CHAPTER SEVENTEEN

Data Quality and Quality Management –Examples of Quality Evaluation Procedures and Quality Management in European National Mapping Agencies

Antti Jakobsson

ABSTRACT

National Mapping Agencies (NMAs) in Europe have recognized the importance of quality but issues like process management especially related to quality evaluation procedures, data management issues such as data specification, selecting quality elements, reporting quality results and competence of personnel remain high priorities. This chapter will give some examples of quality evaluation procedures that are used to assess the quality of topographic data sets in European NMAs. It is based on the author's experiences at the National Land Survey of Finland (NLS) since 1992, when the Topographic Database System (TDB) was introduced (Jakobsson, 1995, 1999). The system covers all the topographic databases that we compile at the NLS at scales 1:10 000, 1:20 000, 1:50 000, 1:100 000, 1:250 000, 1:500 000, 1:1000 000, 1:2000 000 and 1:4500 000. We have developed generalisation processes in order to use the Topographic Database in other databases so that the quality of the data will be maintained. European references are derived from the numerous symposia and working groups that the author has attended since the 1990's.

17.1 INTRODUCTION

National Mapping Agencies in Europe have recognized that data quality and quality management are important issues and their are trying to introduce quality evaluation procedures for data production. This chapter will explain some of the results.

The principles of spatial data quality are first discussed, using concepts accepted in the forthcoming family of International Standard (ISO 19100, etc) for geographical information. Completion of these ISO standards is now approaching. The data quality of geographical information is described as the difference between the universe of discourse and the data set, where the data set is defined as an identifiable collection of related data and the universe of discourse as the view of the real world that includes everything of interest. The universe of discourse is described by a product specification, against which the quality content of a data set is evaluated.

The quality evaluation procedures discussed in this chapter are based on the quality evaluation model that is defined in ISO 19114 Quality Evaluation Procedures (ISO/TC 211, 2001b). Examples of the quality evaluation procedures used for topographic data sets are given using the experience of the NLS and other European mapping agencies.

17.2 QUALITY OF GEOGRAPHICAL INFORMATION

The quality of geographical information is defined in the ISO/DIS 19113 Quality Principles (ISO/TC 211, 2001a, Godwin 1997). In Figure 17.1, the quality of the data set is the difference between the universe of discourse and the data set. This has two different perspectives: the data producer's perspective and the user's perspective. If the user requirements and the product specification are the same, then the quality is also the same.

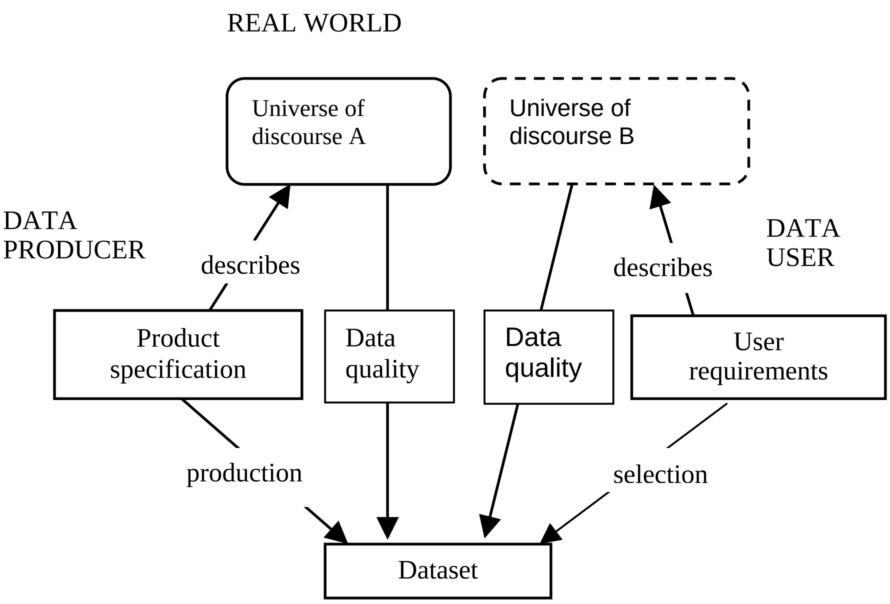

Figure 17.1. The framework of data quality concepts (ISO TC211, 2001a)

A data set is defined as an identifiable collection of related data. The universe of discourse is a view of the real or hypothetical world that includes everything of interest. It is described by a product specification, against which the quality content of a data set is evaluated.

