EUROPEAN COMMISSION

DG INFORMATION SOCIETY & MEDIA

SEVENTH FRAMEWORK PROGRAMME

INFORMATION AND COMMUNICATION TECHNOLOGIES

Coordination and Support Action – Grant Agreement Number 269983

FOT-Net 2

Field Operational Tests Networking and Methodology Promotion

Working Group Data Analysis

Deliverable no.	
Dissemination level	Intermediate report
Work Package no.	WP3.2
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Status (F: final, D: draft)	D
File Name	FOT-Net 2_WG Data Analysis_v1 5.doc
Project Start Date and Duration	01 June 2011, 36 months

Document Control Sheet

Main author(s) or editor(s): A. Zlocki, M. Benmimoun (IKA)

Work area: WP3

Document title: Working Group Data Analysis

Version history:

Version number	Date	Main author	Summary of changes
0.1	04.02.2013	A. Zlocki, M.Benmimoun	Document created based on all input to WG Data Analysis
0.2	16.05.2013	A. Zlocki	Update of input
0.3	30.09.2013	M.Benmimoun	Update
1.0	11.11.2013	E.Thomasson	Minor final edits

Table of Contents

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Furthermore the goal is to invite colleges from evaluation work packages of other FOT/NDS projects.

2 Introduction and Work Plan

Launched in September 2011, five dedicated FOT-Net Working Groups (WGs) were set up to look into a specific set of issues to further enhance and revise the FESTA methodology for FOTs. Experts from the FOT community are invited to discuss (1) data analysis, (2) events and incident definition, (3) legal and ethical issues, (4) impact assessment and scaling up, (5) data sharing. Their discussion should achieve commonly agreed positions on the specific WG topics.

The WGs are led by a FOT-Net convenor with the contribution of other FOT-Net partners and participation to the WGs is open to the wider FOT community. This report was attributed to the first working group "Data Analysis" and its planned activities are given as follows:.

Activities, planning, results, meetings:

Task	**Who**	**Deadline**	**How**	**Result (milestone)**
1. Collect relevant issues on data analysis from FOTNet deliverable 3.2. The focus of the work is on the complete data analysis chain (transfer, quality check, verification, enrichment, pre-processing, filtering, analysis) with the approaches used in conducted FOTs and NDSs (euroFOT[1], TeleFOT[2], SeMiFOT[3], US FOTs[4] etc.)	WG leader	February 2012	Desktop Work	List of issues
2. Conduct bilateral discussions with experts	Data analysis experts and WG	June 2012	Telephone interviews, physical meetings	New input on data analysis methodology
3. Derive recommendations on data analysis	WG leader and core group	Fall 2012	Desktop work, telephone conference	List of recommendations
4. Revise the FESTA approach based on the results, taking into account the experiences gathered in conducted FOTs and NDSs	WG leader and core group	January 2013	Desktop work, telephone conference	Draft proposal

[1] http://www.eurofot-ip.eu/

[2] http://www.telefot.eu/

[3] http://www.chalmers.se/safer/EN/projects/traffic-safety-analysis/projects/semifot-sweden-michigan

[4] http://wiki.fot-net.eu/index.php?title=Volvo_Intelligent_Vehicle_Initiative_Field_Operational_Test

5. Common workshop in the form of a webinar or as a side meeting of a conference participated in by some of the experts (if applicable).	Data analysis experts and WG	Spring 2013, e.g. ITS European Congress	Webinar or physical meeting	
6. Consolidation and documentation of the findings and recommendations	WG leader and core group	October 2013	Desktop work, telephone conference	Final report on data analysis

3 Relevant issues on data analysis

The relevant issues on data analysis have been collected by FOT experts from different FOT/NDS projects in Europe, US and Japan. Some of the issues have already been reported in FOT-Net deliverable 3.2. By means of bilateral discussion with the experts, further issues were collected and are presented here.

All issues have been clustered into the main categories:

- **Experimental design**
- **Data collection, processing, and storage**
- **Data analysis**

In the following sections the relevant data analysis issues for each category are given.

