ON THE FUTURE OF TOPOGRAPHIC BASE INFORMATION MANAGEMENT IN FINLAND AND EUROPE

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Abstract

Topographic information management is essential for the future of National Mapping Agencies (NMAs). Information economy, globalisation, government reorganization and users expectations will change many mapping agencies during the coming years. The implementation of Spatial Data Infrastructures (SDIs) and the meeting of business objectives are major challenges and could have contradictory goals. This research investigated how topographic base information management at the national and European levels might be based on multiple data sources and how information and quality management principles could be utilized for this. Four topics are covered: management of topographic information in Finland, user requirements and the data quality of basic topographic data, Geographic Information Quality Management (GIQM) of topographic base data and European cooperation between NMAs.

The first part of the dissertation introduces the history of topographic mapping in Europe and especially in Finland. The development of SDIs is explored and information management concepts related to basic topographic information are described. The standardization of geographic information is reviewed from the technological, organizational, process and data viewpoints. Geographic Information Quality (GIQ) is described from the quality management viewpoints. The role of harmonization and interoperability in the development of SDIs and related to reference data is discussed.

The research corpus consisted of seven papers and results of a separate research project on the use of municipality data for the Topographic Database. The first two introduced models for topographic information management (Basic Topographic Framework [BTF]) in a multi-producer environment using a database(DB)-driven production paradigm. Quality evaluation practices and quality management principles were studied in a number of European NMAs as part of the work of the EuroGeographics Expert Group on Quality. The standardization of geographic information quality was examined through participation in ISO 19100 work. The usability of the Topographic Database was evaluated using two different applications (land cover mapping, and 3D visualization). User requirements were studied in connection with mobile applications as part of the GiMoDig project. European reference datasets were studied covering thirty-three European countries based on a questionnaire given to the NMAs as part of the EuroGeographics' EuroSpec project.

Finally, the BTF model was evaluated by a case study using municipality basemap data. This part of the research investigated the possibility for a unified specification of topographic information in Finland. Current data catalogues were analysed and the connection between them was established. Empirically, data from four municipalities were used to form a simulated Topographic Database in test areas utilizing only data from municipalities. A quality evaluation of the results was made using visual field inspection. The status of municipality basemaps was explored using a questionnaire. Responses were gained from 135 municipalities. The user requirement study included 13 interviews with 16 participants covering most significant resellers and customer groups of the National Land Survey of Finland.

Implementation of the Basic Topographic Framework (BTF) combining all basic topographic datasets into a unified database is feasible if based on case studies. It is suggested that implementation be based on the Geographic Information Quality Management (GIQM) model combining geographic information quality standards and quality management. Results support the idea that the TDB and topographic databases in general have a key role in the implementation process of SDIs, and that topographic information provides an essential element for reference datasets. Based on user requirement analysis, it is suggested that the NMAs in Europe should introduce harmonized specifications, because many applications could be developed for large consumer markets, if such common datasets were available. It is further suggested that topographic information should be connected with other datasets in order to support user requirements. Investigation of European reference information concludes that harmonization of data specifications have not yet been initiated at the national level and that international geographic standards have not yet been implemented. However, national mapping and cadastral organizations (NMCAs) have an important role in providing reference datasets in Europe. Topographic datasets together with cadastral datasets were identified as one of the main sources of reference information in Europe. Results support the idea that a common data specification for topographic data is feasible at some level. A questionnaire given to Finnish municipalities demonstrate the importance of municipality data in built-up areas. Case studies and an analysis of data catalogues suggest that basemaps can be utilized to compile the TDB in built-up areas supporting the presented BTF model. In Sweden and Denmark, the use of municipality data has progressed significantly, which supports the presented model. Especially in Denmark, the reduction of the number of municipalities has increased the need for cooperation. User requirement results suggests that some improvements are needed in the present data catalogues.

Keywords: Topographic Information, Quality management, Harmonization, Basemap, Joint-use of Geographic information, Semantic interoperability, Data quality, Map production, Spatial Data Infrastructure, History of national topographic mapping.

Tiivistelmä

Maastotietojen hallinnan ratkaiseminen on erittäin tärkeää maanmittauslaitosten tulevaisuuden kannalta. Informaatioyhteiskunta, globalisaatio, hallinnon uudelleen organisointi ja käyttäjävaatimukset tulevat muuttamaan monia maanmittauslaitoksia seuraavien vuosien aikana. Paikkatietoinfrastruktuurien toteuttaminen ja tulostavoitteiden saavuttaminen ovat tärkeimpiä haasteita. Nämä haasteet voivat kuitenkin olla osittain erisuuntaisia. Tässä tutkimuksessa selvitettiin, miten perusmaastotietojen hallinta kansallisella ja eurooppalaisella tasolla voisi perustua useiden tiedon tuottajien aineistoihin, sekä, miten tiedon- ja laadunhallinnan periaatteita voitaisiin soveltaa toteutuksessa. Tutkimusaiheet voidaan jakaa neljään eri osaan: maastotietojen hallinnan järjestäminen Suomessa, perusmaastotietojen käyttäjävaatimukset ja niiden laatu, paikkatietojen laadunhallinnan periaatteiden soveltaminen perusmaastotiedoille sekä kansallisten karttalaitosten yhteistyö Euroopassa.

Ensimmäisessä osassa käsitellään kansallisen maastokarttatuotannon historiaa Euroopassa ja erityisesti Suomessa. Paikkatietoinfrastruktuurien kehittymistä ja perusmaastotietojen hallintaa tarkastellaan informaationäkökulmasta. Paikkatietojen standardointia tarkastellaan teknologia-, organisaatio-, prosessi- ja aineistonäkökulmista. Paikkatiedon laadun eri osa-alueet kuvataan laadunhallinnan näkökulmien avulla. Harmonisoinnin ja yhteentoimivuuden konsepteja tarkastellaan paikkatietoinfrastruktuurien ja keskeisten paikkatietojen osalta.

Tutkimus koostuu seitsemästä eri julkaisusta sekä erillisestä tutkimuksesta, jonka keskeiset tulokset on raportoitu yhteenveto-osassa. Kaksi ensimmäistä julkaisua määrittelevät perusmaastotietojen hallintamallin (Perusmaastotietokehysmalli) usean tuottajan ympäristössä perustuen tietokantapohjaiseen viitekehykseen. Laadunarvioinnin käytäntöjä sekä laadunhallinnan periaatteita tutkittiin eurooppalaisissa karttalaitoksissa (osana EuroGeographics:n laadun asiantuntijaryhmän työtä). Paikkatiedon laadun standardointia tarkasteltiin osallistumalla ISO 19100 sarjan laatimiseen. Maastotietokannan käytettävyyttä arvioitiin kahdessa eri sovelluksessa (maankäyttöluokitus ja 3D -visualisointi). Käyttäjien vaatimuksia arvioitiin mobiilien sovellusten yhteydessä (osana GiMoDig -projektia). Eurooppalaisten referenssiaineistojen tilaa selviteltiin 33 eri maassa karttalaitoksille suunnatulla kyselytutkimuksella (osana EuroGeographics:n Eurospec -hanketta).

Perusmaastotietokehysmallin toteutusta arvioitiin kuntien kantakarttatietojen avulla. Lähtökohtana oli yhtenäisen tietomallin kehittäminen Suomen kaikille perusmaastotiedoille. Nykyisiä kohdemäärittelyjä arvioitiin ja niiden välille luotiin yhteys. Empiirisesti kantakarttatietojen käyttöä tutkittiin neljän kunnan alueella ja koealueilla muodostettiin simuloitu maastotietokanta käyttämällä pelkästään kuntien aineistoa. Muodostettujen aineistojen laatua arvioitiin visuaalisesti maastotarkastuksella. Kuntien kantakarttojen tilan arvioimiseksi tehtiin kysely asukasluvultaan 100:lle suurimmalle kunnille sekä osalle pienimistä kunnista (valinta tehtiin teknisen viraston tai vastaavan olemassa olon perusteella). Vastauksia saatiin 135 kunnasta. Käyttäjien vaatimuksia selvitettiin 13 haastattelussa, joihin osallistui 16 Maanmittauslaitoksen merkittävää jälleenmyyjää ja asiakasta.

Perusmaastotietoviitekehyksen, joka yhdistää kaikki perusmaastotiedot yhtenäiseen tietokantaan, toteutus näyttäisi tapaustutkimusten perusteella aiheelliselta. Toteutuksen ehdotetaan perustuvan esitettyyn paikkatietojen laadunhallintamalliin, joka yhdistää paikkatietojen laadunstandardit laadunhallinnan viitekehykseen. Tulokset tukevat ajatusta, että Maanmittauslaitoksen maastotietokanta ja maastotietokannat yleensä ovat keskeisiä paikkatietoinfrastruktuurien toteuttamisessa, sekä maastotietojen osuuden tärkeyttä keskeisissä paikkatiedoissa. Käyttäjävaatimusten perusteella tutkimuksessa esitetään, että eurooppalaisten maanmittauslaitosten tulisi harmonisoida tietotuotemäärityksensä, koska monia kuluttajasovelluksia voitaisiin kehittää laajoille markkinoille, jos yhtenäiset maastotietokannat olisivat saatavissa. Edelleen tulokseen pohjautuen esitetään, että maastotiedot tulisi kytkeä muiden tietokantojen kanssa käyttäjävaatimusten täyttämiseksi. Selvityksessä eurooppalaisista keskeisistä paikkatietoaineistoista tehtiin johtopäätös, ettei harmonisointia vielä ole tehty eikä paikkatietostandardeja otettu käyttöön. Kuitenkin kansallisilla maanmittauslaitoksilla (kartta- ja kiinteistötietojen tuottajilla) on tärkeä merkitys keskeisten paikkatietojen tuottajina Euroopassa. Maastotietoaineistot yhdessä kiinteistötietoaineistojen kanssa todettiin olevan päälähteet keskeisille paikkatiedoille. Tulokset tukevat ajatusta, että yhteiset tietospesifikaatiot voitaisiin määritellä tietylle tasolle. Kuntien kantakartta-aineistot ovat tärkeitä taajama-alueiden osalta kunnille tehdyn kyselytutkimuksen perusteella. Tapaustutkimusten ja kohdemäärittelyjen analysoinnin perusteella voidaan todeta, että Maanmittauslaitoksen maastotietokannan muodostamisessa voidaan käyttää taajama-alueilla kuntien kantakartta-aineistoja, mikä tukee esitettyä perusmaastotietokehysmallia. Ruotsissa ja Tanskassa kehitys näyttää myös kulkevan tähän suuntaan. Erityisesti Tanskassa tehtävä kuntauudistus on painottamassa yhteistyön tärkeyttä. Käyttäjävaatimusten perusteella voidaan esittää joitain parannuksia nykyisiin tietomäärittelyihin.