17.2.1 Data quality and quality management

Quality is defined as the totality of characteristics of a product that bear on its ability to satisfy stated and implied needs (ISO 8402, 1994). In the new ISO/DIS 9000:2000 standard (2000) the definition of quality is: "Ability of a set of inherent characteristics of a product, system or process to fulfil requirements of customers and other interested parties." This indicates that data quality and quality management are very closely related. Data quality is part of the organisation's total quality management.

Quality management can be based on the ISO 9000, self-assessments using quality award criteria *e.g*. the Excellence Model of the European Foundation for Quality Management (EFQM) (www.efqm.org) , the Malcolm Baldrige National Quality Award (www.quality.nist.gov) in the USA, practical experiences within the company or a combination of those. The ISO 9000 and quality award criteria require the quality system to be documented.

The ISO 9000 Standards series has evolved from the need to control the quality of production. There was a clear need to move from product inspection to an assessment of the ability to produce products that meet the specifications. Recent developments in the series have moved towards process management control. An organization can also apply for a certification showing that its quality management system meets the requirements of the ISO 9000.

There has been considerable criticism of the ISO 9000 because developing and updating the quality system can be expensive. There is a clear difference between Europe and the United States in the popularity of the ISO 9000. Self-assessment has been very popular in the United States applying the criteria given in quality awards model.

17.2.2 Characteristics of data quality

Geographical information or data consists of a geographical location (e.g. coordinates) and attributes linked to it. Geographical location is commonly very stable but its precise determination can be difficult. Positional accuracy is often synonymous with data quality. In traditional cartography, mapmakers decide if the quality of the available data is sufficient to produce a multi-purpose map product. At best, the quality information included: (i) a quality statement furnished by the producing organization, (ii) the reputation of the producer and (iii) and experiences resulting from using the product (Guptill 1998).

Geographical information is a representation of a real phenomena. In order to collect data into a database, an object or a feature has to be defined using a data specification. Data compilation is carried out according to the data specification. The universe of discourse is seen as the truth when defining the quality of the data and anything that is not defined by the data specification does not exist in the universe of discourse. The data specification is thus one of the most important parts of the data quality because errors made in modeling are often difficult or impossible to correct. The quality information is reported against the data specification. For example a building may have restrictions that are not collected i.e. small details or very small areas. It would show up as an error if objects were collected that do not meet the criteria, even thought they are buildings in reality.

Time is one of the special features of geographical information. It is often true that by the time the data has been compiled the information has already changed in reality. Data compilation processes can last several years, which can cause reliability problems. For the data producer, data compilation is virtually a continuous process.

Data compilation from several different sources often requires very good data quality. Positional accuracy, for example, can be the same in two data sets but the result combined may still not be correct i.e. there might be a topological error (a building overlapping a road). Furthermore combining data sets that have no quality information can be very difficult or impossible.

Equipments used for data compilation do not guarantee results. User of the data must be very careful in interpreting the quality results. A particular quality measure can mean little if there is no indication how the quality results have been achieved. For example positional accuracy can mean root mean square error (RMSE) or precision or something else. Producer may state the accuracy of the scanner but not the accuracy of the original map. It is often the case that the accuracy of the data set is not checked in the field because of the costs, and customer has to rely on an estimated value.

