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SIXTH FRAMEWORK PROGRAMME

Authors

Stephen T'Siobbel, Tele Atlas

Hans-Ulrich Otto, Tele Atlas

Daniela Kopp, Zenrin

Kees Wevers, NavTeq

Hans-Sabel, NavTeq

Teun Hendriks, Siemens VDO

Jan Löwenau, BMW

Ernst-Peter Neukirchner, Bosch

Klaus Herrig, Navigon

Christian Ress, Ford

Johannes Angenvoort, Navigon

Hans Anderson, Volvo

Wilhelm Vogt, Blaupunkt

Axel Varchmin, Blaupunkt

Jean-Charles Pandazis, Bosch

Karsten Heinig, University of Hannover

SubProject Leader

Vincent Blervaque

ERTICO – ITS Europe

Avenue Louise, 326

1050 Brussels / Belgium

Phone	+32 2 400 07 24
Fax	+32 2 400 07 01
E-mail	v.blervaque@mail.ertico.com

IP Co-ordinator

Peter Konhäuser

DaimlerChrysler AG

Research and Technology

Information and Communication

096/T729 - RIC/T

70546 Stuttgart / Germany

Phone	+49 711 17 41512
Fax	+49 711 17 41242
Mobile	+49 160 8630458
E-mail	peter.konhaeuser@daimlerchrysler.com

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Technical Abstract

The MAPS&ADAS subproject within the EC PReVENT Project seeks to develop and validate both an applicable standard for the collection, maintenance and provision of safety content enhanced digital map databases to be used in advanced driver assistance systems (ADAS) and Navigation Applications, as well as a standard interface from navigation systems or general positioning and map systems towards ADAS that make use of map data (e.g., for track preview purposes).

The PReVENT SWP12310 activities focus on compiling the requirements for safety related digital map content for driver assistance applications. This is achieved by collecting the results from previous research activities (e.g. NextMAP, ADASIS), and by investigating the needs of the different driver assistance applications that will be supported within the MAPS&ADAS project and within the PReVENT Integrated Project.

Executive Summary

The accelerated research and development, deployment and use of in-vehicle Intelligent Integrated Road Safety Systems including Advanced Driver Assistance Systems (ADAS) will contribute to the road safety goals on European roads by helping drivers to avoid accidents by sensing nature and significance of imminent dangers, while taking the driving situation and the driver status into account. Depending on the significance and timing of the danger, preventive and active systems will subsequently inform the drivers as early as possible, warn them and if they do not react, actively assist or ultimately intervene. PReVENT aims to develop and validate applications leading to early availability of technologies, assesses their impact and accelerates their implementation.

Digital map based safety systems can provide on-the-spot as well as predictive road information e.g. speed alert, curve warning, and require a suitable digital map which contains the respective road safety related data attributes. Today, in-vehicle digital maps can be found in navigation systems. Unfortunately these navigation map databases do not consistently contain all necessary safety related attributes or hold specific characteristics, nor are they accessible from other applications than navigation.

This first document version presents the consolidated requirements for the safety related digital map properties and content that will enable the relevant PReVENT safety applications. Besides of two different types of MAPS&ADAS safety application use cases (Hotspot & Speed Limit Information and Curve Speed Assistance), the map requirements of four PReVENT subprojects were taken into account: SAFELANE, SASPENCE, WILLWARN, and LATERALSAFE. The map requirements are formulated bearing in mind the necessary economic realism. Non map related requirements, but essential or beneficial to the correct functioning of the safety applications, are also included in this document (e.g. positioning).

The final version of this deliverable will include requirement updates from related projects (e.g. SpeedAlert, Profusion), updated application requirements (e.g. Hotspot warning), and input from other MAPS&ADAS work packages (WP12500 *Data Sourcing* and WP12600 *Business Model*). The work presented here will provide the background for the specification of safety related map information (WP12400).

1 Introduction

In the car industry, ADAS applications are given an increasing attention as their potential for increasing driving safety is more and more perceived by engineers and customers. Typical ADAS applications are e.g. Adaptive Cruise Control (ACC) or Adaptive Front Lighting System (AFS), see Appendix 1. Driver assistance systems currently perform their function on the basis of information generated by sensors observing the vehicle's environment.

Soon after the introduction of vehicle navigation systems, the potential of the use of the digital map and vehicle position to support driver assistance systems was realised. In fact, on board digital maps can be seen as a special sensor for a road safety system. The evident role of digital maps is to provide safety relevant information eventually not available by other sensors timely and correctly. Four different types of map use can be identified: (1) prediction along the road (am I driving the correct speed for the curve ahead?, what is around the sharp bend or beyond the hill?), (2) provision of context information necessary to understand the road/traffic situation. This can either be used as such (am I driving the correct speed?) or to correctly interpret other sensor input (is this car in my lane?), (3) acting as an intelligent filter, for example, by controlling other on board systems such as a mobile telephone, possibly delaying incoming calls to avoid information overload for the driver in complex or dangerous traffic conditions, e.g. near a complicated intersection or an accident hot spot, and (4) acting as a spatial memory, e.g. by collecting and storing information such as speed along a frequently travelled route. At the instigation of the driver a speed information application can adjust to the user's preferred speed along the route.

So far, the potential of map usage for safety applications has not been exploited yet, either because today's in-vehicle map databases do not contain safety related data or because they are not accessible from applications other than navigation. It is exactly the objective of MAPS&ADAS to address these two subjects. The map data access for most ADAS applications will probably only use a small map extract around the current vehicle position. This ADAS-specific map extract is here called the ADAS horizon (AH), see figure 1.

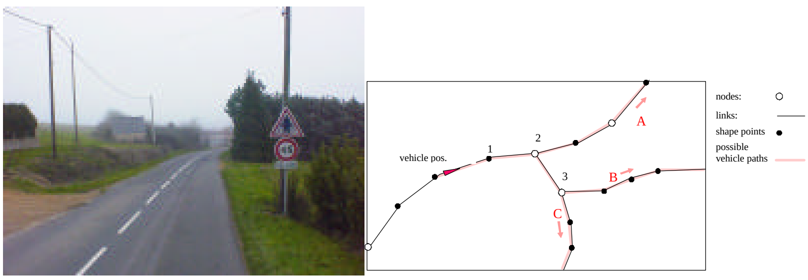

Figure1: Any car mounted sensor (e.g. camera) provides information of the real world near the vehicle. An appropriate part of an enhanced digital map offers a wider 'view' on the surroundings for driver assistance applications.

The work presented here discusses the Safety Map data requirements. It reflects the map requirements from road safety systems that are expected to be introduced to the market in the near and mid term future. The map requirements, which have been formulated for different digital map components (attributes and geometry), stem from investigating the results of the NextMAP project [1], the ADASIS forum [2], and the specific requirements of PReVENT safety applications. As the MAPS&ADAS project will contribute to standardising the interface from navigation systems or general positioning and map systems towards advanced driver assistance systems (ADAS) that make use of map data, this report will discuss general 'data' requirements, including positioning and map matching requirements.

In the recent past, the EC 5FP NextMAP project demonstrated the technical and economical feasibility of the realisation of an enhanced map for ADAS. In its conclusions a roadmap of map requirements was presented along with the indication that the commercial feasibility of map enabled ADAS was not addresses. It must be mentioned that the PReVENT Integrated Project focuses on early availability, assessment and accelerated implementation of technologies. This means that esoteric map requirements (e.g. decimetre accuracy, attribute representing road friction characteristics under various climatic conditions) are not discussed here as it is very unlikely that these requirements can be met soon, or that there will be a commercially viable need for them.

Based upon the map data requirements formulated in this deliverable, in total four test tracks will be digitised by the map makers in the project: Tele Atlas and Navteq. These enhanced map databases containing specific safety content and characteristics (geometry) will enable the validation of two applications which will be developed within the context of MAPS&ADAS project: a warning system (Hotspot and Speed Limit Information) and an assistance system (Curve speed assistance). MAPS&ADAS will also support four other projects within the PReVENT Integrated Project: SAFELANE (enhanced lane keeping support), SASPENCE (safe speed and distance support), LATERALSAFE (lane change assistant) and WILLWARN (obstacle detection and inter vehicle communication) by providing both a test track and an ADAS interface.

Within the context of this project the formulated 'safety map' requirements will play a significant role in the 'Data Sourcing' (WP12500). There, it will be examined what type of safety related map content is available at the public authorities sector and how it can find its way to the digital map databases and finally to the ADAS applications at in-vehicle terminals.

2 Methodology

The following methodology was used to collect the specific requirements regarding digital map databases to enable in-vehicle safety applications to reconstruct the AH.

Initially, the map requirements from all ADAS applications from the NextMAP project were collected. These requirements were investigated and completed by requests formulated by the ADASIS forum members. The MAPS&ADAS partners then identified and discussed the map requirements for the two MAPS&ADAS use cases: a speed limit information and hotspot warning system, and a curve speed assistance system. In the early phase of the MAPS&ADAS project, two workshops (WS) were organized to collect the map requirements from four different PReVENT vertical sub projects (VSP). At the first WS, the preliminary map requirements were formulated by the VSPs corresponding to the needs of the specific envisaged PReVENT application. During a second WS these requirements were further analysed and finally consolidated.

This version of the deliverable must be considered as a first version. A final version is foreseen for December 2005. Updates to this deliverable will reflect input from MAPS&ADAS internal activities, such as from refinements of the MAPS&ADAS use cases (e.g. Hotspot) and from the data sourcing and business model work package, as well as external activities: Profusion [3], and the SpeedAlert project [4]. Input from this project is expected by October 2004. If safety related map requirements from the US EDMAP project are publicly available, these will be presented and discussed too.

3 Terms and Definitions

To define requirements it is necessary to have a common understanding about the technical terms used to describe the content of a digital map database. The definitions for the different items, where appropriate, expressed in existing or anticipated future GDF [5] data entities, are presented in appendix 4.

