ROad **S**afety **ATT**ributes exchange infrastructure in **E**urope

D5.2
Report on data quality management concept

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Abstract: This document presents fundamentals of Data Quality Management, the approach and concept proposed in ROSATTE. The concept consists of two parts: a QM for the project development phase in order to ensure the achievement oft the user requirements but also contains a quality monitoring for the entire data chain. The second part is a QM for process improvement, to be conducted in case the requirements change or quality lacks have been detected in future.

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List of Abbreviations

CTQ	Critical to Quality
DfSS	Design for Six Sigma
DMADV	Define Measure Analyse Design Verify
DMAIC	Define Measure Analyse Improve Control/Check
DPMO	Defect per Million Opportunities
FMEA	Failure Mode and Effects Analysis
LA	Local Authorities
MP	Map Provider
PDCA	Plan Do Check Act
QFD	Quality Function Deployment
QM	Quality management
RPN	Risk Priority Number
SAT	Stand Alone Tool
SIPOC	Supplier Input Process Output Customers
STREP	Specific Targeted Research Project
TQM	Total Quality Management
VOC	Voice of Customer

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Executive summary

The document provides a short introduction into fundamentals of quality management (QM) and the ISO 9000 family with a general description of existing quality management concepts, such as PDCA, TQM and Six Sigma. As conclusion and main objective of the document, the developed approach for ROSATTE is presented together with essential methods and adapted tools. The proposed concept is based on Six Sigma. The key benefits of this concept are presented as well as the resulting advantages of the approach for the project itself.

The proposed ROSATTE concept consists of two regulators to ensure the requested user quality requirements. The first regulator is the quality management for quality assured project development, which helps to develop methods and tools for the exchange of road safety features and ensures the continuous monitoring of data quality. The second regulator is the quality management for process improvement. The included methodology helps to improve processes in case of user requirement changes and/or by detection of errors during continuous monitoring. Both regulators are based on the same approach called DMAIC. Each and every one of the steps of the ROSATTE project can be assigned to DMAIC which consists of the five phases: define, measure, analyze, improve and control. A detailed description is given in the course of the document. Closer attention is paid to QM tools for process improvement. A variety of different tools are being applied depending on the accordant DMAIC phase. The goal is to identify all existing problems.

In the define phase feedbacks from users are being handled and transformed into specific attributes which are then implemented by using the Kano-model. An approximated project flow is fixed and an analysis is performed to find the single project steps and establish a structured process. In the measure phase meaningful corresponding parameters are looked for using Quality Function Deployment (QFD). The analyze phase serves the purpose of finding out the origins of an occurred problem. Simulations, tests of significance and testing for any correlations can help to track down the cause of failure. The improve phase results in the final elimination of the cause or causes of failure within the real process. Failure mode and effects analysis (FMEA) allows minimize or avoid any risks for the process. At the end the control phase is being applied to verify the findings. At this stage all partners involved in the project have to be informed about the implemented improvements and the resulting gain in the process.

The annexes contain practical experiences related to quality management and quality assurances gained during the project. Quality assurance measures are divided in three groups such as prevention of erroneous data input, automated checks for completeness and consistency and finally plausibility checks. They are described with respect to the ROSATTE data specifications. A general quality monitoring plan for future implementations and future prospects including an action plan are presented as conclusion of the document.

1 Introduction

1.1 ROSATTE Contractual References

ROSATTE is a STREP submitted for the call FP7-ICT-2007-1. It stands *for ROad SAfety ATTributes exchange infrastructure in Europe.*

The Grant Agreement number is 213467 and project duration is 30 months, effective from 01 January 2008 until June 2010. It is a contract with the European Commission, DG INFSO.

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1.2 Project Objectives

The ROSATTE project intends to develop the enabling infrastructure and supporting tools that will ensure European access to road safety attributes including incremental updates. This infrastructure will facilitate administrative internal functions as well as supply of data to third parties e.g. for safety relevant services.

The **overall objectives** of the project are to:

1. Facilitate access to, exchange and maintain European-wide core road safety spatial data from national/regional/local sources by standard procedures
2. Enable multi-level aggregation and update of European-wide safety map data
3. Assess the technical and organizational feasibility of this infrastructure

1.3 Key issues / Project scope

Accurate and up-to-date safety related road network attributes are particularly important for efficient road operation and administration, and for safe driving along the European road network.
For data users, the reality today is however a rather complex landscape of multiple data providers, multiple formats, varying availability and quality of data and long delays between data updates. Road authorities and infrastructure operators are usually at the beginning of the information chain, being responsible for the physical implementation, equipment and maintenance of roads.
The major problem is how to ensure timely and easy access to road information owned and maintained by thousands of road authorities. In addition mechanisms are needed to enhance the quality of the available data in terms of accuracy, correctness and up-to-datedness, and to enable multi-level (local/national/European) aggregation of the data. With respect to a future continuous delivery and integration of updates of road attribute data, road authorities that provide such updates will be responsible for the timeliness delivery (within an agreed time period after the change of the attribute on the road), and for the correctness and positional accuracy of the data. Data integrators on their side will be responsible for correct interpretation of the received data, and correct inclusion in their digital map databases. For certain safety critical attributes, an independent

certification body may be created that will be responsible for surveillance of the methods and procedures used.

