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SECUBIDI

Summary deliverable

REPORT

November 2022

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SECUBIDI: Summary report

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Summary of the study

Two-way interurban roads form a vast network of over 400,000 km, managed in part by the State and local authorities, mainly the Departmental Councils.

This network performs multiple functions (transit and/or service) and has diverse characteristics in terms of infrastructure provision. It carries a significant proportion of traffic for a variety of reasons, with a mix of different users such as passenger vehicles, heavy goods vehicles, vulnerable road users, farm machinery, etc.

In terms of accidents, this network accounts for 89% of deaths on roads outside conurbations (1,915 people killed), or 56% of all road deaths. What's more, although spread out along the routes, it appears that one quarter of this network accounts for two-thirds of the fatalities.

Faced with this challenge, the government decided to reduce the maximum authorised speed (VMA) on this network to 80 km/h. More recently, after several months of application, the Departmental Councils have been given the option of raising the VMA to 90km/h locally under conditions that have yet to be defined.

While, overall, the BAAC file provides some information on accident rates, there is a lack of more in-depth knowledge that would enable a diagnosis to be made that is better suited to the heterogeneity of this network. This deficit should be set against the levers that can be mobilised to improve the characteristics of the infrastructure in relation to usage (traffic and speeds).

5 to 10 key words to remember from the study

Accidents	**Factors**
Two-way road	**Geomatics**
Single carriageway road	**Empirical Bayesian estimation**
Issues	**Doctrine**
Mechanisms	

Foreword for publications translated into foreign languages

The purpose of translated documents and publications is to pass on to non-French speaking readers the French know-how set out in the original publication, whether this concerns knowledge, methodologies, tools or best pratices.
Original publications in French are subject to a checking process, which leads to a Cerema commitment regarding their content. English versions do not undergo the same process, and consequently carry no Cerema commitment. In the event of differences between the English and the original French text, the French text serves at the reference.

Communication status of the study

The studies carried out by Cerema using its public service grant are indexed by default and accessible on Cerema's document portal. However, certain studies of a specific nature may have restricted or confidential access. Please specify below the communication status of the study.

This study is capitalised on the CeremaDoc document platform, via the document repository: https://doc.cerema.fr/depot-rapport.aspx

Background and purpose of the report

The SECUBIDI project led by Cerema's Normandy-Centre Regional Division (DTerNC), in response to a call for projects from the DSR, aims to provide detailed knowledge of accidentology and usage on two-way rural roads throughout mainland France in order to :

- Better knowledge for action, in particular estimating and prioritising safety issues by distinguishing between road function, infrastructure characteristics and usage;
- Identify the main accident mechanisms and factors in order to make a diagnosis and estimate the role of infrastructure and users;
- Evaluate the possibility of proposing a specific analysis by territory, typically at the level of a departmental network, based in particular on existing and available data (traffic, speeds, geomatic databases, etc.).

At the same time, Cerema was commissioned by the Direction des Infrastructures de Transport (now the Direction des Mobilités Routières) to lead the work on the technical adaptation of the new requirements introduced by directive (EU) 2019/1936 to directive 2008/96/EC on road infrastructure safety management, which defines the road infrastructure safety approaches required of national road and motorway managers. This work is the subject of a specific project called GSIR[1] and aims to significantly revise the safety assessment approach for an entire road network imposed by the directive, known as the SURE approach[2] in France. As part of this work, it has been decided to use the latest publications[3] from IFSTTAR on determining the accident rate for a section of road.

Part of the network of two-way roads falls within the scope of this directive. As a result, it became clear that the two projects, which were running concurrently, should not ignore each other but rather mutually enrich each other. GSIR has benefited from the accident analyses carried out in SECUBIDI, and the more operational aspects of SECUBIDI have taken into account the ideas developed in GSIR, in particular the framework for using and developing the SURE method.

1Road Infrastructure Safety Management

2User safety on existing roads

3In particular: Thierry Brenac. Quantitative methods for the identification of dangerous road sections - General aspects, empirical Bayesian approaches. [Research report] IFSTTAR. 2020

CONTENTS

1 WORK CARRIED OUT

Knowledge of the influence of infrastructure on safety was reviewed on the basis of a selection of studies carried out in France and abroad. In the case of France, the state of doctrine and methodological tools as well as the existence and availability of usage data (traffic and speeds) were analysed. In other countries, risk modelling approaches were the main focus.

The BAAC database for the period 2013-2017 and the FLAM database of fatal accidents in 2015 were used to define accident issues and analyse accident mechanisms and factors. The FLAM database was enhanced with additional information on the category of road networks in order to distinguish between two networks (main and secondary) and on roadside obstacles (type and distance from the edge of the carriageway).

This work has made it possible to identify the main safety issues on two-way roads in terms of deposits. Analysis of the mechanisms and factors using FLAM has made it possible to specify the influence of infrastructure characteristics in certain accident families. This work was based on the methods normally used in accident studies.

Methodological building blocks have been developed with a view to enriching geomatic data describing road infrastructure with additional safety information. As part of a demonstration project, these were applied to part of the network of two-way roads in the Seine Maritime département (CD76). Several data sources were used: traffic data from the CD76, FCD speeds from the DSR, and the OSM mapping database.

Finally, in relation to the work carried out in GSIR, the potential of Bayesian estimators to identify the most dangerous road sections was analysed on part of the CD76 network of two-way roads, using usage parameters (traffic and speeds).

