Development of innovative safety performance indicators from Naturalistic Driving data

Arnaud Bonnard\textsuperscript{a,1}, Myriam Hugot\textsuperscript{b}, Corinne Brusque\textsuperscript{b}

\textsuperscript{a} IFSTTAR, Marne-la-Vallée, France
\textsuperscript{b} IFSTTAR, Bron, France

Abstract

How to obtain relevant road safety indicators from driving data collected on a vehicle fleet? This paper proposes an approach that aim to answer this question. After presenting the main technical and methodological issues linked to the continuous observation of a fleet of vehicles, the authors highlight different aspects of drivers’ unsafe behaviours and propose a method to compute several road safety indicators which can reflect this various aspects. This method is illustrated with speed related safety indicators. Methodological issues associated to this method are discussed. Finally, a list of indicators that cover a wide range of safety related unsafe behaviours is proposed in order to show how the proposed method can be used.

Keywords: naturalistic driving observation, road safety, safety performance indicators

Résumé

Comment obtenir des indicateurs de sécurité routière pertinents à partir de données longitudinales collectées sur une flotte de véhicules? Ce papier propose une approche permettant de répondre à cette question. Après avoir rappelé les principales difficultés techniques et méthodologiques liées à l’observation en continu d’une flotte de véhicules, les auteurs mettent en avant différentes facettes complémentaires des comportements à risque du point de vue de la sécurité routière et proposent une méthode pour calculer plusieurs indicateurs de sécurité routière capables de rendre compte de ces différentes facettes. Cette méthode est illustrée avec le calcul d’indicateurs liés aux comportements de survitesse. Différentes questions méthodologiques associées à cette méthode sont discutées. Finalement, une liste d’indicateurs couvrants différents comportements d’insécurité routière est proposée afin de montrer comment la méthode proposée peut se décliner.

Mots-clé: observation naturelle de la conduite, sécurité routière, indicateurs de sécurité routière

\textsuperscript{1} Corresponding author. Tel.: +33 1 61 62 63 64
E-mail address: Arnaud.bonnard@ifsttar.fr
Nomenclature

SPI  Safety Performance Indicators
NDO  Naturalistic Driving Observation
NDD  Naturalistic Driving Data
GIS  Geographic Information System
SSC  SubSample Characteristics
ERSO  European Road Safety Observatory

1. Introduction

Road safety researchers use the concept of Safety Performances Indicators (SPI) to reflect the unsafe operational conditions of the three components of the road traffic system: driver, vehicle, road network. These unsafe operational conditions influence the system safety performance and can be used to monitor over time the current safety conditions of the road traffic system (SafetyNet consortium, 2007). SPI have been developed by road safety experts and are currently used in Europe by the ERSO, the European Road Safety Observatory (Hakkert and Gitelman, 2007). SPI related to unsafe driver behaviour are particularly interesting to assess road safety policy impact. These specific SPI are most of the time obtained through observations that rely on reference methodologies. These methodologies follow a similar approach: they consist in counting road safety related events from road side observations (i.e. number of drivers over speeding, number of drivers without seat belt…) performed at specific locations of the road network which are representative from the country general road network and during controlled external conditions (i.e. specific weather conditions, given time of the day…). Such observations last until the target number of drivers to monitor is reached. The result of these observations is the frequency of occurrence of the studied unsafe behaviour in these expected conditions (i.e. rate of drivers over speeding on highway at night …). However, if this approach permits to get a good picture of drivers unsafe behaviours in a specific situation, it does not give any information on the level of exposure of these unsafe behaviours in drivers global mobility.

Naturalistic Driving Observation (NDO) offers the possibility to monitor unsafe driver behaviours on a longitudinal perspective through the observation in naturalistic settings of a sample of drivers (Dingus et al, 2006). The vehicle of each driver is instrumented in order to continuously record data related to the driving activity. Naturalistic driving data (NDD) offer the possibility to assess drivers’ unsafe behaviour in their everyday driving and not in a specific predetermined context (Bonnard et al, 2008). The use of NDD seems to be a promising development of the existing SPI methodologies. Thus, in order to provide road safety researchers with new SPI that complement already existing SPI, a large scale NDO could be set up at the level of a country or of a set of countries. The setting up of this NDO could benefit from the availability of low cost sensors like Smartphone or navigation systems: a large sample of drivers could be formed at reasonable costs. In this perspective, it would be possible to have a basis framework to compute new SPI based on NDD. However, an adequate methodology has to be developed in order to take into account the specificities of NDD and to provide safety researchers with robust NDD SPI, indicators that have clear links with unsafe behaviours. If these new indicators come as extensions of the already existing SPI, they will make it possible to study the elements that cause the unsafe behaviours through data aggregation and disaggregation.

