MODELLING ROAD TRAFFIC SAFETY - THE IN-SAFETY APPROACH

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ABSTRACT

This paper presents a model-based approach to road traffic safety developed within the EU funded project IN-SAFETY. Several existing models, both micro- and macro-models, will be adapted and used to assess safety related effects of ITS measures. Examples of such measures include but are not limited to ADAS and IVIS. While the micro-models will determine the individual vehicles' safety related behaviour, the macro-models will find out about the network wide aspects. Various models will be extended to cope with the ITS measures envisaged and then applied to relevant safety critical conditions. Major input will be available from the different test sites of the project, which are spread to cover the most significant aspects within the EU road environment.

KEYWORDS

Modelling, Traffic Safety, Safety Effects

OVERVIEW

The project IN-SAFETY aims to promote the building and maintenance of European roads according to the concepts of forgiving and self-explaining roads, concluding into relevant implementation scenarios, training curricula and best practice guidelines. To achieve this goal, work starts with the identification of the elements that make a road environment of forgiving nature and the possible ideas of creating such an environment by integrating traditional road elements with in-vehicle and infrastructure based telematics, including all-weather VMS'es, in-vehicle simulation of rumble strips, localised accident-ahead and traffic jam warnings, dynamic navigation principles, ADAS and IVIS.

A number of new tools to support road design and auditing safety assessment is being currently developed, taking into account new technologies and the above concepts. They include micro- and macro-simulators, that incorporate various driver behaviour models and can predict safety effects, human behaviour inclusive risk analysis tools, training schemes for road and tunnel operators, as well as simulation models to influence route choice in a road, which will incorporate the findings of other work within the project as well as will use the relevant improved tools developed.

The tools thus developed will be extensively tested in a series of pilots, including on-road tests in various European cities and a dynamic driving simulator test of critical scenarios on rural roads in Linköping, Sweden.

THE CONCEPT

Existing driver behaviour data from the international literature as well as from other projects like IN-ARTE, SAVE, AWAKE, ADVISORS, TRAVELGUIDE as well as projects running in parallel to IN-SAFETY will be used for upgrading and adapting current microscopic and macroscopic simulation models, in order to better meet the needs for the identification of ADAS safety impact. Additionally, models of ADAS-equipped vehicle drivers will be performed for a number of priority ADAS (ACC, CAS, ISA of specific types). For this purpose, both specific driver profiles will be built and existing models will be expanded and adapted. The methodology to be developed will comprise the following set of microscopic and macroscopic simulation models to be expanded, adapted and articulated suitably for the extraction of quantitative and compatible between them results.

Table 1: Models used within IN-SAFETY

Model	Partner(s)	Road Type	Innovation	Pilot(s)	Description
Micro			-		
VISSIM	PTV, HIT	Highway, Urban	-Include driver behaviour in safety critical situations. -Interface to EUSKa s/w.	Turin, Athens, Stuttgart	Widely used micro-simulation s/w for different types of environments. Allows (parametrical) programming of different driver profiles.
VISSIM	TUDelft	(as above)	Influence of route choice on safety	(as above)	(as above)
RuTSim	VTI	Two-lane Rural Roads	Safety indicators Variable driver/vehicle behaviour for simulation of traffic including ADAS-equipped vehicles	Simulator pilot of VTI	Manages two-lane rural roads with one or more entrances and exits; capable of modelling variations in the traffic flow over time. Gives detailed microscopic (vehicle/ driver) information as well as derived macroscopic traffic measures.
Paramics	SWOV	Urban, rural	Route Choice	Italian and Swedish pilot	
Macro					
VISUM	HIT	Urban	Customisation for ADAS input and safety output	Turin pilot	City-wide macroscopic simulation model
Saturn	NTUA	Urban. Sub-urban	Customisation for ADAS input and safety output	Athens pilot	Traffic assignment and simulation model suitable for complex and large networks
Mtmodel	CSST	Highway,Urban, Extraurban/rural	The safety evaluation will be included	Turin Pilot	Mobility & Traffic models – Decision support system for transport and traffic planning An extension of these models can be used in real time

