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Abstract: This final report presents an overview of the NextMAP project from its motivation and objectives to the achieved results. The evaluation process showed that enhanced map databases with an accurate representation of the road geometry and additional map content such as lanes, speed limits and traffic regulations are technically feasible and enable various new map-based vehicle applications which support the driver in driving safely, comfortably and economically. From an economic point of view, an enhanced map database could also be feasible, but there are significant differences in the cost of the different features and attributes.

Keyword list: NextMAP, ADAS, enhanced digital map.

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1. Executive summary

Today's in-vehicle digital map databases were mainly designed and created for navigation systems. The Geographic Data Files (GDF) standard, major output of former EC R&D projects, has been an essential precondition for the production of digital map databases. However, after the introduction of navigation systems, manufacturers realised that the potential uses for digital maps were much greater than just navigation. Prediction of the road geometry and its related attributes ahead of the vehicle will greatly benefit or enable new Advanced Driver Assistance Systems (ADAS) applications such as Adaptive Cruise Control (ACC), curve warning systems or Adaptive Light Control (ALC).

Launched in January 2000, the NextMAP project was a common effort of European map suppliers and car manufacturers to:

- investigate the technical and economical feasibility of enhanced map databases to enable map-based vehicle applications beyond navigation, in particular ADAS
- develop and propose an extension to GDF reflecting enhanced map data requirements.

Approach and main achievements

During the first phase of the project, a roadmap of preliminary **Enhanced Map Database (EMD) requirements** reflecting ADAS functional requirements was developed. Based on the experience gained during the whole project, final EMD requirements were produced representing the desired evolution in content, accuracy and coverage of digital map databases to be used by future in-vehicle applications, in particular ADAS applications.

In the second phase, map-based path prediction, obstacle classification, curve warning, curve control and driver support in urban traffic situations were developed and demonstrated by car manufacturers in five different test sites (one per application and car manufacturer) - two of which were newly defined and digitised within the NextMAP project (in Coventry by Navigation Technologies and in Stuttgart by Tele Atlas).

In the evaluation phase, map manufacturers performed a technical and economical assessment of the respective test databases against the requirements of the vehicle applications, and car manufacturers measured the performance of their application with and without the enhanced map. They also performed a cost benefit analysis. Evaluation results showed that:

- The road centreline can be digitised with a position accuracy of 4 m absolute and 1 m relative. New map content for urban areas (lane information, traffic regulations, speed limits) can also be collected with sufficient quality. Therefore, **an enhanced map is technically feasible.**
- Although the question of economical feasibility could not conclusively be answered because commercial aspects were not considered, cost estimations extrapolated to a European scale indicated that **an enhanced map could be economically feasible**, but there are significant differences for the cost of some features and attributes**.**
- **Almost all applications benefited from the enhanced map database.** The performance of *path prediction*, *curve warning* and *curve control* were improved by the more accurate road geometry. However for curve control, the accuracy of current navigation databases could be sufficient on some parts of the road network. Finally, test drivers accepted very well map-based *driver support in urban traffic situations*. Information about lanes, speed limits and priority regulations all had positive effect on driving comfort and safety.

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NextMAP also delivered a major contribution to the ISO standardisation. The project developed an extended GDF format including what was identified as necessary to future enhanced map databases. The resulting document contains, in addition to the description of the developed data models, the main technical outcome of the NextMAP project, namely the **NextMAP change request to the ISO GDF standard**. This change request was submitted to the ISO/TC204/SWG3.1 in May 2002.

Future perspectives
NextMAP's success results from the fruitful co-operation between project partners at all levels. Through this common work and problem discussions, NextMAP has enabled new partnerships between the map and car industries. All of this constitutes a precondition to the development of future in-vehicle applications using enhanced digital maps. Even more important, this successful co-operation will continue beyond the duration of the project.

NextMAP's main results were also provided to the ADASIS Forum, which aims at developing ADAS Interface Specifications in order for ADAS applications to access enhanced map data available in the vehicle. This industry initiative launched in 2001 by Navigation Technologies is now an open forum co-ordinated by ERTICO. The first draft specifications should be ready by July 2003.

In the near future, in-vehicle applications benefiting from the use of digital maps will contribute to safer, more comfortable and environmentally sound vehicles. They are also in line with and active contributors to the *e*Safety initiative launched by the EC, ERTICO and the car industry in 2001. The first ADAS applications using digital map database are likely to enter the market as early as 2004-2005.

Web site
Although most of the NextMAP results were restricted to the consortium, public versions of main documents were created and are accessible from the public part of the NextMAP website at the following address:

http://www.ertico.com/activiti/projects/nextmap/public_d.htm

Consortium composition and role of the partners involved
The NextMAP consortium was composed of:

- two major map manufacturers: Tele Atlas and Navigation Technologies
- five major car manufacturers: BMW, DaimlerChrysler, CRF (Fiat Research Centre), Jaguar and Renault

and ERTICO for the project management.

Car manufacturers set the requirements for their future applications using digital maps. They have also implemented and evaluated their ADAS applications with the enhanced map database of their test route.

Map manufacturers brought their expertise in evaluating these requirements and their feasibility with respect to data capturing and data production techniques, as well as the respective cost impact on their future business. They also defined and digitised NextMAP test sites (Coventry for Navigation Technologies and Stuttgart for Tele Atlas).

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2. Project objectives

The NextMAP project was launched under the ADASE Umbrella (Advanced Driver Assistance in Europe) in the area of Map-based applications. Transport telematic applications and in particular Advanced Driver Assistance Systems (ADAS) aim at increasing the comfort and the safety of car drivers and decreasing the negative environmental aspects of driving behaviour. ADAS currently perform their functions on the basis of information generated by sensors, but in the future, ADAS will also use map database content through which the movements of the vehicle will be constantly tracked (positioning and map matching).

NextMAP was a research project to evaluate the technical and economical feasibility of enhanced map databases required by telematic applications, in particular Advanced Driver Assistance Systems (ADAS), in order to enable new applications, and improve or extend existing ones. NextMAP's main objectives were to:

- identify new map database requirements on the basis of functional requirements for anticipated ADAS applications, but also for other potential telematic applications.
- test and evaluate the technical and economical feasibility of these new maps;
- formulate these map database requirements in terms of:
  - extensions to the ISO-GDF standard (defined in the project as the exchange format)
  - cost consequences that the addition of these requirements may have on existing map databases. Cost consequences were formulated in terms relative to the costs involved in the creation of a standard database.

As mentioned in the technical annex, only two test sites were digitised within the NextMAP project - Coventry by Navigation Technologies for Jaguar and Stuttgart by Tele Atlas for DaimlerChrysler. Two other test sites - Paris for Renault and Turin for CRF, used existing map data provided by the IN-ARTE project. BMW provided its own test site and map data in Munich.

Because commercial aspects and business models for the production of enhanced map databases were not in the scope of the project, it was not possible to determine their economical feasibility. Nonetheless, it can be stated that all cost indices indicated that an enhanced map database could be economically feasible (see Chapter 4).

The following two chapters describe how the project team successfully reached the main objectives listed above. Chapter 3 presents the work accomplished during the project and Chapter 4 presents and discusses the obtained results.

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3. Methodology and approach

The work was organised in five Work Packages (WP) in addition to the project management (WP1) as briefly presented in the table below:

WP #	Title and short description
WP 1	**Project management**
WP 2	**Requirements definition** To determine preliminary requirements for enhanced map databases and establish a roadmap of what information component is needed when and for what application.
WP 3	**Feasibility of data capturing and test map realisation** To identify sources of the required new information component and to determine the viability of the data collection techniques; to provide enhanced map data for defined test sites and validate the proposed extended GDF for data exchange; to experimentally test technical/economical feasibility.
WP 4	**Development of test vehicles and applications** To equip and enable the test vehicles to use the provided enhanced map with the different applications/functions (e.g. ACC) to be tested on the site having the suitable requirements.
WP 5	**Test evaluation** To perform the tests and evaluate the technical/economical aspects of the proposed enhanced map database digitised in WP3.
WP 6	**Liaison and dissemination** To link with other projects, build European consensus and disseminate project results.

Table 1 Overview of NextMAP work packages

WP2, 3, 4 and 5, representing the core technical work, were closely related and progressed step-by-step in the following manner:

- The first step (WP2) was to define a roadmap of preliminary Enhanced Map Database (EMD) requirements reflecting ADAS functional requirements.
- The two test sites to be digitised in Coventry and Stuttgart were then specified (WP3) based on the application requirements to be implemented in NextMAP. The necessary extended GDF data models were developed at the same time in order to represent the digitised enhanced map data in the test databases. An evaluation plan was developed (WP5) which defined all parameters to be implemented in the map digitisation process and the map-based application software.
- Each map manufacturer digitised one test site (WP3); while at the same time each car manufacturer prepared a test vehicle and developed its map-based application (WP4).
- During the evaluation (WP5), map manufacturers made the technical and economical assessment of their test databases against the requirements of the vehicle applications. Car manufacturers measured the performance of their application with and without the enhanced map and also performed cost benefit analyses.
- Based on the experience gained during the project, final requirements were produced representing the desired evolution in content, accuracy and coverage of the digital map databases to be used by future in-vehicle applications, in particular ADAS applications. The proposed extended GDF format was also finalised, and the corresponding GDF change request was produced and submitted to the ISO/TC204/SWG3.1.

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Concurrent to the technical work and during the course of the whole project, liaison and dissemination activities (WP6) took place - particularly with the IN-ARTE project to get the map data of the Paris and Turin test site, and with the ADASE2 project to cluster with other ADAS projects and the ISO standardisation.

The project's accomplishments matched the usual logical phases of a project's life cycle when considering that:
- WP2 corresponded to a user needs phase
- WP3 corresponded to a system specification phase
- WP4 corresponded to a developing/testing phase
- WP5 corresponded to a validation/evaluation phase
- WP6 corresponded to an exploitation phase

Project results and achievements will be presented in Chapter 4. The following sections present the work done WP by WP, as well as the problems encountered and the solutions implemented to meet project objectives.