This paper discuss the possibilities offered by a large scale Naturalistic Driving Observations to provide new and innovative SPI, NDD SPI, that could bring a better understanding of safety behaviour in every day driving. The main objective is to discuss the methodological issues that must be solved to infer meaningful SPI describing unsafe drivers’ behaviour from naturalistic driving data.

In a first chapter, methodological considerations in terms of data collection and sample recruitment are presented. Then, the authors focus on the key methodological issues that have to be considered when computing safety performance indicators from naturalistic driving data. They propose an approach based on the creation of three kinds of indicators and illustrate this approach with the example of over-speed behaviours. Finally, the limitation of this approach is presented and a list of potential safety performance indicators is proposed.

2. Collecting and processing NDD to measure road safety related phenomena
2.1. Technical requirements

Technical requirements cover two aspects: the systems that collect the data on the vehicle while driving and the systems that will prepare the data so that the SPI can be computed.

In order to be able to monitor unsafe behaviours in naturalistic driving setting, the data collection equipment embedded in the vehicle has to be as unobtrusive as possible and should have access to a great variety of information:

- Information related to the driver's behaviour (i.e. giving a phone call, programming a navigation system...)
- Information related to the vehicle (i.e. speed, acceleration, seat-belt fastened, speed regulation system activated...)
- Information related to the driving context (i.e. road type, legal speed limit, period of the day, of the week or of the year, weather conditions, presence of passengers...)

Several technical solutions are available to collect such information. The most efficient way is to plug a recording device directly to the car onboard computer, generally via CAN bus (VTTI, 2010). If this solution is straight forward, it requires a perfect knowledge of the message protocol used by the electronic computer units. Unfortunately, these protocols are specific to each make and model of vehicle. For the setting up of a large scale naturalistic driving observation, it would make it difficult to obtain the protocols corresponding to all the different cars of the participants from the car manufacturers or it would make it necessary to recruit only participants that drive a specific car model. This is the reason why the possibility to collect NDD from Smartphones has been investigated (Wideberg et al., 2010). A Smartphone, through its GPS sensors can obtain the position and the speed of the vehicle. It can also collect information on dynamics through its accelerometers. Thus, a dedicated application on the drivers Smartphone, or on the navigation system, could be an effective and low cost solution to collect NDD but without connecting the device to the car onboard computer, it would be difficult to collect vehicle related information. A wide range of other intermediary solutions can be used in between the ultra integrated CAN bus recorder and the nomadic Smartphone. For example, the use of an embedded computer with specific additional sensors can be installed in the car of the participant (Dies et al., 2012). When additional sensors are added or when integrated sensors are used, it is necessary to determine the accuracy of these sensors, as it will have a direct impact on the outcome (for example, recording the car speed through a GPS or directly from the onboard computer can lead to several kilometres per hour of difference as the speedometer generally tends to underestimate the vehicle speed). Finally, for some specific monitoring, when no sensor exists to collect information, video cameras can be installed to film the driving (e.g. the road ahead, the driver, a driver assistance interface...). When recording video, solutions must be found to extract information from the films. This can be done automatically by image processing algorithms or manually by video data coders. In the perspective of a large scale NDO, it is probable that a cost effective solution will be favoured. This will makes it difficult to deploy of fleet of vehicles equipped with high end sensors like oculometer, collision radars or road marking detection systems. In the end, it can be expected that only a small subset of all possibly existing NDD will be collected and available for the SPI calculation.

Once collected, it will be necessary to retrieve the data. This can be done manually or automatically if the data collection systems are equipped with telecommunication functionalities. Each solution has its constraints. The former requires regular meetings with the drivers for (long) data retrieval sessions while the later needs efficient streaming strategy that will support resuming the download when the cell phone network is not reachable or when the driver is abroad. Once the data are retrieved, they are to be inserted in a specific database. The design of this database and the expected volume of data to come must be carefully considered to permit a use over a long period. Third party systems can then be used to enrich the data with additional information. Thus, the use of a geographic information system (GIS) is required to obtain details of the road environment from the vehicle position data, through digital map matching. Several attributes, like the legal speed limit or the road type can be inserted in the database this way. Several other post processing can be applied to add other information that can be helpful to reduce the dataset and to help with the identification of driving situations that are homogeneous enough to be aggregated (for example, compute the luminosity conditions from time and position...)