The following paragraphs summarise the main results of this work and suggest various courses of action.

2 KNOWLEDGE

2.1 Studies and research in France

Since the publication in 1992 of the reference work "Sécurité des routes et des rues" (Road and street safety), there has been a substantial body of studies and research, mainly resulting from the work of Cerema and the Gustave Eiffel University. In relation to the characteristics of the road infrastructure, this work is mainly linked, on the one hand, to the road features that account for the majority of accidents and fatalities (bends, intersections, approaches and obs- tacles, etc.) and, on the other hand, to the principles of road safety design (visibility, legibility, suitability for dynamic constraints, limiting severity, etc.).

The results of this work have been used to establish the doctrine formalised in various design and planning guides, such as ACI[4] , TOL[5] , ARP[6] , etc. With the exception of the ARP guide published in 2022, much of the technical doctrine is based on studies dating back more than 20 years. However, a number of more recent studies (published between 2005 and 2010) seek either to update existing knowledge or to propose new safety measures or even new approaches. These studies include

- The joint Cerema/Gustave Eiffel University "Road Risks" research project[7] , which has produced safety data collection tools such as IREVE and risk indicators for intersections, obstacles and visibility;
- The Roadsense research project[8] , which looked at audio-tactile warnings to prevent lane departures and whose results were used to change the regulations, in particular to allow their use on two-way roads.
- The "Safer Roads, Accident-Free Roads" experiment[9] is being conducted jointly by the Seine Maritime Departmental Council and Cerema. Over a 23km stretch of road, the experiment has mobilised all the methods and tools used in road safety studies, as well as innovative developments, with the aim of eliminating serious accidents.

Despite this, it should be noted that studies into the influence of infrastructure characteristics on safety have declined significantly over the last few years.

Although there are tools and methods for determining unsafety indicators (e.g. ALERTINFRA, Signs and signals on bends), they are only used marginally because of the operational difficulty of obtaining the data needed to calculate the indicators.

[4] Aménagement des Carrefours Interurbains, Cerema, 1998.
[5] Traitement des Obstacles Latéraux, Cerema, 2002.
[6] Aménagement des Routes Principales, Cerema, 2022.
[7] Risques routiers (11K063), Méthodes d'évaluation du risque routier lié aux caractéristiques des infrastructures, final report, Cerema/Université Gustave Eiffel, 2010.
[8] Anelli, P., Violette, E. Roadsense, closing seminar and outlook, RGRA special TRA2014, n°919, 2014
[9] Safer roads, accident-free roads, Cerema, 2017

Similarly, there are few studies that attempt to model road unsafety (number of accidents) as a function of infrastructure characteristics. The few existing models for intersections (the INRETS model[10] and the CETE model[11]) are not used because there is no knowledge of the traffic on the secondary roads at intersections.

In terms of accidents, the information on road infrastructure in the BAAC is limited and does not allow for in-depth studies. Only databases derived from the coding of accident reports allow more detailed analyses. In particular, the databases for detailed accident studies[12] from the Université Gustave Eiffel and the FLAM database[13] from Cerema contain more detailed information on infrastructure, among other things.

Lastly, the integrated methods for identifying dangerous sections of roads (SURE method), which are used to guide road managers on the action to be taken, are mainly used on the national network and are rarely implemented on networks managed by local authorities. Moreover, the actions taken to improve road infrastructure using the SURE method are rarely evaluated and capitalised on. This method is currently being updated as part of GSIR.

2.2 Data available and accessible at France

While accident data is collected, checked, collated, stored and accessed using the TRAxy tool, it is more difficult to obtain the other data required for risk analysis.

This is particularly true of usage. The measurement of road traffic and speeds is left to the initiative of road managers, with no harmonisation (measurement methods, data storage and dissemination). The same applies to information about the characteristics of the infrastructure (assets, geometry, surfacing, approaches, obstacles, etc.). While access to data on the national road network is facilitated by open data platforms, access for local managers is less uniform.

In the specific case of speeds, while there is a national observatory managed by the ONISR[14] which provides global indicators, at local level observatories and the corresponding data are rare. However, the emergence of speed measurements from FCDs[15] provides access to information on a spatial scale (all or part of a route) for detailed knowledge of speeds.

[10] Brenac T., Accidents en carrefour sur routes nationales: modélisation du nombre d'accidents prédictibles sur un carrefour et exemples d'application. INRETS report n°185.
[11] Opération de recherche Risques Routiers, Sécurité des carrefours plans sur routes principales, Cerema, 2009
[12] https://lma.univ-gustave-eiffel.fr/equipements-scientifiques/accidentheque-etudes-detaillees-daccideteeth-eda
[13] https://www.cerema.fr/fr/actualites/facteurs-accidents-mortels-circulation-france-2015
[14] https://www.onisr.securite-routiere.gouv.fr/etudes-et-recherches/comportements-en-circulation/observations/observatoire-des-vitesses

[15] Floating Car Data.

2.3 Work at abroad

The work carried out in other countries includes integrated approaches whose main objective is either to predict and model the number of accidents as a function of the characteristics of the road infrastructure, or to propose a classification of road sections according to how dangerous they are. There are several methods, including :

- The HSM[16] in the USA and the European PRACT project[17] , strongly inspired by the HSM, offer models of the risks of accidents occurring as a function of the characteristics of roads and road traffic;
- The ANRAM[18] in Australia and iRAP[19] in many countries aim to establish a ranking of road sections according to how dangerous they are.

