FFI project final report: Field data acquisition and analysis methods for car active safety development.

Project within: Vehicle and Traffic Safety (Fordons- & Trafiksäkerhet.)
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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

Real world data is important for safety development within the road transportation system. For car safety development in particular, methods to collect and analyse real world data on driver behaviour from normal driving, incidents and accidents are needed to address safety in driving.

The main goal with this project is to explore and develop different analysis methods that can be applied to existing sources of real world data (e.g., accident mail surveys, naturalistic driving studies). The methods are evaluated based on their capabilities to:
1) Estimate how frequent different driver behaviours occur and/or
2) Contribute to the understanding of accident/incident mechanisms.

The following studies were completed in this project during 1st of March 2009 – 31st Dec 2012:

Study 1: Nonresponse analysis in an accident mail survey (Paper I, section 6.2)
Insurance data were retrieved as additional source of information to an accident mail survey for all cases where the mail survey was sent. These data were used to analyse and compensate for nonresponse by using logistic regression analysis and inverse propensity weights.

Study 2: Accident case studies including the driver's own descriptions in a mail survey and insurance documents (Paper II, section 6.2)
In this study, mail survey variables were combined with accident descriptions provided by the involved road users in the mail survey questionnaire and insurance documents. These documents were then analysed for each case to establish if driver distraction or drowsiness were present at the time of the accident. This approach was also assessed on whether it contributed to an additional understanding of why the accident occurred compared to using mail survey variables alone.

Study 3: Incident causation based on naturalistic driving data (Paper III, section 6.2). This study was performed in collaboration with the DREAMi-project. Video-recordings of car-to-pedestrian incidents from a Naturalistic driving study performed in Japan were analysed. A method initially develop to classify accident causation was further developed for incident causation analysis and evaluated for the video-recorded events.

The overall findings for study I-III imply that self-reported (e.g., mail surveys) and observation (e.g., video) data collection procedures are both required as complementary sources of information for car safety development. Mail surveys can be used as a cost efficient method to collect information from a large number of accidents that is useful to estimate *how frequent* different circumstances as well as some driver behaviours are in accident situations. Valuable, additional information for understanding about *how* *frequent different* driver behaviours are as well as the *accident mechanisms* can be obtained by analysing written descriptions from mail survey and insurance documents. This can provide insights into how the driver experienced the accident, facilitate the interpretation of mail survey responses, and provide information that is not captured by the mail survey variables. Video-recordings from naturalistic driving studies can provide detailed information on driver behaviour that can provide insight into incident *mechanisms*. This is especially valuable for aspects of driver behaviour that is difficult to capture with self-report methods.

There is ample opportunity to improve the understanding of driver safety issues in accidents and incidents. By combining data from self-reported and video-recorded events, future studies can improve estimates of the occurrence of different driver behaviours and provide a better understanding of accident and incident causation. A combination of different types of data sources can also be used to further address the validity of accident mail surveys.

2. Background

Real world data plays an important role for the safety development of the road - vehicle - driver system. Different types of data are needed to understand the role of driver behaviour for traffic safety. Accidents and incidents needs to be understood from the car drivers' perspective and be related to normal driving. Although the use of field data is an established part of car safety development in Sweden since many years, more knowledge on methods to collect and analyse field data for active safety development is needed. Field data analysis is used within the car product development process to prioritise which safety issues to address, formulate product requirements, make real world effect estimates on design concepts and verify real world performance once new car models are on the roads.

3. Objective

The objective with this project is to build up competence within analysis methods of real world data that can provide the knowledge that is needed for car safety development regarding the driver needs in relation to the car and traffic environment.

The main goal is to explore and develop different analysis methods that can be applied to existing sources of real world data (e.g., accident mail surveys, naturalistic driving studies). The methods are evaluated based on their capabilities to:

1) Estimate how frequent different driver behaviours are and/or
2) Contribute to the understanding of accident/incident mechanisms.

4. Project realization

This section provides a brief overview of the studies performed in this project. More detailed descriptions can be found in the publications listed in section 6.2.

Study 1: Nonresponse analysis in an accident mail survey (Paper I, section 6.2)
The aim of this study was to analyse and compensate for nonresponse in an accident mail survey, and to identify the most influential weighting variables.

Statistical accident data is continuously collected by VCC by sending out mail survey questionnaires to owners of a Volvo car that has recently been involved in an accident. Variables available for all 8519 mail survey recipients were retrieved from Volvia insurance company database. Response propensity as a function of several independent variables was modelled by using logistic regression analysis. Survey weights were calculated as the inverse response probability. Weighted and unweighted mail survey estimates were compared for driver drowsiness/fatigue and distraction.