17.3 DEFINING QUALITY

The forthcoming ISO and European standards describe data quality. Whether these definitions are the right or correct ones is not discussed here. A data producer can choose at least two different strategies. One is to have a defined data quality as we have at the NLS in our data quality model, and test the data sets against that level and the other is to only report the quality level that has been achieved. In the first strategy, a customer can make decisions even if the data has not yet been collected. That is, of course, the case in data revision.

17.3.1 Data quality definition in the European standard for geographical information

The European Standardisation Committee (CEN) has produced a European prestandard that defines the data quality elements as follows:

- **Lineage** is a description of the history of the geographical data set in terms of source material, dates, processing applied and responsible organisations.
- **Usage** means that a geographical data set can have a set of records describing its previous usage

- **Quality parameters** describe the performance of the geographical data set compared with its nominal ground. Quality parameters are presented in table 17.1
- **Homogeneity**, which is a textual and qualitative description of the expected or tested uniformity of quality parameters in a geographical data set.

Users are allowed to define their own quality parameters, indicators and measures.

Table 17.1 Quality parameters in the European standard (ENV 12656, 1998)

Quality parameter Quality indicators	Description
Positional accuracy	Describing the accuracy of geographical position within a geographical data set
Relative horizontal accuracy	RMSE and vertical bias or vertical threshold
Relative vertical accuracy	
Semantic accuracy	Describing the accuracy of the semantic aspects of geographical data
Accuracy of classification	
Agreement for an attribute	
Temporal accuracy	Describing the accuracy of the temporal aspects of geographical data
Accuracy in time measurement	
Last-update	
Rate of change	
Temporal lapse	
Temporal validity	
Completeness	Describing the presence and absence of entity instances, relationship instances and attribute instances
Omission	
Commission	
Logical consistency	The degree of conformance of a geographical data set with respect to the internal structure given in its specification.

17.3.2 Data quality definition in the International Standard for geographical information

The International Organization for Standardization (ISO) has produced a draft International Standard for quality principles (ISO/TC 211, 2001a). It defines the following data quality elements and sub-elements which are presented in table 17.2.

The main difference between the CEN standard and ISO is that the latter allows users to define their own quality elements. A separate standard will also be produced for quality evaluation procedures not covered by CEN. The wording and some of the quality sub-elements are also different, but the basic concept of quality is the same.

Table 17.2 Data quality elements and sub-elements (ISO TC211, 2001a)

Data quality element Data quality subelement	Description
Completeness	Presence and absence of features, their attributes and relationships
Commission	Excess data present in a data set
Omission	Data absent from a data set
Logical consistency	Degree of adherence to logical rules of data structure, attribution and relationships
Conceptual consistency	Adherence to rules of the conceptual schema
Domain consistency	Adherence of values to the value domains
Format consistency	Degree to which data is stored in accordance with the physical structure of the data set
Topological consistency	Correctness of the explicitly encoded topological characteristics of a data set
Positional accuracy	Accuracy of the position of features
Absolute or external accuracy	Closeness of reported coordinate values to values accepted as or being true
Relative or internal accuracy	Closeness of the relative positions of features in a data set to their respective relative positions accepted as or being true
Gridded data position accuracy	Closeness of gridded data position values to values accepted as or being true
Temporal accuracy	Accuracy of the temporal attributes and temporal relationships of features
Accuracy of a time measurement	Correctness of the temporal references of an item (reporting of error in time measurement)
Temporal consistency	Correctness of ordered events or sequences, if reported
Temporal validity	Validity of data with respect to time
Thematic accuracy	Accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships
Classification correctness	Comparison of the classes assigned to features or their attributes to a universe of discourse (e.g. ground truth or reference data set)
Non-quantitative attribute correctness	Correctness of non-quantitative attributes
Quantitative attribute accuracy	Accuracy of quantitative attributes

