Quality Assured Road Information for ITS-Applications – the Quality Concept of EuroRoadS

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ABSTRACT

For future ITS-applications and particularly for advanced driver assistance systems (ADAS) a harmonised and cross border road data infrastructure of high quality is necessary, fulfilling the requirements stated by the car manufacturers. The project EuroRoadS (Pan-European Road Data Solution) granted by the European Commission will lay the groundwork for the creation of such an infrastructure by national mapping agencies, road administrations, private enterprises, and the research sector. The specific challenge regarding quality is to prepare a common model describing the quality assured data flow from acquisition and updating of the digital map up to its final application. This paper describes a quality concept, consisting of a quality model for describing information quality in ITS-application and an analysing procedure evaluating information quality within information flow. This concept will be the base for the necessary quality assurance of the entire information chain. The application of the quality concept will be illustrated by a system draft of a map-based speed alert system.

KEYWORDS

Quality management, road information, digital map, speed alert system

INTRODUCTION

The current information chain for road data of car navigation systems may be characterised by the collection from national and regional road databases, which are acquired and delivered by different data providers and content providers. Mapping agencies have developed their road databases for cartographic issues, and road administrations for road maintenance. At present many island solutions exist with only few cooperation between the parties involved. For usage of existing databases a common interface is necessary, containing a homogeneous data and exchange format as well as a uniform quality description. The EU-project EuroRoadS will establish a specification of a road network

information model, core European road data, road network exchange model, and exchange format. Specific challenge regarding quality assurance is the provision of a quality concept, which is usable within the entire information chain of acquisition and processing of road data.

It has to be ensured by all actors (data provider, content provider, information provider, and service provider) to apply the quality concept into real applications (cf. figure 1). To carry out the quality assurance a fixed set of inherent quality characteristics is required. All actors of the information chain have to deal with identical quality characteristics in order to make the quality descriptions and requirements comparable. Therefore the relevant standards, like ISO 19100-serie of ISO/TC211 [1], [2] and ISO9000 [3] have to be considered in the quality concept.

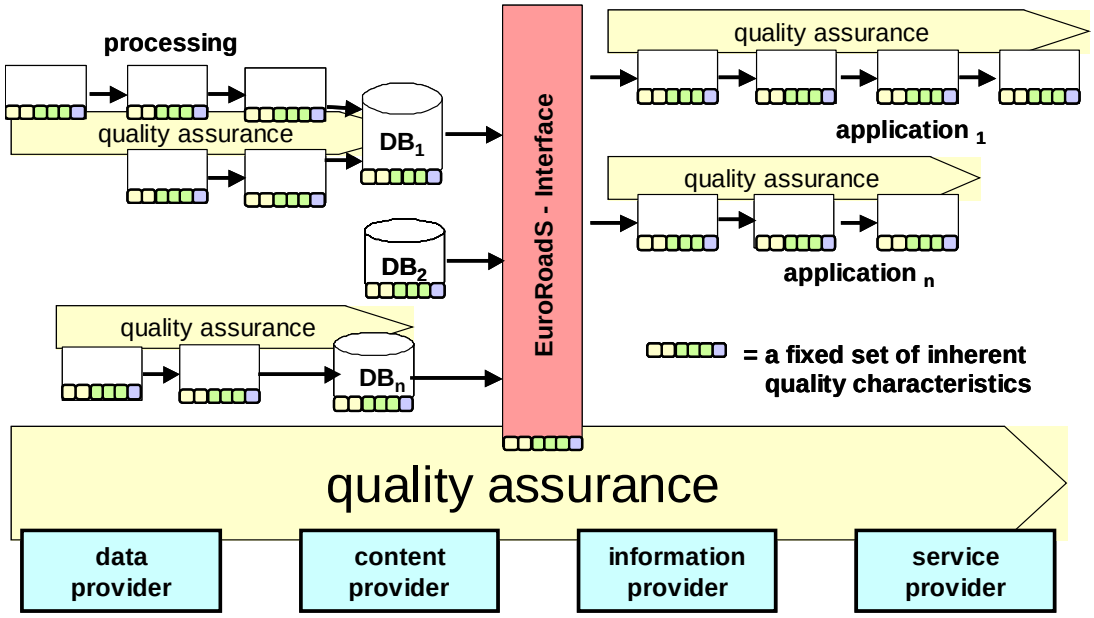

Figure 1 – Information chain with a uniform quality description by a fixed set of quality characteristics as an essential precondition of quality assurance