Avainsanat: maastotieto, laadunhallinta, harmonisointi, kantakartta, paikkatietojen yhteiskäyttö, semanttinen yhteentoimivuus, tiedon laatu, kartantuotanto, paikkatietoinfrastruktuuri, kansallisten maastokarttojen tuotannon historia.

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Paper V was produced in the GiMoDig project. I appreciate the input of all persons, who contributed to this report. Especially, I am grateful to Dr. Tiina Sarjakoski and Prof. Tapani Sarjakoski. Mr. Jorma Marttinen was a co-author to Paper VII giving practical experience to quality evaluation. His long carrier in mapping has been valuable for me and I appreciate the co-operation.

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Kerava, May 8th, 2006 Antti Jakobsson

List of Publications

This dissertation consists of a summary and seven appended publications I-VII.

Paper I

Jakobsson, A. and L. Salo-Merta, 2001. Definition of a Basic Topographic Framework for National GI Policy – One Database for All Basic Topographic Data, In *Proceedings of the 20th International Cartographic Conference*, Beijing, China, Vol. 4, 2197-2205.[1]

Paper II

Jakobsson, A., 2003b. Framework and Requirements for Management of Topographic Data in Europe. In *ScanGIS'2003 Proceedings of the 9th Scandinavian Research Conference on Geographical Information Science* , eds. K. Virrantaus and H. Tveite, Espoo, Finland, pp. 91-102, http://www.scangis.org/scangis2003/papers/.[2]

Paper III

Jakobsson, A. 2002. Data Quality and Quality Management – Examples of Quality Evaluation Procedures and Quality Management in European National mapping Agencies, In *Spatial Data Quality*, ed. Wenzhong Shi et al. London: Taylor & Francis, 313 p., pp. 216-229.[3]

Paper IV

Jakobsson, A., 2002b. The Topographic Database as an Integral Part of the Finnish National Spatial Infrastructure – Analysis of the Present Situation and Some

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Possibilities for the Future, In *Finnish Journal of the Surveying Sciences*, Vol. 20, No. 1-2,2002, pp. 92-107.[4]

Paper V

Jakobsson, A., 2003. User Requirements for Mobile Topographic Maps. Report of the GiMoDig project. 93 p., http://gimodig.fgi.fi/deliverables.php.[5]

The annexes of this paper are not reproduced in this dissertation.

Paper VI

Jakobsson, A. 2005b. European Reference Data Sets for European Spatial Data Infrastructure – State of the Art and Development of Common Specifications. In *Proceedings of the 22nd International Cartographic Conference*, A Coruna, Spain, Cd-Rom.[6]

Paper VII

Jakobsson, A. and J. Marttinen, 2003. Data Quality Management of Reference Data sets - Present Practice in European National Mapping Agencies and a Proposal for a New Approach. In *Proceeding of the 21st International Cartographic Conference,* Durban, South Africa, Cd-Rom.[7]

In Paper I, the author developed the idea of BTF and the case study, while Leena Salo-Merta wrote the chapter on technical advances in spatial data management and assisted with the introduction. In Paper VII, the author developed the GIQM model for reference datasets and Jorma Marttinen provided the example of current practice in Finland.

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Preface

Map making has always utilized the best practices available. The history of science has been closely related to the history of map making and understanding the world we are living in. Pythagoras, Plato and Aristotle established the idea of the sphericity of the Earth based on common observations such as how new stars appeared when travelling north or south and how a ship's hull would vanish first when sailing out from port (Wilford, 2002). Ptolemy (ca. 90 – ca. 170), with his book *Geography,* can be considered to have established scientific cartography. He defined geography as "a representation in pictures of the whole known world together with the phenomena which are contained therein"[8]. Arthur H. Robinson and Barbara Bartz Petchenik have described mapping as "the form of symbolization with special utility for encoding and transmitting human knowledge of the environment" (1976: p. vii).

National Mapping Agencies (NMAs) have produced topographic maps for over 250 years, but only in the last 20 years has the production has been digital. My own experience in national mapping starts in the 1990's with programming project of the propriety GIS system called Fingis[9] in the automation project of the National Land Survey of Finland (NLS). In the period 1991-1994, I had an opportunity to participate in the development of a new production system for the definition of the new digital production of the basic map. The production concept introduced in 1992 was based on the idea of a master database (the Topographic Database), which would be used for the production of other map databases. Another important concept was the introduction of the Data Quality Model (1995), which described the individual quality requirements for each feature type. Later, I was involved with the development of national mapping and with investigating the new possibilities of this. In 1997, I had an opportunity to visit New Zealand, which had just transferred mapping production to a government owned company. The idea presented in this dissertation began to evolve after this visit.

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[8] Cited from Brown (1949), who claims the definition originated in the Ebner manuscript 1406, Geographia of Claudius Ptolemy 1932

[9] Later it was changed to Maagis when Karttakeskus was separated from the National Land Survey of Finland

International cooperation has always been important in map making. Maps have often been kept secret (as still is the case in some countries), but always information has leaked. Map makers have always copied other maps, and still the question of copyright is very valid for map producers. Information gathering for maps is costly and includes long-standing processes. The first efforts to produce a 1:1000 000 map based on international cooperation between nations was proposed in the fifth International Geographical Congress at Bern in 1891 by Albrecht Penck, a young professor of geography at the University of Vienna. Work was begun but it was interrupted by world wars and the reluctance of many governments to support it (Wilford, 2002). Since that, 1:1000 000 world datasets have been produced by the US military (e.g. Digital Chart of the World[10], VMAP 0[11]). The latest civilian effort has been based on the initiative of Japanese mapping agency. The Global Map project was undertaken in 1996 with the goal of achieving global coverage in 2007; so far 87% coverage has been achieved. EuroGeographics has produced the European coverage based on cooperation between European mapping agencies. The experience indicates that the production of unified datasets on even small scales has proven to be expensive and time consuming. Traditional approaches have not given an economical solution to the problem. Another approach might be to abandon the present national datasets and use modern technology to remap Europe, using, for example, satellite imageries. I call this dilemma a double-pyramid paradigm later in this dissertation. Both approaches have benefits, which should be utilized. National mapping agencies have adopted a master-database concept in the management of topographic information. This master database is the utilized to produce generalised datasets. My own involvement in international cooperation between national mapping agencies starts with international conferences (FIG, ICA). In the late 1990s I became involved with the CERCO working group on quality (1997), which was chaired by Mr. François Salgé from the IGN France. Later, when EuroGeographics was formed, I was invited to participate to the EuroSpec project. The GiMoDig project, which investigated how national topographic datasets might be integrated by a common schema and distributed using standards, was also a very important. Based on these influences, this dissertation will discuss the possibility of utilizing large scale topographic datasets produced by the national mapping agencies for the production of European topographic datasets.

The quest for better accuracy has always been important to cartographers. The introduction of new measurement methods have increased accuracy and short-

[10] Digital Chart of the World is a product of the Environmental Systems Research Institute (ESRI), released in 1992 and originally developed for the US Defense Mapping Agency. The primary data source for the DCW was the Operational Navigation Chart (ONC) series, a group of 1:1 000 000 scale paper maps created by the United States Defense Mapping Agency, see http://www.nlh.no/ikf/gis/dcw/dcw.html.

[11]

ened data collection processes. Now, in the 21st century, national mapping has been transformed to form part of the geographic information management paradigm. Surprisingly, quality management principles from the industry have not been utilized fully in the context of geographic information. I became involved with quality already when I did my Masters Thesis on "*On Accuracy of Area and Line features*", which was based on a suggestion of Chief Engineer Matti Vahala and guided by Dr. Pekka Rahkila and Professor Martti Martikainen. After the thesis, I was involved with spatial data sampling at the NLS and, later, with the definition of the Topographic Data Quality Model. At that time, we also developed a process approach using quality management principles for national mapping. At the beginning of the 1990s, CEN initiated the standardization process. I was nominated to the working group on quality, developing the first quality standard. This standard was then utilized later in ISO work, in which I have been able to participate until now. During the period of 1999-2001, I led the quality management project for the whole organization of the NLS. At the same time, I decided to start my post graduate studies. Fortunately, I had an opportunity to follow the lectures of professor Lillrank, which gave me a valuable background for this work. Questions such as why the quality management has not been utilized and what the benefits would be arose in my mind. Hopefully, this dissertation will give some answers.

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List of Acronyms

2D	Two dimensional
3D	Three dimensional
4D	Four dimensional
AAA	AFIS-ALKIS-ATKIS
ACC	Adaptive Cruise Control
AFIS	Amtliches Festpunktinformationssystem
AFLRA	Association of Finnish Local and Regional Authorities (Suomen Kuntaliitto [in Finnish])
AGENT	Automated Generalisation New Technology
AGIL	Adaptation, Goal attainment, Integration and Latency
ALC	Adaptive Light Control
ALIC	Australian Land Information Council, former name of the ANZLIC
ALKIS	Amtliches Liegenschaftskatasterinformationssystem
AmI	Ambient Intelligence
ANZLIC	Australian New Zealand Land Information Council
Anvil	Networked Virtual Interoperability Laboratory
AQL	Acceptable Quality Level, also Acceptance Quality Limit
ASDI	Australian Spatial Data Infrastructure
ATKIS	Amtliches Topographisch-Kartographisches Informationssystem (Topographic Data System in Germany)
BDCARTO	Base de données cartographiques de reference (Cartographic database of the IGN France in scale 1:50 000)
BDTOPO	Description métrique 3D du territoire et de ses infrastructures (Topographic database of the IGN France)
BMS	Business Management System
BTF	Basic Topographic Framework
CEN	European Committee for Standardization
CERCO	Comité Européen des Responsables de la Cartographie Officielle
CGALIES	Coordination Group on Access to Location Information by Emergency Services
CORINE	Coordination of Information on the Environment project
CRUMPET	Creation of User-friendly Mobile services Personalised for Tourism project
CSL	Conceptual Schema Language
DB	Database
DBMS	Database Management System
DCW	Digital Chart of the World
DG	Directorate General
DGIWG	Digital Geographic Information Working Group
DGPS	Differential GPS

