions are able to apply, in order to assess the safety effectiveness of these functions. This assessment is the purpose of the following chapter.

7 Safety function effectiveness

Let us remind that the present study is specifically focused on the human aspects involved in accident producing and the capability to support them by safety devices. In line with this purpose, the safety function effectiveness will be defined as the capacity of the functions to compensate for the drivers needs. By such doing, this effectiveness also represents their ability to avoid the human failure to occur, and consequently to prevent the accident to happen. The assessment of this effectiveness to compensate for drivers needs is the object of the present chapter.

Safety function effectiveness is an indication of capacity which combines:

1- The ability of the functions to meet the drivers needs (proportion of drivers needs covered by the function, as being stated in Chapter 4)

2- The response efficiency of the safety functions (efficiency to compensate for contextual constraints). This efficiency has been defined in the previous chapter (Chapter 6) by taking into account the potential limitations in the effectiveness of the functions due to contextual constraints (cf. Chapter 5).

This indication of the effectiveness of the safety function is so the result of the following procedure:

Safety function effectiveness = % of pivotal needs met **X** % of response efficiency

This chapter is separated in 3 sections:

1- First, will be presented the effectiveness of each safety function at the different moments of the accident process (upstream, rupture and emergency phases). These results will be useful to define which functions are the most adapted to compensate for drivers needs and which ones require improvements in that purpose.

2- Then, will be presented the safety effectiveness of the functions for each need. This section will permit to see which needs are well covered by the safety functions, and which ones deserve more efforts from the technology.

3- Lastly, suggestions will be presented in the purpose of improving the efficacy of safety functions for compensating drivers' needs.

7.1 Safety effectiveness of the functions

Tables presented below integrate the result gained from Chapter 4 “Adaptation of Safety Functions to Drivers Needs” and Chapter 6 “Response efficiency of safety functions to contextual limitations”, in order to calculate the safety effectiveness of each safety function, i.e. their capacity to address drivers needs and their capacity to compensate for the contextual constraints in which these needs are found.

The first table (Table 6) accounts for the capacity of the functions to fulfil the pivotal needs, i.e. the needs corresponding to the human functional failures ("errors") found at the rupture phase of the accident process. As stated in TRACE WP5 deliverable D5.1, these failures are those which turned a difficult situation met by a driver into an accident sequence.

Table 6: Capacity of the safety functions to meet pivotal needs, their response efficiency and safety effectiveness to compensate for them (n=432 pivotal needs)

PIVOTAL NEEDS and SAFETY FUNCTIONS	Capacity of safety functions to meet pivotal needs (n=432)		Response efficiency of the safety functions	Safety effectiveness
	n	%	[10-100%]	(%)
AAFS	0	-	-	-
ACC+	21	4.8	75.2	3.6
ACC1	8	1.9	82.1	1.6
ACC2	15	3.4	51.4	1.7
ACC3	0	-	-	-
AK	25	5.7	98.5	5.6
BA	2	0.5	10.0	0.0
BS	19	4.3	38.0	1.6
CA	137	31.6	44.6	14.1
CBC	6	1.3	53.9	0.7
CW	114	26.4	33.8	8.9
DDS	28	6.6	42.9	2.8
DS	2	0.5	27.1	0.1
ESP	36	8.3	54.0	4.5
IC	125	29.0	42.4	12.3
ISA1	8	1.9	22.4	0.4
ISA2	15	3.5	20.5	0.7
ISA3	18	4.2	39.8	1.7
LCA	18	4.2	38.6	1.6
LKA	21	4.9	42.8	2.1
NV	20	4.6	36.7	1.7
PBA	2	0.6	15.0	0.1
RLBF	7	1.5	16.7	0.3
SAVE-U	28	6.6	47.7	3.1
TPMS	2	0.4	50.0	0.2
TSR	0	-	-	-
	675	**156.7**	**44.4** (mean**)**	**69.4**

Lecture of the table:

For example, the safety function CA has the capacity to meet 137 pivotal needs out of 432 needs diagnosed from human failures found in accident cases. So, CA is potentially addressing 31.6% of drivers' pivotal needs. But the same function only fulfils these needs with a response efficiency of 44.6% on average. As a consequence, the safety effectiveness of CA is considered to be potentially 44.6 % of 31.6% = 14.1%. It means that the function has the capacity to compensate effectively for 14.1% of the whole drivers' pivotal needs. In other words, the introduction of CA in the driving system would allow avoiding 14.1% of human failures which were diagnosed as switching a critical situation into an accident situation.

As a whole it can be seen that the response efficiency of the functions, when they are able to meet needs, is 44.4 %. This result figures out the global capacity of the functions to compensate the internal and external constraints characterizing accident contexts. In other terms, some progresses can be done in their technical specifications in order to fit more with the limiting parameters found in accidental reality.

Dealing with safety effectiveness of the functions, i.e. their capacity to meet the needs corrected by their capacity to compensate for the limitations, the global figure of 69,4 % must be taken cautiously as far as some functions are overlapping, addressing the same driver need (as shown in the table, they globally meet 156,4 % of the needs). That is why these results must be preferably examined function by function than globally, to get a better estimation of their capacity.

Safety functions which show the best safety effectiveness in compensating for pivotal needs are CA, IC, CW, AK and ESP:

- CA - Collision Avoidance: safety effectiveness of 14.1% of the whole drivers' needs

This safety effectiveness is essentially due to the great capacity of CA to meet various needs: 14 different kinds of need out of a list of 22 needs, resulting in CA being able to meet 31.6% of all drivers' pivotal needs. But only half of these needs are met with good response efficiency (i.e. superior or equal to 50% of response efficiency, cf. Table 14 in Annex 2 page 103). So, this safety effectiveness will essentially account for compensating "B04 Detecting a fixed obstacle on the road" and "B05 Detecting a slowly moving obstacle on the road", because these 2 needs are frequently met by CA, and with good response efficiency (cf. Table 18, in Annex 2).

- IC – Intersection Control: safety effectiveness of 12.1%.

IC has the same configuration as CA, in that it is adapted to a wide range of needs (29.0% of all drivers' pivotal needs) but with medium response efficiency. According to our result, IC have the best safety effectiveness to fulfil "B07 Detecting a user in an intersecting course" and "B20 Predicting the appropriate manoeuvre for the functioning of the site" because these 2 needs are frequently met by IC and with a good response efficiency (cf. Table 18, in Annex 2).

- CW – Collision Warning: safety effectiveness of 8.9%.

Like the 2 previous safety functions, CW meets a lot of various needs. But CW has a response efficiency higher than 50% for only 2 kinds of needs, and only one of which represent many drivers. The safety effectiveness of CW will be essentially for meeting the need "B05 Detecting a slowly moving obstacle on the road".

- AK – Alcolock Keys: safety effectiveness of 5.6%.

AK is in a different configuration than the 3 previous safety functions in that it only meets one need ("B01 Diagnosing driver condition") which represents only 5.7% of drivers' pivotal needs, but with very high response efficiency: 98.5% of capacity to compensate the needs for which the AK is adapted.

- ESP – Electronic Stability Program: safety effectiveness of 5.5%.

Like AK, ESP only meets one pivotal need ("B21 Controlling one's vehicle"), which represent 8.3% of drivers' pivotal need, and is able to compensate this need with 54% of efficiency.

But it is important to complete these results by considering the safety functions effects on drivers' needs which appear further upstream and downstream the accident/rupture phase.

The capacity of the functions to satisfy drivers needs found before the accidental degradation are presented on Table 7. These needs correspond to the driving phase, i.e. the moment just preceding the rupture event leading to the accident. Even if the resolution of these needs is not a direct response to safety problems found by drivers, it can act in the sense of preventing drivers from meeting theses problems. That is why we also searched to assess the capacity of the functions studied in the frame of TRACE project to compensate for these upstream 'preventive' needs.

Table 7: Capacity of the safety functions to meet upstream needs, their response efficiency and safety effectiveness to compensate for them (n=86 upstream needs)

UPSTREAM NEEDS and SAFETY FUNCTIONS	Capacity of safety functions to meet upstream Needs (n=86)		Response efficiency of the safety functions	Safety effectiveness
	n	%	[10-100%]	(%)
AAFS	1	0.9	20.0	0.2
ACC+	1	0.9	100.0	0.9
ACC1	1	1.1	50.0	0.5
ACC2	1	0.9	50.0	0.5
ACC3	0	-	-	-
AK	2	2.8	100.0	2.8
BA	0	-	-	-
BS	5	5.7	46.9	2.7
CA	6	7.2	59.4	4.3
CBC	0	-	-	-
CW	8	9.6	27.7	2.6
DDS	2	1.8	34.0	0.6
DS	0	-	-	-
ESP	0	-	-	-
IC	17	19.3	40.4	7.8
ISA1	11	12.8	25.0	3.2
ISA2	22	25.8	22.3	5.7
ISA3	24	28.6	51.2	14.6
LCA	5	5.7	46.9	2.7
LKA	1	0.9	80.0	0.7
NV	4	4.9	19.8	1.0
PBA	0	-	-	-
RLBF	0	-	-	-
SAVE-U	1	1.6	31.4	0.5
TPMS	0	-	-	-
TSR	2	2.5	20.0	0.5
Total	**114**	**133.0**	**39.0**	**51.9**

It can be seen at Table 7 that ISA3 (Mandatory) reaches the best safety effectiveness with upstream needs, 14.6% of them being compensated. This safety function notably meets a quarter of upstream needs in speed regulation (B11 and B1), and has a response efficiency exceeding 50%.

Overall speaking the figures shows a lower efficiency (39 %) of the functions to compensate for limitations than it was the case for pivotal needs. As a consequence the whole functions are able to compensate for a less part (51,9%) of these upstream needs that drivers manifest before entering the real accidental sequence (not forgetting the overlap of some functions to meet some needs).

As mentioned above, such assistance, even if not directly struggling against human functional failures, can lower the risk for the driver to entering an accidental sequence following a logic of preventing driving.

It has also to be considered the capacity of the functions to help the driver in the emergency situation. In fact, even if the main purpose of this report is turned toward preventive safety as a mean to fight again human functional failure production, some functions still have the ability to help the driver at the moment when he tries to recover from his failure. This so-called downstream effect (i.e. at the emergency phase following the rupture phase) is presented on Table 8.

Table 8: Capacity of the safety functions to meet emergency needs, their response efficiency and safety effectiveness to compensate for them (n=142 emergency needs)

EMERGENCY NEEDS and SAFETY FUNCTIONS	Capacity of safety functions to meet emergency Needs (n=142)		Response Efficiency of the safety functions	Safety Effectiveness
	n	%	[10-100%]	(%)
AAFS	0	-	-	-
ACC+	17	11.9	30.8	3.6
ACC1	0	-	-	-
ACC2	0	-	-	-
ACC3	0	-	-	-
AK	0	-	-	-
BA	46	32.5	12.9	4.2
BS	0	-	-	-
CA	24	16.8	45.3	7.6
CBC	6	4.6	50.0	2.3
CW	2	1.2	20.0	0.2
DDS	0	-	-	-
DS	0	-	-	-
ESP	52	36.4	52.0	18.9
IC	0	-	-	-
ISA1	0	-	-	-
ISA2	1	0.6	20.0	0.1
ISA3	1	0.6	40.0	0.2
LCA	0	-	-	-
LKA	2	1.4	28.0	0.4
NV	0	-	-	-
PBA	23	16.6	34.3	5.7
RLBF	0	-	-	-
SAVE-U	2	1.8	10.0	0.2
TPMS	5	3.7	26.6	1.0
TSR	0	-	-	-
Total	**181**	**127.9**	**34.8**	**44.5**

12 functions still have a potential capacity to address needs downstream the accident phase. In this emergency situation, the 2 functions ESP and CA show a strong capacity to compensate for drivers needs when they are trying to perform a corrective manoeuvre. ESP notably must be regarded as an important function at this stage of the accident process, with a safety effectiveness of 18.9% to compensate for the drivers emergency needs (while it accounted for 4.5 % for the pivotal needs).

In Annex 2, will be found 3 tables presenting in detail the safety effectiveness for each safety function, for each need, upstream, in rupture (pivotal) and emergency.

7.2 Drivers needs compensated by the functions effectiveness

Below are presented the same results as above but on the reverse angle: which needs are well or less well answered by the functions. Such a view will allow showing the progress which have still to be dome in order to fit more closely for all the safety drivers needs at the different stages of the accident (in rupture but also upstream and downstream).

- Drivers' needs which are the most compensated by the safety functions are:

B01 Diagnosing driver condition (alcohol, fatigue, health, attention, etc.)

Upstream: by AK (2.8% of safety effectiveness)

In rupture: by AK (5.6% of safety effectiveness) and DDS (2.7% of safety effectiveness)

B03 Detecting an unexpected road difficulty

Upstream: by IC (2.3% of safety effectiveness)

B04 Detecting a fixed obstacle on the road

In rupture: by CA (2.1% of safety benefit)

B05 Detecting a slowly moving obstacle on the road

In rupture: by ACC+ (2.2% of safety benefit), CA (5.0% of safety benefit) and CW (2.3% of safety benefit)

B07 Detecting a user on an intersecting course

Upstream: by IC (4.3% of safety effectiveness)

In rupture: by IC (5.6% of safety effectiveness)

B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)

Upstream: by BS (2.7% of safety effectiveness) and by LCA (2.7% of safety effectiveness)

B11 Adapting speed to the road - 1: road geometry

Upstream: by ISA3 (2.9% of safety effectiveness)

B12 Adapting speed to road network - 2: legislation

Upstream: by ISA1 (2.1% of safety effectiveness), by ISA2 (3.3% of safety effectiveness) and by ISA3 (9.8% of safety effectiveness)

B17 Predicting that another user will pull out or fail to stop

In rupture: by CA (1.9% of safety effectiveness) and by IC (1.8% of safety effectiveness)

B21 Controlling one's vehicle

In rupture: by ESP (4.5% of safety effectiveness)

Emergency: by ESP (18.9% of safety effectiveness), by CA (6.8% of safety effectiveness), by PBA (5.7% of safety effectiveness), by BA (4.2% of safety effectiveness), by ACC+ (3.6% of safety effectiveness) and by CBC (2.3% of safety effectiveness)

- On the opposite way, "critical" needs which are the less answered, and on which engineers will have to be attentive, are:

B15 Assessing gaps when overtaking or changing lanes

No safety function has the capacity to meet this need when it appears in rupture (pivot). When it appears sufficiently early in the accident sequence, CA and CW can sometimes be useful, but for a very limited proportion of needs (respectively, 1.9 and 0.4 % of safety effectiveness).

B02 Diagnosing vehicle condition

This need is rarely a pivotal need. Problems with vehicle state most often contribute to another more important failure. Anyway, only TPMS has the capacity to meet this need. Moreover, when TPMS meets this need, its efficiency is relative considering the potentiality that driver, unaware of the actual danger connected to the tyre pressure, would take the information with relativity.

