Framework and Requirements for Management of Topographic Data in Europe

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Abstract. Topographic data sets produced by the National Mapping Agencies (NMAs) are an essential part of Spatial Data Infrastructures (SDIs). Both global and European developments will denote that the NMAs will have to adopt new strategies for managing topographic data. This paper will embrace some of the requirements and introduce a framework for topographic data management based on the analysis of studies on user requirements, data quality and quality management, change in database management and standardization of geographic information. A multi-tier approach for management of topographic data in Europe is deduced requiring semantic modelling, harmonization and object-based data framework.

1 Introduction

The role of topographic mapping has evolved since its birth in Europe in the 18th century. National mapping agencies have produced digital topographic data sets for close to 20 years. The change from analogue to digital form has meant that topographic information can be used and modelled differently. Users and uses of topographic data are becoming more varied. In Finland and in other European countries nearly everyone can utilize topographic maps on the Internet [7]. National mapping agencies in Europe have adopted different strategies for meeting the user requirements. Geographic information management will be based on general object-based structures instead of specific simple database structures. The key issue of how to manage topographic information in Europe remains. This paper will describe some of the requirements and models for this.

1.1 National topographic data sets

Most national mapping agencies have separate topographic data sets representing different scales. This reflects the history of how geospatial data sets were created and updated using different data sources and non-synchronized processes. One data set might have been copied and compiled into several independent branches to create new products or to support different functions in the organization. The connection to the original source would have been lost, and propagating the updates would be problematic. National mapping agencies have developed new object-based strategies. Examples of initiatives include the Ordnance Survey's Mastermap (Digital National Framework) in Great Britain and the Amtliches Topographisch-Kartographisches Informationssystem (ATKIS) model in Germany. Mastermap will provide a consistent and maintained national base against which GI can be referenced using the National Grid or unique identifiers. The identifiers are given to real-world features such as buildings, roads and land parcels [28].

1. 2 European scenario

Europe needs geographic information. After the failure of GI2000 [2], the Commission started with a new approach. The INSPIRE (Infrastructure for Spatial Information) project aims to make relevant, harmonized and quality geographic information available for the purpose of formulating, implementing, monitoring and evaluating Community policy-making. One of the major tasks is to determine the relevant data needed. This is based on the idea of reference data described by the EteMII project [3]:

- It is a series of data sets that everyone involved with geographic information uses to reference his/her own data as part of their work.
- It provides a common link between applications and thereby provides a mechanism for the sharing of knowledge and information amongst people.

The working group on reference data and metadata [22] has described the main functional requirements that geographical reference data must fulfil:

- Provide an unambiguous location for user information
- Enable the merging of data from various sources
- Provide a context to allow others to better understand the information that is being presented.

Reference data components include: Geodetic reference system, units of administration, units of property rights (parcels, buildings), addresses, selected topographic themes (hydrography, transport, height), orthoimagery and geographic names [22].

National Spatial Data Infrastructures (NSDIs) will also play a major role in the development in Europe [18]. They should support the European context. For example, a new national council for geographic information in the Ministry of Agriculture and Forestry was initiated in Finland in 2001. The new council will study different possibilities for increasing the co-operation between producers and users. It will define a new strategy for the Finnish National Spatial Data Infrastructure. In Europe it will be interesting to observe, whether the EC legislation will be established as a result of INSPIRE proposals.

1.3 Standardization to enable the change

During the 1990s, standardization of GI was initiated in Europe. The results were published in 1996 as pre-standards. At the same time the International Organization for Standardization (ISO) began its operations. The ISO 19100 series now has over 20 standards for GI and the number is increasing. The Open GIS Consortium, Inc. (OGC) is a not-profit membership organization founded in 1994 to address the lack of interoperability among the systems that process georeferenced data, and between these systems and mainstream computing systems.

2 Methods

This paper is based on the analysis of several studies related to topographic data and quality management e.g. [1,10]. The chapter on user requirements is based on the analysis of the results of the data quality questionnaire by Jakobsson, Vauglin [11], and the report on User Requirements for Mobile Topographic Maps by Jakobsson [7], which was prepared as part of the GiMoDig (Geospatial info-mobility service by real-time data integration and generalisation) project. GiMoDig is a research project, which is developing and testing methods for delivering geospatial data to the mobile user by means of real-time data-integration and generalisation [26].