As a conclusion, the design of the technological framework used to support the naturalistic driving observation is an integral part of the design of the NDD SPI.
2.2. Experimental design

One of the main challenges of using naturalistic driving observations to provide performance indicators related to drivers’ unsafe behaviour is to infer relevant unsafe behaviours from the measures. Indeed, in a naturalistic driving setting, data are provided on a continuous basis and the expected SPI must be computed from specific patterns that can be found in the NDD database obtained from a restricted set of drivers. To highlight unsafe behaviour, these specific patterns must be assessed at the level of each driver. Therefore, the selection of the drivers that compose the sample is critical: the sampling and estimation methods that can be used to obtain population values of SPI based on naturalistic driving study data must be carefully considered (Commandeur, 2012). The sample must be representative of the country population or of the country’s driver population to allow generalization of the results at the level of the country. When building such a sample, a good knowledge of the driver population is required. If such information is unavailable, it is possible to create a random sample. If it is expectable that specific subgroups of car drivers can be homogeneous with respect to safety behaviours (for example, it is known that there are structural differences between men and women, between different age groups, and between drivers of a diesel or a petrol car...), then a stratified random sample can be use, i.e. a sample in which the car driver population is first divided into mutually exclusive and homogeneous subgroups and then within each subgroup a random sample is drawn.

If it is possible, with “traditional” SPI to perform an observation until the expected amount of measurement is obtained, with NDD SPI, it is necessary to make sure that the observation period is sufficient to guarantee that the sample will have sufficient driving time collected in a all expected driving contexts (for example, in terms of road type, legal speed limit, period of the day and of the week, traffic conditions and weather conditions...). However, due to the variability of the individual mobility of the participants, it is difficult to predict the amount of driving time that each one will spent in various situations. A challenging target is to collect enough data at night time, as it is very interesting in terms of road safety research, as drivers are more likely to have an accidents (Ward et al., 2005), but it is also generally linked to occasional travels patterns. The extension of the observation period can cope with this issue. However, if it is not possible to obtain sufficient amount of data, the accuracy of the indicators to be computed will not be sufficient to consider the indicators as relevant. Thus, it will be important to monitor the sample mobility and to evaluate if its variety permits the computation of the indicators. To collect as many data as possible, the ideal set up would be to have a continuous data collection over several years. This would make it possible to study unsafe behaviour at different scales: at the level of the month or at the level of the year. This way, it could make it possible to identify both long term trends and seasonal fluctuations (e.g. due to vacations...). When considering such a setup, it is necessary to consider a process to maintain the sample over this long period, as it is expected that some drivers will quit the sample at some point and that they will have to be replaced with drivers with equivalent characteristics in order not to modify the overall composition of the sample.

As a conclusion, the experimental design of the naturalistic driving observation is also an integral part of the design of the NDD SPI.

2.3. Data processing

Once all the cars have been instrumented, the participant recruited and the data are being collected in a database, several methodological considerations must be kept in mind when trying to establish the link between the measurements and the unsafe behaviours. Indeed, the big volume and variety of data makes it necessary to prepare the data before the final exploitation. As the observations conditions are always different from one driving trip to the other, the challenge will be to identify which driving situations can be considered as homogeneous enough to be aggregated and compared. A methodology developed for FOT, called « chunking », is an interesting data reduction approach that aim at assuring a more consistent and robust calculation of parameters (Dozza et al, 2012).
Chunking consists of the division of data within a trip into a number of sections of continuous data of equal length (Fig. 1). On the illustration shown on figure 1, the blue curve represents an example speed profile of a trip performed by a driver on a highway. The objective of the analysis is to compute the mean speed of the driver on highways. The first step is to define the “chunks”. The nature and size of the chunks are decided by the analyst: they are defined according to the analysis objectives (in this case, when studying over speed on highways, the chunks can be set to “1 minute” situations when speed is above 70km/h and road type is highway). On figure 1, the gray strips are separate “chunks”. Each chunk share common properties and can be used to aggregate information (e.g. mean speed during the chunk). The chunking process will be the identification of these chunks in all the data available in the database. Through the chunking process, a large sample of homogeneous data will be obtained as all the chunks will have the same duration and coherent parameters. Also, the transitory effects are eliminated, as shown with the light gray sections on the figure, as they do not satisfy the criterion of the chunks. The final indicators are then computed on a set of chunks that all have the same duration (for example, chunks with mean speed above the speed limit and chunks with mean speed below the speed limit). Such methodology permits to aggregate and reduce data while constantly verifying the homogeneity of the sample of data selected for the indicator computation.