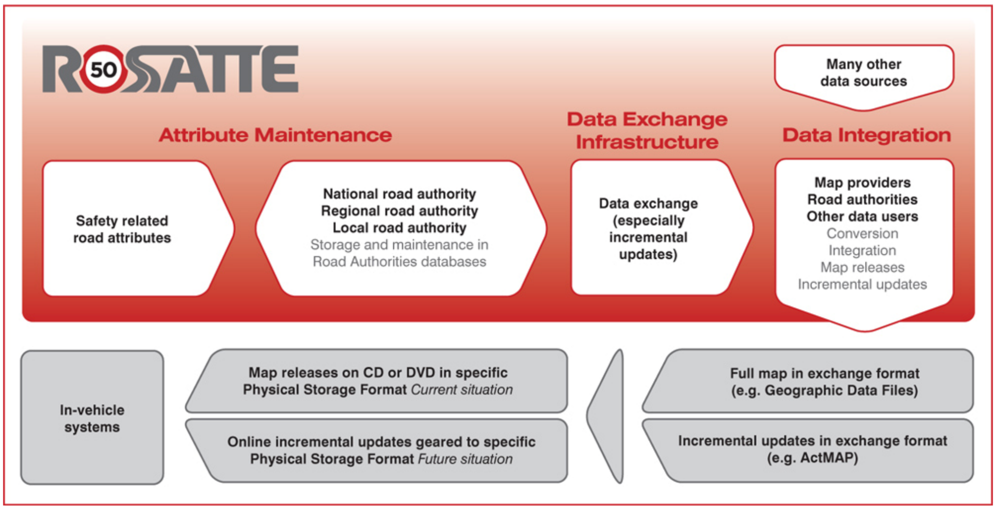

Figure 1 - The scope of ROSATTE

1.4 Purpose of the document

The ROSATTE project focuses on the development of an exchange infrastructure for quality assured road safety attributes. In order to reach that objective, it is therefore very important to develop and implement a quality management (QM) system. The proposed QM concept is based on the respective ISO standard as well as on the experiences of previous projects. It accompanies the project development phase. Requirements on data quality will be formulated and the development of methods and tools will be based on these requirements. After the implementation, the ROSATTE framework will be tested during the final verify phase of the QM concept (see D5.1 Test and validation plan [16]). The test results will be documented in D5.4 Aggregated test report. Finally, a list of quality assurance measures, a monitoring plan and a corresponding action plan are set up. They build the basis of a continuous quality monitoring for future implementations of ROSATTE. Since the experiences of the project test and validation phase are very important inputs, the document has to be updated at the end of the project.

1.5 Structure of the document

Besides the introductory part, this document contains the following chapters:

Chapter 2 - Quality management fundamentals
This chapter provides the theoretical background and gives an overview of some common quality management concepts and related standards.

Chapter 3 -ROSATTE quality management approach
This chapter presents the chosen concept. It consists of two parts: a quality management dedicated for the project development phase and one that accompanies future implementations.

Chapter 4 - Quality management tools
This chapter finally describes the methods related to the developed quality management concept in detail.

2 Quality Management Fundamentals

Quality management is used for the assurance of a defined quality and therefore it must prevent potential errors. It can be used for the improvement of processes as well as for the improvement of products. The first approaches to quality management were undertaken to increase customer satisfaction and the benefit but also to reduce costs caused by the bad quality of products. The quality requirements should ideally be formulated by the customers. Only content customers will use again the same product in future.

Today quality management can be used by nearly every organization. There are different, even specialized concepts for implementation and international standards like the ISO 9000 family. So the adequate quality management concept must be chosen and adapted to the special requirements of the own organization. Then this concept can be implemented to reach a quality standard which is accepted by all users. If there are any problems concerning the quality, the products or even the process itself must be improved to guarantee customer satisfaction.

2.1 Introduction to Quality Management - ISO 9000 family

A continuous improvement of performance is the basis for the successful control of an organization. For that purpose, the needs of all interested parties must be taken into account. Quality management is used to implement this basis.

According to ISO 9000 [10], quality management is defined as "coordinated activities to direct and control an organization with regard to quality." Thereby quality is the "degree to which a set of inherent characteristics fulfills requirements." "Direction and control with regard to quality generally includes establishment of the quality policy and quality objectives, quality planning, quality control, quality assurance and quality improvement."

Some basic requirements to the implementation of quality management are specified in the ISO 9000 family of standards which helps "to implement and operate effective quality management systems." ISO 9000 describes fundamentals of quality management, ISO 9001 specifies requirements for a quality management system for organizations and ISO 9004 provides guidelines which completes the requirements of ISO 9001.

The ISO 9000 family only defines requirements to a quality management system but not to the products, it is only a general guideline for implementation of such a system. Therefore the requirements for products are defined by customers, authorities or the organization itself. The top management of the organization has to cultivate a quality spirit which is implemented by each person.

ISO 9000 also uses a process approach to achieve desired result. Each activity is managed as a process.

"Quality policy and quality objectives are established to provide a focus to direct the organization." [10] Quality policy gives a framework for the definition of objectives. If these objectives are implemented and reached, the process and its products will be improved and costs are reduced. The total process should be documented carefully to have a good control opportunity concerning the keep of requirements. It also enables a retraceability of errors and fixes basis for following trainings.

Evaluations of quality management systems can include a self-assessment or auditing. This should be done regularly to estimate the capability of the systems.

2.2 Existing quality management concepts

For the realization of the quality management described in the ISO 9000 series quite a big number of different QM concepts have been worked out. In the following three concepts which are basically suitable for the ROSATTE project are introduced.

2.2.1 PDCA

The PDCA cycle that is also known as Deming cycle, was developed by William Edward Deming [13]. It consists of the 4 phases plan, do, act and check. Most of the common quality management concepts are based on or derived from the PDCA cycle. The individual phases have been defined in detail in ISO 9001 [11] as

- Plan: establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies
- Do: implement the processes
- Check: monitor and measure processes and products against policies, objectives and requirements for the product and report the results
- Act: take actions to continually improve process performance

The phases form a continuous circle for process improvement. Quality assured process development is not addressed in the PDCA concept.

The EuroRoadS project had similar requirements with regards to data quality management as ROSATTE. Therefore the EuroRoadS quality management concept, will be considered here as well. It is based on the PDCA cycle, but was especially adapted for road data processing [2]. The four general PDCA phases were subdivided into several tasks:

1. Plan: - specification of quality requirements
   - detection sources of errors
   - development of quality assurance measures
   - verification of the efficiency of quality assurance measures
2. Do: - implementation of quality assurance measures
3. Check: - determination of information quality
   - proof efficiency of quality assurance measures
4. Act: - documentation of quality
   - documentation of processes

For the realization of each task, different methods and tools like FMEA and Cause and Effect diagrams have been used.

2.2.2 TQM

Total Quality Management, also called TQM, is a management philosophy which is focused on the value-added process. This method is orientated at all persons having requirements to the quality of products: Customers and participants being also internal customers.

Within TQM, the required quality of products is reached by fulfilling all user requirements and wishes. But these requirements change permanently, so there is a continuous need for improvements. So each action is considered to be a process with room for improvements. These improvements shall also improve the business case. This means that the quality intensification leads to a reduction of costs and of the production period. The general objective of TQM is to be market leader for all provided products, it therefore should be introduced in the whole company or organization.

Therefore errors must be avoided in all sectors of the organization and the objective is a strategy of zero defects which is a main aim of TQM [14]. So errors can't be tolerated, their causes must be detected. And each known cause is an opportunity to learn more about performing qualitative results.