All these methods require extensive data collection (accidents, detailed road characteristics, traffic, etc.) and use models or decision rules based on in-depth knowledge of the impact of road characteristics on accident rates.

As a result, they are difficult to transpose to France unless one assumes that the principles of road design and layout as well as usage (traffic and speeds) are similar[20] . In fact, there are no French models to confirm or refute this principle.

[16] https://www.highwaysafetymanual.org/Pages/default.aspx
17 https://doi.org/10.1016/j.trpro.2016.05.397
[18] https://austroads.com.au/publications/road-safety/ap-r451-14
[19] https://irap.org/fr/
[20] IRAP, EuroRAP: ses méthodes, ses résultats. Study report, Cerema, 2021.

3 ACCIDENT ISSUES ON TWO-WAY ROADS

The accident stakes on two-way roads have been estimated from the BAAC database over the period 2013-2017[21] so that the analysis is not biased by the switch to 80 km/h and the COVID containment periods.

Overall, two-way roads outside built-up areas are the biggest road safety issue in terms of both accidents and fatalities. They account for 58% of accidents outside built-up areas and 80% of fatalities outside built-up areas (respectively 19% of accidents and 56% of fatalities in France). These accidents fall into the following three categories:

- 84% outside intersections and without pedestrians (1,600 fatalities) ;
- 12% at intersections with no pedestrians (230 fatalities) ;
- 4% involved a pedestrian (90 fatalities).

For non-intersection accidents involving pedestrians, the road safety issues are :

- Accidents on **bends**: with 41% of fatalities (650 fatalities per year) on this type of flat section, although the proportion of bends on the entire length of the road under consideration is lower than on straight sections;
- **Night-time** accidents account for 39% of fatalities (630 fatalities per year). Given the lower levels of traffic at night, the risk appears to be much greater than during the day. Deaths at night (22) is higher than during the day (16). This can be explained in part by the higher speeds used[22][23] ;
- **Single-vehicle** accidents **against a fixed obstacle** (610 fatalities per year), in which almost one in two fatalities is against a tree;
- **Head-on collisions** (510 fatalities per year). These accidents are proportionally more frequent on main roads than on secondary roads (48% of fatalities on main roads and 32% of fatalities on secondary roads respectively);
- Accidents involving a **driver under the influence of alcohol or drugs** (480 deaths per year), with a higher proportion on major roads than on minor roads.

Considering the RN and RD, significant differences appear:

- Accidents on **bends**: 42% of fatalities on RD / 33% of fatalities on RN ;
- **Single-vehicle** accidents **against a fixed obstacle**: 39% of fatalities on main roads / 15 of fatalities on RN ;
- **Head-on collisions**: 32% of fatalities on RD / 48% of fatalities on RN ;

[21] From 2018 onwards, the information contained in the BAAC no longer makes it possible to separate with certainty those occurring on the RCS from those occurring on two-way roads.

[22] https://www.onisr.securite-routiere.gouv.fr/etudes-et-recherches/comportements-en-circulation/observations/observatoire-des-vitesses

[23] Accidentology and night-time traffic: quantification and possible explanations for the increased risk at night, Ce- rema, 2004.

- Accidents involving **a driver under the influence of alcohol or drugs**: 35% of road deaths / 20% of road deaths.

4 ACCIDENT MECHANISMS AND FACTORS ON TWO-WAY ROADS

The accident factors and mechanisms were analysed using the FLAM database of fatal accidents in 2015. This FLAM database was enhanced with additional information on the category of road networks in order to distinguish between two networks (main and secondary as defined by the ONISR[24]) and on roadside obstacles (type and distance from the edge of the carriageway).

4.1 Accident mechanisms

In terms of **primary safety**, an analysis of accident mechanisms showed that 55% of the drivers involved in accidents on dual carriageways outside built-up areas had left the carriageway. These lane departures occurred on curves in 54% of cases, and on straight sections in 45% of cases.

When it is known (around 90% of cases), the side of the lane exit is overwhelmingly to the left (71% compared with 29% to the right), whether the road user is initially on a straight section (73% of exits to the left) or a bend (70% of exits to the left).

These lane exits break down as follows:

- 37% of drivers with driver error, generally progressive (falling asleep, dozing off, inattentiveness, etc.);
- 63% of drivers with loss of vehicle control (loss of dynamic control due to inadequate speed in relation to grip constraints, loss of control following avoidance or collision with an animal).

This breakdown (37% vs. 63%) is fairly similar to that of the Roadsense[25] study in 2012 (35% vs. 65%).

With regard to lane departures due to a guidance problem (other than a fainting spell), it appears that this problem is present on all the networks, although it is more of an issue on the RRN: 30% of accidents on the RRN involved a lane departure due to a guidance problem (other than a fainting spell), compared with 20% on the RD1 and 18% on the RD2.

It also appears that the majority of drivers :

- Driving in a straight line (55% of cases, involving 180 drivers);
- Twice as often on right-hand bends (75 drivers involved) as on left-hand bends (39 drivers involved);
- Made an initial offset to the left (88% of them, and 255 drivers concerned).

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[24] Accident rates on two-way roads outside built-up areas: Issues relating to the main network, ONISR, 2019.

[25] Étude accidentologique des sorties de voies, deliverable 2.2 of the Roadsense project, Cerema/Ceesar, 2012.