Future ITS-applications and particularly ADAS need a defined quality level for information. For such a kind of driver assistances systems (e.g. speed alert, traffic light, right-of-way assistance) safe operation has to be ensured. The requirement of technical safety transmits to information quality. It has to be stated that safe operation of map supported ADAS requires quality assured information processes to provide the necessary information quality for the road data [4], [5].

PROJECT EUROROADS

EuroRoadS is a project funded by the European Commission within the eContent-Progamme. The project started in March 2003 with a duration of 30 months and is 50 % funded with a budget of 3.7 million Euro. The project consortium consists of representatives from surveying and mapping agencies (Lantmäteriet (S), Ordnance Survey (UK), Institut Géographique National (F), Bundesamt für Eich- und Vermessungswesen (A)), department of transportation (Vägverket (S), Oberste Baubehörde des Bayrischen Staatsministerium des Inneren (D)), the organisations ERTICO and EuroGeographics, PTV AG (D) as service provider and the Institute for Application of Geodesy to Engenieering of University of Stuttgart.

The main objective of EuroRoadS is to build a platform for a European road data. For this purpose a specification framework consisting of descriptions of structure and content of road data, a quality framework, and exchange mechanism will be developed and tested by prototypes. The focus is to make existing data from public sector (surveying agency, department of transportation, local authority) available for service providers. Within EuroRoadS the entire information will be treated: data provider – content provider – information provider – service provider. It is not the aim of the project to create a pan-European road data base, but to develop a metadata server or virtual shop to realize an easy access to local and regional road data bases for users and interested parties.

EuroRoadS will lay the ground for the creation of a pan-European standardised, seamless, updated and quality assured road data infrastructure based on identified user requirements. Close connections to further European projects and initiatives in the area of geoinformation (e.g. INSPIRE) and ITS (e.g. ActMap, SpeedAlert, Map&ADAS) exist.

The activities of IAGB within EuroRoadS are focused on preparation of a quality concept and development of quality assurance measures, their implementation in test fields, and the verification of the new approach of quality management and assurance within the entire information chain of map-based applications and services.

STRUCTURE AND COMPOSITION OF EUROROADS QUALITY CONCEPT

The specified EuroRoadS quality concept enables an objective quality description and evaluation of information in processes and is applicable for all actors. It consists of a quality model and an analysing procedure (cf. figure 2).

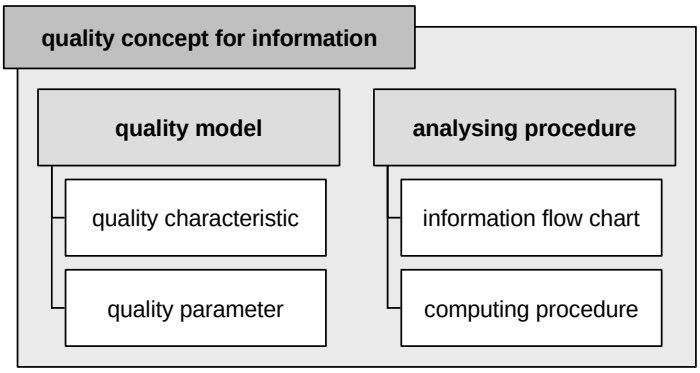

Figure 2 – Structure of EuroRoadS quality concept

Quality Model

The quality model is specified for uniform and objective description of quality of all data and datatyps within the entire information chain. In opposite to ISO 19113, which has the scope of quality description of geographic dataset, the quality model for EuroRoadS has the aim of describing and evaluating the quality in the entire information chain. The quality model should be usable for the quality description of a geographic dataset as well as the quality description of geographic information within processes [6].