VISSIM/VISUM Application and Adaption

Critical locations found will be modelled with the standard simulation tool VISSIM. Special focus lies on the driver behaviour, which leads to the accident in these infrastructure conditions. This driver behaviour under critical situations is currently not included in any traffic simulator; it will be derived from theoretical approaches, accident data, data deriving from on road tests, as well as for driving simulator studies. This approach allows not only to recreate accidents but also to define the criticality of an infrastructure condition (design, layout) on a broader basis, since critical situations can be assessed that do not lead to accidents (near-misses). This methodology further allows assessing changes in infrastructure made to improve the situation. In addition, micro-simulation allows a relatively easy inclusion of ADAS-induced behaviour; VISSIM already offers a dedicated interface to co-simulate particular driver behaviour and/or behaviour adaptation due to ADAS/IVIS. The VISSIM modelled network, including the above mentioned driver behaviour parameters, is going to be further assessed in a macro scale, by importing the model in VISUM macro simulation tool. The proposed model-based methodology will be applied in alternative infrastructure layouts designed within the project allowing for a set of reliable results to be tested using actual test data.

VISSIM Application

Concerning the study of drivers' behaviour influenced by the use of ADAS (Advanced Driver Assistance Systems), the VISSIM micro simulation model is being used to simulate this behaviour under different penetration rates and the use of different ADAS. The ADAS that are being taken into consideration are the Collision Avoidance System (CAS) and the Lane Departure Warning (LDW). The simulation is being performed using data from real tests. This data is available from pilot tests conducted within the framework of the AIDE project and more data will derive from the pilot tests that are going to take place within the IN-SAFETY project. A number of different scenarios are going to be elaborated. These include different vehicle types and, subsequently, different vehicle classes (equipped and non-equipped cars), including passenger cars and HGVs (Heavy Goods Vehicles). Additionally, the scenarios will vary according to the penetration rate of ADAS equipped vehicles, from 0% (reference condition) to 100%, with an interval of 5% (21 combinations). The network that is used is a highway network, including junctions.

As far as the CAS is concerned, the "following" driving mode of VISSIM is being considered. Wiedemann [1], [2], has proposed two different sets of parameters to define the drivers' behaviour in this mode (Wiedemann 74 and Wiedemann 99 models). These parameters are being studied and modifications of their values are going to be suggested, depending on the actual data and the scenario. The basic parameters to be taken into account are:

WIEDEMANN 74 model:

- Average standstill distance.
- Additive part of desired safety distance and multiplicity part of desired safety distance

WIEDEMANN 99 model:

- CC0: standstill distance.
- CC1: headway time.
- CC2: "following" variation.
- CC3: Threshold for entering "following".
- CC4-CC5: negative and positive speed differences defining the "following" threshold.
- CC6: Speed dependency of oscillation.

All these parameters are going to be modified each time according to the specific scenario, following of course the theoretical background within which they have been defined.

Concerning the LDW, the "lane change" driving mode is being considered. The parameters in this driving mode are also subject to modifications, according to the data from real tests used and the scenarios mentioned above. The parameters that are mainly taken into account are:

- Maximum deceleration of the own and trailing vehicle
- Accepted deceleration of the own and trailing vehicle
- Minimum headway (front/rear)

After all these scenarios are implemented, results will derive from the VISSIM model and the relevant assessment of the drivers' behaviour and the resulting network performance. The evaluation will be performed in network element scale (i.e. in link scale) in order to assess the performance of each separate link, as well as in network scale, by importing the VISSIM network and the specific scenarios in VISUM macro simulation model, thus assessing the network performance with the use of two different ADAS and in 21 different penetration rates for the whole network under consideration.

This procedure is expected to provide valuable results in terms of the use of such systems in a broader scale than the one met currently in the roads and any deficiencies that may result would be a useful stimulus for further research in this area, for the improvement of the systems as well as the traffic simulation models.

VISSIM Adaption

Current implementations of micro-simulation model are unable to correctly reflect accidents and thus accident numbers in traffic. This is due to the fact that their behaviour models are intended to reproduce normal driving behaviour. In safety critical situations, however, drivers perform differently due to a "shock effect". If the focus of investigation lies in safety effects, as it is the case more and more recently, it makes sense to introduce such special behaviour features in micro-simulation. Generally, this tool is very effective for such investigations for several reasons:

- It can produce a large amount of traffic, in terms of vehicle-mileage, in a reasonable amount of time. This means, that a certain scenario can very well be observed for a time corresponding to several years in real life. This is required because accidents occur rarely.
- A certain situation can be investigated with changed infrastructure or with ADAS. This allows to select cost-effective measures. In real life, this is impossible.
- Apart from these special safety relevant points all other advantages of simulation still hold.