17.4 QUALITY EVALUATION PROCEDURES

17.4.1 Quality evaluation in the International Standard for geographical information

The ISO/DIS 19114 quality evaluation procedures (ISO/TC 211, 2001b) describes a process for evaluating and reporting data quality results. First an evaluator selects applicable data quality elements and sub-elements. Next the data quality scope (e.g. a certain area in the data set) and a data quality measure are defined. A quality evaluation method is then chosen and applied. If a conformance level is set the evaluator determines conformance comparing the data quality result. Quality evaluation methods are classified to direct and indirect methods. The direct evaluation method is further subdivided into internal and external. Internal method uses only data from the data set. Full inspection and sampling are the means to accomplishing the direct evaluation. The standard gives examples of sampling methods (e.g. simple random sampling, stratified sampling, multistage sampling and non-random sampling). ISO 2859 and ISO 3951 standards may also be applied. Indirect evaluation methods are based on estimates and may be derived from knowledge of the data set's lineage.

17.5 EXPERIENCES IN NATIONAL MAPPING AGENCIES

17.5.1 National Land Survey of Finland (NLS)

17.5.1.1 Quality management

The National Land Survey of Finland has developed quality management since the 1990's. It has been based on the ISO 9000 standard. The new process-focused organisation was adapted in 1999. The quality management is based on three perspectives: Organisation, processes and data sets. The organisation perspective has two different levels: NLS-wide and a unit level. Both NLS and different units have quality manuals defining the responsibilities and resources. Processes are defined with a process map. We have four key processes. Each of them has a process owner and a process team. A process team is responsible for process manuals. The manuals are updated over the intranet and every person in the organisation has access to them.

The Chief Director carries the main responsibility for quality. The management team will audit the main processes each year, and the surveying counselors are responsible for the quality of the main processes. There are no quality management staff as such and the operative management carries the responsibility.

17.5.1.2 The data quality definitions in the NLS

In the National Land Survey of Finland, definition of data quality is based on several documents (Figure 17.2).

The Process Manual is based on ISO 9000 and defines the responsibilities and organisation for topographic data production. The Topographic Data Model defines the features in the real world and the Data Compilation Guide gives instructions on data collection. The Data Quality Model defines the quality elements and sets the requirements for quality. The missing parts are: **Quality reports** (should give information about the quality achieved) and **Product guides** (give information about a product, such as formats and copyright).

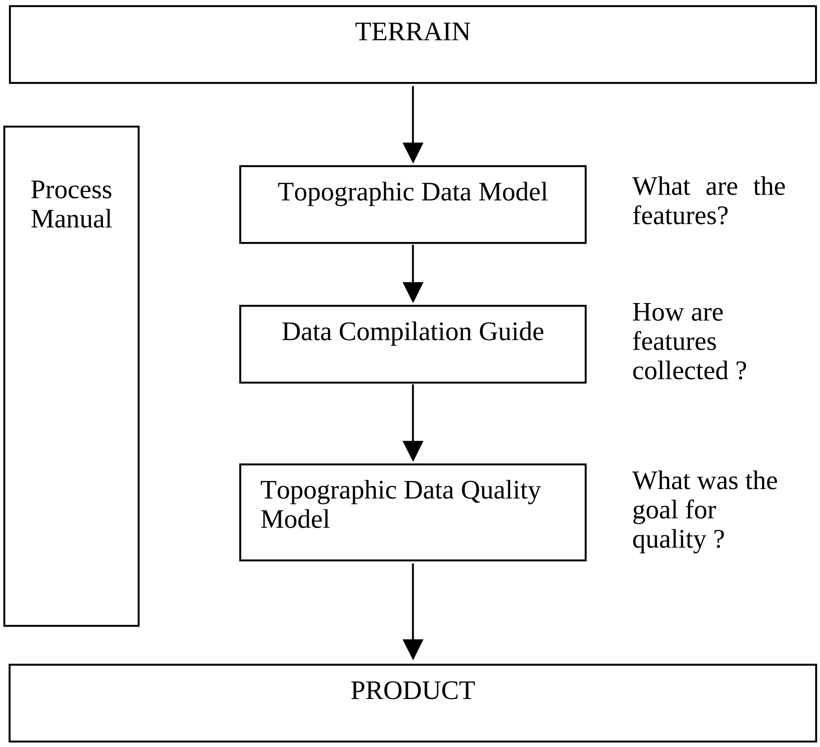

Figure 17.2 **Quality documents in the Topographic Data System (TDS)**

In the Data Quality Model, the quality factors are (Jakobsson, 1994):

