European Large-Scale
Field Operational Tests on In-Vehicle Systems
7th Framework programme
INFORMATION AND COMMUNICATION TECHNOLOGIES
ICT-2-6.2 ICT for Cooperative Systems
Large-scale integrating project
Grant agreement no.: 223945

Bringing intelligent vehicles to the road

Report on Exchanges with U.S. Organisations May 10-14, 2010

Version number	Version 1.0
Dissemination level	PU
Lead contractor	FFA
Due date	28.05.2010
Date of preparation	28.05.2010

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Revision and history chart

Version	Date	Reason
0.1	2010-05-14	First draft by GA (ALC)
0.2	2010-05-18	Additions on Volpe Center by MvN (TNO)
0.3	2010-05-19	Additions on VTTI by MvN (TNO)
0.4	2010-05-19	Additions by GSP (INRETS)
0.5	2010-05-19	Additions on VTTI and Volpe by MLA (VCC)
0.6	2010-05-20	Additions by AB (IKA)
0.7	2010-05-21	Additions by MLA (VCC)
0.8	2010-05-21	Contributions by RB (TNO)
1.0	2010-05-24	Editing / integration of contributions, addition of summary and conclusions by GA

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1 Executive summary

The euroFOT project is starting its experimental activities and therefore consolidating the methodologies and guidelines defined so far, during the specification phase. As a contribution to setting out these coming activities, the project management, in agreement with the EC Project Officer, has decided to organise a trip to some leading institutions in the USA. A major consideration for this initiative is that these organisations have developed a significant experience on FOTs in the last years, from the conduction of several experiments sponsored by the DOT[1].

Accordingly, in the period from May 10 to May 14, a team of six researchers, representing different euroFOT partners, visited the following organisations:

- Virginia Tech University Transportation Institute (VTTI),
- University of Michigan Transportation Research Institute (UMTRI),
- J.Volpe National Transportation Systems Center.

The main **objective** for these contacts has been to analyse and compare the *methodologies for data analysis and for the assessment of safety impacts, w*ith a view to assure a good quality for the future activities. Other related goals have been: updating our knowledge on recent FOTs, establishing a basis for common procedures and tools at international level, and disseminating information on the European initiatives regarding road safety.

The following part of this executive summary outlines a few major **topics from the meetings** with the three institutions, and finally presents some conclusions.

a) VTTI

The meeting with VTTI has shown their consolidated experience in the analysis of **naturalistic driving** (ND). In ND studies, as opposed to euroFOT, there is no system that is evaluated. Hence, VTTI is more focused on the analysis of driver behaviour and on the factors affecting the crash risk. This university has developed proprietary systems for data acquisition, eye tracking and data mining/reduction, where the focus, for the recent generations, has been on cost and size reduction, and simplification of the procedures. This is linked to the need to manage increasing numbers of test subjects.

An interesting topic for euroFOT has been the modelling of **crash likelihood**, where mathematical techniques are applied to estimate the enhanced probability of a risk factor in the near-crash and/or crash events, compared to normal driving conditions. These methods will be taken into account, during the coming data analysis within euroFOT.

Video recording is considered by VTTI as a very powerful tool for the analyses of FOTs. Their assumption is that video observations are needed to check specific results for their validity. For example, if a high deceleration is found without video data it is unknown whether that is the result of avoiding a crash or braking in order to take a turning that the driver almost missed. This approach is of course related to the specific topics of their research on ND: in euroFOT, even if the goals are somehow different, it seems interesting to pay particular attention to those vehicles where video cameras are installed.

[1] Abbreviations are listed in the following Annex 3

b) UMTRI

This institute has been quite active in several FOTs, for both light and heavy vehicles. UMTRI projects are well aligned with euroFOT, considering that a large part of current research is dedicated to the evaluation of **driver assistance applications**, in term of both system performance and driver reactions. However, the systems under test - although quite developed - are not in series production.

The most interesting topic discussed during the meeting has been the use of **surrogate measurements for the analysis of safety impacts**. This aspect should be further elaborated in the coming phases of euroFOT. Especially for functions like LDW this approach could be very useful, as the Volpe alternative method might not work in such a case. In particular, it has been proved that the statistical approach of UMTRI can establish a correlation between incident rates derived by the FOT and accident risk derived by the statistics.

A second useful topic discussed during the meeting has been the **analysis of warnings**, which is a current area of work at UMTRI: some possible approaches relevant for euroFOT have been derived. This part of the data analysis will be applied more conveniently to the cars equipped with cameras, but the study will hopefully allow a validation of the methods for other vehicles within euroFOT.

The visit has conformed the opportunity to continue the collaboration of euroFOT with UMTRI scientists, and to have representatives from this university in the International Advisory Board.

c) J.Volpe Center

The Crash Avoidance and Advanced Safety Systems group at the Volpe Center focuses on the estimation of safety benefits of ITS systems, in terms of the annual number of crashes that can be avoided if the systems were widely deployed. An interesting aspect of this research is the extensive use of **crash databases**, favoured by the very high quality of the information on road accidents which is available in the USA.