All this has lead to the idea to incorporate driver behaviour under safety critical situations. In order to comply with the existing models, a stimulus-response type model is sought. The main difficulties to determine such behaviour are

- In real life it is impossible to observe this behaviour because of the stochastic nature of traffic. Post-accident analyses provide information about the driver's reaction but not the cause of the reactions (reaction only, no stimulus).

- Due to the rare occurrence of such situations a large number of experiments is needed. Such experiments must not inflict danger to possible candidates.
- A detailed recording of all relevant data is needed. This applies to the situations triggering the special behaviour as well as to the driver's actions.

These points plus the advantage of reproducibility, especially with different drivers or driver groups in similar situations, prove a driving simulator is essential to set up a model for determining behaviour in safety critical situations.

Within the IN-SAFETY project, the Swedish partner VTI has such a simulator available and will conduct experiments for the project. It is planned to use these experiments for a first step to model driver behaviour in safety critical situations. The concept includes two major parts

- What are the surroundings, the parameters triggering this behaviour? It is assumed that these are speed differences and distances. However, in order not to omit any relevant parameter all parameters defining the driving situation will be recorded.
- What is the driver's reaction? Current models imply that a driver decelerates when the combination of distance and speed differences requires so; the deceleration is determined so that the situation is improved. However, it could well be that a driver simply brakes to the full extend when startled although only a – however high – fraction is really needed. In what situations does a driver brake, when does he perform a swerving action and when a combination of both? Such a combination will be a new concept for micro-models

The work to be performed within IN-SAFETY in this context can by no means be exhaustive. However, it is a first step towards driver behaviour in safety critical situations. With this topic gaining more and more importance, it seems very worthwhile to direct further development efforts in this direction.

RuTSIM Application and Adaption

Rural highways dominate the road mileage in many countries. It is therefore important to have access to tools for evaluation of the safety and performance on these types of roads. The objective of this part of the IN-SAFETY approach is to meet this need and to focus on the safety effects of ITS applications on rural highways.

Micro-simulation of traffic flows has proven to be useful in several types of traffic performance studies. Most micro-simulation models are however, with a few exceptions, developed for urban and motorway traffic. The requirements for rural road traffic simulation differ substantially from the requirements for urban or freeway traffic simulation. A simulation model for rural highways is for example required to consider the road alignment in more detail. In addition, when modelling traffic on a two-lane highway, it is also essential to consider interactions between the oncoming lanes, e.g. in overtaking/passing situations. One micro-simulation modelling platform specifically developed for rural highways is the Rural Traffic Simulator (RuTSim) [3]. The model has been used for, among other things, studies of road design and traffic control alternatives. RuTSim is developed to be as flexible as possible to allow further model developments. The driver behavioural models and the derived model output can for example be extended, or replaced, in a straightforward manner.

The IN-SAFETY project will together with a national project sponsored by the Swedish Road

Administration extend RuTSim to allow use of the model for safety evaluations of vehicle based ITS, e.g. ADAS and IVIS. [4] studied the requirements placed on a traffic simulation model to be used for safety evaluations of driver assistance systems. The results of this study indicated that the traffic simulation model should include both the system functionalities, i.e. ACC distance controllers, overtaking aids and ISA speed limiters as well as driver behaviour for equipped vehicles. The main goal of the IN-SAFETY project is consequently to to allow inclusion of both ITS system functionalities and driver behaviour in the RuTSim model. The first step includes identification of important vehicle based ITS applications for rural highways together with corresponding impacts on driver behaviour. This step will consist of studies of the results of previous projects in the ITS and driver assistance systems area. As a second step models describing driver and vehicle behaviour of ITS equipped vehicles will be developed or modified to allow model use for rural road traffic simulation. The developed models will then be implemented in the RuTSim framework.

To allow the RuTSim model to be used for safety evaluations, the model output will also be completed with safety indicators derived from the simulated vehicle driving course of events. Examples of possible safety indicators include time-to-collision based indicators that separate safety critical situations from situations in which the driver is assumed to remain in control.