WP2: Requirements definition
During the first phase of the NextMAP project, a roadmap of preliminary Enhanced Map Database (EMD) requirements reflecting ADAS functional requirements was developed and presented in the Deliverable *D2.1 "Roadmap of preliminary enhanced map database requirements"*. Other major topics inherent to these new maps were also included, in particular: definition of applications and map usage, definition of data items (e.g. geometry, urban attribute), definition and discussion on absolute/relative accuracy. The development and agreement on such issues were more difficult than expected, mainly because the process to reach a common understanding on all of the issues related to the production of these requirements was underestimated. This resulted in a two-month delay in the production of this deliverable. But its results were strategic and very important for the success of the project.

Based on the evaluation results (WP5) and the experience gained during the project, final EMD requirements were developed and presented in the Deliverable *D2.2 "Final enhanced map database requirements"* (see reference Table 12 on page 26). This essential work represents the possible evolution in content, accuracy and coverage of digital map databases to be used by future in-vehicle applications, in particular ADAS applications.

The other major activity of WP2, was the development of the necessary extension to the ISO GDF standard in order to reflect the enhanced map database requirements. An initial version of the resulting the Deliverable *D2.3 "GDF extension format for transport telematic applications"* (see reference Table 12 on page 26) concentrated on the elaboration of the logical data models for the extended GDF, in particular the topological lane model. These data models were used by map manufacturers to produce their enhanced map data in WP3. The extended GDF exchange format part was produced and integrated in the final version of the document at the end of the project. This final document was produced as a change request document for submission to ISO and was submitted to the ISO/TC204/SWG3.1 in charge of the GDF standardisation.

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WP3: Feasibility of data capturing and test map realisation
At the beginning of the project, the first task in this WP was the investigation and presentation of possible data collection techniques (current state of the art). This was developed and presented in the Deliverable *D3.1 "Classification of data capturing / production techniques"* (see reference Table 12 on page 26) giving a good overview of the major map data collection techniques used by map manufacturers. The sharing of this information among the partners was very important as it brought all partners to the same understanding of the process required to build a digital map database. It also contributed to one of the underlying goals of NextMAP, which was to develop a common understanding between both map and car manufacturers on the issues related to the production of enhanced map databases.

After formulation of the preliminary map database requirements in WP2, map providers identified the possible source of the data to be gathered and consequently, the data capturing techniques enabling the digitisation of the new maps. Retained techniques were prototyped to assess their technical/practical feasibility as well as the cost consequences on the data collection process (see *D3.3 "Test map realisation and results"* and *D5.2 "Overall technical and economical assessment"*; see reference Table 12 on page 26).

As a major consequence of the limited funding allocated to the project, only two test sites were effectively digitised: Coventry (Jaguar) digitised by Navigation Technologies and Stuttgart (DaimlerChrysler) digitised by Tele Atlas. The test sites were defined and specified by car manufacturers in co-operation with the map manufacturers, and were digitised for all information components specified for the testing of the applications (see D3.3).
The Paris (Renault) and Turin (CRF) test sites used the map data digitised within the TR4014 - IN-ARTE project. The precision of this data was in the range of three meters; which was sufficient for the planed Renault and CRF applications. Finally, in Munich, BMW used proprietary map data digitised outside NextMAP.

The digitisation of the Coventry and Stuttgart test sites was performed in successive steps with initial delivery of sample data and a final delivery of the data. Although delays in the digitisation process occurred, the major problem encountered in NextMAP was the conversion of the data into a format that could be used by the car manufacturers application software. In fact, map databases were not delivered in an extended GDF format as originally planned because such a format could not be directly used by car manufacturers' applications and no software tools could be developed within the project budget.

This major problem was approached and solved in the following manner:
- *NextMAP digitised map databases* (Coventry/Stuttgart): It was proposed and decided early in the project to use the RMF map format developed by Telcontar (a US-based company) with its corresponding API and software tools. For the duration of the project, Telcontar offered access to its real time map data access and management software free of charge to the NextMAP consortium. An acknowledgement note was made to Telcontar in *D6.1 "Project presentation"* as part of the above agreement. Navigation Technologies digitised the Coventry test route and then produced conventional GDF map data and extended tables for the enhanced map data. Finally Telcontar created the RMF file for Jaguar. Tele Atlas digitised Stuttgart and created the corresponding filter directly from the NextMAP extended GDF format to produce the RMF file for DaimlerChrysler.
- *IN-ARTE map databases* (Turin, Paris) were adapted by Navigation Technologies, when necessary, delivering the data in GDF 3.0 and extension tables for the enhanced map data.
- *BMW map database* (Munich) had its own format and API tools.

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These rather complicated solutions guaranteed each car manufacturer access to map data from their applications. Table 2 presents an overview of what each car manufacturer realised in NextMAP: the implemented application, the test route location and who did the digitisation, the data format produced and the API used.

The map database data were delivered on a CD in *D3.2 "Test Map Databases"* which was data internal to the project.

Car man.	Application	Test site and *digitisation*	Data format and *API from...*
Jaguar	Vehicle path prediction and obstacle classification for a radar-based collision warning system.	Coventry *NavTech*	RMF *... Telcontar*
DC	Driver information in urban traffic situations	Stuttgart *Tele Atlas*	RMF *... Telcontar*
CRF	Curve approach warning and intervention	Turin *IN-ARTE*	SDAL + Extension tables *... NavTech*
Renault	Curve speed warning & control	Paris *IN-ARTE*	SDAL + Extension tables *... NavTech*
BMW	Curve speed control	Munich *Proprietary*	Internal *... Internal*

Table 2 Overview of NextMAP applications, test sites, data format and API

WP4: Development of test vehicles and applications

The main task of this WP was to prepare the test vehicle for the testing/evaluation to be performed in WP5. During an initial phase, each car manufacturer defined their application and the system architecture to be used/developed as presented in the Deliverable *D4.1 "Specification of test vehicles/applications"*. The principal representation of the architecture used for the test vehicle is presented in the figure below.

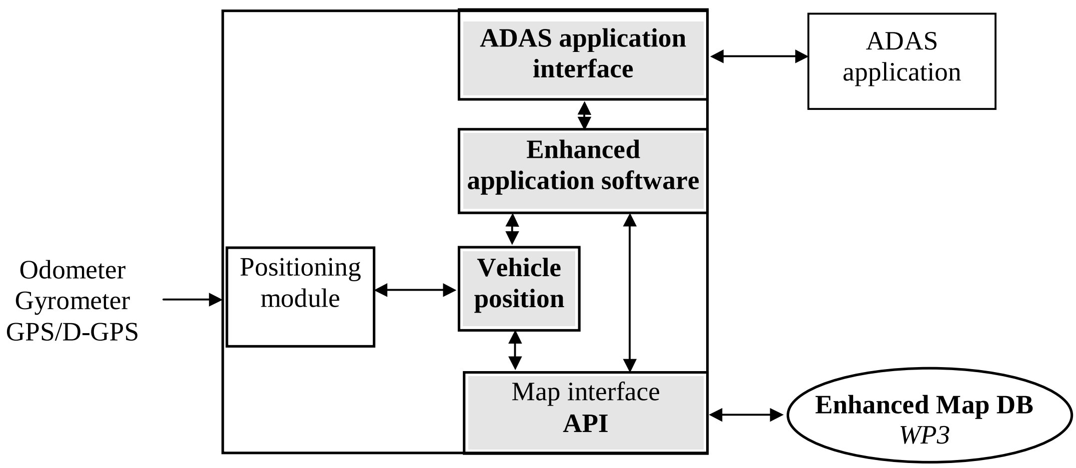

Figure 1 General architecture used in the test vehicles.

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In the second phase, the following applications were implemented:

- *Obstacle classification for radar based collision warning systems* (**Jaguar**): path prediction for obstacle classification was implemented, in order to reject false targets while maintaining long range stopped obstacle detection in collision warning systems.
- *Driver information in urban traffic situations* (**DaimlerChrysler**): the aim was to implement functions to enhance driver alertness and improve assistance functionality in complex urban traffic situations, such as intersections with complex topologic layout or multi-lane sections of the street network requiring difficult lane-changing manoeuvres.
- *Curve approach warning and intervention* (**CRF**): the aim of the system was to indicate to the driver how to correctly approach/enter the curve and respect the traffic signs (stop, pedestrian cross, etc.) ahead of the vehicle (e.g. slow down, brake), based on current vehicle parameters (e.g. speed) and the map data. The intervention function was also developed, i.e. in the same road scenario, the vehicle automatically slowed down / braked.
- *Curve speed warning & control, speed limit assistant* (**Renault**): for the first function in ACC mode, the system adapted the set-up speed to a value fitted to the curve. In manual drive, the driver was warned if he/she was driving too fast for the curve. In the second function, the driver, in ACC or manual drive, was warned if he/she exceeded the speed limit. The warning/intervention on crossings could not be tested within the project due to the inadequate content of the IN-ARTE database in Paris.
- *Curve speed control* (**BMW**): this application implemented an active throttle and brake control dependent on roadway geometry and attributes that were available from the enhanced map database.

The final implementation of each car manufacturer application was presented in the Deliverable *D4.2 "Test vehicles featuring ADAS applications with Enhanced Map"*.

WP5: Test evaluation

The purpose of WP5 was to assess both the data capturing methods used for the digitisation of NextMAP test routes and the vehicle applications. The process to be followed and the methods to be used for this assessment were defined in the Deliverable *D5.1 "Evaluation plan"*. Due to the budget cuts in the NextMAP project, partners agreed on the following decisions in order to obtain best possible results:

- Each car manufacturer would test and evaluate its application only on its own test site.
- Only testable requirements would be considered for test site digitisation.
- Applications to be demonstrated in the NextMAP project would be grouped into non-urban applications (motorways and rural roads) and urban applications (urban roads).
- Requirements of all non-urban applications would be considered for digitising the Coventry test site (85 % of which consisted of non-urban roads).
- Requirements of all urban applications would be considered for digitising the Stuttgart test site (which contained only urban roads).
- Map manufacturers would provide a cost estimation for all required and testable features when available on the digitised test site (i.e. Coventry, Stuttgart).
- The quantitative evaluation of the enhanced map database production cost is very difficult from a scientific point of view and would exceed the resources of the NextMAP project. However, the results from the test site digitisation and the experience of the map manufacturers would be used to derive some qualitative conclusions for the EMD production cost.