To fulfil this extended spectrum the EuroRoadS quality model was specified allowing an objective, complete, and unambiguous description by using a fixed set of inherent quality characteristics. The *fixed set of quality characteristics* is defined as:

availability (AV)	completeness (CM)	consistency (CN)	correctness (CR)	up-to-dateness (UP)	accuracy (AC)

Therefore each quality characteristic has to deal with one definite attributable phenomenon (cf. figure 3). Availability and up-to-dateness are dependability characteristics describing time-related aspects of data quality. The integrity characteristics completeness, consistency, and correctness describe the fitness of use of data. Finally the accuracy: considering that geographic data result from measurement or interpretation, or can be derived from such data, and furthermore considering the fact that a measurement or interpretation can be only given with a certain accuracy or resolution, characteristics referring to this problem are essential for an information quality model.

Concretion of quality characteristics is carried out by *quality parameters.* In opposite to the quality characteristics for the quality parameters no fixed set is defined, because, depending on data type and applied quality evaluation, different parameters will be used (e.g. absolute or relative positional accuracy for street geometry, attribute accuracy for quantitative attributes and temporal accuracy of time measurement for time-depending data).

The quantification of a quality parameter is carried out by a *quality parameter value* which is a numerical value. A quality parameter value is determined by a *quality evaluation method*. Furthermore a *quality requirement*, which means a mandatory level of quality, can be formulated by a quality parameter value.

For example the quality phenomenon "how complete are the data?" will be described by the quality characteristic *completeness*. This quality characteristic will be concretised by the quality parameter *rate of omission*. The actual rate can be effected by the quality parameter value (e.g. *98%*) which can be determined by a *sampling procedure*. The required level of quality can be *rate of omission* = 99%.

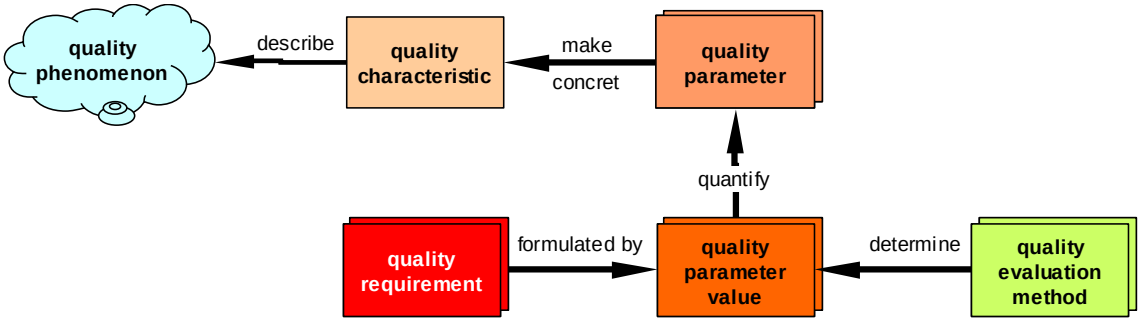

Figure 3: Structure of EuroRoadS quality model

The quality model uses quality elements and quality sub-elements like ISO 19113. But for clear notational separation from ISO 19113, the quality elements are termed as quality characteristics and the quality sub-elements as quality parameters. The EuroRoadS quality contains all sub-elements of ISO 19113 whereas these assigned partly to other characteristics.

