SAFEMAP: SOCIO-ECONOMIC ASSESSMENT OF A DEDICATED DIGITAL MAP FOR ROAD SAFETY APPLICATIONS

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ABSTRACT

SafeMap is a joint German-French project with partners from industry (car manufacturers, map providers) and governmental research institutes which was launched within the DEUFRAKO initiative in January 2004. The main objective of the SafeMap project is to assess the socio-economic feasibility of a dedicated digital map data base comprising safety related data.

To reach this objective, the project has been organised in two main phases. A milestone has been defined by the end of the first phase where a first rough estimation of the effectiveness of this digital map was provided, which has been detailed further on in the second phase. In this paper the technical approach and main results are described: the project will be finished in May 2007.

1. INTRODUCTION

Navigation systems are increasingly becoming standard equipment in modern cars. Based on the positioning capability of the vehicle, driver information applications (e.g. speed alert, curve warning, gradient warning systems) can be built that increase road safety by providing advance warning to the driver on road hazards ahead.

The implementation of map-based safety applications that provides this kind of road information requires an appropriate digital map in the vehicle which contains the necessary safety related road data. These data must be of particularly high quality, and moreover, a permanent update process is required to ensure this data quality over the lifetime of the on-board system in the vehicle. In the past, the lack of a high quality digital map containing safety related road data has turned out to be one main barrier for the implementation of autonomous “eSafety”-systems, which are considered as the most promising approach to further improve road safety.

Thus, the main objective of the SafeMap project is to provide a comprehensive feasibility assessment of a dedicated digital map database comprising safety related data. This assessment should cover all relevant socio-economic, organisational, legal and technical aspects which can be used by relevant stakeholders (public authorities, map providers, car industry) to support their decisions on the implementation of “eSafety” systems.

2. TECHNICAL APPROACH

The German-French SafeMap project consortium consists of partners from the car industry (DaimlerChrysler, Renault Trucks, PSA), map providers (Teleatlas, NavTeq) and public road research institutes (BASt, LCPC/LIVIC). The co-ordinator of the overall project is ISIS from Groupe EGIS (France). The joint activities within this project started in January 2004.

A first milestone has been reached at the beginning of 2005 (see Figure 1): the main objective of the first phase was to provide a preliminary cost benefit analysis of the potential of the digital map database on road safety.

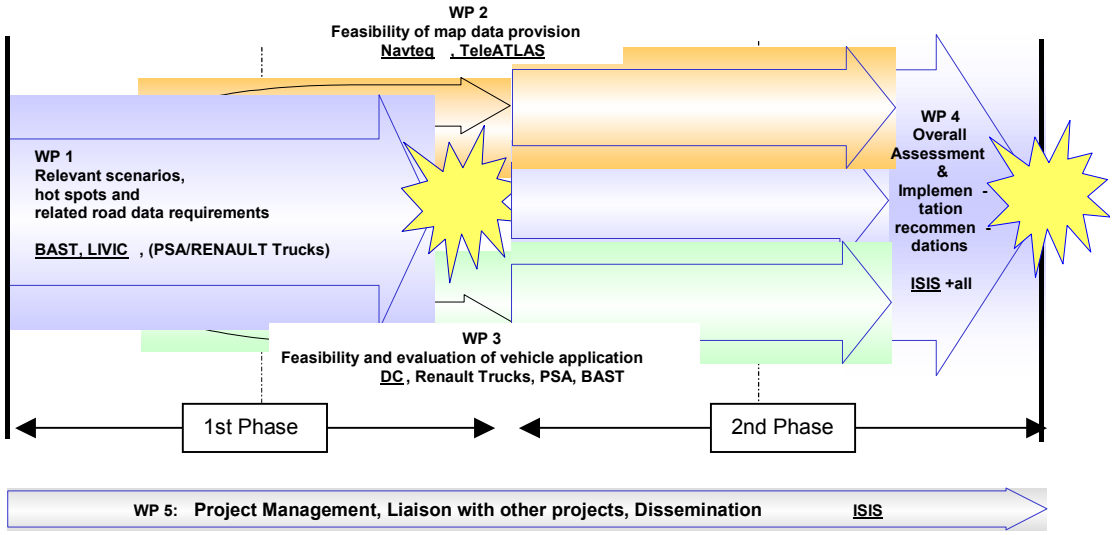

Figure 1 - Structure of the SafeMap workplan (two phases)