GDF is an international standard for the definition and exchange of geographic databases. It consists of a conceptual and logical data model, the exchange format for geographic databases for ITS, a specification of potential content of such databases and how such content shall be represented.

At the time of document creation, some of the map data requirements could not be expressed by GDF terminology but as they are important for MAPS&ADAS (e.g. curvature), they have been added using specific terminology (see appendix 4).

4 PReVENT Safety Map data requirements

4.1 ADAS Interface Specifications

First convened in 2001 by ERTICO Partner Navteq (former Navigation Technologies), the ADASIS (Advanced Driver Assistance Systems Interface Specifications) initiative is now an open forum coordinated by ERTICO. The ADASIS forum members, representing vehicle, navigation, ADAS and map database manufacturers, made a distinction between two ADASIS versions or generations. In the first generation, map attributes and characteristics which are currently available or partly available were identified, whereas ‘future generation’ indicates map attributes and properties that are not available today.

The data requirements necessary for the construction of the ADAS horizon are illustrated in the tables in Appendix 4. The data entities are described with the terminology provided in Appendix 3. An important differentiation is made between data entities from digital maps, with sub categories: Geometry, Feature, Attribute, and Relationship, and System data, which represent data provided by sensors or data calculated by the system (navigation & vehicle). The tables specify whether this particular data entity is available from today’s map databases or systems; empty cells indicate that the data entity is not available today.

The ADAS interface which will be developed in MAPS&ADAS shall support the delivery of the metadata related to the characteristics of the underlying map database. A set of so called Basic Metadata will consist of a unique key representing information as a unique map provider identification, the unique ADAS horizon provider identification, a unique database identification, the coverage area, and the version of the ADAS horizon and protocol.

4.2 PReVENT data requirements

4.2.1 Consolidated data requirements

The detailed data requirements necessary for the construction of the ADAS horizon that will enable the PReVENT driver assistance applications can be found in the table of Appendix 5.

This table discusses the data requirements in terms of digital map and system requirements for a first (‘1’) and future (‘F’) generation of the ADAS interface specification. The data specification column indicates if the data element will be supplied by the digital map, with the GDF generation (4, 5) or metadata specification, or by the system, either from sensor information or calculated by the system.

As the VSPs will require support for map data for a test track and map access, different categories of support were identified (D1: will be provided, D2: Additional effort/resources required. D3: Out of scope of MAPS&ADAS). The current map database accuracy levels and resolution are indicated.

The different MAPS&ADAS and VSPs applications are discussed in more detail in the following chapters.

4.2.2 MAPS&ADAS use case applications

The MAPS&ADAS project will develop and validate two driver assistance applications for different goals: one driver warning application to validate the developed safety-enhanced digital map database including Hotspot and Speed Limit Information, and one assistance application (curve speed assistance) to validate the specification of the developed ADAS interface to map and vehicle positioning data.

4.2.2.1 Hotspot Warning

The concept of Hotspot Warning is to inform the driver about a potentially dangerous situation ahead which in the past has already led to an accident under certain circumstances.

The warning will be generated when the comparison of the circumstances that led to the accident with the current status of the vehicle (speed, position, probable route) in combination with environmental data (e. g. date, time, temperature, light condition and weather as far as available) shows a high possibility of an accident in the next seconds.

The conditions in which relevant accidents occurred in the past are available via the accident reports collected by the police. In Germany, for example, those reports contain information about [6]:

- the driver, the vehicle, as well as the date, time, weather conditions and categories of road users (like motorized two-wheeler, bus, truck, tram, etc.).
- The ‘accident cause’ describes the probable causes of the accident in terms of driver behaviour (e. g. driving fitness, speed, overtaking, etc.).
- The ‘accident kind’ describes the complete course of events in an accident, the direction into which the involved vehicles were heading when they first collided on the road or, if there was no collision, the first mechanical impact on a vehicle.
- Additionally the ‘type of accident’ describes the conflict situation which resulted in the accident, i. e. a phase in the traffic situation where the further course of events could no longer be controlled because of improper action or some other cause. Unlike the kind of accident the type of accident does not describe the actual collision but indicates how the conflict occurred before this possible collision. Hence the type of accident might be the most important information.

The accident data sets of the Statistical State Office Lower Saxony were analysed (Appendix 7, table A.7.1) to evaluate the content and data format matters (e.g. storage size). These characteristics will be used to build the hotspot data in a format to be defined and stored in the map database, in order to be exploited by the Hotspot warning application.

Map or navigation related data like position, route, etc. will be made available via the ADAS Interface. Hence the requirements of Hotspot Warning are contained in table A.6.1

The third part of necessary data is not available via the interface and will not be included in the digital map with safety related information. This applies to data available via the vehicle bus, like information from light or rain sensors, or alternatively the status of wipers (indicating rain), and/or of the headlights (indicating twilight or darkness). This third part will be specified in WP 12400.

4.2.2.2 Speed Limit Information

The concept of Speed Limit Information is to inform the driver when the vehicle speed is higher than the legal speed limit. This will be done by comparing the speed of the vehicle with the appropriate legal speed limit stored in the map database. The speed limit information could be provided by public road authorities (depending on countries and regulation). It corresponds generally to speed limit signs, general speed limits (like 50 kmph within residential areas in Germany or 100 kmph on rural roads, etc.) or specific information about inadequate speed near schools, old people's homes, etc. Speed limits may also depend on weather conditions, vehicle type, period of the year, etc. As a consequence, speed limit data should also contain these conditional characteristics (Remark: this excludes restrictions of driving speed resulting from POIs or road geometry, unless they are clearly defined by law).

Dynamic update of speed limit information to the map is not addressed within MAPS&ADAS. However, speed limit information related to planned road works (speed restrictions with time domain) will be investigated.

The data requirements of Speed Alert are shown in table A.6.1

Since part of the warnings of Hotspot Warning might result in instructions to slow down, the two warning applications will be developed as different modules, offering the advantage to investigate their own features as well as their combination (e. g. prioritisation).

4.2.2.3 Curve Speed Assistance application

BMW has developed a driver assistance application (Curve Speed Assistant) adapting the vehicle's speed depending on the given speed of a road sign along the road or the geometry of the road network. A vehicle navigation system is an excellent basis that comprises two of the necessary prerequisites for speed adaptation: a road network database, stored on e.g. a CD-ROM, and a positioning instrument, being the GPS receiver.

The main parameters for determination of the advisable speed are legal speed limits (e.g. via speed sign), curve radius, the change of direction of a turn and the roadway type. The estimated (safe) speed will be compared with the current vehicle speed. If the speed of travel is too high the driver will be warned.

BMW has developed two approaches for speed related driver assistance. Speed adaptation can be a part of conventional cruise control, where the speed is automatically adjusted (through downshifting or braking). The other principle is based on a feedback from an information system, which is used for the evaluation in the MAPS&ADAS project. The active information system helps the driver keep an adequate distance from the vehicle in front. Whenever the distance becomes too small, the information system gives an inoffensive but clear information by introducing a slightly increased resistance at the accelerator pedal, discretely telling the driver to reduce his speed and increase the distance to the vehicle ahead. By controlling the relative distance, the active information system also "suggests" the right speed to the driver. This nevertheless always remains a suggestion for the driver to take into account at his discretion.

The driver remains in the loop and the amount of feedback is based on the deviation between expected and actual behaviour.

The geometry of a street alone does not completely describe the curve speed that a driver in a particular curve would select. In general the desired curve speed is a function of radius and curve angle. Additional parameters which can change or adapt the velocity are position (town), speed signs, surface quality, street width, and number of lanes, shoulders, (daytime) visibility, weather (friction) and driving style of the driver. These additional parameters can be superimposed on the calculated curve speed limit.

Hardware architecture

Figure shows the existing hardware architecture in the vehicle, which has to be adapted to the MAPS&ADAS interface. Until today the input data is read from the CAN bus and the Differential GPS Sensor. The sensors used for DGPS are low cost sensors with an accuracy below 5m. The differential signal is provided by a low frequency AM Radio Beacon. The PC provides the digital map and of course the application that drives the HMI.

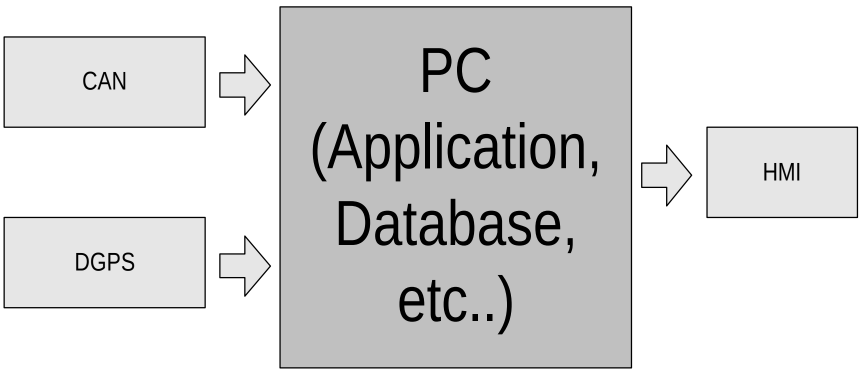

Figure 2: BMW client hardware architecture.

Software architecture

Figure shows the software architecture used today that has to be adapted to the new MAPS&ADAS interface. Once the map-matching starts to have good, reliable matches within the database, the database API can provide the necessary data to the curve speed assistant.

In case of a change of the velocity via a speed sign the curve speed assistant will adapt the driven velocity to the velocity given by the speed limit. In case of adapting the velocity to the road geometry, the curve speed assistant compares the actual speed to the speed for approaching the curve as calculated by the curve speed assistant. This geometry based speed limit is used to warn the driver from entering the curve too fast.

For MAPS&ADAS, the existing curve speed assistant software is using an ADAS compliant map given by NAVTEQ and will be processed by the SDAL/look-aside conversion module.