The improvement of quality is reached by formulating concrete objectives specifications. So it can be checked whether the objective is fulfilled. For this purpose information about quality requirements must be available.
A specification of objectives must always include following items to comprehend later the original objectives and their achievement [14]:

- Concrete formulation of the content
- Time frame
- Responsibilities of the objectives
- Specification of intensity of labor
- Required resources
- Description of general conditions
- How will be measured if the objectives are achieved?
- Kind of documentation
- What will happen after having finished the improvement?

2.2.3 Six Sigma

The origin of the Six Sigma concept lies in the quality engineering for the implementation of a zero defects strategy and leads to a high quality capability of processes.
The name Six Sigma has its origin in statistics, where Greek word sigma (σ) depicts the single standard deviation, e.g. of a measurement value. If the measurements are normal distributed, 68.3% of the measurements lie within an interval of ± 1 σ around the true value. Consequently, Six Sigma describes the portion of measurements that lie within an interval of ± 6 σ around the true value, which is 99.7%.

6σ -quality does not mean that only 3.4 defects do exist in an amount of 1 Million product units, but that each product unit is considered as a potential defect opportunity and hence 3.4 defects do exist in an amount of 1 Million defect opportunities [15]. So the objective of the Six Sigma concept is to realize as less defects as possible. This would lead to a Yield value of 99.7% faultless safety attributes.

Six Sigma projects demand a raising user satisfaction by fulfilling the user requirements like Data discovery or INSPIRE conformance. All problems which prevent this objective must be identified so the problems can be eliminated. The general aim is to implement the strategy of zero defects. Defects must be avoided to realize all requirements.

The first step in a Six Sigma project is to identify the potential users and their requirements. Then the process optimization task can start. To be successful it is important that the participants think and act in processes. All involved people should be sensitized regarding quality and its importance. The different Six Sigma grades are named after the different belts of Asian martial arts. A master black belt for instance is the top-level degree that works full-time in quality management and educates others employees [15].

The project participants can detect problems and initiate an improvement process. The benefit of such an improvement project is that quality improvement also increases benefit by minimizing costs of errors.

Table 1 - Six Sigma methods [15]

Method	Description
Stand-Alone-Tool (or SAT)	Individual selected tools are used to achieve punctual improvements
DMAIC	Define – Measure – Analyse – Improve – Control/Check: standard method for the improvement of existing processes. Often Six Sigma is only reduced to this method.
QuickHit	Short form of DMAIC method which is used to achieve quick and unique effects. These helps to establish acceptance for innovates.
Design for Six Sigma (DfSS)	Method for developing new products and processes

There are different methods for realizing a Six Sigma project. The development of new processes and products requires different implementations like Design for Six Sigma (DfSS) with own methods like DMADV (see chapter 3.2, 4.1). A well-known method which is often used for process improvement is DMAIC (see also chapter 3.3, 4.2). This DMAIC method is an advancement of the PDCA-cycle which uses especially statistical tools for such improvement projects.

Six Sigma projects are only implemented in cases of existing problems and if user requirements cannot be satisfied. Furthermore Six Sigma projects are only profitable if no solutions for a defined problem do exist yet.

3 ROSATTE Quality Management approach

The Quality Management within the ROSATTE project guarantees the development of processes and its results fulfilling user requirements. There shall be no problem for users to integrate data about safety related road network attributes into their own databases. Furthermore the quality of safety attributes corresponds to the user requirements.

3.1 Proposed concept

ROSATTE quality management concept is based on Six Sigma. The proposed concept helps to develop and realize an optimal data processing chain with its methods and tools. The quality management concept can also be used for process improvement. This is either necessary if the user quality requirements cannot be met, if the user quality requirements have been changed or if the requirements on the process flow have been changed.

The ROSATTE QM concept is based on Six Sigma, because

- In contrast to PDCA and TQM, Quality improvement in Six Sigma is not a continuous process. The improvement cycle is only executed if necessary and ends with the attainment of the quality objectives
- In contrast to PDCA, Six Sigma offers two possibilities to reach the user quality requirements:
    - Quality assured process development (Design for Six Sigma)
    - Process improvement (DMAIC)
- In contrast to TQM, it is not necessary to implement the Six Sigma concept in the whole organization
- Six Sigma can be implemented in the sectors where it is necessary and helpful
- Six Sigma is strongly focused on the fulfillment of user quality requirements
- Six Sigma delivers quantitative results

Since the Six Sigma concept is an enhancement of PDCA, the ROSATTE quality management concept is conform to the respective ISO 9000 series standards.

In contrast to big industrial companies, where the Six Sigma concept is usually used, the ROSATTE project respectively the ROSATTE consortium is more of small or medium size. Therefore we will concentrate on the development of the quality management concept and its procedures and will neglect the hierarchical structures and the training of dedicated quality staff that normally would be also part of the Six Sigma concept.
Therefore, in the ROSATTE approach the project members act in order to fulfill the data quality management objectives.

The proposed ROSATTE concept consists of two parts (seeFigure 2):

1. **QM for quality assured project development (q.v.3.2, 4.1)**
   This part helps to develop methods and tools for the exchange of road safety features that fulfill the user requirements. It also provides a concept for the continuous monitoring of data quality for future implementations of ROSATTE.

2. **QM for process improvement (q.v. 3.3, 4.2)**
   This part provides a methodology that helps to improve processes if
   - the user requirements change in future
   - an error is detected by continuous monitoring

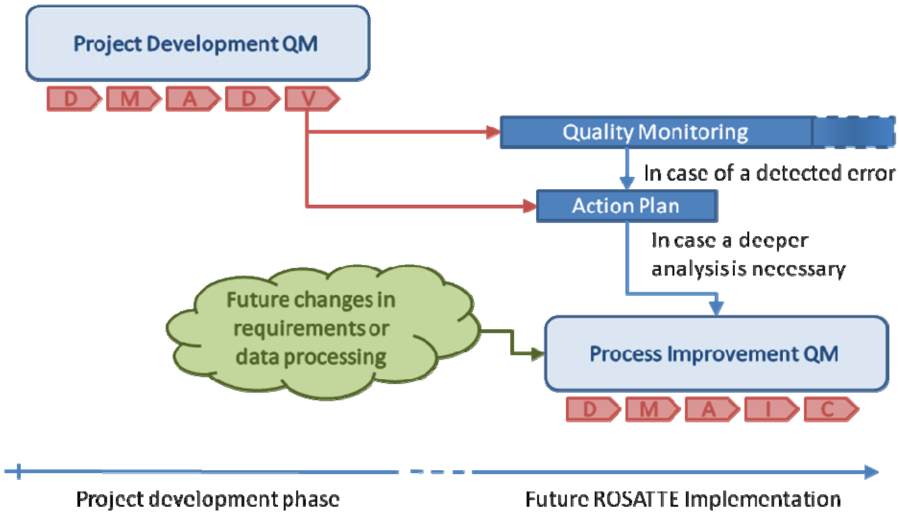

Figure 2 - ROSATTE quality management concept

These two phases are described in more detail in the following paragraphs. Chapters 3.2 presents the methods for the realization of the described quality assured process development concept in general. The implementation of these methods is shown in chapter 4.1. Since ROSATTE is already in the design phase (3.2 IV) at the time this document was written, the practical implementation of all previous phases is shown. Also a prospect to the verify phase (3.2 V) is given. Chapter 3.3 describes the methods for the proposed process improvement concept, chapter 4.2 gives recommendations how to implement them.