1) **lineage**, which means the source of data compilation, the data compilation date, the currency of the source material, the history of the data compilation and the name of those who were in charge of the compilation;
2) **completeness**, which means how completely each data object was compiled into the data set;
3) **currency**, which means how well the data set meets the required up-to-dateness;
4) **accuracy of geographical location,** defined using positional accuracy, geometric accuracy and topological accuracy (Positional accuracy is defined as the root mean square error (RMSE). Geometric accuracy

means how well the geometric description (line, point or area) defines the real object. Topological accuracy means how well each object is compatible with other objects);

5) **thematic accuracy,** defined by object class accuracy, attribute accuracy and temporal accuracy (Object class accuracy, defines how well each object class has been compiled. Attribute accuracy defines the quality of each attribute class, and temporal accuracy means the accuracy of the time measurement of the objects.);
6) **logical consistency,** which means whether the objects meet the logical requirement defined in the data specification.

Quality requirements are defined for positional accuracy, completeness and thematic accuracy. The requirements for logical consistency are defined in the test procedures and all those tests should pass. The positional accuracy requirement for a road is 3 metres (RMSE) in quality level A and the requirement for completeness for a road is that only 4 errors per hundred unit are allowed (acceptable quality level). For object class accuracy only 4 errors in classification of the road type is allowed. There can be a different requirement for each object class and attribute class (NLS, 1995).

17.4.1.3 Quality requirements and quality evaluation

From the point of view of the user, it is important how well the producer is able to guarantee the quality he has reported. The customer, of course, can go to the field himself and check some of the details but this is not usually possible for technical, cost or other reasons. On the other hand, it is important for the producer that the quality information is accurate, otherwise compensation for damages may be payable. Statistical tests are a good way of ensuring that the requirements are met at moderate cost. For example, the Ordnance Survey of Great Britain uses statistical methods for their test procedures. The NLS uses a statistical test for completeness and thematic accuracy.

In practice, we have found that customers tend to evaluate different quality requirements in the following order: coverage, currency and completeness, accuracy (positional, attribute), logical completeness, lineage and usage. As the requirement at the top of the list is met the next one becomes more important.

The quality evaluation procedures that were developed when the TDS was introduced in 1992 are documented below. The Topographic Database will now cover nearly the whole of Finland (some northern parts of Finland are still not covered). In fall 2000 the Topographic Database was exported to a Smallworld GIS and new quality evaluation procedures are now under development.

17.5.1.4 Testing of completeness and thematic accuracy at the NLS 1993-1998

Testing for completeness and thematic accuracy is carried out by applying the principles of standard SFS 4010 (Sample test procedures and tables; attribute inspection), which corresponds to standard ISO 2859 (1995). The standard defines the sample procedures for attribute inspection.

All the features on which data is collected are checked from the data source used if the quality requirement for the feature type is one nonconformity per 100 units (Acceptable Quality Level, AQL=1). An inspection based on sampling is made when the AQL of the feature type is 4 or 15. The inspection level is general inspection level I, the single sample programme for normal inspection (NLS 1995).

17.5.1.5 Test for completeness

A lot must consist of map databases produced as far as possible at the same time and using the same methods. A lot is the minimum unit for which quality is evaluated. From the lot, an area of as many 1 km x 1 km squares is sampled as is needed to ensure a sufficient number of features with AQL=4.
The sampling is done using the default weights of the features. The weighting can be changed if necessary. In weighting, a default value of 1 is given to those features which have a significant presence in the lot or for which no AQL for completeness has been set. Features whose AQL is 4 or 15 are given a weight of 2 or 3. Weight 3 is given to features of which there are few. Otherwise, a weight of 2 is used.