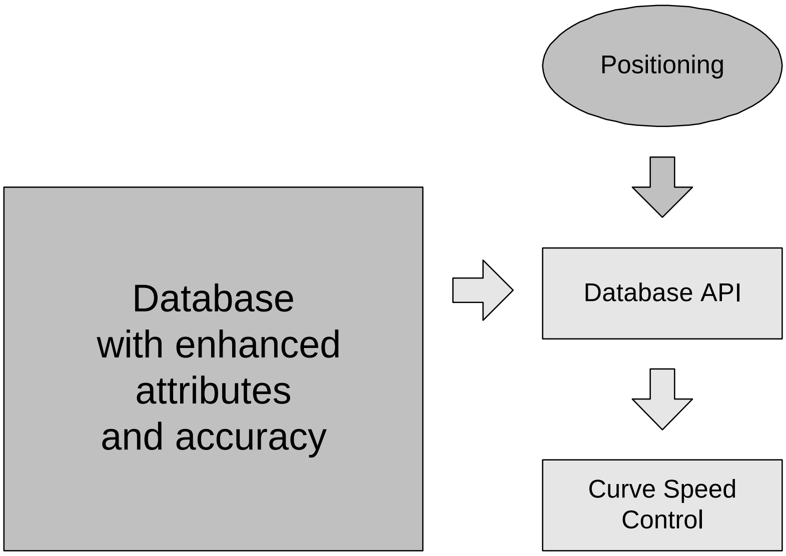

Figure 3: BMW client software architecture.

Test vehicle

BMW uses an X5 car as test vehicle. The MAPS&ADAS interface, PC, the DGPS receiver, the information system and the sensors will be installed in the vehicle. The display will be mounted on the dashboard. Technical tests with the MAPS&ADAS interface and the vehicle will be performed by verifying that the expected outputs are presented to the driver in the expected order (will be defined in the validation plan). The main parameters for speed estimation as already mentioned speed signs on roads or, in case of the geometry, the curve radius, the change of direction of a turn and the roadway type, e.g. the estimated (safe) speed will be compared with the recommended map speed.

4.3 Vertical Sub Projects (VSPs) and data requirements

MAPS&ADAS will support four VSPs within the PReVENT Integrated Project. These projects focus on developing and validating map enabled driver assistance applications and plan to use the MAPS&ADAS interface and the enhanced digital map containing safety related information. The consolidated data requirements for all VSPs are summarized in table A.6.1.

The following chapters present an overview of the four different PReVENT VSPs for a better understanding of the role that enhanced map databases and digital map access will play.

4.3.1 WILLWARN

WILLWARN develops a system for on-board hazard detection, in-car warning management, and decentralised warning distribution by communication between moving vehicles on a road network.

Positioning and maps are used to determine which messages transmitted from other vehicles are relevant to the own vehicle. These so called relevance checks shall be performed on the basis of known position (and history trace) of the sending vehicle and the current position and intended path of the receiving vehicle.

The latter implies that there should be an access to the navigation map and a preview of the track to be driven within the next minutes (if available). On the other hand, the major problem about WILLWARN is that inter-vehicle communication will only work if the employed technology is simple and cheap and the equipment rate is reasonably high. Consequently, the main focus is on simple solutions for relevance checks that even need no navigation and digital maps at all but only use GPS position chains. Advanced systems may be based on navigation systems and digital maps.

The following figures shall illustrate the proceeding for the two possible variants the message receiving vehicle may be equipped with (GPS only or GPS+MAP preview):

1. vehicle is only capable of recording past position points and matching a received trace onto this past trajectory.
2. receiving vehicle is additionally capable of predicting its own intended track by means of a navigation system digital map preview - then, the own track used for matching may be extended by also using the 'intended track'.

The latter will result in a greater stretch of track overlap and consequently result in a higher detection quality. The two setups are illustrated in figure 4 and 5..

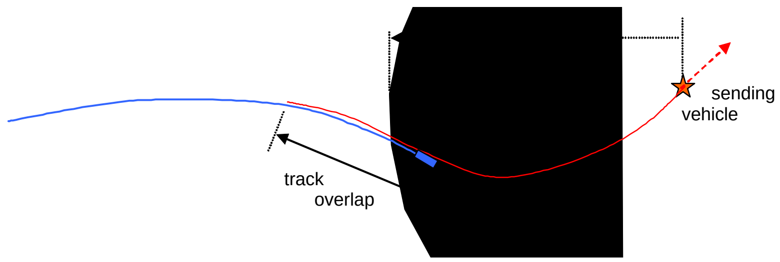

Figure 4 : Following vehicle uses only driven track to detect match.

In case 1 the overlap between the transmitted track data (red) with limited backward extension and the receiving vehicle's track (blue) is relatively short, giving less certainty of really following the same path. These conditions would be different for case 2 where the receiving vehicle is capable of additionally using a predicted track.

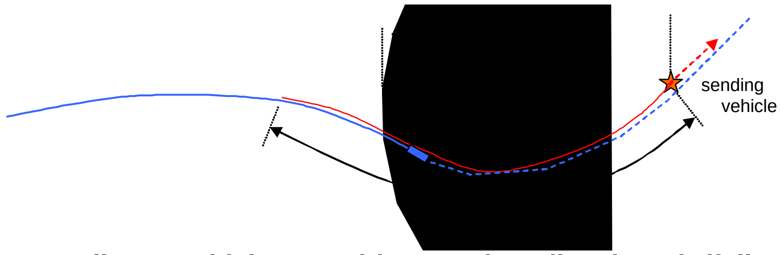

Figure 5: Follower vehicle uses driven *and* predicted track (full and dotted blue lines)

As can be immediately understood by examining the figures, extending the track overlap by track prediction will increase matching reliability, especially when the prediction extends unto the event location itself.

The more sophisticated system option (2) needs an interface to receive the track preview information from a map based system, being the contribution of MAPS&ADAS to the WILLWARN Sub-Project.

Key items for the position (and eventually map)-based relevance check algorithms are the functions of:

- **Trace Point Casting** – i.e. the optimal geometrical representation of vehicle trace by eliminating position points with redundant information (see figure 6),
- **Trace Matching** – the matching of own GPS-positions onto a received trace point chain.

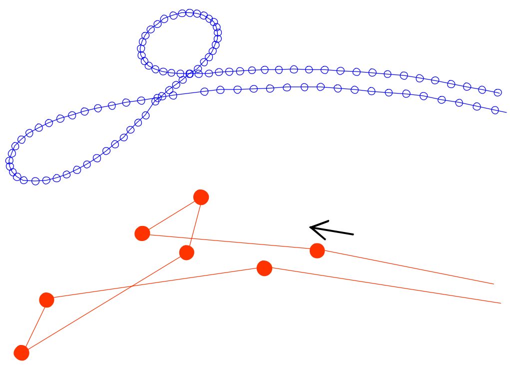

Figure 6: Position trace (top) and cast trace points representing vehicle's driven path (bottom)

For these tasks, position representation form and accuracies as available today and as specified by the MAPS&ADAS SP are fully sufficient. Consequently, besides the requirement for

- Relevance checks through map horizon and preview function,

additional attributes extractable from maps may give added value to WILLWARN applications. Especially attributes informing about possible road hazards ahead are useful here, for example:

- dangerous hotspots / frequent accident locations (speed and weather depending)

- traffic signs warning of potential dangers (speed and weather depending)
- specific road attributes for trucks or high center of gravity vehicles
- singular (difficult/dangerous) road geometry for preview

The benefits derivable from a coupling to a map system are:

- A WILLWARN system with autonomous map based functions could be sold better when equipment rates are low.
- WILLWARN relevance checks can be improved through MAPS&ADAS.

4.3.2 SASPENCE

The main goal of SASPENCE is to develop and evaluate an innovative system able to perform the Safe Speed and Safe Distance concept, that means to aid the driver in avoiding accident situations related to excessive speed or too small headway. So, the system should co-operate seamlessly with the driver, suggesting the proper velocity for the given condition (road structure, traffic situation, etc. – such as: dangerous curve ahead, frontal obstacles,) preventing risky and dangerous situations (due to wrong and inappropriate distance and speed for that particular scenario) and thus avoiding collision. This system concept will be implemented in two demonstrator vehicles, showing the benefits on safety impact by means of a set of tests on real roads.

In detail, the main objective of the SASPENCE can be split into:

- Development and evaluation of the Safe Speed & Safe Distance application (as aforementioned), fitted for the two test vehicles, considering the different system configuration and taking into account the real external situation, as well as the technical limitation of the system itself (i.e., due to the sensorial system constraints). In particular, new criteria will be taken into account for the assessment of the safety impact of the Safe Speed & Safe Distance concept in the on-road traffic scenarios.
- Design and development of the proper HMI channels, especially the tactile accelerator pedal with a specific attention in warning strategies and criteria selection, which has to satisfy not only the issues to be always “on demand”, private and personalised, but also ‘lean and efficient’ .

The system performance and reliability will be based on the selected sensorial system and on the relative strategies for the data fusion, as well as on optimal reference manoeuvre plans (which considers both obstacles and curves ahead) and related comparison with real driver’s behaviour. In order to reach an accurate external scenario detection, a combination of sensor information will be used:

- the radar sensor's direct object detection capability
- the radar sensor's overlaid communication signal (in order to fit critical scenarios such as oncoming vehicles in rural roads hardly detectable by ‘ordinary’ sensors)

- image processing data from camera
- information from enhanced digital maps (and the navigation system)

In particular, specific algorithms for the scenario assessment and sensor data integration will be developed for an enhanced environment perception; algorithms for manoeuvre planning according to safe-optimal criteria will be surveyed and implemented in order to best assess the risk level and provide indication of safe distance and speed (according to all possible threats identified in the scenario).

Relation to MAPS&ADAS

SASPENCE functionality is critically dependent on an accurate description of the road ahead as contained in enhanced digital maps. Information about speed limits, dangerous curves, road geometry, upcoming intersections and right-of-way regulations will be blended into the SASPENCE environment interpretation to generate proper warnings to the driver.

MAPS&ADAS will provide this information about the roads ahead through a standardized interface (via a car-bus) from a navigation system with an enhanced digital map to the SASPENCE system.