3.1 Experimental design

The experimental design defines all necessary steps to be conducted within an FOT. These include the process of how and who to recruit for the experiment, the duration, the data acquisition systems as well as the number of vehicles and drivers to be included.

The definition of the experimental design is conducted early at the beginning of a FOT. According to the FOT experts, the major objective of the experimental design is to ensure that all necessary information is going to be collected, in order to test the pre-defined hypotheses and the research questions. Based on the discussions within the working group the following issues were addressed by the FOT experts:

3.1.1 Distribution of participants (e.g. male/female, age, experience with tested systems)

Issue:

- Selected drivers are representing only a specific type of driver

Consequence on data analysis:

- Results are not representative, due to limited driver group
- Comparisons between different driver profiles are not possible
- Analysis of whether the determined effect is due to tested function or specific type of driver behaviour is not possible

Recommendations:

- Define required driver profiles at an early stage based on defined research questions by taking into account number of vehicles to be used in FOT
- Selection process needs to be monitored and assessed with respect to consequences on defined analysis process
- Identified deviations need to be communicated at an early stage, in order to adapt the experimental design and data analysis plan accordingly

3.1.2 Selection of test vehicles (e.g. customer vehicles, test vehicles that are already equipped with measurement devices)

Issue:

- Drivers refuse to drive test vehicles equipped with certain measurement devices (e.g. cameras) or refuse installation of devices that require modification on their vehicles

Consequences on data analysis:

- Required information cannot collected, due to missing sensors
- Customer vehicles cannot be used for integration of extensive measurement devices
- If required sensors (e.g. camera systems) cannot be integrated in vehicles, required information for data analysis might be missing

Recommendations:

- Breakdown hypotheses to the required signal needing to be collected from the vehicle
- Check at an early stage whether all required signals are going to be collected by the selected data acquisitions
- If not all signals are collected, determine consequences on data analysis
- Communicate and raise awareness on consequences of data acquisition process (e.g. hypotheses that cannot to be tested due to missing information)

3.1.3 Duration of the experiment (Duration of baseline and treatment periods)

Issue:

- Data collection phase is too short

Consequence on data analysis:

- Amount of needed information (e.g. critical situations) is not sufficient to derive valid conclusions
- Comparison between different phases due to short duration is not possible (assessment of impact not possible)

Recommendations:

- Duration of data collection needs to consider the type of data analysis and ensure that sufficient data is collected, in order to have enough information to determine valid conclusions
- Duration of data collection needs to be defined in accordance to the number of vehicles to be used in experiment as well as the annual mileage of the recruited drivers (if drivers have a low annual mileage duration needs to be adapted accordingly to ensure collection of required information)
- In general, the driver collection phase should be at least 6 months (depending on defined research questions), because data analysis is focused on relevant

scenarios, which are in some cases very rare (e.g. a certain type of incident under specific weather conditions)

3.1.4 Usage of system within baseline phase

Issue:

- Drivers are asked in baseline phases not to use the systems (voluntary basis)

Consequence on data analysis:

- Tested systems are used also during the baseline phase
- Comparison baseline vs. treatment not possible (due to usage of the system in baseline phase), which means no impact assessment is possible

Recommendations:

- If possible, deactivate the systems completely within the baseline phase (no activation by driver possible)
- If deactivation not possible, make sure that drivers are aware of consequences on the experiment if they use the system during the baseline
- Consider online monitoring process of system status (e.g. a warning is issued to data administrator as soon as the function is activated)
- Stay in close contact to drivers, in order to ensure that drivers stay motivated

3.1.5 Combination of functions

Issue:

- More than one function is tested in one vehicle (combined functions are tested)

Consequence on data analysis:

- Testing of individual effects is not possible due to combined functions, because both functions are used at the same time

Recommendations:

- Conduct analysis for bundle of functions
- Define hypotheses and research questions for bundle of functions

3.2 Data collection, processing, and storage

The data collection phase starts after the experimental design is defined and all necessary equipment has been integrated into the vehicles. Normally the data collection phase starts with the baseline period, during which the functions are not used. Within this phase normal driving behavior is observed. Afterwards, the functions are then activated and can be used by the drivers as they would usually.