B12 Adapting speed to road network - 2: legislation

In rupture, this need is weakly compensated by ISA2 (0.1% of safety effectiveness) and by ISA3 (0.2% of safety effectiveness), and not at all by ISA1 (0.0% of safety effectiveness). Automatic deceleration seems necessary to avoid human failure at rupture situation, even if information (ISA1) may be useful further upstream in a sense of precaution more than prevention.

8 Conclusion

The analysis put forward in the present deliverable is specifically devoted to a human-centred approach on drivers' needs diagnosed from accidents analysis and on the capacity of safety functions to meet these needs. It shall be viewed as complementary to the other evaluations realized in TRACE, more devoted to the cinematic and technical aspects regarding safety functions benefit and possibilities. Moreover, the work put forward develops an operational investigation based on the data effectively gained on the accident production process in the frame of in-depth accident study. It does not addresses overall parameters such as general opinions and attitudes towards safety and ITS, behavioural adaptation, etc., all variables needing other kinds of data and other kinds of studies, experimental or 'naturalistic', in order to be analysed (Reagan, 2006). So the purpose of this deliverable is to bring an added value to the evaluations which are made of the appropriateness of safety functions to road users' safety problems, as they can be precisely and undoubtedly diagnosed from in-depth accident data.

Evaluating the capacity of electronic safety functions to compensate for, or mitigate, the impact of road accidents is one of the main purposes of the European TRACE project. Work done toward this purpose is specifically inscribed in the WP4 of this project. The principle behind the assessment performed inside this WP is twofold. It first deals with '*a priori* evaluation' of the potential benefit of safety functions under the hypothesis they were equipping cars. This prospective method, also referred in the literature as '*ex ante*', allows determining the strength and weaknesses of the safety systems on study before they are already implemented. The second method, more classical, is based on an *a posteriori* (or *ex post*) assessment of the safety benefit offered by systems actually equipping the vehicles.

Thus, the present D4.1.5 report constitutes a specific contribution to the first trend, presenting a prospective analysis directed toward road user's needs, as they are expressed through accidents. It develops an original human centred approach which contributes to the other evaluations done in the frame of TRACE WP4 (e.g. report D4.1.4). It develops an in-depth case by case analysis allowing taking into account the true difficulties found by drivers and the accident context reality in the assessment of the potential appropriateness of safety systems.

As a result, the in-depth analysis of drivers' failures expressed in accident scenes, following the method put forward in TRACE WP5 ("Human Factors"), has allowed in a first step the precise definition of the drivers' needs in safety the most crucial to address, whether they correspond or not to a technological device.

In a second step, the most promising safety functions defined in TRACE WP6 have been evaluated as regard to their adaptation to the needs diagnosed above. The overall result gives an optimistic figure of 85% of drivers' needs potentially met by the functions. This result can be regarded as an ideal representing the potentiality of the systems if working in a perfect world.

But in the accident world there are possibly lowering parameters that have to be taken into account. Therefore a third step of analysis has been performed in order to define the contextual constraints found in accident reality, whereas they deal with human parameters (behaviour, attitude, etc.) or with external limitations (space, time, velocity, etc.), which could lessen the ideal performance of each function regarding their ability to compensate for drivers' difficulties.

Then is analysed, function by function, their potential capacity to compensate for these constraints, considering their specifications. The results show the potential drawbacks and weaknesses of each function when confronted with actual accident contexts. They allow, in turn, defining the parameters that these functions should integrate in order to maximise their safety benefit.

By integrating 1) adaptation to drivers' needs and 2) capacity to compensate for accident contextual constraints, the last step of the study establishes the safety effectiveness of each function. An overall result gives a figure of 52% of capacity of these functions to compensate for drivers' needs. The detailed results give indications on the parameters to integrate for improving the potential safety effectiveness of the functions studied as regard to drivers needs found in accidents.

By showing the gap between the potential optima and the possible limits of the safety functions, such a research work is not so much directed toward telling what the future will be, than toward defining how this future would be better. Following such an 'Ergonomics of conception' trend, the present study contributes to the efforts done in TRACE project in direction of a significant safety increase inside the overall driving system.

The added value on this analysis is that it brings helpful input on the real difficulties found by drivers in accident contexts, to which electronic function could compensate for Of course this research work needs additional works in the purpose of progressing toward a safe driving system, with other data and other methods, addressing the technological, ergonomic, psychological and sociological aspects to consider when implementing a disposal in an integrated task

Strong efforts are notably to be put on the technical aspects to improve for these electronic devices to be efficient. For example, a well known overall essential question that is addressed to most of the safety functions remains the capacity to get reliable information on friction capacity (road surface adherence) allowing to setting up the appropriate action to initiate on the wheels. The estimation of the 'friction potential' (Lechner et al, 2006) between the car and the road can be considered as one of the most critical challenges for safety functions benefit.

Another overall essential challenge for these devices consists in the development of appropriate HMI ergonomic works to develop so that the safety functions could be a real aid without becoming an additional burden on the driver with possibly counter effects on safety. In this purpose, it will be claimed that it is useful to define ergonomic standards, such as those proposed in the European Statement of Principles on human machine interface; but it is not sufficient. For such an important question, it can be simply relying upon a catalogue. It must be continuously considered that each HMI has to be adapted to the users (taking account of their heterogeneity and weaknesses) of the device, and to the specificities of the task in which it is integrated.

9 Bibliography

Barrios, J-M. et al. (2007) Common catalogue of existing safety functions and corresponding system platforms. Report D6.1, TRACE project.

Bastien, J.M.C., Scapin, D. (1993) Ergonomic Criteria for the Evaluation of Human-Computer interfaces. Institut National de recherche en informatique et en automatique, France (http://www.inria.fr)

Biehl, B.; Aschenbrenner, M.; Wurm, G. (1987) Einfluss der Risikokompensation auf die Wirkung von Verkehrssicherheitsmassnahmen am Beispiel ABS. Unfall-und Sicherheitsforschung Strassenverkehr, No. 63, Symposion Unfallforschung".

Karabatsou, V., Pappas, M., Van Elslande, P., Fouquet, K., Stanzel, M., Fildes, B., & de Lange, R. (2007). A priori evaluation of safety functions effectiveness: Methodologies. Report D4.1.3, TRACE project.

Laapotti S., Keskinen E. Differences in fatal loss-of-control accidents between young male and female drivers. Accident Analysis & Prevention, 1998, 30, pp 435-442.

Lechner, D., Malaterre, G. & Fleury, D. (1986). La reconstitution cinématique des accidents. Rapport de recherche INRETS n°21

Lechner D., Schaefer G., Yahiaoui G., Colinot J-P., Naude C. (2006) On-board estimation of friction potential. Congrès FISITA 2006. Japon. N°F2006V228.

Malaterre et Saad (1984 et 1986) In dans Malaterre G., Fontaine H., (1992) Les aides à la conduite : quels enjeux pour la sécurité ? Recherche Transport Sécurité, vol. 35, p. 43-53.

Malaterre G., Fontaine H. & Van Elslande P (1991). Analyse des besoins des conducteurs à partir des procès-verbaux d'accidents: Evaluation à priori des fonctions PROMETHEUS. Rapport INRETS n°139

Malaterre G., Fontaine H., (1992) Les aides à la conduite : quels enjeux pour la sécurité ? Recherche Transport Sécurité, vol. 35, p. 43-53.

Moessinger M., GIE RE PSA Peugeot Citroën – Renault & LAB. (2003).

Rumar (1987) In Malaterre G., Fontaine H., (1992) Les aides à la conduite : quels enjeux pour la sécurité ? Recherche Transport Sécurité, vol. 35, p. 43-53

SIRC (Social Issues Research Centre) Sex differences in driving and insurance risk – An analysis of the social and psychological differences between men and women that are relevant to their driving behaviour, 2004.

Thackray, R. I. & Touchstone, R. M. (1991). Effects of monitoring under high and low task load on detection flashing and coloured radar targets. Ergonomics, 34, 1065-1081.

Van Elslande, P., & Malaterre G. (1987). Les aides à la conduite Analyse des besoins en assistance des conducteurs. Rapport INRETS n°23.

Van Elslande, P., & Nachtergaele, C. (1992). Aide à la conduite et fonctionnement du conducteur en situation- L'accident de la route révélateur de limitations potentielles à la prise en compte des aides informatives. Rapport INRETS n°149.

Van Elslande, P. & Nachtergaele, C. (1992). Fonctionnement humain et accident de la route:une contribution à l'étude des limitations potentielles à la prise en compte des aides informatives. Recherche Transport Sécurité, vol. 35, p. 55-64.

Van Elslande, P., & Nachtergaele, C. (1993), Evaluation qualitative des CED4 et CED5 de PROMETHEUS – Une analyse a priori sur dossiers détaillés d'accidents et données d'opinion. Rapport de convention REGIENOV-GIE-PSA/INRETS/29

Van Elslande P., Alberton L. Scénarios-types de production de "l'erreur humaine" dans l'accident de la route. Rapport INRETS n°218, 1997.

10 Annex

10.1 Annex 1: Use of reconstruction data for estimating the influence of the safety-functions

When necessary, were used reconstitution data from in-depth analysis of accident.

The reconstitutions were done with ANAC software developed at Inrets (Lechner, Malaterre, & Fleury, 1986). This software uses simple equations of kinematics (quantities of movement and conservation of energy). Through the accident phases, we go back in time, starting from the final positions of the vehicles, in order to obtain the initial data of the accident (speeds of approach of the vehicles, outdistances at the impact, moment of perception of the conflict by the drivers...). Additional information is provided below.

There are three phases to most automobile accidents: pre-collision, collision and post-collision. When investigating an accident, there are distinct physical evidence patterns that should be documented for each phase. Measurement and photographs of the evidence is then used to assess vehicle motion.

- Pre-Collision

Vehicles are often at their tire adhesion limit before a collision occurs, whether it is full braking, full yawing (cornering) or a combination. When tires are at their limits, they leave rubber on the road in the form of skid marks and/or yaw marks. Most modern vehicles have antilock braking systems, which prevent wheel lock and reduce the likelihood of finding pre-collision skid marks.

The length and character of this pre-collision evidence usually represents energy loss. In other words, when a vehicle locks its brakes, it loses energy and speed. When a vehicle is fishtailing it also loses energy, dependent upon its slip angle, i.e., the more sideways it gets, the more energy it loses. Published coefficient of friction values on different surfaces help understand the energy loss.

- Collision

When a vehicle collides with an object or another vehicle, it deforms. The exact amount of this deformation also represents energy loss. Collision damage can often be compared to crash test data, in which the energy loss is a known quantity.

Measurement of the crush damage is compared to an undamaged vehicle. Measurement accuracy and detailed photographs can greatly influence the reconstruction. Some late model vehicles have black boxes onboard that record speed loss, which can be used to confirm crush energy calculations.

- Post Collision

After collision, damaged vehicles cause surface gouges/scrapes, drag marks, fluid trails and debris trails, all of which help understand post-collision motion. The nature of sliding contact with pavement and/or grass/dirt changes the energy loss. The harder a vehicle drags/scrapes the surface, the more energy it loses. Resulting surface damage and the corresponding vehicle component should be determined.

All three accident phases and their associated energy loses are added up to give the initial vehicle speed (total energy). Careful documentation of each accident phase combined with the basic laws of physics will enhance the reconstruction results.

For illustration, an example of kinematics reconstitution of accident is presented below:

<u>Accident summary:</u>

Tuesday August 5, 2003, around 8h10, with clear weather, the driver of Peugeot 206 circulates on motorway. She is with a 23 year old girl that she must drop at the bus station of Aix en Provence. The traffic is dense. She drives at 110 Km/h, on the middle lane (3 lanes motorway) in a large curve (to the left) when she approaches the toll area. At this moment she vaguely perceives a Peugeot van decelerating in front of her. She slows down but keeps progressing on her lane. But while approaching this Peugeot, she understands at the last time that this vehicle is stopped in the middle of her lane. She brakes "to death" (according to the driver's declaration) but cannot avoid the collision. The 206 front hits the back of the van in a rear-frontal shock.

With the seat belt on, the occupants of the Peugeot 206 will be slightly injured. The van driver, wearing his seat belt as well, will leave unscathed this accident.

Cinematic Reconstitution

For this accident, the reconstruction table resulting from the analysis is as follows:

Time characteristics	**Vehicle 1: Van**			TIME	**Vehicle 2: Peugeot 206**		
	Distance m	Speed Km/h	Acceleration m/s²	s	Distance m	Speed Km/h	Acceleration m/s²
Approach both vehicles	- 10	20	- 1.5	**- 3.00**	- 53	85	- 1
206 ' s Perception of the hazard	- 8	18	- 1.5	**- 2.62**	- 45	84	- 1
206's braking start (including reaction duration of braking system)	- 5	14	- 1.5	**- 1.92**	- 28	81	- 8
Beginning of the brake marks of the 206	- 4	13	- 1.5	**- 1.72**	- 24	76	- 8
Front- rear collision between van and 206	0	4	- 5	**0**	0	26	- 8

- The van circulates on the second lane of the motorway at a very low speed due to a very dense traffic.
- During the approach, the two vehicles do not have very high speeds. At the beginning of the braking, the 206 had a speed close to the 80 Km/h.
- The van is in weak deceleration (raised foot, motor brake).

Cinematic estimation of safety-functions effect: example of PBA

In order to integrate the braking benefit of the PBA safety function (this system prepares the brake system in advance for panic braking and allows a profit of about 0.2s in case of emergency braking), it is necessary to simulate the accident on the basis of the initial data resulting from the reconstitution of the accident. Then, the 0.2s profit of braking duration has to be taken into account at the moment the driver starts her emergency braking.

For this accident case, we must thus start the simulation at a time of -2.1s. The initial data are thus:

Vehicle 1: Distance: -5.7m, speed: 15km/h

Vehicle 2: Distance: -33m, speed: 82km/h

This gives an inter distance of 27.3m between vehicles, at the beginning of the simulation. The 0.2s braking profit begins approximately 4.4m earlier than at the time of the real situation.

This braking profit makes possible vehicle 2 do not strike vehicle 1. The simulation indicates that the vehicles will stop less than one meter one from the other.

This estimation is based on statistical data established before the time of the in-depth analysis of the case. All these data need nevertheless to be balanced because they result from a reconstitution which, by definition, is based on assumptions made on the different phases of deceleration without mark (use of motor brake for the van's driver). All the results from simulation are coherent with the reconstitution but they only remain theoretical concerning the real profit of the safety function.

