An approach to Evaluating Usability of VANET Applications

Ciprian Dobre
Computer Science Department
University POLITEHNICA of Bucharest
Bucharest, Romania
ciprian.dobre@cs.pub.ro

Catalin Fratila
Computer Science Department
University POLITEHNICA of Bucharest
Bucharest, Romania
catalin.fratila@cti.pub.ro

Liviu Iftode
Department of Computer Science
Rutgers University
New Jersey, USA
iftode@cs.rutgers.edu

***Abstract*— Vehicular Ad-Hoc Networks (VANETs) are becoming increasingly important for researchers trying to find solutions to improve safety and comfort of passenger in modern urban traffic. Typically, VANET applications demand some form of attention and interaction with the driver, raising a legitimate concern on how safe is their use while driving. In this paper, we propose an approach based on simulation to evaluate the safe usability of VANET applications together with a testing methodology to assess the impact of their use on driving capabilities. We present results showing how different ways of presenting information (graphical, acoustical) to the driver affect differently the driving capability.**

Keywords-VANET; usability;simulation, methodology.

I. INTRODUCTION

Vehicular Ad-Hoc Networks (VANETs) are wireless ad-hoc networks formed among vehicles on the roads equipped with short range wireless communication devices. Such networks are particularly attractive because of their potential to improve comfort and safety of people in modern urban and highway situations. With the increase of the number of people depending on cars and road infrastructures, VANETs have the potential to optimize traffic conditions, and to reduce congestions and pollution.

In their vast majority, VANET applications require mobile device interacting with the car's driver, the car itself, and with other cars and the road infrastructure. An increasingly concerning side-effect of introducing VANET applications in real-world situations is their effects on the driving behavior of people. Drivers become more and more besieged with information coming from a wide range of surrounding sources. Scientific psychological studies have shown the negative effect of driving while talking on the mobile phone [1]. Following such studies, many countries currently forbid by law the use of mobile phone when driving. However, there has been little research evaluating the effect of the interaction with embedded computing devices on the behavior of the drivers.

This situation is further amplified by introducing VANET applications in real-world scenarios. Such applications are designed to assist the driver in making correct decisions (regarding safety, navigation, etc). They usually have an informative role, presenting a particular situation to the driver, who can further act upon the information and decide on the correct action.

The explosion of information invading the user's environment is a psychological problem insufficiently addressed before. Today, car manufacturing companies introducing a new VANET application are more interested in testing its capability to provide the correct service. However, usability and the psychological parameters of the Human-Computer Interaction (HCI) aspect are becoming increasingly important.

In this paper, we present an approach to evaluate the usability effects of introducing vehicular applications. The approach consists in the use of a driving simulator augmented with additional capabilities: an interface between the user and various VANET applications, and the components necessary to monitor and assess the influence of the interface on the driving capability of the test subjects. We also present how this solution can be used together with a usability test methodology to evaluate the psychological impact of using such applications on the driving capabilities of persons. Finally, we present results showing how different ways of presenting information (graphical, acoustical) to drivers affect differently their driving capabilities.

The simulator, the proposed methodology and the obtained results in the evaluation of usability are important tools for researchers interested in validating the safe usage of VANET applications in real-world situations. Such results, coupled with potential solutions to addressing usability, have great potential to saving lives as the drivers, today, are becoming more surrounded with technology and information.

The paper is organized as follows. Section 2 presents related work. In Section 3, we present the application being used in the simulation experiments. We next present the methodology to use for evaluating usability of VANET application. In Section 5, we present results obtained using the

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proposed solutions. Finally, in section 6 we give conclusions and present future work.

II. RELATED WORK

Driving is a skill that requires full attention to safely control the vehicle and respond to events happening on the road ahead. The driver is said to be distracted when its focus moves from driving to other activities. Based on the type of distracting events, there are three types of distractions [4]: visual (the driver takes his eyes from the road), cognitive (the driver do not mind the road), and manual (when the driver takes his hands off the steering wheel). Previous studies ([5], [6]) demonstrated, using real-world conditions, the existence of a relation between safety and the activities that can distract driver's attention. However, such "uncontrolled" studies have limitations compared to our approach. By uncontrolled we state the lack of repeatability, predictability, and control over the conditions of the experiment. Interestingly enough, such studies showed that, for example, having a bug in the car or watching an external object have higher negative impact on the driving behavior than talking on the mobile phone.