DEM	Digital Elevation Model
DIGEST	Digital Geographic Information Exchange Standard
DIGIROAD	National Digital Road Data Set
DIS	Draft International Standard
DQL	Declared Quality Level
DTM	Digital Terrain Model
E112	Enhanced 112
E911	Enhanced 911
EC	European Community
eContent	European Digital Content on the Global Networks, programme funded by the European Community
EEC	European Economic Community, former name of the now-called European Community
eEurope	Programme of the European Commission aiming to make the EU the most competitive and dynamic knowledge based economy in the world
EFQM	European Foundation for Quality Management
EGII	European Geographic Information Infrastructure
EO	Executive Order
ESA	European Space Agency
ESDI	European Spatial Data Infrastructure
ESRI	Environmental Systems Research Institute
ETeMII	European Territorial Management Information Infrastructure, former project partly funded by the EC
EU	European Union
EUROGI	European Umbrella Organization for Geographic Information
EuroRoadS	A pan-European Road Data Solution
EuroSpec	EuroGeographics programme for building the ESDI
FACC	Feature Attribute Coding Catalogue
FGDC	Federal Geographic Data Committee
FGDP	Focus Group on Data Providers
FGI	Finnish Geodetic Institute
Fiksu	AutoCAD based GIS system
FOT	Fælles objekttyper (Common catalogue)
Galileo	European Satellite Navigation System
GB	Great Britain
GDDD	Geographical Data Description Directory, former metadata service of Euro-Geographics
GDF	Geographic Data File
GDP	Gross Domestic Product
GeoTIFF	Geographic Tag Image File Format
GEOROUTE	La Base de Données la mieux adaptée aux multiples applications du calcul d'itinéraires et des études géomarketing (Road database of the IGN France)
GI	Geographic Information
GI2000	Consultation paper “Towards a European Geographic Information Infrastructure”
GiMoDig	Geospatial info-mobility service by real-time data integration and generalisation project
GIQM	Geographic Information Quality Management
GINIE	Geographic Information Network in Europe, former project partly funded by the EU.
GIS	Geographical Information System
GML	Geography Markup Language

GMES	Global Monitoring for Environment and Security
GPS	Global Positioning System
GSDI	Global Spatial Data Infrastructure
HyperGeo	Easy and Friendly Access to Geographical Information for Mobile Users
ICA	International Cartographic Association
IGN	Institut Géographique National
IHO	International Hydrographic Organization
IHO S-57	Standard for interchanging hydrographic data
IMPACT	former EU funded programme for stimulating the multimedia content industry
INFO2000	former EU funded programme for stimulating the multimedia content industry
INSPIRE	Infrastructure for Spatial Information in Europe
INTERLIS	Data Exchange Mechanism for LIS in Switzerland
INUSE	Information Engineering Usability Support Centers
IPTS	Institute for Prospective Technological Studies
IR	Implementing Rules
ISO	International Organization for Standardization
IST	Information Society Technologies
ISTAG	IST Advisory Group
IT	Information Technology
IWA	International Workshop Agreement
JAKO	National Land Survey's GIS
JUHTA	Julkisen hallinnon tietohallinnon neuvottelukunta (Advisory Committee for Information Management in Public Administration)
KATKO	Kunnallishallinon tietotekniikkatoimikunta (Advisory Board for Information Management of Municipal Administration), former cooperation body of municipality associations
KEN	Key Usability and Ethical Issues
KKJ	Kartastokoodinaattijärjestelmä (Finnish National Map Coordinate System)
KL	Kommunernes Landsforening (Municipality association in Denmark)
KMS	Kort & Matrkelstyrelsen
KVAKK	KvalitesKontroll av Kartdata (Quality control of map data)
LBS	Location-Based Services
LC	Land Cover
LCA	Lane Change Assistant
LIF	Location Information Format
LINZ	Land Information New Zealand
LIS	Land Information System
LoVEUS	Location aware Visually Enhanced Ubiquitous Services
LQ	Limiting Quality
LQR	Limiting Quality Ratio
Magic	Initiative for proprietary industry standard, based on GDF
MB	Megabyte
MEGRIN	Multi-purpose European Ground Related Information Network, former cooperation body of the NMAs
MODV	Control Unit at the IGN
MRDB	Multiple Representation Database
m-ToGuide	Mobile Tourism Guide
NATO	North Atlantic Treaty Organisation
NAVI	Personal Navigation Programme

Navikärki	Henkilökohtainen navigointi -kärkihankkeen suunnittelu (Project in NAVI programme)
NextMAP	Next MAP for transport telematic applications
NLS	National Land Survey of Finland
NMA	National Mapping Agency
NMCA	National Mapping and Cadastral Agency
NMO	National Mapping Organization
NCGI	National Council for Geographic Information
NSDI	National Spatial Data Infrastructure
ODGIS	Ontology-Driven GIS Framework
ODIN	Geographic Distributed Information Tools and Services for the Mobile Information Society
OGC	Open Geospatial Consortium
ONC	Operational Navigation Chart
OO	Object-orientation
OpenGIS	Adjective describing specifications and other products of OGC's consensus process that support transparent access to heterogeneous geodata and geoprocessing resources in a networked environment
OS	Ordnance Survey
OWL	Web Ontology Language
PALIO	Personalised Access to Local Information and services for tourists.
PC	Personal Computer
P-Com	Personalized Communications Device
PDA	Personal Digital Assistant
PDCA	Plan-Do-Check-Action
PDF	Portable Document Format
PEPTRAN	PEdestrian and Public TRAnsport Navigator
PETIT	Pathfinder towards the European Topographic Information Template
PNS	Personal Navigation Services
preAnvil	Design of the Networked Virtual Interoperability Laboratory
PYRY	Paikkatietojen yhteiskäytön yhteistyöryhmä (Collaboration group in shared-use of geographic information)
QIP	Quality Implementation Plan
QM	Quality Model
QMS	Quality Management System
RDS	Resource Description Framework
RMSE	Root Mean Square Error
ROI	Return On Investment
SABE	Seamless Administrative Boundaries of Europe, a dataset produced by the EuroGeographics
SALAR	The Swedish Association of Local Authorities and Regions
SDI	Spatial Data Infrastructure
SDTS	Spatial Data Transfer Standard
SLICES	Land cover dataset in Finland
SPC	Statistical Process Control
SME	Small Medium Enterprises
SOSI	Samordnet Opplegg for Stedfestet Informasion (Systematic Organisation of Spatial Information)
Stella	Bentley’s GIS for municipalities
SVG	Scalable Vector Graphics
TC 211	Technical Committee 211 in the ISO
TC 287	Technical Committee 287 in the CEN

TDB	Topographic Database (Maastotietokanta [in Finnish])
TDS	Topographic Data System (Maastotietojärjestelmä [in Finnish])
TopDK10	Topographic Database produced by the KMS
TopTK	Common database for topographic information in Denmark
TourServ	Personalised Tourist Services Using Geographic Information Systems via Internet
TQC	Total Quality Control
TQM	Total Quality Management
TR	Technical Report
UKTJ	Uusi valtakunnallinen kiinteistöjärjestelmä (New National Cadastral Data System)
UML	Unified Modelling Language
UNESCO	United Nations Educational, Scientific and Cultural Organization
UK	United Kingdom
USGS	United States Geological Survey
USINACTS	Usability In Advanced Communications Technologies and Services
VDT	Visual Display Terminal
VidGIS	AutoCAD based GIS
VMDS	Version Managed Data Store
VNET5	User-Centred Product Creation in Interactive Electronic Publishing
WFS	Web Feature Service
WMS	Web Map Service
WP	Work Package
WWW	World Wide Web
Xcity	Tekla's GIS for municipalities
XML	Extensible Markup Language
YTCAD	AutoCAD based GIS system
ZetMap	VM-Data's GIS for municipalities

Chapter 1

Introduction

1.1 Background

The role of national topographic mapping has evolved since its birth in Europe in the 18th century. Military, government and scientific reasons were important in the development of National Mapping Agencies (NMAs). Economy, planning and taxation became more important through time. The development of national mapping has been greatly dependent on the progress of science and technology. First, the development of measurement instruments such as theodolites, aerial photogrammetry, and stereo autographs, together with the development of printing technology improved mapping processes. This was followed by the progress of automated map production first with propriety geographical information systems (GISs), and now with commercial GISs, together with improvements in measuring capabilities, relating to, for example, satellite imageries, Global Positioning Systems (GPSs) and airborne laser scanning.

Now, European NMAs have produced digital topographic datasets for close to 20 years. The change from analogue maps to digital datasets has increased the number of possible ways of utilizing topographic information. Topographic information will be used for multiple purposes and combined with other datasets. The use of spatial analysis and feature-based information is increasing and now supplements the use of topographic information as a static vector layers or raster maps. NMAs are becoming aware of this challenge. 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 (Jakobsson, 2003). There is an increasing pressure to use topographic information in other uses and for non-cartographic purposes. Topographic information should not only be available for professional use, but, combined with other information, should be made available to the general public also. NMAs in Europe have adopted different strategies for meeting the user requirements. Some NMAs have adopted a business-oriented approach, others have adopted infrastructure enabling approaches, or have tried to meet the demands of both. From the technical viewpoint, geographic information management will be based on general object-based structures instead of specific database structures. Topographic information will be used with other datasets and services over the Internet. Lawrence (2004) summarizes challenges that NMAs face as: a) changing models of government, b) technology, c) globalization, and d) changing customer needs. Governments are investigating options to deregulate, privatise or outsource traditional public-sector activities. Globalization emphasizes the importance of international standards and interoperability. The Ordnance Survey became a public-sector Trading Fund in 1999 and over 80% of revenue is derived from digital data sales. The Ordnance Survey has introduced a MasterMap concept for reference data in Great Britain (Murray & Shiell, 2004). It contains the topographic layer, imagery, addresses and transport network. NMAs datasets are important for creating and maintaining the national spatial infrastructures (NSDIs). Many NSDIs are based on the concept of reference data (also known as core data and fundamental data), which can be combined with other datasets. However, most datasets are not currently interoperable or there is no information about quality.

