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USING EVENT DATA RECORDER TO DETECT ROAD INFRASTRUCTURE FAILURES FROM A SAFETY POINT OF VIEW

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1. INTRODUCTION

Accident data are useful to contribute to road safety policies definition and particularly to locate where road infrastructure should be improved. But the international trend of reduction of accidents amount in most of Middle and High-income countries this last decade (the annual death toll decreased by nearly 40% between 2000 and 2012 for the 38 IRTAD country members according to IRTAD (2014)) induced a lack of reliable data: there are less accidents and their location is more diffuse. Thus, local authorities might face difficulties to set priorities in their intervention strategy on their road network.

This issue is particularly relevant on the secondary road networks. In France, for instance, the risk of being killed on secondary road is more than twice higher than on main roads and seven times higher when compared to Highways (ONISR, 2012). Nevertheless, due to its length and traffic volume, the rate of road fatalities per kilometre is four times lower than on the main road network. In addition, the number of road fatalities on this network was reduced by 40% within ten years. Consequently, local road authorities face increasing difficulties to identify risky locations using only crash data analysis.

In light of these difficulties, the French government (DSCR) decided to support the SVRAI project (Saving Lives through Road Incident Analysis Feedback). One of the project objectives is to investigate if incident data (near-crash data) collected by Event Data Recorders (EDR) can be used by local road authorities to detect safety failures or defaults in road infrastructure.

Event Data Recorders (EDR) are usually used to collect safety-relevant events related to driver's behaviour and to provide feedback in order to positively influence their behaviour (Horrey and al., 2012). Up to now, very few studies have tried to extend their use to other purposes. Nevertheless if EDR provide relevant information on driver's behaviour it suggests that they can also detect infrastructure defects or failures considering they strongly contribute to driver's behaviour. Therefore, the aim of this study is to assess if usual parameters recorded by EDR can identify road locations where infrastructure could be improved.

First, the paper will present a general overview of the project and some global results. Then, focus will be given on the results obtained in a French Department, where 24 instrumented vehicles were in use. Inputs will be given regarding to the proportions and types of roads that were circulated by those

vehicles, and regarding to detected incidents. The proportion of incidents occurrence in which road infrastructure could be totally or partially incriminated, will be given. The methodology implemented for this analysis will be described. Then the results will be discussed. Finally, the paper ends with conclusions and perspectives.

2. THE SVRAI PROJECT

2.1 Objectives

The main objective of the project is to collect incidents (near miss crashes) data to enrich accident databases. In order to do so, it includes the following tasks:

- Equip vehicle fleets with Event Data Recorders
- Massively acquire incident data (at the scale of a large territory)
- Develop tools adapted to incident analysis
- Evaluate the contribution of their analysis to diagnose road infrastructure and drivers behaviour
- Study the impact of the presence of Event Data Recorder in a vehicle on road safety and evaluate their acceptability
- Improve knowledge for the accident or incident mechanisms analysis
- Ensure the legality of the experimentation

This paper will only focus on the evaluation of the potential interest of incident collection and analysis to diagnose road infrastructure.

2.2 EDR's description

SVRAI project relies on the use of an Event Data Recorder called EMMA2 (Enregistreur eMbarqué des Mécanismes d'Accidents, version 2) which was specifically designed in 2007 by IFSTTAR-LMA with help of KERLINK, a small business society specialized into "Machine to Machine" (Lechner & Naude, 2011) (see Figure 1).

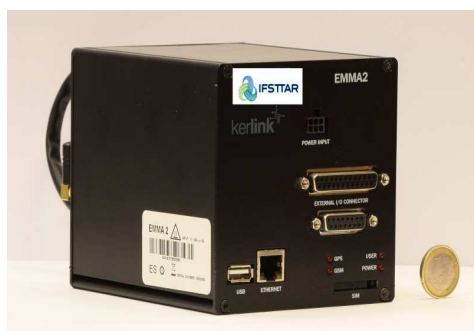


Figure 1 : The EMMA2 device.

EMMA2 acquires:

- Analog data from low cost sensors directly integrated into the EDR (accelerometers and gyrometers) at a frequency of 100 Hz,
- Data provided by low-cost GPS: position and speed at 1 Hz frequency,
- Data available on vehicle on-board diagnostic system (CAN bus), depending on the car model.