There is a clear difference here with the Roadsense study, which identified 32% of left-hand exits and 68% of right-hand exits, but on a different study perimeter (all networks) and with the study of accidents against obstacles on narrow lanes[26] , which identified 43% of left-hand exits and 57% of right-hand exits.

Despite the different scopes of the two studies mentioned above, this difference is a cause for concern, because for many years now, priority has been given to improving the right-hand side of the road for the benefit of user safety: widening of the carriageway, possibly with a reduction in the width of the traffic lanes, implementation of multi-functional lanes (MFLs).

Partial knowledge of the lateral position[27][28] of vehicles travelling on dual carriageways shows that "free" vehicles[29] tend to be positioned more in the centre of their lane during the day and to the left of their lane axis at night.

The audible warning devices (AWS)[30] influence this lateral position: edge AWSs shift users slightly towards the centreline of the road, while centreline AWSs direct users into their lane and away from the centreline.

In terms of secondary safety, accidents (excluding intersections) without a third party hitting an aggravating obstacle represent 29% of all accidents on the two-way network outside built-up areas. In 1 case out of 2, the obstacle hit was a tree.

The distance of the obstacles from the edge of the carriageway was estimated. If only the aggravating obstacles with a known distance are taken into account, it can be seen that :

- 60% were less than 2 m away. This proportion is 54% on the main network (RRN+RD1) and 66% off the main network (RD2+VC);
- 83% were less than 4 m away.

These figures are fairly close to the statistics given in the "Treatment of Lateral Obstacles" technical guide (43% of obstacles less than 2 metres and 78% of obstacles less than 4 metres).

It also emerges that most accidents involving obstacles (outside intersections, without third parties) take place on bends (53% of cases), particularly on the less structuring network: 58% on the RD2, compared with 49% on the RD1, and 39% on the RRN.

This is a real cause for concern with regard to the effective treatment of trackside obstacles, despite a policy that has been in place for many years. In fact, it appears that more than 2/3 of the obstacles hit are point obstacles (trees, poles, wrecks, etc.). In 1/4 of cases, these obstacles are less than 1 m from the edge of the carriageway and in 2/3 of cases less than 2 m from the edge of the carriageway.

[26] Étude des accidents contre obstacles sur voies étroites de rase campagne, study report, Cerema, 2016.
[27] Warning strips dug into banks Experimentation on the RD 6014, Roadsense project, Cerema, 2014.
[28] Influence des véhicules croiseurs sur la trajectoire des véhicules, Rapport de stage INSA Emilie Lévêque, Cerema, 2011.
[29] A vehicle is considered "free" if its trajectory (speed and lateral position) is not constrained by other road users.
[30] Évaluation de lignes d'alerte audiotactiles en axe associées à des bandes dérasées de droite sur la RD490, Cerema, 2015.

Thus, despite the explicit recommendations of the TOL, a significant proportion of untreated resident obstacles remain involved in fatalities on two-way roads. Road managers should make it a priority to treat roadside obstacles (as defined by the TOL), particularly those closest to the road (< 2 m) and those on bends.

4.2 Factors of accidents

Human factors account for the vast majority (92%) of fatal accidents on two-way roads outside built-up areas. Inappropriate or excessive speed (38%) and alcohol (31%) are the main factors.

The Infrastructure factors are divided in a similar way between triggering factors (33%) and aggravating factors (36%).

The main factors relating to infrastructure or traffic conditions are :

- Visibility defects, mainly caused by fixed masks (7%) linked to the environment (4%) and the profile or layout of the road (2%);
- Poorly legible infrastructure that prevents road users from adapting their behaviour: poor legibility of curves (4%) and intersections (2%);
- Inadequacy of the infrastructure to cope with dynamic constraints: grip problems on wet roads (7%), poor road condition in 2% of accidents;
- Recovery or avoidance possibilities limited by insufficient shoulder widths (8%) or by the presence of an obstacle on the shoulder (3%);
- Collision with an aggravating fixed obstacle on the shoulder was present in 35% of accidents.

Thus, inappropriate speed on roads where infrastructure factors are more present than on other types of road can contribute to a significant fatality rate on two-way roads.

The infrastructure factors include road objects or features that have already been highlighted in the issues and accident mechanisms, such as bends and obstacles (and more generally approaches). Poor visibility also has to do with the speeds at which people travel, which can severely restrict requirements.

In this respect, a more in-depth knowledge of the speeds used on the routes (particularly V85) could be useful to the managers to better identify the critical zones from this point of view. Finally, better knowledge of grip, particularly in areas likely to be subject to the greatest stress (bends, speed adaptation zones), would be useful in limiting the involvement of this factor in accidents.

4.3 Analysis by network category

The FLAM database has been enriched with the network category according to the classification proposed by the ONISR in 2018. This classification distinguishes :

- The national road network: RRN ;
- The main departmental network [RD1]: sums of categories 1 and 2 (defined by the managers) if the proportion of linear category 1 and 2 is less than 42%, otherwise it is category 1 only;
- The non-main departmental network [RD2]: the rest of the departmental network ;
- Local roads: VC.

The primary network is made up of RN and RD1 roads, while the secondary network is made up of RD2 roads and VCs.

Analysis of the location of accidents shows that departmental roads [RD2] account for the highest proportion of fatal accidents, with 877 accidents, or 52% of the total two-way network outside built-up areas. Departmental roads [RD1] accounted for 570 accidents, or 34% of the total, ahead of trunk roads (144 accidents, or 9%) and local roads (140 accidents, or 8%).