In the second phase of the SafeMap project the preliminary assessment of the impacts on road safety has been refined by a more comprehensive cost/benefit assessment (Workpackage 1). Moreover, the proposal of business models (Workpackage 2) and the evaluation of the effects on driver acceptance and driving behaviour (Workpackage 3) resulting in an overall assessment of the socio-economic, organisational and technical assessment of the feasibility of the SafeMap database (Workpackage 4) are provided.

3. FIRST PHASE RESULTS

We can classify driver assistance features in three categories:

- On-board replication of existing traffic signs, with the objective of reminding the driver of signs that he may have misunderstood, forgotten about, or not even have seen.
- Innovative applications allowing the driver to anticipate the approaching difficulties curves, junctions, ..
- Fully driver assistance functions (lateral control, longitudinal control, collision avoidance, etc).

It was decided to concentrate the SafeMap approach on the two first categories. According to first assumptions concerning the cost benefit ratio and accident analysis, assistance applications using the following functional categories were selected:

Table 1 - definition and classification of the selected functions

Id	Functions based on:
A	Speed limit
B	Curve
C	Intersections
D	Overtaking
E	Hazardous areas
F	Accident spots
G	Physical restrictions*

E and F functions are both based on accident statistics, but they differ fundamentally: while, for triggering a warning, function F compares the current driving situation to past situations with occurring accidents, function E is based on accident analysis in relation with road geometry, mainly curves and crossings. With E, the warning will be triggered by comparing the vehicle dynamics to the infrastructure configuration.
This difference between E and F reflects the different approach taken by French and German partners during the first phase of the project. The objective was to explore the two different options and assess them during the project.
The "German Approach" (function F) was developed by the Ruhr-University of Bochum (Prof. Brilon) as a subcontractor of BASt (1).

4. BENEFITS

The expected benefits, in terms of fatalities, serious or slight injuries have been based for a first approach, on the assumption that a driver in a vehicle equipped with the selected assistance application, takes fully into account the warnings and that these applications do not generate perverse effects.

Based on 2002 accident statistics in France (400 000 km of motorways, national highways and main rural roads), the potential economic gain is around 8 billion Euros. In Germany, the potential estimated benefits are a reduction of 46% of all accidents which occur outside built-up areas, which represents a theoretical gain of 6.8 billion Euros.

5. REQUIRED DATA AND THEIR COLLECTION COSTS

First phase activities of the SafeMap project have also defined the data required by the selected driver assistance applications and estimated the costs for collecting them.

Three types of specific equipped vehicles, already widely used by road maintenance organisations, would allow the required geometry measurement to be carried out (for the French approach). The total cost for the French road network has been estimated around 60 million Euros (to be compared with the expected benefits…).

For the German approach (based on accident statistics), no costs have been given yet as most of the work would normally be based on the processing of existing data.

* Only for trucks.

These preliminary results presenting very encouraging Benefit/Cost ratios led to the decision to pursue the project: it is clear that the real benefits depend on various parameters that require further investigations. Among these parameters we can quote the market penetration of the system, the potential driver reaction, etc.

6. SECOND PHASE

One important activity of the second phase was therefore the investigation of drivers' acceptance and the effects of the SafeMap in-vehicle-applications on driving behaviour. Three test sites have been used for that purpose. In Germany, on-road-tests have been performed by DaimlerChrysler and BASt, with the support of Tele-Atlas maps, on a test route near Stuttgart by the end of 2005. In France, on-road-tests have been performed on a circuit located in the West of Paris during 2006 spring by PSA and LCPC with the support of Navteq maps. Additional tests involving trucks, have been performed by VOLVO - Renault Trucks near Lyon in autumn 2006.