4.3.3 SAFELANE

The goal of SAFELANE is to develop the technology for a safe, reliable, highly available, acceptable and legally admissible onboard lane keeping support system for use in commercial and passenger vehicles on motorways and rural roads. The system reaction in critical lane departure situations comprises the control of warning actuators and an active steering actuator. The input to the system comes from cameras, which are supplemented by active sensors (e.g. radar, lidar), vehicle CAN bus data, digital road maps and a precise vehicle positioning. The essential contribution to the new quality of the approach comes from:

- A decision component that analyses the incoming sensor data, detects the lanes, determines the relevant situation, predicts vehicle paths, computes the most likely vehicle trajectory and synthesises data for controlling the system actuators. For this, a flexible model based technology is envisaged. It allows the system to be adaptive to several situations and to be configured to different sensors or actuators. An essential feature is a self-assessment that tells the driver in each situation how reliable the support is he gets.
- The fusion of the camera-based lane detection system with other supplementary data, especially the information derived from the path prediction and precise vehicle trajectory calculation, will - together with the model-based approach - create a system with substantially improved lane tracking availability and reliability. In addition to vehicle-side technologies, special lane or infrastructure elements suitable for automated detection are considered.

- In addition, with active steering available, the system may enhance the safety by actively supporting the driver in avoiding unintended lane or road departures.

Relation to MAPS&ADAS

SAFELANE functionality strongly depends on an accurate description of the road ahead as contained in enhanced digital maps. Information about speed limits, number of lanes, curves, road geometry, will also be used within the SAFELANE environment interpretation to perform accurate path prediction for proper lane –tracking capability.

For those data requirements which are specific for the lane keeping related functionalities in SAFELANE and the truck specific requirements two issues are important:

- In general, the data requirements reflect the need for guidance and redundancy for the vision and radar systems in determining lane position for the host vehicle and its road- & traffic environment. Information about the road, lane, lane dividers, slope, banking, etc. will facilitate the task of the SAFELANE system and make it more reliable.
- For heavy vehicles (trucks and buses), information about slope and banking is important because of their different size, mass and dynamics. Information about the maximum height, width and buoyancy for different lanes would create the possibility to avoid dangerous road- or lane choices for these vehicles.

MAPS&ADAS will provide this information about the roads ahead through a standardized interface (via a car-bus) from a navigation system with an enhanced digital map to the SAFELANE system.

4.3.4 LATERALSAFE

The three objectives of LATERALSAFE are to develop and validate:

- A lateral and rear area monitoring application enhancing the driver's perception and decreasing the risk of collision in the lateral and rear area of the vehicle; in particular when the driving task is critical because of limited visibility or critical workload of driver's attention.
- A lateral collision warning application that detects and tracks obstacles in the lateral and rear field and warns the driver about an imminent risk of accident (collision, road departure, merging etc.). This application can be a stand-alone system or improved by the surrounding model developed in the monitoring application.
- A stand-alone lane change assistance system with integrated blind spot detection assisting the driver in lane change manoeuvres while driving on roads with more than one lane per direction.

Existing sensing systems can identify the presence of obstacles and are able to support the driver, generally, in front of the vehicle or only on "single slices" of the scenarios around the vehicle. Consequently, different sensor technologies need to be integrated today in the vehicle in order to cover the complete area around it and to provide a complete support in all traffic and environmental scenarios and in particular in urban congested situations.

LATERALSAFE intends to allow the extension of the operative scenarios of the Assistance Systems beyond their current limits and to advance the actual development and implementation of data fusion techniques. The envisaged lane change assistance and collision warning system will be based on short- and long range radar sensors and is aiming for a rear view with sufficient driver warning time for approaching vehicles with high relative velocity (more than 100 km/h) and a direct measurement of absolute speed of approaching vehicles greater than 200 km/h. With this performance most overtaking situations on highways should be covered. A warning should alert the driver when he is changing lane before the lane crossing of the vehicle. Also, Blind Spot Detection down to Zero Speed will be integrated which will extend usability also to urban area environments.

<u>Relation to MAPS&ADAS</u>

Among others, LATERALSAFE functionality is relying on an accurate description of the road ahead as contained in enhanced digital maps. Information about speed limits, number of lanes, curves, road geometry, will be used for the LATERALSAFE environment interpretation to generate proper warnings and corrections to the driver.

MAPS&ADAS will provide this information about the roads ahead through a standardized interface (via a car-bus) from a Navigation System with an enhanced digital map to the LATERALSAFE system.

4.3.5 INTERSAFE

Representatives from the INTERSAFE project supplied additional information during the PReVENT General Assembly on Wednesday, 19 May 2004, about the potential use of high precision digital map (or sensor-specific feature level maps). It was agreed that the INTERSAFE subproject will provide to MAPS&ADAS their map and positioning requirements by the end of their activities. Therefore, these specific requirements will not be integrated in MAPS&ADAS Deliverables D12.31 and D12.32.

5 Context of defining map requirements

When formulating map data requirements for driver assistance systems both the technical prerequisites and the economic context of map provision and update should be taken into account. These considerations are of utmost importance as PReVENT focuses on the early deployment of safety applications. This approach must be followed to have a significant positive impact on road safety before the end of the decade.

The feasibility of production and maintenance of enhanced map databases enabling driver assistance systems has technical, economical and commercial aspects. The NextMAP project did not fully elaborate the economic feasibility aspects as no commercial and business models were considered. However, the stated cost indexes for the production of enhanced digital maps generally indicated that high investments would be required for their realisation. A major difference between NextMAP and MAPS&ADAS is that the latter project aims to explore the feasibility of the provision of safety related map content by public authorities. NextMAP assumed that map makers would collect the required data and make the necessary updates to the digital maps. This difference might have significant impacts on costs and will be explored in WP12600 (*Business model*).

A correct assessment of technical matters related to driver assistance systems is essential when formulating (map) requirements. Over-definition of map database requirements by engineers is a phenomenon which is frequently observed (‘Engineers’ view’). A typical example of this is the request for sub-meter accurate road geometry in digital maps (in absolute terms), e.g. for the precise location of a vehicle in a lane in combination with a high end differential GPS system. A more realistic view of future positioning performance figures (despite GPS, Galileo, EGNOS, differential signal services etc.) will probably lead to the development of systems where information from different sensors is fused to augment the performance by eliminating the weaknesses in individual sensors. In the ‘lane’ example above, it is believed that the option of lane detection via a camera, combined with consumer grade GPS positioning and current map geometry, but enhanced with number of lane information for the road, could very well meet the functional requirements of the envisaged driver assistance system.

6 Conclusions

This version of the document summarises the safety related map requirements common to a general collection of map supported driver assistance systems. It was observed that almost all map data requirements for safety related information collected from application-oriented subprojects within the PReVENT scope are contained in this collection.

These ‘safety digital map requirements’ will be a guideline in the PReVENT SWP 12500 (*Data Sourcing*) which aims to establish the sourcing of the specific map data. Further work within the MAPS&ADAS project (e.g. SWP12600), and input from other projects such as SpeedAlert (Oct2004) [4] and EDMAP, will lead to the revision and update of this document.

7 References

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Annex 1 Keywords

Digital map

Map requirements

ADAS

Annex 2 Glossary

Term	Definition
ACC	Advanced Cruise Control
ADAS	Advanced Driver Assistance System
ADASIS	Advance Driver Assistance Systems Interface Specifications [2]
AFS	Adaptive Front Lighting System
AH	ADAS Horizon. ADAS Data Model and structure entity representing a data container for storing segments, points and attributes that are in the vicinity of the current vehicle position
AGMP	ADASIS Generic Message Protocol. An abstract, implementation independent protocol that defines the messages that are sent over some (in-vehicle) transport medium. Based on this message (layer) a specific bus- or system-dependent implementation can be realized (e.g. for the CAN bus).
API	Application Programming Interface
GDF	Geographic Data Files version 4.0, ISO 14285 [5]
GNSS	Global Navigation Satellite System
ITS	Intelligent Transport Systems
NextMAP	EC research project on enhanced map databases for ITS including ADAS
SWP	Sub Work Package
VSP	Vertical Sub Project. Projects in the PReVENT Integrated projects focusing on one driver assistance application.

Annex 3 ADAS applications

Table A.3.1. The definition of a number of ADAS applications which have been developed by the EU funded project NextMAP, see references. Also indicated are those map enabled driver assistance applications that will be studied in PReVENT.

Application	Application description	PReVENT
Adaptive Cruise Control (ACC)	? Automatic control of speed and distance in relation to the preceding vehicle in the same lane ? longitudinal control ? v > 60km/h ? tracking of leading vehicle ? moving obstacles recognition	
Adaptive Light Control (ALC)	Dynamic swivelling headlamps and situation adaptive lighting (e.g., urban, highways, country)	
Autonomous Driving	Fully automatic driving	
Collision Warning	Warns the driver in case a collision may occur	LATERALSAFE
Collision Avoidance	Warning and avoidance of a pending collision	
Curve Speed Warning	Warns the driver before entering a curve too fast, predicts lateral acceleration in curves based on road geometry	
Curve Speed Control	Controls the speed in curves, calculates curve speed based on road geometry and attributes	MAPS&ADAS SASPENCE
Fuel Consumption Optimi-sation	Adjusts speed for reason of lower fuel consumption, calculate fuel consumption based on road geometry and speed attributes	
Heavy Trucks ACC	? longitudinal control ? distance keeping ? v > 60km/h ? moving obstacles recognition ? tracking of leading vehicle ? limited acceleration and deceleration	
Lane/Road Departure Warning	Assists the driver to stay on the road / within the lane. Informs the driver (for example with a rumble noise) that he is departing the lane unintentionally.	LATERALSAFE
Lane Keeping Assistant	Assists the driver constantly to stay in a lane. E.g., if the driver departs the actual lane (without any turn signals on) he will feel some force feedback in the steering wheel.	SAFELANE
Path Prediction	Predicts drivable alternatives in the road network and assigns probabilities if the driver will take them (even if the driver is not using route guidance)	
(Hybrid) Power Train Management	Assistance to the driver for comfort driving, the control strategies take into account curves and slopes of the road in front of the vehicle. Information on allowed speed	
Speed Limit Assistant	Assists the driver in choosing the correct speed in speed limit sections	MAPS&ADAS
Stop & Go (S&G)	Assist the driver in typical Stop & Go situations, typically at travel speeds below 60 km/h. The Stop & Go Assistant can handle various situations: ? longitudinal control ? wide range radar	