Should the required sample size not be achieved, the program selects from the sampled squares those with the greatest number of stereoplotted features fulfilling the required sample size. At the same time, features with AQL=15 are tested according to the inspection level achieved.
All features in the sampled squares are checked in the field. A feature does not conform if it is absent in the data set (omission) or if the feature in the 1 km x 1 km square does not exist in the field (commission).

17.5.1.6 Test for thematic accuracy

The test for thematic accuracy is made on the same material as the test for completeness. The number of errors permitted and the inspection level achieved are given on the test form if the completeness AQL is not 4. The quality supervisor inspects each item of attribute data on the basis of the source material. Attribute data are erroneous if they differ from the source material or are missing.

17.5.1.7 Processing nonconforming units

If the number of nonconformities is greater than permitted in the test of feature types, all features in the lot must be checked. The method is chosen on the basis of the source of information used, and is carried out on all features in the lot.

17.5.1.8 Experiences of tests performed

The results of tests performed provide information about the functionality of the data compilation processes and also about the quality of Topographic Database (TDB) data. Data digitized from graphic basic maps may also contain those errors made during the previous mapping process. Not all of the features are checked in the field during the data compilation process.

About 15 % of the annual production was tested during the year 1996. There were 33 tests made by our District Surveying Offices. Two or three 1 km x 1 km test squares can be checked in the field during one working day on average. The test results show that the biggest problems in completeness concern buildings, water less than 2 m wide, light-traffic routes and agricultural land. Not all of the features can be seen in a stereoplotter because of trees or shadows, for example. Time spent on field checking is minimized and not all the unseen features can be checked in the field. Results of tests for thematic accuracy have been mostly good, though there have been some errors with the usage information of buildings and classification of agricultural land.

The results of tests performed have come up to expectations in general. As a result of the tests, the quality requirements for some feature types have been changed and the instructions for data compilation have been adjusted. Quality tests provide information for maintenance of the TDS and its quality management. They also help the District Survey Offices to improve the quality and efficiency of their work (Pätynen et.al. 1997).

17.4.1.9 Testing positional accuracy and logical consistency

In 1996 and 1997 the NLS carried out a positional accuracy test in order to evaluate the accuracy of the TDB. The quality requirements set in the Data Quality Model were already tested in 1994. The test concerned covered about 1000 object instances (Jakobsson, 1994).

In 1997, 11 test areas where chosen for the positional accuracy test. The test was made using differential GPS. Only the most accurate feature classes, which have good identifiabilty in the field, were tested. They comprised buildings and roads that should have positional accuracy of 3 meters according to the Data Quality Model. 500 buildings and 200 crossroads were measured and the result showed that the average positional accuracy of these feature classes was 2.2-2.3 m (Tätilä 1997).

During 1993–1998, the NLS carried out logical consistency tests. The number of errors per 1:10 000 map sheet decreased from a high 2.5 m to less than 1 m error in 1998. This included every kind of errors possible in a data set.

17.5.2 Norwegian Mapping Authority

The Norwegian approach to quality evaluation is based on the Norwegian national standard for geographical information, called SOSI (Systematic Organisation of Spatial Information). The national standard includes data definitions for standardised geometry and topology, data quality, coordinate systems and metadata. All national mapping programs are based on the SOSI standard, which is also supported by all major GIS and mapping software providers (Sunde 1998).

Quality control can be carried out easily using three different software packages. KVAKK (KvalitesKontroll av Kartdata – Quality control of map data) is a tool for automatic structure, coding and syntax control for data in the SOSI format. SOSIVIS is a free downloadable SOSI viewer and it can be used for interactive and visual content, structure, coding and syntax control. A full version called FYSAK is used internally at the mapping authority (Sunde, 1998).