10.2 Annex 2: Complementary Figures and Tables

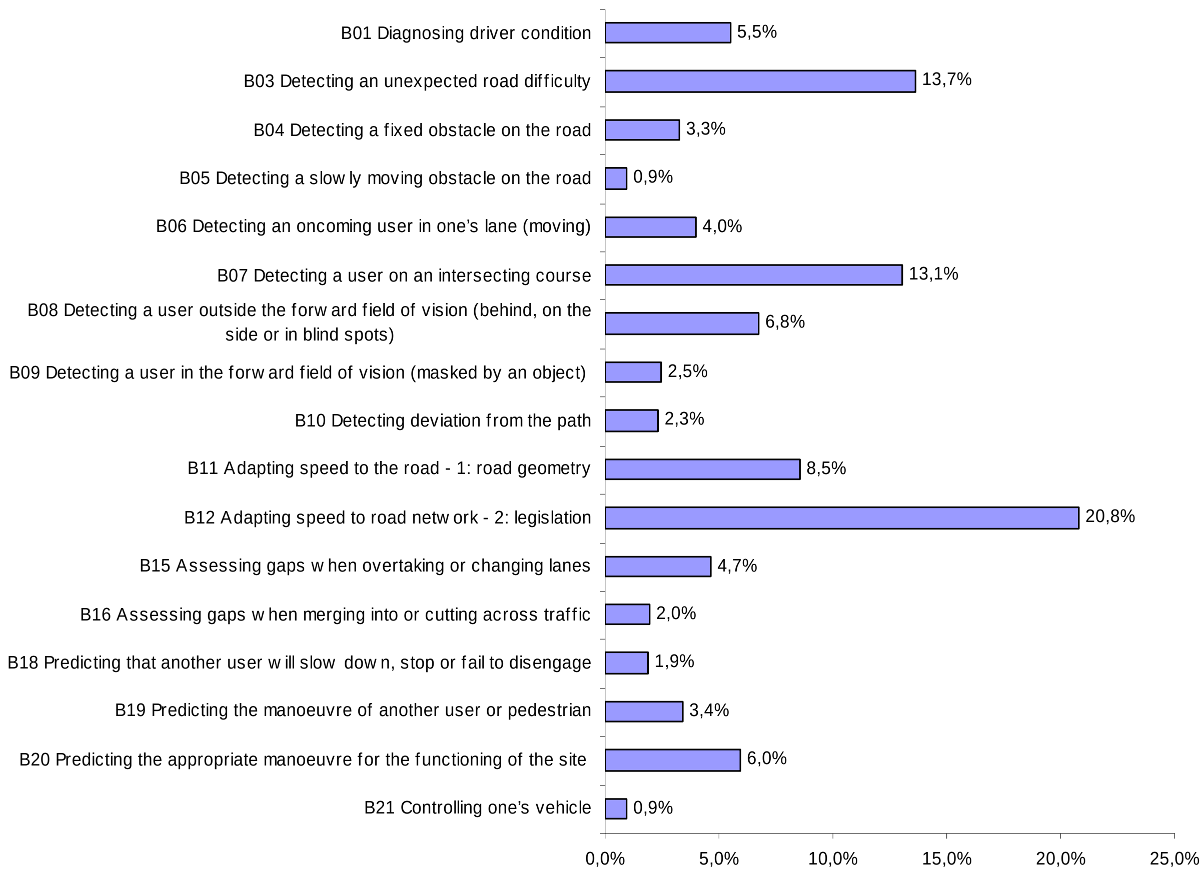


Figure 45. Drivers further upstream needs distribution (n=86)

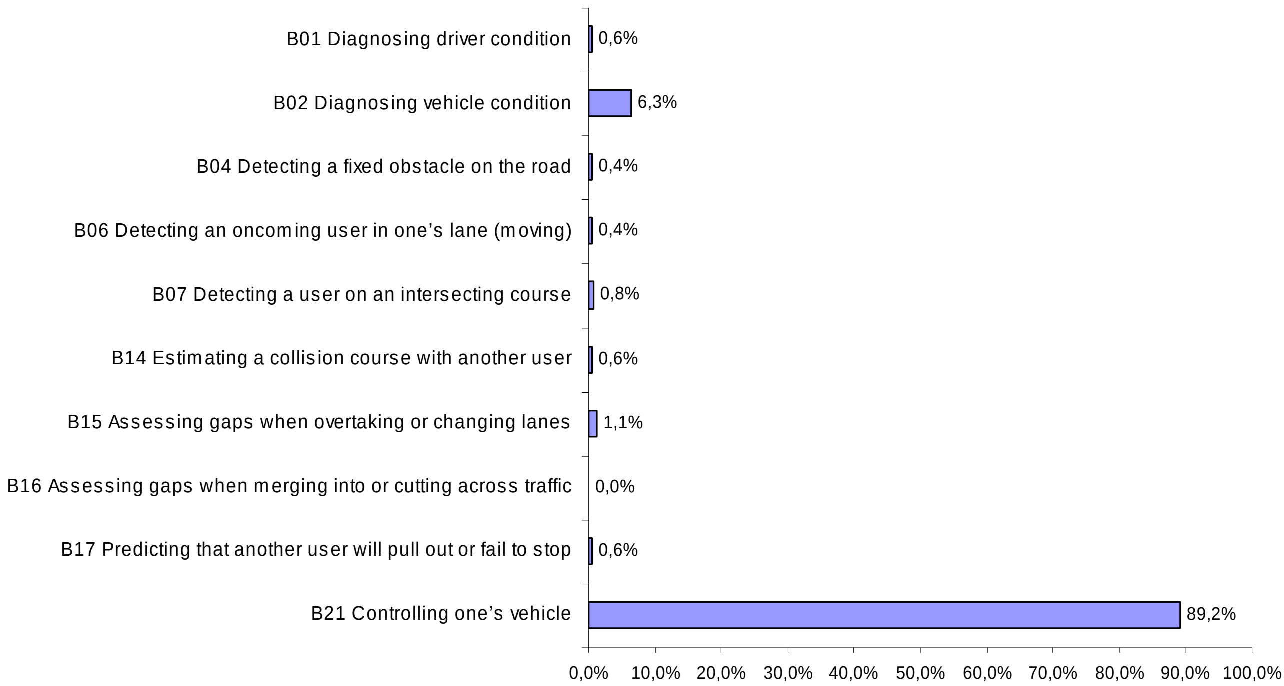


Figure 46. Drivers emergency needs distribution (n=142)

Table 9: Percentage of 'pivotal needs' covered by the functions (675 relevancies for 432 pivotal needs)

Pivotal needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	Total (n)
B01 Diagnosing driver condition						**5.7%**						**6.4%**								0.4%							53
B02 Diagnosing vehicle condition																									0.4%		2
B03 Detecting an unexpected road difficulty									0.1%		0.3%				1.2%												7
B04 Detecting a fixed obstacle on the road		0.9%	1.6%	0.7%					**2.7%**		**2.7%**										1.4%		0.3%	0.3%			46
B05 Detecting a slowly moving obstacle on the road		**2.5%**	0.3%	**2.0%**					**8.4%**		**7.5%**				1.5%						**2.1%**		0.6%	**3.3%**			121
B06 Detecting an oncoming user in one's lane (moving)									**4.0%**		**3.4%**				1.9%						0.3%			0.3%			42
B07 Detecting a user on an intersecting course									**5.8%**		**3.8%**				**12.8%**									1.7%			103
B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)								**3.2%**	0.2%						0.2%				**2.6%**	0.3%							28
B09 Detecting a user in the forward field of vision (masked by an object)								0.1%	1.9%		0.7%				0.7%				0.4%					0.6%			19
B10 Detecting deviation from the path									0.5%		0.5%	0.2%							0.4%	**3.6%**							22
B11 Adapting speed to the road - 1: road geometry																1.8%	**2.6%**	**3.2%**									33
B12 Adapting speed to road network - 2: legislation																	0.7%	0.7%									6
B13 Evaluating a catching up on a slower user		0.5%		0.3%					0.5%		0.7%												0.2%				10
B14 Estimating a collision course with another user									0.8%		0.8%				0.2%												8
B15 Assessing gaps when overtaking or changing lanes																											0
B16 Assessing gaps when merging into or cutting across traffic								0.6%			0.4%				**2.0%**				0.6%								16
B17 Predicting that another user will pull out or fail to stop		0.3%					0.3%		**4.6%**		**3.6%**				**5.7%**						0.3%	0.6%		0.4%			68
B18 Predicting that another user will slow down, stop or fail to disengage		0.2%		0.2%					0.9%		1.4%												0.2%				12
B19 Predicting the manoeuvre of another user or pedestrian		0.4%		0.1%				0.2%	0.9%		0.3%				0.2%								0.1%				10
B20 Predicting the appropriate manoeuvre for the functioning of the site							0.2%	0.2%							**2.5%**	0.2%	0.2%	0.2%	0.2%		0.6%		0.1%				19
B21 Controlling one's vehicle									0.4%	1.3%	0.4%		0.5%	**8.3%**						0.7%							50
Total	0.0%	**4.8%**	1.9%	**3.4%**	0.0%	**5.7%**	0.5%	**4.3%**	**31.6%**	1.3%	**26.4%**	**6.6%**	0.5%	**8.3%**	**29.0%**	1.9%	**3.5%**	**4.2%**	**4.2%**	**4.9%**	**4.6%**	0.6%	1.5%	**6.6%**	0.4%	0.0%	675

Caption :	
(dark grey)	higher than 10 %
(hatched)	higher than 5 %
(light grey)	higher than 2%

Table 10: Percentage of 'further upstream needs' covered by the functions (114 relevancies for 86 upstream needs)

Further upstream needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	Total (n)
B01 Diagnosing driver condition						**2.8%**						1.8%															4
B02 Diagnosing vehicle condition																											0
B03 Detecting an unexpected road difficulty	0.9%										1.6%				**4.9%**						1.9%						8
B04 Detecting a fixed obstacle on the road			1.1%						1.1%		1.8%										1.1%						4
B05 Detecting a slowly moving obstacle on the road		0.9%		0.9%							0.9%																2
B06 Detecting an oncoming user in one's lane (moving)															0.7%												1
B07 Detecting a user on an intersecting course									0.9%		0.9%				**9.0%**						0.9%			1.6%			12
B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)								**5.7%**	[2]										**5.7%**								10
B09 Detecting a user in the forward field of vision (masked by an object)									1.4%						1.4%												2
B10 Detecting deviation from the path																				0.9%							1
B11 Adapting speed to the road - 1: road geometry																**2.5%**	**6.0%**	**6.0%**								**2.5%**	14
B12 Adapting speed to road network - 2: legislation																**10.4%**	**18.0%**	**20.8%**									42
B13 Evaluating a catching up on a slower user																											0
B14 Estimating a collision course with another user																											0
B15 Assessing gaps when overtaking or changing lanes									1.9%		1.9%																3
B16 Assessing gaps when merging into or cutting across traffic									0.9%						1.1%												2
B17 Predicting that another user will pull out or fail to stop																											0
B18 Predicting that another user will slow down, stop or fail to disengage																	1.9%	1.9%									3
B19 Predicting the manoeuvre of another user or pedestrian											1.4%																1
B20 Predicting the appropriate manoeuvre for the functioning of the site									1.1%		1.1%				**2.2%**						1.1%						5
B21 Controlling one's vehicle																											0
Total	0.9%	0.9%	1.1%	0.9%	0.0%	**2.8%**	0.0%	**5.7%**	**7.2%**	0.0%	**9.6%**	1.8%	0.0%	0.0%	**19.3%**	**12.8%**	**25.8%**	**28.6%**	**5.7%**	0.9%	**4.9%**	0.0%	0.0%	1.6%	0.0%	**2.5%**	114

Table 11: Percentage of 'emergency needs' covered by the functions (181 relevancies for 142 emergency needs)

Emergency needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	Total (n)
B01 Diagnosing driver condition																											
B02 Diagnosing vehicle condition																									**3.7%**		5
B03 Detecting an unexpected road difficulty																											0
B04 Detecting a fixed obstacle on the road									0.4%													0.4%					1
B05 Detecting a slowly moving obstacle on the road																											0
B06 Detecting an oncoming user in one's lane (moving)									0.4%																		1
B07 Detecting a user on an intersecting course																											0
B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)																											0
B09 Detecting a user in the forward field of vision (masked by an object)																											0
B10 Detecting deviation from the path																											0
B11 Adapting speed to the road - 1: road geometry																											0
B12 Adapting speed to road network - 2: legislation																											0
B13 Evaluating a catching up on a slower user																											0
B14 Estimating a collision course with another user											0.6%																1
B15 Assessing gaps when overtaking or changing lanes																											0
B16 Assessing gaps when merging into or cutting across traffic																											0
B17 Predicting that another user will pull out or fail to stop									0.6%																		1
B18 Predicting that another user will slow down, stop or fail to disengage																											0
B19 Predicting the manoeuvre of another user or pedestrian																											0
B20 Predicting the appropriate manoeuvre for the functioning of the site		**11.9%**					**32.5%**		**15.4%**	**4.6%**	0.6%			**36.4%**			0.6%	0.6%		1.4%		**16.2%**		1.8%			173
B21 Controlling one's vehicle																											0
Total	0.0%	**11.9%**	0.0%	0.0%	0.0%	0.0%	**32.5%**	0.0%	**16.8%**	**4.6%**	1.2%	0.0%	0.0%	**36.4%**	0.0%	0.0%	0.6%	0.6%	0.0%	1.4%	0.0%	**16.6%**	0.0%	1.8%	**3.7%**	0.0%	181

Table 12: List and frequency of the 39 types of endogenous limitations linked to accident context

Type of accident context endogenous limitations	n
Expected absence of interference	184
Inattention	82
Feeling of right of way	75
Attentional focus on other potential hazards	62
Expected regulations by other	42
"Active" distraction	41
Poor interpretation of a signal	41
Opposite action by the driver	39
Upset - Stressed	38
Unexpected road user (powered two-wheeler)	32
Motive for speeding	32
Unexpected road user (pedestrians)	28
Confidence in self judgment	27
Attentional focus on traffic flow with right of way	24
Well-known itinerary	24
Spontaneous speeding	24
Influence of alcohol	19
Hypovigilance (fatigue)	18
Uncontrolled reaction due to surprise	16
Assistance system disconnected by the driver	15
Danger carelessness	15
Motive for the journey	15
Expected absence of deceleration of the vehicle in front	14
Strong motive for the manœuvre	14
Cognitive capacities overwhelmed – beginners	13
Slow reaction	13
Unexpected road user (bicycle)	12
Hypovigilance (falling asleep)	11
"Passive" distraction	9
Influence of a drug	9
Fatigue assumed	9
"Dragging" effect (tendency to follow an other vehicle spontaneously)	8
Cognitive capacities overwhelmed – elderly people	7
Deliberate traffic violations	7
Chronic alcoholism	5
Hypovigilance (drowsiness)	5
Faintness	5
Signs of faintness detected	2
Freezing up	2

Table 13: List and frequency of the 43 types of exogenous limitations linked to accident context