The data is collected by means of data acquisition systems (DAS). The DAS are configured according to the experimental design and are integrated in the vehicles. After the data is collected by the DAS it is stored either in the vehicle (e.g. storage system in the trunk of the vehicle) or transmitted to a server. At the server side the data is processed for the planned analysis steps. Within data processing, several steps are conducted. Normally the data is

converted to a standardized format before being checked with respect to data quality. Afterwards the data is aggregated into relevant events and situations needed for the data analysis. Finally the processed data is uploaded to a database where the data analysis is conducted.

For the data collection phase, data processing and storage, several issues have to be considered in order to avoid that data is missing. According to the FOT experts in this WG the following issues have major consequences on the data analysis task.

3.2.1 Data collection of required information

Issue:

- Not all required data is collected

Consequence on data analysis:

- Analysis cannot be conducted, due to missing relevant data
- Not recorded (obvious) relevant information might be necessary after data analysis started, e.g. for interpretation purposes

Recommendations:

- “Record everything that you can get”
- Check collected data during the piloting phase in order to perform a test analysis
- Use test analysis to assess whether all needed data is collected, If not, communicate consequences and raise awareness
- Make to whole consortium very clear what consequences are expected due to the limited data collection

3.2.2 Data collection needs to consider needed accuracy

Issue:

- Data accuracy too bad (Frequency is too low, e.g. acceleration gathered with 1Hz)

Consequence on data analysis:

- Detailed data analysis not possible
- Time-critical events are not detected due to bad frequency (e.g. abrupt hard braking event (<1s)
- Interpretation of results not always possible, because of missing information due to low frequency (e.g. analysis of causation before event occurred)

Recommendations:

- Adapt the frequency according to the characteristics of the signal
  - e.g. 10 Hz for dynamic signal such as acceleration, speed, yaw rate etc.
  - e.g. 1 Hz for status information such as turn indicator, system status, weather conditions etc.

3.2.3 Event-based or continuous data collection approach

Issue:

- Event-based detected events are not correct (e.g. thresholds are too high)

Consequence on data analysis:

- Data analysis is not possible due to missing information
- Interpretation of results not possible due to missing information on causation of events etc.

Recommendations:

- Event-based data collection requires clear understanding of event definition (detailed information on required thresholds etc.) before data collection
- Continuous data collection results in larger data sets, but it also provides data for other research activities, even after the project end
- Continuous data collection provides data that might be interesting / valuable for interpretation of results
- Complete understanding of results is only possible by continuous data collection

3.2.4 Collection and handling of large data sets

Issue:

- High Frequency of vehicle data or video data as well as duration and number of vehicles generates a huge amount of data that needs a long processing time

Consequence on data analysis:

- Analysis time needs to be reduced, due to of increase of needed processing time
- Analysis time is not sufficient to evaluate all collected data

Recommendations:

- Estimate amount of data at the early beginning of the project, based on the number of vehicles, data collection process etc.
- Estimate time needed to process and analyse data test (test processing and analysis process in advance)
- Monitor status of data collection during the collection phase and start processing of data at beginning of data collection phase (don't wait until all data is collected)
- Develop automated processes:
  - Data processing and data analysis of large data sets by means of automated processes
  - Automated scripts are required, in order to reduce the time for data analysis

3.2.5 Analysis by means of database

Issue:

- Large data sets exceed the performance limits of databases

Consequence on data analysis:

- Limited access to required data causes delay of data analysis
- Provision of requested information can take several days to several months

Recommendations:

- Post-processing: Provision of aggregated data sets based on analysis requirements
- Consider employing experts for relational databases in the project, in order to optimise and tune database according to planned analysis
- Define structure and content of database in advance
- Start testing of database related analysis within piloting phase

3.3 Data analysis

The analysis of the data is conducted at the end of the FOT after the data is processed and stored on a database the analysis is started. Normally the analysis includes the testing of hypotheses and the impact assessment based on the defined research questions. The analysis is conducted by means of statistical methods (hypothesis testing) as well as using simulations (impact assessment). Within the data analysis, additional data is used (e.g. data on accidents from an accident database) in order to perform the data analysis. The analysis is conducted by means of standardized analysis tools (statistical analysis tools) as well as specific developed tools (especially for the analysis of video data).