17.5.3 Institut Géographique National (IGN), France

The Institut Géographique National (IGN) already started to implement total quality control in 1987. In 1995 a decision was taken to start ISO 9000 implementation beginning at the topographic database 1:50 000 to 1:500 000 (BDCARTO) production. The organisation has published a quality chart that defines its quality policy and objectives. It has a quality director, with a separate quality unit for managing and coordinating the quality approach.

There is a separate control unit (MODV) that acts as a customer and has the right not to accept a product if it does not meet the specifications. The unit performs the quality evaluation of the BDCARTO, the topographic database 1:5000 to 1:25 000 (BDTOPO) and the road database (GEOROUTE). The MODV has (had) a staff of two and it takes about two weeks to inspect a one BDCARTO sheet.

The tools the IGN uses are:

1) a **counting set** for statistics, detection of cross errors (e.g. missing attribute), verification of logical consistency and comparison of toponomy;
2) a **comparison tool** with a reference data set, which calculates positional accuracy and semantic differences;
3) a **visual check** with a raster (scanned data).

Using these tools, the control report is compiled and a decision is made on whether the data set should be accepted or not. The reference data set should be near to the nominal ground (the universe of discourse), so a surfaced road in BDCARTO is checked against a surfaced road in BDTOPO, for example.

In producing BDTOPO, quality is evaluated using two different types of measurements: the punctual **positional accuracy** of the data set entities compared with the nominal ground entities, the **exhaustivity** and **semantic accuracy** of the data set compared with nominal ground.

The measurement of geometric quality is carried out only to the feature categories represented by a point and they cover 19 point categories. The reference for horizontal accuracy is buildings and for vertical accuracy spot elevations. Two quality parameters are used in measuring semantic accuracy. Exhaustivity means the presence or absence of the data set entities compared with the nominal ground (rate of deficit, rate of excess), and semantic accuracy is the conformity of the data set entity classification compared with the nominal ground entities. Measurements are obtained by exhaustive sampling of part of the BDTOPO sheet. Any errors detected are noted on tracing paper that is kept for the next update of the database. Measures of deficits and excess items are accounted by entity class in an exhaustivity board. Measures of confusions are accounted by types of confusions between entity class or attribute values of an entity class in four different confusion matrices; practicability of roads, buildings, orography, hydrography and vegetation, and public, commercial and industrial activities (IGN, 1998).

All the results are registered and reported by the BDTOPO sheet. The results for all the year’s measurements are registered, yielding a general report on the year and providing a mean for users of the database. Quality specifications are to be set in the future, when more measurements have been carried out.

17.6 CONCLUSIONS

In December 1996 the International Cartographic Association (ICA) and its Commission on Spatial Data Quality sent a worldwide questionnaire to producers of spatial data. The questionnaire went to 288 national mapping agencies and altogether 56 responded most of them in Europe (59%). Table 17.3 gives a brief summary of results (Östman, 1997).

Table 17.3 Results of the ICA questionnaire: percentage of answers indicating a subjective evaluation or no evaluation as the quality assurance routine (Östman, 1997)

Quality parameters	Percentage
Positional accuracy	43%
Thematic accuracy	48%
Temporal accuracy	68%
Completeness	56%
Logical consistency	32%

The questionnaire showed no quality estimate is made or only subjectively estimated in many instances. This situation need to improve. As the examples show, national mapping agencies in Europe understand the importance of quality, but so far have not really invested in quality evaluation. The reasons are, of course, that the market has not demanded more and producers have got funding from government budgets. Now that the geographical information market is evolving and data sets are coming into everyday use, however, the role of the customer is changing. Customers are no longer professionals who know how the information is gathered and know what to expect. National mapping agencies therefore have to take quality seriously.

The European National Mapping Agencies have co-operated to improve the knowledge of quality management and data quality, especially through the work of EuroGeographics (formerly CERCO). The quality working group was created in 1997, and it has produced several documents related to these issues. In 1999 the working group conducted a questionnaire survey about data quality. The key issues are process management, data set specifications, standards, quality reports and training of personnel (Chapter 15).