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The last point was a real change to the original project plan and work description. Only after long and controversial discussions about the evaluation plan did it become clear that the economical evaluation of the test site digitisation only had local validity for Coventry and Stuttgart. In general, map manufacturers' experience shows that as soon as economical aspects are taken into account, different data capturing methods have to be applied at different site, depending on the locally available source material. In addition, the 50 to 60 km of road digitised in NextMAP was a small amount compared to a European wide network. Therefore, the common opinion amongst project partners was that a qualitative evaluation of the enhanced map database production cost was not reasonable. Instead, a qualitative order of magnitude estimation was to be provided by the map manufacturers (see Chapter 4).

At the end of the project, the evaluation took place and results were presented in Deliverable *D5.2 “Overall technical and economical assessment”* (see reference Table 12 on page 26). In particular, the results of the technical and economical assessment of the data capturing methods were provided by the map manufacturers and car manufacturers presented their results regarding the evaluation of their vehicle applications and the cost benefit analysis. Finally a cost benefit analysis was performed to combine the technical evaluation of the vehicle applications with the economical assessment of the data capturing methods (see Chapter 4).

During the digitisation of the test routes, the implementation of the vehicle applications and the preparation of the evaluation tests it turned out that some of the assessment methods defined in the evaluation plan could not be implemented as planned or had to be changed in order to ensure the quality and reliability of the results.

WP6: Liaison and dissemination

The main objectives of this WP were to establish active links with relevant projects/initiatives and standardisation, as well as disseminate project results.

The main NextMAP liaison activities were with the following:

- former IN-ARTE project to get the map data for the Paris and Turin test route
- ADASE 2 project - participating in the concertation meetings organised by ADASE 2 where information on NextMAP progress and results were provided
- ISO/TC204/SWG3.1 in charge of standardising GDF
- ADAS Interface Specification (ADASIS) Forum aiming at standardising the access of the in-vehicle map database for ADAS applications

The NextMAP dissemination activities included (see reference Table 12 on page 26):

- Production of Deliverable *D6.1 "Project presentation"*
- Production of Deliverable *D6.2 "Dissemination and use plan"*
- Production of Deliverable *D6.3 "Liaison and dissemination activities"* (see also Chapter 5 listing all papers and conferences where NextMAP was presented)
- Creation of the NextMAP web site
- Creation of the NextMAP project logo
- Creation of a poster presenting NextMAP for the ITS World Congress in Turin (November 2000)

The major achievements of this WP are presented in the next chapter.

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Peer review of NextMAP deliverables:

All deliverables were peer reviewed by partners' experts not directly involved in the production of the document. In general, comments were fruitful and supportive to the quality of the work produced in NextMAP. Project partners are thankful to all the peer reviewers for supporting project work and recognising its importance.

In particular, it is important to mention that the peer reviewers of the Deliverable *D2.3 " GDF extension format for transport telematic applications"* were MM Rob van Essen (Chairman of ISO/TC204/SWG3.1 on GDF and member of the Dutch delegation) and Mr James Herbst, a member of the US delegation in the same ISO group. Their assistance gives high merit to this major NextMAP output, ensuring its compliance with ISO rules and in a format/content ready to be discussed within the ISO standardisation.

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4. Results and achievements

Despite the budget cut that led to the problems mentioned in the previous chapter, NextMAP achieved very good and strategic results for the future development and production of enhanced map databases. NextMAP's work should be seen as a groundbreaking activity in the first investigation ever made on the feasibility of enhanced map databases by key partners in both the car and map industries.

The work performed in NextMAP and described in the previous chapter has successfully led to key results, which are in fact represented by the following four final project deliverables:
- D2.2: Final enhanced map database requirements
- D2.3: GDF extension format for transport telematic applications
- D3.3: Test map realisation and results
- D5.2: Overall technical and economical assessment

These results are closely related - in particular D2.2 and D2.3 are based on the cost/benefit analysis described in D5.2. These results are also the ones considered by the partners in the *TIP "Technology Implementation Plan"* document (see reference Table 12 on page 26).

Finally, liaison and dissemination activities showed the great interest and the potential seen by many organisations in NextMAP's work.

All of these results are presented in the next sections.

4.1. Final enhanced map database requirements

The final requirements for Enhanced Map Databases (EMD) presented in Deliverable D2.2 shows the desired evolution in content, accuracy and coverage of digital map databases to be used by future ADAS applications.

The proposed EMD requirements were divided into two main groups:
- requirements concerning the geometric accuracy of the road network (e.g., road curvature, slope, etc.)
- requirements concerning additional information - i.e. new attributes and new features to be collected (topological lane information, traffic regulations and signs with their position, etc., see Table 3).

Different aspects for the creation of an EMD have been addressed, in particular:
- definition of relative versus absolute accuracy
- definition of geometric accuracy
- evolution of map content and road network coverage over time, resulting in an alignment of possible ADAS introduction and EMD creation strategy.

Not only is the content of a map database important, but also the point in time at which it will be available and the parts of the road network for which the information has to be collected (database coverage). All three aspects together (content, time, coverage) have been presented in D2.2.

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Table 3 Potential map content (columns are independent)

Map Objects	Street/Lane Info (begin and end)	Traffic Regulations and Signs
bridges	braking visibility	speed limit and speed relevant signs
bridge abutments (substructure)	number of lanes	stop sign
tunnels	width of road and lane	traffic lights
overhead structures	road classes	priority, right of way, give way signs
side obstacles (houses, walls, trees)	street access restrictions (e.g. weight)	pedestrian or bike crossing (location of sign)
parking lots (with driveway)	access restrictions per lane (e.g. bus)	
intersections	emergency lane	
toll booths	pre-selection (left turn, right, straight)	
railway crossings	shoulder lane	

Table 4 gives an overview about the content, time and coverage aspects as well as all-important map items over time. The 2001 column represents data available in today's map database, while the other years represent the possible map data available if digitisation was started in January 2002. It is important to mention that the feasibility of the enhanced map database has technical, economical and commercial aspects. NextMAP has addressed the technical and economical aspects, but commercial aspect of making such maps was not in the scope of NextMAP.
This summary table takes into account evaluation results of car and map manufacturers.

Table 4 Summary table: Roadmap of enhanced database requirements

Roadmap Requirements Summary	2001	2004	2006	2008	2010	2012
Desired Map Availability						
- First countries of introduction	EU	EU	EU	EU	EU	EU
- Map available (year)	Today	2004	2006	2008	2010	2012
Geometry Related Accuracy						
Vehicle-position-accuracy (GPS, DGPS, INS…)	+/- 15m	+/- 3m	+/- 3m	+/- 1-2m	+/- 1-2m	+/- 1m
Absolute accuracy	5-25m	4m	4m	2-4m	2-4m	2m
Relative accuracy	5-15m	1-2m	1-2m	0.5 -1m	0.5 -1m	0.5 m
Map objects	5-25m	5-10 m	5-10 m	1- 5m	1- 5m	1m
Lane width	n/a	0,5 m	0,5 m	0,3 m	0,3 m	0,3m
Speed limit	n/a	5m	5m	3m	3m	1m
Priority regulations	n/a	…	…	Incl.	Incl.	Incl.

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Roadmap Requirements Summary	2001	2004	2006	2008	2010	2012
Coverage						
Non Urban Roads						
-Motorway/Fast Dual carriageways		10%-40%	40%-80%	80%-100%	100%	100%
- Dual carriageways	…	10%-30%	30%-60%	60%-80%	80%-100%	100%
- Single carriageways	…	10%-30%	30%-50%	50%-70%	70%-100%	100%
- Minor roads	…		10%-20%	20%-50%	50%-70%	70%-100%
Urban Roads	…					
- Roads	…	10%	10%-50%	50%-70%	70%-90%	90%-100%
- Intersections	…		10%-30%	30%-60%	60%-80%	80%-100%

Table 4 contains both coverage versus time as well as accuracy aspects towards future digital maps. It indicates that enhanced map databases could be available starting in 2004 if the digitisation mentioned above would start in January 2002. The table also shows the evolution from a small coverage area in 2004 on part of the road network to complete coverage by 2012. These figures are estimates and ranges indicating possible coverage, and are based on application needs and lag time considerations from the map manufacturers' estimations (i.e. the amount of time needed to digitise once a commercial decision is taken to produce such maps).
These figures should therefore be interpreted as magnitude statements and taken only as indicators for the future development of maps and ADAS applications.

Table 5 Usage of digital maps in different applications

	Application	2001	2004	2006	2008	2010	2012
Longitudinal control	Curve Speed Warning	(x)*	x				
	Adaptive Light Control (ALC)		x				
	Vision Enhancement		x				
	Speed Limit Assistant		x				
	Fuel Consumption Optimization		x				
	(Hybrid) Power Train Management		x				
	Heavy Trucks ACC		x	x			
	Adaptive Cruise Control (ACC)		x	x			
	Curve Speed Control			x			
	Visual and Audible Driver Assistance			x			
	Collision Warning			x	x		
	Stop & Go (S&G)				x		
Lateral control	Lane/Road Departure Warning					x	
	Lane Keeping Assistant					x	
	Lane Change Assistant (LCA)					x	
	Collision Avoidance						x
	Autonomous Driving						x

* Possible on some part of the road network

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Table 5 presents the considered ADAS applications and shows their evolution with the different maps on a two-year basis. A detailed description of these applications with the corresponding map usage can be found in Appendix A.

This result is extremely important for all future map-based driver assistance systems, as it will enable map and car manufacturers to develop future EMD and in-vehicle applications taking these requirements as a basis. Both industries have also developed a common understanding of these requirements and the possible availability of the corresponding map content with respect to time.