	? v < 60 km/h ? recognition of relevant obstacles ? recognition of stationary targets	
Vision enhancement	Improvement of vision in adverse lighting and weather conditions perceiving (by instrumental means) what the human eyes cannot see and providing to the driver enhanced visual information. Build-up of the scenario in front of the vehicle in critical environment (darkness, fog, etc.)	
Visual and Audible Driver Assistance	Gives audible and visual information before passing potentially dangerous spots depending on intelligent selection algorithm (urban). Stores information to determine if a potentially dangerous spot, like traffic signs/ installations, number of lanes, etc. lies ahead.	MAPS&ADAS (HotSpot warning based upon accidentology data) WILLWARN

Annex 4 Terms and Definitions

Table A.4.1: GDF 4.0 Terminology

GDF 4.0 Data Entity	Definition
Alternate Name	The name of a feature which has no official status but is used or known by the general public.
Blocked Passage	Indication of a physical obstruction on a Road Element.
Construction Status	Whether a feature such as a Road Element is currently under construction or in the planning stage.
Direction of Traffic Flow	The direction(s) of traffic flow allowed on a Road Element or Ferry Element.
Enclosed Traffic Area	An Enclosed Traffic Area is any confined area within which unstructured traffic movements are allowed. Example: a piazza in the centre of small Italian cities.
Enclosed Traffic Area Type	The type of enclosed traffic area
Ferry Connection	A Ferry Connection is a vehicle transport facility between two fixed locations on the road network, which uses a prescribed mode of transport, for example ship or train.
Form Of Way	Certain aspects of the physical form that a Road Element takes. It is based on a number of certain physical and traffic properties. Examples: • Part of a Motorway • Part of a Roundabout Circle • Part of a Pedestrian Zone
Freeway	Indicates whether a Road Element is part of a Freeway.
Functional Road Class	A classification based on the importance of the role that the Road Element or Ferry Connection performs in the connectivity of the total road network.
Grade Separated Crossing	A relation between exactly two Transportation Elements and one Structure representing parts of the road, railway or waterways network that passes directly over each other. For example, this relationship can be applied if a motorway passes over a local road without crossing each other.
Intersection	Is a complex feature composed of one or more Junctions, Road Elements, or Enclosed Traffic Areas. For example, a big motorway crossing, that consists of many Junctions and Road Elements can be represented as a single Intersection.
Intersection Type	The classification of an Intersection.
Junction	A junction is a feature that bounds a road element or a ferry connection.
Junction Type	The classification of a junction
Lane Dependent Validity	An attribute which is only valid for a restricted number of traffic lanes of the associated Road Element.
Number of Lanes	The number of lanes existing on a Road Element.
Official Name	The name assigned to a particular feature by the official organisation responsible for the existence and the maintenance of the feature.
Opening Period	The period in which the function of an associated feature is available to the public
Pedestrian Crossing	A specially marked location of a Road Element where pedestrians are privileged to cross the street, with or without signs or traffic lights and with or without a zebra crossing.
Positional Accuracy	An indication of the accuracy of the associated Feature.
Prohibited Manoeuvre	A Manoeuvre, which is physically possible but which is prohibited by means of legal measures, as denoted by traffic signs.
RDS-TMC	The RDS/TMC Code belonging to a feature as agreed by the RDS/TMC coding organisation.

GDF 4.0 Data Entity	Definition
Restricted Manoeuvre	A manoeuvre, which is explicitly permitted by means of legal measures, as denoted by traffic signs.
Road	Is a complex feature composed of one, many or no Road Elements. For example, a stretch of motorway consisting of two physically divided carriageways (and consequently multiple road elements) can be represented as a single Road. A Road always forms a connection between two Intersections.
Road Conditions	Specification of the state of the surface of the associated Road Element.
Road Element	A road element is a linear section of the earth, which is designed for, or the result of, vehicular movement.
Route Number	The route number of a Road Element or Ferry Element. The Route Number is the ID-number of a particular route in a given road network as attributed by a national, sub-national or international organisation (e.g. the E-roads in Europe).
Service	Service is a generic term for an activity at a specific location. It is important to notice that a Service represents an activity and not the building in which this activity (possibly) takes place.
Service Along Road Element	Services that are situated along a particular Road Element.
Service At Junction	Services that are situated at a particular Junction.
Service belonging to Service	Services that functionally belong or are related to a particular Service.
Signpost Information	A collection of boards and plates that are physically attached and which contain directional information
Special Restriction	Special legal restrictions placed upon the use of a particular Road Element.
Speed Restriction	The maximum speed limit allocated to a Road Element.
Structure	A Structure is a significant construction that is part of a transportation network, such as a bridge, a tunnel or a retaining wall.
Structure Type	The classification of a Structure.
Toll Road	A Road Element, which requires an access toll to be paid.
Traffic Light	A multi coloured light governing the traffic flow.
Traffic Light in -/+ direction of Road Element	A traffic light that is relevant for traffic moving in a negative/positive direction of the Road Element, i.e. from End point to Start point/from Start point to End point.
Traffic Sign	A board containing symbols and (possibly) some additional text, expressing a traffic restriction, recommendation or information.
Traffic Sign Class	The classification of traffic sign
Traffic Sign in -/+ direction of Road Element	A traffic sign that is relevant for traffic moving in a negative/positive direction of the Road Element i.e. from End point to Start point/from Start point to End point.
Traffic Sign Information	A description of the information contained in a traffic sign. The information should comprise the information contained in the traffic sign itself, as well as supplementary information present on e.g. additional text plates.
Travel Time	The one-way travel time that a ferry connection takes to complete a journey.
Validity Period	An attribute which is valid for a restricted period of time.
Vehicle Type	An attribute which is only valid for a restricted number of vehicle types.

Table A.4.1: Anticipated terminology for upcoming GDF 5.0

GDF 5.0 Data Entity	Definition
Connectivity	Representation of connectivity between lanes across junctions are based on a directed Manoeuvre of the incoming ("From") Road Element, a Junction to indicate the direction, optional intermediate ("via") Road Element(s), and the outgoing ("To") Road Element.
Give Way Regulation	A Manoeuvre at the end of which a driver must give way to other intervening traffic.
Lane Info	Information associated with individual lane(s) of a Road Element. Composite attribute consisting of many sub-attributes.
Lane Dependent Validity	Sub-attribute of Lane information to indicate for which lane(s) the other sub-attributes apply
Lane Type	Sub-attribute of Lane information to indicate the type of lane.
Lane Divider Type	Sub-attribute of Lane information to indicate which divider is inbetween the current and the next lanes.
Direction	Sub-attribute of Lane information that stores which direction arrows are painted on the lane relative to the travel direction.
Overhead Structure along Road Element	The indication of a linear Structure spanning a Road Element or part of it.
Pedestrian Crossing Along Road Element	The presence of a Pedestrian Crossing along a Road Element.
Pedestrian Crossing Priority	The priority of a Pedestrian Crossing in relation to cross traffic.
Pedestrian Crossing Signage	The signage present at a Pedestrian Crossing.
Pedestrian Crossing Type	The type of Pedestrian Crossing with respect to its physical appearance.
Right Of Way Regulation	A Manoeuvre, which has the right of way over other intervening traffic.
Road Furniture Position	The position of a Road Furniture relative to a Road Element.
Road Under Structure	Identifies a Road Element that is entirely underneath or within a Structure whose dimensions are not negligible in regards to its coverage of the Road Element.
Speed Measuring Unit	The unit in which sign-posted speed values are measured.
Structure Abutment	Identifies constructive parts of a Structure directly alongside a Road Element.
Traffic Light Info	The Traffic Light Info permits to specify the driving direction to which a number of special traffic light apply and where these signalling units are positioned relative to the road.
Traffic Light Regulation	Which Road Element entering a Junction is regulated by a Traffic Light.
Tram Crossing (Value of Attribute Junction Type)	A tram crossing is a crossing at grade between a road and a tramway.

Table A.4.3. Some of the data requirements cannot be expressed by GDF terminology, in particular the application-related data entities or other entities not (yet) covered by GDF.