6.1. Selection of applications for the tests

Starting from the basic functions that were selected, various applications can be built: in particular many choices can be made in relation with the level of interaction between the vehicle and the environment and the level of interaction with the driver (information, warning, etc).

The following table presents the choices that have been made by the different automotive manufacturers, concerning the SafeMap test applications:

Table 2 - selection of applications for the tests

	TEST APPLICATIONS		
FUNCTIONS - based on:	DaimlerChrysler	PSA	Renault Trucks
A) Speed limit	Warning according to vehicle speed	No	Warning according to vehicle speed
B) Curve	Warning according to vehicle speed and predefined threshold	Information on difficulty level (5 levels)	Warning according to vehicle speed and predefined threshold (radius)
C) Intersections	No	Information	No
D) Overtaking	No	No	No
E) Hazardous areas	Included in B and F	Included in B and F	no
F) Accident spots	Warning according to comparison of present situation to reference situation	Information	Information
G) Physical restrictions	No	No	Information

6.2. Test sites

The German test track is located in the Black Forest in the area of Herrenberg and Nagold about 15 min. away from the DaimlerChrysler premises in Sindelfingen (Figure 2).

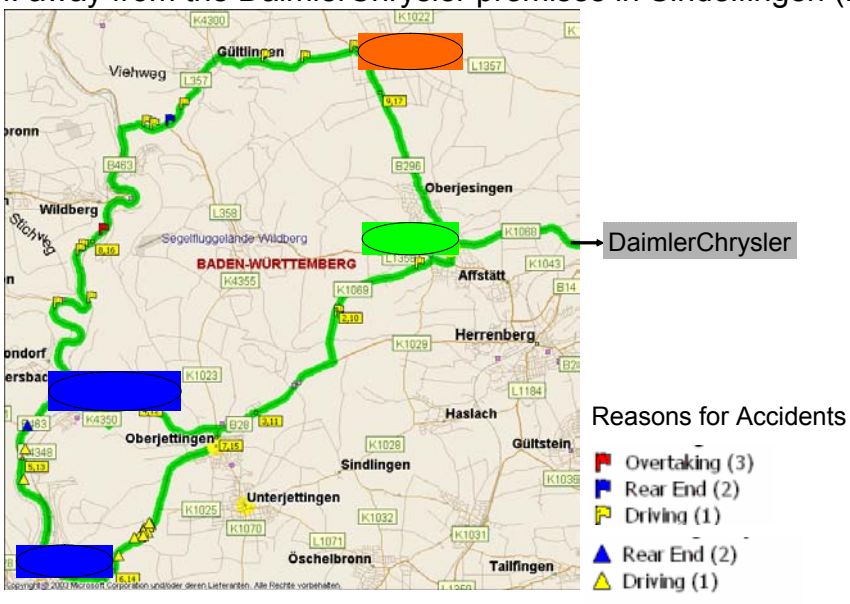

Figure 2 - German test site area with accident spots and their cause

The French test site for light vehicles is located in the western part of Paris, about 20 km from Versailles, while the test site for trucks is located near Lyon:

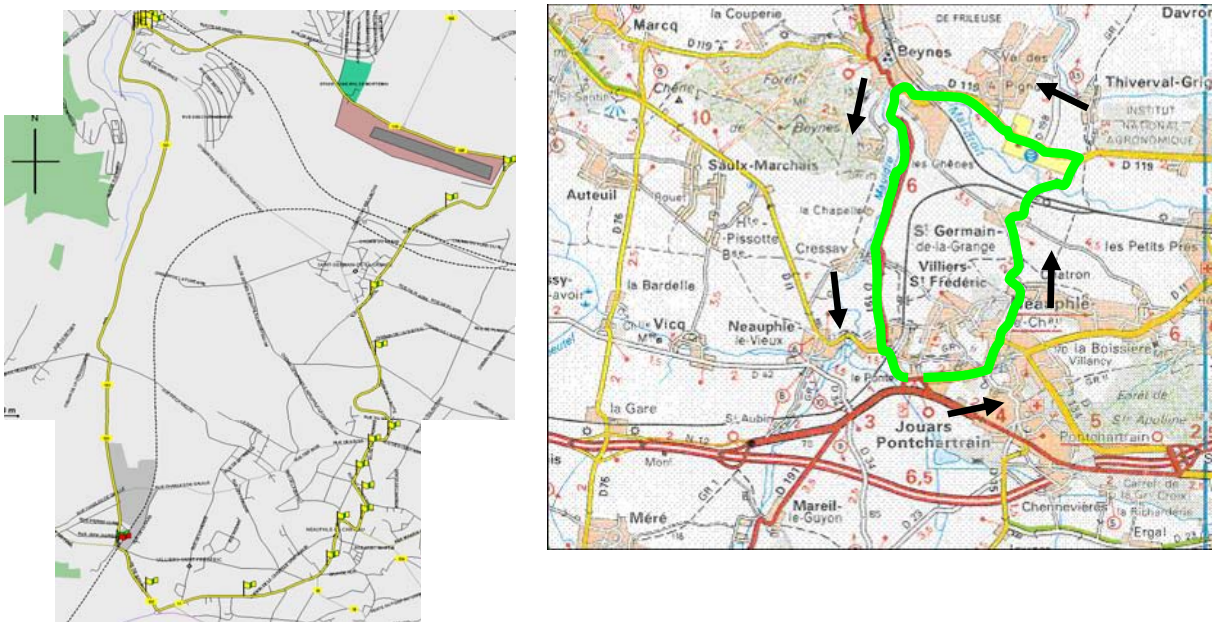

Figure 3 - French test site with curves warning

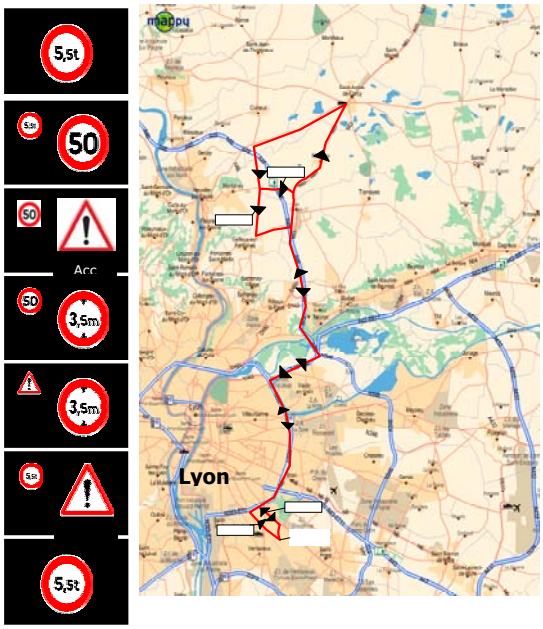

Figure 4 - French test site for trucks and type of in-vehicle display

6.3. Applications using curve information

Using information on curves, various assistance applications can be imagined. For the SafeMap project tests, Daimler Chrysler (DC) and PSA Peugeot Citroën have developed 2 different applications:

- DaimlerChrysler's Curve application is a warning that is triggered according to predefined thresholds depending on the current speed, the environment (wet or dry surface), radius and banking. The following diagram gives the maximum admitted speed according to these factors.