The chapter on the framework for the management of topographic information is based on the user requirements presented. The results of the study [11] carried out by the CERCO working group on quality (now EuroGeographics Expert Group on Quality) in 1999, are used to represent the current state of the topographic data sets in Europe. The main results are published in Jakobsson, Vauglin [12] and Jakobsson [8]. The questionnaire dealt with 17 European NMAs producing a total of 226 datasets. The basis for the analysis will be SDIs (national, European and global) together with the role of NMAs (i.e. Rhind [23]) and national mapping polices (i.e. USA [29] and Finland [30,31]). Standardization (i.e. ISO and OpenGIS) will allow the change in geographic information management.

3 User requirements

Topographic data has many uses. According to a survey by Jakobsson and Vauglin [11,12], the main users of the topographic base data (the NMAs' most accurate data sets) are governmental agencies, municipalities, environmental agencies, telecommunications, utilities and transportation. If this is compared with the small-scale topographic data sets, then emergency and public safety are main user groups.

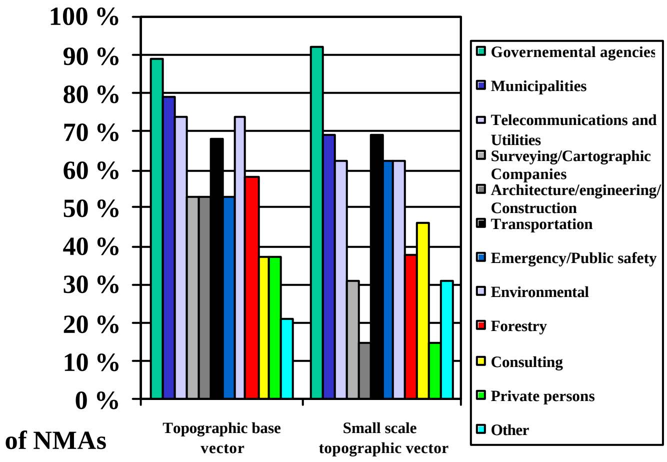

Fig. 1. Main users of topographic information according to the NMAs [10]

A recent study of the user requirements for mobile topographic maps show the new ways, in which topographic information is used. Several user groups were identified in general and specific application domains. The GiMoDig project identified 14 different user scenarios. The importance was evaluated using several criteria by analysing the use of topographic information, they concluded that users would need mobile topographic information in safety or emergency situations and, on the other hand, hiking in the wilderness as well as other hobbies related to nature. Major reasons for using topographic information are security and crisis management. Recent examples in Europe (floods in the Czech Republic and Germany, 2002) and the Homeland Security policy in the USA, demonstrate that current topographic information is needed even in remote areas. However, topographic information only has value when linked to other information relevant to the application or service.

A study carried out in Finland [10] on the use and importance of geographic data sets identified the Topographic Database (TDB) as the most important map data set in Finland, and users utilized it in conjunction with other data sets (thematic, orthoimagery). Even the study concentrated on map data sets and the number of respondants was quite small (n=27), the study illustrates the role of the TDB as a reference data set. The reference themes were (in order of importance): hydrography, transportation, metadata, buildings, height, geographic names, cadastral information, geodetic reference, addresses, orthoimagery, depth (of waters), navigation, satellite imagery and others. The study also identified the relevance and urgency of some of the development projects. Of 8 development projects listed, the top three comprised: describing the data quality requirements, describing the content and harmonization of reference data sets and organizing metadata services.

3. 1 How to set requirements

If we consider the European context, the EU has a major role in setting the requirements. The goals set in the INSPIRE project [16] are as follows:

- Data should be collected once and maintained at the level at which this can be done most effectively
- It should be possible to combine seamless spatial information from different sources across Europe and share it between many users and applications
- It should be possible for information collected at one level to be shared between the different levels: detailed for detailed investigations and general for strategic purposes
- Geographic information needed for good governance at all levels should be abundant and must allow unlimited extensive use
- It should be easy to discover the geographic information available, which fits the needs of a particular use and under conditions which allow the information to be acquired and used
- Geographic data should be easy to understand and interpret because it can be visualized within the appropriate context selected in a user-friendly way.