Type of accident context endogenous limitations	n
Strong dynamic stress (speed)	50
Insufficient radar/camera width (in intersection)	48
Lighting conditions (night)	44
Limited visibility (infrastructure-vegetation)	40
Limited visibility (vehicle)	37
Reduced adherence (wet road)	36
Limited visibility (infrastructure-construction)	27
Lighting conditions (dazzle)	21
Strong dynamic stress (loss of control)	19
Poor pinpointing of the source of information	19
Road design defect (atypical intersection)	18
Road design defect (signals)	17
Limited visibility (infrastructure-curve)	15
Tyre problems (under inflated)	14
Weather conditions (rain, wind, snow)	13
Inappropriate perceptive channel	13
Lighting conditions (diminished)	12
Insufficient radar/camera width (multi-lane road)	12
Obstacle (non-visible vehicle)	10
Pedestrian outside the pedestrian crossing	7
Intersection configuration (roundabout)	7
Lighting defect in the zone	5
Inappropriate regulation (speed in bend)	5
Insufficient alarm intensity (sound)	4
Intersection configuration (central storage)	4
Road design defect (verge)	3
Road design defect (miscellaneous)	3
Insufficient radar/camera width (opposite side of the road)	3
Limited visibility (pedestrian in dark)	3
Intersection configuration (car park)	3
Reduced adherence (gravel)	2
Reduced adherence (oil)	2
Wrong-way driving	2
Strong dynamic stress (load)	2
Insufficient radar/camera length	2
Limited visibility (infrastructure-roundabout)	2
Assistance trigger threshold (late braking by the driver)	2
Intersection configuration (private road)	2
Reduced adherence (ice)	1
Obstacle (e.g. toll booth)	1
Inappropriate regulation (intersection speed, outside the city)	1
Assistance trigger threshold (e.g. insufficient speed)	1

Table 14: Average response efficiencies of the safety functions for 432 drivers' pivotal needs

Pivotal needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE -U	TPMS	TSR	Mean
B01 Diagnosing driver condition						**98.5**						42.7								40.0							**60.4**
B02 Diagnosing vehicle condition																									**50.0**		**50.0**
B03 Detecting an unexpected road difficulty									**50.0**		20.0				42.7												37.6
B04 Detecting a fixed obstacle on the road		**96.8**	**79.0**	**71.9**					**76.3**		**55.2**										**56.8**		10.0	**90.0**			**67.0**
B05 Detecting a slowly moving obstacle on the road		**88.8**	**100.0**	49.2					**59.4**		40.3				34.3						27.2		14.8	**55.0**			**52.1**
B06 Detecting an oncoming user in one's lane (moving)									29.9		31.0				44.2						10.0			20.0			27.0
B07 Detecting a user on an intersecting course									31.4		24.0				43.9									41.3			35.2
B08 Detecting a user outside the forward field of vision (behind. on the side or in blind spots)								36.4	30.0						40.0				38.1	10.0							30.9
B09 Detecting a user in the forward field of vision (masked by an object)								**50.0**	13.3		13.1				**58.0**				30.0					34.2			33.1
B10 Detecting deviation from the path									**52.0**		40.0	**50.0**							**50.0**	48.7							48.1
B11 Adapting speed to the road - 1: road geometry																23.7	22.5	40.9									29.0
B12 Adapting speed to road network - 2: legislation																	13.8	32.5									23.2
B13 Evaluating a catching up on a slower user		**61.8**		42.9					**61.8**		**52.0**												10.0				45.7
B14 Estimating a collision course with another user									32.0		14.3				10.0												18.8
B15 Assessing gaps when overtaking or changing lanes																											0.0
B16 Assessing gaps when merging into or cutting across traffic								35.6			43.3				46.4				35.6								40.2
B17 Predicting that another user will pull out or fail to stop		10.0					10.0		40.4		24.7				32.1						**60.0**	15.0		25.0			27.2
B18 Predicting that another user will slow down, stop or fail to disengage		**50.0**		40.0					41.6		34.2												**50.0**				43.2
B19 Predicting the manoeuvre of another user or pedestrian		22.6		10.0				**50.0**	25.3		15.7				30.0								10.0				23.4
B20 Predicting the appropriate manoeuvre for the functioning of the site							10.0	**50.0**							**57.5**	10.0	20.0	**50.0**	**50.0**		23.3		10.0				31.2
B21 Controlling one's vehicle									**100.0**	**53.9**	10.0		27.1	**54.0**						27.3							45.4
Mean	0.0	**75.2**	**82.1**	**51.4**	0.0	**98.5**	10.0	38.0	44.6	**53.9**	33.8	42.9	27.1	**54.0**	42.4	22.4	20.5	39.8	38.6	42.8	36.7	15.0	16.7	47.7	**50.0**	0.0	44.4

Caption :	
100.0%	Equal to 100 %
76.0%	Higher than 75 %
51.0%	Higher than 50%
	Does not apply

Table 15: Average response efficiencies of the safety functions for 86 drivers' upstream needs

Upstream needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	Mean
B01 Diagnosing driver condition						**100.0**						34.0															**74.6**
B02 Diagnosing vehicle condition																											0.0
B03 Detecting an unexpected road difficulty	20.0										38.6				47.4						25.0						38.6
B04 Detecting a fixed obstacle on the road			**50.0**						**60.0**		32.0										20.0						39.3
B05 Detecting a slowly moving obstacle on the road		**100.0**		**50.0**							**50.0**																**66.7**
B06 Detecting an oncoming user in one's lane (moving)															10.0												10.0
B07 Detecting a user on an intersecting course									**50.0**		40.0				47.5						20.0			31.4			43.3
B08 Detecting a user outside the forward field of vision (behind. on the side or in blind spots)								46.9											46.9								46.9
B09 Detecting a user in the forward field of vision (masked by an object)									10.0						10.0												10.0
B10 Detecting deviation from the path																				**80.0**							**80.0**
B11 Adapting speed to the road - 1: road geometry																44.8	24.9	49.0								20.0	35.6
B12 Adapting speed to road network - 2: legislation																20.3	18.5	47.4									31.1
B13 Evaluating a catching up on a slower user																											0.0
B14 Estimating a collision course with another user																											0.0
B15 Assessing gaps when overtaking or changing lanes									**100.0**		20.0																**60.0**
B16 Assessing gaps when merging into or cutting across traffic									**60.0**						30.0												44.1
B17 Predicting that another user will pull out or fail to stop																											0.0
B18 Predicting that another user will slow down. stop or fail to disengage																	**50.0**	**100.0**									**75.0**
B19 Predicting the manoeuvre of another user or pedestrian											10.0																10.0
B20 Predicting the appropriate manoeuvre for the functioning of the site									**60.0**		10.0				30.0						10.0						28.0
B21 Controlling one's vehicle																											0.0
Mean	20.0	**100.0**	**50.0**	**50.0**	0.0	**100.0**	0.0	46.9	**59.4**	0.0	27.7	34.0	0.0	0.0	40.4	25.0	22.3	**51.2**	46.9	**80.0**	19.8	0.0	0.0	31.4	0.0	20.0	39.0

Caption :	
100.0%	Equal to 100 %
76.0%	Higher than 75 %
51.0%	Higher than 50%
	Does not apply

Table 16: Average response efficiencies of the safety-functions for 142 drivers' emergency needs

Emergency needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	Mean
B01 Diagnosing driver condition																											0.0
B02 Diagnosing vehicle condition																									26.6		26.6
B03 Detecting an unexpected road difficulty																											0.0
B04 Detecting a fixed obstacle on the road									**70.0**													10.0					40.0
B05 Detecting a slowly moving obstacle on the road																											0.0
B06 Detecting an oncoming user in one's lane (moving)									20.0																		20.0
B07 Detecting a user on an intersecting course																											0.0
B08 Detecting a user outside the forward field of vision (behind. on the side or in blind spots)																											0.0
B09 Detecting a user in the forward field of vision (masked by an object)																											0.0
B10 Detecting deviation from the path																											0.0
B11 Adapting speed to the road - 1: road geometry																											0.0
B12 Adapting speed to road network - 2: legislation																											0.0
B13 Evaluating a catching up on a slower user																											0.0
B14 Estimating a collision course with another user											20.0																20.0
B15 Assessing gaps when overtaking or changing lanes																											0.0
B16 Assessing gaps when merging into or cutting across traffic																											0.0
B17 Predicting that another user will pull out or fail to stop									**70.0**																		**70.0**
B18 Predicting that another user will slow down. stop or fail to disengage																											0.0
B19 Predicting the manoeuvre of another user or pedestrian																											0.0
B20 Predicting the appropriate manoeuvre for the functioning of the site																											0.0
B21 Controlling one's vehicle		30.8					12.9		44.4	**50.0**	20.0			**52.0**			20.0	40.0		28.0		35.0		10.0			35.0
Mean	0.0	30.8	0.0	0.0	0.0	0.0	12.9	0.0	45.3	**50.0**	20.0	0.0	0.0	**52.0**	0.0	0.0	20.0	40.0	0.0	28.0	0.0	34.3	0.0	10.0	26.6	0.0%	34.8

Caption :	
100.0%	Equal to 100 %
76.0%	Higher than 75 %
51.0%	Higher than 50%
	Does not apply

Table 17: Estimated effectiveness by safety function and by upstream need (86 upstream needs, 114 safety functions relevancies)

Upstream needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	total
B01 Diagnosing driver condition						**2.8**						0.6														**3.4**
B02 Diagnosing vehicle condition																										0.0
B03 Detecting an unexpected road difficulty	0.2										0.6			**2.3**						0.5						**3.6**
B04 Detecting a fixed obstacle on the road			0.5						0.6		0.6									0.2						1.9
B05 Detecting a slowly moving obstacle on the road		0.9		0.5							0.5															1.9
B06 Detecting an oncoming user in one's lane (moving)														0.1												0.1
B07 Detecting a user on an intersecting course									0.5		0.4			**4.3**						0.2			0.5			**5.8**
B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)								**2.7**										**2.7**								**5.4**
B09 Detecting a user in the forward field of vision (masked by an object)									0.1					0.1												0.3
B10 Detecting deviation from the path																			0.7							0.7
B11 Adapting speed to the road - 1: road geometry															1.1	1.5	**2.9**								0.5	**6.0**
B12 Adapting speed to road network - 2: legislation															**2.1**	**3.3**	**9.8**									**15.3**
B13 Evaluating a catching up on a slower user																										0.0
B14 Estimating a collision course with another user																										0.0
B15 Assessing gaps when overtaking or changing lanes									1.9		0.4															**2.2**
B16 Assessing gaps when merging into or cutting across traffic									0.6					0.3												0.9
B17 Predicting that another user will pull out or fail to stop																										0.0
B18 Predicting that another user will slow down, stop or fail to disengage																0.9	1.9									**2.8**
B19 Predicting the manoeuvre of another user or pedestrian											0.1															0.1
B20 Predicting the appropriate manoeuvre for the functioning of the site									0.6		0.1			0.7						0.1						1.5
B21 Controlling one's vehicle																										0.0
Total	0.2	0.9	0.5	0.5	0.0	**2.8**	0.0	**2.7**	**4.3**	0.0	**2.6**	0.6	0.0	**7.8**	**3.2**	**5.7**	**14.6**	**2.7**	0.7	1.0	0.0	0.0	0.5	0.0	0.5	**51.9**

Caption	
11.0%	Higher than 10 %
6.0%	Higher than 5 %
2.5%	Higher than 2%
	Does not apply

Table 18: Estimated effectiveness by safety function and by pivotal need (432 pivotal needs, 676 safety functions relevancies)

Pivotal needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	total
B01 Diagnosing driver condition						**5.6**						**2.7**								0.1							**8.5**
B02 Diagnosing vehicle condition																									0.2		0.2
B03 Detecting an unexpected road difficulty									0.1		0.1				0.5												0.6
B04 Detecting a fixed obstacle on the road		0.9	1.3	0.5					**2.1**		1.5										0.8		0.0	0.3			**7.3**
B05 Detecting a slowly moving obstacle on the road		**2.2**	0.3	1.0					**5.0**		**3.0**				0.5						0.6		0.1	1.8			**14.4**
B06 Detecting an oncoming user in one's lane (moving)									1.2		1.1				0.9						0.0			0.1			**3.2**
B07 Detecting a user on an intersecting course									1.8		0.9				**5.6**									0.7			**9.0**
B08 Detecting a user outside the forward field of vision (behind, on the side or in blind spots)								1.2	0.1						0.1				1.0	0.0							**2.3**
B09 Detecting a user in the forward field of vision (masked by an object)								0.1	0.2		0.1				0.4				0.1					0.2			1.1
B10 Detecting deviation from the path									0.2		0.2	0.1							0.2	1.7							**2.5**
B11 Adapting speed to the road - 1: road geometry																0.4	0.6	1.3									**2.3**
B12 Adapting speed to road network - 2: legislation																	0.1	0.2									0.3
B13 Evaluating a catching up on a slower user		0.3		0.1					0.3		0.4												0.0				1.1
B14 Estimating a collision course with another user									0.3		0.1				0.0												0.4
B15 Assessing gaps when overtaking or changing lanes																											0.0
B16 Assessing gaps when merging into or cutting across traffic								0.2			0.2				0.9				0.2								1.5
B17 Predicting that another user will pull out or fail to stop		0.0					0.0		1.9		0.9				1.8						0.2	0.1		0.1			**5.0**
B18 Predicting that another user will slow down, stop or fail to disengage		0.1		0.1					0.4		0.5												0.1				1.1
B19 Predicting the manoeuvre of another user or pedestrian		0.1		0.0				0.1	0.2		0.1				0.1								0.0				0.6
B20 Predicting the appropriate manoeuvre for the functioning of the site							0.0	0.1							1.5	0.0	0.0	0.1	0.1		0.1		0.0				**2.0**
B21 Controlling one's vehicle									0.4	0.7	0.0		0.1	**4.5**						0.2							**5.9**
Total	0.0	**3.6**	1.6	1.7	0.0	**5.6**	0.0	1.6	**14.1**	0.7	**8.9**	**2.8**	0.1	**4.5**	**12.3**	0.4	0.7	1.7	1.6	**2.1**	1.7	0.1	0.3	**3.1**	0.2	0.0	**69.4**

Caption	
11.0%	Higher than 10 %
6.0%	Higher than 5 %
2.5%	Higher than 2%
	Does not apply

Table 19: Estimated effectiveness by safety function and by <u>emergency need</u> (142 emergency needs, 181 safety functions relevancies)

Emergency needs	AAFS	ACC+	ACC1	ACC2	ACC3	AK	BA	BS	CA	CBC	CW	DDS	DS	ESP	IC	ISA1	ISA2	ISA3	LCA	LKA	NV	PBA	RLBF	SAVE-U	TPMS	TSR	total
B01 Diagnosing driver condition																											0.0
B02 Diagnosing vehicle condition																									1.0		1.0
B03 Detecting an unexpected road difficulty																											0.0
B04 Detecting a fixed obstacle on the road									0.3													0.0					0.3
B05 Detecting a slowly moving obstacle on the road																											0.0
B06 Detecting an oncoming user in one's lane (moving)									0.1																		0.1
B07 Detecting a user on an intersecting course																											0.0
B08 Detecting a user outside the forward field of vision (behind. on the side or in blind spots)																											0.0
B09 Detecting a user in the forward field of vision (masked by an object)																											0.0
B10 Detecting deviation from the path																											0.0
B11 Adapting speed to the road - 1: road geometry																											0.0
B12 Adapting speed to road network - 2: legislation																											0.0
B13 Evaluating a catching up on a slower user																											0.0
B14 Estimating a collision course with another user											0.1																0.1
B15 Assessing gaps when overtaking or changing lanes																											0.0
B16 Assessing gaps when merging into or cutting across traffic																											0.0
B17 Predicting that another user will pull out or fail to stop									0.4																		0.4
B18 Predicting that another user will slow down. stop or fail to disengage																											0.0
B19 Predicting the manoeuvre of another user or pedestrian																											0.0
B20 Predicting the appropriate manoeuvre for the functioning of the site																											0.0
B21 Controlling one's vehicle		**3.6**					**4.2**		**6.8**	**2.3**	0.1			**18.9**			0.1	0.2		0.4		**5.7**		0.2			**42.6**
Total	0.0	**3.6**	0.0	0.0	0.0	0.0	**4.2**	0.0	**7.6**	**2.3**	0.2	0.0	0.0	**18.9**	0.0	0.0	0.1	0.2	0.0	0.4	0.0	**5.7**	0.0	0.2	1.0	0.0	**44.5**

Caption	
11.0%	Higher than 10 %
6.0%	Higher than 5 %
2.5%	Higher than 2%
	Does not apply

10.3 Annex 3: Safety functions functionalities

This section presents the 21 primary safety functions and their variants which have been evaluated.