The data is analysed, using real-time processing performed by the embedded software, to detect potential situations of interest (events). The processing is based on the following principles: when acceleration and jerk signals exceed simultaneously some thresholds, an event is triggered. The data acquired 30 seconds before and 15 seconds after the trigger are stored in the device. The retained thresholds are the following:

- Speed \leq 80 km/h and acceleration norm $>$ 0.6 g and jerk $>$ 2 g/s,
- Speed $>$ 80 km/h and acceleration norm $>$ 0.5 g and jerk $>$ 2 g/s,
- Speed $>$ 100 km/h and acceleration norm $>$ 0.4 g and jerk $>$ 2 g/s.

Jerk is the rate of change of acceleration. Indeed Bagdadi et al (2011, 2013) proved possible to identify safety critical driving behaviour or “accident prone” drivers from jerk analysis. Finally the levels chosen are quite similar to those proposed in Nagai et al (2006) modulated by the influence of speed.

The file containing the whole data set is automatically sent to a secured server using GSM network. The event is then examined by an operator and if considered of interest, classified as incident or simple event and stored as such in the global database.

Simple Events are mostly characterized by very short durations of acceleration peaks, generally not produced by a driver action even though they can be felt by the driver. Often, those single events are produced by road out-of-flatnesses. Meanwhile, genuine incident criteria are defined by higher durations of accelerations, resulting from driver actions (up to 3 Hz). This difference is detailed in Serre and al. (2013). Genuine incidents are clearly of major interest for the SVRAI Project and will be the ones considered in this paper.

In addition, all the itineraries are also recorded from GPS and stored at a frequency of 1 position/minute. Finally, it should be noticed that for different reasons (notably legal) it was decided not to equip EMMA2 with video camera.

2.3 EDR's dissemination

50 EMMA2 were implemented on public vehicles fleets on 3 sites in France: Rouen, Clermont-Ferrand, and Salon-de-Provence.

All the legal conditions to implement EDR in French public fleets of vehicles in SVRAI are in accordance with the prescriptions of the CNIL (French administrative authority protecting privacy and personal data) which comply European regulations and the respect of Human Rights:

- data collection is limited to driving situations of interest from a research point of view.
- drivers are volunteers and informed about the experiment objectives and details : their written consent should be free, enlightened and specific.

EDR are inactivated by default, and volunteers have to opt-in by pushing a button to start the recording at each itinerary.

3. SYNTHESIS OF THE DATA COLLECTION

3.1 At the global level

The data collection started in August 2012 and lasted one year. Finally, 221 drivers volunteered to take part to the experimentation. Over this period, 339 incidents were collected from 3 052 itineraries, a travelled distance of 116 000 km and 1 507 hours of driving. Thus, incident occurs, on average, every 340 km or 5 hours of driving.

3.2 At the level of one French Department

Because one of the aims of the study was to determine if incident analysis could be useful for local road authorities to help them to manage their network, this section will focus on the results obtained at the scale of one French Department. Indeed, a large part of the road network is managed by Department.

The Seine-Maritime Department was retained as 24 of the 50 equipped vehicles were based in the region of Rouen, the main city of the Department. It offers a large variety of rural, suburban and urban environments. According to administrative classification, its road network is composed of 247 km of Highways, 124 km of National Roads, 6 374 km of Departmental roads and 8 074 km of other types of roads (mainly urban roads).

As all the travelled routes of equipped vehicles were recorded, it was possible to map match them using specific algorithms. This process allows to calculate how many times a road section was circulated by an equipped vehicle. In addition, extraction of available information in the geographical database associated to each section is allowed. The Figure 2 shows the result of the map-matching process on the Seine-Maritime road network.