Spatial Data Infrastructure (SDI) has its beginning in the US with President Clinton's Executive order (EO) in 1994. In this order, all future federal geographic information collection, storage and reporting was required to adhere to information standards of the Federal Geographic Data Committee (FGDC). One of the initiatives launched was Digital Earth aiming to join the georeferenced information globally. Especially important was the Digital Earth reference model demonstrating the use of the geographic information standards developed in the International Organization for Standardization (ISO) and the interoperability specifications of the Open Geospatial Consortium (OGC) in the implementation. This reference model was then used later in the INSPIRE (Infrastructure for Spatial Information in Europe) process of the European Commission. In 1995, the EC's Information Market Directorate published a preliminary consultation paper known as "GI2000: Towards a European Geographic Information Infrastructure (EGII)". This initiative was not successful; the second try, named INSIPRE, started in 2001 within the environmental policy. The work has now progressed to a proposed directive that sets requirements for reference datasets providers in Europe.

The National Land Survey of Finland (NLS) has been a pioneer in promoting the joint-use of geographic information in Finland. In the 1980s, the LIS project in Finland already recognized that geographic information is important to society (Rainio, 1988b). After that, the NLS led the effort to define the National Spatial Data Infrastructure (NSDI). The work was completed in 1996 (Rainio, 1996). Several actors have been active in promoting geographic information. One effort was a description of the core datasets in Finland by the Ministry of the Interior's

Advisory Committee for Information Management in Public Administration (JUHTA, 1998). Following from that, the Ministry of Agriculture and Forestry has prepared a strategy for geographic information in administration in 2001 (Vertanen & Vajavaara, 2001) and a new strategy for national mapping in 2002 (Vertanen & Vajavaara, 2002). The National Council for Geographic Information was nominated in 2001 to prepare an NSDI. The committee could follow the work of European SDI development (INSPIRE), and use the INSPIRE principles in the Finnish NSDI. The National Geographic Information Strategy was published in 2004, followed by the continued nomination of the National Council for Geographic Information (NCGI) aiming to implement the strategy. One of key aspects of the strategy is the harmonization of reference datasets. This dissertation will study this from the perspective of one aspect: topographic base information management.

1.2 Concepts

The term ***topographic base information*** can be derived from the definitions of geographic information, topographic map and reference data. ***Geographic information*** is "information concerning phenomena implicitly or explicitly associated with a location relative to the Earth" (ISO, 2005b). In Spatial Data Infrastructures, the reference (or core) datasets are important. ***Reference datasets*** are series of datasets that everyone involved with geographic information uses to reference his/her own data as part of their work. They provide a common link between applications and thereby provide a mechanism for the sharing of knowledge and information amongst people (FGDC, 2005; Rase et al., 2002). According to the dictionary[12], the word topographic comes from the Greek word topos [a place] and graphein [to write]. In the Oxford English Reference Dictionary[13], the word topographical is described as "dealing with or depicting places (esp. towns), buildings, natural prospects, etc., in a realistic and detailed manner". Traditionally, ***topographic map*** has been defined as a map that shows a relief. Topographic maps have also been recognized as general purpose or reference maps (e.g. Robinson, 1973). This categorization was also suggested by Fisher (1979), based on a comprehensive analysis of definitions of thematic and other maps. In the general reference cartography, he suggests "road maps, general reference atlas and wall maps, and topographic maps (including aeronautical and nautical maps of topographic type)". Fisher (1979b) also discusses the characteristics of topographic maps based on the glossary of geographic terms (Stamp, 1966): (1) "being concerned with quite small rather than large spaces"; (2) "concerned with multiplicity of things"; (3) "concerned with physical matter that is

[12] New Webster's Dictionary and thesaurus, New York, 1991
[13] Oxford University Press, 1996

relatively fixed in contrast to matter that moves, or to abstractions"; (4) "on the earth's surface"; (5) "concerned with surface relief". In the GIS dictionary[14], topographic map refers to "a map whose principal purpose is to portray the features of the Earth's surface. These features might include the cultural landscape, but normally refer to the terrain and its relief (e.g. Krzanowski et al. 1995; MacEachren, 1995; Monmonier, 1995). In this dissertation, topographic base information refers to the representation of the topographic base features either man-made or natural, and their horizontal and vertical location in the terrain, that can be used in building a reference framework. A topographic base feature can have multiple representations based on the intended use of the dataset.

While this dissertation does not try to cover data management issues in geographic information comprehensively, some terms related to it are used. ***Feature*** has been defined in ISO 19110 as an "abstraction of real world phenomena" (ISO, 2005b). ***Feature type*** is again according to ISO 19110 a "class of real world phenomena with common properties" (ISO, 2005). ***Schema*** is a formal description of a model. ***Interoperability*** has been described in ISO 2382 (ISO, 1993) as the "capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units." Further, ***semantics*** can be described as the relationship between the computer representations and the corresponding real world feature within a certain context (Bishr, 1998). The basic description of the real things in the world, the description of what would be the truth, is called ***Ontology.*** The result of making explicit the agreement within communities is what the Artificial Intelligence community calls ***ontology*** (Fonesca, 2001)***. Schema integration*** tries to establish a formal relationship between two schemas using expert knowledge. Harmonization and schema integration can be perceived to have the same objectives. ***Harmonization*** integrates schemas or feature types that share a common ontology with a new integrated schema.

Information management has been defined as an application of management principles to the acquisition, organization, control, dissemination and use of information relevant to the effective operation of organizations of all kinds. Information here refers to all types of information of value, whether having their origin inside or outside the organization. Information management deals with value, quality, ownership, use and security of information in the context of organization performance (Wilson, 2002). The distinction between knowledge management and information management is not very obvious. Kakabadse and others (2001) suggest that "information and data management are important pillars of knowledge management" but the latter "encompasses broader issues and, in particular, creation of processes and behaviours that allow people to transform information

[14] http://www.geo.ed.ac.uk/agidict/welcome.html (accessed May 4th, 2006).

into the organisation and create and share knowledge." Dalkir (2005) explains that a good definition of knowledge management incorporates both the capturing and storing of the knowledge perspective, together with the valuing of intellectual assets. He gives an example of a good definition of the ***knowledge management***:

> the deliberate and systematic coordination of an organization's people, technology, processes, and organizational structure in order to add value through reuse and innovation. This coordination is achieved through creating, sharing, and applying knowledge as well as through feeding the valuable lessons learned and best practices into corporate memory in order to foster continued organizational learning.

Data is often defined as factual information, i.e. measurements or statistics, used as a basis for reasoning, discussion, or calculation. ***Information*** has been defined as communication or reception of knowledge or intelligence and knowledge as the condition of knowing something gained through experience or the condition of apprehending truth or fact through reasoning. Information can be seen as data in context (Bouthillier & Shearer, 2002). The term ***Geographic Information Quality Management*** is used in this dissertation to cover all aspects of how an organization should manage its geographic information including quality. The approach taken here is based on quality management and Spatial Data Infrastructure development.

Quality management or total quality management (TQM) has evolved from its engineering origins to a general management philosophy in 1980s. Quality management has been defined in ISO 9000 standards (ISO, 2005c) as "coordinated activities to direct and control an organization with regard to quality". ***Quality*** can be defined as fitness for use, including both quality of design, conformance to the design (production oriented quality), customer satisfaction and the needs of society or environment. ***Usability*** is defined in ISO 9241 (ISO, 1997)as "the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments". Normally, quality management is applied inside an organization. In this dissertation, quality management is used as a holistic approach to cover several organizations that produce, maintain and uses topographic base information. This approach has some relation to system thinking, which has its roots in the early work of Barnard (1948), Selznick (1948) and von Bertalanffy (1969). ***System thinking*** considers the organization as a complex network of elements and relationships, and recognizes the interaction with the environment in which the organization is contained (Beckford, 2002). The selected approach is then applied in the context of development of Spatial Data Infrastructures.

1.3 Objectives and Methodology

1.3.1 Introduction

The work documented in this dissertation is a contribution to topographic base information management in Finland and Europe. The hypothesis for the research was to advocate that **topographic base information at the national and European level might be based on multiple data sources and that information and quality management principles could provide a solution for this**. Related research questions following the hypothesis were:

> What are the users needs for topographic information?
>
> Which problems are related to the use of multiple sources from the organizational and information management points of view?
>
> How can industrial management principles, especially those relating to quality management, be applied to the processes of national mapping and production of European-wide datasets?
>
> Which common characteristics and differences there exists in the topographic information gathered in the Europe?

The hypothesis and research questions were explored from the perspective of the organization, of technology, process and user's needs (Figure 1.1); their focus was on their implications for topographic information at the levels of logic and semantics. Data quality, new products, standards and quality management might give a solution for these problems. This work did not try to explore the technical implementation of a multiple representation database, nor the political or reorganizational aspects of public agencies.

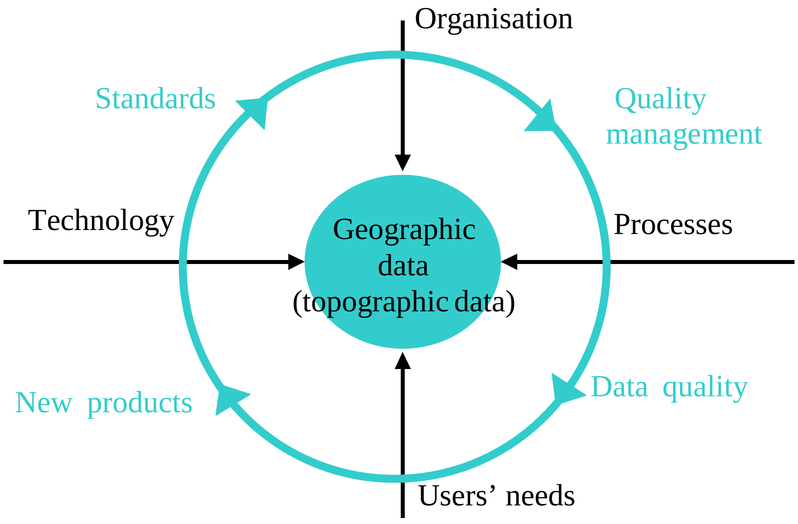

Figure 1.1 Framework for the research

Users of topographic information can be categorized into two main groups customers and citizens. This is a key characteristic of topographic base information; it should provide useful information for the customers, both private and professional, while, on the other hand, satisfying the public needs of the society in general. This dilemma has led to different strategies in the national mapping agencies. Some have adopted a business-oriented approach while others provide information and services for a Spatial Data Infrastructure (SDI).