The evaluation of the usability of an application is an activity involving both time and human resources. Automating this activity can reduce such costs, and can also produce better results. This is already used in testing Web-based designs, where information about the user behavior is collected and stored in logs, and latter analyzed to find, for example, navigation problems in Web pages. These experiments deal with both qualitative and quantitative aspects of usability. The former tests the satisfaction of the user requirements and needs, or the ease of use. The latter include measures such as the time to complete an activity, number of errors, and success and failure to complete a task. Such results are based on creating a gauge to which the results are further compared. The number of successful completion of the tasks is used to further determine the difficulty of the activity.

Simplicity is today an important aspect when referring to designing interfaces between humans and computers. The lack of content is no longer a problem; but the lack of time to correlate, categorize, analyze and act based on presented information is an important issue. This is why an important research direction in usability is towards estimating psychological and physiological aspects affecting the user. Up until recently, the evaluations followed a traditional approach that separates the study of utility by the study of emotions. Still, research showed that emotions play an active role and should be considered when designing interfaces between applications and users.

DRIVE is a project targeting the experimental validation of the service performances in case of inter-vehicular applications [12]. Unlike our approach, the DRIVE project assume hardware components designed to test under real-world conditions the effect of using inter-vehicular services. It actually includes several services implemented using an OGSi based communication framework. Examples include an intelligent driving assistant capable of informing the driver when various dangerous situations occur on the road, and a service capable to monitor the driving pattern of a particular subject and create a profile that can be further used by insurance companies. However, the focus of the DRIVE project is towards creating the infrastructure to test the utility and performance of such services in a framework providing real-world driving conditions. Unlike this, we propose a solution to evaluate the usability of such services, what impact they have on the safety of driving.

III. SYSTEM DESIGN

The architecture of the system is presented in Figure 1. It consists of several inter-connected driving-simulators running on several workstations. On each station a user runs a custom driving simulator, which includes a user interface specific to a particular VANET application. This emulates driving in a real-world scenario, while having a mobile device (a smart phone for example) running a particular VANET application.

The main window of the application consists of a road-driving simulator. It serves to test the reflexes of the user while performing specific driving activities: drive straight, make turns, etc. In addition, while driving, the user is also presented with a user interface specific to a typical VANET application, in the lower right corner of the screen. In the backend, there are specific components for measuring the physiological impact of the VANET application on the driving behavior of the user. They measure the driving accuracy, speed to complete a driving circuit, etc. In addition, the system also includes a component that facilitates the evaluation of the application when involving communication with other distributed workstations.

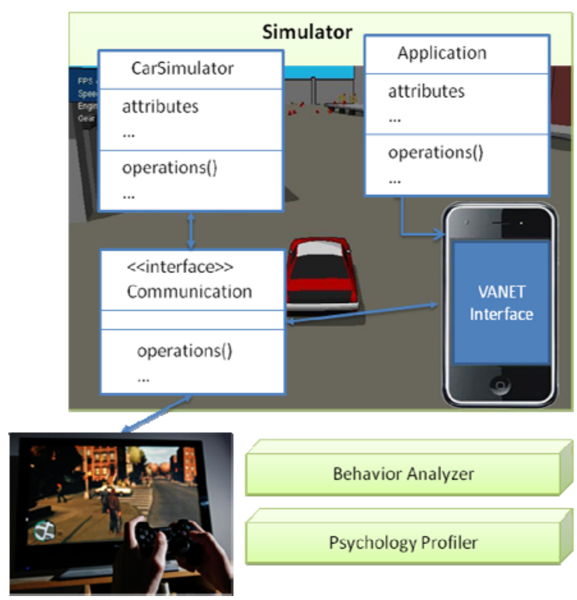

Figure 1. The design of the system.

The architecture provides complete separation between components. This facilitates the integration of different

VANET applications, the change of the driving scenes, monitoring new psychological parameters.

The driving simulator is based on the Vehicle Dynamics Engine, provided by Insight Machines [2]. It is a Java-based 3D engine, with a realistic vehicle dynamics engine. The engine is built with a virtual 3D simulation of a landscape to navigate around. The car realistically reacts according to the environmental physical forces. The landscape can feature even and uneven grounds with hills and cliffs, obstacles such as trees, rocks, building, and vehicles. The driving simulator also includes realistic interactions between objects in the scene (collisions, bumps, etc).