Overall, the most structured network (RN+RD1) accounted for 702 accidents, or 42% of all accidents on the two-way network outside built-up areas.

Differences[31] were noted between network categories, particularly for the following types of accident:

- Head-on collisions account for 71% of lane departure accidents on RNs, 40% on RD1s and 32% on RD2s. These proportions suggest that the level of traffic plays an important role, despite the significantly different cross-sections of the different road categories;
- The proportions of accidents at intersections are relatively similar depending on the type of network: 14% on RNs, 17% on RD1s and 16% on RD2s. On the RD, the majority of accidents occur at crossroads, followed by T-junctions. The opposite is true on RRN ;
- Obstacles (aggravating factors) are present in 17% of fatal accidents on RNs and 17% and 20% respectively on RD1s and RD2s. Regardless of the network, trees were the most common cause of death. Although obstacles are hit in the same proportions on both the right and left of the road, they are closer to the carriageway on the RD2 than on the RD1.

So, on the one hand, it appears that the categories of the network concentrate significantly different volumes of accidents and, on the other hand, the mechanisms and factors of accidents also present differences which are due both to the characteristics of the infrastructures and to their uses.

[31] Readers will find detailed information in the deliverable: Fatal accidents on two-way roads.

However, the accident families remain similar and mainly involve curves, roadside obstacles and, to a lesser extent, intersections. Analysis by network category was only possible on the basis of a categorisation that combines administrative classification with a functional classification specific to road managers.

To make accident analysis more consistent, it would be useful to have a harmonised functional classification according to road type (two-way, dual carriageway).

4.4 Focus on vulnerable road users[32]

A specific analysis of accidents involving vulnerable road users on two-way roads highlighted the following main points:

- Of the 80 accidents involving a pedestrian, 55% were on the main road network (RN+RD1) and 42% on the secondary network (RD2+VC). 92% occurred outside intersections and 66% at night;
- Of the 70 accidents involving a cyclist, 39% occurred on the main road network and 61% on the secondary network. 29% occurred at junctions;
- Of the 379 accidents involving 2WDs (mopeds and motorbikes), 40% occurred on the main road network and 60% on the secondary network. 26% occurred at junctions. The two main types of accident were single vehicle lane departures (pictograms 502 and 503 in the FLAM analyses) and lane departures into the opposite lane (pictograms 103 and 203). The proportions are relatively similar, respectively 32% on the main network / 36% on the secondary network and 27% on the main network / 26% on the secondary network.

This analysis shows that for these users, all the networks are concerned, and that inter-sections are a relatively important issue. For these users, visibility is essential.

[32] Readers will find detailed information in Cerema's reports on the specific work carried out using the FLAM database on 2WD, cyclists and pedestrians.

5 GEOMATICS FOR ROAD SAFETY : POTENTIAL AND LIMITS

The geomatics component of the SECUBIDI project focused on the feasibility of using different databases (infrastructure characteristics, uses, public data, cartography) to enrich public geographic databases with a 'road safety' focus, based on the contribution of road infrastructure to user safety. To do this, we are drawing on previous work describing these relationships.

Initially, the work sought to quantify and qualify the road objects involved in road unsafety (bends, intersections) on the basis of existing knowledge (e.g. Alertinfra, Sécurité des Routes et des Rues, etc.) by developing semi-automatic building blocks in an open source GIS environment (QGIS). In a second phase, we took account of usage by combining road objects with traffic data (AADT) where known, and with speed data (FCD). This combination has made it possible to create additional added value in the GIS environment.

As a demonstration, this work was carried out on the main network of the Seine-Maritime département, mainly because of the availability of open source data.

The work sought to add value for both bends and inter-sections, based on knowledge gained from previous work:

- For **bends**: 1) automatically identify bends and determine the value of the radius in order to apply some of the Alertinfra safety rules[33] without necessarily having measurements of the characteristics of the road geometry. 2) apply the[34] bend signalling assistance method based on determining the deceleration required to negotiate the bend using FCD speeds;
- For **intersections**: 1) identify and classify intersections according to their geometry (X, T, Y, etc.) and the hierarchy of the network. 2) automatically apply unsafety rules such as non-perpendicular branches, intersection on a bend, intersection after loss of alignment. 3) calculate the intersection unsafety model[35] based on traffic data. 4) automatically determine visibility requirements based on FCD speeds;
- For **road sections** (as defined by the SURE method): 1) establish speed indicators at section level based on FCD speeds. 2) assess the feasibility of setting up observatories of speeds based on FCD speeds.

[33] G. Dupre, P. Flachat, G. Gratia, M. Latorre and J.C Olivier: Detection of safety alerts linked to road infrastructure malfunctions. Bulletin des Laboratoires des Ponts et Chaussées, 213:3-16, 1998.
[34] Comment signaler les virages. Guide pratique, Cerema, July 2002.
[35] Brenac, T. (1994), Accidents en carrefour sur routes nationales. Modélisation du nombre d'accidents prédictible sur un carrefour et exemples d'applications. INRETS Report No. 185, August 1994.