Technology has been a key mechanism for the development of NMAs. The research of multiple representation databases and generalisation (e.g. Kilpeläinen, 1997; Harrie, 2001; Dunkars, 2004) provide one of the building blocks for this work from the technical point of view. The present research concentrated on solving the problem at the data management level inside one organization (see e.g. Salo-Merta & Helokunnas, 2002). In this study, the emphasis has been at the information management level, where important aspects are spatial data infrastructures and standardization; thus the focus is on an area wider than one organization alone.

The use of multiple sources is not self-evidently necessary in data production. Even inside the mapping organizations generalized topographic datasets had their own production processes that gathered the same features from the terrain. The reason lay in differences between revision schedules and difficulties in generalisation techniques. One of the challenges in the topographic base data production has been the long-standing and expensive production processes. Traditionally, production of topographic base information has been considered to cover compiling information in the field and/or interpreting aerial photographs. The quality of, for example, topological relationships between objects, was guaranteed by using the same production methods for all feature types compiling information covered by one map sheet. Figure 1.2 depicts the traditional mapping approach. The same production method guaranteed data quality using a “closed” production process. This denotes that the mapping agencies had a full control of the process methods and used same production methods for the whole mapping area. Now, most of the mapping agencies have completed the first digitalisation phase of topographic information. Some feature types are collected more frequently than others, which highlights the importance of data quality management.

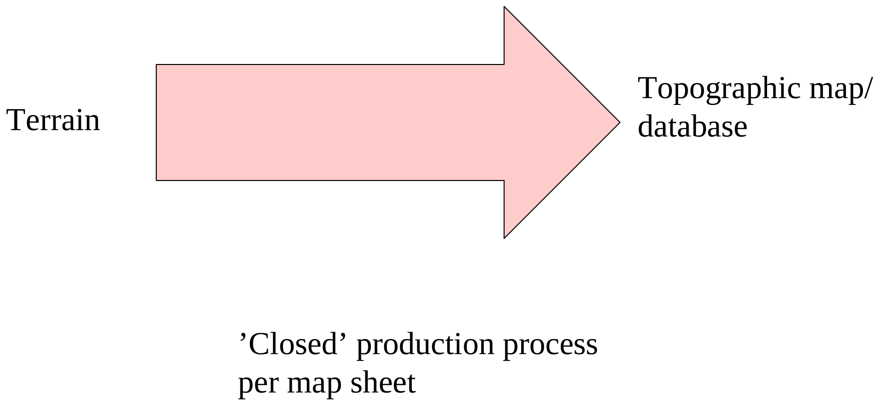

Figure 1.2 Traditional production of topographic information

The user needs, of both customers and the information society, have raised questions relating to the traditional production methodology. The development of satellite technology has provided new means for everyone to compile accurate information locally. In the information society, the role of mapping agencies will have to change from being production-oriented to being infrastructure-oriented. The need for change in the national mapping agencies' production paradigms was already recognized in the late 1990s (e.g. Morrison, 1997). The approach in this study was to provide a solution to this paradigm change by using quality management principles as a holistic approach.

The challenges in data quality have not been realized by many mapping, or even user, organizations. Users do not require data quality information from the mapping agencies (e.g. Jakobsson & Vauglin, 2000; van Oort, 2006). One of the key challenges in the use of multiple sources is to solve problems in data quality. Standardization of geographic information is providing methods for this process. A lot of effort is put into the building of metadata services at the discovery level. At the same time, not so much effort is put into providing data quality information. In this study, quality management was utilized to provide a model for handling data quality challenges in a process involving multiple organizations.

Harmonization of feature types is one of the challenges in using multiple sources. If feature types do not represent the same real-world phenomena, it is not very useful to combine those into a unified dataset. The research has concentrated on solving the interoperability challenge using a common feature model with selected common features (e.g. Sarjakoski et al., 2002). Research into ontology tries to build a semantic model between different datasets (e.g. Fonseca, 2001). In case of topographic base information, harmonization of specifications at the national and European level is considered a requisite. Figure 1.3 illustrates the hypothesis used.

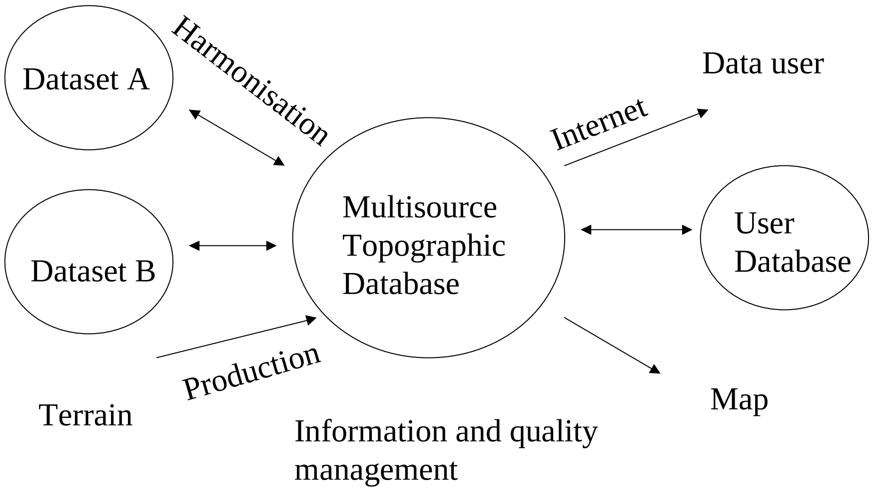

Figure 1.3 Production of topographic base information from the information and quality management point of view.

1.3.2 Research Topics

This study can be divided into four different topics: 1) how to manage topographic base information at the national level using multiple sources (Paper I, VIII), 2) user requirements and data quality of topographic base data (Paper IV, V, VIII), 3) Geographic Information Quality Management (GIQM) in topographic base data (Paper II, III, VII), and 4) European cooperation in NMAs (Paper II, VI, VII) from the quality management perspective. The hypotheses of the study are set mainly in Papers I and II. The methods and material of the study is presented in Papers III, IV and V. The main results are presented in the Papers VI, VII and VIII.

Topic I: Management of Topographic Information in Finland

Objectives

The National Land Survey of Finland manages the Topographic Database at the national level. Production of topographic mapping has been digital since 1992 when the present model for the Topographic Database was defined.

The objective in this study was to explore the **possibilities of deriving the Topographic Database from multiple sources and from different organizations and at different levels of accuracy.** In Finland, the concept of using multiple sources in the production of spatial datasets is not new. The aim of the LIS-project (Rainio, 1988) was to establish the proposition that different organizations could utilize collected geographic information as the building block of the concept of the joint-use, or shared-use, of geographic information, was that different organizations could utilize collected geographic information. Then, the emphasis was on data transfer. The aim of this study was to **advocate that the problem is more organizational, process and data content dependent**.

Methodology

The introduction of object-oriented methodology and object-relational databases gives rise to new possibilities for handling geographic information. In this study, the object-based model is used to conceptualise the real world. In the past, topographic base data were collected in order to produce a topographic map. Now the paradigm has changed more towards the production of topographic base information and the utilization of this information for multiple purposes. One of these is the production of a topographic map. This has changed the construction of the database. In the past, the modelling was based on the cartographic modelling paradigm, in which specific map symbols present real-world features. Now, a real-world feature is presented, using appropriate spatial representation, in a database with attributes, behaviours and relationships. The purpose in which this information is used still affects the modelling process. For example, how accurately should a certain feature be modelled? In the generalisation literature, the concept of the ***multiple representation database*** (e.g. Kilpeläinen, 1997) is defined as consisting of datasets, in which those objects that represent the same physical entities are connected (Harrie, 2001). While the purpose of this study was not to study generalisation, the concept of multiple representation is useful. Many mapping agencies have introduced a concept of a ***master database***, which contains information at the most detailed level. This master database is then used to produce ***derived databases.*** Together these concepts can be described as a ***database (DB)-driven production paradigm*** that emphasizes up-to-date mapping and multiscale, multiproduct capabilities of a master database representing the real world. The aim in this study was to investigate how this DB-driven production paradigm could be introduced at the national level for topographic mapping. Similar concepts in other mapping agencies were explored and then a framework in which to handle topographic information based on multiple sources is described. **The research approach selected involves the hypothetico-deductive method using case studies** (Paper I). **An empirical study using municipality data is used to verify the model created** (Chapter 7).

Topic II: User Requirements and Data Quality of Basic Topographic Data

Objectives

There were several aims in the study of user requirements. One aim was to investigate whether **topographic base information has a role of a reference dataset.** One question addressed, for example, was whether it satisfies many types of users. Specifications of topographic databases have been derived using a mapping paradigm and many users still utilize them as background maps. The second objective was to **investigate whether users require topographic features instead of just a static vector layer or raster map**. A topographic database usually consists of many types of features representing the terrain. Many other datasets are not so complex or rich in their context, cadastral datasets, for example. The third objective was **to explore whether there is a need for this type of datasets rather than a need for other option: theme-base datasets**. The fourth main objective was **to investigate the need for data quality**. What do users require of quality and how might topographic base information satisfy this need? Are users aware of data quality and how it be presented?

Methodology

User requirements were studied based on the **literature review and desktop study** presented in Paper V. EuroGeographics' Expert Group on Quality made **a survey of data quality among NMCAs** (Jakobsson & Vauglin, 2000, 2001). The results of this survey were utilized in Paper III. The Finnish Council for Geographic Information made **a survey of user requirements in the development of NSDI** (Jakobsson & Takala, 2003). Finally, in the case study of using municipality data use for the creation of the Topographic Database, the author studied the user requirements in densely populated areas using **an interview method** (Chapter 7).