Every safety system is presented in 2 parts:

- What we know. This part describes the specifications granted from WP6 reports on the basis of their investigation from different sources of information.
- What we assume. This second part must be seen as a complement of the previous one. It states a certain number of assumptions made on the safety systems functioning when it was felt necessary to compensate for the lacks in descriptive data.
-

What we know

This part is composed of 3 sub-parts:

1. A description frame

For example:

Safety System – **CORNERING BRAKE CONTROL**

Classification: **Primary Safety**
Proposed for: **Cars**
Safety Function: **Braking Systems**

Description: The cornering brake control system works together with traditional anti-lock braking systems to overcome any over-steer which results from attempting a corner too quickly. The braking for each wheel also works independently such as in the Sensotronic Brake Control system.

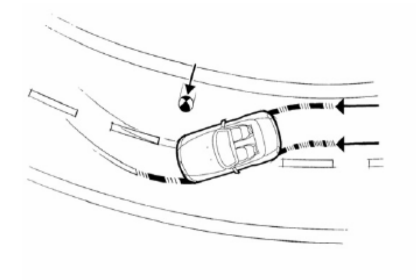


Figure 47: Extract of the descriptions given by WP6.

This presentation was taken from WP6 (TRACE deliverable D6.1).

2. Mode and phase of the accident

For example:

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Automatic mode		Rupture	Emergency	

This table is extract from the document *trace-chose.xls* given to us from WP6.

Driving mode

The driving mode was evaluated by questionnaire: The instruction was:

> *"Safety systems in cars can be classified into 4 driving aid modes (type/level of intervention with driver) categories: Perceptive mode, Mutual control, Delegation of function and Automation. These subsequently can be subcategorised into various types of co-operation. The definitions are stated below. Please indicate in the column titled 'Evaluation of Driving Aid Modes ', your opinion on the various driving aid modes present in safety systems. Designate a value from 1 (Low) - 10 (High) for each Driving Aid Mode. The assessment should be kept as homogenous as possible for each value."*

<table>
<tr><th colspan="3">Definitions</th></tr>
<tr><td>Perceptive mode</td><td colspan="2">Sensorial extension. The device informs the driver of a variable, such as speed indicated on the speedometer. The driver is free to take the information into account and retains the power to decide whether to take action or not.</td></tr>
<tr><td rowspan="4">Mutual control</td><td rowspan="4">Type of cooperation: the device takes over various control activities.</td><td>WARNING MODE: The device transmites a judgement on driver performance in the form of a warning.</td></tr>
<tr><td>LIMIT MODE: The driver request the device to control actions by limiting its own actions so they do not exceed a pre-defined level of risk.</td></tr>
<tr><td>CORRECTIVE MODE: The driver request th device to control actions by correcting his actions if they result in exceeding a predefined risk level.</td></tr>
<tr><td>ACTION SUGGESTION MODE: It suggests an action to the driver.</td></tr>
<tr><td rowspan="3">Delegation of function</td><td rowspan="3">Type of cooperation: the decision to take action is delegated to the device in more or less a durable fashion</td><td>REGULATED MODE: The driver explicitly requests the device to take the necessary decisions and then implement</td></tr>
<tr><td>PRESCRIPTIVE MODE: At the initiative of the infrastructure, which forces the device to take the necessary decisions and implement.</td></tr>
<tr><td>MEDIATISED MODE: The driver retains the initiative but an action initiated by the driver must be amplified to avoid the accident.</td></tr>
<tr><td>Automation</td><td colspan="2">Implemented when no driver action is possible to avoid an accident. The device takes control.</td></tr>
</table>

Figure 48: Table extract from *WP6 Questionnaire2-risk.xls*

Phases I, II, III and IV mean respectively:

I. The Driving Phase: during this phase no unexpected event or hazard has occurred or been detected.

II. The Rupture Phase: an unexpected event or hazard has presented itself. The demand on the driver exceeds the average ability of response.

III. The Emergency Phase: defined as the distance and time between the rupture phase and collision.

IV. The Crash Phase: when the impact is taking place

3. Risk addressed

For example:

RISK I	RISK II	RISK III	RISK IV	RISK V
12 Non-adapted speed and exceeding at the same time the speed limit	35 Mistakes made when turning	36 Mistakes made when making U-turn or reversing	111 Moving, turning, towing mistakes	

Figure 49: Factors of Risk addressed

Risk I, II, III, IV and V

The 'risk' addressed was evaluated by questionnaire. WP6 have proposed a table which contains 138 vehicle accident causation factors. The instruction was:

> *"Please indicate in the column titled 'Evaluation of Risk Factor' your opinion on the level of importance in considering the specific risk factor in safety systems for vehicles.*
>
> *Designate a value from 1 (Low) – 10 (High) for every safety factor. The assessment should be kept homogenous at around 10%-15% for each value."*

The principle was to define which vehicle accident causation factors the systems could avoid, minimize, etc.

Risk I, II, III, IV and V are the most important risks of accident.

But for the purpose of the present study turned toward in-depth analysis of human and contextual parameters, even all this information given was not always sufficient to evaluate the safety benefit of the functions. So, we had to make some assumptions in order to compensate for lack of knowledge.

What we assume

This second part of the definitions of the safety functions was designed in order to give a clearer idea about specifications which remained unclear. It was built for each function with the following resources:

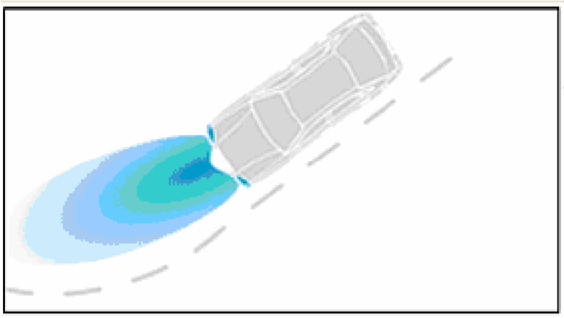
A series of exchanges have been put forward with TRACE WP 6.

We called upon the expertise of a researcher and a technician specialized in vehicle dynamics at INRETS.

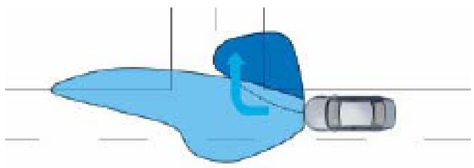
A complementary research on Web sites specialized in the field (for example: http://www.cartalk2000.net/) has been done.

AAFS - Advanced Adaptive Front Light System

What we know

Safety System – **ADVANCED FRONT LIGHT SYSTEM**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Visibility**	
Description: Concept of intelligent lighting, according to curves, weather and speed. At night, it lets you see around corners. It estimates where you will be in three seconds' time, using sensors that monitor your speed and the angle of your front wheels, and shines the car's headlights in that direction. The left and right headlamps swivel by different amounts depending on the way you are turning. So when you approach a corner, your lights follow the road ahead rather than simply illuminating the edge of the road.	

Components	**Related problems**	**Current diagnosis method.**
Sensors Communicating systems Lights actuators ECU	- Not optimum illumination - Unwanted illumination of oncoming traffic	- Self Vehicle Checking - Light function cheking at PTI

Safety System – **ADAPTIVE LIGHT**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Visibility**	
Description: The adaptive light system has an additional light unit located between the low-beam and main-beam bulbs of the xenon plus headlights. With the low-beam lights switched on and up to a speed of 70 km/h, this light unit is activated if the turn indicator is operated for some time or if the driver steers sharply. If the driver engages reverse gear, the additional headlights are automatically activated on both sides of the vehicle. This considerably improves visibility and orientation when reversing.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Automatic mode	Driving	Rupture	Emergency	

RISK I	RISK II	RISK III	RISK IV	RISK V
80 Fog	84 Storm or other weather influences	111 Moving, turning, towing mistakes	78 Insufficient road lighting	

What we assume

We supposed Advanced Adaptive Front Light System is the combination of 2 systems:

- Advanced front light system
- Adaptive light

ACC - Advanced Adaptive Cruise Control

What we know

Safety System – ADVANCED ADAPTIVE CRUISE CONTROL

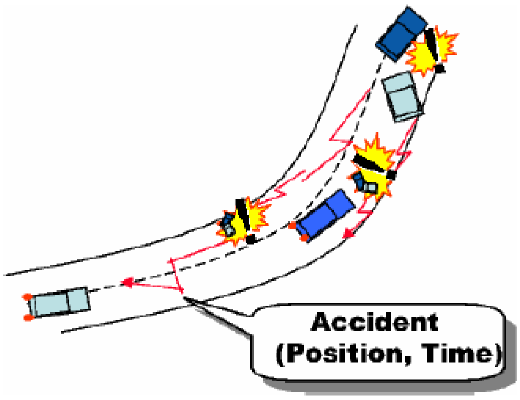
Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description:

1. **Information and Warning system**
   A Vehicle will transmit a warning message when it detects a vehicle breakdown, high traffic density and congestion or dangerous road surface conditions
2. **Communication-based Longitudinal Control System**
   Existing ACC only react to vehicles in front of them. By integrating communication, these systems may adapt longitudinal control to the traffic in front and can allow anticipating to an early braking manoeuvre when an invisible vehicle beyond the direct predecessor in front is braking. This leads to more natural following behaviour.
3. **Co-operative Assistance system**
   A Typical scenario for co-operation is the highway entry and margining scenario. By exchanging information up to simple trajectory plans, critical situations can be foreseen and solved by the vehicles.



DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV	LEVEL
Mutual control, corrective mode	Driving	Rupture	Emergency		high+

RISK I	RISK II	RISK III	RISK IV	RISK V
12 Non-adapted speed and exceeding at the same time the speed limit	94 Not conscious of the traffic	98 An inadequate or faulty observation of the environment	101 Did not identify the danger of the traffic situation	18 Overtaking in spite of unclear trafic situation

What we assume

ACC is based on inter-vehicle communication with a wireless system. So, we suppose all vehicles are equipped with ACC.

ACC seems particularly useful to avoid any over-accident. But ACC is also useful to avoid any kind of accident. ACC reacts to the "other vehicles". We suppose ACC reacts to cars and trucks (even stopped on the carriage way), but can not react to bikes, pedestrians, road signs, billboards, pavement, rock.

We are not sure that the system reacts perfectly to motorcycles. That's why this term will be noted as potential limitation, in this study.

Adverse visibility conditions (e.g. heavy rain, icy conditions) may affect sensors.

ACC can be used on motorways and extra-urban roads, also on urban roads if applicable (e.g. major arterials, but not intended for residential streets). It is also required that the curve radii must be "large enough" (>300 - 500m).

According with literature, ACC is composed of 3 clusters.

In our study, we evaluate these 3 clusters plus a 4th one (which can brake) as 4 independent safety-systems:

1. **Information and Warning System (ACC1)**

   A vehicle which has a problem will transmit a warning in a radius of 1000 meters, to all the vehicles. ACC1 detects potential danger out of the field of view of the driver and the car sensors: invisible vehicle (breakdown, high traffic density and congestion) and dangerous road surface conditions (rain). This information allows an early warning of the driver of following vehicles on the same road. We assume vehicles in the opposite direction are averted too.

   ACC1 allows driver to anticipate a breaking. We assume ACC1 only detect, it does not brake.

   We supposed ACC1 provides to the driver double warning:

   - Visual: a textual message displayed on the dashboard (Figure 50);
   - Acoustic: a voice reading the textual message displayed on the dashboard.

   We suppose the speed transmission of information is about 100m/s.

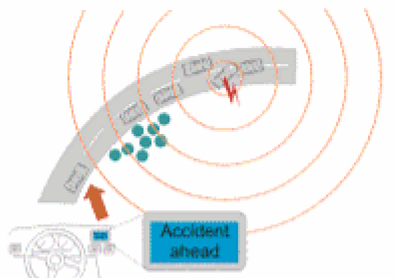


Figure 50: Information and Warning System
(source: http://www.cartalk2000.net/)

   ACC1 can detect stopped vehicles, but not obstacles.

   According to our expert in vehicle dynamics, we supposed ACC1 works on every type of road, but not in agglomeration because of the too many decelerations.

2. **Communication-based Longitudinal Control System (ACC2)**

   By integrating communication devices, ACC2 get enabled to adapt longitudinal control to the traffic in front and can allow anticipating early braking manoeuvres when an "invisible" vehicle in front is braking. This leads to a more natural following behaviour. Moreover, it helps avoiding accidents that occur due to the inattention of the vehicle in front. ACC has a "look-through" capability: a signal from vehicle 1 can be received by vehicle 3 in real-time. So, the vehicles 1 and 3 should not be distant of more than 500 meters.

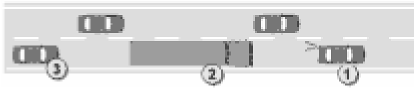


Figure 51: Communication-based Longitudinal Control System (source: http://www.cartalk2000.net/)

We suppose ACC2 also reacts to the vehicle directly in front : ie vehicle 3 reacts to a deceleration or breaking of vehicle 2.