Analysing Procedure

The analysing procedure contains a *graphical part* for representation and for modelling the information flow, and a *computational part* for evaluation of information quality within information flow. The method is derived from the event fault tree and event tree analysis, which are applied in the special field of mechanical engineering for reliability analysis [7]. This method bases on the Boolean model and uses probabilistic calculation. The probability of fulfilling the quality requirements for the quality characteristic will be used as quantity. In opposite to the reliability analysis, which deals with the reliability only, several quality characteristics have to be investigated simultaneously. This fact requires an adaptation of the equations particularly with respect to dependency and transition between the quality characteristics.

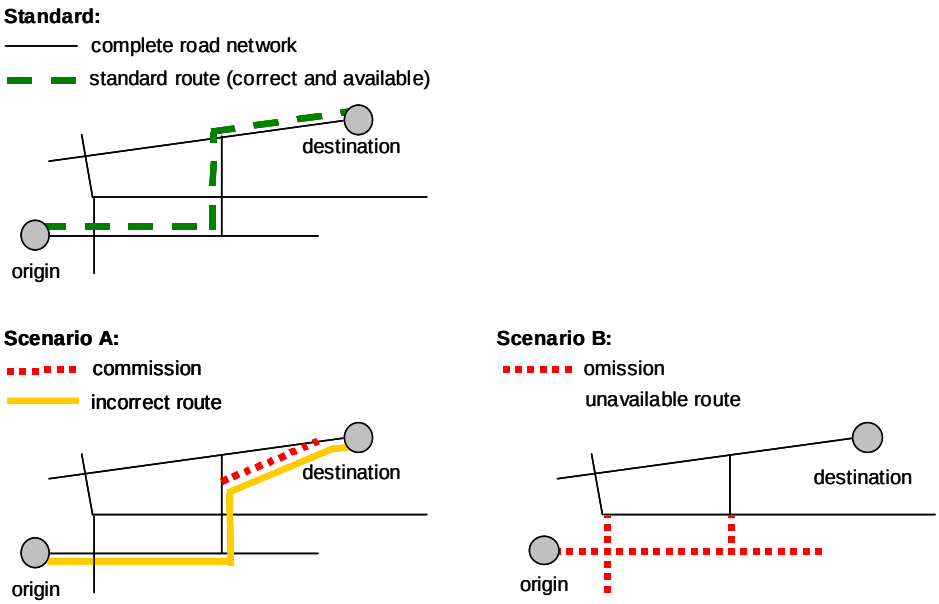

Figure 4 – Example of the influence of commission and omission of input data on the provided output data

Figure 4 illustrates an example for the dependencies between the quality characteristics as they occur in a quality description within an information providing process. In this example the shortest route is calculated based on a digital map. Scenario A shows a commission in the data base, i.e. the map contains a road element with no correspondent road in reality. A calculation of the route is possible, but it will deliver an erroneous result, i.e. the route is incorrect. Scenario B shows an omission, a part of the road network is not captured. In case that the origin or destination is located in this part, a calculation of the route cannot be carried out. This means the omission of the map induces an unavailable route.

For modelling the information flow, the logical connections between the data have to be appointed. Based on the reliability analysis the connections *AND*, *OR*, and *Branching* are defined. An additional symbol is the *Check*, as a special kind of branching. Dependencies between quality characteristics are modelled by the *Transition* symbol. Table 1 illustrates the equations for the AND-linkage and Check. The derivation of the equations and detailed description of the symbols are given in [8].

The quality tupel is defined as ordered sequence in conformity with the fixed set of quality characteristics:

$$\boldsymbol{I} = \left[I^{AV}, I^{CM}, I^{CN}, I^{UP}, I^{CR}, I^{AC}\right] \quad bzw. \quad \boldsymbol{O} = \left[O^{AV}, O^{CM}, O^{CN}, O^{UP}, O^{CR}, O^{AC}\right]$$

for the input data (***I***) resp. output data (***O***). Each element shows the probability of fulfilling the requirement concerning the quality characteristic.