Topic III: Geographic Information Quality Management in Topographic Base Data

Objectives

While the National Mapping Agencies (NMAs) in Europe have recognized the importance of quality, issues like process management especially related to quality evaluation procedures, information management issues, such as data specification, selecting quality elements, reporting quality results and competence of personnel remain high priorities. The term *Geographic Information Quality Management* is used in this dissertation to cover all aspects of how an organization should manage its geographic information, including that relating to quality. While standardisation of geographic information has progressed, the key question for data producers is; how standards should be applied. At the same time, the development of SDIs are essentially important for many NMAs. The objective for the research **was to develop a model how to apply geographic information standards using the quality management approach in the framework of an SDI.**

Methodology

The description of data quality principles in the ISO 19100 standards are examined and compared to some approaches at the national mapping agencies (Paper III). A Geographic Information Quality Management model is then presented using ISO 19100 standards and other international standards (especially quality management, ISO 9000) (Paper VII). The presented model is currently applied in the EuroGeographics Quality Policy and Quality Implementation Plan for the Eurospec programme (Jakobsson, 2004, 2005c). Papers I and II present the scenarios for multisource topographic databases, where information management is essential and the data quality model is applicable. A set of requirements based on the model is then discussed at the national and European level (Paper II). **The research approach selected is the hypothetico-deductive method using case studies.**

Topic IV: European Cooperation in NMAs

Objectives

The need for change at the NMAs production paradigms was recognized already in the late 1990s (e.g. Morrison, 1997). In Europe, the NMAs have a long tradition of cooperation. First, NMAs were presented by CERCO (Comité Européen des Responsables de la Cartographie Officielle), which was founded in 1980. CERCO has the role of exchanging the best practices among of NMAs . In 1993, MEGRIN was founded for the production of European datasets. In 2000, CERCO and Megrin were merged to form EuroGeographics. The main objective of the association is to build the European Spatial Data Infrastructure (ESDI) together with other key players. The objective of this study was to **examine the differences between national mapping agencies in Europe and to investigate the possibility of utilizing the Basic Topographic Framework (BTF) model in the European context.**

Methodology

The author has had the privilege of participating in many European projects dealing with this issue. One of the most important forums has been the EuroGeographics' Expert Group on Quality, which was formed in 1997. The author has participated in this group from the beginning and has chaired it from 2001. The results of the investigations are presented in Papers III and VI. The GiMoDig (*Geospatial info-mobility service by real-time data integration and generalisation*) project during 2001-2004 was especially useful for demonstrating the usefulness of how standards could be applied in providing topographic data from several countries from a unified user-interface. Finally, the Eurospec programme in EuroGeographics has provided the platform to test the quality management principles in harmonization with the topographic dataset. Based on this experience, the author has made a case study of using the national BTF model in Paper I in the European context. The quality management principles in Paper VII have been utilized to develop the Quality Policy for the EuroGeographics and the Quality Implementation Plan (Jakobsson, 2004, 2005c). These documents will be utilized for the development of harmonized datasets among the NMCAs in future. **The research approach can be described as belonging in the qualitative research paradigm using a case study.**

1.4 Organization of the Dissertation

This dissertation consists of two parts. The first part of this dissertation consists of Chapters 1 to 9, while the second part contains papers describing the hypotheses, material and methods, results and discussion. The references for the Part I are given in the end of the dissertation.

Part I

In the introduction, the theoretical background to this dissertation is briefly described. In Chapter 2, the development of SDIs is explained in connection with the role of topographic databases. An historical review of the development of topographic mapping in Europe and especially in Finland is given. In Chapter 3, the development of standardization concentrating on data quality is described. Chapter 4, gives a review of research into quality management and data quality. In Chapter 5, interoperability and harmonization of geographic information is considered. In Chapter 6, papers and conclusions are summarised.

Chapter 7 introduces the main results from the research project that studied the possibility of using municipality data for the production of the Topographic Database. The results are published in the report "*On needs for harmonization and joint use of topographic information produced by the National Land Survey and municipalities*", which is published in Finnish in the research notes of the Finnish Geodetic Institute (Jakobsson & Huttunen, 2005). The author was responsible for the project and was the main author of the report, while Harri Huttunen was a research assistant responsible for making the practical work relate to the test materials and GI system used in the tests.

A summary of results from the Papers I-VII and the Chapter 7 is reported in Chapter 8. Finally, Chapter 9 gives a discussion and the main conclusions and recommendations for future research.

Part II

Paper I

Jakobsson, A. and L. Salo-Merta, 2001. Definition of a Basic Topographic Framework for National GI Policy – One Database for All Basic Topographic Data, In *Proceedings of the 20th International Cartographic Conference*, Beijing, China, Vol. 4, 2197-2205.[15]

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Paper II

Jakobsson, A., 2003b. Framework and Requirements for Management of Topographic Data in Europe. In *ScanGIS'2003 Proceedings of the 9th Scandinavian Research Conference on Geographical Information Science* , eds. K. Virrantaus and H. Tveite, Espoo, Finland, pp. 91-102, http://www.scangis.org/scangis2003/papers/.[16]

Paper III

Jakobsson, A. 2002. Data Quality and Quality Management – Examples of Quality Evaluation Procedures and Quality Management in European National mapping Agencies, In *Spatial Data Quality*, ed. Wenzhong Shi et al. London: Taylor & Francis, 313 p., pp. 216-229.[17]

Paper IV

Jakobsson, A., 2002b. The Topographic Database as an Integral Part of the Finnish National Spatial Infrastructure – Analysis of the Present Situation and Some Possibilities for the Future, In *Finnish Journal of the Surveying Sciences,* Vol. 20, No. 1-2,2002, pp. 92-107.[18]

Paper V

Jakobsson, A., 2003. User Requirements for Mobile Topographic Maps. Report of the GiMoDig project. 93 p., http://gimodig.fgi.fi/deliverables.php.[19]

The annexes of this paper are not reproduced in this dissertation.

Paper VI

Jakobsson, A. 2005b. European Reference Data Sets for European Spatial Data Infrastructure – State of the Art and Development of Common Specifications. In *Proceedings of the 22nd International Cartographic Conference*, A Coruna, Spain, Cd-Rom.[20]

Paper VII

Jakobsson, A. and J. Marttinen, 2003. Data Quality Management of Reference Data sets - Present Practice in European National Mapping Agencies and a Proposal for a New Approach. In *Proceeding of the 21st International Cartographic Conference,* Durban, South Africa, Cd-Rom.[21]

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In Paper I, the author developed the idea of BTF and the case study, while Leena Salo-Merta wrote the chapter on technical advances in spatial data management and assisted with the introduction. In Paper VII, the author developed the GIQM model for reference datasets and Jorma Marttinen provided the example of current practice in Finland.

Figure 1.4 represents contributions of the papers to the framework of the dissertation that was presented in Figure 1.1.

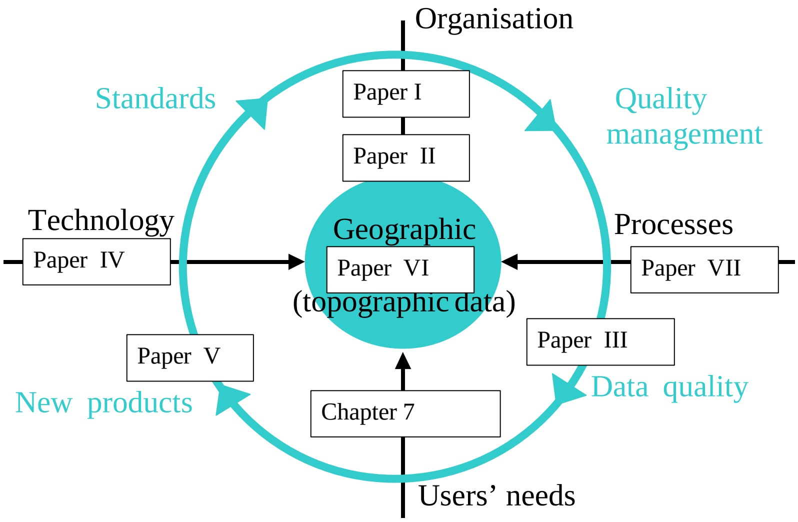

Figure 1.4 Contributions of the Papers I-VII and Chapter 7 to the framework of the dissertation

Chapter 2

Topographic Information and Spatial Data Infrastructures

2.1 Introduction

This chapter will give a review of the development of topographic databases from the information management perspective. The role of geographic information (GI) in the information society[22] is increasing; governments and people are more aware of the potential of the GI. However, one of the reasons why geographic information is not utilized or shared is the lack of information about it (metadata). A recent survey in the UK, points out that a major barrier to data sharing is a lack of awareness of the information held by other organizations. Information technology is providing tools for handling geographic information (Cabinet Office, 2005). The Internet is changing fundamentally, not only the way the geographic information will be utilized, but also how available information can be combined. The topographic mapping has already changed to topographic information production. The development of SDIs means change in the topographic information production concept. The topographic information will be departing from its mapping paradigm to be part of an SDI. The most value of topographic features or real-world features relates to their provision of a national framework to combine different types of information. The concept and theory of an SDI is explained with review of the developments in Europe and Finland. The discussion of change in the topographic mapping paradigm was started in the Cambridge Conference for National Mapping Organizations (NMOs) in 1995. This conference is a descendant of a conference held every four years since 1928

[22] An information society is one in which the creation, distribution and manipulation of information is becoming a significant economic and cultural activity (source: Wikipedia http://en.wikipedia.org accessed May 4th,2006.)

for senior staff in NMOs in the Commonwealth. In 1995, the tradition was changed and invitations were issued to all known NMOs, which resulted in attendances from 78 countries. The results of the discussion and presentations were published in the book "*Framework for the World*" edited by David Rhind (1997). It explains the change in the mapping paradigm to provide the framework, which is now known as an SDI.

2.2 The Role of Topographic Information in the Information Economy

Information is one of the economic resources besides land, labour and capital. In the information economy the importance of information has increased because it possesses number of characteristics that make it very different from other economic resources. The information economy is an economy based on the exchange of knowledge information and services rather than physical goods and services[23].

Ian Masser (1998) has considered the role of geographic information in the information economy. He cites the works of Goddard (1989) and Cleveland (1985) when discussing the characteristics of information. The unique qualities of information according to Cleveland (Masser, 1998) are: "

1. Information is expandable, it increases with use.
2. Information is compressible, able to be summarised, integrated, etc.
3. Information can substitute for other resources, e.g. replacing physical facilities.
4. Information is transportable virtually instantaneously.
5. Information is diffusive, tending to leak from the straightjacket [sic] of secrecy and control and more it leaks, the more there is.
6. Information is sharable, not exchangeable, it can be given away and retained at the same time."

According to Masser, geographic information can be considered from four different standpoints: as a resource, a commodity, an asset or as infrastructure. Here topographic information is discussed from these viewpoints.

[23] http://www.agimo.gov.au/publications/2001/11/ar00-01/glossary (accessed May 4th, 2006).