Data Entity	Definition
Banking class	Specifies several classes of tolerances for the banking of roads, between +/- 7% and +/- 1%.
Braking visibility	It is an attribute of the whole database and refers to any information content needed to judge restricted visibility. Visibility refers to the capability of viewing into the distance.
Curvature	In mathematics, the rate of change of the direction of a curve with respect to the distance along the curve. In NextMAP defined as 1/radius. For this specification, the NextMAP definition is applied.
Heading change at junction	Is the angle between the incoming road element and each outgoing road element at a given junction
Entry / Exit angle at Junction	This is the angle between the true north and a road element that is entering/exiting a Junction.
Estimated position	The most probable position of the vehicle, based on sensor information and algorithms, e.g. specified as WGS84 co-ordinate pair. The position is not necessarily located on a segment in the road network. Note that map matching may still have been used, for instance for calibrating sensors or resetting dead reckoning.
Estimated position accuracy	Indicates the amount of tolerance to be expected in the estimated position.
Lane Category	Alternative to the GDF attribute Number of Lanes. The number of lanes is not specified as accurate number but by certain ranges. E.g. 1 lane, 2-3 lanes, 4 and more lanes.
Map Matched Position	The most probable location of the vehicle on a part of the road network of a digital map based on sensor information, algorithms and a digital map, e.g. on the second shape point of a road element 4711. If the probability of such a position is too low, there need not be a Map-matched position.
Map Matched position accuracy	Indicates the amount of tolerance to be expected in the Map Matched Position.
Map matched position index	Assignment of an index to the Map Matched Position to enable connecting points for multiple trajectories

Data Entity	Definition
Map Matched /estimated position integrity	Positioning Integrity is a measure of trust, which can be placed in the correctness of the positioning information supplied by the total system. Positioning Integrity includes the ability of the system to provide timely warnings to the user when the system should not be used for the intended operation. For ADASIS purposes, positioning integrity is defined as follows: the probability of the correctness of the supplied position information (including accuracy). Since this probability is very hard to estimate, across the ADASIS interface only integrity indicators (i.e. a reliability level) are supplied as indicators in the following fashion: *GNSS integrity indicator:* I – Position was determined with a GNSS - 3D fix (4 or more satellites in good constellation) for at least the last 60 seconds. Hence latitude, longitude, and altitude can be determined correctly. II – Position was determined with at least a GNSS - 2D fix for at least the last 60 seconds (including perhaps for some period a 3D fix, but not over the complete period). Hence latitude and longitude can be determined approximately, using assumed altitude, and a possibility exists for inaccuracies due to wrong altitude value. III – Position was determined without a GNSS fix for some period in the last 60 seconds *Dead-reckoning integrity indicator:* I – Position was determined with aligned GNSS fix and dead reckoning for at least the last 60 seconds, GNSS and dead-reckoning agree on position, no reflections in GNSS /drift in DR sensors influences II – Position was determined with dead reckoning for at least the last 60 seconds, but GNSS fix and dead reckoning where not always aligned in last 60 seconds, due to reflections/GNSS intermittent failure of reception/drift in sensors, disconcordance dead-reckoning estimate and GNSS fix occurred. III – Position was determined without dead reckoning for some period in the last 60 seconds *MAP integrity indicator:* I – Position in fully digitised map area II – Position in partly digitised map area III – Position outside digitised map area
No explicit Sign	A priority regulation that is not explicitly indicated but implicitly via law, e.g. right before left in Germany, all way stop in US.
Probability of travel of a road element (static and dynamic)	Indicates the likelihood that the car will choose a certain road element as a continuation of travel given the current position of the car. **Static**: This probability may come from a planned route, and/or an assessment of the most likely continuations based on characteristics of the road elements and their relative interconnection. **Dynamic**: Probability based on adaptation of the static probability according to car dynamics parameters (e.g. speed, heading).

Data Entity	Definition
Slope	It is the division of the vertical elevation by the horizontal translation expressed as a percentage.
Timestamp of Estimated position	The moment in time when the vehicle was expected to be at the estimated position.
Timestamp of Map Matched position	The moment in time when the vehicle was expected to be at the Map matched position.
Vehicle acceleration	The rate that the vehicle’s speed is changing.
Vehicle heading	The direction that the vehicle is moving. It includes at least the direction in the horizontal plane and may be enhanced with a vertical component.
Vehicle speed	The rate that the vehicle’s position is changing in the direction of the vehicle heading. Note that the vehicle speed can either be measured in the horizontal plane or in 3 dimensions.
Vehicle yaw rate	The rate that the vehicle heading is changing measured in the plane local to the vehicle.
Vehicle Status	Information about properties of a car, such as vehicle type, number of passengers, trailer, dangerous goods loaded that is available from additional in-vehicle sensors. These properties are not static and may change during the drive.

Annex 5 Data elements table

Table A.5.1: Data Requirements for first generation ADAS Interface Specification versions. The data requirements are expressed in the form of a table using the following columns:

- Data Entity: This column specifies the name of the data entity using the terminology as described in chapter **Error! Reference source not found.**.
- Source: Describes whether the Data Entity comes from the:

  Map – data from digital map database, with the sub-categories:

    G – Geometry

    F – Feature

    A – Attribute

    R – Relationship

  System – data from sensors or data calculated by the system
- Available today: Specified whether this particular data entity is available from today's map databases or systems.

  'Yes' means the data entity is generally available today

  An empty cell means the data entity is not available today
- Accuracy today: Specifies the range of the relative accuracy of the data entity available today.
- Resolution: Specifies the smallest distance unit that shall be used for representing the data entity.
- Remarks: Clarifying comments.

Data Entity	Source	Available	Accuracy	Resolution	Remarks
		today	today		
Latitude / Longitude (Shape)	Map G	Yes	20m-5m	1 decimetre	Shape as function of the track length, not continual but discrete function, i.e. provide the position in x metres [1]
Curvature	Map G	calculated from shape	low accuracy		Curvature as function of the track length, not continual but discrete function, i.e. provide the curvature in x metres[1].
Road Element	Map F	Yes	20m-5m		
Speed Restriction	Map A	partly	N/A		Speed restriction as function of track length, not continual but discrete, i.e. provide the speed restriction in x metres (when changing the next time in the map)
Number of Lanes	Map A	partly	N/A		
Lane category	Map A	partly	N/A		
Lane Information	Map A	partly	N/A		Composite attribute
Lane Dependent Validity	Map A	partly	N/A		Sub-attribute of Lane information to indicate for which lane(s) the other sub-attributes apply
Lane Type	Map A	partly	N/A		Sub-attribute of Lane information. Following attribute values are specified: – Exit/Entrance Lane – emergency lane – shoulder lane – lay-by lane – overtaking lane

[1] Some ADAS applications are interested only in curvature and not in shape, while others are interested in shape and not in curvature, therefore both representations need to be supported by the ADAS interface specification.

Lane Divider Type	Map A	partly	N/A		Sub-attribute of Lane information. Following attribute values are specified: – dashed line (long line sections) – double solid line – single solid line – combination of (inner) single solid line and (outer) dashed line – combination of (inner) dashed line and (outer) single solid line – dashed line (short line sections) - physical divider - shaded divider area
Direction	Map A	partly	N/A		Sub-attribute of Lane information. Following attribute values are specified: – no direction indicated – ahead – between ahead and right – right – between right and backward – backward (u–turn) – between left and backward – left – between ahead and left – merge into right lane (lane ends) – merge into left lane (lane ends) – merging lanes (no priority lane)
Road Conditions	Map A	Yes	N/A		E.g. pavement of roads
Direction of Traffic Flow	Map A	Yes	N/A		
Blocked Passage	Map A	Yes	N/A		Will not be directly delivered but considered by the AHP when constructing the horizon

Vehicle Type	Map A	Yes	N/A		Restrict validity of Direction of Traffic Flow, Blocked Passage attributes to certain classes of vehicle; will not be distributed via ADASIS, but taken into account to build ADAS horizon
Validity Period	Map A	Yes	N/A		Restrict the validity of Direction of Traffic Flow, Blocked Passage attributes to certain times; will not be distributed via ADASIS, but taken into account to build ADAS horizon
Positional Accuracy	Map A	Yes	N/A		In the ADAS horizon it is an attribute of each feature. Today vendor-specific classification, to be modified according to the needs of ADASIS into accuracy classes
Freeway	Map A	Yes	N/A		
Functional Road Class	Map A	Yes	N/A	max 8 classes	Does not allow plug and play when changing system provider. Generated for route planning and not for ADAS. Describes the (subjective) importance of a road in the network. E.g. in an area with a sparse network a secondary road can have the same functional road class as a motorway in an area with a dense network. Furthermore, the system vendors often extend the functional road class by own values. For ADAS other attributes are more usable such as freeway, form of way etc.
Form Of Way	Map A	Yes	N/A		Subset of attribute values is useful for ADAS: Part of a Motorway; Part of a Multiple Carriageway which is not a motorway; Part of a Single Carriageway; Part of a Roundabout Circle; Part of a Slip Road;
(ISO Country Code)	Map A	Yes	N/A		will be delivered as metadata (see section 3.4)
(Driving side)	Map A	Yes	N/A		country-specific, will be delivered as metadata (see section 3.4)
Route Number	Map A	Yes	N/A		
Ferry Connection	Map F	Yes	N/A		
Junction	Map F	Yes	20m-5m		Only implicitly supported via Junction attributes such as Junction Type
Junction Type	Map A	Yes	N/A		E.g. mini roundabout; border crossing, railway crossing

Entry / Exit angle at Junction	Map A	Yes	low		Today to be calculated from the shape
Heading change at Junction	Map G	calculated from shape	low accuracy	1 degree	Is the angle between the incoming road element and each outgoing road element at a given junction; to avoid gaps in curvature
Structure	Map F	partly	see remarks		In GDF 3.0 it was called Brunnel Type available for bridges, tunnels with a minimal length (vendor-specific)
Structure Type	Map A	Yes	N/A		In GDF 3.0 it was called Brunnel Type
Topology	Map R	Yes	N/A		implicit relation in the GDF data model
Restricted Manoeuvre	Map R	Yes	N/A		
Prohibited Manoeuvre	Map R	Yes	N/A		
Road Element in Build-up Area	Map R	Yes	N/A		Tells whether or not a road element is inside of an urban area
Estimated position, Latitude, Longitude	System	Yes		1 decimetre	From sensor with or without map (absolute position)
Map Matched Position	System	Yes		1 decimetre	Position at a road element Deliver the most probable positions, if their estimated probabilities differ less than 20%
Estimated position accuracy	System	Yes	N/A		
Map Matched position accuracy	System	Yes	N/A		
Map matched position probability	System				
Time stamp of Estimated position	System	Yes		2 ms	Remark: potential synchronisation problem if the AHP and ADAS application do not use the same or a synchronised clock