Figure 1: Chunking of trip (Dozza et al, 2012)

3. Safety Performance Indicators from NDD

3.1. Context and origin of the proposed SPI

An extensive literature review, performed in the scope of the FP7 DaCoTA project, permitted to build an inventory of the most relevant variables to monitor road safety within ERSO (Talbot and Al., 2010). This work, based of SafetyNet, lists SPI that are already used by road safety experts. Indeed, some of these indicators are computed in several European countries through a common methodology and reported to ERSO, the European Road Safety Observatory. The work presented in this paper about the development of NDD SPI was based on these already existing indicators, with the aim to provide ERSO with complementary SPI computed from NDD, that permit to gain better knowledge on drivers unsafe behaviour in their global mobility. Thus, the NDD SPI proposed in this paper are innovative as they require a whole new methodology, from data collection and participant sampling to SPI computation and interpretation. The first methodological issues have already been discussed in part 2.

3.2. Key methodological issue : the impact of driving context to assess unsafe behaviour

One of the main interests of using NDD to compute SPI is the possibility to compute indicators at the level of each driver in order to gain knowledge on the specific safety behaviour of each participant. When studying unsafe behaviour, three different scales can be considered:

- At the level of the global driver mobility: during a period of mobility, it means computing the general occurrence of a safety related event. Its helps to understand the exposition of this driver to a specific unsafe behaviour. (i.e. On his/her global mobility, driver A wears his/her seatbelt 95 % of the time...)
• At a more detailed level of mobility: in more specific driving contexts, it means computing if a safety related event is systematic and recurring. It helps to highlight the characteristics of a driver’s behaviour in specific driving contexts. (i.e. During trips lasting less than 5 minutes, a driver A wears his/her seatbelt 50% of the time...)
• At a very local level of mobility: at the level of a driving manoeuvre, it means computing if this manoeuvre is performed in the safest way. It helps to determine if the driver makes specific driving errors (i.e. when taking the car out of the car park, driver A wear his/her seatbelt 35% of the time...).

These three levels must be considered together when trying to describe the behaviour of a driver as they each show a different perspective of a unique unsafe behaviour. Indeed, this makes it possible to highlight drivers unsafe behaviour that have a very low occurrence when considered at the level of the global mobility (e.g. Driver B goes over the speed limit 2% of its global driving time) but a far more important occurrence rate when considered at the level of more favourable driving conditions (e.g. Driver B goes over the speed limit 25% of time he/she drives outside of traffic jams). By studying these three aspects for each driver, road safety researchers can discover specific unsafe behaviour (e.g. Driver B generally drives most of the time below the legal speed limits but when he/she is not in a traffic jam, he/she tends not to respect the speed limits). Indeed, studying the behaviour at these different levels makes it possible to uncorrelate the effect of specific driving contexts (i.e. driving in traffic jams...) that prevent the occurrence of unsafe behaviours.

3.3. Illustration: the impact of driving context when studying over-speed behaviour

The impact of driving context can be illustrated when monitoring unsafe behaviours linked to over-speeding with NDD, as it is required to understand in detail the driver behaviour. Indeed, when focusing on speed behaviours, it is important to know if the speed behaviour is freely chose by the driver or if the driver has to constrain its speed behaviour as he/she in a flow of vehicle or in a specific infrastructure that dictate the pace. As such, it is possible to differentiate «free flowing driving conditions>>, which are driving situations where the driver can drive at the speed he/she likes, from the «constrained driving conditions>>, which are driving situations where the driver cannot choose the speed. Thus, when studying speed related unsafe behaviour, it is interesting to select only «free flowing conditions» in order to focus on the safety related events decided by the driver. Different manners can be considered to detect automatically “free flowing conditions” using a naturalistic driving dataset. Following a traffic engineering approach, the density of the traffic on a lane can be measured from the average values of vehicles speed and headway. However, this approached in limited with the data of only one vehicle as it is hard to generalise a single behaviour to the global traffic. Another approach consists in filtering out all data collected during “peak hours”. The morning and evening peak hours correspond to the time period when drivers commute and when the most important traffic density can be expected. Finally, to obtain more accurate information, video data coders can watch the driving films and assess if the driver is constrained or not. However, if this solution is feasible in a pilot study, it could certainly not be applied on a large scale NDO as it is very time consuming.