According to the FOT experts in this WG the following issues have major consequences on the data analysis task.

3.3.1 Development of data analysis tool

Issue:

- Different data analysis tools used within one FOT

Consequences on data analysis:

- Results are not completely comparable
- Analysis tools might be only applicable for one data set
- Not accessible for all consortium members

Recommendations:

- Development of standardised data analysis tools

3.3.2 Availability of standardized tools

Issue:

- No standardized tools are available and hence, different individual tools are used in FOTs

Consequence on data analysis:

- Results of the FOTs are not completely comparable
- Usage of data sets from other FOTs require usage of self developed tools
- Self-developed tools might not be available for sharing with other parties
- Working with self-developed tools requires a manual which is normally not available

Recommendations:

- Standardization partly available for accident data might be also done for FOT/NDS data in the future
- Comparison of results from different FOTs is not always possible, when the same definitions and tools are not applied, e.g. frequency of data collection, trigger or continuous recording, quality indicators, definition of relevant events

3.3.3 Manual video analysis and annotation

Issue:

- Essential to understand safety analysis, but this produces high costs due to time-consuming manual video analysis by several persons

Consequences on data analysis:

- Reduced time or budget to perform data analysis
- Efforts for manual video analysis could result in reduced efforts for data analysis
- Subjective video analysis by different persons might results in different data sets, which might be comparable and lead to false conclusions

Recommendations:

- Development of automated annotation methods (not all problems will be solved by automated annotation)
- Further research on objective triggers to reduce efforts for video analysis
- Define detailed descriptions how to conduct video analysis, in order to keep results from different persons comparable
- Perform tests on video analysis by means of same data sets and compare results between involved persons, in order to define process for manual video analysis

3.3.4 Analysis of driver relevant data

Issue:

- Usage of expensive Eye-Tracking systems

Consequences on data analysis:

- Different conditions (driver sizes, environment, glasses etc.) lower the quality of data collection possibilities
- Increased efforts and workload for data processing and data analysis, due to video annotation

Recommendations:

- Usage of Eye-Tracking vehicle only in few vehicles (controlled test) where the Eye-Tracking systems can be adjusted to each driver and to environment conditions
- Use monitoring tools to adjust Eye-Tracking systems online over the time

3.3.5 Subjective data from driver

Issue:

- Not all participating drivers fill out provided questionnaires or take necessary time to fill out questionnaire adequately

Consequence on data analysis:

- Subjective data is not from all drivers available
- Answers of drivers are inconsistent and hence not trustable or usable for data analysis

Recommendations:

- Provide incentives and define the process of how to contact drivers, in order to collect questionnaires
- Use an online questionnaire application
- First experience: travel diaries seems to work (experts from TeleFOT)

3.3.6 Data sharing:

Issue:

- Due to confidentiality, not all partners have access to data

Consequences on data analysis:

- Data analysis by only a few partners can cause delays

Recommendations:

- Define at the beginning of project process how data will be accessed
- Consequences because of limited or restricted access to data needs to be estimated and presented to the consortium at an early stage, in order to raise awareness and to discuss possible solutions

3.3.7 Usage of data and developed tools after FOT

Issue:

- Follow-up data analysis (e.g. in new project) is only possible if raw data and good documentation is available.