4.2. GDF extension format for transport telematic applications

GDF (Geographic Data Files) is a European standard (CEN-ENV 14825) that is used to describe and exchange road networks and road related data. It is much more than a generic GIS-standard, because GDF gives rules how to capture the data, and how the features, attributes and relations have been defined. In 1995, this CEN standard was given as input to ISO, which should finally release an ISO-GDF standard by the end of 2002.

One of the major outputs of NextMAP is the development of an extended GDF format including what has been identified in the project to be the new content necessary in future enhanced map databases. This Deliverable, *D2.3 "GDF extension format for transport telematic applications"*, written in the format of an ISO change request document, was submitted to ISO/TC204/SWG3.1 in May 2002. It will be discussed and perhaps modified within the ISO group to finally be integrated in a new release of the GDF standard after acceptance by the ISO representatives.

This document describes all data models relevant for NextMAP which were developed during the project. The proposed data models correspond to the NextMAP requirements, particularly as they were relevant for the test site digitisation. It includes the following topics:

- Topological lane modelling and associated geometric aspects
- Attributes and relationships of bridges and other overhead structures
- Priority regulations
- Traffic light regulations
- Speed restrictions
- Tram crossings/Pedestrian crossings

As key new content of enhanced map databases, topological lane modelling is given here as an example. It represents topological lane information in a digital road database, and includes modelling lane specific attributes, legal or physical restrictions on changing lanes, and modelling relations between incoming and outgoing lanes at intersections.
In the proposed data model, lane information is attached to road elements in the form of simple and composite attributes. Each road element has an attribute “Number of Lanes”. Lane specific information is described by the Lane Info attribute. Its restrictive sub-attribute “Lane Dependent Validity” specifies to which lane the attribute applies. The counting direction is explicitly coded in the actual attribute value (i.e. from left to right in feature direction, or from right to left in feature direction).

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This is illustrated in Figure 2, using the NIAM modelling (Nijssens Information Analysis Method) for the representation of the Entity-Relation Modelling (see Appendix B)

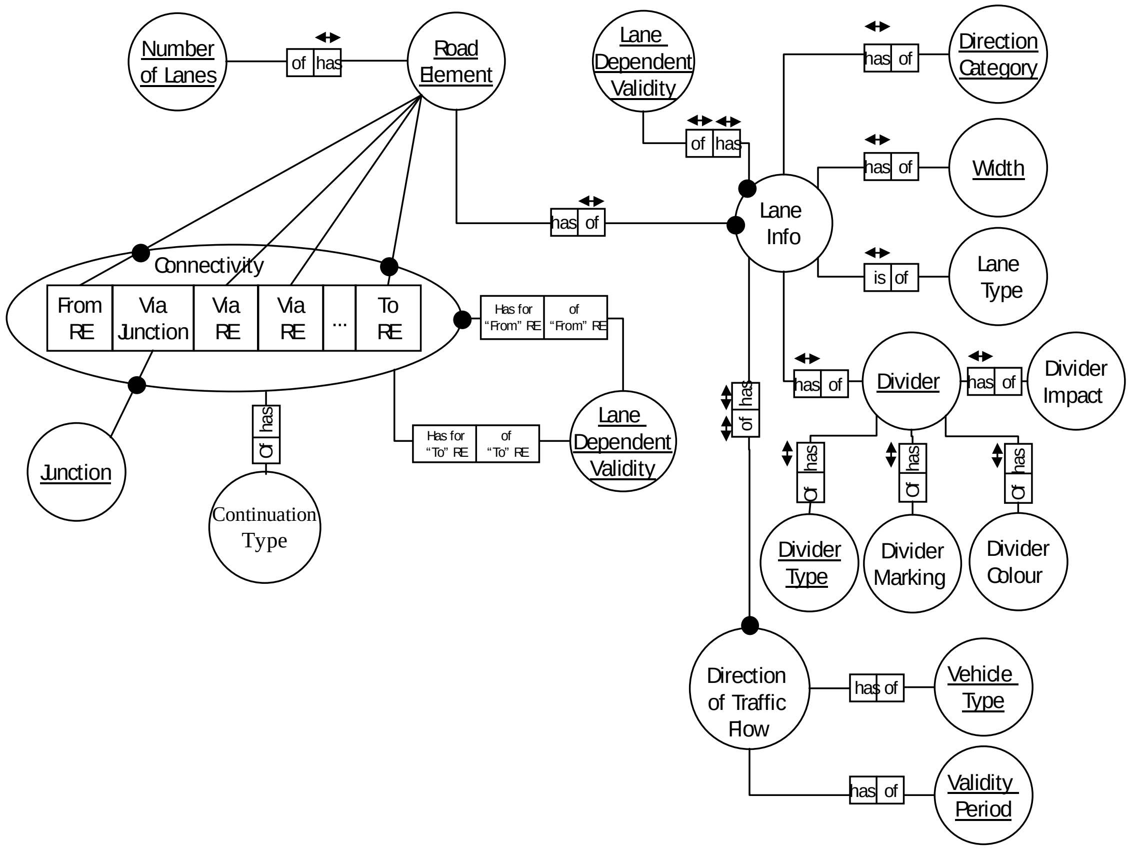

Figure 2 The topological lane model developed in NextMAP

As with the development of GDF, which has enabled map manufacturers to digitise today's navigation map based on standardised data models, future production of enhanced map databases will be preconditioned to the availability and the usability of the extended GDF format. This will enable the production by map manufacturers of enhanced digital map databases for ADAS and telematic applications.

4.3. Test map realisation and results

Test map realisation and results were presented in deliverable D3.3 (see reference Table 12 on page 26), in particular:

- OEM requirements as released to the project map manufacturers prior to the mapping of the NextMAP test routes
- actual digitisation techniques which were utilised in Coventry and Stuttgart

The technical assessment of the digitisation was part of the evaluation reported in D5.2 and is presented in the section 4.4.

Table 6 presents the map focus and the type of road used by the tested car manufacturer application for both test routes digitised in NextMAP. It also shows that test routes were com-

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plementary for the coverage as well as for the map content. As already mentioned, no other test routes were digitised in the project.

Car man.	Application	Test site and *digitisation*	to be used on			focus on	
			motor-ways	rural roads	urban roads	fine geom-etry	map con-tent
Jaguar	Vehicle path prediction and obstacle classification for a radar-based collision warning system.	Coventry *NavTech*	x	x		x	
DC	Driver information in urban traffic situations	Stuttgart *Tele Atlas*			x		x

Table 6 NextMAP digitised test routes and applications

The map database requirements set by Jaguar Cars and DaimlerChrysler served as the basis for producing the NextMAP digital maps. These requirements depended directly on the application which was tested. The test routes in Coventry and Stuttgart were mapped according to new standards. The characteristics of both test routes and applied digitisation methods are summarised hereafter.

Coventry test route and used digitisation methods

The Coventry test route included:

- 17 km of high speed inter-urban road: partly three lanes and partly two lanes containing numerous road signs and bridges
- 2.5 km of rural road, very narrow with tight bends.

The map database requirements set by Jaguar Cars for the application "*vehicle path prediction and obstacle classification for a radar-based collision warning system*" were:

Preliminary Map Database Requirements Coventry test route	**Required accuracy (maximum error)**
Geometry Related Accuracy	
- longitude & latitude (m) absolute/point	<4m
- longitude & latitude (m) relative/line	<2m
- slope (in %) (1m height → 100m length → 1%, min height change 10-100))	<1%
- curvature = 1/radius (%) (100m radius 1% → +/- 1m)	<1%
Street / Lane information	
- number of lanes	Exact number
- width of road / lane (m)	<0.5m
- road class (Start, End in m)	<10m
- parking lanes (lay by)	<4m
- slip road.	<4m
- shoulder lane	N/a
Traffic Regulations	
- speed limit and speed relevant signs (exact location in m).	<10m
- stop Sign (exact location in m).	<4m
- traffic lights (exact location in m, 3 phases and blinking).	<4m

Table 7 Preliminary map database requirements for the Coventry test route

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The data collection included:

- Geometry data collected by using aerial photographs and mobile mapping units (i.e., using a specially equipped vehicle with high accuracy positioning, video and other sensors)
- Attribute data, gathered through field data collection using data plots, aerial photograph interpretation and video analyses.

The resulting digitised map database contained:

Geometry information	Attribute information
• Link Information describing the total amount of elements present in the data set. Number of links: 164 Number of shape points: 745 Raw data sets: 9 • Segment length, describing the length of the data elements in the set. Shortest: 4.8 m Longest: 2535 m Average: 236 m • Lane information, number of links with lane numbers. Links with 3 lanes: 77 Links with 2 lanes: 83 Links with 1 lane: 1	Total number of attribute collected: Bridges 42 Bridge Abutments 26 Generic Traffic Sign 189 Traffic Light 12 Speed Limit 11 Overhead Structure (other than Bridges) 2 Parking Lanes 11

Stuttgart test route and used digitisation methods

The Stuttgart test route contained urban roads only, with a total length of 20 km.

The DaimlerChrysler application "*Driver information in urban traffic situations"* was divided into three main functions to support the driver:

- Speed selection support
- Lane selection support
- Support at intersection

The map database requirements for these functions were:

Speed selection support	Lane selection support	Support at intersection
• Speed limits • Warning signs	• Lane information (number of lane, lane marking, lane type, legal/physical restrictions)	• Representation of intersections • Information about oncoming traffic • Traffic lights • Right of way • Pedestrian crossing • Tram crossing
Required absolute geometric accuracy of the projected position of the map object on road element:		
< 10 m	< 5m	< 5m

Table 8 Preliminary map database requirements for the Stuttgart test route

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Tele Atlas used aerial imagery as the principal source for digitising geometry and lanes. However, not all features could be identified from the air - mainly due to two major reasons: implicit (e.g. traffic signs) and occlusion (trees, shadows).
A large amount of additional information was required to be collected at several crossings, therefore surface imagery was used to augment traditional field survey. In order to fulfil the quality requirements outlined in the evaluation plan, a digital video camera was also used along the test track to capture continuous footage.