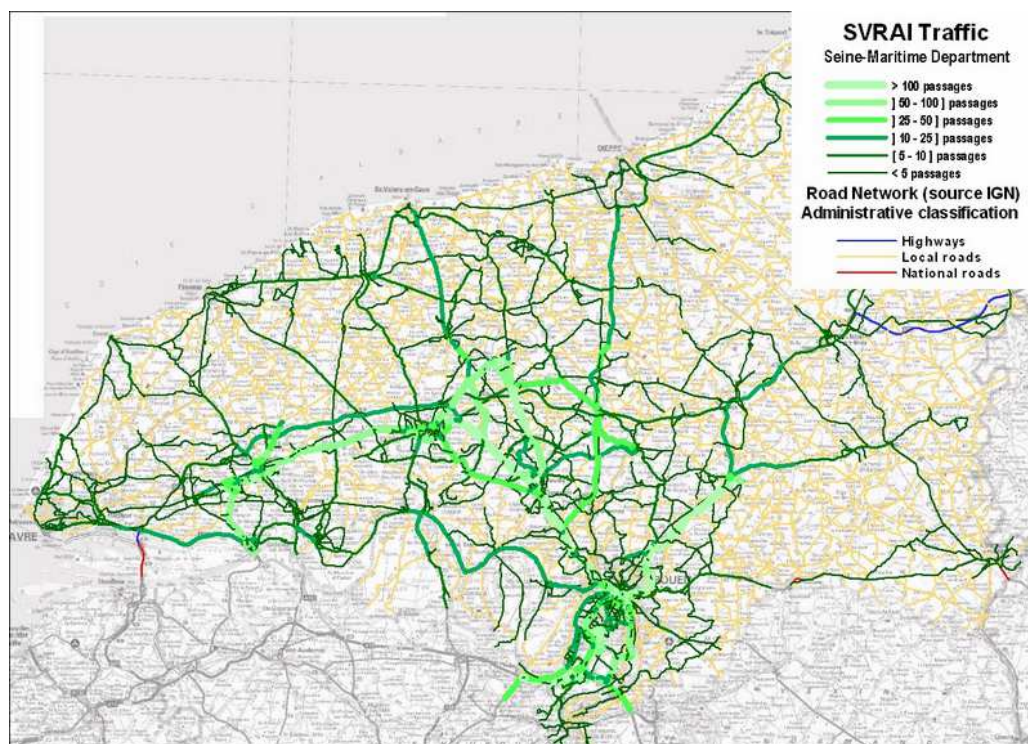


Figure 2 : The « SVRAI Traffic » in the Seine-Maritime Department

Further calculations indicate that equipped vehicle travelled almost 35 000 km on the Department road network. 84% of Highways, 93% of National roads, 37% of Departmental roads and 8% of the other types of roads were borrowed at least one time by an instrumented vehicle. Thus, few vehicles were able to cover a reasonable proportion of the network.

In one year, this traffic generates 62 incidents (see Figure 3). Table 1 provides some outputs on road category where incidents happened. Almost all incidents occurred on the secondary road network meaning drivers seem faced more frequently risky driving situations on this one.