The visit to Volpe has been highly useful, in particular for the exchange of information regarding the **safety impact assessment.** The objective of Volpe's research in safety analysis (namely, the effect of ITS on the number of crashes) is in line with the EuroFOT objective for safety analysis (namely, the effect of ADAS on the number of crashes, fatalities and injuries). They clearly have a lot of expertise in the scientific methods in this field, coupled with the development of best practices in the analysis of FOT data.

Volpe researchers have expressed a willingness to share their knowledge and tools, and have a strong wish for cooperation with other parties. One specific goal in this respect is to develop a **standardized approach** to safety impact assessment. They are therefore very interested in the progress and approach of EuroFOT.

d) Conclusions and next steps

All the US teams have been rather open about their methods and results. In some cases, they expressed a willingness to share data, results, methods and tools with us, and they were certainly interested in a standardization of assessment methodologies worldwide.

In general terms, interesting results have been obtained from the visits to the US organisations, substantially according to the expectations. These concern the evaluation methods, the information exchange and the best practices for FOTs. EuroFOT researchers will therefore further elaborate some of the topics discussed during the meetings in the course of future activities.

The following next steps have been defined:

- Euro FOT will continue to favour liaisons with these US institutions
- A researcher form VTTI and a researcher from J.Volpe will be invited at the coming workshop on data analysis (to be organised together with the FOT-NET support action)
- The contribution of UMTRI to euroFOT will be further consolidated by the appointment of a second scientist as member of the Advisory Board: the purpose is to extend their support not only for the design of experiments, but also for the statistical evaluation
- Additional reciprocal exchanges of scientific and technical reports on FOTs have been agreed.

2 Introduction

This report presents the main outcomes of scientific exchanges between a team of euroFOT researchers and some selected US organisations, particularly active in Transportation Research and the conduction of Field Operational Tests.

A specific trip to the US has been organised between May 10 and May 14 - 2010, based on the following considerations and objectives:

- The present phase of euroFOT, when tests are starting, is particularly important for finalising all the methodologies defined so far in the project.
- While euroFOT is - in Europe - the first activity of relevant size and trans-national dimension, a more consolidated experience is available in the US[2], where several FOTs have been sponsored by DOT in the last years.
- Direct contacts with scientists are seen as a powerful mean to analyze and compare different evaluation methodologies, with a view to assure a good quality for the future activities.
- The trip allows updating information on recent FOTs performed in the US, and not yet published in the open literature.
- Finally, improving the liaisons with leading institutions is expected to contribute to the dissemination of European initiatives for road safety and to the definition of common methods and tools at international level.

The euroFOT participants to the trip are indicated in Annex 1.

The following Universities / Research Organisations have been visited in the US:

- VTTI – Virginia Tech Transportation Institute,
- UMTRI – University of Michigan Transportation Research Institute,
- Volpe National Transportation Systems Center.

During the preparation phase, a number of topics have been defined for the meeting agendas, with a focus on areas relevant for the coming work, such as: the selection of events in the data stream, the control of statistical significance for the data, the evaluation of accident risk, and the impact assessment. A more detailed list of topics of interest is shown in Annex 2.

The following chapters present and comment the specific visits at the three institutions.

[2] For a general review of FOTs in USA, see the euroFOT Document Centre, under SP6 Evaluation / SOA Review

3 Visit to Virginia Tech Transportation Institute

Participants

VTTI	
Myra Blanco	Group leader, Safety and Human Factors Engineering Contact person
Thomas Dingus	Director VTTI
Richard Hanowski	Director of Center for Truck and Bus Safety
Feng Guo	Assistant Professor, Statistics Dept.
Jon Antin	Research Scientist, Light Vehicle Safety Group
Doug McGraw	Senior Research Associate
Rebecca Olson	Research Associate, Center for Truck and Bus Safety
Greg Fitch	Senior Research Associate, Center for Truck and Bus Safety
euroFOT	
Whole team	

The agenda for the meeting is presented in Annex 2

Fig. 1: Meeting at VTTI

Meeting at VTT (May 10-11)

Short presentation of VTTI:

VTTI activities are focused on Driving Safety research, particularly Human Factors (e.g., driver distraction, fatigue, driver behaviour), ITS Technologies, and Teen and Elderly Driving Safety. A strong focus of VTTI research is the investigation of naturalistic driving.

The Institute has about 300 researchers and several facilities including a high performing computing center, a test track (called “smart road”) with artificially reproducible weather conditions, and a fleet of cars and trucks with advanced on-board functions. VTTI has developed its own systems for data acquisition and reduction (different hardware generations progressively more compact and economic, different software generations progressively

more sophisticated). The activities are mostly funded by public agencies, with a minor part sponsored by industrial automotive partners.

The meeting started with a presentation of the euroFOT project and current achievements in Europe; this stimulated a discussion on data quality control, the definition of baseline conditions and data sharing. Methods for driver recruitment and incentives were also commented.