A driving simulator was chosen as a better alternative then using real-world driving conditions because of the costs involved, but also the possibility to adjust and control driving conditions, as well as the possibility to measure driving parameters more accurately. As the authors in [3] previously shown, the learner drivers' simulator measures actually relate to on-road driving. In fact, according to the study, a higher chance of passing the driving test the first time was associated with making fewer steering errors on the simulator and could be predicted in regression analysis with a correlation of 0.18.

Our system allows the user to model the scene, and to specify the user interface of a VANET application. The user interface can include sounds, graphical aspects, etc. We added, for example, a special text-to-speech component capable of emulating an application where the user has to actively listen to various indications.

A typical VANET application includes communications components that allows for car-to-car or car-to-infrastructure communications. In our system, we allow a distributed testing where we want to evaluate the psychological impact of the VANET application when used in scenarios involving communications with other drivers. When analyzing the driving behavior pattern, we also correlate the results between the distributed involved nodes.

The behavior analyzer looks at the user's capability to correctly finish a predefined driving circuit. It monitors parameters such as time to finish, driving accuracy in terms of collisions, and number of breaks. The usability testing methodology, further discussed in the next Section, is based on a number of statistical results. The study group is composed of a population of users and statistical results of their driving capabilities, collected when users are and when they are not affected by the VANET application. A profiler component extracts statistical results and creates a profile for each driving scenario. The analyzer then looks at statistical deviations, based on these profiles, and reports back inconsistencies.

IV. USABILITY TEST METHODOLOGY

The interface for Human-Computer Interaction is a critical component when designing services designed for use in cars. Today, many car manufacturers and software companies are working together to provide modern services to the driver. The driver faces a complex human-computer interaction, which demands occasionally the focus of the driver and can distract his attention from driving.

Driving is a skill that requires full attention to safely control the vehicle and respond to events happening on the road ahead. The driver is said to be distracted when its focus moves from driving to other activities.

The usability testing methodology considers both visual and auditory factors affecting the driving behavior. Using the proposed simulator, the driver has to correctly finish, as fast as possible, a predefined driving circuit. We are interested in the driver's reactions when confronted with various obstacles, how well he adapts speed. At the same time, the VANET application can use a wide variety of distractions, such as text, colors, and sounds. The methodology is based on the one proposed in [7].

At the beginning of '90s, Jacob Nielsen proposed testing the usability using small-size target groups (usually up to five test subjects) and small-size tests during the stages of software development [7]. He later published his findings and proposed a mathematical model for the heuristic evaluation of usability. Behind this model, there is a formula that states that the number of usability problems found in test involving *n* users is $N(1 - (1 - L)^n)$. In this formula, N is the number of actual problems, and L is the probability of finding problems when using one user. A typical value for L is 31%, which yields a usability detection pattern as presented in Figure 2.

The graph shows that one test subject can discover almost a third of the usability problems. When testing with a second subject, he will repeat many of the actions already taken by the first subject. Therefore, the number of discovered errors is reduced. But subjects are different and, because they still take different actions, it leads to an amount of different usability problems being discovered. This continues for the other test subjects. After the fifth test subject, collecting more data will not lead to many new findings.

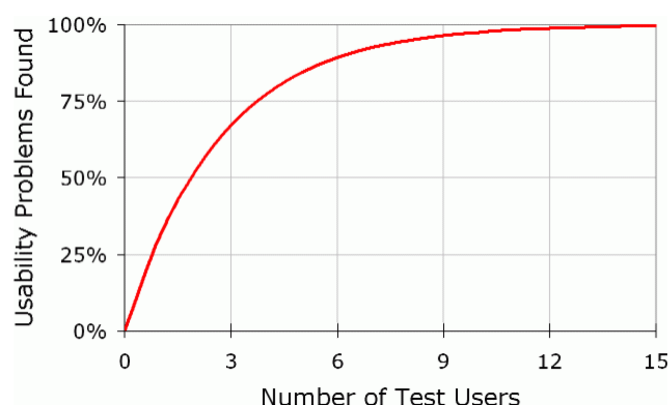

Figure 2. Typical usability results [12].