Study 2: Accident case studies including the driver's own descriptions in a mail survey and insurance documents (Paper II, section 6.2)
The first aim of this study was to evaluate whether a case study approach, combining mail survey data and insurance case documents, can serve as reliable sources for estimating how frequent different driver safety issues occur in accident situations. The second aim was to evaluate the additional value of the information provided in understanding driver fatigue/drowsiness and distraction with this approach compared to using mail survey variables alone.

The prevalence of three driver safety issues (low vigilance, non-driving related distraction, and driving related distraction) were estimated based on mail survey variables for 158 accidents randomly selected from a larger dataset. Additional information, mainly written descriptions by the driver and other road users from insurance case files, i.e. insurance claim reports, witness statements, a few police reports, were gathered. A case analysis was then performed, and the presence of each driver safety issue estimated. The agreement between the data sources and different road users were also analysed.

Study 3: Incident causation based on naturalistic driving data (Paper III, section 6.2)
One aim of this study was to identify what video-recordings from naturalistic data can contribute when analysing causation of safety critical events and if DREAM (driving reliability and error analysis method) is useful for this purpose. This study was performed in collaboration with the DREAMi-project.

The data were collected in a naturalistic driving study in Japan. The vehicles were instrumented with video cameras that covered external views, the driver, and the foot/pedal area. Video-recordings of 90 car-to-pedestrian incidents were analysed from the drivers' perspective. The DREAM-method was modified and used to identify the most common causation patterns. The causation patterns were also compared to previous studies involving in-depth accident investigations of car-to-pedestrian accidents.

Study 4: Analysing driver distraction in normal driving using naturalistic driving data (in progress).
The aim with this study is to develop a method to analyse driver distraction in normal driving by using whole trips of naturalistic driving data. This part is initialised during the VINNOVA-project and will be completed within the PhD-project that extends for another 15 months after the end of the VINNOVA-project.

5. Results and deliverables

Study 1: Nonresponse analysis in an accident mail survey (Paper I, section 6.2)
The results from study 1 shows that driver age, driver gender, accident type, vehicle age, ownership (private/company), and town size of where the registered owner reside influenced response propensity. Nonresponse weighting had a moderate influence on survey estimates for driver drowsiness and distraction. Driver age and accident type were the most influential weighting variables, since they were related to both response propensity and the survey variables.

Study 2: Combining mail survey and insurance data including the driver's own descriptions (Paper II, section 6.2)
Low vigilance was identified as present in 9%, non-driving related distraction in 8%, and driving related distraction in 6% of the accidents in the case analysis. There was a good agreement between the sources when several documents were available, and the written descriptions provided valuable additional information. A clear relationship was found between survey variables and the case study results for low vigilance and non-driving related distraction. Driving related distraction was more difficult to capture with this approach.

Study 3: Incident causation based on naturalistic driving data (Paper III, section 6.2)
The results from study 3 shows that drivers frequently failed to observe the pedestrian they were in conflict with due to visual obstructions, and/or their attention was directed towards something other than the conflict pedestrian. There were also cases where the driver expected the conflict pedestrian to behave differently than s/he did.

The present study shows that the DREAM method can successfully be used for the analysis of incident causation based on video-recordings. The drivers' visual behaviour and activities, as well as the traffic environment were directly observable from the video-recordings. The driver's expectations and cognitive demand, on the other hand, have to be inferred from other cues. There were a number contributing factors available in the DREAM manual that were not identified in the present study. Some of these factors may be addressed by additional camera views or continuous data collection. However, there are factors that cannot be collected by using video-recordings alone but require complementary methods such as interviews or diaries.

Study 4: Analysing normal driving behaviour in naturalistic driving data (in progress).
No project deliverables are available during the VINNOVA-project, but are scheduled during the PhD-project that extends for another 15 months.

Overall project results and deliverables:
Each completed study in this project has contributed with new methods to analyse field data that enhance precision in estimating *how frequent* different driver behaviours occur in accidents (methods from study 1-2) and/or provide methods to analyse *incident and accident mechanisms* (methods from study2-3). These methods have been introduced in the project development process at VCC as tools for making priorities and formulating safety requirements. The project has also contributed to a better understanding of the strengths and limitations with different sources of field data, and how these sources may be used in the product development process. Further, collaborations with other projects (e.g., EuroFOT, DREAMi) and partners (Chalmers, Volvia, SAFER, Autoliv, JARI) has been beneficial for dissemination of knowledge and results as well as creating contacts for future collaborations.

5.1 Delivery to FFI-goals

The FFI-programme contributes to the following main goals: 1) Reducing the number killed and injured in traffic and 2) Strengthening international competitiveness concerning the development safe vehicles and systems for vehicle safety.