The following activities have been presented by VTTI researchers:

Light vehicle naturalistic driving:

Several projects have been conducted, starting from the 100 car FOT in 2003-04; these projects covered different topics such as risk exposure, teen driving, behaviour of older drivers and, more recently, safety for motorcycles. A large project is currently being launched, which is part of the Strategic Highway Research Program 2 (SHRP2). This effort will include ~2000 cars for a period of 2 years, to be operated by six Management Centers in different areas of the USA. Data are continuously recorded and stored for future analysis. In general, fatigue and driver distraction have been found to be the most relevant factors contributing to unsafe driving.

Drivers are typically recruited via advertisements or calling, and are given small incentives to participate. A questionnaire is used only at the intake.

Heavy vehicle research:

FOTs for heavy trucks are the subject of intense efforts at VTTI. The presentations regarded in particular a study on drowsy driver warning, the use of blind spot systems, and the safety benefits of FCW. The next step will be a study of naturalistic driving based on 250 trucks, travelling for 18 months with 500 subjects.

Modelling of crash likelihood:

Interesting techniques are used to derive the increase in the risk connected to several factors (exposures), like driver distraction, road conditions, secondary tasks, etc.

VTTI categorises the events which may occur during driving into three categories, namely a) safety related incidents, b) near-crashes and c) crashes. Risk is phrased in terms of the number of events in these categories. VTTI uses a rather broad definition of a crash (any contact with another object). The risk is not connected to fatalities or injuries, except in one study where VTTI reviewed a previous work on safety benefits done by Battelle. How to define a crash, near crash, etc is not trivial. The definition determines the outcome. A very strict definition (e.g., that takes into account the level of injury) results in less crashes than the definition as used by VTTI.

Relevant differences between the data from accident databases and from naturalistic driving are that accident databases concern all drivers, are limited to police reported crashes, may contain biased reporting and have limited information on driver behaviour. Naturalistic driving on the other hand concerns the selection of drivers, and uses data logging to provide data on all crash related events in an unbiased and accurate way. The statistical modelling of crash likelihood needs to take these aspects into account. The model identifies risk factors, that is, aspects of the driver or traffic environment that influence the probability of being involved in a near-crash or crash relevant event, for example drowsiness or traffic intensity.

Models are applied to obtain the odds ratio (a measure of the odds of an event - e.g. drowsiness - happening in one situation - e.g. crashes - compared to the odds of the same event happening in another situation). Statistical techniques are applied to minimise (or account for) individual variations or confounding factors. Indeed, each driver has a “base risk”, and this needs to be accounted for as the variation in base risk can be large compared to other variations. Recent VTTI works take account of such individual correlations by using generalized estimated equations (GEE) or mixed models.

In an FOT one typically does not expect a significant number of crashes[3], so safety analysis needs to rely on non-crash data as well. The question arises whether there is any relation between the frequency of crashes and near-crashes in the naturalistic data. The results at VTTI show that for most risk factors, the mean impact of the risk factor for near-crashes is lower than for crashes, which suggests that the results for near-crashes can be used as a conservative estimate. However, the confidence intervals for crashes are very large (due to the small number of cases), so the studies are not very conclusive at present.

Furthermore, comparisons have been made on the relation between the frequency of crashes and near-crashes for different circumstances, such as driver age, level of service, lighting conditions, and road alignment. The comparison suggests a fixed proportionality although strong conclusions are hard to obtain because of the limited number of data points.

Data collection:

VTTI presented some advanced techniques used to collect and store the huge amount of data generated by FOTs, particularly in view of the coming SHRP2 project[4]. Massively parallel processing is employed, using a university cluster of 128 processor machines (12 of which are dedicated to VTTI). Specialized agents have been defined to perform a single task (such as transferring data from the vehicle hard disk to the central system and perform an integrity check). According to VTTI, this has led to a very efficient operation, with the longest query taking about 2 minutes. Procedures for data security and for tracking the data flows are especially considered and put in place. The system allows for flexible access control to the data, currently with three levels of access. According to the presentation, this required a significant step forward beyond the state of the art on data base techniques.

Data mining and data reduction SW:

A practical demonstration of the proprietary data mining / data reduction SW was done in the lab. The tool allows different analyses like: plotting and comparing dynamic signals and video records, extracting a class of events from the data base by queries, and annotating each event with a set of attributes according to a pre-defined scheme.

Events are found by automatic triggers, and subsequently processed by hand. A good data analyst needs about 10 minutes to process one event. The triggers are defined based on experience from previous FOTs, and adapted interactively during the analysis. Finding triggers for trucks is easier than for passenger cars because the variation in driving styles is smaller and the accuracy of kinematic triggers is higher. The triggers are preferably chosen loose, so that missed true events are rare. The processing by hand is done to augment the data and to weed out false alarms. Also, detailed gaze coding is done by hand, i.e. by manually clicking through each video frame in the events (10 frames per second) and for each frame code the driver's gaze direction in that frame. For lateral events, lateral acceleration and swerve are used as triggers, and then video is used to confirm whether this was a true crash related event or not. Accidents with pedestrians have not been subject of analysis (triggers could be swerving or hard braking).