We will consider the following speed profile (described in figure 2) and use it as a reference profile to illustrate the importance of free flowing driving conditions to interpret driver behaviour. In this profile, the driver drives both in urban and highway area (respectively dark blue and light blue). If the road type changes, the legal speed limit also evolve to different values (dotted line). Finally, during this trip, the driver encounters different traffic conditions: free flowing conditions and constrained conditions (respectively yellow and orange).

Figure 2: importance of free flowing conditions: illustration of a speed profile
If we focus on the indicator “time spent driving above the speed limit on highway”, which is an indicator at the level of the global driver mobility, we will proceed with the data reduction to keep only data that correspond to the expected driving context. Then it will be possible to compute the expected indicators. The result is illustrated in figure 3 a. We can see the driving situations when the driver was driving above the speed limits circled in green and the global mobility is shown with the red strip. As a conclusion, when analysing this speed profile with this indicator in mind, one could say “this driver drives above the speed limit 5%-10% of the total time spent on highway”.

Then if we focus on another indicator “time spent driving above the speed limit on highway in free flowing traffic conditions”, which is an indicator at a more detailed level, we will also proceed with the data reduction but we will filter out more data than for the previous data. The result is illustrated in figure 3 b. We can see the driving situations when the driver was driver above the speed limits circled in purple (the same situations as the previous indicator) and the specific driving situations, when the driver can freely choose his/her speed, are shown with the red strips. As a conclusion, when analysing this speed profile with this indicator in mind, one could say “on highway, in free flowing driving conditions when this driver can freely select the speed, he/she drives above the speed limit 40% of the time”.

The difference that lies between these two indicators highlights the interest of the approach. On one hand, this driver shows very few unsafe speed related behaviours at the level of his/her general mobility, but on the other hand, as soon as he/she is free to select freely the speed of the car, he/she will tend to drive over the speed limit. We can clearly see with this illustration that for this driver, the exposure to over-speeding behaviour is limited by his/her mobility pattern.

3.4. A typology of SPI

Authors propose to extract from the NDD three kinds of indicators on unsafe behaviours (Bonnard et al, 2012). These three kinds are link to the different scales presented in paragraph 3.1.

- Descriptive SPI that quantify the occurrence of a phenomenon and can be useful to assess if a safety policy is followed or not (for example, participants’ total time spent driving over the speed limit);
- Behavioural SPI that describe drivers’ behaviour toward a specific safety issue and permit to identify some of its determinants (for example, participants’ behaviour in terms of speeding on different road types and in light traffic);
- Situational SPI that describe driver behaviour in very specific situations which are relevant in term of road safety issues. They require a very accurate assessment of the driving situation and current manoeuvre in order to be relevant (for example, participants’ speeding behaviour during overtaking manoeuvres on highway).

These three families of SPI are complementary and offer a different point of view on a given safety related issue. The calculation of the SPI of these categories sometimes differs only from a filtering or a clustering, as the illustration has shown. As we already saw, when using NDD, it is harder to control the data collection as driver can drive on any kind of road, in any kind of traffic, whatever the weather. This makes it crucial to be able to
identify all the variables that might have an impact on the expected SPI, in order to compute meaningful indicators with proper filtering and aggregation data processes.