Consequences on data analysis:

- New or other partners cannot use the tools or understand the structure and the content of the database due to missing documentation and hence cannot conduct the analysis

Recommendations:

- Consider usage of the processes and tools in other projects from the very beginning of the project
- Create documentation of each tool and process to be developed within the FOT
- Provide a detailed description of database structure and content, especially the documentation of the aggregated data (definition of events, triggers and thresholds used) are crucial to re-use the data in a follow-up project

3.3.8 Many research questions

Issue:

- In depth analysis of few research questions (RQ) vs. general analysis of many RQ (especially for uncontrolled NDS data). Due to limited time and resources an analysis of all research questions might not feasible

Consequences on data analysis:

- Analysing all defined RQ results in very general analysis without any meaningful results

Recommendations:

- Focus on few RQ to get scientific sound results
- Adapt number of research questions to be analysed according to deviations in FOT

4 Recommendations for revision of FESTA Handbook

In the following section, recommendations gathered from the different FOT-Net workshops are summarized. The recommendations address issues that are not mentioned or not described in detail in the original version of the FESTA handbook. The majority of the recommendations address planning and interaction issues within the analysis task. Furthermore, additional recommendations on the actual data analysis task, documentation and testing as well as on cooperative FOTs are considered.

4.1 Planning and interactions

1. Be involved in the overall FOT/NDS process from the very beginning, not only focusing on data analysis
2. Make sure that data analysis process is included in planning activities
3. Be involved in the interactions and iterations between planning, using, and analysing
4. Be part of the project monitoring, in order to be informed about project status
5. Adapt regular planning of analysis task according to deviations from original project planning and elaborate consequences on analysis task
6. Open communication with regards to project monitoring in order to reduce expectations, if things go wrong in the implementation and data acquisition stage
7. Think about processes and tools for gathering questionnaires at the beginning of the project
    i. e.g. provide smart phone apps to fill out questionnaires
    ii. e.g. keep drivers in the analysis loop
8. Define all necessary steps including all activities. Even little things can cause big problems
9. Consider differences in system-time
    i. e.g. GPS, control unit, vehicle CAN-Bus, roadside sensor, operation center etc.

4.2 Data analysis task

10. Keep in mind that less is more, since in the end the complete data set cannot be analyzed due to
    i. delays,
    ii. missing data,
    iii. bad data quality,
    iv. budget restrictions,

v. limited time,

vi. restricted access to gathered data in database

11. Define the process and consequences with respect to in-depth analysis of few research questions vs. general analysis of many RQ (especially for uncontrolled NDS data)

12. Focus on few research questions get scientific sound results

13. Limit video analysis to minimum and try as far as possible to use automated processes

4.3 Documentation and testing

14. Create documentations of developed tools and processes in order to enable usage after the project end (e.g. usage in follow-up project)

15. Provide a detailed test protocol with all relevant test scenarios and potential risks

16. Make sure that the complete data analysis process (data processing and analysis tools) is developed before piloting phase, in order to test and assess all data analysis step within piloting phase

4.4 Cooperative FOTs

17. Define all necessary activities per Vehicle and to roadside and central stations (cooperative FOT)

18. Consider reiteration of tests, in order to compensate wrong settings. A second test more or less can make a huge difference (cooperative FOT)

5 Conclusions

The FESTA handbook provides an overview and a description of the necessary steps to be carried out within the data analysis task in FOTs and NDS. However additional information, especially on the interactions between the single steps are not described with all necessary detail. Hence the working group on data analysis gathered experiences gained while conducting an FOT or NDS. Within this working group a specific set of issues to further enhance and revise the FESTA methodology for FOTs have been discussed. An expert group from the FOT community was involved in these discussions, in order to achieve a commonly agreed position on the specific WG topics. The discussions were conducted on different FOT-Net workshops and focused mainly on issued with respect to the experimental design, data collection, data processing, data storage, and data analysis. Within these workshops, the consequences on the analysis task were discussed and afterwards, recommendations based on the experience of the expert group were derived.

One major issue that was discussed in several workshops are missing interactions and links to the planning and implementation phase. Hence it is of major importance to be involved in the planning, implementation, and data collection task, in order to adapt the analysis according to the specific needs of the FOT. Furthermore it is recommended to regularly monitor the project status and to assess potential consequences on the analysis planning. Hence it is crucial that the analysis team is involved in the planning and the implementation of the FOT from very beginning of the project. It is recommended to include these interactions and iterations in the FESTA-implementation plan, in order to illustrate that the planning and the definition of the analysis task has to start at an early stage of the FOT.