The application of root cause analysis for definition of scenarios in automotive domain

M. Alonso[(2)]; L. Macchi [(1)]; M. Marchitto[(3)]; J. Plaza[(2)]

(1)European Commission
Joint Research Centre,
IPSC
21020 Ispra (VA), Italy
luigi.macchi@jrc.it

(2)Fundación
CIDAUT
47151, - Valladolid
(SPAIN)
maralo@cidaut.es
juapla@cidaut.es

(3)*KITE Solutions s.n.c*
21014 Laveno Mombello
Varese (Italy)
mauro.marchitto@kitesolutions.it

Abstract

This paper aim at presenting the work done within the European project RANKERS. The main focus of the paper is the definition of accident scenarios to be implemented in experimental tests to improve the road safety from the infrastructural point of view.

The mean applied has been developed from the ISAAC root cause analysis methodology. The choice of using a root cause analysis method has been done with the goal of identifying the factors that could be responsible in some part in the happening of accidents on the European roads.

In this article four scenarios have been identified and described from a descriptive and inferential point of view.

Keywords : automotive domain, accident scenarios, ISAAC root cause analysis.

Introduction

Automotive Safety is a critical theme that have been taken into consideration several times in the last decades projects because of its criticality on the societal and economic costs management difficulties of automotive transport.

The great part of scientific literature about automotive safety tends to individuate three Safety Pillars that compose the driving situation: the driver, with its personal features (age, experience, psycho-physical state), the vehicle (and its performance metrics) and the environment, or more precisely in the road infrastructure, analysed in its design and in the presence or not of different safety countermeasures (barriers, road signals, etc...) that are able to influence in some way driver performance,

The Rankers project distinguish itself form a considerable number of scientific studies because of its focus on road infrastructure as an active factor in determining driver performance. Rankers main objective is to merge a set of practical and comprehensive recommendations for road infrastructure safety to be used by road authorities and road operators in order to eliminate particularly dangerous sections (“black spots”) and to promote sustainable roads.

The project aims at delineating these recommendations through three phases: the first one is summarised in this paper and consists in the identification of some critical accident scenarios starting form national accident databases and a Human Factors analysis of the available data: the ISAAC methodology has been applied in order to individuate some accident causation factors to be investigated in the execution of the built scenarios.

The investigation phase is performed through field tests and simulator trials: all the session are described in experimental protocols that are currently under the final editing phase: the experimental hypotheses are formulated taking into consideration road infrastructure in terms (as well as possible) of an independent variable.

The statistical analysis of all the collected data will lead to the last phase, which is dealing with the building of useful recommendations for road constructors that include a Human Factors perspective and a drivers performance monitoring analysis (and validation phase) in their background framework.

The method: SHEL and ISAAC

This research, developed framed in the RANKERS European Project, has been carried out following an approach of data structuring well-known in literature, i.e. SHEL (Edwards, 1972), and a particular technique in the identification of the accidents' causes, i.e. ISAAC (Integrated Systemic Approach for Accident Causation).

The SHEL approach is mainly a framework that allows the description of an activity taking into consideration the four elements involved: Software, Hardware, Environment and Lifeware. From the definitions given by the author the Hardware is intended as all the physical sources that are involved in the interaction between the Liweware (i.e. the human being) in the performance of his/her activities; all the rules, regulations, procedures and practices are what con be termed as Software while the Environment covers the social, physical and technical aspects of the activity context (Cacciabue, 2004).

Contextualized in this conceptual framework, we have applied the ISAAC root cause analysis with the aim of identifying the personal, contextual and casual factors that are involved in the car accident causation mechanism. This root cause analysis method has been usually in the literature applied in order to highlight the latent cause that can be triggers to the causation of accidents in more structured domain than the automotive is.

The tentative of application of a reduced version of ISAAC, in this paper the authors did not check for latent causes but ended their work on the factors, has the goal of provide the experimental protocols with some reliable information on the variables to be taken into consideration.

In the ISAAC approach the personal factors account for the effect of individual physical or mental conditions on active errors, the contextual factor account for the physical environmental and local conditions and the casual factors for random system contingencies affecting system failures (Cacciabue, 2004).

The data collection: national databases.