3.2 QM method for quality assured process development

The ROSATTE quality management concept for the project development phase is based on the Design for Six Sigma methodology [16]. It consists of the following phases (DMADV, see also Figure 3) which are described in more detail in the following paragraphs:

1. D = Define
2. M = Measure
3. A = Analyse
4. D = Design
5. V = Verify

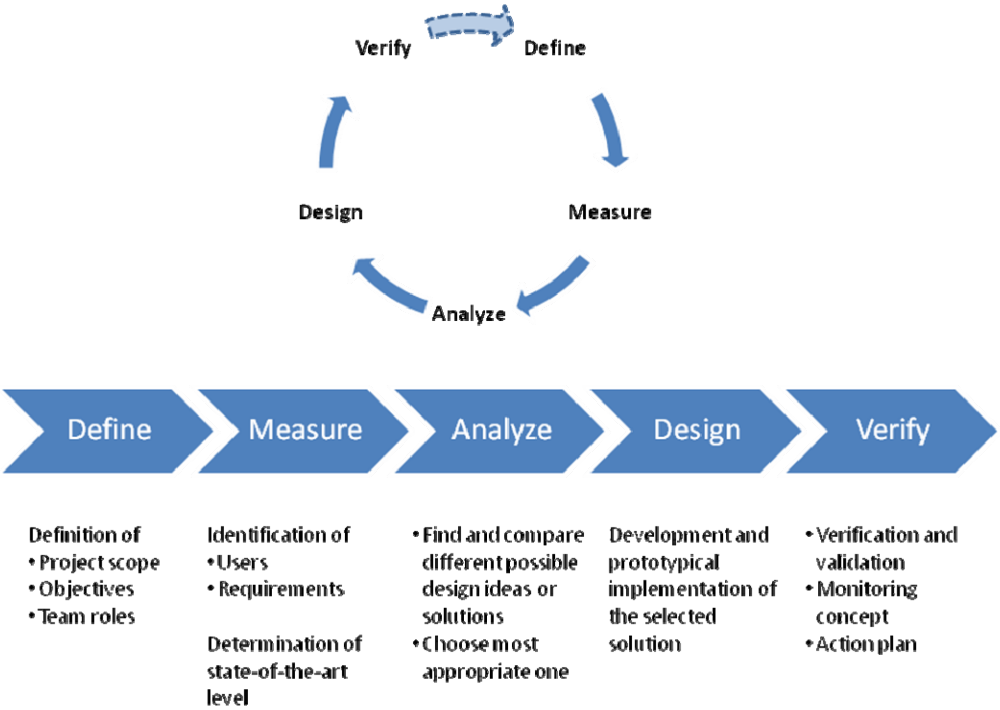

Figure 3 - DMADV approach

These phases cannot only be used for the development of the project as such but also to find proper solutions for individual problems like location referencing, communication, db tools, data formats etc.

I. Define

DfSS projects start with a DEFINE-phase. At the beginning, the participants must define objectives, the scope and the team roles of such a DfSS project. They have to delimit the DfSS project against other processes or projects but also have to find interfaces to them.

II. Measure

At the beginning of the MEASURE-phase, the customers and their requirements must be identified. Potential customers are interviewed regarding their requirements. If the project team has received all contributions, it can start to transform them into measurable parameters.
The state-of-the-art level is determined by measuring the process performance of comparable products or processes using the previously defined parameters.

III. Analyse

During the ANALYSE-phase, different possible design ideas or solutions for a concrete technical problem have to be found, concretized and compared. This assessment should be based on the previously defined requirements and their parameters. The most appropriate idea will be chosen and then further developed in the next phase.

IV. Design

The chosen system architecture will be optimized with regards to the user requirements and realized prototypically during the DESIGN-phase.

V. Verify

In the first step of the VERIFY-phase, all developed processes are passed once and the process performance is determined. If all requirements are fulfilled and there are no more problems, the new process will be implemented and documented. Henceforward in the second step, a process monitoring concept is to be developed in order to continuously monitor the performance of the implemented processes.
An action plan defining counter measures for possible errors has to be worked out. If the process monitoring shows an unexpected error, the process improvement method described in the next chapter has to be used.

3.3 QM method for process improvement

If a process improvement is necessary, the DMAIC (see Figure 4) method can be used. The individual phases of this procedure are described in the following paragraphs [12]:

1. D = Define
2. M = Measure
3. A = Analyse
4. I = Improve
5. C = Check/Control

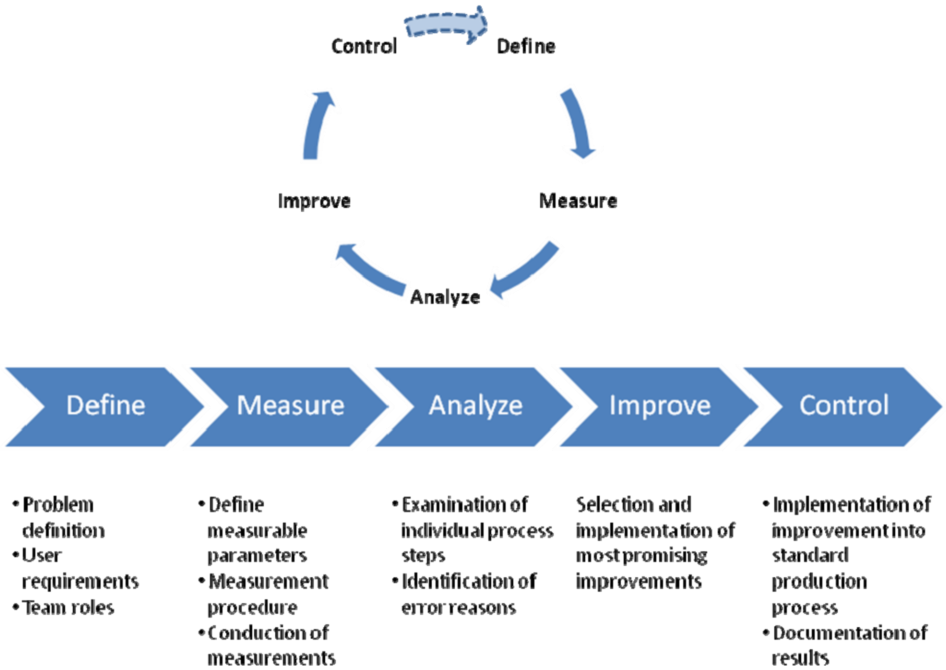

Figure 4 - DMAIC approach

Define

First of all, the improvement project starts with identifying the actual problem. Therefore the (most important) user requirements should be recapitulated. It is not necessary to start a Six Sigma project if any solution strategies for the problem do already exist. Another task of the DEFINE-phase is to define the scope, the team roles and the milestones of the improvement project.

Measure
In the following MEASURE-phase, it must be determined how far the user requirements could already be achieved. Therefore these user requirements are translated into measurable parameters. Then a measurement procedure is to be defined and it also must be stated when and how often this procedure has to be executed. Now the measurements can be accomplished. The problem is described statistically by calculating the actual process performance from the measurement results and thereby determining its Sigma level.

Analyse
The third phase aims in identifying the reasons for a failure of the requirements, wherefore the single process steps are examined carefully. Probably several different causes exist, but it could be uneconomic to eliminate all of them. So the most crucial ones are chosen and will be resolved in the following step.

Improve
The following IMPROVE-phase serves for selection and prototypical implementation of the most promising improvements/solutions. Now a test run for the improved process can be performed.

Check/Control
In the final CONTROL- or CHECK-phase, the improvement is integrated in the standard process. It is checked with statistical tools to what extent the original objectives could be reached. The previously defined monitoring procedures and action plan have to be adapted to the improved process design.

At the end of each phase it has to be checked whether the chosen way of improvement leads to a profitable result. Otherwise this improvement project has to be stopped. If it is not possible to reach a profitable result, possibly the process development has to be started from the very beginning.

4 Quality Management Tools

4.1 QM tools for quality assured project development

During *ROSATTE,* a new process to exchange up-to-date safety related road network attributes is implemented. The *ROSATTE* project can be understood as a new process like it is described for DfSS. So the single steps can be integrated in the five phases of the DfSS DMADV method.

4.1.1 Define

At the beginning of this DfSS project a Project charter [15] is worked out to describe exactly the following project. All agreements of a Project Charter are included in *Annex I – Description of Work* [8]. In this document the structure of such a charter is only shown with the help of a short summary:

- Business Case: Data users can choose between multiple data providers with multiple formats and quality. Road authorities and infrastructure operators are responsible for the physical implementation, equipment and maintenance of roads, but the data management and provision varies across Europe. Some countries like Sweden, Norway or Finland already have established national road databases, but most of the other countries don't have consistent national databases.

- Problem Statement: Advanced driver assistance systems (ADAS) require up-to-date and consistent safety attributes of national authorities for a transnational use.

- Goal Statement:
    1. Facilitate access to, exchange and maintain European-wide core road safety spatial data from national/regional/local sources by standard procedures.
    2. Enable multi-level aggregation and update of European-wide safety map data.
    3. Assess the technical and organizational feasibility of this infrastructure.
- Project Scope: Development of a process to generate a European-wide database with safety related road network attributes and of tools to integrate changes of these safety attributes just in time.

- Team Roles: ERTICO-ITS Europe (Belgium), ASFA (France), Laboratoire Régional de l'Ouest Parisien (France), Flanders DoT, Vlaamse Overheid – Dept MOW (Flanders Traffic Centre) (Belgium), NAVTEQ (Netherlands), Norwegian Public Road Authorities (NPRA) (Norway), OBB, Bavarian Department of Highways and Bridges (Germany), PTV AG (Germany), SETRA, French Ministry of Transport (France), SINTEF (Norway), SRA, Swedish Road Administration (Sweden), Tele Atlas (Belgium), TRIONA (Sweden), University of Stuttgart (Germany), Transport of London
  Also responsibilities for the single steps of the project are fixed.

- Milestones:
  Milestone 1 – Requirements and overall architecture defined and agreed
  Milestone 2 – Infrastructure and tools developed
  Milestone 3 – Testing conducted and demonstration developed
  Milestone 4 – Organizational recommendations and project finished

The future general process flow was furthermore set (see Figure 1).

4.1.2 Measure

Since there are no real end-user applications available at the moment, it has been decided to regard the map providers to be the end-users within ROSATTE.
The present safety attribute exchange mechanism in different countries has been evaluated in *D 1.1 State of the art* [3].

If the customers (users) of the safety attributes are known, the user requirements can also be identified (see *D1.2 Requirements and Overall Architecture* [3]). They are called Voice of Customer (**VOC**). VOCs are formulated subjectively by the customers and must be transformed into quantitative characteristics, the so-called Critical to Quality (**CTQ**) [15]. These characteristics are often not measurable, so we need special quality parameters for each single feature to receive a concrete measuring result and to make a statement concerning the quality of data (see also quality parameters in *D5.1 Test and validation plan* [17]).