START

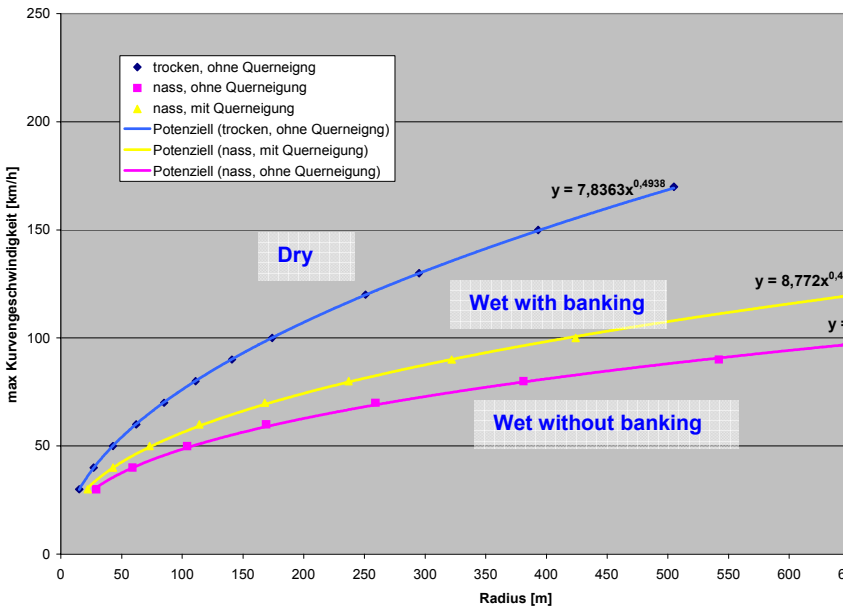

Figure 5 - Curve radius and maximum vehicle speed for different road surfaces [RUB]

- PSA's Curve application is more an information that is displayed to the driver and presents the difficulty level of the approaching curve and the next one after that. Difficulty levels have be classified in 5 categories that are represented by various colours and shapes.

6.4. Applications using accident spots information

To determine frequent accident spots in Germany a detailed accident analysis was conducted by the University of Bochum. A relative accident probability is determined by aggregating individual accidents on road segments. Size of road segments for aggregation can be adapted in order to produce more or fewer warnings. In addition, the warning is activated according to a decision matrix comparing circumstances of past accidents (e.g. day, night, season) and actual circumstances.

For the French test sites, the choice has been made to display an information message on past accident locations when approaching them, in all circumstances. It is worth mentioning that the different approaches in France and Germany are not dependent on any policy but have been deliberately chosen to be able to compare different solutions, and the difference in behaviour between warning and information.

6.5. Tests methodology

About 20 drivers participated in the test drive, in each site. The driving tests were designed to take into consideration the time for familiarisation with the vehicle, and to compare driving behaviour with and without systems.

The vehicles have been equipped with cameras observing the driving tasks, the environment and drivers' eyesight. All manoeuvres have been registered (accelerator pedal, brake, steering wheel, etc) and an observer was in charge to note additional information. Subjects have been interviewed at intermediate stages of the tests and at the end with a common questionnaire on the usability and comprehensibility of the system.

Analysis concerning the German site is now complete concerning accident spots warning. For other applications and the French test sites, analysis is still currently underway. Preliminary results are presented in the following sections.

6.6. Results of the second phase

The most important effect which is expected from the drivers that are warned of or informed of a potential hazardous situation is a reduction in speed (release of the accelerator pedal and/or braking).