4. Computing and reporting of the indicators

4.1. Clustering and accuracy

From a road safety policy maker point of view, NDD present promising possibilities as it permit to gain more information about drivers’ unsafe behaviours. Such knowledge is valuable as it is as step forward to understand on a longer term how drivers comply with specific policies. However, when focusing on very specific behaviour (i.e. for example, “what is the speed behaviour of young male drivers that drives at night?”), the impact of the steps of clustering and filtering can be significant on the accuracy of the final assessment (i.e. for example, “the proposed question turns out to be difficult to investigate as less than 1 hour of driving data corresponding to the specific context have been collected”). Thus, the clustering of the SPI according to the different driving conditions that are relevant for the analysis must be carefully considered in order to make sure that the final dataset used for the indicator computation is relevant. This is even more important when several clusters are combined. This is an important limitation of the analysis possibilities of NDD as it has a direct impact on the investigations that can be performed. Another limitation is linked to the “time windows” selected for the reporting. Indeed, if the objective is to produce indicators per time period (for example, unsafe behaviours on a monthly basis…), the selection of the length of the time window should also be carefully considered, in relation with the clustering. Indeed, it is necessary to make sure that the final dataset, limited to a specific time frame, still keeps a sufficient number of measurements in order not to decrease the precision of the indicator estimation. As a general rule, it seems difficult to produce indicators on a daily or weekly time window, as the collected data will not be sufficient to fill in all clusters corresponding to the expected driving conditions.

These two limitations, clustering and time window length, are both strongly linked to the mobility of the monitored sample. This mobility is difficult to predict and has to be assessed as the same time as the indicators are computed. As such, it seems necessary to give an estimate description of the final data set used for the SPI calculation.

4.2. Aggregation and subsample characteristics (SSC)

Authors recommend that alongside each SPI value, a second value should be given to indicate the amount of data included in the calculation. Authors propose to name this second value the “Sub sample characteristics”, or SPI SSC, as it characterises the volume of information of the subset of naturalistic driving data. The sub sample characteristics may have a different expression depending on the level of the calculation.

At the participant level, each SPI should be given with its SPI Sub Sample Characteristics that gives the volume of data included in the calculation, for example expressed in minutes of driving or expressed by the total number of chunks retained for the analysis. As an illustration, when selecting the time window (for example, during the month of March or during year 2011…), when adding a filter (for example, only during peak hours…) and a specific clustering (for example, to compare motorway situation from urban situations…), with the objective to compute the following SPI : “percentage of time spent above the speed limit during the month of March, in peak hours, on motorway”; the SPI results could be “15% of time” but the associated SPI SCC could only be “5 minutes”. This second value gives a direct description of the amount of data included for the calculation with the criteria “month of March”, “during peak hours” and “on motorway” and permit to assess immediately the relevance and the potential accuracy of the indicators.

At the country level, another question is a stake. Indeed, when aggregating individual contributions from all the participants, the amount of data that characterise a participant (i.e. the participant SPI SSC) should be studied to determine if it is relevant or not to use the results of each participant for the country level aggregation and it requires the use of weighting factors.

5. Proposition of indicators
Authors propose six categories of new SPI that can be computed from NDD to complement existing SPI. These six categories proposed have been built by assessing the technical feasible of the required data for the indicator and by taking into account the interest in term of road safety. Then, for each family: "excessive speed", "seat belt use", "daytime running light use", "short headway", "strong deceleration" and "safety system use", several indicators have been proposed.

All these indicators are classify according to the “Behavioural SPI” and “Descriptive SPI” families, as defined in chapter 3.3. As “situational SPI” are very specific to driving manoeuvres and turned out to be very technically very challenging, none have been presented here.

The illustration below gives a list of the proposed SPI.