The analyses performed in this work have been done on the basis of the national databases of 5 European countries. The databases refer to the accident data of France,

Sweden, Spain, Slovenia and Finland. The data collected refers to the accidents occurred in the highways and in the dual carriage ways roads of the above mentioned countries between 2001 and 2005. The data collected are obviously referring to the accidents that were registered by police and road administration authorities. These data are, by matter of fact, only a small sample of all the accidents that occur on the roads. It is estimated that the global number of accidents that are reported is about 10% of the total amount. This fact is due to the intrinsic nature of the database. Since only major accidents, and most probably the ones with injured or died people, are registered and reported to the authorities while most of the less serious ones are solved by the drivers without the engagement of the possible reporting authorities. This gap is, at the present time, not possible to fill. The impossibility to have really reliable data of all the accidents that occur on European roads will remain until a voluntary reporting system, as the one developed for the aviation domain, will be developed and accepted by the population. To partially solve this bias the only possible solution has been taken into consideration with the work performed by expert analysts. Their work is aiming at the consolidation and check of the data reported in order to avoid the possible mistakes that could happen in the activity of registering the accidents on the roads. Being aware of the fact the data are somehow affected in their reliability, the work of trying to identify the causes the accidents happening and then the definition and construction of scenarios to be used in the definition of experimental protocol is an activity that could have an important role in trying to reduce the number of accidents on European roads.

The role scenarios will have in this ambitious work is mainly the identification of some main features that can influence a certain typology of accident. Due to the nature of data and of the analysis performed the authors are aware that the results of this research are mostly a set of recommendations concerning the variables that have to be taken into consideration in the design of field tests.

The analysis: variables definition

From the databases the first step to be performed was the selection of the appropriated variables to be included in the statistical analysis. The selection of the variables has been done according to two criteria. The first one was the application of the root cause analysis approach bearing in mind the final goal of the European Project within this activity has been performed and in particularity the need of application the results f the analysis to the performance of field tests on the European roads.

For this reason the following variables have been taken into consideration:

- weather conditions;
- road conditions;
- light conditions;
- traffic density;
- vehicle type;
- driver's familiarity with the road;
- driver's age;
- driver's gender.

In a second stance the variables have been checked for their consistence and statistical features. The variables that have passed the two previous filters have been included in the statistical analysis. The analysis performed consisted in a preliminary study of the correlation existing among the eight variables.

As a first general result of the analysis we can see that in the global set of accidents recorded the following variables are correlated:

- Weather conditions and road conditions;
- Light conditions and road conditions;
- Weather conditions and light conditions;
- Light conditions and driver's age;
- Vehicle type and driver's familiarity with the road.

The first correlation indicates that bad weather conditions, as easily expected, are strongly linked with bad road conditions in terms of road surface (wet/dry/ice….)

The second correlation shows that many accidents happen when both light conditions and road conditions are degraded.

Light conditions are also directly correlated with the weather conditions that indicates that there is a statistically significance co-presence of this two factors in many f the accidents of the database analysed.

A more difficult result to be interpreted is the inverse correlation between the light conditions and the driver's age. It seems that there is a tendency of happening accidents for older drivers during the day.

The last correlation found is between the type of vehicle driven and the familiarity of the driver with the road. It seems that the lighter/smaller the vehicle is the less familiar with the road driven the driver is.

The second step in the analysis performed was the Multiple Linear Regression. The methods used and the results obtained are described in the following chapter.

The scenarios: descriptive analysis and regression results

The multiple linear regression analysis has been applied in this research aiming at identifying a number of features characterizing scenarios to be tested on real road. Through the analysis performed four scenarios have been identified: Loss of car's control with no driver's reaction; Loss of car's control with driver reaction; Rear end collision, and Lane changing collision.

In the following chapters the description of the results of the regression analysis and a detailed descriptive analysis has been reported.

1.1 Loss of car's control with no driver's reaction

From the analysis of the data concerning this typology of accident is possible to highlight that the only independent variable that is statistically significant in predicting the accident causation is *road conditions*. The relationship between these two variables

is “inverse”. This situation gives an indication that this typology of accident occurs less frequently when the road is wet or icy and more frequently in normal driving conditions.

The driving situation that is mainly represented in these accidents is a male driver, driving a light vehicle, when the traffic is fluid. In these accidents the uncontrolled vehicle, in the majority of the cases, directly ends up against a barrier to which in half of the cases follows a rollover of the car.