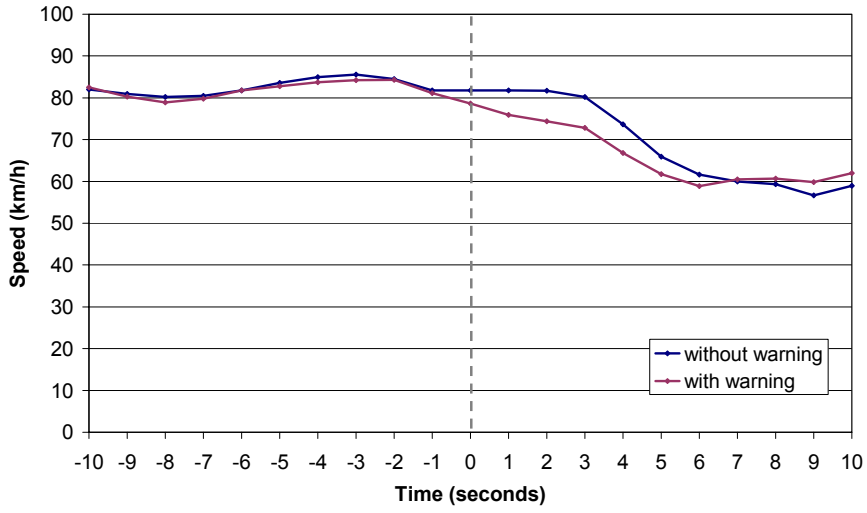

Figure 6 : reduction of speed with and without warning (German test site)

This behaviour has been observed among the majority of drivers on the German site, but due to the sample size it is difficult to obtain significant results. In addition, the reduction of speed that can be observed is not really significantly different between drives with and without warnings (Figure 6).

Distribution of speed reduction was also analysed on German and French side. Examples are given below :

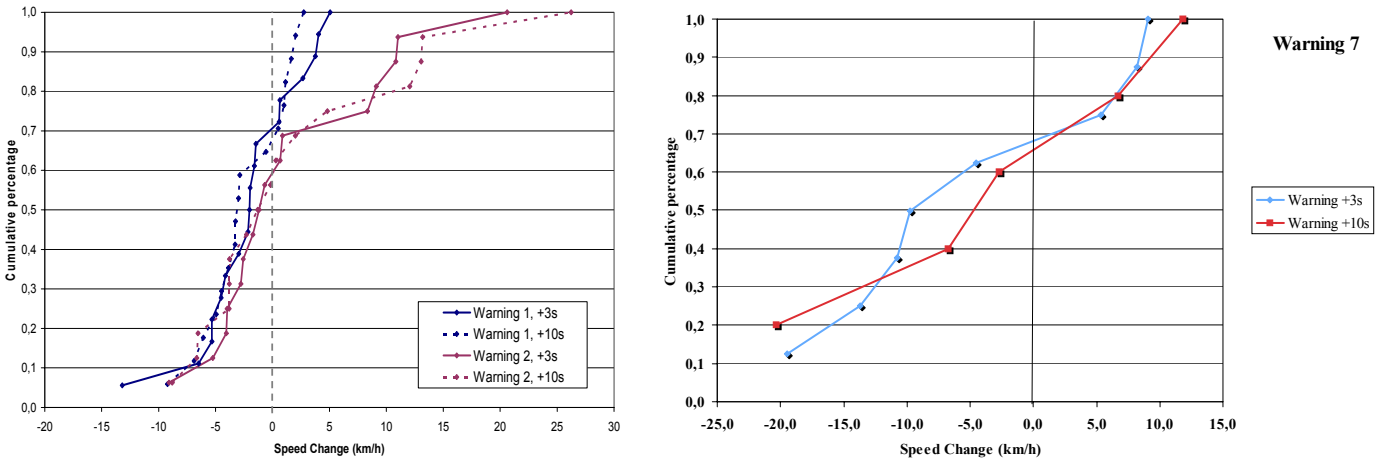

Figure 7 : distribution of speed reduction (German and French sites)

From these measurements, we can presume that the “test conditions” influenced the driver to consequently pay more attention to the driving tasks than in a normal situation. A confirmation is given by the interviews: most of drivers stated having found the warning useful and having been influenced…

Acceptability expressed in terms of opinions about the system was measured by means of German and French translations of a user acceptance test published originally by van der Laan and colleagues in 1997. Subjects were requested to make their judgements after the test drives on nine items with 5 point rating scales. Items are formulated as adjective pairs (see figure 8). However, due to the unknown psychometric properties of the translations of this instrument results are presented descriptively item by item and without aggregation on two scales as proposed by van der Laan et al. (1997). To summarise the results presented in figure 8, it can be stated that the average judgements of our subjects are without any exception closer to the “semantically positive” end of the scales, indicating generally positive attitudes towards the system.