The resulting digitised map database was embedded in a standard navigation database of the Stuttgart area and contained the following additional data categorised by application functions:

Speed selection support	Lane selection support	Support at intersection
• Speed limit attributes (value and type) for each road edge • 10 "Caution Children Signs"	• 2198 Lane Connectivity Relationships • 1745 Lane Divider Type Attributes • 1414 Lane Direction Attributes	• 249 Traffic light regulations • 311 Pedestrian Crossings • 29 Tramway Crossings • 149 Yield Regulations • 11 Stop Regulations • 6 Dangerous Crossings
Improved geometry with 1516 road edges to represent the test route.		

4.4. Overall technical and economical assessment

As a major achievement of NextMAP, the evaluation concludes that:

- The road centreline can be digitised with a position accuracy of 4 m absolute and 1 m relative. New map content for urban areas (lane information, traffic regulations, speed limits) can also be collected with sufficient quality. Therefore, **an enhanced map is technically feasible.**
- Although the question of economical feasibility could not conclusively be answered because commercial aspects were not considered, cost estimations extrapolated to a European scale indicated that **an enhanced map could be economically feasible**, but there are significant differences in the cost of some features and attributes**.**
- **Almost all applications benefited from the enhanced map database.** The performances of *path prediction, curve warning* and *curve control* were improved by the more accurate road geometry. However for curve control, the accuracy of the current navigation database could be sufficient on some parts of the road network. Finally, test drivers warmly accepted map-based *driver support in urban traffic situations*. Information about lanes, speed limits and priority regulations had positive effect on driving comfort and safety.

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These results were obtained through a rather complex evaluation process as illustrated in Figure 3. The map manufacturers performed the technical and economical assessment of the data capturing methods used in Coventry and Stuttgart. Each car manufacturer carried out the verification of its application in order to assess the benefits gained by the use of enhanced map database. Together with the economic assessment of the data capturing methods extrapolated to a European scale, the verification results were used as input to a cost benefit analysis.

Finally, the objective of the cost benefit analysis was to compare the costs of collecting and digitising these data for different sets of map features and attributes with the application performance and decide if obviously expensive features were really needed. The results of the cost benefit analysis were therefore used for the definition of the final map data requirements presented in section 4.1. The next two sections briefly present the evaluation results that led to the above results.

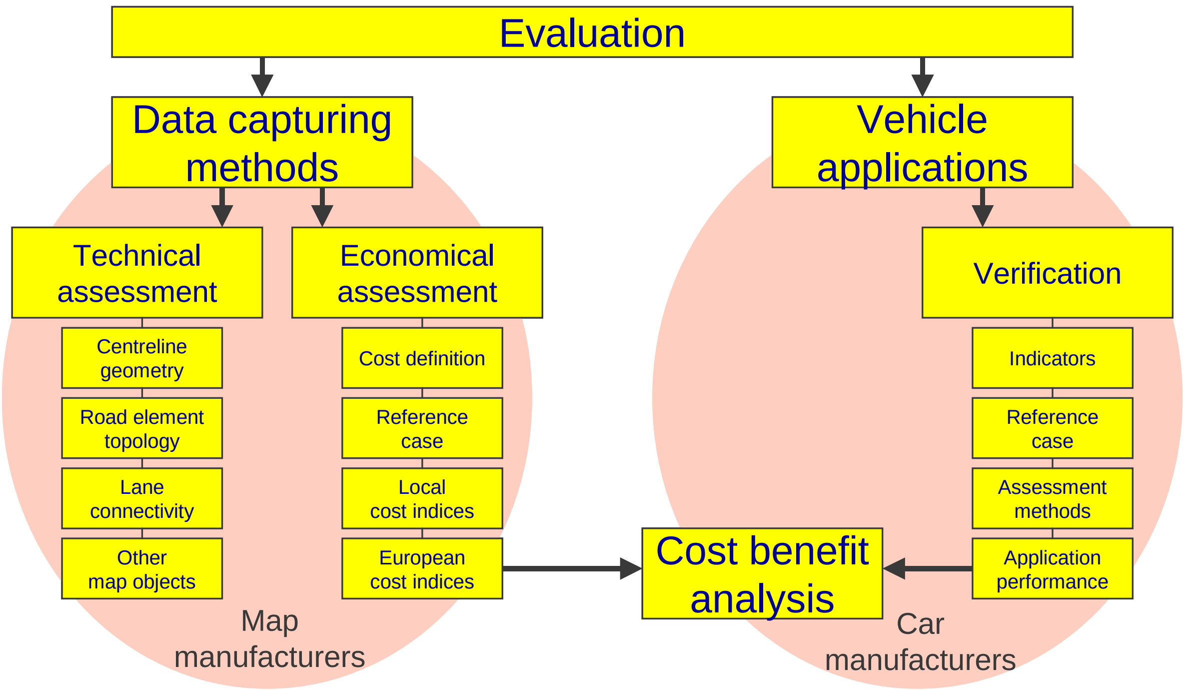

Figure 3 NextMAP evaluation process

4.4.1. Technical and Economical Assessment of Data Capturing Methods

Technically, the map database quality which is required by the vehicle applications, must be achieved. Accurate representation of road geometry is of vital importance to non-urban applications, whose requirements were considered for digitising the Coventry test route. Therefore, the geometric accuracy of the digitised road centreline was one important quality indicator determined for the Coventry test route. In the results, the absolute positional accuracy when compared to a reference database was smaller than 4 m for 77 % of all shape points, and smaller than 6 m for 96 % of all shape points. The relative positional accuracy was smaller than 1 m for 70 % of all shape points, and smaller than 2 m for 91 % of all shape points.

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These results show that the map data requirements for the path prediction application of Jaguar Car (see Table 7 page 16) are met for the majority of, but not all shape points. However, taking into account that for map manufacturers, NextMAP was the first step towards future maps with increased geometric accuracy, the experiences gained during the project will lead to improvements in their tools and methods. Thus:
Centreline geometry digitisation with an absolute positional accuracy of 4 m and a relative accuracy of 1 m, which satisfies the requirements of all map-based applications under consideration, seems to be technically feasible for non-urban roads.

For the urban application of DaimlerChrysler, the content of the enhanced map database (e.g. lane information, traffic regulations, speed limits, etc.) is most important. For this reason, the technical assessment of the Stuttgart database focused on the quality of the new map content. The different quality indicators, which were computed for a sample representing approximately 10 % of the test route, showed that almost no errors were contained in the map. This extremely positive picture should be taken with some caution, because additional map errors detected while testing the vehicle application on the test route indicated that the sample might be too small for being representative. On the other hand, the database creation process was implemented as a test project, which might lead to different quality figures when implemented in a large-scale industrial production process. Nevertheless, all of the information that was crucial for the performance of the tested application was available and the overall quality of the map database was sufficient, i.e.:
The enhanced map database is technically feasible for urban areas.

For assessing the economic aspects of an enhanced map database compared with current navigation maps, local cost indices were computed for each test site and for the different sets of map features and attributes. These local cost indices were then extrapolated to European cost indices in order to roughly estimate the cost of a European enhanced map database (see Table 9 and Table 10). Cost indices are expressed in terms of € symbols: the more € symbols, the more expensive it is to create the respective map data. VE means very expensive.

It turned out that the cost for increasing the geometric accuracy of the map was nearly identical for Coventry and Stuttgart, despite the different characteristics of the test routes (see row "Positioning 2D" in Table 9 and Table 10). This could be an indication that the cost for refining the map geometry in urban and non-urban areas are in the same order of magnitude and do not differ as much as foreseen at the beginning of the project.

Another common result is that lane information is obviously very useful, but very expensive information. Nevertheless, various possibilities were identified to cost effectively collect and digitise lane information in urban areas without decreasing the application performance. The results from Coventry and Stuttgart are quite different with respect to the speed limits. It could not be determined if this effect results from the different capturing methods and tools deployed in Coventry and Stuttgart or if it was due to a peculiarity of the test routes. The digitisation of the Coventry test route also showed that the collection of altitude and slope information, i.e. the third dimension of the road geometry, was more expensive than all of the other information, because totally different capturing methods had to be applied. Nevertheless, as for lane information, a significant cost reduction for 3D geometry can be expected for the future due to foreseeable improvements and synergy of data collection methods.

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Whether the enhanced map is economically feasible could not be answered by the NextMAP project because this answer depends on commercial considerations and business models, which were not considered in this project. Yet it can be stated that all cost indices indicate that an enhanced map could be economically feasible, and that there are significant differences in the cost of different features and attributes.

Function	Attributes and features	Capturing method(s)	Local Cost Index CI $_{Coventry}$	Rural Cost Index CI $_{Europe}$
ACC /Curve warning / Curve control	• Speed limit: a) type b) value • Speed relevant signs locations	Field survey	€ € € €	€ € - € € €
Vehicle path prediction	• Lane attributes: - number of lanes - lane dividers • Road side attributes • Radar obstacles (Noise) • Lane connectivity relationships	• Field survey • Aerial pictures • Ordnance Survey maps	VE	€ € € € - VE
Positioning 2D	Rural Geometry excluding altitude	• Field survey • Aerial pictures	€ € €	€ - € €
Positioning 3D	Enhanced Rural geometry:	Survey (D-GPS/INS)	VE	€ € - VE

Table 9 Cost indices for the rural parts of an enhanced map database.

Note: Cost indices are expressed in terms of € symbols: the more € symbols, the more expensive is the creation of the respective map data. VE means very expensive.

Function	Attributes and features	Capturing method(s)	Local Cost Index CI $_{Stuttgart}$	Urban Cost Index CI $_{Europe}$
Speed Selection Support	• Speed limit: a) type b) value • Speed relevant warning signs (“Caution Children”)	Field survey	€ €	€
Lane Selection Support	• Number of lanes • Lane divider type • Lane direction of traffic flow • Vehicle restrictions • Pre-selection • Lane connectivity relationships	• Field survey • Aerial pictures • Civil engineering maps of intersections from local authorities	€ € € € €	€ - € €
Support at Intersections	• Pedestrian crossings • Tram crossings • Traffic light regulations • Priority regulations	• Field survey • Aerial pictures	€ € € €	€ - € €
Positioning 2D	Enhanced urban geometry: • Road elements • Junctions • Pedestrian crossings	• Aerial pictures • Survey (D-GPS /INS)	€ €	€

Table 10 Cost indices for the urban parts of an enhanced map database.