5.1 General organisation of geographic databases ill-suited to use in the dimension of the road (x, y)

The project has made it possible to identify a number of (semi-automatic) functional building blocks, limited by the existing data and cartographic representation. This development has brought to light limitations linked mainly to the very design of the geo-graphical databases, which are not optimised for automatic processing in the (x, y) dimension of the road in the sense of itineraries. In fact, the two main sources, IGN and OSM, have the same shortcomings, which mean that their use is necessarily limited:

- The length of the segments describing the road varies from a few metres to a few hundred metres. This variability is random. The numbering of the segmentation is not ordered. Consequently, it does not allow simple automation of calculation processes by distinguishing between traffic directions. With regard to the above-mentioned limitations, it should be noted that the speed database developed by Carte Blanche Conseil[36] and used as part of the project is organised using an ordered segmentation with a grid of no more than 100 metres;
- Some descriptors that are essential for road safety are missing, in particular the urban/interurban distinction. In the absence of explicit mapping of urban entrances and exits[37] , the alternatives explored during the project did not produce satisfactory results. Similarly, there is no mapping of speed limits (value of VMA, start, end);
- The hierarchy of roads is specific to each database and differs from that adopted by the managers. As already mentioned in the analysis of accidents, this point would benefit from a harmonised functional definition of the hierarchy of road networks.

5.2 Identifying bends and determining the radius

Work on identifying bends was limited by the geographical representation of the roads, which was ill-suited to automatic calculations. Initially, however, it was possible to classify bends into useful families of radii. From this stage onwards, it was possible to identify the class of road signs to be used, based in particular on the speeds experienced before and when negotiating bends (calculation of the acceleration required to negotiate bends).

However, it has become apparent that the method of classifying bend signs, which was developed more than 20 years ago, needs updating. It is based on a straight V85 of 102 km/h[38] which has now been reduced to 93 km/h. This estimate of 93 km/h was established for the main roads in Seine Maritime as part of the

[36] https://www.cbconseil.com/
[37] For example, the Doubs département has produced this map, which is open source.
[38] Louah, G., Dupré, G., Violette, E. Updating the French V85 formulae for cornering, PRAC 2010 conference, Paris 3-4 May 2010.

project based on a location draw where users are free to travel at their desired speed. This value is similar to that determined in the[39] evaluation of lowering the VMA to 80 km/h. As a result, the deceleration values used for the various classes are no longer appropriate.

A new bend speed model would be worth developing, but with the diffi culty of having two possible VMAs for two-way roads (80 and 90 km/h).

With regard to determining the radii of bends (and their length), the various solutions developed (trigonometry using GIS) and tested[40] have not produced satisfactory results, particularly in terms of accuracy and reproducibility.

Alternatively, the cubic spline approach proposed by Cerema[41] has real potential once it can be automated in a GIS-type environment. In addition to calculating the geometry of bends, it can be used to determine the stresses involved in crossing a bend as a function of speed. In this respect, its coupling with knowledge of FCD speeds opens up interesting prospects.

5.3 Intersections: useful advances and relevant

For intersections, the native content of the databases has enabled relevant safety-related parameters to be determined automatically, such as the type of intersection, the hierarchy of intersecting lanes, and the identification of visibility limits (non-perpendicular angle of secondary branches, presence of a high point nearby, curved intersection).

It has been possible to automatically determine the visibility requirements in both directions of traffic on the basis of FCD speeds on approach, in particular V85. This is an interesting advance because it makes it possible to identify and classify intersections with regard to this parameter, which is essential for intersection safety, in relation to the speeds actually travelled (not capped at the VMA), as recommended in the road guides[42] . Such a classification avoids the need for road managers to carry out costly speed measurement campaigns and enables them to optimise the actual visibility of the most demanding intersections.

However, the absence of traffic data, generally on intersecting lanes, makes it impossible in practice to rank intersections using accident modelling (Brenac model[43] or CETE model[44]). This is a major shortcoming, and it would be particularly useful if this information were systematically available for intersections on main roads.

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39 Abaissement de la vitesse maximale autorisée à 80 km/h, final evaluation report, Cerema, July 2020.
40 https://doi.org/10.1371/journal.pone.0208407
41 Géométrie et sécurité routière, proposition de méthode pour une solution numérique : le cas de la détection des virages potentiellement dangereux, internal Cerema document, 2022.
42 Comprendre les principes de conception géométrique des routes, Cerema, 2006.
43 Accidents at junctions on national roads. Modelling the predictable number of accidents on a crossroads and examples of applications. INRETS Report No. 185, August 1994.
44 Conche, F., Patte, L., Dupré, G., Désiré, L., Glaser, S. Opération de recherche Risques Routiers, Sécurité des carrefours plans sur routes principales. Research report, December 2009.

5.4 FCD speeds: a major potential use for managers

The development of FCD speeds applied in particular to part of the main network of the Seine Maritime department (feasibility) has shown a real potential for using these data after temporal aggregation in order to have sufficient numbers in the distributions. From a geomatics point of view, the DSR speed data developed by Carte Blanche Conseil has the advantage of being linked to road segments of up to 100m in length. This data structure is particularly well suited to road-scale processing. In this way, these speeds can be used either at the level of individual road objects (see above for bends and intersections) or spatially on the scale of road sections or, more broadly, the network.