1.2 Loss of car’s control with driver’s reaction

For this typology of accidents two independent variables have been found as predictors of accident causation: *road conditions* and *light conditions*. These two variables are able to explain 15% of the variance of the dependent variable. Looking at the direction of the relationship we can assume that these accidents happen more frequently in case of bad road conditions (wet or icy surface) and during the day.

The driving situation that usually occurs in these accidents is when there is a male driver on a light vehicle driving in fluid traffic conditions. There are three main mechanisms during the impact situation:

- the uncontrolled car strikes a safety barrier and rolls over;
- the uncontrolled car strikes a safety barrier but does not roll over;
- the uncontrolled car rolls over while attempting to get back on the carriageway.

1.3 Rear end collision

In this typology of accidents there is only one independent variable that is statistically significant in predicting the accident causation *light conditions*. The typical driving situation that can be found in these accidents is of a male driving a light vehicle on a dry surface in fluid traffic conditions. These accidents mainly occur in sunny conditions during the day. The descriptive analysis performed on the data collect does not show a specific pattern in the accident causation. The primary cause of injuries derives from the rollover that cars have after the impact with a leading vehicle.

1.4 Lane changing collision

The predictive variable of this typology of accident is the *driver’s gender*. From the analysis it is possible to derive that these accidents happen more frequently when the driver is *female.*

These accidents happen mainly during the day in fluid traffic conditions. The principal impact in lane changing accidents is the central concrete barrier and secondly the front of another vehicle.

The second impact is usually against the lateral barriers and in more than 10% of the recorded cases the car ends its run with a rollover. The rollover is the main injuries generating impact.

Conclusion: experimental protocol implementation

The identification of these main features influencing the happening of a certain accident typology (i.e. the set of scenarios defined) allows the proposal of some

recommendations for the specification of the experimental protocol. In particular, these recommendations resulting from the scenarios definition will concern the variables to be considered in the design of field studies.

In this way, the correlations found through the analysis work presented in this paper show the different contexts to be considered in the field experiments. As an example of the application of the scenarios to the experimental design, it has been found a correlation between weather and road conditions, so that the experimental protocols should consider the study of a given road infrastructure section in different weather conditions (such as rain, sun or fog). This relationship between both variables has been found in previous literature too (Lombardo, 2000 and ISTA, 2002). Moreover, this study is also motivated by some evidence found in the literature which shows that weather conditions influence driver's performance in different infrastructure situations, affecting for instance signals perception (Maki and Pamela, 1995). So that the results obtained from the definition the scenarios are going to point at different study conditions which should be to taken into account in the experimental plan., such as light conditions, namely day and night.

Thus, an experimental protocol can be defined as a detailed plan of a field study which specifies the experimental method, the variables of the study, the sampling schedules, and the data collection procedure, among some other features describing the experiment itself.

Within RANKERS project, there are two different experimental protocols since two kinds of field tests will be carried out, one intended for infrastructure analysis and its interaction with the vehicle, and another one for human factor analysis. The former aims at identifying objective infrastructure information that can be used to measure the safety performance of a road section, whereas the latter aims at studying the influence of the infrastructure characteristics in drivers' behaviour and performance. However, both of them seek to improve road infrastructure safety in order to reduce the number of accidents and mitigate their consequences.

Consequently, the description of a set of scenarios has an important role in the experimental definition, ensuring that field studies will have an adequate research focus. The experimental phase of RANKERS is foreseen to start in July 06, lasting along this second year of the project.

References

Cacciabue, P.C. (2004). *Guide to Applying Human Factors Methods*. Springer Verlag, London.

Edwards, E. (1972). Man and Machine: systems for safety. In Proceedings of British Airline Pilots Association Technical Symposium. British Airline Pilots Association, London. pp 21-36

Lombardo, Louis, 2000.Overview of U.S. Crashes & Environment. OFCM WIST II Forum, 4-6 December 2000

ITSA (Intelligent Transportation Society of America), 2002: 511's Weather and Road Condition. *Reports Most Valuable, Survey Shows.*

Maki and Pamela J. 1999. Adverse Weather Traffic Signal Timing, P.E. *69th Annual Meeting of the ITE,* Las Vegas.