The extended RuTSim model will be an important tool to study system effects of vehicle based ITS. The impact of observed changes in driver/vehicle behaviour due to ITS can via the traffic micro-simulation be aggregated to the traffic system level and the road safety impact can thereby be assessed. As a first test and application of the model, data and findings from the IN-SAFETY pilot studies will be implemented and the road safety effects of the IN-SAFETY rural road scenarios will be estimatied.

SATURN APPLICATION AND ADAPTATION

Background

SATURN (Simulation and Assignment of Traffic to Urban Road Networks) is an assignment model and as such it is mainly used for investigating traffic management strategies. It was developed in the Institute for Transport Studies of Leeds University ([5], [6]) and is a widely used commercial simulation software for a variety of applications ([7], [8], [9]).

SATURN analyses traffic macroscopically, hence the individual vehicle characteristics and driver behaviour are not included in the simulation but are embedded only in an aggregated manner. It has been previously applied to estimate the impact of specific intelligent transport systems on driver behaviour through calculating the effect of their use on traffic conditions, within the framework of the EU project ADVISORS [10]. The systems that were included in that study were the variable speed limiter (VSL) and adaptive cruise control (ACC) system. Driver behaviour was simulated using microscopic models and the aggregated driver behaviour was estimated and inputted into the SATURN simulation.

The traffic simulation model DRACULA (Dynamic Route Assignment Combining User Learning and micro-simulation) which is microscopic and can be linked with SATURN allows for the incorporation of specific ADAS and ATIS by appending its output as SATURN input. Several studies on the estimation of the effect of the use ADAS and ATIS on road safety with the use of microscopic simulation models have been performed [11]. However, macroscopic models and more specifically traffic assignment models have not been employed for the estimation of the safety effect of the intelligent transport system use. The obvious reason is that because of the inherit nature of the models the specific parameters involving the effect of the use of ITS on road safety cannot be accommodated.

Incorporation of road safety features

Within the framework of the IN-SAFETY project, a feature of SATURN will be manipulated to simulate the use of ITS systems that are anticipated to improve road safety. Managing traffic by assigning them into different routes based on the prevailing traffic conditions, can improve the congestion levels of urban networks. The framework of this SATURN application is based on the hypothesis that managing traffic by assigning them into safer routes improves the road safety level of the networks. The system that will be implemented is an advanced traveller assistant system (ATIS) that could either be an in-vehicle system being a function of a navigation system or a roadside system such as a Variable Message Sign (VMS). The information provided by the system will involve the road safety level of the route. This could include information on an incident, warning of risky weather or pavement conditions, or simply the safety level of the route as estimated through specific parameters (accident rates etc).

In general, drivers – who have good knowledge of the road network – choose their route on the basis of the anticipated travel times and delays, and the SATURN model simulates this exact procedure to assign traffic to specific routes. Hence, for each route the attributed cost is estimated and is a function of the travel time on the route and its distance. SATURN model allows the user to introduce further parameters in the cost estimation, as illustrated in the following equation:

$$Cost = PPM * Time + PPK * Dis\tan ce + \sum_i PPU(i) * DATA(i) ,$$

where PPM and PPK are the weighting factors of time and distance respectively and PPU (pence per unit) are those attributed to the introduced units (DATA). The additional parameter that will be introduced, for the incorporation of safety related ITS, is the safety level of the route. Hence, the simulation will now assume that each driver will have knowledge of the time, distance and safety level of the route. Such knowledge is provided through the information systems described earlier in this section.

The investigated approach requires the definition of the weighting factor for the safety level parameter. A stated preference questionnaire survey will be conducted in which drivers will be asked to choose between routes for which their travel time, distance and safety level will be determined. This approach has been adapted ([12], [13]) and can provide quite valid results and insight on drivers preferences. Furthermore, a real-traffic study will be conducted in which participants will be asked to drive a vehicle equipped with an information system, which will provide information on the travel time, distance and safety level of specific routes, and their route choice will be recorded. The analysis of drivers preferences (from both the questionnaire and real-traffic studies) will determine the weight factor for the road safety level parameter which will be introduced into the SATURN cost function.

Drivers' preferences will then be simulated with SATURN using a fictional or real road network and their choices will be described in an aggregated manner.

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