From time to time, FCD speeds have been used to create information for bends and intersections (see chapters above). However, the interest of FCD speeds lies in their spatial dimension which can be expressed on the scale of larger road sections in association with other parameters such as traffic. Locally, for each 100 m step, the speed practised is described by various indicators such as: the average speed V_{moy}, the percentiles V_{85}, V_{50}, V_{15} and a dispersion indicator $V_{85}-V_{15}$. Thus, in order to reduce the amount of information while retaining relevance, aggregate indicators have been calculated prospectively for SURE-type road sections (a few km), based on the previous indicators. Indicators such as V_{moy85}[45], V_{moy50}, V_{moy15}, V_{8585}, V_{8550}, V_{8515} have been proposed with, for example, the following interpretation assumptions:

- For a straight SURE section on which users can travel at their desired speed, the V_{8585}, V_{8550} and V_{8515} indicators will have relatively high values with little dispersion;
- For a winding SURE section with a variety of facilities that lead users to adapt their speed, the V_{8585}, V_{8550} and V_{8515} indicators will have lower values with a wider spread.

These indicators were used to define Bayesian estimators in order to identify the most dangerous sec- tions, taking account of speed.

Finally, FCD speeds can also be used to define network-wide speed observatories. In order to estimate the V_{85} in a straight line on the two-way roads of the main network of the Seine Maritime department, a virtual observatory has been created based on a hundred or so points where users can travel at their desired speed.

On this network with a VMA of 80 km/h, this observatory showed that the V_{85} is 93.5 km/h with a standard deviation of almost 5 km/h. This value is similar to that of Cerema's VMA80 observatory.

[45] Vmean85 is read as the 85th percentile of the distribution of mean speeds calculated for each FCD distribution of a SURE section.

This feasibility study confirms the potential use of such data, as already demonstrated in other studies[46][47][48] . For example, it would enable observatories to be set up in departments that have reverted to 90 km/h on all or part of their network.

Consequently, it would appear desirable to perpetuate the existence of the FCD speeds in a format that can be used by GIS for the entire road network.

5.5 Development of functional bricks under QGIS

The geomatics work carried out as part of the project has led to the development of a number of functional building blocks using the QGIS geographic information system (free and open source) based on OpenStreetMap mapping data. These bricks have been developed and tested on part of the road network of the Seine Maritime department, taking into account the following additional data, which may require specific handling to integrate:

- Road traffic (TMJA) supplied by the 76 departmental council;
- SURE sectioning supplied by the Conseil Départemental 76 ;
- Road hierarchy provided by the Conseil Départemental 76 ;
- Accidents based on BAAC data ;
- FCD speeds on the main network of the Seine Maritime département extracted and formatted by Carte Blanche Conseil (supplier of FCD speed measurements to the DSR).

[46] Le floating car data au service de la sécurité routière, profils de vitesse sur itinéraires, INSA internship report by Khaoula Benyahya, Cerema, 2019.
[47] Floating car data to improve road safety, VMA80, INSA internship report by Othman Mak- chadi, Cerema, 2021
[48] Analyse des vitesses pratiquées sur routes bidirectionnelles: application à l'évaluation de politique de sécurité routière, INSA internship report by Hamza Katim, Cerema, 2021.

6 EMPIRICAL BAYESIAN ESTIMATORS FOR IDENTIFYING DANGEROUS SECTIONS

In connection with the GSIR project, additional work on empirical Bayesian estimators to identify dangerous sections of road was carried out on part of the main network of the Seine Maritime department, using the following information: the SURE sectioning of the network with the corresponding accident rate, traffic expressed in terms of AADT, and various aggregated indicators of speeds practised. The value of such estimators is widely discussed in the literature[49][50] and the associated methodology used is also well described[51] .

Here, the challenge was to propose estimators that take account of sectioning, traffic and speeds, and to see how taking the latter into account can influence the relative ranking of sections in terms of accident risk. The result is that sections are ranked differently depending on whether speed is taken into account or not. However, the various tests carried out using aggregated speed indicators from the geomatic work did not produce conclusive results, mainly because the current SURE sections are too long for the speed indicators to be representative of the variability of user behaviour in relation to the infrastructure encountered.

However, this forward-looking approach seems relevant because it would allow us to determine the relative contribution of the usage variables that explain the Bayesian estimators (traffic and speed). To do this, a sectioning method adapted to these two variables is required. This point needs to be taken into account in the current GSIR project.

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[49] E.Hauer. Empirical Bayes Approach to the Estimation of "Unsafety" The Multivariate Regression Method", Accident; Analysis and Prevention volume 24, n°5, p 457-477, November 1992.
[50] Allain, E., Brenac, T. Models linéaires généralisés appliqués à l'étude des nombres d'accidents sur des sites routiers : le modèle de Poisson et ses extensions ", Recherche Transports Sécurité, vol. 72, p. 3-18, 2001.
[51] Brenac, T. Méthodes quantitatives pour l'identification de sections de route dangereuses - Aspects généraux, approches bayésiennes empiriques", August 2020. https://hal.archives-ouvertes.fr/hal-02935354.

7 COURSES OF ACTION AND PROPOSALS

The work and results of the SECUBIDI project suggest courses of action and proposals that have been divided into several areas:

- Measures to improve the characteristics of the road infrastructure with regard to the main accident issues and the main mechanisms and factors involved. Most of the proposals put forward are based on the existing technical doctrine, the implementation of which can still be improved on two-way roads;
- A change in technical doctrine to fill current gaps and take account of developments (European directive on infrastructure security and the associated GSIR project);
- The data needed for road safety, in particular that relating to road use (traffic and speeds), which is still too incomplete and would require appropriate tools to be used in geographic information systems;
- Users, because human factors are essential in the occurrence of accidents.