Table 1 – Extract of the symbols to evaluate the information flow chart

Symbol	***Equation***
AND	$O^{QC(q)} = \prod_{i=1}^{n} I_i^{QC(q)} \quad \text{for } k \in [1..5]$
Check	$O_{Yes}^{AV} = p_{Yes} \cdot 1$ $O_{No}^{QC(k)} = p_{Yes} \cdot \left(C_{No}^{QC(k)} \cdot \sum_{i=1}^{n} I_i^{QC(k)} + C_{No}^{QC(k)} \right) \quad \text{for } k = q$ $O_{No}^{QC(q)} = p_{Yes} \cdot I^{QC(q)} \quad \text{for } k \neq q$ with $q, k \in [2..5]$ and $p_{No} = 1 - I^{AV} \cdot \left(C_{Yes}^{QM(k)} \cdot I^{QM(k)} + C_{No}^{QM(k)} \right)$ for k $\in [2..5]$ $p_{Yes} = 1 - p_{No}$

MODELLING OF PROCESSES FOR SPEED ALERT SYSTEM

The application of the quality concept will be shown by a system draft of a speed alert system as example of an ADAS. Aim of this driver assistance system is to protect the driver from disregarding information of current speed regulation. With the help of the functional architecture of different system concepts the information quality will be determined. Different quality characteristics will be predetermined by means of nowadays achievable quality of sensor information, digital databases, and road maps.

In figure 5 system design of map supported speed alert system is illustrated. Within the example the quality tuple is limited to the three quality characteristics availability (AV), completeness (CM), and correctness (CR). The system design includes a check for completeness and correctness on the side of the content provider. Without this quality assurance measure information quality will be on lower level with

$$\boldsymbol{I}_{SA} = [0.999, 0.968, 0.922]$$

By using a video camera within the vehicle as independent redundant data source for the current speed limit indicated by the speed traffic signs another quality assurance can be effected on the side of the system with the result of further increase of quality.

The information process can be characterized as follows: *Data providers* supply a road map and a data source of road signs with speed control. The *content provider* connects these two data sources to a homogenised data set. Without quality assurance methods and with the given quality of the data sources, the following quality tuple would result for the map:

$$\boldsymbol{I}_{\text{map}} = \left[I_{\text{map}}^{\text{AV}}, I_{\text{map}}^{\text{CM}}, I_{\text{map}}^{\text{CR}} \right] = [1.0, 0.968, 0.931]$$