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4.4.2. Evaluation of Vehicle Applications and Cost Benefit Analysis

The enhanced map database was used for path prediction, obstacle classification, curve warning, curve control and driver support in urban traffic situations.

For the **path prediction**, a map-based algorithm was compared with a conventional prediction technique based on angular rate sensors. It turned out that on transition curves of motorways, which are critical for path prediction, the map-based path prediction had a significantly better performance. However, on a single carriageway road with both plane and vertical curvature, the good results achieved on the dual carriageway could not be repeated but offered significant added value. The conclusion is that the most accurate map-enhanced path prediction is possible if the road geometry is represented as accurately as it was in the Coventry test database and the slope of the road is negligible. If the slope is not negligible, then it must also be contained in the map.

For the **obstacle classification**, the co-ordinates of radar objects were compared with co-ordinates of map objects (traffic signs, overhead structures, etc.) in order to distinguish relevant obstacles on the road from non-relevant objects besides or above the road. The performance of this application was very poor. Although it is difficult to say how much each system component (vehicle positioning, radar sensor, and enhanced map) contributed to the overall system error, it can be concluded that a map-based obstacle classification is not feasible with the Coventry test database and the system components integrated in the test vehicle.

Curve warning and curve control are applications with similar requirements for digital maps. The performance of both applications depends mainly on an accurate computation of the road curvature from the shape points stored in the map database. Curve warning and curve control were tested on test sites which were digitised outside the NextMAP project. The respective test databases contain approximately twice as much shape points as a standard navigation database, which should result in a more accurate representation of the road geometry and improved application performance. In fact, the results of the evaluation tests were very different. The curve warning application was tested in Munich, and as expected, it turned out that the application was feasible only with an enhanced map database. Curve control was tested both in Turin and Paris. In Turin, the curve control application was feasible in principle with the standard navigation database. However, the performance of the application with the enhanced map was in some cases significantly better. In Paris, there was almost no difference between the application performance with a standard navigation database and an enhanced map database. The interpretation of these heterogeneous results was not easy, since a lot of factors contribute to the overall results. Application performances not only depend on the quality of the map database, but also on the characteristics of the test route and the algorithms used to compute the road curvature and control the vehicle. Despite all of these uncertainties, the results showed that at least for some parts of the road network, the accuracy of today's navigation databases is good enough for curve warning and curve control applications. However, curve warning and particularly curve control systems must be very reliable, so that an accurate representation of the road geometry is guaranteed for large parts of the road network. This is a requirement for the enhanced map database.

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Finally, **driver support in urban traffic situations** was tested in Stuttgart. Results showed that information about lanes, speed limits and priority regulations were very beneficial for the driver in demanding urban traffic situations and were also very well accepted. The additional information significantly eased the driving task and increased driving safety compared to a standard navigation system. Thus, the enhanced map database had a very positive effect on the application.

Table 11 shows the relationship between the importance of the demonstrated driver support functions and the estimated cost of a European map database containing the respective information for urban areas.

Function	Importance of information		European cost index
	Information	Rank*	
Speed Selection Support	Speed limit Caution, children	A B	€
Lane Selection Support	Lane	A	€ - € €
Support at Intersections	Priority regulation (right before left) Pedestrian crossing Priority regulation (stop, yield) Tram Priority regulation (traffic light)	A B B C C	€ - € €
Positioning	Accurate geometry	-	€

* Information ranking: A = very important, B = important and C = not important.

Table 11 Grouping of information and related cost indices for urban driver support

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4.5. Liaison and dissemination

NextMAP achieved three major liaison activities with the following initiatives:

- **ADASE 2** project - presenting NextMAP at concertation meetings, which fostered great interest from all other IST projects focused on future ADAS development
- **ISO/TC204/SWG3.1**, in charge of standardising GDF. NextMAP was invited to present its activities and results at an ISO meeting held in Amsterdam (9/8/2001). The change request to GDF developed in NextMAP (D2.3) was submitted to this standardisation group in May 2002.
- **ADASIS** (ADAS Interface Specifications) Forum, an industry initiative aiming at standardising the access of in-vehicle map database for ADAS applications. The final enhanced map database requirements produced by NextMAP were presented and will be used as input by the working group on map requirements.

Besides the production of deliverables, dissemination achievements included:

- A project fact sheet developed per request of the EC and accessible on the CORDIS web site (http://www.cordis.lu/ist/projects/99-11206.htm)
- A NextMAP web site created by ERTICO and used by the partners as a working tool during the whole duration of the project. It can be reached at the following address:

  http://www.ertico.com/activiti/projects/nextmap/home.htm

- The creation of the NextMAP project logo proposed by DaimlerChrysler. It was included on all documents produced by NextMAP, and contributed to the creation of a project “corporate identity” presented to the outside world.

All other dissemination activities (e.g., articles) are listed in the next chapter.

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5. Deliverables and other outputs

Deliverable D6.3 lists all NextMAP outputs. The following table presents all deliverables produced and delivered by the project with the corresponding web link when publicly available.

Table 12 NextMAP deliverables and corresponding website links (for public documents)

<table>
<tr><th colspan="2">Deliverable number and title</th><th>Dissemination level</th><th>Electronic reference</th></tr>
<tr><td>D1</td><td>Final report</td><td>Public</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D1.zip</td></tr>
<tr><td colspan="4">The present report.</td></tr>
<tr><td>TIP</td><td>Technology Implementation Plan</td><td>Public</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_TIP.zip</td></tr>
<tr><td colspan="4">The Technology Implementation Plan covers the intentions for dissemination and exploitation of the industry partners in NextMAP related to the potential knowledge generated under the project.</td></tr>
<tr><td>D2.1</td><td>Roadmap of preliminary enhanced map database requirements</td><td>Restricted</td><td>035v20-D21</td></tr>
<tr><td colspan="4">This document defines the preliminary requirements of a digital map database supporting in particular Advanced Driver Assistance Systems (ADAS). Map database content and accuracy are part of these requirements. Since these requirements are directly related to the applications and their availability in time, ADAS applications and their map usage were first defined. Then a preliminary coarse roadmap was presented in a table.</td></tr>
<tr><td rowspan="2">D2.2</td><td rowspan="2">Final enhanced map database requirements</td><td>Public version</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D22p.zip</td></tr>
<tr><td>Restricted version</td><td>141Rv06-D22</td></tr>
<tr><td colspan="4">This document contains the results of the NextMAP requirements process, including the desired evolution in content, accuracy and coverage of future digital map databases to be used by ADAS. It contributes to the state of the art by presenting final map data requirements derived from the evaluation results (D5.2) and knowledge gained during the project by the partners.</td></tr>
<tr><td>D2.3</td><td>GDF extension format for transport telematic applications</td><td>Public</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D23.zip</td></tr>
<tr><td colspan="4">This document describes data models for enhanced digital maps developed in the NextMAP project. It also contains the corresponding change request to ISO/TC204/SWG3.1 to extend the GDF standard which was submitted to this group as an input document in May 2002.</td></tr>
<tr><td>D3.1</td><td>Classification of data capturing / production techniques</td><td>Public</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D31.zip</td></tr>
<tr><td colspan="4">This report describes how cartographers design and build maps. Several techniques for collecting map data are presented, from air photography to field surveys as well as advanced mobile mapping. Finally, some issues regarding cost and techniques to be applied in order to meet requirements enabling ADAS are considered.</td></tr>
<tr><td>D3.2</td><td>Two Test Map Databases</td><td>Restricted</td><td>087v10-D32</td></tr>
<tr><td colspan="4">In order to evaluate the benefits of using a map database for in-vehicle applications, several test routes have been digitised. Each of the map suppliers engaged in NextMAP mapped one test route as part of the project. IN-ARTE map database were also used. The document presents a description of the mapped test routes as well as the format in which they have been delivered to the car manufacturers.</td></tr>
</table>

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Table 12 (continue)

<table>
<tr><th colspan="2">Deliverable number and title</th><th>Dissemination level</th><th>Electronic reference</th></tr>
<tr><td rowspan="2">D3.3</td><td rowspan="2">Test map realisation and results</td><td>Public version</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D33p.zip</td></tr>
<tr><td>Restricted version</td><td>099v08-D33</td></tr>
<tr><td colspan="4">This deliverable presents the map database requirements for the mapping of two test routes, namely in Coventry, United Kingdom and Stuttgart, Germany. Jaguar Cars and DaimlerChrysler set their requirements prior to the mapping and used those advanced digital maps to run the NextMAP applications that supported the assessment of the map database. Navigation Technologies and Tele Atlas, the two mapmakers involved in the project, carried out the mapping according to the OEMs specifications. The tools and techniques that were used are also presented.</td></tr>
<tr><td>D 4.1</td><td>Specification of test vehicles/applications</td><td>Restricted</td><td>037v30-D41</td></tr>
<tr><td colspan="4">The document describes the application for each vehicle that was implemented and the system architecture which was used on-board. It also describes the scenarios where the vehicles were tested.</td></tr>
<tr><td>D 4.2</td><td>Test vehicles featuring ADAS applications with enhanced map</td><td>Restricted</td><td>088v11-D42</td></tr>
<tr><td colspan="4">The document describes the application for each test vehicle with the chosen senarios that were finally implemented as well as the system architecture used on-board.</td></tr>
<tr><td>D5.1</td><td>Evaluation plan</td><td>Internal</td><td>059v20-D51</td></tr>
<tr><td colspan="4">The evaluation plan defines the process and the methods which were used to evaluate the technical and economical feasibility of enhanced map databases and the added value for the vehicle applications using these new maps. The evaluation plan assured that single results were comparable and project goals were met.</td></tr>
<tr><td rowspan="2">D5.2</td><td rowspan="2">Overall technical and economical assessment</td><td>Public version</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D52p.zip</td></tr>
<tr><td>Restricted version</td><td>104v20-D52_restricted</td></tr>
<tr><td colspan="4">This document contains the results of the NextMAP evaluation process, including the technical and economical assessment of data capturing methods, the evaluation of map-based vehicle applications and a cost benefit analysis, which combined the economical and technical aspects.</td></tr>
<tr><td>D6.1</td><td>Project presentation</td><td>Public</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D61.zip</td></tr>
<tr><td colspan="4">This document presents the project as a fact sheet including an overall description of the NextMAP project with its main goal and objectives, the intended work programme, and contact details. The text of this fact sheet was integrated at the beginning of all NextMAP deliverables except the present final report.</td></tr>
<tr><td>D6.2</td><td>Dissemination and Use plan</td><td>Restricted</td><td>039v21-D62</td></tr>
<tr><td colspan="4">This document describes the plans for dissemination of knowledge gained during the work, and to the extent that this can be foreseen at the beginning of the project, the exploitation plans of the results for the consortium as a whole or for individual or groups of participants.</td></tr>
<tr><td>D6.3</td><td>Liaison and dissemination activities</td><td>Public</td><td>http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_D63.zip</td></tr>
<tr><td colspan="4">This deliverable lists all liaison and dissemination activities undertaken during NextMAP in order to give a short overview to the reader with the corresponding complete references at the end of this document.</td></tr>
</table>