7.1 Development of the road infrastructure

- **Install audible warning devices**, mainly at the centre of the carriageway, to limit lane departures due to guidance problems (excluding those involving discomfort). At least 328 fatal accidents occurred in this configuration in 2015, i.e. 19% of all accidents studied. In cases where the information is known, the phenomenon is much more prevalent on the centre of the carriageway (255 accidents: 15%) than on the edge (39 accidents: 2%), and with 34 cases where the direction of offset is unknown. It should be noted that since the FLAM database only includes 97% of all BAAC accidents on this type of network in 2015, the above figures are probably underestimated. Changes to the regulations[52] allow such installations, and the accompanying technical documents should be made widely available to managers;
- **Initiate or continue steps to deal with side obstacles**. Priority can be given to obstacles located within 2 metres of the edge of the carriageway, a distance that covers 60% of cases of collisions with aggravating obstacles in accidents (excluding inter-vehicle accidents) without third parties, i.e. at least 270 cases of collisions among the 1,685 accidents studied. In relation to the issue of accidents occurring on curves, obstacles on curves must be considered with great care, since 54% of accidents involving obstacles take place on curves, and in particular on the RD2 (58%);

[52] Order of 14 January 2020 relating to the equipping of roads and motorways with audible warning devices. https://www.legifrance.gouv.fr/loda/id/JORFTEXT000041450831

- **Carry out grip measurements** to limit loss-of-control accidents in wet weather, an accident factor encountered 121 times out of the 1,685 accidents studied. Itineraries with curves could be treated as a priority because of the greater stress than on straight sections (transverse and longitudinal acceleration). If the coefficients turn out to be low, it may be possible to propose lowering the speed limit while waiting for the wearing course to be repaired;
- **Limit the use of masks,** particularly fixed masks, which were a factor in 115 of the 1,685 accidents studied;
- **Pay particular attention to the legibility of the road**, especially curves, which were a factor in 60 of the 1,685 accidents studied. Tight bends after a long straight stretch represent a challenge that seems to be more pronounced for motorbikes. To this end, the ALERTINFRA method and the principles of signposting bends should be applied more systematically in practice;
- **Check that sections with authorised overtaking offer good visibility conditions**. Overtaking accidents account for 13% of all accidents on the main network, and 11% on the secondary network. It would be appropriate to limit overtaking opportunities upstream of junctions with a high rate of left-turns, which presupposes an improvement in the current level of traffic knowledge;
- **Expand the policy of creating cycle routes and facilities**
  on the secondary network, which accounted for 61% of accidents involving cyclists, i.e. 43 cases.

7.2 Developments in the technical doctrine

- Take into account the elements of knowledge put forward in this project to **guide the methodology to be implemented for road infrastructure safety management (GSIR project)** for the two-way roads of the RRN and to adapt it to the main RD managed by local authorities:
  - **Pool the descriptive data on the infrastructure collected by the managers** in order to estimate the impact of the characteristics of the infrastructure on accidents (modelling approach);
  - **Continuing work on taking into account the speeds travelled** to identify dangerous sections using empirical Bayesian estimators, with particular attention to network sectioning. This work could lead to the determination of accident rate estimators that take into account the relative weight of the variables: inherent safety of the infrastructure, traffic, speeds used, etc;
- Take into account the knowledge elements put forward in this project to **question the distribution of the cross-section of two-way roads**, in particular the reduction of lane widths in favour of the recovery zone so as not to reduce the safety of road users;
- To take into account the knowledge gained from this project, with a view to **modifying the TOL (Traitement des Obstacles Latéraux - Treatment of Lateral Obstacles) guide.** This consideration should lead to a differentiation of the proposed solutions according to the type of networks concerned, which do not present the same challenges (obstacles closer together on the secondary network);

- More broadly, **technical doctrine should take account of the diversity of issues associated with the variety of two-way networks**, which calls for appropriate responses. To do this, it will be necessary to improve knowledge of usage (traffic on secondary networks and speeds on all networks);
- **Revisit the elements of technical doctrine that are based on knowledge of the speeds practised** because of the multiplicity of VMAs on two-way roads. This applies in particular to the modelling of speed on bends and the method of signalling bends.

7.3 Data: existence, availability and access

- **Continue to collect FCD speed measurements for the** entire network. To be usable, this data must be geo-referenced at a sufficiently fine fixed interval (typically 100 m);
- **Use FCD speeds to develop observatories of speeds at** different scales (network, routes, sections, points);
- **Encourage road managers to measure traffic at all intersections on the main network** (main and secondary branches) so that existing models of accidents at intersections can be used;
- **Using existing road maps (OpenStreetMap, IGN), build a fixed-step indexed breakdown of** the road infrastructure to provide an effective tool for two-dimensional processing.

7.4 Users

- **Check speeds, blood alcohol levels** (particularly at night and off the main road network) and **drug use.** There are 630 people killed at night on two-way roads and 480 killed when they are under the influence of alcohol or drugs. The two main human factors are excessive or inappropriate speed (38%) and alcohol (31%);
- **Carry out information/communication campaigns on the risks associated with fatigue and inattention**, which are more prevalent on the main RN and RD networks;
- **Step up communication on the need to share the road in** order to take account of the presence of vulnerable road users, particularly at junctions, taking into account the increase in cycling (link with cycling master plan).

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