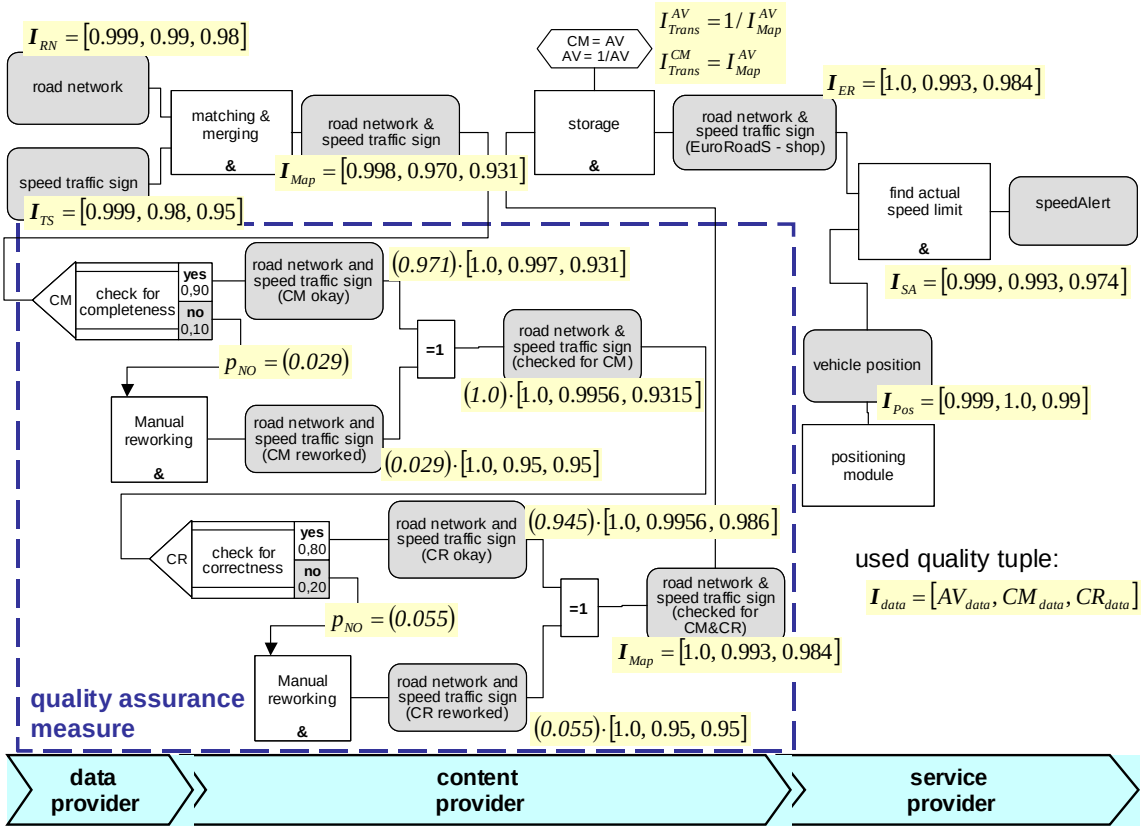

Figure 5 – Information flow with quality evaluation of a speed alert system

Exclusively for reasons of better clarity the quality tuple in the example is limited to three characteristics availability (AV), completeness (CM), and correctness (CR). By integration of a quality insurance method as check of completeness and correctness of the data set, and with a review a clear increase of quality can be achieved:

$$I_{\text{map}} = \left[I_{\text{map}}^{\text{AV}}, I_{\text{map}}^{\text{CM}}, I_{\text{map}}^{\text{CR}} \right] = [1.0, 0.993, 0.984]$$

By means of control steps an examination of the data takes place on completeness resp. correctness. Modelling of check routines considers that not all incorrect data are identified. Thus an error recognition rate of 90 %. can be assumed. All data identified as incorrect will be manually reviewed with a probability of $p_{\text{no}} = 2{,}9\,\%$. Manual review is also not assumed as absolutely correct. The two disjunctive system states are merged by the exclusive OR-linkage. Regarding completeness an increase of quality from 97,0% to 99,56% is shown in the result. Similarly the checking of the data on correctness is proceeded and so an increase from 93,2% to 98,6% is achieved.

QUALITYMANAGEMENT OF ROADDATA

Quality assurance of road information as described above, can be integrated into the so-called PDCA-cycle (s. figure 6). This cycle which includes the four components *Plan, Do, Check and Act* (PDCA), was originally conceived by Walter Shewhart in 1930`s, and later adopted by W. Edward Deming. The model provides in general a framework for the improvement of a process or system.