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The main articles produced and conference presentations are listed in the following two tables:

Date location	***Event/ presentation title***	***Description/outcome (web link to document when available)***
06-09/11/2000 Turin	Poster for the 2000 Turin ITS World Congress	Presentation of the project with a poster, hosted by the IN-ARTE project at the EC booth and at each partner booth. http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_067v12.zip
07/11/2000 Turin	Special Session 9 of the 2000 Turin ITS World Congress	PL was invited to participate in a Special Session dedicated to digital maps in which future maps were addressed.
07/11/2000 Turin	Concertation meeting at the 2000 Turin ITS World Congress	First 5FWP-IST-ADAS concertation meeting where NextMAP status was presented.
01/02/2001 Brussels	Concertation meeting	Second 5FWP-IST-ADAS concertation meeting.
10/05/2001 Frankfurt	ADASIS group meeting	Participation in the Kick-off meeting of ADASIS (ADAS Interface Specifications).
22/05/2001 Brussels	ERTICO Info Day	Presentation of NextMAP objectives and status to the ERTICO partners after the ERTICO General Assembly.
18/06/2001 Brussels	CPA3 Information day	Presentation of the project objectives and status to the CPA3 call info day organised by the EC.
26/06/2001 Frankfurt	ADASIS group meeting	Participation in the second meeting of ADASIS
27/06/2001 Paris	EUCAR workshop	Presentation of NextMAP objectives and status to EUCAR
09/08/2001 Amsterdam	ISO/TC204/SWG3.1	Presentation of NextMAP objectives and status to the GDF ISO standardisation in particular the new data models developed by the project for ADAS applications (e.g. topological lane model) to support enhanced map database. Consequences for the current ISO-GDF standard were discussed as a basis for the production of GDF change request.
26/09/2001 Untertürkheim	ADASIS meeting	Participation in the third meeting of ADASIS where NextMAP was officially presented, in particular excerpt of D2.1.
25-26/10/2001 Brussels	Concertation meeting	Third 5FWP-IST-ADAS concertation meeting
13-15/11/2001 Nice Acropolis	"NextMAP: investigating the future of digital map databases for transport telematics applications" NavSat 2001 (Satellite Navigation and positioning World Convention)	Presentation of the NextMAP objectives, work and results at this conference. *This paper was selected as the best paper of its session.* http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_145.zip
20-21.11.2001 Brussels	EUCAR conference 2001	A poster was created and presented at this yearly EUCAR event.

Table 13 NextMAP presentations and conferences

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Finally Table 14 presents all publications/papers produced by the project.

Date	***Paper title***	***Type / journal of publication*** ***Web link to document when available***
10/2000	NextMAP project to help digital map databases evolve to meet future needs	Article / its@ertico newsletter
06/11/2000	NextMAP project to define digital map databases for future in-vehicle applications	ERTICO press release / 2000 Turin ITS World Congress http://www.ertico.com/newsroom/pressrel/2000/nextm_to.pdf
03/2001	Digital map databases: key to future in vehicle applications?	Article / ITS solutions 2001 magazine http://www.ertico.com/activiti/projects/Doc_Library/Nextmap/2_084v30.zip
03/2002	“L'information géographique et son rôle dans les SIT“	Paper published in "Revue Générale des Routes et Aérodromes (RGRA)", France.
06/2002	NextMAP project deliver final results.	Article / *its@ertico* newsletter (to be published)
09/2002	NextMAP: Investigating the future of digital map databases.	Proceeding of the Conference on eSafety in Lyon, September 2002 (to be published).

Table 14 NextMAP publications

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6. Project management and co-ordination aspects

The objective of this central activity was to provide sound internal project management with an efficient interface to Commission services and to ensure that the project was capable of attaining its objectives.

Project Management was structured and organised in two committees (see Figure 4):

- A Project *Steering Committee* which included all contractors met twice and was responsible for all contractual issues and decisions. In particular, the elaboration of the Consortium Agreement required a a very long discussion process in order to reach an agreement from all contractors.
- A Project *Management Committee* which included all contractors held eight meetings and was responsible for the management of the project, detailed monitoring of the project's progress and the formulating of recommendations about the project as necessary. It was mainly operated according to a Project Quality Plan developed at the start of the project.

The Project Management was the point of contact with the Commission and other external bodies – namely the ADASE2 project and the ISO standardisation. The Project Steering Committee met twice, once every twelve months.

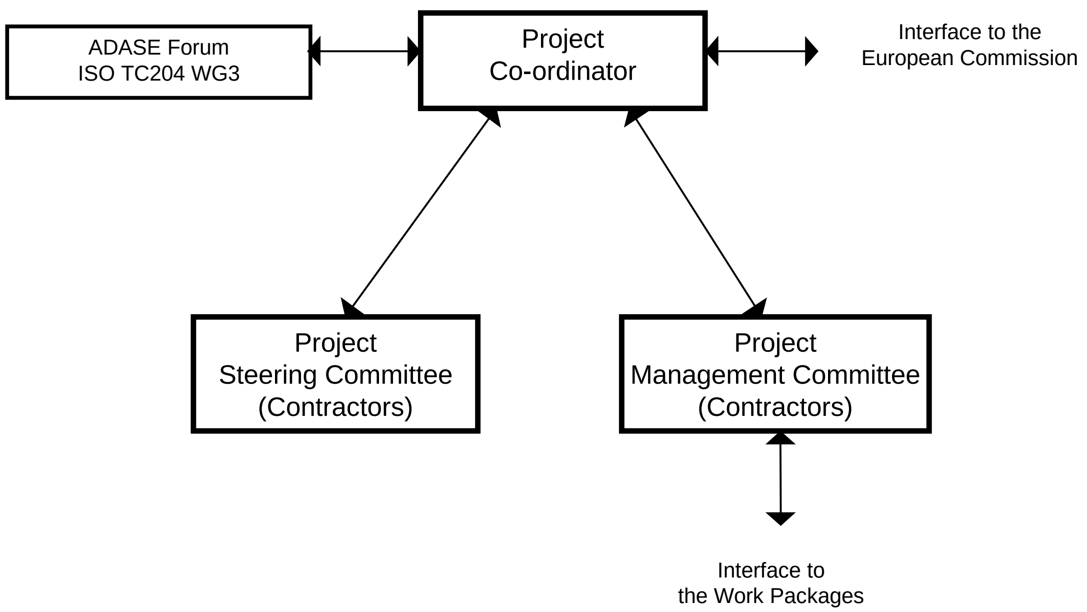

Figure 4 Project management structure

Each Work Package leader contributed to the management of their WP activities within the overall structure. This aided the consensus formation process as well as proved to be an efficient way of solving problems together. The Project Management was operated according to quality assurance procedures as defined by ISO 9002.

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Quality Manual
At the operational level, the management was based on the Quality Manual developed at the beginning of the project. All partners used this document as a reference, which ensured the quality of all NextMAP outputs. The quality Manual provided:

- Contractual references
- Project objectives
- Project organisation and responsibilities
- Project documentation guidelines for management/progress reports and deliverables
- Peer review process to assess deliverable quality
- Cost Statements guidelines
- Activity quality procedures (e.g. contract management, documentation control, documentation exchange rules and NextMAP web site)
- Description of the project filing system

Main problems encountered and delays
- The production of a consortium agreement that can be accepted by all partners has been very difficult mainly because the project representatives were not able to directly comment on the proposed document, but this document was required to be circulated within each partner's legal department. The final consortium agreement entered the signature phase at the end of September 2001.
- As already mentioned in Chapter 3, the major problem encountered in NextMAP was the access of the map database for the in-vehicle applications. The solution proposed with Telcontar led to an overall delay of about two months. Nevertheless, the chosen solution enabled the project to achieve good results.

Despite these problems, appropriate solutions were always found by partners in order to meet project objectives. Collaboration between partners and the willingness to achieve relevant results were always the focus of the NextMAP project team.

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7. Conclusions and outlook

The potential use of enhanced digital map databases by future in-vehicle applications and the resulting benefits in particular for Advanced Driver Assistance Systems, were at the origin of the NextMAP project.

NextMAP was a unique opportunity for the map and car industries to join efforts for investigating the technical and economical feasibility of an enhanced map database and its effects on applications' performance. This fruitful co-operation at all levels was key to the success of the project - constituting a precondition for the development of future map-based in-vehicle applications. Even more important, this co-operation strengthened European leadership in this vital sector, which will continue beyond the duration of the project.

NextMAP has successfully tested and evaluated the technical and economical feasibility of enhanced map databases. In particular, project results showed that:

- Enhanced map databases with an accurate representation of the road geometry and additional map content such as lanes, speed limits and traffic regulations are technically feasible and enable various new map-based vehicle applications which support the driver in driving safely, comfortably and economically.
- From an economic point of view, an enhanced map database could also be feasible, but there are significant differences in the cost of different features and attributes.