While the list above is only one example of the European requirements, it effectively summarizes the current trend in geographic information management in general. The role of standardization has already been discussed. It enables new models for data management and transfer to be used. However, there are still some open questions that data producers must resolve. Table 1 lists some of the issues.

Table 1. Requirements for topographic data management

Requirement	Questions	Possible answers
Data content		
• Resolution	How to set the level of detail	Classification of the geographic regions using variation in nature and community structures i.e. urban-rural-mountainous
• Data themes and objects	What themes should be covered?	Classification of the user requirements using geographic regions: European-National-Regional-Local.
	What objects represent the real world?	Harmonisation in three levels: National (local and regional levels) and European (national-European), Global (European- Global)
	Type of model 2D-3D-4D	Depends on application and user requirements
Data Specification		
• Modelling	What should be model used?	Relational object-based databases Standard modelling languages (UML and XML)
• Data models	What is the specification	Use ISO standards (ISO 19109, ISO 19110, ISO 19131)

	structure?	19110, ISO 19131)
• Metadata, data quality	How to discover data sets?	Build a metadata service to enable decentralized update of the metadata elements
	What is the quality of the data sets?	Set data quality requirements, define data quality measures and evaluate data quality
Process management	How to produce and update data sets?	Common procedures for achieving the required data quality Generalisation techniques
Data access	How to access data sets	Use ISO and OpenGIS specifications (i.e. XML, GML)
	Incremental updates?	Use object identifiers

4 Framework for the management of topographic data sets in Europe

A framework for the management of topographic data is presented in this chapter. The framework includes the reference data themes described by Rase et al. [21]. A number of current databases at a global, European, national, regional and local level are presented. The levels represent either the geographic extent or coverage of the data sets. In this context, the levels do not represent resolution.

The present situation is based on the concept of separate data sets managed by different organizations. The NMAs usually have all the data sets at the national level. We can deduce the following characteristics based on the results of the questionnaire by the CERCO working group on quality (now Eurogeographics' Expert Group on Quality) [11]:

- National vector-based topographic database (90% of the NMAs)
- Small-scale topographic database (71% of the NMAs, vector-based 61%)
- Geographical names (71%)
- Administrative boundaries (76%)
- DEM/DTM (71%)
- Cadastral data (52%)

There are some commercial data sets (i.e. road data) and some European data sets (i.e. SABE, European administrative boundaries) at the European level. EuroGeographics is currently producing some data sets i.e. the Global Map, which is a 1:1000 000 map data set and the EuroRegional map, a 1:250 000 map data set.

Of the topographic data sets, the national topographic data sets, which are usually gathered by the NMAs are most important. The NMAs typically include combination of different data sets to meet user requirements. The situation differs from country to country.

The majority of the NMAs use photogrammetry (either digital or analytical), field collection, and old maps, which have been digitized, for compiling the topographic database (11/19). Some NMAs didn't use field collection to collect information (5/19) and 3 NMAs didn't use digitzed information. The revision schemes comprise total revision every 5 years and the annual update of some object types [11].

There are at least two options when producing European-wide data sets. Traditionally, it would mean the production of separate data sets for different purposes (e.g. the EuroRegional and Global map projects). Problem in these approaches is that they require significant investments in production and updating. We can identify this approach as a continuation of map paradigm. The next choice could be to use national, regional or local data sets directly. The problem here is that conceptual models, resolution of data and data quality are not consistent in Europe. The harmonization and semantic modelling of data sets would be necessary.
There are already some examples of harmonization of data sets at the national level. In Germany, the AAA (AFIS-ALKIS-ATKIS) project is developing a common specification for geodetic reference data, cadastral and topographic data [3].
The suggested framework for the management of European topographic data sets is illustrated in Figure 2. It comprises of the multi-tier harmonization of data sets at the global, European, national, regional and local level. This includes the implementation of the requirements identified in the previous chapter, user requirements studies, the semantic modelling of data sets and the harmonization of specifications.