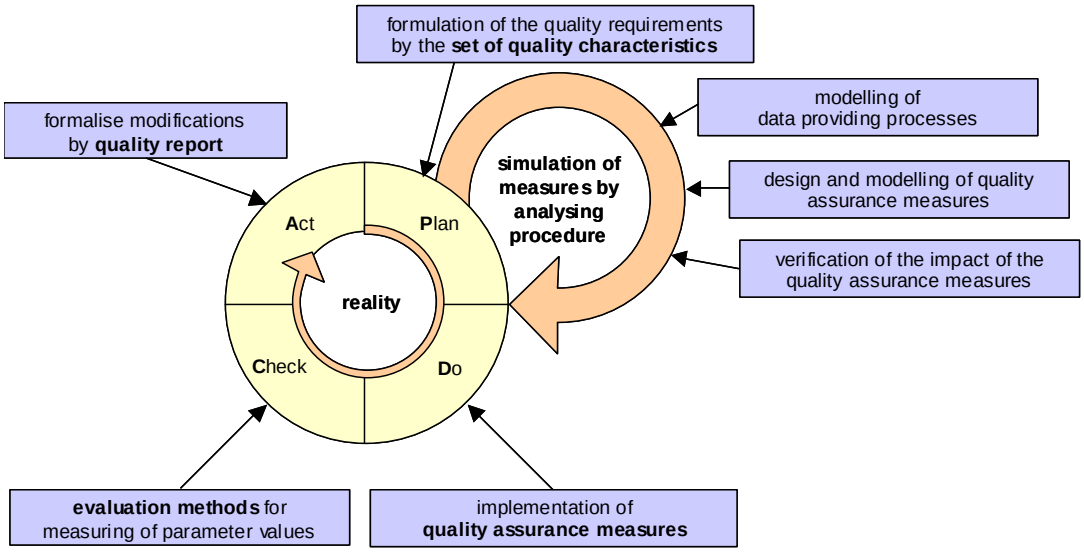

Figure 6 – Integration of EuroRoadS quality concept into the extended PDCA-cycle

In the phase *Plan* objectives and processes necessary to deliver results in accordance to a specification will be established. For this purpose, the required quality of road information can be described by the fixed set of quality characteristics and formulated by variable quality parameters. Furthermore, the simulation of processes by using the analysing procedure can be included into the phase *Plan*. I.e. additional to the cycle for real processes a second cycle for simulated processes can be useful. This includes firstly modelling of data providing processes. On the basis of the model of the data providing process, quality lacks in the process can be identified and quality assurance measures can be designed and modelled. Their impact on quality can be evaluated by the analysing procedure. In this procedure the new parameter values in consequence of the simulated assurance measures will be calculated and compared with the required parameters values. If this check will lead to the result, that the quality required is reached, the simulated assurance measure can be implemented into real processes. Otherwise, if the quality requirements are not fulfilled, additional measures have to be simulated in a second iteration. For all these phases of simulation the analysing procedures, existing from information flow chart and computing procedure, can be a helpful tool.

After planning, including the described simulation, the phase *Do* follows. It contains an implementation of measures in a real data providing process. The following phase *Check* includes monitoring and evaluating processes and results against objectives and specifications. The outcome can be documented in a quality report. Therefore evaluation methods for measuring quality parameter values can be used. Afterwards it has to be verified whether the required product quality is fulfilled. The modifications have to be formalised in a quality report using the quality framework (*Act*). For this purpose the processes of road information by using the analysing procedure will be published in a quality report. Furthermore the measured quality parameter values will be integrated into a metadata catalogue. I.e. the road data will additionally receive quality description according to the metadata catalogue within the information chain at the EuroRoadS interface.

The target is the specification and implementation of quality management components for processes of road information according to the PDCA-cycle. In 2004 and 2005 the components *quality model*, *analysing procedure*, *metadata catalogue*, and *quality evaluation methods* are specified. In the following these components will be implemented into testfields in cooperation with EuroRoadS-partners.

OUTLOOK

The presented quality concept allows a uniform quality description of all occurred data and information within the entire information chain of an ITS-application. In combination with the analysing procedure the method stands for development and implementation of quality assurance measures in ADAS. Within the scope of the project EuroRoadS a test site for a speed alert system will be build up to demonstrate and validate the application of the quality concept.

In the future ADAS will use more and more digital map data content as an additional sensor for vehicle safety functions. It has to be stated that safe operation of map supported ADAS requires safe information and information processes to provide the necessary information quality for digital road maps. A safe information can be described as an information containing a quality that an action based on this information has an accepted limitation of risk of personal injury and material damage [9].

The EuroRoadS project delivers an approach for an easier access to the required road data. With the proposed quality concept a methodology for uniform quality description and an implementation of quality management concept for information as pre-condition for a quality assured provision of road data is available.

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