J. Nielsen also introduced an heuristic usability evaluation method based on several usability heuristics and aspects [9]: visibility of system status means, relation between the system and real-world, user control and his freedom, consistency and standards being used, error prevention, recognition, flexibility, esthetics and minimalist design, help in error recognition and recovery, and help and documentation. For example, the system should be able to communicate with the user using his language, and using words and phrases that are familiar to the user, rather than technocratic idioms. The user should not waste time wondering if a particular context was already deal with. The dialogs should communicate just enough information as required.

The methodology we use is similar with the one proposed in [12]. Figure 3 shows the steps involved in designing the usability experiments. We begin by carefully defining the objectives of the evaluation experiment. The objectives can be generic (improving user satisfaction) or specific (evaluating the efficiency in using a particular component).

The next step consists in choosing the subjects that participate in the experiment. This involves decision on representative categories of subjects, based on: experience level, age, experience in using similar applications, etc. Various research experiments show that using between three and five subjects is enough to discover around 80% of the usability problems.

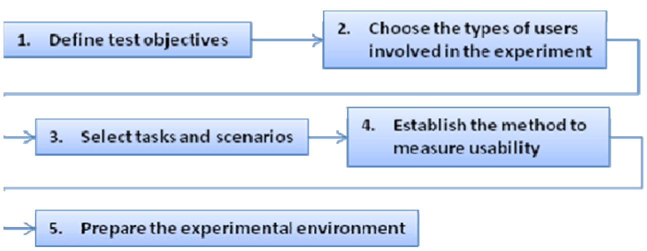

Figure 3. The methodology for evaluation of usability [12].

Subsequently, we decide on the types of tasks and scenarios to use. The tasks must resemble real situations, they should represent activities that users are normally expected to perform when operating the real application. The scenarios can be expressed by defining the set of constraints, and usually include both normal and unexpected situations.

The next step involves measuring the usability level of the system under test. This involves collecting subjective data (customer satisfaction, difficulty of use, etc.) and quantitative data (time to finish a task, the number of times the user requested help, etc). Additional testing methods involve instructing the user to narrate all of his actions (the "Thinking Out Loud" procedure), the collaborative discovery procedure where two participants execute the same tasks in parallel, and the active intervention procedure where one person stimulates the participants to reflect on the events occurring during the test session. The experiment can also involve other evaluation methods, such as questionnaires and interviews [10].

The final step involves preparing the environmental stage for the experiment. This means introducing sensors and other devices to record information, establish the role of each members of the testing team, and prepare support materials.

The methodology was further tested in different scenarios using the proposed driving simulator. We were interested to see the relation between various stimuli and the driving behavior. For these experiments, we chose subjects based on their experience on driving and using smart devices, their age and fatigue.

V. Experimental Results

We conducted three sets of experiments: 1) simulation using a simulated navigation application running on the simulation screen in the bottom right corner; 2) simulation using a navigation application running on the smart phone; and 3) experiments conducted while driving in an real-world urban environment, and the same navigation application running on the smart phone.

These experiments involved five subjects that were chosen such that to cover various degrees of driving experiences and experiences in using modern technology. The drivers have similar technical skills and the environment used was the same for all of them, one in which users do not have any other distractions beside the ones generated in the test applications, controlling their behavior.

For the simulation experiment we constructed a circuit resembling one used in driving schools (Figure 4). The circuit is equipped with driving poles. The monitored parameters were the time needed to complete the circuit, number of collisions with the poles, and the number of sudden breaks.

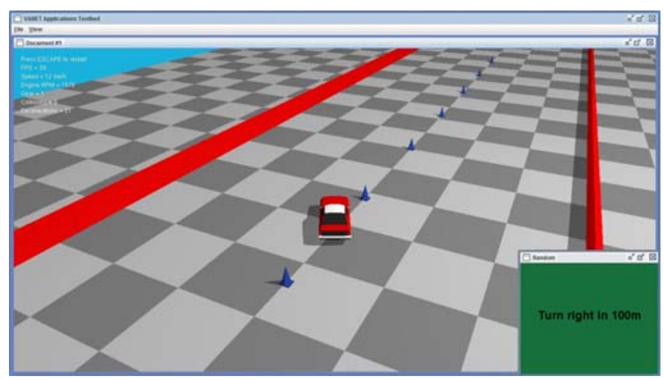

Figure 4. The simulation experiment (in the bottom right corner is the disturbing application simulating a navigation application).