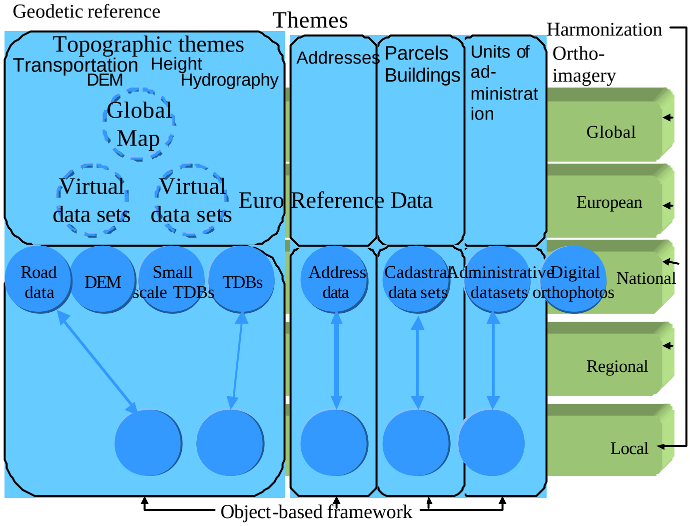

Fig. 2. A multi-tier harmonization of themes and levels and an object-based framework

At the national level, this approach could be implemented by using an object-based framework. This approach has been explained in detail in Jakobsson, Salo-Merta [9] and illustrated in Figure 3 An object-based framework comprises of the semantic modelling of data sets into a unified database. In some countries, for example, municipalities have some local topographic data sets, or different authorities might have regional topographic data sets (i.e. Germany). Utilization of an object-based framework would mean a unified database that all organizations could utilize for the management of reference data objects. Each organization could have own object types but core objects would be harmonized and managed by the unified database.

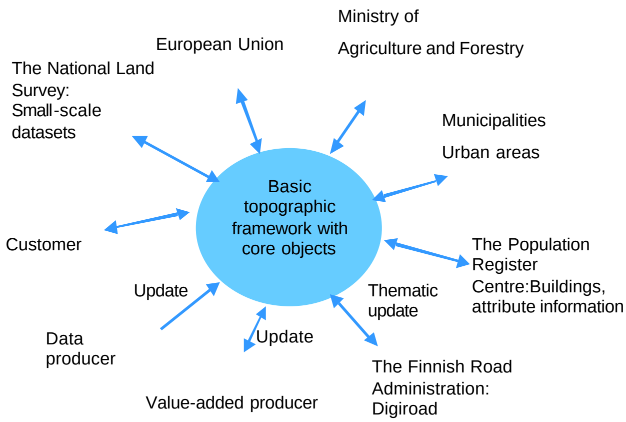

Fig. 3. An example of an object-based framework at the national level in Finland

5 Discussion

The major technical problems that have currently inhibited the combination of different datasets will be removed if geographic standards are utilized. The harmonization of geographic data sets and semantic modelling is required to ensure that the same feature types in different countries and data sets are identical in reality. However, this might not be the only perceivable choice. If the quality of the data sets could be managed, we could meet the user requirements differently. Figure 4 illustrates the process flow of the data from real world to the user. It is derived from the concept of data quality described in ISO 19113. The process includes the conception or modelling of the real world into a universe of discourse (D1). Data is collected using different methods according to data specification. The user's conception process describe the user requirements (R), which comprise another universe of discourse (D2). User requirements are usually met with either analysis or representation of the data set (A). In an attempt to eliminate uncertainty in the conception process, semantic modelling of the data sets has been used. If we could access reality as easily as the data sets then we could build a model of the errors related to the conception processes C and R. For example, a road object in one dataset and another road object in other data set could be combined automatically to a new data sets that meets the user requirement.