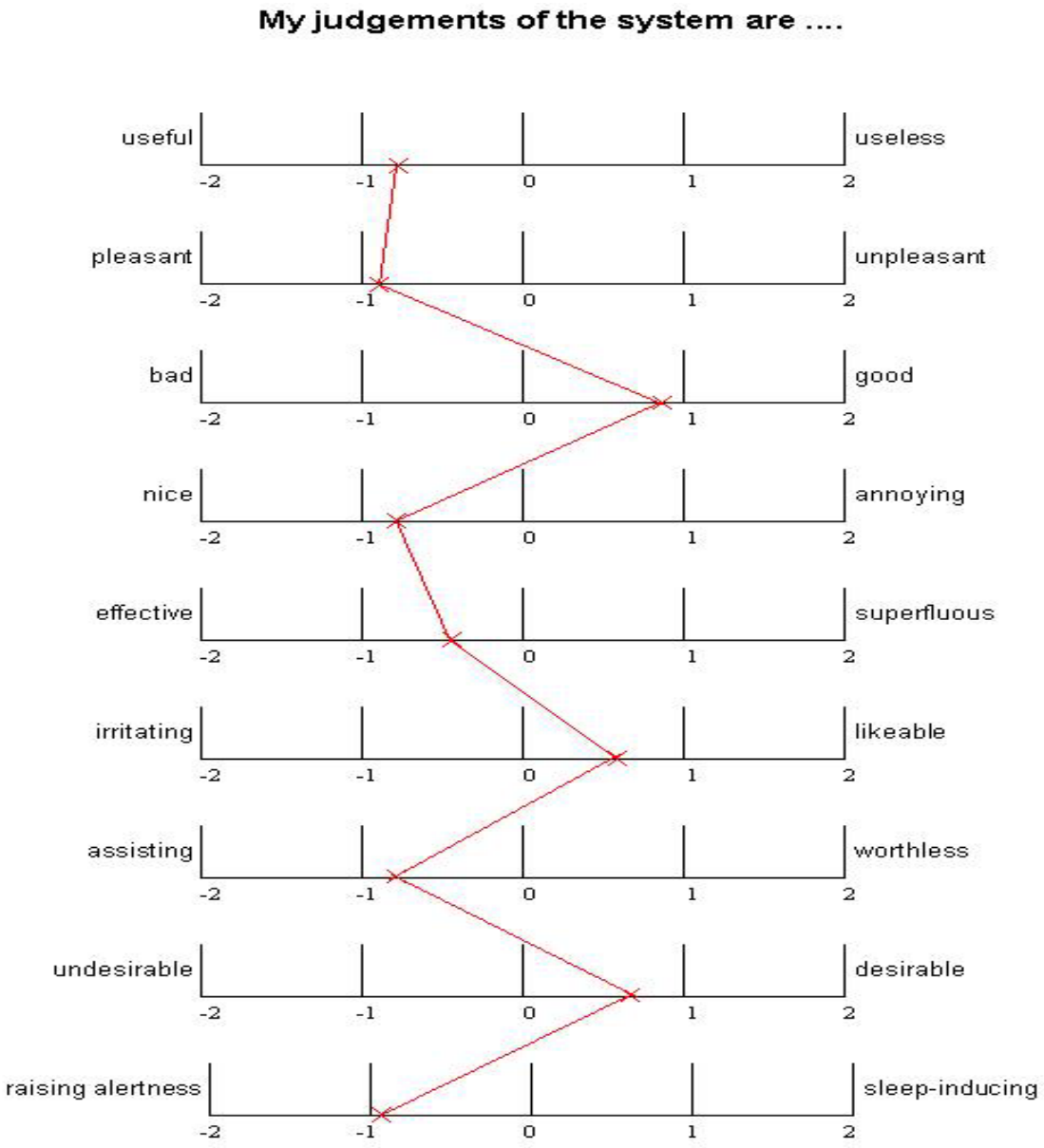

Figure 8 : Arithmetic Means (AM) of subjects ratings on the nine adjective pairs of the acceptance questionnaire (van der Laan et al., 1997) (n=22).