4.1.3 Analyse

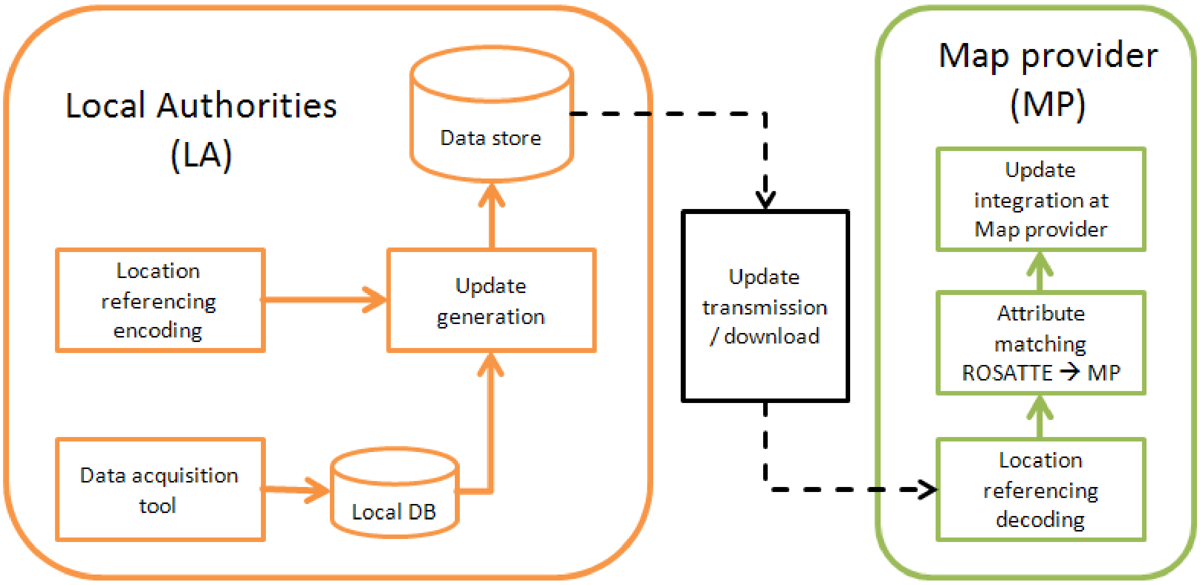

Figure 5 - General process flow

A general process flow was already drawn up during the DEFINE-phase. This general structure must be worked out now. First different opportunities of process development and implementation were discussed (see *D2.1 Conceptual specification of how to establish a data store* [5], *D3.1 Specification of data exchange* [7] and later *D4.1 Description of applicable and viable data integration methods* [8]). The different test sites and the existing structures in the different countries differ a lot in some parts. Figure 5 shows a general process flow. More detailed test site description can be found in *D2.2 Implementations of tools for demonstration of data maintenance and access in different test beds* [6]. So it was necessary for each country/ region to coordinate the process flow in its test site depending on the involved authorities and the test site-specific requirements. But at the end the resulting safety attributes of all these sub-processes must be available in a common format. Finally a corresponding concept was decided which guarantees the determination of all important requirements.

Besides the specific situations at the test sites, different possibilities for common project parts as for instance data format and location referencing (D3.1 [7]) were analyzed and the most promising technique was chosen respectively.

4.1.4 Design

The developed concept was enhanced, optimized and the necessary tools were developed and implemented. The refined processes must always be conform to the user requirements and guarantee their implementation. (See *D2.2* and later *D4.2*).

4.1.5 Verify

Before its implementation, the developed processes are assessed whether they are working in the desired way and if the results reach the required quality. This assessment procedure is described in *D5.1 Test and validation plan* [17].

The final process implementations at each test site i.e. at the project partners will be documented by updating the respective project deliverables (D2.1, D3.1, D4.1). In future all participating persons will therefore know exactly what to do and which data quality shall be achieved.

For guaranteeing a homogenous data quality a monitoring concept is to be developed, so that appearing errors can be identified easily in the future implementation of ROSATTE. The parameter values are captured and can be compared with given reference values. In case the respective limits are exceeded it must be decided whether the appeared error(s) are either outliers, an exceptional case or whether the limits are exceeded significantly. A significant loss of quality is a serious problem, its causes must be detected and the determined authorities must be informed (for example data acquisition authorities, software producer or data base operators) and the corresponding countermeasures must be initiated according to the reaction plan. This plan defines the exact procedure to follow in case a certain quality problem was detected by the monitoring system.

Finally the project team finishes the project with a detailed documentation of the project flow, where the single project steps and their results are questioned critically (see later *D8 Final project report*).

4.2 QM tools for process improvement

The continuous monitoring of data quality may detect errors which can't be solved by the defined countermeasures of a reaction plan. In this case an improvement project should be started, so that the safety attributes will satisfy the requested data quality. Another reason for an improvement process would be changes in the user requirements.

All users of the ROSATTE concept on each level should perform Quality Management with the aim to improve the sub-process in their sphere of influence. The effect would be an optimization of the total process. For example: If local authorities refine data acquisition they would not start an improvement project including the total process. Such projects can as well be started by each test site itself.

This chapter provides guidelines how to implement the process improvement concept presented in chapter 3.3.

4.2.1 Define

First of all the existent problems must be identified. For that reason the users' requirements are compared to the achieved quality. Hence these requirements (VOCs) are collected. There are different opportunities to collect them, for example carrying out a survey to the map providers. But there are still some known requirements of users due to received feedbacks (Feedback-loop) which can be used as VOCs. These requirements must be transformed into CTQs.
There is of course a variety of CTQs, not all can be taken into account. Therefore the most important ones, the so called Project Ys, are chosen to be implemented in any case. This happens by using the Kano-model [13]: All CTQs are divided into Threshold (or basic) attributes, Performance Attributes and Excitement Attributes. Threshold attributes are expected by customers without any special request; the implementation of Performance attributes increases the customer satisfaction proportionally; Excitement Attributes are unexpected but their implementation increases customers satisfaction significantly.
Now a Project Charter is written including the following statements:

- Business Case
- Problem Statement
- Goal Statement

- Project Scope
- Team Roles
- Milestones

A rough project flow is fixed at the end of this phase. SIPOC analysis is a Six Sigma tool to find the single project steps [15]. The project team installs a table with five columns: Supplier, Input, Process, Output, and Customer. The columns are answered for each rough project step so the result will be a structured process.

4.2.2 Measure

The actual process performance must be determined. For this reason, concrete measurement parameters must be found as well as a measurement concept and a measurement schedule (SIPOC analysis helps to find the right moments) must be fixed (see *D5.1 Test and validation plan* [17]). Corresponding parameters can be found by using Quality Function Deployment (**QFD**).

For the accomplishment of QFD [15] it is necessary to draw a table; all CTQs or Project Ys are written into the first column. Each of them is prioritized with a weighting value (1-5) which is inserted into the last column. Now possible parameters must be found, therefore the project team conducts Brainstorming. These ones are written in top of each column. Now it is checked how much each single parameter depends on each CTQ. The weighting of this assessment (0: no correspondence, 1: weak, 3: medium, 9: strong) is written into the corresponding fields. These weights are multiplied with the weighting of the several CTQs and the result is also noted in the fields. The products of each column are added and the sum is fixed below the column. The sum of a column represents the importance of its parameter. Parameters having a high score represent several CTQs so it is rational to use them in measurements.