When a deceleration is detected, ACC2 provides to the driver double warning:

- Visual: a textual message displayed on the dashboard (Figure 50);
- Oral: a voice reading the textual message displayed on the dashboard.

ACC2 can detect stopped vehicles (in the same longitudinal way), but not obstacles. More than detecting stopped vehicles, braking vehicles and decelerating vehicle, ACC2 can detect the differentials speed.

According to our expert in vehicle dynamics, we supposed ACC2 works on every type of road, but not in agglomeration because of the too many decelerations.

3. Co-operative Assistance System (ACC3)

ACC3 allow exchanging information between vehicles to assist the driver in predicting critical situations and even solving them by the vehicles themselves, for example for the highway entry and merging. So, the vehicles should not be distant of more than 500 meters.

We suppose the speed transmission of information is about 100m/s.

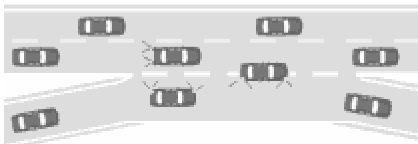


Figure 52: Co-operative Assistance System (source: http://www.cartalk2000.net/)

We assume this ACC3 only detect, it cannot brake.

We supposed ACC3 works only on motorway and highway, because ACC3 is useful for the highway entry and merging.

We make a fourth evaluation:

4. Communication-based Longitudinal Control System : Warning + braking (ACC+)

ACC+ is like ACC2, but ACC+ has the capacity to brake:

By integrating communication devices, ACC+ get enabled to adapt longitudinal control to the traffic in front and can automatically brake when an "invisible" vehicle in front is braking. This leads to a more natural following behaviour. Moreover, it helps avoiding accidents that occur due to the inattention of the vehicle in front. ACC+ has a "look-through" capability: a signal from vehicle 1 can be received by vehicle 3 in real-time. So, the vehicles 1 and 3 should not be distant of more than 500 meters.

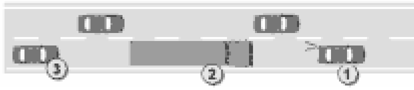


Figure 53: Communication-based Longitudinal Control System
(source: http://www.cartalk2000.net/)

We suppose ACC+ also reacts to the vehicle directly in front : ie vehicle 3 reacts to a deceleration or breaking of vehicle 2.

When a deceleration is detected, the vehicle automatically reacts by a deceleration, with a warning. We also suppose that the vehicle is able to automatically brake ($8m/s^2$, is the maximum deceleration, according to our technician specialized in vehicle dynamics).

ACC+ can detect stopped vehicles (in the same longitudinal way), but not obstacles. More than detecting stopped vehicles, braking vehicles and decelerating vehicle, ACC+ can detect the differential speed.

According to our expert in vehicle dynamics, we supposed ACC+ works on every type of road, but not in agglomeration because of the too many decelerations.

AK - Alcolock Keys

What we know

Safety System – **ALCOLOCK KEYS (PREVENT DRUNK DRIVING)**	
Classification: **Primary Safety**	
Proposed for: **Cars, Heavy Vehicles**	
Safety Function: **Drive Safe**	
Description: Alcohol ignition interlocks (alcolocks) are devices that require the driver to take a breath test before starting the car. If the driver fails the test, the device locks the ignition so the engine will not start. Alcolocks are most commonly used to prevent drink driving offenders from committing further violations. They are placed in vehicles of convicted drink drivers as part of a reinstatement requirement or a restricted driving license. PHILADELPHIA - Breath-alcohol detectors installed in the cars of convicted drunken drivers prevented them from driving under the influence more than 10,000 times in the first year of Pennsylvania's Ignition Interlock Law, according to a study.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Automatic mode	Driving			

RISK I	RISK II	RISK III	RISK IV	RISK V
1 Influence of alcohol	2 Influence of other intoxicating substances (e.g. drugs, narcotics)			

What we assume

We make the hypothesis that the user of this safety system is actually the driver (and so not a potentially healthy passenger).

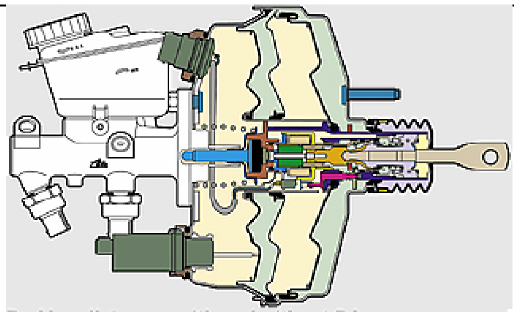
When drivers are under influence of alcohol, between 0 and 0.25g of alcohol per litre of expired breath, AK give information to the driver, but the vehicle can start.

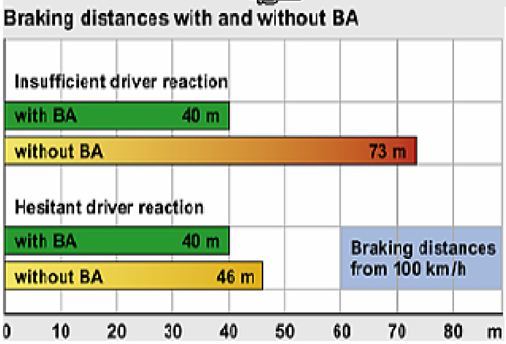
Over 0.25 g of alcohol per litre of expired breath, the vehicle cannot start.

BA - Brake Assist

What we know

Safety System – **BRAKE ASSIST SYSTEM**
Classification: **Primary Safety**
Proposed for: **Cars,Heavy Vehicles**
Safety Function: **Braking Systems**
Description: Brake assist systems are an important aid in emergency braking situations - such as when the driver applies the brake fast, but not with sufficient pressure, which leads to dangerously long braking distances. The brake assist recognizes the brake application speed to detect this type of panic situation and activates the brake booster or the EBS hydraulic unit, so that even with moderate pedal forces maximum deceleration is achieved. There are several methods to implement these features. The Electronic BAS interacts with the vacuum brake booster, the ABS, the ESP and the ACC. The Mechanical BAS replaces the electronic system that detects pedal velocity by an inertial mechanism. The Hydraulic BAS bases directly in ESP components. The assist function is triggered through extension of the software routines.





Components	**Related problems**	**Current diagnosis method.**
Hydraulic pressure generator and modulator Wheel speed sensors Accelerator velocity sensor ECU	- No assist braking action - Unwanted excessive braking action - Involuntary activation of the brakes or different brake force between the tyres	- Self Vehicle Checking

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Delegation of a function, mediatised mode			Emergency	

RISK I	RISK II	RISK III	RISK IV	RISK V
12 Non-adapted speed and exceeding at the same time the speed limit	14 Insufficient safety distance	15 Abrupt braking without compelling reason by the vehicle in front	88 Other obstacle on the carriageway	108 Braking mistakes

What we assume

BA is an assistance for emergency braking..

BA starts according to the speed of depression of the brake pedal (typical of an emergency braking)

With BA, the vehicle brake earlier, at the maximum intensity, ($8m/s^2$, is the maximum deceleration, according to our technician specialized in vehicle dynamics). The saving of time is between 0.5 and 0.6 second.

We suppose that all vehicles which dispose of BA also have ABS.

BS - Blind Spot Detection

What we know

Safety System – **BLIND SPOT DETECTION**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: The camera-based monitoring system keeps watch for other vehicles travelling in the blind spot. When another vehicle enters the monitored zone, a warning light is illuminated near the exterior side mirror. Both sides of the vehicle are monitored in the same way. This visual warning gives the driver a clear indication that another vehicle is alongside. The system also alerts the driver both to vehicles approaching from behind and vehicles in front being overtaken.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Perceptive mode	Driving	Rupture		

RISK I	RISK II	RISK III	RISK IV	RISK V
3 Over fatigue	98 An inadequate or faulty observation of the environment	20 Overtaking without observing the rear traffic without timely and clearly indicating	95 Interest in activities other than driving	

What we assume

We suppose that when another vehicle (car, motorcycle), a bike or a pedestrian enter the blind spot zone - an area of 9.5 meters by 3.0 meters, according to WP6 - a yellow warning light comes on beside the appropriate door mirror in the driver's peripheral view. The driver is thus given an indication that there is a vehicle very close alongside.

Since Blind-spot detection is camera-based, it has the same limitations as the human eye does. This means the system will not function in conditions of poor visibility, for instance in fog or flying snow.

CA - Collision Avoidance

What we know

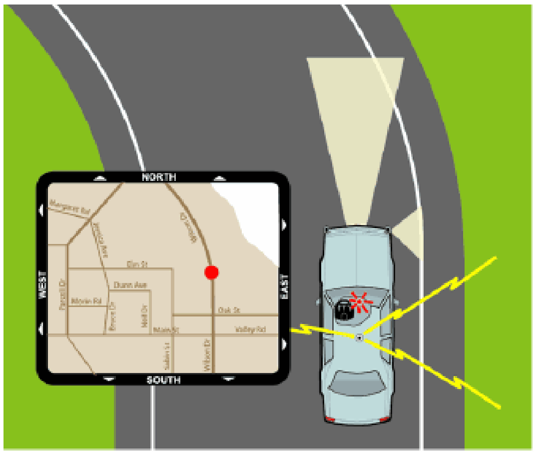
Safety System – COLLISION AVOIDANCE SYSTEM

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: The crash avoidance system is a relatively new technology. With the aid of a radar system, this system actively assesses the driving environment, with added alerts to the driver in any dangerous situations. The system also works in a similar way to prevent the driver from making any mistakes which could lead to or cause and accident.
Future developments of this system could provide recommendation to the driver on the appropriate actions to take in dangerous situations or possibly even assume partial control of the vehicle in order to avoid the prevention of an accident.



DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Mutual control, warning mode		Rupture	Emergency	

RISK I	RISK II	RISK III	RISK IV	RISK V
80 Fog	81 Heavy rain, hail, flurry of snow and the like	96 Did not notice other participant or situation	78 Insufficient road lighting	101 Did not identify the danger of the traffic situation

What we assume

CA is like CW: When visibility is limited (rain, night, snow and fog), CA scans in front of the vehicle (length: 150m, width: the roadway) and informs the driver of a danger, such as obstacles stationary (rock) or in movement (vehicles, motorcycles, bikes, pedestrians).

Concerning the alarm, variations exist: some will have audio alert increasing in intensity as risk increases, and some others start with a visual alert (a light on the dashboard) to signify that something "is suspicious" and then become an audio alert if system detects higher risk.

A number of CA systems being developed are coupled with GPS.

CA works in intersection only if the hazard is yet present in its range of detection (for example, if the vehicle manoeuvre is yet engaged).

CA can not detect road signs, billboards or pavement. The radar of CA cannot see when visibility is limited by an object.

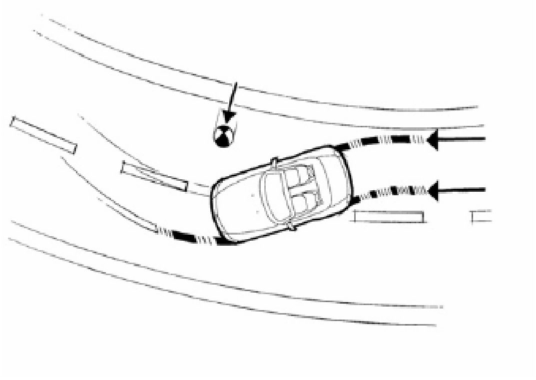
CA has something more than CW: CA can assume a partial control of the vehicle. We suppose CA can brake ($8m/s^2$, is the maximum deceleration, according to our technician specialized in vehicle dynamics), but cannot turn wheels.

We can make 2 hypotheses: with or without future developments.

In our study, we evaluate CA with the future developments. If one does not consider future developments, the safety benefit of CA are the same ones as those of CW.

CBC - Cornering Brake Control

What we know

Safety System – **CORNERING BRAKE CONTROL**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Braking Systems**	
Description: The cornering brake control system works together with traditional anti-lock braking systems to overcome any over-steer which results from attempting a corner too quickly. The braking for each wheel also works independently such as in the Sensotronic Brake Control system.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Automatic mode		Rupture	Emergency	

RISK I	RISK II	RISK III	RISK IV	RISK V
12 Non-adapted speed and exceeding at the same time the speed limit	35 Mistakes made when turning	36 Mistakes made when making U-turn or reversing	111 Moving, turning, towing mistakes	

What we assume

This safety system is suitable for all the situations in which the driver brakes and in which there is an over-steer risk, in a curve.

CBC is a kind of "ameliorated ESP", thanks to its over-steer control capacity.

Using ABS calculator, CBC works to prevent over-steers by distributing the braking pressure on each wheel.

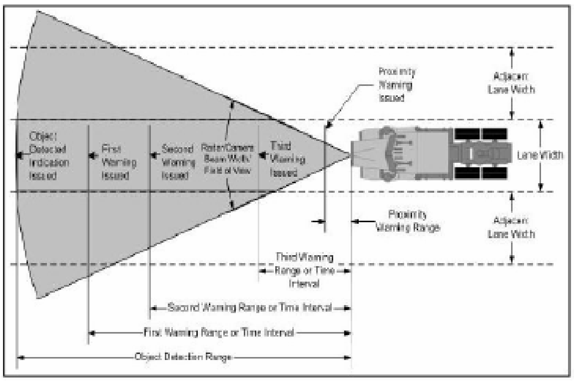
CBC cannot work to avoid an obstacle.

According to our expert in vehicle dynamics, CBC is a priori less efficient if the driver brakes when the over-steer has yet begun.

We suppose that all vehicles which dispose of CBC system also have ESP and ABS system.

CW - Collision Warning

What we know

<table>
<tr><th colspan="2">Safety System – COLLISION WARNING SYSTEM</th></tr>
<tr><td>Classification: Primary Safety</td><td rowspan="4">
</td></tr>
<tr><td>Proposed for: Cars, Heavy Vehicles</td></tr>
<tr><td>Safety Function: Drive Safe</td></tr>
<tr><td>Description: The crash warning system works in a similar way to the crash avoidance systems. A radar system is used in order to detect any particular hazards which may present themselves in the course of driving, such as another vehicle intercepting the path of this. The system is particularly useful in bad driving conditions, such as heavy rain or snow as well as at night when visibility is limited. An alarm will sound to warn the driver with progressively louder signals as the vehicle closes in on the hazard.</td></tr>
</table>

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Perceptive mode		Rupture	Emergency	

RISK I	RISK II	RISK III	RISK IV	RISK V
80 Fog	81 Heavy rain, hail, flurry of snow and the like	96 Did not notice other participant or situation	78 Insufficient road lighting	101 Did not identify the danger of the traffic situation

What we assume

This safety system corresponds to an anti-collision radar.

This system seems particularly useful when visibility is limited (rain, night, snow and fog). But it is also useful when visibility is good.