The first experiments involved the use of the driving simulator, together with a **simulated navigation application**. The navigation application runs on the same screen as the driving simulator, in the bottom right corner (see Figure 4). We measured the effects of using within the simulated navigation application of texts with various colors for fonts and background (measuring the effect of the contrast perception for example), and sounds.

The results obtained for these experiments are presented in Figure 5. The subjects were asked to use the driving simulator and complete the circuit.

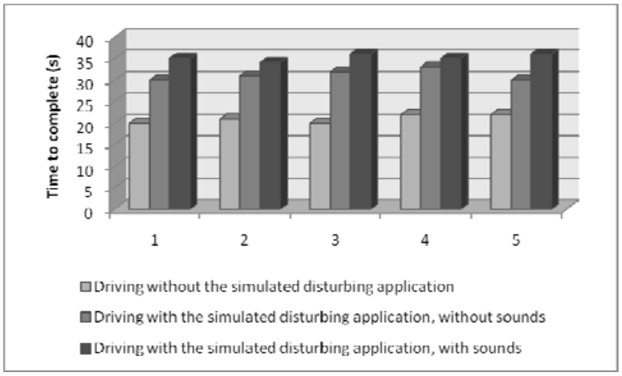

Figure 5. Results for the simulation experiment with the simulated navigation application running in the bottom right corner of the simulation screen (see Figure 4).

In the first experiment we used only the driving simulator, without showing the simulated navigation application. We next compared the obtained results (see "Driving without the simulated navigation application" in Figure 5) with the ones obtained when the subjects were presented with the simulated navigation application. In this case, the subjects were again asked to complete the same circuit, but now we used a simulated navigation application running in the same screen as the driving simulator, on the bottom right corner. The second series in Figure 5 correspond to the results for the time needed to complete the circuit when the simulated navigation application involves text (an example is presented in Figure 4), but without sounds. The third series of results were obtained in similar conditions, but this time we also introduced a voice reading the textual information out-loud.

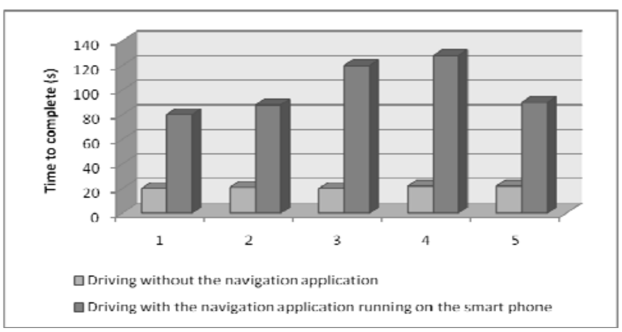

Figure 6. Results for the simulation experiment with the navigation application running on the smart phone.

The increase in the time needed to complete the circuit corresponds to a psychological effect on the driving behavior previously noticed by a team from Carnegie Mellon [11]. They too showed that sounds leads to a dramatic effect over the capability of people to concentrate on solving various tasks. The visual and acoustics factors have, therefore, different capabilities of affecting the driving accuracy.

Next, we conducted experiments where the subjects were again asked to use the driving simulator, but this time they were presented with a **navigation application running on a smart phone**. To evaluate the effect of driving using one hand while performing some actions, we asked our subjects to interact with the application and change certain parameters. Figure 6 shows the results obtained for the time needed to complete the circuit. The first results are obtained when the subjects were not under the influence of any application. The second results (series "Driving with the navigation application running on the smart phone") correspond to the experiment where drivers were asked to use a navigation application running on the smart phone.

In the third experiments we asked our subjects to **drive a car on a predefined real-world circuit**, in an urban environment. In the first experiments, each subject finished the circuit without any disturbing application, and then they were asked to complete the same circuit but using a navigation application running on a smart phone. We tried to obtain results under similar conditions. This is difficult because in the real-world the driving conditions change constantly.

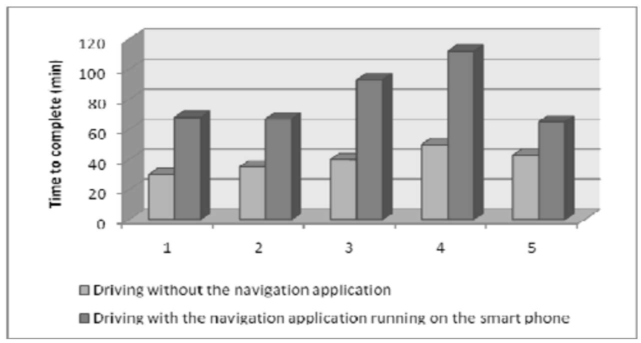

Figure 7. Results for the real-world experiment with the navigation application running on the smart phone.