Now the measurements can be started. The measuring results are used to determine the Sigma-level by calculating the defects per million opportunities (DPMO) [15]:

$$DPMO = \frac{D}{N \cdot O} \cdot 1{,}000{,}000$$

D: number of occurring defects
N: number of entities
O: number of defect opportunities

4.2.3 Analyse

At the beginning of this phase, the total process is considered carefully to find the origins of the detected errors. Therefore the single steps of the SIPOC analysis must be refined so an exact flowchart can be drawn. The origins of the problems can be found by examining the Input of the individual steps. The project team can collect them by conducting a brainstorming. The use of an Ishikawa diagram (also called fishbone diagram or cause-and-effect diagram) would be the best to ascribe the causes to the categories environment, machines, management, materials, measurements, methods, people. Each found cause must be judged how much it influences the process result and if it can be eliminated by the project team. Otherwise the team must be extended with a responsible person.

It also can be tried to eliminate single causes or to reduce their effects in simulations. For example if defective safety attributes has an already well-known cause of failure, they can be divided in categories according to their cause of failure. All safety attributes of the same category can now be ignored. Only safety attributes with an unknown cause of failure are used for a simulation. The simulated process results can be used to run tests of significance. If the results of a test show a significant improvement for the simulated values, the relevant cause of failure had been eliminated.

Perhaps more than one factor will be detected. In this case it must be examined if there are any correlations and some causes are depending on others. Finally the most important causes are detected.

4.2.4 Improve

The found causes of failure shall now be eliminated within the real processes using strategic solutions to be developed. In this case the project team again conducts brainstorming and chooses the most promising strategies. Each team member chooses his Top Five of all strategies and values them with 1-5 points. The strategies receiving the most of the points are developed further to be later integrated in the process flow. The developed processes are shown in a flowchart.
The effects of such an improvement are tested in simulations or models by insert a special scenario into the data base, like it is described in *D5.1 Test and validation plan.* A Failure Mode and Effects Analysis (**FMEA**) is used to avoid any risks for the process [13]. A likely example is presented beneath in Table 2. The criteria O, S and D are evaluated with the scale from 1 (low) to 10 (high implication).

Step	Failure Mode	Effects	Cause(s)	Current controls	O	S	D	RPN	recomm. actions	Resp. and target completion date	Action taken	O	S	D	RPNn
1	Speed road sign assigned to wrong position	Speed limit attached to false street section	Unintentio-nally activated measure-ment	Compari-son of new signs and number of actual measure-ments	9	6	5	270	Matching of the parallel video recording and each measure-ment	Data collectors of the test site X; due till Tuesday	Measure-ments tagged with time stamps	8	2	5	80

Table 2 - Failure Mode and Effects Analysis used to determine process risks

1. Potential errors, their effects and causes are registered for each step in the columns 2-4.
2. Current controls of each defect are proposed in column 5.
3. Columns 6-8 are served for a quantitative valuation with a scale from 1 (minimal) until 10 (maximal).
4. O determines the occurrence rating of potential defects, S illustrates the severity rating and D the detection rating.
5. The values of these three columns are multiplied for each row and the result is a risk priority number RPN, noted in column 9. RPN quantifies a relative risk.
6. Countermeasures in the following columns shall reduce the risk: The countermeasures or recommended actions are noted in column 10, responsible persons and a target completion date in column 11.
7. Actions which have already been taken are written down in column 12.
8. A new quantitative valuation like in columns 6-8 accounting all these actions is fixed in columns 13-15. So a new risk priority number RPNn is calculated.
9. The difference between RPN and RPNn shows the actions which minimize most the risk of errors.

Now there are strategic solutions for the most important causes of failure available and the improved process can be implemented (first of all tentatively).

4.2.5 Control

The CONTROL-phase corresponds basically to the VERIFY-phase of DMADV (see above).

If one partner identifies possible improvements of standard process, all other partners using the same standard process should be informed about the identified problems and the improvements so that they can implement the improvements themselves.

Annex A: Quality assurance measures

This annex includes practical recommendations for the quality assured implementation of the methods and tools developed in the project. They shall be used so that future ROSATTE implementations can profit from the experiences made earlier.

The current document contains examples since not all of the implementations are finalized and tested at the current stage. Therefore this annex will be updated after the project test and validation phase (particularly A.3-A.5).

For reasons of clarity, the annex is subdivided into the main data processing steps in the following subchapters.

A.1 Data Acquisition tool

Quality assurances measures for the data acquisition tools can be structured in 3 groups. They are described in more detail in the following:

Prevention of erroneous data input
The design of the data acquisition tool's user interface can already help to assure the data quality from the very beginning. The following list shows contains exemplary design recommendations:

- The entry of free text should be avoided wherever possible. The input mask should either show a drop-down menu for the selection of a limited number of possibilities or dedicated input fields for numbers, dates, coordinates, etc.
- The tool should ask the user for decisions or input in a logical order, e.g. first the user has to decide the type of the safety feature to be inserted and then input details like speed limit value.
- The user interface could change its appearance according to prior decisions of the user, e.g. for a point location it is only necessary to enter one point where for a linear object a start and an end point are required.

Automated checks for completeness and consistency
The data that is entered can immediately be checked against the ROSATTE data specifications and reject user input, if it does not correspond with the specifications.
It could be checked,

- whether all mandatory attributes have been filled in
- whether the correct user interface with the corresponding obligatory attributes appears (according to the safety feature type to be inserted)
- whether the data corresponds to its format specification

Plausibility checks
If the inserted data is formally correct, the content still could be wrong. Therefore different kinds of plausibility checks are recommended:

- The location of the road safety feature should lie within the respective city or county
- The respective traffic regulation should be in line with the implicit rules (e.g. no 30km/h speed limit on motorways, no 120km/h speed limit in housing areas, …)
- The respective traffic regulation should be in line with its neighboring regulations (e.g. no 30km/h speed limit directly following a 100km/h speed limit, …)

A.2 Location referencing encoding and decoding

The rules for AGORA location referencing encoding are publicly available. But it turned out that there still is some room for interpretations. During the AGORA pre-testing earlier in the project, different encoders and decoders, all based on the same standard were used. But unfortunately the implementations slightly differed in the interpretation of some of the AGORA rules. This resulted in many decoding failures at the beginning. It was therefore necessary to find a common understanding of the rules and correct the implementations accordingly. The involved project partners are still working on that issue in order to further improve and finally come to a solution that fulfills the requirements on the location referencing in the project.