Comments (VTTI)

The meeting has shown how VTTI is building a considerable *experience* in ND techniques, which has been consolidated thorough several research projects during more than ten years.

The Institute is concentrating significant efforts in the analysis of *naturalistic driving*. Since larger fleets are being used for the new FOTs, efforts are going on to simplify the operational

[3] Surprisingly, VTTI found around 80 crashes in 12 months in the 100 car study. This seems due to the fact that their definition of a crash considers any physical contact with an object (including e.g. some debris on the road). Only 16 of the crashes were police reported.

[4] The SHRP2 project is estimated to generate a total of about 90 TB sensor data and 1200 TB video data, excluding database indexing, which may add another 40%.

aspects (e.g., mounting the equipment, training the subjects, etc.) and to reduce the costs of DAS. Differently then euroFOT, the emphasis is less focused on ADAS, but instead more concentrated on accident causations, driver behaviour in the pre-crash phase and the analysis of all the contributing factors.

According to VTTI researchers, *video recording* is an absolutely necessary tool. In fact, they use external and internal cameras in all the studies. Events are typically extracted by triggers, related to parameters in vehicle dynamics, but they are always interpreted, filtered and classified by analysts using the video data.

Data publication and privacy issues have been discussed. Similarities with euroFOT have been found in the approach when dealing with subjects and the contractual issues. VTTI considers three levels for data publication: a) raw data, b) data assuring the protection of driver ID (including usual destinations) and confidential automotive information; c) public data.

A part of the discussion has addressed the *extrapolation* of experimental results to the whole population of drivers. The opinion of VTTI investigators is that great caution is needed when trying to derive general conclusions, since the population of road users is not represented by the sample of test subjects.

4 Visit to University of Michigan – Transportation Research Institute

Participants

UMTRI	
Jim Sayer	Associate Research Scientist, Human Factors Group euroFOT advisor, contact person
Mary Lynn Buonarosa	Research Associate (Human Factors, FOT operation)
David LeBlanc	Assistant Research Scientist (Data analysis and tools)
Daniel Blower	.Director, Center for National Truck and Bus Statistics (Vehicle Safety Analysis)
Scott Bogard	Lead Engineer in Research Engineering Division (Engineering, Data treatment)
Carol Flannagan	Assistant Research Scientist (Experimental Psychology)
Dillon Funkhouser	Engineer in Research Senior Human Factors Division (Human Factors, video analysis)
Paul E Green	Assistant Res. Scientist, Transportation Safety Analysis Div. (statistical analysis)
euroFOT	
G.Alessandretti, A.Benmimoun, R.Brouwer	

The agenda of the meeting is presented in Annex 2

Meeting at UMTRI (May 13-14)

Short presentation of UMTRI:

UMTRI is active in interdisciplinary research to increase driving safety and enhance transportation systems knowledge. Current research covers accident data collection, traffic safety, bio-engineering, human factors, mechanical engineering, psychology, economics and public policies. Several FOTs, particularly focused on ADAS, have been conducted at UMTRI. The most recent (and still on-going) study, is the Integrated Vehicle-Based Safety Systems (IVBSS) project, which evaluates data from both heavy and light vehicles, equipped with warning systems for CSW, LDW/lateral drift, LCW, FCW, and headway monitoring. Most of the research at UMTRI is sponsored by the DOT.

Fig.2: Part of the IVBSS Fleet (Light Vehicles) at UMTRI

During the two days meetings, UMTRI researchers have shown an open attitude, providing comments to the approach chosen by euroFOT, and explaining several techniques developed at their institute. The discussions have therefore covered (more than the general research topics) detailed technical aspects which are important for the future work.

After a discussion on euroFOT objectives and approach, the following subjects have been addressed, mostly via informal discussions with questions and answers.

Conflict analysis:

A substantial agreement has been found regarding the definition of metrics for identifying the level of conflict and of suitable parameters for isolating the interesting scenarios.

Problems associated with the rarity of crashes in an FOT and the need to use surrogate measures have been discussed rather deeply. By analysing various segments of the road network, UMTRI has found interesting correlations between the rate of some surrogate measures (e.g., time to road edge crossing) and the rate of crashes, as derived by the accident data bases. This type of studies can provide relevant clues for the statistical verification of surrogate measurements.

Impact analysis:

The discussion on impact analysis pointed out some difficulties to be faced when extrapolating safety benefits from the FOT data as this will always be linked to assumptions. Surrogate measurements can indicate an improvement for pre-crash situations, but additional assumptions are clearly needed to derive a corresponding improvement related to crash events. Some of the methods to control the plausibility of these assumptions have been discussed. UMTRI presented a statistical approach for LDW, used to investigate correlations between the ratio of incident risk (e.g. incident risk on curved segments/ incident risk on straight roads) and the ratio of accident risk (e.g. accident risk on curved segments/ accident risk on straight roads). The correlation is related to road segments. The accident risk is determined from accident databases whereas the incident risk is derived from FOT data. Taking into account this correlation of incident and accident risk the impacts of LDW can be determined assuming that the improvement due to the LDW correlate in the same way. This statistical method is called “seemingly unrelated regression”. A paper with details on this method was handed over to the euroFOT team.