The obtained results are presented in Figure 7. When not using the navigational software, their average time to complete the circuit was 40 minutes. The subjects were then asked to complete the same circuit, but this time they had to use a navigation application running on the smart phone. Again, the subjects were asked to interact with the application and change certain parameters. When using the smart phone, the subject completed the circuit in almost twice the previous time.

In all these cases, the navigation application increases the time needed to complete the circuit. When using the simulated navigation application the increase is roughly 48%. When sounds are involved the times are even longer, the increase being of roughly 67%. The number of breaks also increases dramatically by almost an order of magnitude when the subject uses the simulated navigation application.

When using a real smart phone navigation application that does not appear on the screen the impact is even higher, as in the second experiments. This increase is similar to what is happening when using the navigation application on the smart phone while driving in a real urban scenario.

VI. Conclusions and Future Work

In this paper, we presented an approach to evaluate the usability effects of introducing VANET applications in cars. With the increased interest in VANETs coming from scientists trying to find solutions to increase safety of passengers, or solve congestions and decrease pollution in urban road scenarios, we believe it is important to properly evaluate usability of such applications. Still, little research was conducted in this area. This is surprising as usability of VANET applications is ultimately a safety issue. For example, previous studies showed the negative effect of talking on mobile phones while driving, and as a result in many countries this is forbidden by law. Nevertheless, currently, people drive while using intelligent assistants designed to help with navigation, with fuel economy, or just entertain the user. And yet, researchers failed to test their psychological and physiological effects of their use on the driving capabilities of users.

The simulator, the proposed methodology and the obtained results in the evaluation of usability are important tools for all researchers interested in validating the safety of using VANET applications in real-world situations. To our knowledge, no previous experiments managed to evaluate the safety of using real-world applications already in use on a large-scale by drivers around the world. Our solution consists in the use of a driving simulator augmented with additional capabilities: an interface between the user and various VANET applications, and the components necessary to monitor and assess the influence of the interface on the driving capability of the test subjects. We presented how this approach can be used together with a usability test methodology to evaluate the psychological impact of using such applications on the driving capabilities of persons. We also presented results showing how different ways of presenting information (graphical, acoustical) in a car affect differently the driving capabilities of users. We validated our results by comparing them with results obtained using a real-world driving experiment.

The results can be used by application designers, as we demonstrated the different effects of using various types of interface controls between applications and the drivers. In particular, we showed how different sounds and graphical controls affect the driver's behavior. Such results can be the basis of a methodology that can be used by the developers of VANET applications to better assist the end user, the driver.

We also evaluated the usability of some of the most popular today applications for navigation assistance. Surprisingly, we revealed several problems when using such applications while driving. We plan to investigate further our discoveries, as we feel that the safety issue has been insufficiently addressed before, resulting in potential hazardous controlled applications. Such scientific results, coupled with potential solutions to addressing usability, have in our opinion a great potential to saving lives, as the drivers, today, are becoming more surrounded with technology and information.

As future work, we plan to further develop the approach. We plan to collect more information about the usability of HCI controls in VANET applications, which can further assist the developers of such applications. Also, in the current area of usability, researchers try to approach the third dimension of usability, namely emotions. Various results were obtained in this area, based on tracking face expression or using various sensors. In the future, we also plan to include in the usability methodology solutions designed to test the effect of VANET applications on the emotions dimension of usability.

The next step is to compare the conclusions with known results (for example, we all know that talking to the phone has great repercussions on driving, but what if we can demonstrate that using Google Maps is also harmful, we need then to determine which one of these is the most harmful with the driving style) and then we can demonstrate that different developers should be interested in our framework.

Last, but not least we need to be able to modify test case scenarios so that we can recreate a real life circuit, could make possible the comparisons between real life test bed data and statistical ones. A needed feature will be to give the ability to introduce unexpected factors, but when we do so, we will need to highlight the used methodologies (E.g. if we have a scenario in which a hole appears before the car we need to test an application that warns or assists the user, not a navigation application).

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