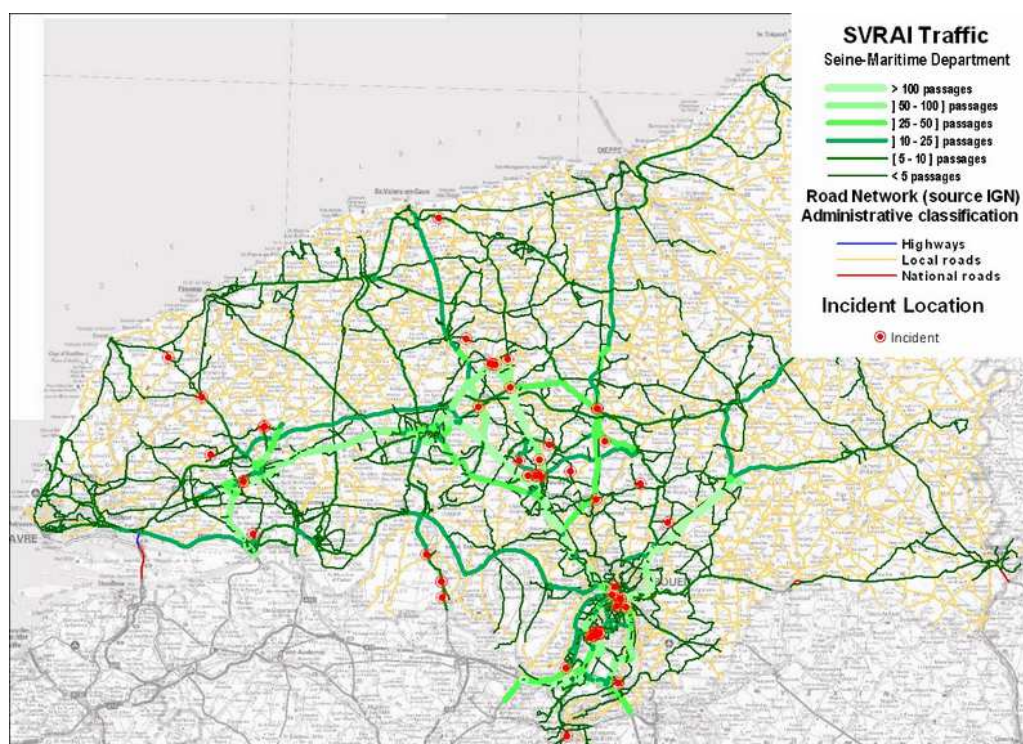


Figure 3 : Incidents and « SVRAI Traffic » in the Seine-Maritime Department

Table 1 : Incidents distribution and incident rate according to administrative road classification

Administrative road classification	Number of Incidents	Distance travelled (km)	Incident rate (km / incident)
Highways¹	1 (1.6%)	7 429	7 429
National roads	0 (0%)	3 373	-
Local Roads	34 (54.8%)	20 250	596
Other Roads (urban roads...)	27 (43.6%)	3 446	128
Total	62 (100%)	34 499	556

¹ The incident occurred on an exit ramp of the Highway

After this general insight on the results, the next section will describe the study that was carried out to evaluate the role played by road infrastructure in incident occurrence.

4. THE ROLE OF ROAD INFRASTRUCTURE

4.1 Methodology

The methodology relies on several successive tasks:

- 1) Extract all the incident data that occurred in the Department
- 2) Inspect the road sections where the incidents occurred
- 3) Collect reference trajectory using an instrumented vehicle
- 4) Establish a summary sheet for each inspection
- 5) Conclude if road infrastructure could be incriminated in the happening of the incident

1) Incident data extraction

First, several data were extracted from the database: location of the incident and vehicle trajectory (speed, longitudinal and transversal accelerations) during the 45s of the recording. These parameters are required to investigate the link between driver's behaviour and road infrastructure. Because this data was expressed as a function of time, it was converted into distance in order to match the infrastructure.

2) Safety visit on each incident location

Each location was inspected by a team composed of two or three road safety experts. The aim of these visits was to try to understand why a high vehicle solicitation was recorded at this place. The expert observations were based on the road safety fundamentals that are: visibility and legibility criteria, fitting of road characteristics to the dynamic demands of the vehicles, secondary safety related to the infrastructure, traffic flow management.

The team circulated several times on the considered road section with a laboratory vehicle able to acquire the same parameter as the EMMA2 (speed, acceleration...). During the first passage, they immersed the environment taking into account different contextual elements regarding road profile, road equipment including road signs and marking, movements and other road design aspects (curves, intersections...). The second passage was carried out at the speed limit in order to determine if this limit can cause difficulties for the driver. For the third passage, the team tried to reproduce the same driving conditions (e.g same speed) than during the incident (if it not dangerous), in order to check the incident's reproducibility.

3) Collection of reference trajectory using an instrumented vehicle

For some incidents, additional passages have been realized at different speeds to record several trajectories and get a better understanding of the dynamic solicitation at the origin of incident.

4) Inspection report

A report is established at the end of the visit (see Figure 4). It includes:

- Location and pictures of the incident location,
- Infrastructure diagnosis
- Graphical representation of the data recorded by the EMMA2,
- Graphical representation of the data recorded by the laboratory vehicles.