According to UMTRI researchers, this assumption is a reasonable approach but cannot be verified before the regarded system is fully implemented in the market (compare to ESC).

Another approach uses a model with a stochastic component for the driver that can also provide good useful indications (Volpe approach).

In the same context of impact analysis, the importance of the baseline tests planned in euroFOT has been underlined.

Situation variables:

UMTRI scientists have provided indications, coming from their experience, on the most important situation variables in an FOT study (like the traffic conditions, road geometry, visibility, age of the driver, etc.). In particular, specific variables are used for truck drivers. Generally speaking, the parameters to be chosen depend largely on the research question under investigation. The approach presently used by euroFOT has been compared to the tests conducted in the US. Additional references to the scientific literature on this topic will be provided by UMTRI.

Data collection:

UMTRI has developed specific structures for the data base used to store FOT data. This structure considers a combination of a time-based approach and an event-based approach, mostly to speed up the queries to the data base. The event based approach consists of generation of tables containing start-times and durations for all the events belonging to a specific class. Other important aspects for the data collection are the normalisation of the

data base, and the definition of a subset of “valid” trips, which are extracted from the original complete dataset of each experiment; this method is used by UMTRI to deal with possible problems in the vehicle sensors or in the data bus, but euroFOT should have less difficulties of this type, since production systems are used instead of prototypes.

Tools for data analysis:

During a practical demo, several features of the data analysis tools have been shown by UMTRI: the session has been quite interesting in order to understand what are the most useful types of analysis and some possible pitfalls. Moreover, several real driving situations where the system delivered a warning to the driver were seen in the videos.

The data analysis tools include a well developed database Management system (used to formulate queries: Microsoft SQL Management), an interface to matlab (or to a simpler/cheaper SW called Igor) for data treatment, and a sophisticated tool for video analysis. (Videos are kept in a separated data base and not with the other data).

Subjective aspects:

An additional session has been focused on how to review an FOT with the test subjects, in order to get their opinions especially on the adequacy and usefulness of the on-board system in different situations. Map data and especially videos are a powerful tool for this task, and also allow the experimenter to check for the validity of system interventions. UMTRI researchers also have provided useful indications on how they take into account some privacy and confidentiality issues.

Comments (UMTRI)

The meeting has been particularly useful, since practical methods and tools for the *analysis of FOT data* have been addressed. UMTRI is well aligned with euroFOT, considering that a large part of current research projects is dedicated to the evaluation of *driver assistance systems*, in term of both performance and driver reactions. However, the systems under test - although quite developed - are not in series production.

An interesting topic has been how to link FOT data with the analysis of specific events and the use of *surrogate measurements* to estimate safety benefits. This aspect should be further elaborated in the coming phases of euroFOT. Especially for functions like LDW this approach could be very useful as the Volpe method might not work for this kind of application. It has been proved that the statistical approach of UMTRI can establish a correlation between accidents and surrogate measurements.

A second useful topic during the meeting has been the *analysis of warnings,* which is a current area of work at UMTRI: some possible approaches relevant for euroFOT have been derived. This part of the data analysis will be applied more conveniently to the cars equipped with cameras, but the validation of the techniques will then follow for all the tests.

Special attention is now given by UMTRI to the applications on *heavy vehicles.*. Truck drivers are showing different behaviours, in relationship with the type of mission for their trips, from long distance interstate delivery to daily schedules for urban delivery.

The visit has conformed the opportunity to continue the collaboration of euroFOT with UMTRI scientists, and to have representatives from this university in the International Advisory Board.

5 Visit to Volpe National Transportation Systems Center

Participants

J.Volpe Center	
Wassim George Najm	Technical Expert, Head of Crash Avoidance and Advanced Safety Systems group – Contact person
Bruce H. Wilson	General Engineer
Emily Nodine	Expert, Crash Avoidance and Advanced Safety group
Gary T. Ritter	Expert, Surface Transport Infrastructure and Operations
euroFOT	
M. Ljung Aust, G. SaintPierre, M. van Noort	

The meeting was mostly based on open discussions and some demonstrations; the main topics for the agenda are presented in Annex 2.

Meeting at Volpe Center (May 13)

Short presentation of J.Volpe Center:

The J.Volpe Center is part of the DOT's Research and Innovative Technology Administration. The Crash Avoidance and Advanced Safety Systems group at the Volpe Center focuses on the estimation of safety benefits of ITS systems, in terms of the annual number of crashes that can be avoided in the USA if the systems were widely deployed. There are plans to extend the method to also address effects on injuries. They have a long expertise with conducting FOTs, mainly with FCW but also with run off road accidents and LCW (lane change warning). Currently they are doing their own analysis of the IVBSS FOT (in parallell to UMTRI's analysis of the same data), with light and heavy vehicles. About 100 drivers and 5 systems are involved: CSW, LDW/lateral drift, LCW, FCW, and headway monitoring. They are also thinking about a FOT for V2V cooperative systems. The group has 5-10 staff members. In the USA, only J.Volpe, UMTRI and VTTI have the data collection systems needed for large scale FOT's.