It can be concluded, that it is not advisable to only rely on the coding rules given by the standard, but also to refer to the implementation rules developed within ROSATTE.

Experiences from ROSATTE will be documented in deliverable D6 *Organisational aspects and expected benefits*. It is also very important to test this important part of the data exchange infrastructure intensively.

Annex B: Quality Monitoring Plan

This annex contains a quality monitoring plan for future implementations of ROSATTE. Figure 6 shows the proposed monitoring plan that is currently tested. If necessary, it will be updated with the gained experiences.
Special focus will be put on the monitoring of accuracy and correctness of the road safety features during their processing and especially right after the reception and location decoding at the map providers. However, the evaluation procedures proposed in D5.1 and used during the test and validation phase are based on manual interaction. Therefore, we will test procedures that are capable for automated processing and update the quality monitoring plan accordingly.

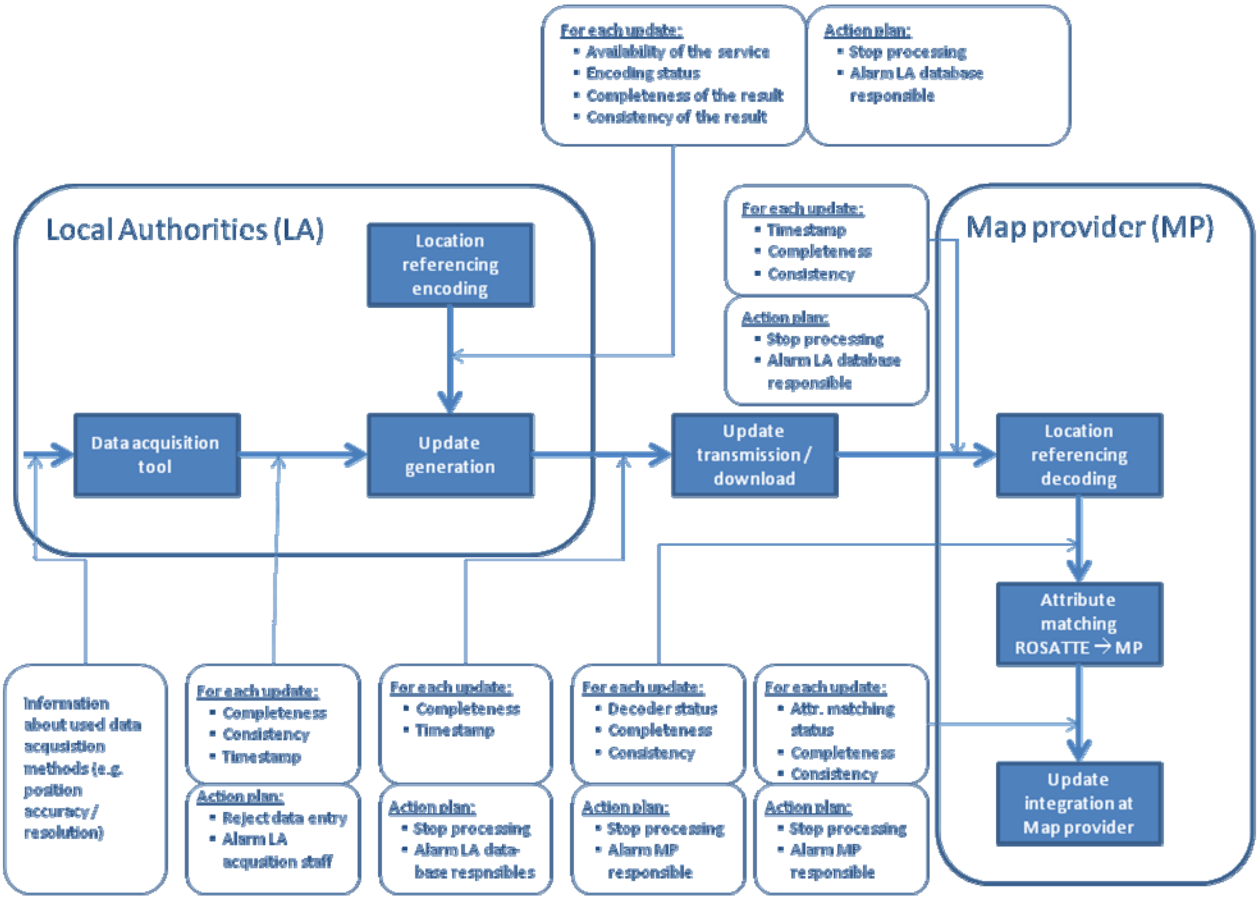

Figure 6 - Quality monitoring concept

Annex C: Action Plan

This annex contains an action plan for a future implementation of ROSATTE. Figure 6 already contains the actions according to the respective monitoring step. They are explained in more detail in the following.

It is foreseen to record all quality-related problems that will occur during the test and validation phase and the corresponding actions that the partners at the test sites will take. This gives the opportunity to update this action plan with real-life information and experiences in order to make it more valuable for future implementers of ROSATTE.

Data acquisition
In case the inserted dataset is neither complete nor consistent, the update should not be processed on. The user should be informed about the incorrect or missing input and asked for correction. The update should be integrated in the local authority's database only if these requirements are fulfilled.

Location referencing encoding
If the location referencing service is not available, the update cannot be processed on. If there is no immediate need to process the new update, it can be stored temporarily. The location referencing service could be tried to reach some time later. If this does not lead to a successful connection to the service, the responsible person at the service provider should be informed about the incident.

In case the service does respond but returns an error status, the content of the provided location information has to be checked and resend. In case that does not help, the responsible person at the service provider should be informed about the incident.

The completeness and correctness of the location referencing decoding has also to be verified. In case the service returns a binary location code, that might only be possible very limited, but in case the service provides xml code, this can be checked.

Exchange of updates
The receiver should check, whether the dataset is complete and consistent. If that is not the case, the update cannot be processed and the responsible person at the local authority's data processing center has to be contacted.

Location referencing decoding
The decoding result has to be checked for any kind of error messages. Furthermore, the completeness and consistency need to be checked. If an error occurs, it has to be found out, whether it is caused by the decoder or a probably erroneous location reference code. The respective responsible have to be contacted.

Attribute matching ROSATTE → Map Provider
The Attribute matching result has to be checked for any kind of error messages. If an error occurs, it has to be found out, whether it is caused by the attribute matching or another cause. The respective MP responsible has to be contacted.