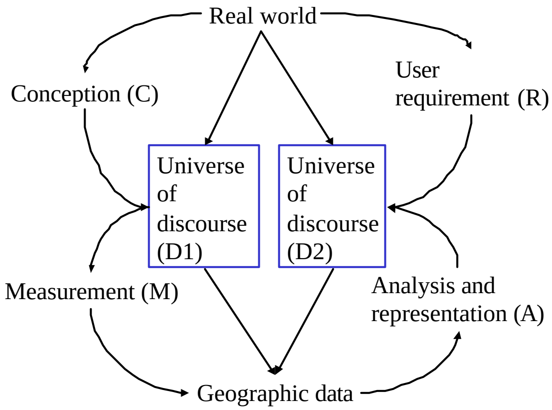

Fig. 4. Model of uncertainty (or quality) in geographic data

Longley et al. [17] describe the conceptual view of uncertainty. They state that it is impossible to make a perfect representation of the world, so uncertainty is inevitable. Zhang et. al [32] describe uncertainty as a measure of the difference between the data and the meaning attached to the data by the current user. Quality, on the other hand, is described in the ISO 9000:2000 standard as "Degree to which a set of inherent characteristics fulfils requirements". According to these definitions, uncertainty and quality seem to be antonyms of the same phenomena in the same way that accuracy and error are.

If we consider the process illustrated in Figure 4 from the GIS perspective then there are three stages:(1) conceptualization of geographical 'reality'; (2) formalization; and (3) computational implementation [13,21]. In this process information is lost through abstraction and also there is epistemological break as realist conceptions of geographic phenomena are reinterpreted into internally regulated universe by formalization [27]. In this context, a pragmatic approach is taken and it is assumed that ontologies of data models can be agreed on for topographic information.

Considering the model presented it might be reasonable to manage only the data as a theme basis. This would mean that there would be no need for a national topographic database at the national level. The author has presented a basic topographic framework model, in which different organizations or actors could produce either themes or some geographical extent of the national topographic data set [9]. There is still a need for a combined reference data set in Finland. At the moment the National

Land Survey of Finland is the only authority ensuring that all data themes are collected and maintained.

Several techniques could be used to implement the proposed model. Agent framework (i.e. Lamy et. al [15] and Ruas [24]) and multiple representation databases could be used for data management at the national or European level. Kilpeläinen and Salo-Merta [14] have carried out a case study of an object-oriented approach to the multiple representation of buildings. At the national level, the management of multiple resolutions is needed at least in large and medium scale range as illustrated in Figure 5. The GiMoDig approach, which is explained earlier, might be used at the European level but there is the need for object-based databases at the large or medium scale level, if the users want to connect their data to the topographic reference and utilize updates. The changes in data are not so frequent in the small scales and traditional approaches may be utilized at least in the 1:1000 000 level.

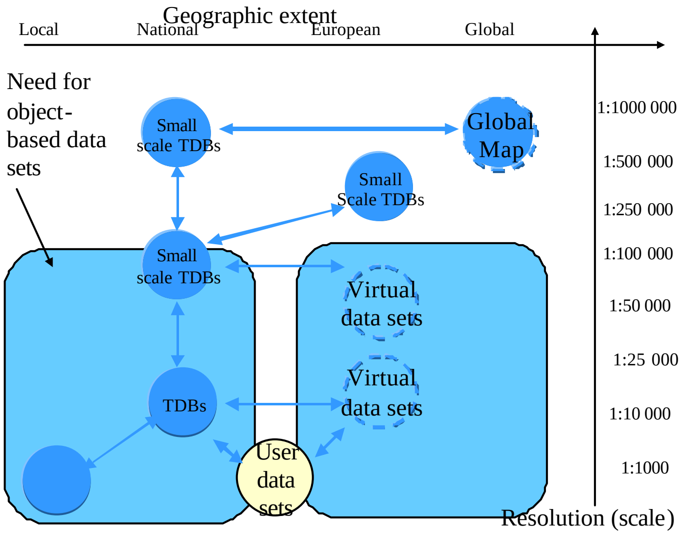

Fig. 5. Need for object-based data sets

6 Conclusions

Both European and national co-operation are required to achieve the best results. The NMAs have a key role in this. Geographic information standards are the basis for the SDIs in Europe. The harmonization of different specifications and procedures will be a key issue. European harmonization will not only benefit users who require cross-border data or large geographic extents (i.e. several countries). Common principles will also benefit application developers and ultimately private citizens, who will be able to benefit from topographic information in their every day life using different applications.

Future research is needed to derive the minimum level of requirements, which produce the most benefits. This might lead to prioritizing data update processes to certain regions, themes and object types. Quality management principles have to used to meet the requirements.

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