Volpe has developed a method to perform safety estimates based on FOT data and historic accident data. The method is guided by the available data, and a boundary condition is that it should be simple to understand, yet complete in the sense that it connects FOT data to real safety benefits. The discussion was centered mostly on the impact assessment method, while data analysis was briefly touched upon.

During the one day meeting, the Volpe researchers were very open about their methods and results. They expressed a willingness to share data, results, methods and tools with us, and are very interested in a standardization of assessment methodologies worldwide.

The agenda for the day was mostly free discussion, with some presentations and a demonstration of the video analysis tool.

The safety impact assessment method (presentation and discussion):

The assessment method estimates the number of avoided crashes. This cannot be done directly because the number of crashes in an FOT is too low to yield significant results. Therefore, the method estimates the number of conflicts (and near-crashes, which are simply a more severe kind of conflict) with and without the system. In some projects, the presence and severity alone of the conflict has been taken as a relevant predictor of actual crash risk. In some other projects, simulation has been used as a complement to the crash and FOT data to estimate the probability that a conflict will lead to an accident, again with and without

the system. The system effectiveness is measured per driver, and then aggregated, in order to take into account the variation between drivers.

Conflicts are crash-prone situations, and are defined by numerical thresholds on certain crash-related variables such as TTC (the variable depends on the crash type under investigation). The preferred measure, at least for crashes which involve heavy braking, is a combination of range and range.rate, where data from a CAMP study on hard and emergency braking behaviour is used to set the conflict thresholds. Conflicts are detected automatically from the numerical data, without intervention from the analyst. A conflict is judged as relevant only if there is a significant driver response such as swerving or braking (to minimize false alarms). Conflicts are defined as follows:

- First, the targeted crash types (i.e., the crash types for which the system is supposed to have an effect) are determined. For example, “rear-end crashes”.
- Cases where the system is not viewed as helpful are excluded. For example, cases where the crash data codes the driver as “driver incapacitated” or “experiencing sudden illness” are excluded, as the driver cannot be expected to react as intended to a system warning.
- For the remaining cases, the relevant pre-crash scenarios are obtained from the GES crash database. For example, “lead vehicle stopped”. This uses the pre-crash variables “accident type”, “critical event” and “pre-event movement”.
- For these pre-crash scenarios, conflict types are defined in terms of thresholds of certain objective variables such as TTC or range and range-rate. A sensitivity analysis can be carried out to check that the outcome does not depend on the exact threshold chosen. Care needs to be taken not to count conflicts multiple times when the kinematic data is oscillating around the threshold. In Volpe’s experience, range combined with range rate is always the best measure.

Occasionally, video is used to classify conflicts. For example, for conflicts with oncoming vehicles, radar data cannot be used because the radar filters out oncoming objects. In those cases, video is used to estimate TTC.

In some projects, the relation between conflict and accident risk is determined by Monte-Carlo simulation, taking the FOT data point as starting point and probability distributions for crash-relevant parameters. These distributions are based on FOT data, or (where necessary, for example to obtain the tail of a brake force distribution) on data from controlled experiments.

Global changes in driving style (such as speed changes) due to an ITS are included in the sense that these changes can only affect accidents by affecting conflicts[5].

The safety impact of a system maybe correlated to its performance and the driver acceptance. Hence these factors need to be taken into account. Validation of the method is not possible because there is no before and after data for sufficiently large populations.

Accident databases (discussion):

The Volpe center has access to a large number of accident databases. Most of these are generally accessible through the NCSA (National Center for Statistics and Analysis, an office of the National Highway Traffic Safety Administration). The databases contain representative weighted samples of crashes of certain types, sometimes also including detailed pre-crash data. The table below lists some details:

[5] For road departure accidents, speed is a major contributing factor, especially in curves. For rear-ends, speed is not so relevant.

Database and access	Quality	Vehicles	Crash types	Pre-crash variables	Comments
Fatality Analysis Reporting System (FARS) Public, www.nhtsa.gov/FARS	Special analysts	Motor vehicle involved	Fatalities	After year 2010	Database can be downloaded. Representative: include all US fatal collisions.
General Estimates System (GES) Public, www.nhtsa.gov/NASS	Police reported	Motor vehicle involved	All	Yes	From 1988, database can be downloaded, underestimates 30-day fatalities, ~60000 cases per year Non representative but provide a scale.
Crashworthiness Data System (CDS) Public, www.nhtsa.gov/NASS	Field research team	Light motor vehicles	Light vehicle towed	Yes, also impact speed	Limited query format, ~5500 cases per year. Non representative but provide a scale.
National Motor Vehicle Crash Causation Study (NMVCCS) Public (?)	On scene interview	Light motor vehicles	Light vehicle towed	Yes	Cannot find website
Event Data Recorder (EDR) Public, www.nhtsa.gov/EDR	Objective black box data	GM and Ford vehicles	In CDS	From black box	pdf files only. Non representative.
Crash Injury Research and Engineering Network (CIREN) Public, nhtsa.gov/ciren	?	?	?	?	From 1996, Relation between crashes and human damage