NextMAP also defined and developed:

- enhanced map database requirements with their possible evolution in content, accuracy and coverage
- the corresponding data models as an extension to GDF. This was delivered to the ISO/TC204/SWG3.1 standardisation group as change request to the ISO-GDF standard.

Through its liaison activities and web site, NextMAP's work and results were widely disseminated to the ADAS and IST communities.

Outlook

NextMAP's contribution to standardisation will dramatically accelerate the development of the extended GDF standard, which will enable map manufacturers to digitise enhanced digital map databases in order to be used by ADAS applications.

For car manufacturers, NextMAP provided the opportunity to investigate this new research field. Results will be used for further research work and support for the development of map-based in-vehicle applications, which will contribute to safer, more comfortable and environmentally sound vehicles in the near future. It is in line with and contributes to the *e*Safety initiative launched by the EC, ERTICO and the car industry in 2001. The first ADAS applications using digital map databases are likely to enter the market as early as 2004-2005.

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One current activity benefiting from NextMAP results and led by car manufacturers is carried by the ADASIS Forum, which aims at developing ADAS Interface Specifications in order for ADAS applications to access enhanced map data available in the vehicle. This industry initiative was launched in 2001 by Navigation Technologies, and is now organised as an open forum co-ordinated by ERTICO. Members of this forum include all actors required to define such specifications: Car manufacturers, Navigation system manufacturers, ADAS manufacturers and Map manufacturers. The first specifications should be released by the autumn of 2003.

Beside the availability of an enhanced map database providing more accurate geometry and enhanced map content, one of the main challenges for future map-based in-vehicle applications will be the "up-to-dateness" of the map database. ActMAP, a new IST project started in April 2002, addresses these challenges. Its overall objective is to investigate, develop, test and validate standardised mechanisms to deliver actualised map components to be integrated and used by in-vehicle applications.

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8. Project data and contact details

Project Data

Contract : IST-1999-11206 - NextMAP

Starting date : 01-Jan-2000 **Duration :** 24 months

Total Cost : 1,800,002 EURO **EC Contribution :** 900,000 EURO

Project URL : http://www.ertico.com/activiti/projects/nextmap/home.htm

Project Participants:

Contractors	Country	Role*
ERTICO (European Road Transport Telematics Implementation Co-ordination Organisation S.C.R.L.)	B	CO
Navigation Technologies B.V.	NL	CR
Tele Atlas B.V.	NL	CR
Bayerische Motoren Werke Aktiengesellschaft AG	D	CR
DaimlerChrysler AG	D	CR
C. R. F. Società Consortile per Azioni	I	CR
Jaguar Cars Ltd.	UK	CR
REGIENOV EIG (RENAULT Recherche Innovation acting on behalf of each of its members including in particular RENAULT and RENAULT Véhicules Industriels)	F	CR

* CO = Co-ordinator, CR = Contractor

Contact details

Project Co-ordinator:

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Appendices

Appendix A – ADAS application description and map usage

The following two-page table presents considered ADAS applications in the first column and their description in the second column. The third column describes the possible map introduction date if digitisation would start in January 2002 (and possible ADAS introduction) with respect to time (feasibility) necessary for each application based on the NextMAP experience. The last column describes the digital maps usage used for each application.

Application	Application description	Map time	Map usage for application
Curve Speed Warning	Warns the driver before entering a curve too fast	**2004**	Predicts lateral acceleration in curves based on road geometry
Adaptive Light Control (ALC)	Dynamic aiming headlamps and situation adaptive lighting (e.g. urban, highways, country roads)	**2004**	• Area type • Path prediction
Vision enhancement	Improvement of vision in adverse lighting and weather conditions perceiving (by instrumental means) what the human eyes cannot see and providing the driver with enhanced visual information. Build-up of the scenario in front of the vehicle in critical environment (dark, fog, …)	**2004**	• Detail of the traffic signs • Recommendation when the system cannot provide the output to the driver (e.g., tunnel, …) • Limit Region of interest for vision sensor (surface type, banking) • Help in object classification (i.e., dynamic)
Speed Limit Assistant	Assists the driver in choosing the correct speed in speed limit sections	**2004**	direction and location of speed relevant signs
Fuel Consumption Optimisation	Adjusts speed for reason of fuel consumption	**2004**	Calculates fuel consumption based on geometry and speed attributes
(Hybrid) Power Train Management	Assistance to the driver for comfort driving	**2004**	The control strategies take curves and slopes of the road in front of the vehicle into account Information on allowed speed
Heavy Trucks ACC	• Longitudinal Control • Distance keeping • v > 60km/h • Moving obstacles recognition • Tracking of leading vehicle • Limited acceleration and deceleration	**2004**	• Path prediction • Fuel consumption optimisation • Slope prediction
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	**2004**	• Path prediction • Location specific use (e.g., exit and on ramps) • Avoidance of false alarm (e.g., under the bridge) • Speed adaptation with speed relevant signs • Junctions (Warning) • Assignment of Radar targets to parallel tracks off road • Avoid tracking failure (i.e., leading vehicle exits) • Support object tracking when road slope causes target miss
Curve Speed Control	Controls the speed in curves	**2006**	Calculates curve speed based on geometry and attributes
Visual and Audible Driver Assistance	Gives audible and visual information before passing potentially dangerous spots depending on intelligent selection algorithm (urban)	**2006**	Stores information to determine if a potentially dangerous spot lies ahead, such as traffic signs/ installations, number of lanes, etc.
Collision Warning	Warns the driver in case of an eventual collision	**2006**	• Path prediction • Avoidance of false alarm
		2008	• Path prediction • Avoidance of false alarm (rule out false targets) • Detection of on/out lane targets

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Application	Application description	Map time	Map usage for application
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	**2008**	• Avoidance of false alarm (e.g., under the bridge) • Determination of complex situations (road merging, etc.) • Restrict usage (e.g., only on highways)
Lane/Road Departure Warning	The system allows the driver to stay on the road / within the lane The Lane/Road Departure Warning informs the driver (for example with a rumble noise) that he is departing the lane unintentionally.	**2010**	• Improve vision systems • Provide the information in case the camera cannot recognise the road/lane marks • Detection of in/out lane targets • Path prediction • Avoidance of false alarm • Support vision system in case of irregularities of lane markings (i.e., exits)
Lane Keeping Assistant	The Lane Keeping Assistant constantly assists the driver to stay in a lane. E.g., if the driver departs the actual lane (without using any turn signals) he/she will feel some force feedback in the steering wheel.	**2010**	• Improve vision systems • Positioning of the car between the lane marking • Knowledge of the lane marking type • Support vision system in case of irregularities of lane markings (i.e., exits)
Lane Change Assistant (LCA)	The Lane Change Assistant helps the driver to gather information about vehicles in adjacent lanes. The Lane Change Assistant will warn the driver if a lane change is not possible because of a potential collision threat.	**2010**	• Improve vision systems • Positioning of the car between the lane marking • Knowledge of the lane marking type • Support vision system in case of irregularities of lane markings (i.e., exits)
Collision Avoidance	Avoidance and Warning before a pending collision.	**2012**	• Path prediction • Avoidance of false alarm (rule out false targets) • Detection of in/out lane targets
Autonomous Driving	Fully automatic driving.	**2012**	• Precise Positioning in the lane • Path prediction • Provide track geometry as backup (short term dropout of vision sensor)

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Appendix B – Nijssen Information Analysis Method.

Many of the basic concepts of GDF are best expressed diagrammatically in data models. For this, a variant of Entity-Relation Modelling referred to as NIAM modelling (Nijssens Information Analysis Method[1]) is used.
Figure 5 presents an overview of the notation elements applied by this method and used by NextMAP to represent the extended GDF Data Model developed in the Deliverable D2.3.

The model is composed of four main components:

- Circles, representing individual information components
- Non-arrow headed lines between circles representing relations between information components
- Arrow headed lines representing a sub-typing of information components
- Rectangles representing a specification of the relation between two information components

Since generally a relation is not symmetrical, the relation specification rectangle is divided into two parts, each one representing the relation in a particular direction.

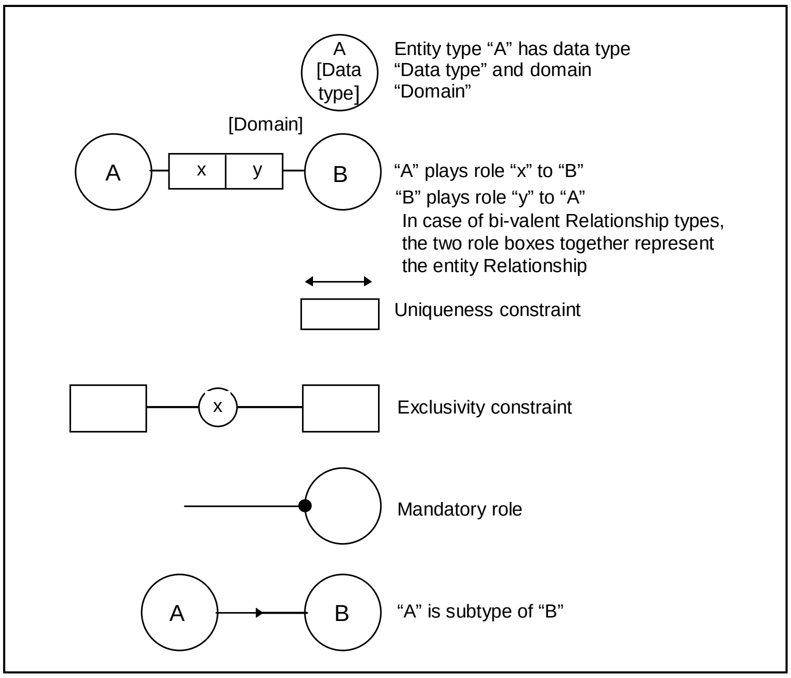

Figure 5 Notation elements of the NIAM modelling

[1] Nijssen, G.M., Halpin, T.A. *Conceptual Schema and Relational Database Design - A fact oriented approach*. Prentice Hall, Sydney ’89.

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