CW can detect hazard, such as stationary (rock) or moving obstacles/vehicle on the roadway up to 150m ahead of the vehicle, according to the dimension of the road (like PBA system).

CW works in intersection only if the hazard is yet present in its range (for example, if the vehicle manoeuvre is yet engaged).

CW can not detect road signs, billboards or pavement. The radar of CW cannot see when visibility is limited by an object.

DDS - Drowsy Driver Detection System

What we know

Safety System – DRIVER DROWSINESS DETECTION

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Drive Safe**

Description: Driver drowsiness is an important cause of truck crashes. There are some ways of detecting drowsiness, but they are based in eyes closure. One way is a video system that detects the eyes of the driver and measures directly the eye closure. Another way is a neural network model used to estimate the eye closure using measures associated with lane keeping, steering wheel movements and lateral acceleration of the vehicle. The warnings can begin as the driver becomes fatigued and intensify as the system detects increasing drowsiness, providing the driver with the opportunity for countermeasures such as taking a nap or getting a cup of coffee before they endanger themselves and/or others.

Components	**Related problems**	**Current diagnosis method.**
IR camera Image processor system Alert system	- No drowsiness detection - Unmotivated warning signals and/or actions	- Self Vehicle Checking

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Mutual control, warning mode	Driving	Rupture		

RISK I	RISK II	RISK III	RISK IV	RISK V
3 Over fatigue	90 Falling asleep	92 Loss of consciousness	1 Influence of alcohol	2 Influence of other intoxicating substances (e.g. drugs, narcotics)

What we assume

If the driver looks away more than 15 seconds, we suppose the video system will not detect the eyes anymore. So, DDS will warn the driver.

We suppose DDS could often work if the driver is hypovigilant because of alcohol or medicine.

DS - Dynamic Suspension

What we know

Safety System - **DYNAMIC SUSPENSION SYSTEM**

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Handling/Kinematic Assist**

Description: This system enhances on- and off-road handling, by varying the amount of torsional stiffness in the front and rear stabilizer bars. When the driver is travelling at high speeds on paved roads, the stabilizer bars have maximum stiffness, to keep the vehicle flat during cornering. However, if the driver goes off-road, the bars disengage. This allows the wheels to articulate according to need. The result is better traction on uneven trails, and a more comfortable ride.

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Automatic mode	Driving			

RISK I	RISK II	RISK III	RISK IV	RISK V
71 Other impurities caused by road users	74 Other influences	111 Moving, turning, towing mistakes		

What we assume

This system seems after all suitable for a better comfort in the vehicle, more than for safe, according to our experts in vehicle dynamics.

ESP - Electronic Stability Program

What we know

Safety System – **ELECTRONIC STABILITY PROGRAM**

Classification: **Primary Safety**

Proposed for: **Cars/Heavy Vehicles**

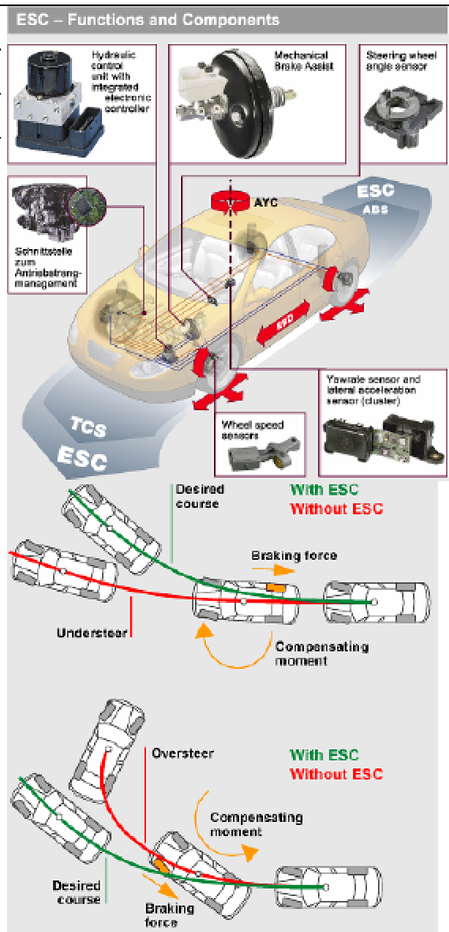
Safety Function: **Handling/Kinematic Assist**

Description: Electronic Stability Program (ESP) is an active safety system that recognizes unstable driving conditions at the very outset and applies automatic, corrective action. Utilizing the active build-up of direction-stabilizing brake forces, ESP helps the driver overcome critical situations and keep his vehicle safely under control.

ESP continuously evaluates the measured data from numerous sensors and compares the driver's input with the actual behaviour of the vehicle. If an unstable condition develops - such as a sudden evasive manoeuvre - within a fraction of a second, ESP intervenes via engine electronics and the brake system to help stabilize the vehicle.

If the front wheels of an under-steered vehicle drift outwards, braking applied to the rear wheel on the inside of the curve develops a compensating yaw moment which returns the vehicle to the desired course again.

If the vehicle threatens to over-steer with the rear of the car breaking away, braking is applied to the front wheel on the outside of the curve. The compensating moment operating in a clockwise direction turns the vehicle into the desired direction again.



Components	Related problems	Current diagnosis method.
Steering angle sensor Wheel speed sensors (4) Yaw rate sensor Hydraulic control unit ECU	- No stability control - Involuntary activation of the brakes or different brake force between the tyres	- Self Vehicle Checking

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Automatic mode		Rupture	Emergency	

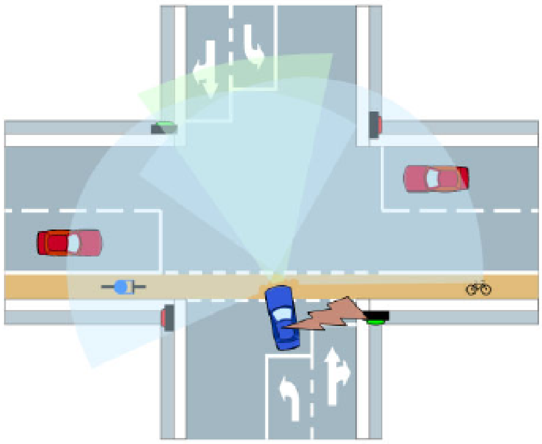
RISK I	RISK II	RISK III	RISK IV	RISK V
83 Sinde wind	72 Snow, ice	73 Rain	107 Faulty steering movement	76 Other road condition

What we assume

ESP is very efficient to avoid loss of control. We assume that ESP start to avoid the sudden wrenching of the steering wheel. But ESP is not very efficient if the car is thoroughly out of control.

IC - Intersection Control

What we know

Safety System – **INTERSECTION CONTROL (INTERSAFE)**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: A driver warning function based on communication with traffic lights and path prediction of all objects using the intersection.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Perceptive mode	Driving	Rupture		

RISK I	RISK II	RISK III	RISK IV	RISK V
32 Failure to observe the priority of oncoming vehicles	97 Faulty observation of the other participant or situation	104 Faulty interpretation of the traffic environment	28 Failure to observe the trafic signs regulating the priority	35 Mistakes made when turning

What we assume

According to PReVENT project, IC is composed by 3 clusters:

1. "Turning assistance" (left-turning) in intersection: warnings (e.g. visual/auditory) or recommendations (assessment of the gap to the vehicles circulating in opposite direction). Outdistance detection: 120m when speed approaches 60 kph and 134m when speed approaches 70 kph. This warning is based on the predictive trajectories of the case vehicle and other nearby vehicles.
2. "Right-of-way assistance (audience)": special attention to lateral traffic. IC will warn the driver if he seems to violate a right-of-way, and will support him in finding a good gap between vehicles, but also if somebody else is expected not to give the right-of-way, the driver will be supported with warnings (e.g. visual / auditory) or recommendations (as "turning assistance"). Distance of detection: 100m for an approach's speed of 60 kph and 120m for an approach's speed of 70 kph. This system would also take into account the pedestrians.
3. "Traffic light/Stop sign assistance": The driver is prevented from violating neither a traffic light showing red nor a stop sign at his side of the intersection. There will be a visual and acoustic warnings as soon as the system identifies a potential hazard, and a fast recommendation (particularly about speed being appropriate for the situation).

The high-level map is a computer representation of the objects present in the scene.

We suppose IC cannot predict the path of stopped vehicles.

We suppose IC detects cars, trucks, motorcycle, bikes and pedestrians.

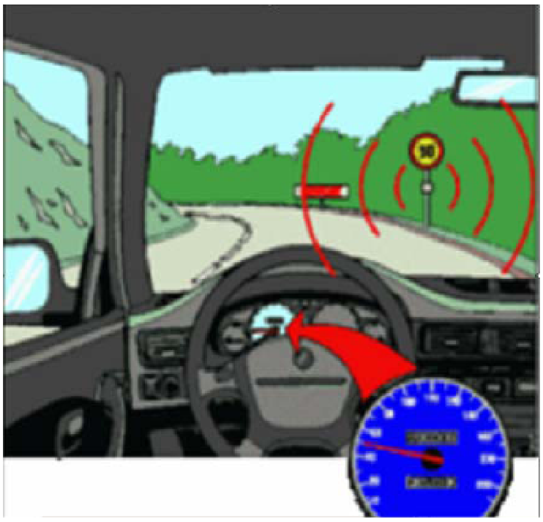
We suppose also IC can't work when visibility is limited by an object (it cannot see through it).

We suppose also IC can't work by night, paddle and twilight.

Information is degraded when there is fog, rain and snow that is why, we will note these elements in limits.

ISA - Intelligent Speed Adaptation

What we know

Safety System – **INTELLIGENT SPEED ADAPTATION**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: Research and development on the concept of Intelligent Speed Adaptation is going on both regarding speed limits and dynamically changing limits due to the prevailing conditions (e.g. adverse road-, or weather conditions). Some systems are based on the Active accelerator pedal. The Active accelerator pedal provides a counter-force whenever the driver tries to depress it beyond a pre-set speed limit. The performance of the vehicle is not affected at speed levels below the pre-set maximal speed. The Active accelerator pedal also restricts the engine's fuel injection when the vehicle reaches the actual speed limit.	

Components	**Related problems**	**Current diagnosis method.**
Vehicle sensors Vehicle transmitters and receptors Road transmitters and receptors Control unit	- Error in speed limit - Error in current vehicle speed	- Self Vehicle Checking - Auto-diagnosis routines on the road control equipment

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Mutual control, limit mode	Driving			

RISK I	RISK II	RISK III	RISK IV	RISK V
12 Non-adapted speed and exceeding at the same time the speed limit	13 Non-adapted speed in other cases	109 Mistake in use of accelerator		

What we assume

The ISA system limits the vehicle to the speed limits in the area, street etc.

We supposed that «road condition» only concern the rain.

According to WP6, the system can work by means of electronic signals transmitted to the vehicle from roadside beacons attached to speed signs or other roadside infrastructures (e.g. lampposts). (The trial in Sweden used this approach). An alternative approach which is more widely being tried out right now is, utilising GPS technology combined with map-matching dead reckoning techniques.

As we do not know if ISA use electronic signals from roadside beacons or other roadside infrastructures or GPS technology, we make the following choice: we assume that the speed limitations mapped by GPS is the same as the current speed limitations (on the road) indicated by signals. So, when there is no road sign, we indicate it as a potential limitation, in our coding.

According with the literature[11], ISA systems are divided into broad classes of **Advisory** (or informative), **Voluntary** (or driver activated or driver select) , and **Mandatory** systems.

In our evaluation of ISA, we evaluate the three one:

ISA1 - Advisory system (or informative),

Advisory ISA displays the speed limit and reminds the drivers of changes in the speed limit.

Information is given to the driver by 2 channels: oral and visual:

- On the display, there are speed limits and current speed practiced by the driver.
- A voice informs the driver of changes in the speed limit and of an exceeding current speed practiced by the driver.

ISA2 - Voluntary system (or driver activated or driver selected)

We suppose Voluntary ISA transmits a message about speed (exactly the same than Advisory ISA).

Voluntary ISA is linked to the vehicle controls but allows the driver to enable or disable control by the vehicle of maximum speed.

When the speed limit is reached by the driver, Voluntary ISA restricts the engine's fuel injection and the speed automatically and directly decreases. But the driver can have an action of acceleration, if necessary. This "kick down" function enable the driver to temporary override the system, which automatically came back into operation when the speed dropped back below the speed limit.

ISA3 - Mandatory system

We suppose Mandatory ISA transmits a message about speed (exactly the same than Advisory ISA).

With Mandatory ISA, the vehicle is limited at all times (ie : the driver cannot enable or disable control by the vehicle of maximum speed)

As for Voluntary ISA, when the speed limit is reached by the driver, Mandatory ISA restricts the engine's fuel injection and the speed automatically and directly decreases. But the driver can have an action of acceleration, if necessary. This "kick down" function enable the driver to temporary override the system, which automatically came back into operation when the speed dropped back below the speed limit.

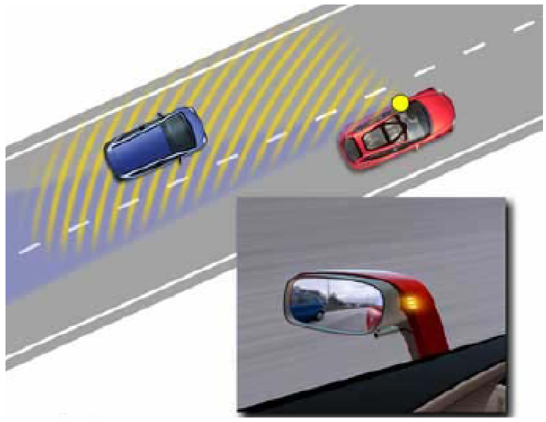
[11] Jamson S., Carsten O., Chorlton K. & Flowkes M., (January 2006). *Intelligent Speed Adaptation, Literature Review and Scoping Study* – project funded by Transport for London, at :

http://www.tfl.gov.uk/assets/downloads/corporate/Intelligent-Speed-Adaptation-Literature-Review-and-Scoping-Study-Jan-2006.pdf

Driscoll R., Page Y., Lassare S & Ehrlich J (sous presse). LAVIA – An evaluation of the potential safety-benefit of French intelligent speed adaptation project.