The GES database does not use the AIS scale to rate injuries, but more sophisticated criteria. These can be translated to the AIS scale. A drawback of the AIS scale is that it measures the “nearness to death”, not the long-term severity of the injury (i.e. it does not take healing into account). The GES database underestimates the number of fatalities because it should include all fatalities within 30 days of the accident but it does not include the delayed ones.

The CDS database contains the impact speed at collisions, which enables researchers to relate the impact speed to injury level. Important risk factors are seatbelt use and airbag presence. A precondition for the analysis is that the first impact is at the front of the vehicle and also is the most harmful one (in case of multiple impacts).

On the NCSA website there are also other databases (not discussed) such as crash test data (http://www.nhtsa.gov/Research/Databases+and+Software) and Special Crash Investigations (SCI) (http://www.nhtsa.gov/SCI).

Demonstration of the video analysis tool:

The tool allows researchers to synchronize video with numerical performance indicators (like vehicle speed, time headway, etc). Synchronization is a big practical problem, because the data acquisition is done by several machines in parallel.

Some additional variables (e.g. relating to the driver state) are coded from the video by data analysts. For experienced analysts and relatively simple events, this typically takes about 1 minute per event. The coding variables used are fewer and mostly have much lower resolution than the one used at VTTI. Volpe says this is in order to avoid coding errors and unuseful complexity. On a general level, it seems like they code on the level of detail which matches the crash data that form the basis of their analysis. For example, both Volpe and VTTI have access to frame-by-frame video data in their events. However, while VTTI codes gaze direction on a frame by frame basis and only draws conclusions on distraction based on the aggregated material, Volpe codes distraction on an event-by-event basis. The Volpe criteria is that the driver should look away from the forward roadway at least 1.5 seconds continuously at some point during the 10s segment prior to the evasive manoeuvre. If the driver does so, it is coded as distraction and if not, the driver is coded as attentive. In terms of resources, the video based analysis is the biggest component of the analysis work. The importance of clear and objective definitions for the additional variables is stressed.

The triggers for the video analysis are the alerts of the system under test (or the silent alerts in the baseline).

SafeTrip 21 (presentation):

This project concerns FOTs for market-ready systems. The experimental setup is special in the sense that participants can self-register through the web. This project concerns mainly the use of cell phone technologies for forecasting traffic throughput.

Comments (Volpe)

The visit to Volpe was highly useful, in particular for the *safety impact assessment.* The objective of Volpe's research in safety analysis (namely, the effect of ITS on the number of crashes) is well aligned with the EuroFOT objective for safety analysis (namely, the effect of ITS on the number of crashes, fatalities and injuries). They clearly have a lot of experience and expertise in this field. The quality of the USA historic accident databases is impressive.

Volpe has expressed their willingness to share their knowledge and tools, and has a strong wish for cooperation with other parties. Their goal in this respect is to develop a *standardized approach to safety impact* assessment. They are very interested in the progress and approach of EuroFOT.

The method developed by the Volpe center shows great similarity with the proposals in EuroFOT WP6400.

6 Conclusions and next actions

Interesting results, substantially along the expectations, have been obtained from the visits to the US organisations active in FOTs.

In particular, a deeper and more general view has been gained regarding the evaluation methods for experimental data, and especially the use of precursor events for the analysis of safety impacts. EuroFOT researchers will therefore further elaborate some of the techniques discussed at the meetings, in the course of future activities.

Another achievement of the trip is the availability of updated information for some on-going FOTs, like the IVBSS and the SHRP2 projects. The establishment of direct contacts with the US teams involved in these experiments set the basis for future interactions, aimed to the exchange of best practices and in particular the definition of standardized assessment procedures.

In several cases, US researchers have expressed a great interest for the on-going euroFOT activities.

The following next steps are therefore anticipated:

- Euro FOT will continue to favour liaisons with these US institutions
- A researcher form VTTI and a researcher from J.Volpe will be invited at the coming workshop on data analysis (to be organised together with the FOT-NET support action)
- The presence of UMTRI inside euroFOT will be further consolidated by the appointment of a second scientist as member of the Advisory Board: the purpose is to extend their support not only for the design of experiments, but also for the statistical evaluation
- Additional mutual exchanges of scientific and technical reports on FOTs have been agreed