Topographic Information as a Resource

Masser considers the six unique characteristics of information from the resource standpoint. Cleveland (1982) draws attention to the synergetic qualities of information: “The more we have, the more we use and the more useful it becomes.” Masser cites David Rhind (1992), who has concluded that “all GIS experience thus far strongly suggest that the ultimate value is heavily dependent on the association of one dataset with one or more others; thus in the EEC’s CORINE (and perhaps every environmental) project, the bulk of the success and value came from linking datasets together.” This observation has been noted also in the context of topographic information. In the user requirement study of the GiMoDig project (Jakobsson, 2003) topographic information was considered useful for many services but only if topographic information when linked to other information relevant to the application. Rhind (1992) also notes that topographic information is the basis for an SDI: “Almost by definition, the spatial framework provided by topographic data is embedded in other datasets (or these are plotted in relation to it, or both): without this data linkage, almost no other geographical data could be analysed spatially or displayed”.

Geographic information is compressible. It can be used to make summaries, and generalized products. One of many good examples of this is the Google Earth[24] service that uses satellite information and road data. First the user will have an image of the Globe and, by zooming in, the information comes more detailed. In the context of topographic information, there is a clear need for managing several different user groups. European users do not require detailed topographic information, but at the same time there is a need for keeping the quality at the most detailed level.

Geographic information is substitutable. In the context of information, this means that it can save labour, capital or physical materials. In geographic information, this characteristic is quite evident. The main reason for using geographic information is to save the labour and capital of many users. Topographic information has a great potential in the information economy; however, this potential is not fully exploited at the moment. A good example of this is that even the government it self is not using the topographic information because of a lack of knowledge and a lack of funding. In Great Britain, the OS has dramatically increased the government usage by introducing the Pan Government Agreement that enables easy usage of the OS data. The market size of GI in the GB has been estimated to be around 320 million euros in 2006, but the impact of the OS has in the GDP is around 8% (Lawrence, 2005).

[24] http://earth.google.com/

Geographic information is transportable. The Internet has revolutionized the capability to exchange information between people. A great potential lies in the open geospatial standards like GML and services like WMS and WFS, which could provide the users the opportunity to gain easy access to the various datasets. In the case of topographic information, the main challenge lies with the NMAs. Some already provide information over the Internet. A good example is the National Land Survey of Finland, which has provided its topographic base information in the raster format on the Internet to the citizens since 1996 through its Mapsite service. This was the first national service providing the extend of a whole country at that time. Figure 2.1 illustrates the second version of the Mapsite launched in 2005.

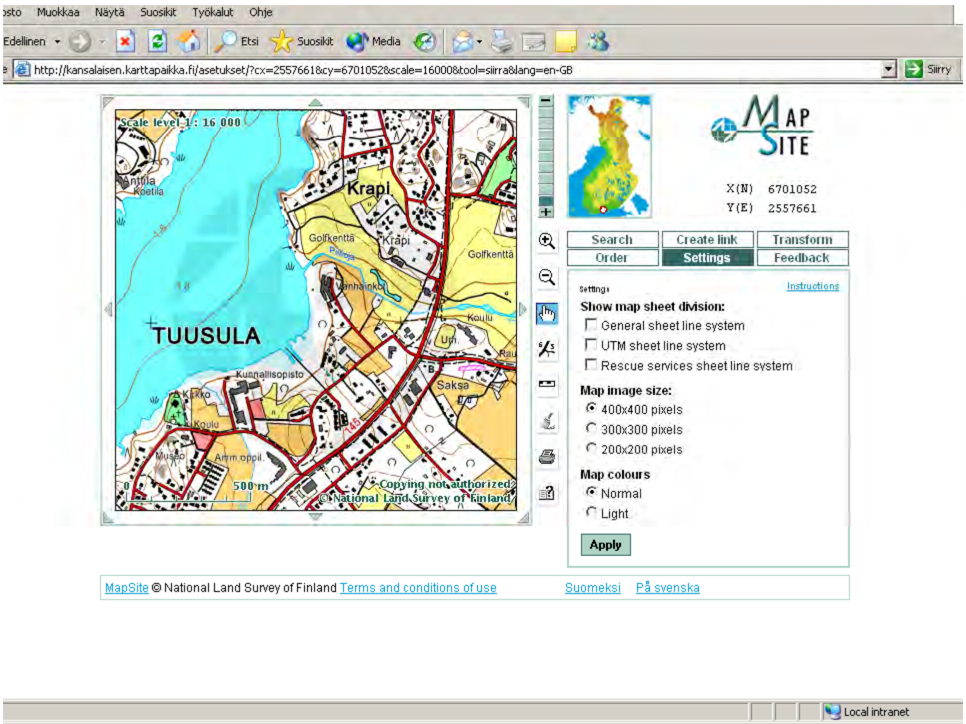

Figure 2.1 Mapsite service in the Internet from the NLS[25]

[25] The map in the figure is derived from the Topographic Database. The most detail scale in the free service is 1:16 000 and the image size is limited to maximum of 400 x 400 pixels.

Geographic information is diffusive and shareable. The IT technology and the Internet are the mechanisms that are providing information to the people. The fact that the Internet has no central control, has been a challenge to many information providers that would like to charge for the use of their products. In Europe, there has been a debate over the copyright and free of charge data from the public authorities.

Topographic Information as a Commodity

The basic concept in the information economy is that information can be bought and sold like any other commodity. On the other hand the unique characteristics of information mean that ownership of information is problematic. The debate over the public administration information is still ongoing. The main argument on behalf of free public data is that it would increase the usage of datasets and private enterprises that developed services based on the datasets. The value of information is heavily dependent on its usage. One of the characteristics of the geographic information is that it loses value over time. The more recent the data are, the more valuable they are to the users, except for historical datasets. Arguments against of the free public datasets, are concentrated on the fact that more and more geographic datasets are maintained on the basis of the income from sales of the datasets. Currently, OGC is looking to create a Geospatial Digital Rights Management (GeoDRM) standard for geospatial services. This would improve the geospatial marketplace (FGDC, GeoData Alliance and OCG, 2006).

Topographic Information as an Asset

This aspect highlights the fact that geographic information often has a value to the national interest. The Mapsite service discussed earlier was selected in 2002 from among the most valued web brands in Finland (Talentum, 2002). In the case of topographic mapping, this has been the case since the beginning of topographic mapping. The concept of custodianship of public information is also important in this context. In the 1990s the Australian Land Information Council considered that "all data collected by a state government agency forms part of state's corporate data resource. Individual agencies involved in the collection and management of such land related data are viewed as custodians of that data. They don't own the data they collect but are custodians of it on behalf of the state " (ALIC, 1990). The responsibilities of the custodian were also defined: "These are that the custodian should be responsible for principles and procedures for the accuracy (integrity), currency (timeliness), data storage (definition and structure) and security of a data item or data collection. In so doing, the custodian must consult with, and take account of, the needs of users other than itself." (ALIC, 1990). This emphasises the need of a national geographic information strategies or (SDIs) in which the roles of the different agencies should be defined. This has led to a concept of core datasets or reference datasets.

Topographic Information as an Infrastructure

The idea of geographic information as an infrastructure such as transport networks or schools, has led to the development of SDIs. The term *infrastructure* is defined as *basic facilities that are required to meet the needs of society with respect to road networks etc.* The concept of a spatial data infrastructure for the US nation was described by the Mapping Sciences Committee of the National Academy of Sciences in 1993 "to cover the materials, technology, and people necessary to acquire, process, store and distribute such information to meet a wide variety of needs" (National Research Council, 1993). This definition has now generally been accepted in various national spatial infrastructures. The development of such an infrastructure has led to the need of describing the datasets that are belonging to it. The concept of core or reference datasets has been adopted in many SDIs. In the INSPIRE (EC, 2004) process, the core datasets were defined as themes of data. Those themes were divided to three different categories of importance. The first category included co-ordinate reference systems, geographical grid systems, geographical names, administrative units, transport networks, hydrography and protected sites. The second category included elevation, identifiers of properties, cadastral parcels, land cover and orthoimagery. The third category included statistical units, buildings, soil, geology, land use, human health and safety, government service and environmental monitoring facilities, production and industrial facilities, agricultural and aquaculture facilities, population distribution – demography, area management/restriction/regulation zones & reporting units, natural risk zone, atmospheric conditions, meteorological geographical features, sea regions, bio-geographical regions, habitats and biotopes and species distribution. Most of the topographic base information belongs to categories 1 and 2. Building information is listed in category 3.

2.3 Topographic Base Information

2.3.1 Development of National Topographic Mapping

Topographic mapping based on scientific measurements has its roots in Germany, where triangulation was used to make a map of Bavaria in 1554-61. However, it took nearly 200 years to start mapping whole countries using scientific measurements. In France, there was a need to build roads, bridges, canals and dams, but there was no map that would cover the whole country. The topographic mapping was initiated in 1750 and it was completed in 1789 at a scale of 1:86

000. The concept of topographic mapping spread to other countries; national mapping was started in England in 1783, when mapping was based at a scale of one inch to the mile (1:63 600). The Ordnance Survey bought Jesse Ramsden's theodolite in 1791, which is now accepted as the beginning of the organization (Owen and Pilbeam, 1992). Even at the beginning of the 19th Century the general public was not satisfied with maps. In 1853, the international statistical conference decided that the basic scale for national mapping should be 1:2500 and 1:10 000 for some special purposes.

The following paragraphs discuss the beginning of topographic mapping from the Finnish point of view. Finland belonged to Sweden until 1809, although the borders changed many times between Sweden and Russia during the period. After 1809, Finland was a grand duchy of Russia until independency in 1917. Both Sweden and Russia spend a lot of effort in mapping of Finland, because it was a border area.