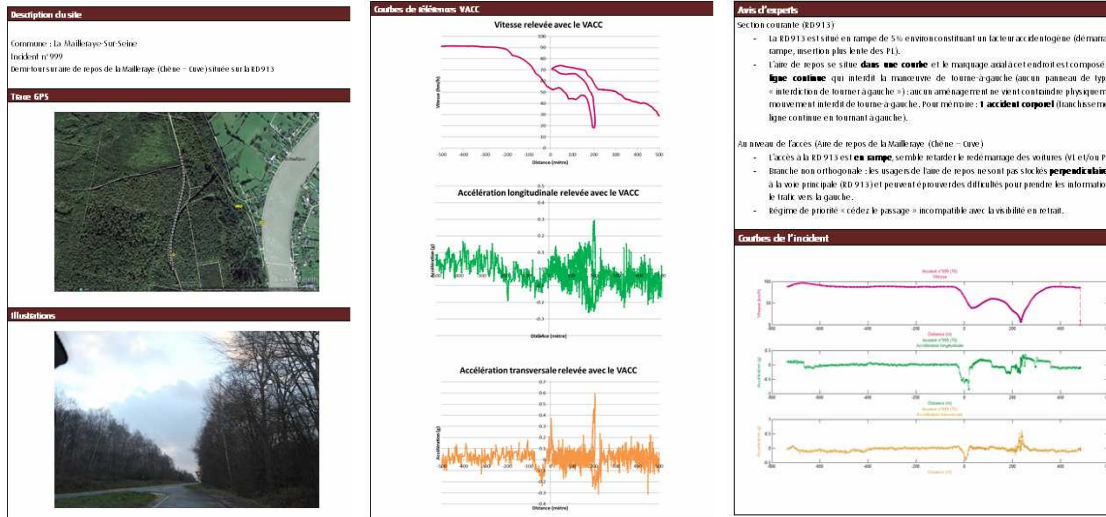


Figure 4 : Example of inspection report (picture from the road on the right, data recorded by the laboratory vehicle in the middle, infrastructure diagnosis and data recorded by EMMA2 on the right)

5) Conclusion about the role of infrastructure

Based on this report, the expert team concludes on the implication of the infrastructure on the incident occurrence according to three levels:

- **Yes**, identified road infrastructure defects or failures were certainly at the origin of the incident. Defects and failures are due to improper road design, lack of maintenance, inconsistency of road signing...
- **No** major problem has been identified by the field visit and the infrastructure cannot be incriminated.
- **Undetermined**, the expert cannot state if infrastructure has played a role or not in the incident.

4.2 Application of the methodology: example

To illustrate the methodology, **Figure 5** represents speed, longitudinal and transversal accelerations recorded by the EMMA2 during an incident. The graph indicates that the drivers circulated at 60 km/h when he suddenly braked with a deceleration of about -0.8g.