Annex 1: List of euroFOT participants

Name	Organisation and country	Role in project	Experience / specific topics to be covered
Giancarlo Alessandretti	Alcor (IT)	Scientific coordination (SP1)	Physicist. Automotive ICT technologies and test methods; driver-vehicle interaction. General topics at project level.
Ahmed Benmimoun	IKA (DE)	SP6 leader	Engineer, PhD in automotive technologies. Evaluation methods and tools; impact analysis
Rino Brouwer	TNO (NL)	SP4 leader	Psychologist, involved in the analyses for the German VMC; involved in the development of the impact analyses method and subjective questionnaires
Mikael Ljung Aust	Volvo Cars (SE)	Analysis for Swedish VMC (SP6)	Psychologist. Works with driver behaviour analysis at Volvo Cars Safety Center and Chalmers University of Technology. Focus on methods for evaluating ADAS performance and other driver-vehicle interactions. Involved in the development of the impact analyses method.
Guillaume SaintPierre	Inrets/Livic (FR)	WP2500 coordinator Analysis for French VMC (SP6)	Mathematics and statistics. Evaluation of ADAS. Risk assessment methods (studied during the French LAVIA project). Focus on statistical methodology and data mining tools.
Martijn VanNoort	TNO (NL)	WP6400 coordinator	Mathematics and statistics. Assessment of safety impact, use of accident data bases, modelling of critical situations by micro-simulation

Annex 2: Topics for discussion / Agendas

a) Agenda for VTTI Meeting

DAY 1: Monday, May 10, 2010

9:00 - 9:30:	Introductions
9:30 - 10:30:	euroFOT project
10:30 - 11:30:	VTTI Overview
11:30 - 12:00:	Data Acquisition and Instrumentation – Garage Demo
12:00 - 1:00:	Data Storage and Retrieval (Clark)
1:00 - 2:00:	Statistical Techniques
2:00 - 3:00:	Light Vehicle Naturalistic Research: From 100 Car to SHRP 2
3:00 - 4:00:	Heavy Vehicle Naturalistic Research: From DDWS to 250 Truck

DAY 2: Tuesday, May 11, 2010

9:00 – 4:00: Data Reduction and Analysis Workshop (Rebecca)*

b) Agenda for UMTRI Meeting

Day 1: Thursday, May 13

9:00 – Noon Analysis Theory

- Choices and boundary conditions in the IBA methodology: intended vs. unintended effects, global changes in safety, calibration and validation, assumptions
- Alternative methods: considerations in choosing this method and not choosing others; Resources / time needed
- Models for prevention ratio / physical risk: Which models, relation to FOT data, dealing with lack of data, driver modeling, reaction time (with/without the function), incorporation of crash severity
- Scaling up: Higher penetration levels, cost-benefit analysis
- Link between conflicts and crashes: Assumptions, reliability, overlaps, method for creating the link
- Selecting crash types (accident types): criteria, definition, accident database

1:00 – 4:00 Analysis practice

- Situational variables: which ones, interactions, consequences for FOT data processing
- Conflicts: source of conflict definitions, reliability, definition, missed events, triggers (with/without video), determining the exposure ratio (with/without video)
- Missing data: how to identify conflicts in absence of (most logical) trigger indicators

Day 2: Friday, May 14th

- 9:00 – 10:30: Database structure and queries (Scott, Room 204)
- 10:30 – Noon: Data Visualization and behavioral coding (Dillon, Shan and Mary Lynn, Room 342 A/B)
- 1:00 – 2:30 Facilities tour, including IVBSS vehicle demo (Dillon and Mary Lynn)
- 2:30 – 4:00 Open for any follow-up conversations.

c) Agenda for J.Volpe Meeting

Day 1: Thursday, May 13

Short presentation of J.Volpe Center

The safety impact assessment method (presentation and discussion)

Accident databases (discussion)

Demonstration of the video analysis tool

SafeTrip 21 (presentation)

Annex 3: List of abbreviations

Abbreviation	Expansion
ACAS	Automotive Collision Avoidance System (US Field Operational Test)
ADAS	Advanced Driver Assistance Systems
AIS	Abbreviated Injury Scale
CAMP	Crash Avoidance Metrics Partnership (US Field Operational Test)
CAN	Controller Area Network
CDS	Crashworthiness Data System (accident database)
CIREN	Crash Injury Research and Engineering Network
CSW	Curve Speed Warning
DOT	Department of Transportation
EDR	Event Data Recorder (accident database)
ESC	Electronic Stability Control
FARS	Fatality Analysis Reporting System (accident database)
FCW	Forward Collision Warning
FOT	Field Operational Test
GEE	General Estimates Equation
GES	General Estimates System (accident database)
HW	Hardware
ID	Identity
ITS	Intelligent Transportation Systems
IVBSS	Integrated Vehicle-Based Safety Systems (US Field Operational Test)
LCW	Lane Change Warning
LDW	Lane Departure Warning
NASS	National Automotive Sampling System
NCSA	National Center for Statistics and Analysis,
ND	Naturalistic Driving
SCI	Special Crash Investigations
SHRP2	Strategic Highway Research Program 2
SQL	Structured Query Language
SW	Software
TTC	Time to Collision
UMTRI	University of Michigan – Transportation Research Institute
VTTI	Virginia Tech Transportation Institute