LCA - Lane Changing Assistant

What we know

Safety System – **LANE CHANGING ASSISTANCE**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: The system monitors traffic approaching from behind or in the driver's blind spot, will warn the driver if they are about to make a potentially unsafe change lanes or turn. The same radar sensors also provide information for a safe door-opening function, warning the driver of any cyclists, people on rollerblades or vehicles approaching from behind before opening the door.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Mutual control, warning mode	Driving	Rupture		

RISK I	RISK II	RISK III	RISK IV	RISK V
3 Over fatigue	25 Failure to observe the rear traffic when driving past stationary vehicles, barriers or obstacles	20 Overtaking without observing the rear traffic without timely and clearly indicating	95 Interest in activities other than driving	18 Overtaking in spite of unclear traffic situation

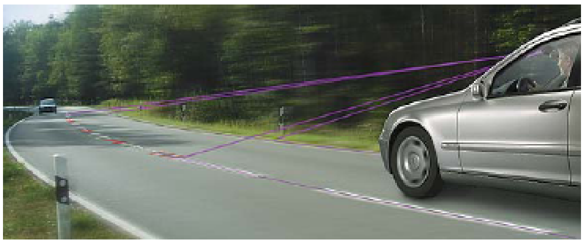
What we assume

We suppose LCA can detect vehicles, cyclists and pedestrians in a distance of 50 meters behind the vehicle and in the blind spot, according to WP6. We know that it could be increased to 120m by the addition of a special 3rd radar sensor. But we make the hypothesis that the range of the radar is 50 meters long, according to WP6.

The sensor/radar technology used means that LCA is unaffected by darkness, soiling or other adverse weather conditions.

LKA - Lane Keeping Assistant

What we know

Safety System – **LANE KEEPING ASSISTANCE**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: Lane Departure Warning System (LDW) will warn the driver if he or she is on the verge of inadvertently drifting out of the lane. Using a CMOS Camera and an image processing algorithm, this driver assistance system registers the course of the lane in relation to the vehicle. The system "sees", as it were, the course of the road and where the car is going. If the warning algorithm detects an imminent leaving of the current driving lane, the system warns the driver with haptic, kine-static, or acoustical feedback. Possible warning alerts can be a trembling in the steering wheel, a vibrating seat or a virtual washboard sound (a noise people recognize as generated by driving over a lane marker at highway construction sites). Lane Keeping System (LKS), as a next step, becomes an active lane keeping assistant, through an intervention in the steering. Just like LDW, the LKS measures the vehicle position relative to the lane, but offers active support in keeping the vehicle to the lane. However, the driver always retains the driving initiative, meaning that although he can feel the recommended steering reaction as a gentle movement of the steering wheel, his own decision takes priority at all times.	

Components	**Related problems**	**Current diagnosis method.**
CMOS camera Image processing computer Warning signals Steering actuator	- Not correctly detecting the lane - Unwanted activation of the warning/control method.	- Self Vehicle Checking

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Mutual control action suggestion mode	Driving	Rupture		

RISK I	RISK II	RISK III	RISK IV	RISK V
3 Over fatigue	90 Falling asleep	106 Faulty drive line	95 Interest in activities other than driving	116 Wrong place on the road

What we assume

LKA detects its own exit of way (crossing of central line or drift on the verge). It detects the markings. When the vehicle moves across road markings (white line lane markers) without the indicator being used, infrared sensors detect the movement and warn the driver. The sensors can detect white lines as well as the temporary road markings (yellow, red and blue) that are used in some European countries. The system identifies lines (continuous and broken) and other road markings such as directional arrows (except non-standard symbols).

If the driver goes out of the lane, LKA emits an alarm tactile/kinesthetic/oral and can have an automatic action on the direction system (=by a little movement of the wheel)

The system may fail to operate in case of strong reflections (e.g., due to sunlight glare or water on the road surface) inhibit the visibility of the road markings.

LKA does not operate at speeds below 60 kph for convenience.

We suppose LKA is inefficient if:

- there is not side or middle markings
- markings is worn
- there is already a loss of control of the car
- in city
- in sinuous roads

In our coding, these 5 last conditions will be noticed as limitations of the safety systems.

NV - Night Vision

What we know

Safety System – **NIGHT VISION/ (HEADS UP DISPLAY)**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Visibility**	
Description: This system provides a display of the dashboard instruments on the inside of your windshield and will make you feel like a jet fighter pilot. The luxury version option available on some cars incorporates night-vision technology that allows the driver to see further down the road than the headlights illuminate.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Perceptive mode	Driving	Rupture		

RISK I	RISK II	RISK III	RISK IV	RISK V
78 Insufficient road lighting	80 Fog	98 An inadequate or faulty observation of the environment	81 Heavy rain, hail, flurry of snow and the like	

What we assume

NV can detect up to 300m ahead the vehicle.

(source: http://www.journaldunet.com/solutions/0610/061010-systemes-embarques-automobile/3.shtml)

PBA - Predictive Assist Braking

What we know

Safety System – PREDICTIVE BRAKE ASSIST

Classification: **Primary Safety**

Proposed for: **Cars**

Safety Function: **Braking Systems**

Description: The Predictive Brake Assist (PBA) is the first safety system that in advance processes the relevant information from the vehicle's surroundings and reacts before the impending accident actually takes place.

Using the data from the Adaptive Cruise Control's radar sensor, PBA detects situations which could be dangerous enough to develop into an accident, and in which it is more than likely that emergency braking will be needed. If such a dangerous situation does occur, PBA prepares the brake system in advance for panic braking. Pilot pressure is applied to the brake system so that the required brake pressure can be generated more quickly, and the brakes are applied very gently so that the driver doesn't notice. In addition PBA lowers the triggering threshold for the hydraulic brake-assist system in three stages. Studies have proven the effectiveness of these measures. Even in critical situations, only about a third of the drivers reacts appropriately and hit the brakes hard enough. Most drivers are hesitant, and don't apply enough pressure with the result that the hydraulic brake-assist system is not triggered.

As soon as the driver reacts and hits the brakes, the full braking effect becomes available milliseconds earlier thanks to the measures that have already been initiated in advance. Valuable milliseconds that can decide between life and death. Here, the total braking distance can be reduced considerably due to the interaction between the driver's reactions and the driver-assist system.

Components	**Related problems**	**Current diagnosis method.**
Hydraulic pressure generator and modulator Wheel speed sensors Sound radar Infrared laser Computer vision system	- Not predicting braking emergency situations - Involuntary activation of the brakes or different brake force between the tyres	- Self Vehicle Checking

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Delegation of a function, mediated mode		Rupture	Emergency	

RISK I	RISK II	RISK III	RISK IV	RISK V
14 Insufficient safety distance	15 Abrupt braking without compelling reason by the vehicle in front	101 Did not identify the danger of the traffic situation	103 Faulty interpretation of the intent of others or the situation	108 Braking mistakes

What we assume

We suppose the radar adjusts the scan in front of the vehicle according to the dimension of the road (see Figure 54).

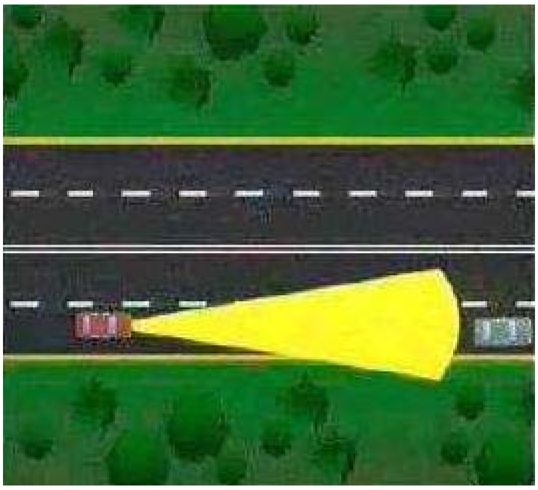


Figure 54: The radar adjusts the scan in front of the vehicle according to the dimension of the road

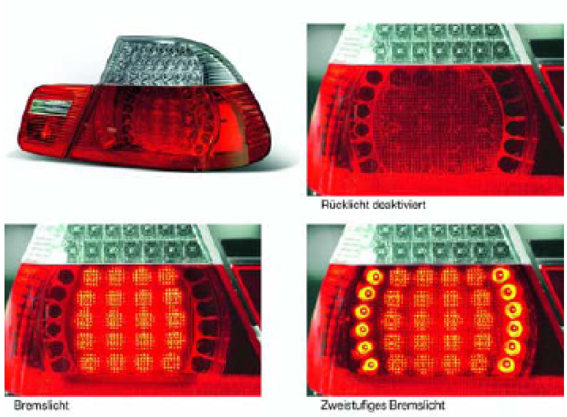
Thanks to ACC, PBA detects every potentially dangerous situations (generated by vehicles in movement) and prepares the braking system so that it will be generated more quickly (a saving of 0.2 seconds time, according to our technician specialized in vehicle dynamics) and with more intensity ($8m/s^2$, is the maximum deceleration, according to our technician specialized in vehicle dynamics).

We suppose so, that all vehicles which have PBA also have ACC (for the 2nd part: Communication based longitudinal control, Cf ; page 25).

PBA can only detect vehicles which are equipped with ACC. So, in this study, we assume all vehicles have ACC

RLBF - Rear Light Brake Force Display

What we know

Safety System – **REAR LIGHT BRAKE FORCE DISPLAY**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Visibility**	
Description: Rear Light Brake Force Display works by increasing the intensity of the brake lights in the rear lamp clusters by expanding the number of illuminated LEDs when heavy braking is detected. The extra lighting is triggered after the brake sensors detect a certain rate of deceleration, e.g. in excess of 5 m/s^2. The Rear Light Brake Force Display is not triggered by pedal pressure in order to avoid unnecessary illumination. The system reacts within a few tenths of a second to increase the intensity of the stoplight illumination, projecting a highly visible warning beacon to following traffic.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Perceptive mode	Driving	Rupture		

RISK I	RISK II	RISK III	RISK IV	RISK V
97 Faulty observation of the other participant or situation	98 An inadequate or faulty observation of the environment	15 Abrupt braking without compelling reason by the vehicle in front	114 Missing, delayed or faulty signal giving	

What we assume

No specific assumptions.

In our coding, we often code this safety system for the driver who needs to see the hard braking; and not to the driver who should be equipped by RLBF.

SAVE-U - Vulnerable Road Users Protection

What we know

Safety System – **VULNERABLE ROAD USERS PROTECTION (SAVE-U)**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: The system calculates in a matter of seconds the movement of pedestrians within the 'capture zone' which can be up to 30meters away from the vehicle. The camera tracks the pedestrian movement and the information is correlated with the data received from the radar network (speed of and distance to object). SAVE-U can consequently identify any pedestrian or cyclist coming within the trajectory of the vehicle and after analysing the situation, warn the driver or apply automatic braking if there is a risk of collision.	

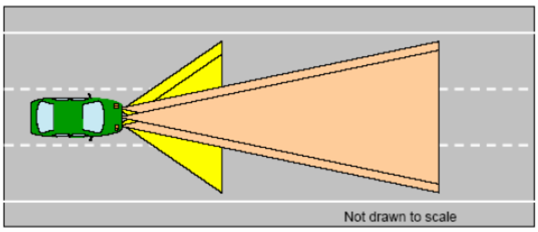
DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Automatic mode		Rupture	Emergency	

RISK I	RISK II	RISK III	RISK IV	RISK V
94 Not conscious of the traffic	68 Playing on or near carriageway	64 without paying attention to the traffic	78 Insufficient road lighting	69 Other improper behaviour of pedestrians

What we assume

SAVE-U detects pedestrians or cyclist in movement up to 30m in front of the vehicle according to the road wight.

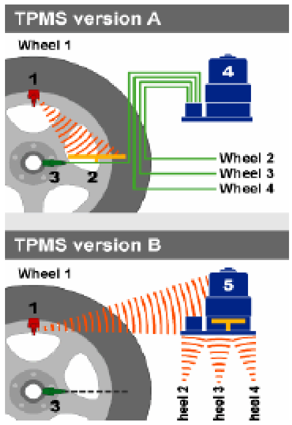
After having analyzed the situation, SAVE-U informs the driver or starts an emergency braking if there is any collision risk.



SAVE-U is efficient by night. But its camera is inefficient when visibility is limited by an object (it cannot see through it).

TPMS - Tyre Pressure Monitoring and Warning

What we know

Safety System – **TYRE PRESSURE MONITORING**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: The system for tyre pressure monitoring detects small pressure fluctuations, locates the affected tires and informs the driver with warnings of varying urgency. A co-rotating wheel module with an integrated valve measures tyre pressure and temperature and transmits these data as an HF radio signal. In a system with 4 wheel modules, 4 antennas with HF coupler, the receiving antennas are located on the connecting cables for the wheel speed sensors. They send the data to the EBS-ECU, which then analyzes them in an intelligent warning strategy unit.	

Components	**Related problems**	**Current diagnosis method.**
Wheel module EBS-ECU with HF coupler Wheel speed sensor	- Not warning about a pressure fluctuation - Not detecting punctures - Faulty indication of pressure fluctuation	- Self Vehicle Checking

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Perceptive mode	Driving			

RISK I	RISK II	RISK III	RISK IV	RISK V
51 Tyres	126 Lowering of the tire pressure	123 Loss of wheel		

What we assume

TMPS monitors pressure, speed, temperature, and damaged tire. TPMS won't detect worn tire.

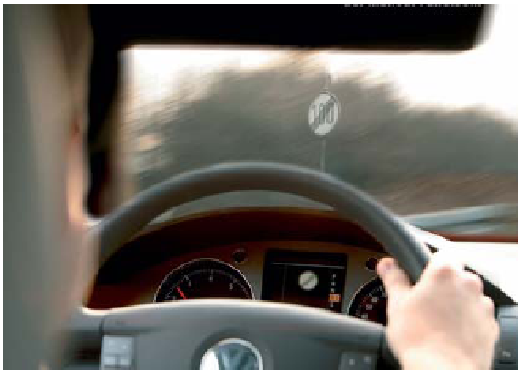
We make so the hypothesis that TPMS can detect overload when temperature will increase (only if the initial pressure is correct).

TPMS will inform the driver when there is an under-pressure at a threshold of -0.5bar and an over-pressure at a threshold of +0.5bar.

TPMS will be useful to avoid loss of control linked to an under-pressure.

TSR - Traffic Sign Recognition

What we know

Safety System – **TRAFFIC SIGN RECOGNITION**	
Classification: **Primary Safety**	
Proposed for: **Cars**	
Safety Function: **Drive Safe**	
Description: The system incorporates a digital display which informs the driver of all the respectively applicable road signs along the motorway. The image processing system is most effective in areas where traffic signs or traffic lights have only been installed or are in operation temporarily - for example, at construction sites or on highway bridges equipped with electronic signs that change according to the traffic situation.	

DRIVING MODE	PHASE I	PHASE II	PHASE III	PHASE IV
Perceptive mode	Driving			

RISK I	RISK II	RISK III	RISK IV	RISK V
95 Interest in activities other than driving	84 Storm or other weather influences	77 Irregular condition of traffic signs or installations	78 Insufficient road lighting	28 Failure to observe the traffic signs regulating the priority

What we assume

Only on motorway, TSR displays traffic signs which the system captures (speed limits indication, working areas). We suppose that the way of displaying them in the vehicle is on a heads-up display.

It is useful when the conditions of visibility are limited. But it is also useful when visibility conditions are good.