<table>
<thead>
<tr>
<th>SPI category</th>
<th>Behavioural SPI</th>
<th>Descriptive SPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive speed</td>
<td>Mean speed and standard deviation of speed in free flowing traffic conditions</td>
<td>Percentage of driving time over the legal speed limit</td>
</tr>
<tr>
<td></td>
<td>VSD in free flowing traffic conditions</td>
<td>Percentage of driving time 10 km/h over the legal speed limit</td>
</tr>
<tr>
<td></td>
<td>Percentage of driving time over the legal speed limit in free flowing traffic conditions</td>
<td>Percentage of driving time over the legal speed limit</td>
</tr>
<tr>
<td>Seat belt use</td>
<td>Percentage of trips without seat belt use, with partial seat belt use, with total seat belt use</td>
<td>Percentage of driving time with seat belt fastened for drivers, front passengers and rear passengers</td>
</tr>
<tr>
<td></td>
<td>Systematic use of seat belt percentage of trips with immediate seat belt fastening</td>
<td></td>
</tr>
<tr>
<td>Daytime running light use</td>
<td>Percentage of trips without DRL use, with partial DRL use, with total DRL use during daytime and clement weather conditions</td>
<td>Percentage of driving time with DRL switched on during daytime and clement weather conditions</td>
</tr>
<tr>
<td></td>
<td>Systematic use of DRL percentage of trips with immediate DRL switching on during daytime and clement weather conditions</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPI category</th>
<th>Behavioural SPI</th>
<th>Descriptive SPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short headway</td>
<td>15th percentile of the headway in vehicle following situations</td>
<td>Percentage of driving time with headway greater than 2 seconds, between 1 and 2 seconds, between 0.5 and 1 second and less than 0.5 second in vehicle following situations</td>
</tr>
<tr>
<td></td>
<td>Percentage of driving time with headway greater than 2 seconds, between 1 and 2 seconds, between 0.5 and 1 second and less than 0.5 second</td>
<td>Percentage of occurrences of short headway epochs (headways less than 0.5 second during at least 0.2 seconds) per hour driven</td>
</tr>
<tr>
<td></td>
<td>Frequency of occurrences of short headway epochs (headways less than 0.5 second during at least 0.2 seconds) per hour driven</td>
<td></td>
</tr>
<tr>
<td>Strong deceleration</td>
<td>15th and 65th percentile of the vehicle in deceleration situation</td>
<td>Frequency of occurrences of strong decelerations per hours driven (deceleration less than -0.5 g during at least 0.2 seconds)</td>
</tr>
<tr>
<td></td>
<td>Percentage of deceleration time with deceleration greater than -0.25g, between -0.25g and -0.50 g and less than - 0.50 g, in deceleration situation</td>
<td></td>
</tr>
<tr>
<td>Safety Systems use</td>
<td>Frequency of occurrences of safety system (Anti-lock braking system and Electronic stability control system...) activation per hours driven</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Extract of tables presenting innovative SPI computed from NDD

These indicators have been developed and described in detail in deliverable 6.2.A of FP7 DaCoTA project (Bonnard et al, 2012).

6. Conclusion and discussion
The general approach presented in this paper, the three kinds of indicators that are proposed (i.e. “descriptive”, “behavioural” and “situational”) and the list of indicators that have been built using the approach have the common objective to highlight methodological issues that must be considered when using NDD to compute safety performance indicators. The three kinds of indicators as such may be discussed, as one could say that any “behavioural SPI” turns out to be “descriptive” of a more specific unsafe behaviour. Authors built these three families and selected the labels by focusing on the difference of point of view on the unsafe behaviours each one of them could bring. The indicators that have been proposed in each family sometimes only vary from filtering or clustering conditions, but the way to interpret the result may be very different. A complete picture about unsafe behaviours can be provided by the computation of several different indicators from each family.

At this stage, the indicators proposed in this paper have not yet been tested on a large scale fleet of vehicles. Indeed, some of the criteria presented in this paper, like the definition of “free flowing traffic conditions”, have turned out to be very difficult to determine from the NDD that authors could access. To determine “free flowing traffic conditions”, one need to know the speed of the vehicle, the distance to the vehicle ahead, the road type, the presence of surrounding vehicles and combine all this information to have a single indicator, which had not yet been feasible. This difficulty highlights the needs in terms of research to develop robust methods to recognise driving manoeuvres or driving contexts (Brusque et al., 2012). Such tools would make it possible to investigate new indicators that require a very detailed description of the contextual driving situations (e.g. determine when drivers have an “inappropriate speed”).

As a final conclusion, it is important to highlight that even though the scope of this paper was reduced to a naturalistic observation with passenger vehicles, the methodological considerations and issues raised in the paper remain true for other vehicles. Indeed, trucks, buses or motorcycles can also be equipped and studied in a naturalistic way and specific safety related indicators can be created.

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- DaCOTA project, which focus was set on safety performance indicators
- EuroFOT project, which consisted in studying the effect of driving assistance systems on driving behaviour from a fleet of vehicles
- Interaction project, which aims was to study how a fleet of drivers interacted with their on-board systems (such as telephone, navigation system, cruise control and speed limiter)

This paper reflects solely the authors’ view and neither the projects consortiums nor the European Community are liable for any use that may be made of the information contained therein.

References


Commandeur, J. (2012) Study design of Naturalistic Driving observations within ERSO – sSampling techniques and naturalistic driving study designs, deliverable 6.2.B of EC FP7 project DaCoTA


“Fatigue and Road Safety: A Critical Analysis of Recent Evidence”, Road Safety - Web Publication No. 21, Department for Transport, 2011