Time stamp of Map Matched position	System	Yes		2 ms	Remark: potential synchronisation problem if the AHP and ADAS application do not use the same or a synchronised clock
Estimated/map-matched position integrity	System	to be calculated	N/A		Will be delivered by means of three indicators: - GNSS integrity indicator - Dead-reckoning integrity indicator - Map integrity indicator
Vehicle speed	System	Yes	N/A		
Vehicle yaw rate (relative heading)	System	Yes	N/A		
Vehicle heading (absolute)	System	Yes		360 deg/2^{16}	
Probability of travel of a road element	System	Yes	N/A		The ADAS horizon will only include the static probability, the dynamic probability needs to be computed by the application. The static probability will be specified in a way to have comparable metric results between different systems., to be worked out by WG2 and 3 (requires field tests).
Estimated position, Altitude	System	Yes	200m-10m		available from GPS raw data
Vehicle Status	System	partly	N/A		Information is partly available in trucks and high class cars If available, the ADAS horizon provider can use Vehicle Status information when constructing the ADAS horizon, but it will not be explicitly delivered via ADASIS

Table A.5.2 : Data Requirements future ADAS Interface Specification versions

Data Entity	Source	Available Today	Accuracy Today	Remarks
Altitude (Z co-ordinate)	Map G		N/A	
Construction Status	Map A	Yes	N/A	
Tram Crossing (Value of Junction Type)	Map A		N/A	
Enclosed Traffic Area	Map F	Yes	20m-5m	
Enclosed Traffic Area Type	Map F	Yes	N/A	
Traffic Sign	Map F		N/A	
Traffic Sign Class	Map A		N/A	
Traffic Sign in +/- direction of Road Element	Map R	partly	N/A	
Traffic Sign Information	Map A	partly	N/A	
Pedestrian Crossing	Map F		N/A	
Pedestrian Crossing Along Road Element	Map R		N/A	
Pedestrian Crossing Signage	Map A		N/A	

Pedestrian Crossing Priority	Map A		N/A	
Pedestrian Crossing Type	Map A		N/A	
Structure Abutment	Map F		N/A	
Traffic Light	Map R		N/A	
Traffic Light in+/- direction of Road Element	Map R		N/A	
Traffic Light Info	Map A		N/A	
Traffic Light Regulation	Map A		N/A	
Road Furniture Position	Map A		N/A	
Right Of Way Regulation	Map R	partly	N/A	
Give Way Regulation	Map R		N/A	
Road Under Structure	Map R		N/A	
Overhead Structure along Road Element	Map R		N/A	
(Lane) Connectivity	Map R	partly	N/A	The data model of version 1 needs to be extendible for lane connectivity.
No explicit Sign (no GDF)	Map		N/A	will be supported only in a very future version
Braking visibility (No GDF)	Map		N/A	will be supported only in a very future version
Banking class (No GDF)	Map		N/A	

Slope (No GDF)	Map		N/A	Profile attribute, to be delivered as function of the track length, i.e. provide the slope in x metres
Vehicle acceleration	System		N/A	not directly available, but can be calculated from speed/time/location
Map matched position index	System		N/A	Assignment of an index to the map matched position to enable connecting points for multiple trajectories

Annex 6 Data elements table for VSPs and MAPS&ADAS applications

Table A.6.1 Data elements for VSPs and MAPS&ADAS applications. The structure of the table follows the ADASIS interface logical model as it is presented in MAPS&ADAS D12.320 [7]. The letters in the Data Specification column indicate S for system, G for geometry, 4 for GDF4.0, 5 for GDF5.0, and M for Metadata.

Definition	Data element	ADASIS Generation	Data Specification	M=Mandatory; O=Optional	SAFELANE	LATERALSAFE	WILLWARN	SASPENSE	CURVESPEED ASS.	HOTSPOT WARNING	SPEEDLIMIT	Support D1: Will be provided D2: Additional effort/resources req. D3: Out of Scope	Accuracy	Resolution
The most probable position of the vehicle, based on sensor information and algorithms, e.g. specified as WGS84 co-ordinate pair. The position is not necessarily located on a segment in the road network. Note that map matching may still have been used, for instance for calibrating sensors or resetting dead reckoning.	Estimated position													
Longitude according to WGS84	Absolute coordinate, Longitude	1	S	M	*	*	*	*	*			D1	5-15m	dm
Latitude according to WGS84	Absolute coordinate, Latitude	1	S	M	*	*	*	*	*			D1	5-15m	dm
Positioning Integrity is a measure of trust, which can be placed in the correctness of the positioning information supplied by the total system. Positioning Integrity includes the ability of the system to provide timely warnings to the user when the system should not be used for the intended operation.	Position integrity	1	N	O	*	*	*	*	*			D1		

The moment in time when the vehicle was expected to be at the estimated position. (After the maximum value the time is set to 0 again)	Time stamp (since reference)	1	S	M				*	*			D1		
The time difference between the time-stamp for which this position is determined and the current time. Note that if the position has been extrapolated the age can be set to 0 even if it is based on sensor data that was captured some time ago.	Age	1	S	M					*			D1		
either of the above, determined by meta data	Time stamp or age	1	S	M					*			D1	depen ds on bus; e.g. 20ms	2ms
The rate that the vehicle's position is changing in the direction of the vehicle heading. Note that the vehicle speed can either be measured in the horizontal plane or in 3 dimensions.	Vehicle speed	1	N	M						*	*			
The direction that the vehicle is moving. It includes at least the direction in the horizontal plane and may be enhanced with a vertical component.	Vehicle absolute heading	1	N	O	*	*		*	*			D1 (not with accuracy)	Depe nds on GPS & vehicl e speed , gyro, 1.5°	0.35
The rate that the vehicle's speed is changing.	Vehicle acceleration	F	N	O						*	*			
The most probable location of the vehicle on a part of the road network of a digital map based on sensor information, algorithms and a digital map, e.g. on the second shape point of a road element 4711. If the probability of such a position is too low, there need not be a Map-matched position.	Map-matched position													

	Link ID	1	S	M	*	*	*		*	*	*	D1		
	Offset (m/dm)	1	S	M	*	*	*	*	*	*	*	D1	5-15m	1
Positioning Integrity is a measure of trust, which can be placed in the correctness of the positioning information supplied by the total system. Positioning Integrity includes the ability of the system to provide timely warnings to the user when the system should not be used for the intended operation.	Position integrity	1	N	O	*	*	*	*	*	*	*	D1		
	Position probability	1	S	O					*	*	*	D2		
The moment in time when the vehicle was expected to be at the map-matched position.	Time stamp (since reference)	1	S	M				*	*			D2	depends on bus; e.g. 20ms	2ms
	Age (since capture)	1	S	M					*	*	*	D1	See above	2ms
The vehicle speed as projected on the link	Vehicle speed (projected on link)	1	S	M						*	*	D1	0.25m/s above 5m/s, also tacho dep.	0.25m/s
Heading of the vehicle relative to the direction of the directed link	Heading relative to link	1	S	O	*	*		*	*	*	*	D2	5 degrees	1.43 degrees
The current lane where the vehicle is driving	Current lane	F	S	O	*	*		*	*	*	*	D3		
When multiple map-matched positions are available this index is used to create trajectories, such that the correct previous map-matched position can be overwritten	Map matched link position index		S	O						*		D3		
Part of a road with a direction, which is drivable by a vehicle. A directed link has a	<u>Directed link</u>													

start and an end point.														
	Link ID	1	S	M					*	*	*	D1		
	Length projected on horizontal plane	1	S	M					*	*	*	D1	1m	1m
Not explicitely required, see probability of travel	Part of planned route	1	S	M	*				*	*	*	D1 (some systems have no route calculation)		
Direction of Traffic Flow	Driving allowed in this direction	1	4	M					*	*		D1		
Direction of Traffic Flow	Driving allowed in opposite direction	1	4	M					*	*		D1		
An entity that is located along a link.	<u>Link attachment</u>													
	Link ID	1	S	M				*	*	*	*	D1		
	Offset	1	S	M				*	*	*	*	D1	5-15m	1m
Mandatory types are identified by their position in the field. Optional types are identified by an enum.	Attached entity type	1	S	M					*	**New Type and data structure necessary: HotSpot**	*	D1 (only definition, not content)		
See below (Attached entity types)	Attached entity value	1	S	O					*	*	*	D1 (only definition, not content)		

See below (Attached entity types)	Attached entity accuracy	1	S	O					*	*	*	D2		
An attribute which is only valid for a restricted number of traffic lanes of the associated Road Element.	Lane dependent validity	1	4	O	*	*			*	*	*	D2		
	<u>Attached entity types</u>													
Shape as discrete function of the track length.	Absolute coordinate, Longitude	1	G	O	*	*	*	*	*	*		D1	5m	dm
Shape as discrete function of the track length.	Absolute coordinate, Latitude	1	G	O	*	*	*	*	*	*		D1	5m	dm
	Altitude	F	G	O					*			D3		
Indicates the change of the heading of the directed link at the indicated offset. Can be used as an alternative for curvature and shape points	Heading change	1	S	O	*							D2	TBD (T-juncti on proble m)	1.43 degrees
A board containing symbols and (possibly) some additional text, expressing a traffic restriction, recommendation or information.	Traffic sign	F	4	O			*	*	*		*	D2		
A specially marked location of a Road Element where pedestrians are privileged to cross the street, with or without signs or traffic lights and with or without a zebra crossing.	Pedestrian crossing	F	5	O					*			D2		
The presence of a Pedestrian Crossing along a Road Element.	Pedestrian crossing along road element	F	5	O					*			D2		

The signage present at a Pedestrian Crossing.	Pedestrian crossing signage	F	5	O					*			D2		
Identifies constructive parts of a Structure directly alongside a Road Element.	Structure abutment	F	5	O		*						D3		
Property of a directed link that has a value for any location along a link	<u>Link profile</u>													
	Link ID	1	S	M					*	*	*	D1		
	Offset	1	S	M					*	*	*	D1	5m	dm
Mandatory types are identified by their position in the field. Optional types are identified by an enum.	Profile property type	1	S	M					*	*	*	D1 (definition only)		
See below (Profile property type)	Profile property value	1	S	M					*	*	*	D1 (definition only)		
See below (Profile property type)	Profile property accuracy	1	S	O					*	*	*	D2		
See below (Profile property type)	Profile property interpolation type	1	S	O					*	*	*	D1		
Part of Lane Info	Lane dependent validity	F	5	O	*	*			*	*	*	D3		
The type of property which the profile shall represent	<u>Profile property type</u>													
Indicates whether a Road Element is part of a Freeway.	Freeway	1	4	M					*	*	*	D1		
A classification based on the importance of the role that the Road Element or Ferry Connection performs in the connectivity of the total road network.	Functional road class	1	4	M					*	*	*	D1		
Certain aspects of the physical form that a Road Element takes. It is based on a number of certain physical and traffic properties.	Form of way	1	4	M					*	*	*	D1		