Further investigation with other applications and the other sites have been undertaken. Based on the preliminary results, that should be considered as hypothesis to be confirmed or disproved, the available figures give a median absolute speed reduction factor at 3 seconds and 10 seconds after the warning between 0,954 and 0,971 (average: 0,964)

Based on this figure and using the Power Model by NILSSON ELVIK and al. (2004), this could lead to a reduction of 12% in fatalities and 4% in damage-only accidents.

Of course, these benefits need to be corrected with other factors:

- market penetration
- acceptance/usage of the system
- warning ratio for applications dependent on external conditions…

Market penetration includes 2 aspects that are strongly interlinked:

- the penetration of navigation systems integrating SafeMap applications, derived from navigation market forecast
- the road network part that is covered by the service.

It is clear that the main national road network can be covered quite easily: limited length, data collection easy or already done, but with less stakes in term of accidents, while the secondary network is an extended network, multi-jurisdictional, where data collection is costly, but with major expected benefits…

These factors have been incorporated in a comprehensive cost/benefits analysis tool. This tool allows to develop scenarios based on a selection of combination of applications, e.g.:

- Speed warning + curve warning
- Speed warning + intersection warning
- Speed warning + accident spots + curve warning

…

One difficulty for assessing these combinations is that elementary impacts cannot be added: a speed warning can be triggered due to sharp curve and accident spots can coincide with a legal speed limit, etc. This difficulty can been solved by ranking applications, e.g. by giving precedence to speed warning.

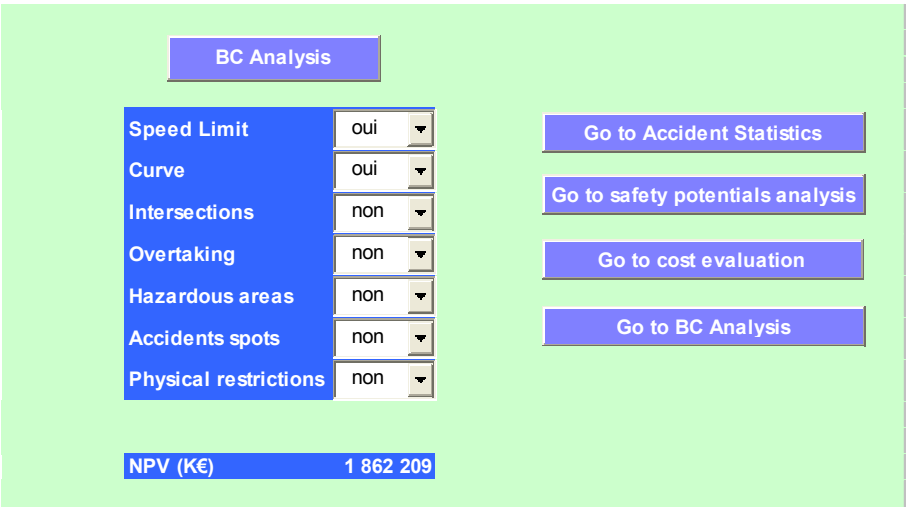

Figure 9 : CBA tool interface

The Cost Benefits analysis is still underway at the time this paper is written. Consolidated results will be available and presented during the Road World Congress in September. Considering the first estimations, there is no doubt that the socio - economic evaluation will be positive in most of the case. However, this does not mean that SafeMap applications can be easily deployed. As in many ITS services, the key of a successful deployment is to build a suitable public private partnership and find a suitable business model in order that the SafeMap applications are profitable for the private investors while improving safety.

It is worth mentioning that on these subjects, the SafeMap project co-operates actively with the Map&Adas project funded by the EC and co-ordinated by ERTICO.

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