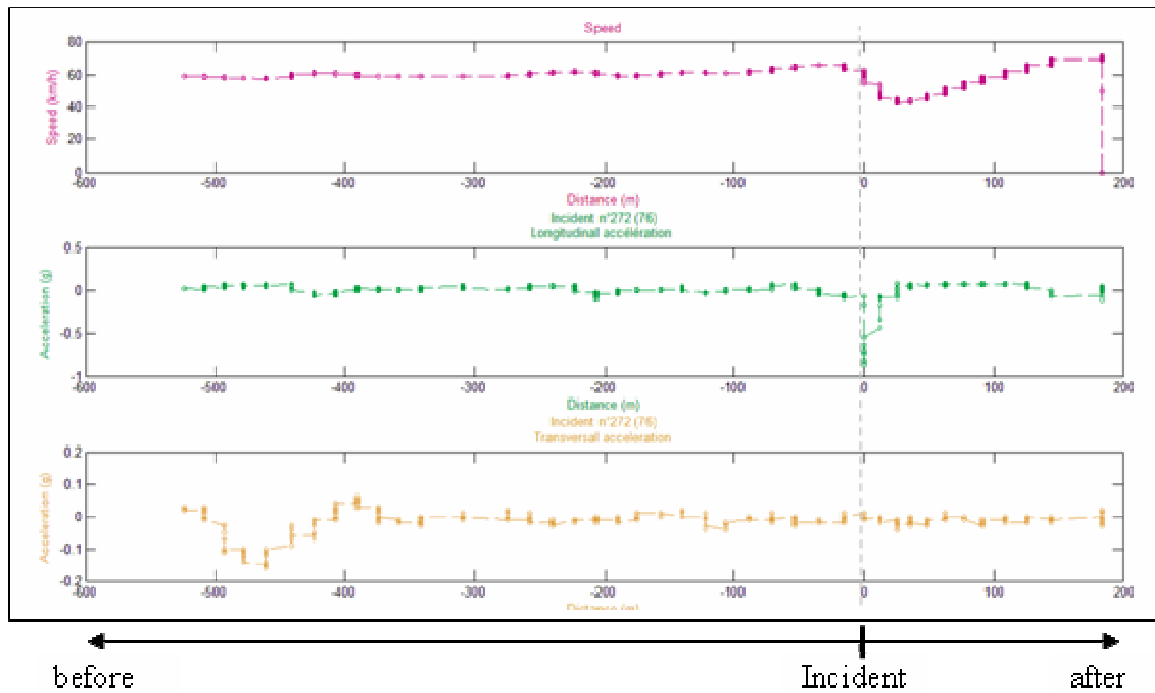


Figure 5 : Speed, longitudinal and transversal accelerations vs distance during 30s before and 15s after the incident.

Positioning the incident GPS coordinates on digitalized map indicates that incident occurred on rural roads at Y-intersection between a priority main road, on which circulated the equipped vehicle, and a secondary secant one (see Figure 6).

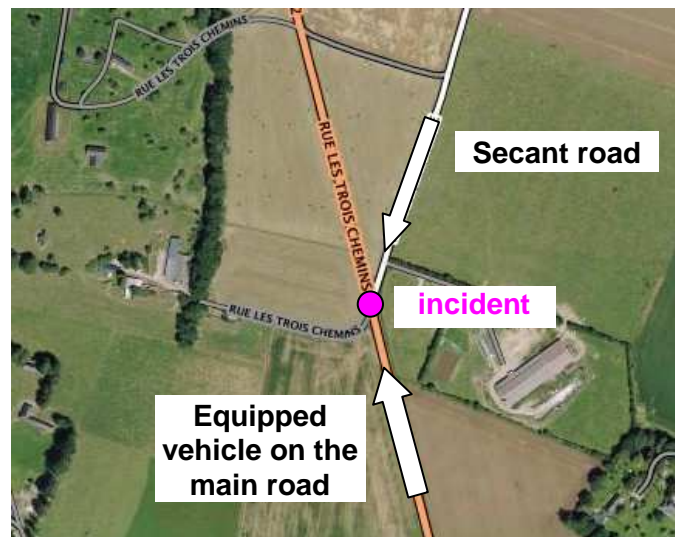


Figure 6 : Location of the incident on digital map

The field visit reveals several interesting elements:

- The intersection is situated on the top of the hill on the main road which harms its visibility (see Figure 7)



Figure 7 : View from the main road

- The secant road is not perpendicular to the main road. It can cause some difficulties for the drivers to get appropriate information. In order to improve its visibility triangle the driver is forced to encroach on the main road. In addition several roadside features (the excavation slope, waterside culture, the post, the top of the hill) mask the visibility on the left side. Thus, the driver shall meet difficulties to detect vehicle arriving on the main roads (see Figure 8).



Figure 8 : View from the secant road at the level of the intersection

From all these elements it can be concluded that the driver circulating on the main road was probably surprised by a vehicle located on the secant road. In this case the field inspection indicates that several infrastructure elements impact the mutual visibility. We can also notice that in this case it was not relevant to analyze the data from the laboratory vehicle to get more clues.

4.3 Application of the methodology to all incidents

The methodology described previously was applied to the 62 incidents of the Department. The proportion of incidents linked to the infrastructure was analysed in function of the type of environment and road category.

The results show (see Table 2) that infrastructure was involved in almost 31% of the incident, not involved in 31% of them and that its role was undetermined in 38,8% of the cases.