This project addresses these goals by developing methods to analyse driver behaviour in real traffic and accidents. The methods capabilities to capture driver behaviours according to the project specific goals (e.g., quantify behaviours, understand mechanisms) are important to understand existing safety problems and which countermeasures that are efficient. This project has taken important steps in the area of driver behaviour which address FFI goal 1) above. Combining the methods evaluated in this project with existing analysis methods for passive and active safety as well as different data sources (e.g., accidents with and without personal injuries) will strengthen and even further enable to link driver behaviours to injuries in traffic.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The methods and results are now widely available through the research community through journal papers. These methods are also implemented in the safety development process at VCC. The methods may be further disseminated by using some of them in future research projects involving several partners.

6.2 Publications

Paper I: Published in Journal (Accident Analysis & Prevention)

Tivesten, E., Jonsson, S., Jakobsson, L., Norin, H., 2012. Nonresponse analysis and adjustment in a mail survey on car accidents. Accident Analysis & Prevention 48 (2012), 401-415.

Paper II: Published in Journal (Accident Analysis & Prevention)

Tivesten, E., Wiberg, H., 2013. What can the drivers' own description from combined sources provide in an analysis of driver distraction and low vigilance in accident situations? Accident Analysis & Prevention 52 (2013), 51-63.

Paper III: Published in Journal (Accident Analysis & Prevention)

Habibovic, A., Tivesten, E., Uchida, N., Bärgman, J., Ljung Aust, M., 2013. Driver behavior in car-to-pedestrian incidents: An application of the driving reliability and error analysis method (DREAM). Accident Analysis & Prevention 50 (2013) 554-565.

Licentiate thesis: Defended on the 21st of May 2012, Published at Chalmers

Tivesten, E., 2012. Licentiate thesis. Real world data on driver behaviour in accidents and incidents: Evaluating data collection and analysis methods for car safety development. Technical report - Department of Applied Mechanics, Chalmers University of Technology, Göteborg, Sweden, ISSN 1652-8565; nr 09. http://publications.lib.chalmers.se/records/fulltext/157243.pdf

7. Conclusions and future research

The findings imply that self-reported (e.g., mail surveys) and observation (e.g., video) data collection procedures are both required as complementary sources of information for car safety development. Mail surveys can be used as a cost efficient method to collect general information from a large number of accidents as well as information on some driver behaviours. Valuable, additional information about accidents can be obtained by analysing written descriptions from mail survey and insurance documents. This can provide insights into how the driver experienced the accident, facilitate the interpretation of mail survey responses, and provide information that is not captured by the mail survey variables. Video-recordings from naturalistic driving studies can provide detailed information on driver behaviour. This is especially valuable for aspects of driver behaviour that is difficult to capture with self-report methods.

There is ample opportunity to improve the understanding of driver safety issues in accidents and incidents. By combining data from self-reported and video-recorded events, future studies can improve estimates of the occurrence of different driver behaviours and provide a wider picture of accident and incident causation. A combination of different types of data sources can also be used to further address the validity of accident mail surveys. Data collection procedures on driver behaviour such as a robust and reliable eye-tracker devices and physiological measurements would be highly beneficial topics for future research project. Currently the VHM-project is developing knowledge and tools to perform and analyse these types of measurements in an experimental setting (e.g., on-road experiments). These tools may be further developed to suit the needs for making unobtrusive measurements and capture larger variations present in naturalistic driving. Future research projects that enhance data collection procedures for driver behaviour, road characteristics and detecting other road users present in naturalistic driving would be beneficial for the safety development. This type of projects would build up knowledge about data collection methods, driver behaviour in real world driving as well as provide technical prototypes that can generate ideas for the next generation of active safety systems.

8. Participating parties and contact person

Participating parties: Project partners: Volvo Car Corporation and Chalmers. Collaboration with Volvia, SAFER, JARI.

Persons involved in project group:
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Lotta Jakobsson (Industrial supervisor, co-author), VCC
Hans Norin (Academic supervisor, co-author), Chalmers
Hans-Erik Pettersson (Academic co-supervisor), Chalmers
Trent Victor (Academic co-supervisor), Chalmers/Volvo
Sofia Jonsson (Insurance data and questionnaire preparation, co-author), Volvia IF
Henrik Wiberg (Case analysis, method development, co-author)

Additional persons contributing to this project:
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Dan Gustafsson (Statististical analysis), VCC

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Bengt Lökensgård (Accident case analysis), VCC
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Carloline Gustafsson (FOT-analys), VCC (summer 2012)
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Persons involved in the collaboration with the DREAMi-project:
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