Quality management and quality information together constitute a significant competitive advantage for producers. Further better quality often saves costs too and raises process output.

ACKNOWLEDGMENTS

The author wishes to acknowledge the help given by the experts in ISO TC 211 working group that developed the forthcoming standards, especially editors Ms.

Leslie Godwin (quality principles), Mr. Frederick Broome and Dr. Ryosuke Shibasaki (quality evaluation procedures). The author is also grateful for the information he gained from visits to the IGN and from the working group on quality in EuroGeographics/CERCO (Comité Européen des Responsables de la Cartographie Officielle), which is an association of European National Mapping Agencies.

REFERENCES

Godwin, L.S., 1997, Coordinating Standards on Data Quality: An Important Ingredient for Cartographers. In *Proceedings of the 18th ICA International Cartographic Conference* (Gävle: Swedish Cartographic Society) pp. 533–540.

Guptill, S.C., 1998, Building a Geospatial Data Framework, Finding the "Best Available" Data. In *Data Quality in Geographic Information From Error to Uncertainty*, edited by R.Jeansoulin and M.F.Goodchild (Paris: Hermes) pp. 31-36.

ENV 12656, 1998, Geographic Information - Data description – Quality, Adopted European Prestandard (www.cenorm.be).

IGN, 1998, Measuring the geometric and semantic quality of the BD TOPO, Institut Géographique National, France, unpublished.

ISO 2859-0:1995, 1995, Sampling procedures for inspection by attributes -- Part 0: Introduction to the ISO 2859 attribute sampling system, The International Organization for Standardisation (www.iso.ch).

ISO 3951, 1989, Sampling procedures and charts for inspection by variables for percent nonconforming, The International Organization for Standardisation (www.iso.ch).

ISO 8402, 1994, Quality management and quality assurance – Vocabulary, The International Organization for Standardisation. This standard is now replaced by ISO 9000: 2000 (www.iso.ch).

ISO 9000: 2000, 2000, Quality management systems -- Fundamentals and vocabulary, The International Organization for Standardisation (www.iso.ch).

ISO TC211, 2001, ISO/DIS 19113, Geographic Information – Quality Principles, Text for DIS 19113, The International Organization for Standardisation (www.iso.ch).

ISO TC211, 2001, ISO/DIS 19114, Geographic Information – Quality Evaluation Procedures, International Standard Committee Draft (www.iso.ch).

Jakobsson,A., 1999, Quality Evaluation of Topographic Datasets –Experiences in European National Mapping Agencies. In *Proceedings of the International Symposium on Spatial Data Quality*, (Hong Kong: Polytechnic University). pp.154-162.

Jakobsson, A., 1995, The Topographic Data System –A New Way to Compile and Update Topographic Information. In *Proceedings of the 17th International Cartographic Conference* (Barcelona: Institute Cartogràphic de Catalunya) vol. 1, pp. 993-1000.

Jakobsson, A., 1994, Quality Procedures of the National Topographic Data System in Finland, *GIM, International Journal for Surveying, Mapping and Applied GIS*, **October 1994**. pp 39-41.

NLS, 1995, Topographic Data Quality Model, (Helsinki, National Land Survey of Finland).

Pätynen, V., Kemppainen, I., Ronkainen R., 1997, Testing for Completeness and Thematic Accuracy of the National Topographic Data System in Finland. In *Proceedings of the 18th ICA International Cartographic Conference* (Gävle: Swedish Cartographic Society) pp. 1360- 1367.

Sunde, K.O., 1998, Presentation of data standards, specifications and quality measurement tools used for data quality control, unpublished.

Tätilä, P., 1997, Report on positional accuracy tests, in Finnish, National Land Survey of Finland, unpublished.

Östman, A. 1997, The specification and Evaluation of Spatial Data Quality. In *Proceedings of the 18th ICA International Cartographic Conference* (Gävle: Swedish Cartographic Society) pp. 836-847.