Due to the small sample sizes, the results must be interpreted with precaution. Nevertheless, they reveal useful outputs:

- In rural environment, the infrastructure is involved in half of the incidents (removing undetermined situations). It appears that the infrastructure is particularly involved on the secondary network. Thus, two third of the incidents that occurred on the minor local roads of the Department are due to infrastructure defects.
- In urban areas, the lack of knowledge concerning contextual elements at the time of the incident raises some difficulties. Indeed urban context is particularly complex due mainly to the numerous potential conflicts with a wide variety of road users. The use of video recording could improve the understanding of the incident sequence and their causes and therefore give more clues to assess the infrastructure influence.

Table 2 : Role played by the infrastructure according to the type of environment and road category

Type of environment		Number of incidents	Proportion of incident in which infrastructure plays a role		
			Yes	No	Undetermined
Rural environment		20	45%	45%	10%
Road category	Highways	1	100%	0%	0%
	National roads	0	-	-	-
	Main Local road	8	12.5%	87.5%	0%
	Minor Local roads	9	66.7%	11.1%	22.2%
	Communal roads	2	50%	50%	0%
Rural environment with small residential areas		5	20%	80%	0%
Urban environment		37	24%	16%	60%
Total		62	30,6%	30,6%	38,8%

6. DISCUSSION

These results suggest that collection and analysis of incidents could be very helpful for road managers in different ways. First, road managers have a limited knowledge on the secondary network as the major part of the resources is concentrated on the main network which supports the majority of traffic. The presented infrastructure defects or failures were not previously identified by the road manager. It means that incidents represent an original and new source of information complementary to the ones already used like accident, reports from road patrols.... In addition, incident cases could contribute to the training of the staff in charge of road maintenance in order to illustrate and highlight potential effects of maintenance failure.

The study also demonstrated that incident diagnosis can be carried out at the scale of local territory with a limited number of equipped vehicles. An interesting proportion of the local road network was circulated at least one time by an equipped vehicle although only 35000 km were travelled by 24 equipped vehicles. It suggests that a very large proportion of the network could be “inspected” with few equipped vehicles, but wisely chosen in terms of geographical repartition and annual mileage.

Video camera was not available on the EDR used in this study. As stressed out previously, video recording could provide relevant information on the incident’s circumstances and on the role played by the infrastructure. Their integration, as well as further new developments on incident detection criteria, could assist an operator in deciding if a field visit should be, or not, considered optimizing the expert’s intervention. These last statements illustrate that incident data collection process could be easily upgraded and therefore offers more reliable and relevant assistance to road managers at an affordable cost.

Simple to more complex developments of the process are now envisaged on different components of the system. A new cheaper and more powerful EDR integrating a video camera was developed. Works are under progress on the one hand to improve process automation and on the other hand to define new criteria to extend incident detection.

In addition to incident analysis, EDR may offer additional services to road managers: evaluate the impact of road layouts on drivers’ behaviour, determine speed statistics on some road section...

Nevertheless, beyond technical and practical aspects, legal issues about privacy and personal data protection must be carefully taken into consideration as they greatly impact data collection and analysis that can be carried out.

7 CONCLUSIONS AND PERSPECTIVES

The collection of incidents generated by the SVRAI fleet of instrumented vehicles showed it relevance for the diagnosis of the road infrastructure, in particular in the Seine-Maritime Department.

That incident collection and analysis proved to allow the detection of road sections where the infrastructure may present defects. It has to be noticed that this detection is based on a limited number of parameters collected by the EDR “EMMA2” which are used for the analysis: GPS coordinates, speed, longitudinal and transversal accelerations. These parameters can be easily understood and interpreted by local road services. However, the added value for the infrastructure diagnosis is largely brought by the visit and human expertise based on a thorough knowledge of the links between road characteristics and safety. Nevertheless, the incident detection would allow the road manager service to identify road locations on which it should pay a specific attention.

While many studies have demonstrated some safety behavioural benefits in the use of EDR, this one highlights one of the benefits that can be expected from their use to improve road infrastructure safety management. Others benefits can also be expected from new developments on the device, data treatments and analysis. Some of them have been already implemented and tested in the framework of SVRAI project; others will be available in a close future in order to offer new tools for road manager extending. EDR implementation on other vehicle type such as powered two-wheelers or trucks are also envisaged.

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