Specification of the state of the surface of the associated Road Element.	Road conditions	1	4	O					*	*		D2		
	Construction status	F	4	O					*			D2		
The maximum speed limit allocated to a Road Element. Discrete function of track length.	Speed restriction	1	4	O			*	*	*	*	more information necessary	D1		
In mathematics, the rate of change of the direction of a curve with respect to the distance along the curve. In NextMAP defined as 1/radius. For this specification, the NextMAP definition is applied. Discrete function of track length.	Curvature	1	N G	O		*		*	*	*		D2	0.003; by recording (gyro)	0.0002(1/m)
It is the division of the vertical elevation by the horizontal translation expressed as a percentage. Function of the track length.	Slope	F	N	O					*			D3		
Specifies several classes of tolerances for the banking of roads, between +/- 7% and +/- 1%.	Banking class	F	N	O					*			D3		
The number of lanes existing on a Road Element.	Number of lanes (for own direction)	1	4	O	*	*			*	*		D1		
	Number of lanes (for opposite direction only)	1	4	O				*	*			D1		
Alternative to the GDF attribute Number of Lanes. The number of lanes is not specified as accurate number but by certain ranges. E.g. 1 lane, 2-3 lanes, 4 and more lanes.	Lane category	1	N	O	*				*	*		D1		
Sub-attribute of Lane information to indicate the type of lane.	Lane type	1	5	O	*	*			*	*		D3		

Sub-attribute of Lane information to indicate which divider is inbetween the current and the next lanes.	Lane divider type	1	5	O	*	*			*			D2		
Sub-attribute of Lane information that stores which direction arrows are painted on the lane relative to the travel direction.	Direction	1	5	O					*			D3		
A Structure is a significant construction that is part of a transportation network, such as a bridge, a tunnel or a retaining wall.	Structure	1	4	O					*	*		D1		
The classification of a Structure.	Structure type	1	4	O		*			*	*	*	D2		
Identifies a Road Element that is entirely underneath or within a Structure whose dimensions are not negligible in regards to its coverage of the Road Element. / The indication of a linear Structure spanning a Road Element or part of it.	Road under structure / Overhead structure along road element	F	5	O					*			D3		
tells whether or not a road element is inside of an urban area	In built-up area	1	4	M						*	*	D1		
An Enclosed Traffic Area is any confined area within which unstructured traffic movements are allowed. Example: a piazza in the centre of small Italian cities.	Enclosed traffic area	F	4	M						*		D1		
The type of enclosed traffic area	Enclosed traffic area type	F	4	M						*		D1		
A relationship between two directed links (a from-link and a to-link) where it is possible to drive from the from-link to the to-link	<u>Connection</u>													
	Link ID from	1	S	M					*	*	*	D1		
	Link ID to	1	S	M					*	*	*	D1		
Calculated out of attributes and relations	Driving possible from-to (physically)	1	S	M	*				*	*	*	D1		

Calculated out of attributes and relations	Driving allowed from-to	1	S	M	*				*	*	*	D1		
Calculated out of attributes and relations	U-turn	1	S	M					*	*	*	D1		
Indicates the likelihood that the car will choose a certain road element as a continuation of travel given the current position of the car. (Static or dynamic)	Probability of travel	1	N	O					*	*	*	D2		
Optional parameter of a connection.	<u>Connection attribute</u>													
	Link ID from	1	S	M					*	*	*	D1		
	Link ID to	1	S	M					*	*	*	D1		
Mandatory types are identified by their position in the field. Optional types are identified by an enum.	Connection attribute type	1	S	M					*	*	*	D1		
	Connection attribute value	1	S	M						*	*	D1 (definition)		
	Connection attribute accuracy	1	S	O						*	*	D2		
	<u>Connection attribute types</u>													
	Heading change			O					*	*		D2	TBD (T-junction problem)	1.43 degrees
The classification of a junction	Junction type	1	4	O					*	*		D1		

A manoeuvre, which is explicitly permitted by means of legal measures, as denoted by traffic signs.	Restricted Manoeuvre	1	4	O					*	*		D1		
A Manoeuvre, which is physically possible but which is prohibited by means of legal measures, as denoted by traffic signs.	Prohibited Manoeuvre	1	4	O					*	*		D1		
Representation of connectivity between lanes across junctions are based on a directed Manoeuvre of the incoming ("From") Road Element, a Junction to indicate the direction, optional intermediate ("via") Road Element(s), and the outgoing ("To") Road Element.	Lane connectivity	F	5	O	*	*						D3		
	Meta data													
Key that contains map provider, AHP and database ID, coverage area and protocol version. Can be decoded by using a look-up table	Basic key	1	M	M					*			D1		
	Unit of length	1	M	M					*	*		D1		
for speed restriction (km/h or miles per hour)	Unit of speed	1	M	M					*	*	*	D1		
	Unit of time	1	M	M					*	*		D1		
	Default driving side	1	M	M					*	*		D1		
	ISO Country Code	1	M	M					*	*		D1		

Annex 7 Accident data for Hotspot Warning

Table A.7.1 Accident data of the Statistical State Office Lower Saxony [6]

Rec. No.	Position From - to	bytes	Content / remarks
4 4U1 4U2 4U3	9 - 14 9 10 - 11 12 - 14	6 1 2 3	District identification key - administrative district - rural district - municipality, empty
5	15 - 20	6	Authority identification key
6 6U1 6U2 6U3	21 - 26 21 - 22 23 - 24 25 - 26	6 2 2 2	Date of accident - Day - Month - Year
7	27	1	Day of Week 1 = Sunday 2 = Monday 3 = Tuesday 4 = Wednesday 5 = Thursday 6 = Friday 7 = Saturday
8 8U1 8U2	28 - 31 28 - 29 30 - 31	4 2 2	Time of accident, empty - hour - minute
9	32 - 33	2	Quantity of involved road users
10	34 - 35	2	Quantity of persons killed, empty
11	36 - 37	2	Quantity of seriously injured persons, empty
12	38 - 39	2	Quantity of slightly injured persons, empty
13	40	1	Kind of Accident 1 = Collision with another vehicle which starts, stops or is stationary 2 = Collision with another vehicle moving ahead or waiting 3 = Collision with another vehicle moving laterally in the same direction 4 = Collision with another oncoming vehicle 5 = Collision with another vehicle which turns into or crosses a road 6 = Collision between vehicle and pedestrian 7 = Collision with an obstacle in the carriageway 8 = Leaving the carriageway to the right 9 = Leaving the carriageway to the left 0 = Accident of another kind
14 15 16	41 42 43	1 1 1	characteristics at accident location 1 = intersection 2 = entry (T-junction) 3 = gateway to premises 4 = ascending slope 5 = descending slope 6 = curve 1. code digit 1-6, empty 2. code digit 2-6, empty 3. code digit 3-6, empty
			specifics at accident location 2 = railway level crossing 3 = zebra crossing 4 = pedestrian crossing 5 = stopping point 6 = construction site 7 = traffic calmed area

Rec. No.	Position From - to	bytes	Content / remarks
17 18 19	44 45 46	1 1 1	1. code digit 2-7, empty 2. code digit 2-7, empty 3. code digit 2-7, empty
20	47	1	Traffic light, empty 8 = traffic light in use 9 = traffic light out of service
22	49 - 51	3	Speed limit 005, 010, 015, 020, 025, 030, 040, 050, 060, 070, 080, 090, 100, 110, 120, 130, Z07, Z20, Z30, empty
23	52	1	lighting conditions 0 = daylight 1 = twilight 2 = darkness
     26 27	 55 56	 1 1	Road 0 = dry 1 = wet/ wettish 2 = frosted 5 = slippery (oil, ding, foliage, icy, etc..) 1. code digit 0-2, 5 2. code digit 1, 2, 5, empty
29	58	1	Collision with an obstacle alongside the carriageway 0 = tree 1 = mast 2 = abutment 3 = guardrail 4 = other obstacle 5 = no collision
  32 33	 61 - 62 63 - 64	 2 2	Causes of the accident 70-89 due to road or weather conditions or obstacles on the road 1. code digit 70-89, empty 2. code digit 70-89, empty
34	65	1	location 1 = inside built-up areas 2 = outside built-up areas
35	66	1	Category of accident 1 = accident with persons killed 2 = accident with seriously injured persons 3 = accident with slightly injured persons 4 = severe accident involving material damage in the narrow sense (criterion: operating condition) 5 = other accident involving material damage 6 = other accident involving material damage under the influence of alcohol
36 37	67 68 - 69	1 2	Type of accident 1. code digit 1 = driving accident 2 = accident caused by turning off the road 3 = accident caused by turning into a road or by crossing it 4 = Accident caused by crossing the road 5 = Accident involving stationary vehicles 6 = Accident between vehicles moving along in carriageway 7 = other accident 2.-3. code digits to specify type to accident in-depth, empty
38	70	1	class of street (in Germany) 1 = Autobahn 2 = Federal roads 3 = Landesstraße 4 = county road 5 = municipal or other road
39	71 - 74	4	Number of road, empty

Rec. No.	Position From - to	byt es	Content / remarks
40	75	1	Character of number of road, empty
41	76 - 81	6	mileage (3 digits), empty
42	82	1	Driving direction, empty 1 = ascending 2 = descending
43	83 - 91	9	Street coding, empty
44	92 - 95	4	House number, empty
45	96 - 102	7	From node A, empty
46	103	1	Character to node A, empty
47	104 - 110	7	To node B, empty
48	111	1	Character to node B, empty
49	112 - 116	5	station (km, m), empty