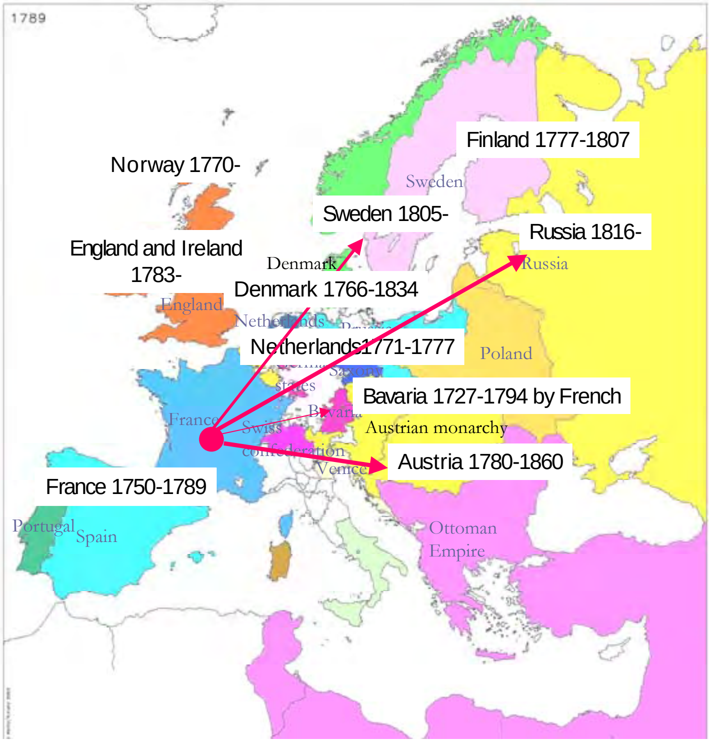

Figure 2.2 Beginning of national topographic mapping in Europe (Basemap represents political boundaries of 1789 modified from Kunz [2004][26])

Sweden

Figure 2.2 represents how topographic mapping spread to different European countries. In Sweden the first topographic mapping was carried out in Swedish Pomerania during the Seven Years War (1756-63) and in Finland in the border areas (Helmfrid, 1990). Some of the personnel from the Finnish brigade moved to Sweden and formed the core of the Swedish field survey corps (svenska fältmätningskåren) (Gustafsson, 1926, Brown, 1949). The corps was established in 1805 based on the idea of Major General G.W. af Tibell, who had worked with the map of Italy for Napoleon I (Postnikov, 1993, Brown, 1949). The work discontinued already in 1807, but was continued by the field measurement brigade (fältmätningsbrigaden). The mapping was carried out in 1:20 000, and later in 1:100 000 in order to accelerate the production. In 1829, the scale of 1:50 000

[26] IEG-Maps Server for digital historical maps, http:// www.ieg-maps.uni-mainz.de (accessed, May 5th, 2006).

was selected, but it was not until 1845 that the scale finally was taken into use in the Southern and Middle Sweden. In 1821, the brigade was reorganised into the Topographic Corps (topografiska corpsen).

The making of a general topographic map in 1:100 000 was started in 1815. The content was secret and it was not until 1857 that the king allowed it to be distributed to the general public (Brown, 1949). At that time, the content was partly outdated. In 1833, the mapping by a private organization was transferred to the topographic service (Peterson-Berger, 1928). In 1859, the Office of the Economic Atlas in the county of Norrbotten was established. This office produced economic maps at a scale of 1:100 000 in some other counties also. In other counties, the scale was 1:50 000 and in small areas 1:20 000. The idea was to get information about area, characteristics of land and division from the economic viewpoint (Peterson-Berger, 1928). In 1869, this office was placed under the National Land Survey of Sweden, to be transferred again under the Topographic Corps, now a department of the General Staff, in 1873. In 1912, the Economic and Topographic Offices were combined as the Geographical Survey Office of Sweden within the Ministry of Agriculture (Helmfried, 1990). Gustafsson, who made a benchmarking trip to Scandinavian and Germany in 1924, describes in great detail the mapping process in his report (1926). Field measurements were made mainly by soldiers. In 1974, the Geographical Survey Office was merged with the National Land Survey of Sweden.

Russia

In Russia, Peter the Great commissioned the topographic mapping in 1720 by 30 young men from the naval academy, who were sent to the provinces to make measurements. Early measurement work was conducted by Ivan Kirilov, who later published general topographic maps near the Swedish border (1724 Swedish-Russian Frontier, 1726 Vyborg, 1727 Keksholm[27]). Bagrow (1975) gives a detailed description of Kirilov’s efforts in cartography. In 1726, Catherine II ordered all surveyed maps to be moved to the Academy of Sciences for correcting and revision. This was the time when the French geographers arrived from Paris and took over the lead. Peter the Great had visited the French Royal Academy of Sciences and asked Joseph Desilie to come to Russia to establish an astronomic school. In 1739, the Deslies (Joseph and his brother Louis) organized a special Geographical Department within the Academy of Sciences. Peter the Great laid the foundation for a military mapping of Russia by establishing the post of Quartermaster-General, whose duty was to collect information for the

[27] Vyborg (Viipuri, in Finnish) and Keksholm (Käkisalmi, in Finnish) was annexed by Russia in the Treaty of Uusikaupunki 1721

War College. In 1763, Catherine II established the General Staff. The French School of Military Topography still had a great influence in the Russian Military Topographic Service. Prior to the war of 1812, Prince P.M. Volkonsky was sent to France to learn surveying in the French General Staff. Later four volumes of the Napoleon's army manuals were translated and published in 1806-1809 (Postinikov, 1993). In 1816, the first systematic scientific triangulation was begun in Vilnius, Lithuania under the direction of Professor W.G. Struve. He then continued with a survey of Livonia[28], part of the present day Latvia and Estonia. This work also initiated the Struve Geodetic Arc[29], which now is accepted in the UNESCO World Heritage List. The first map that was published by the Topographic Section of the General Staff was of European Russia at the scale 1:126 000 with 792 map sheets including Poland. The original field measurements were made at a scale of 1:21 000 and 1:42 000. Russian topographic surveys had a great influence in Europe. Russia controlled a vast extent of European territory and Russian topographers were famous for the accuracy of surveys. In 1835, cooperation was started with Sweden in Åland to connect the Swedish triangles with Russia (Brown, 1949).

Finland

In 1603, King Charles IX, who reigned 1600-1611, commissioned mathematician Andreas Bureus, also Anders Bure, to construct a general map of Sweden based on geographic measurements. He published a first map from Lapland in 1611, which was the first engraved map in Sweden. The map of Sweden was completed in 1626; this was the first map in Sweden based on measurements. It dominated all the maps of Sweden for over 60 years and it was copied in several atlases and maps abroad (Brown, 1949, Petterson-Berger, 1928). The first surveyor was assigned to Finland in 1633, which is the year that land surveying in Finland is considered to start. Based on the regulation of surveying, land surveyors compiled geographic maps based on surveys from 1641; in 1650 there were measurements carried out throughout all of Finland (Gustafsson, 1933).

The topographic mapping in Finland was commenced for military reasons. The National Land Survey of Finland was not able to fulfil the demand, so the military was given the responsibility. King Gustav III commissioned the first military surveys in 1777 by the Finnish Recognition Brigade. The model came from the map of Pomerania (1761-1762). The work was based on the maps made in land surveying and reduced to a scale of 1:20 000. The instruments were the plane table, diopter and surveying chain. Maps were drawn at a scale of 1:40 000, and

[28] http://en.wikipedia.org/wiki/Livonia (accessed, May 4th, 2006).
[29] http://www.maanmittauslaitos.fi/Control_Points/Struve_Geodetic_Arc (accessed, May 4th, 2006).

then generalized to 1:60 000, 1:320 000 and 1:640 000 (see Figure 2.3). Road maps were drawn at a scale of 1:20 000. The brigade was dissolved in 1805 (Gustafsson, 1932).

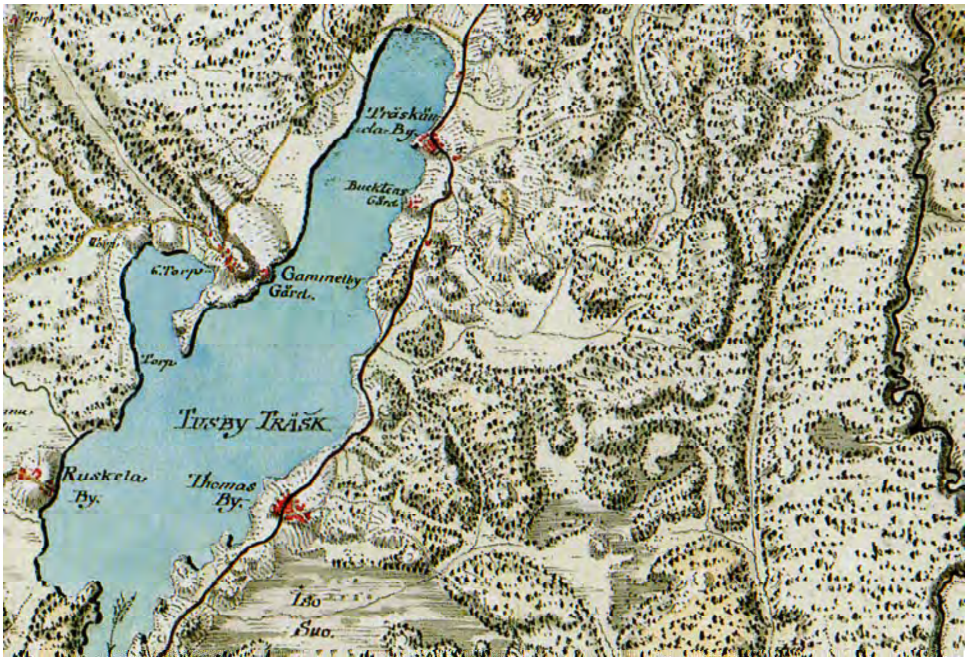

Figure 2.3 Recognization map from Tuusula in the Kings Atlas of Finland (Scanned from Alanen & Kepsu, 1989)

Russia had commissioned a survey at a scale of 1:42 000 in “Old Finland”, i.e. areas handed over to Russia in the peace treaties of Uusikaupunki and Turku, in 1798-1804 (Gustafsson, 1932, Postnikov, 1993). In 1809, when the whole of Finland was handed over to Russia, the military began surveying of the country. In 1870, the surveying based on an astronomical-geodetic base using a plane table and alidade at a scale 1:21 000 was initiated. The whole of Southern Finland was mapped by 1907, consisting of 471 sheets covering 57,000 km^2. These sheets were downsized to scale 1:42 000 (see Figure 2.4) using a camera and printed with one colour using lithography (Gustafsson, 1932; Haataja, 1929). A more detailed presentation of Russian topographic mapping has been described by Juntunen (1993). Postinkov (1993) denotes that surveys and mappings were performed as part of the mutual influence between the Swedish-Finnish and

Russian schools of field cartography. The main sources were land-surveying maps.

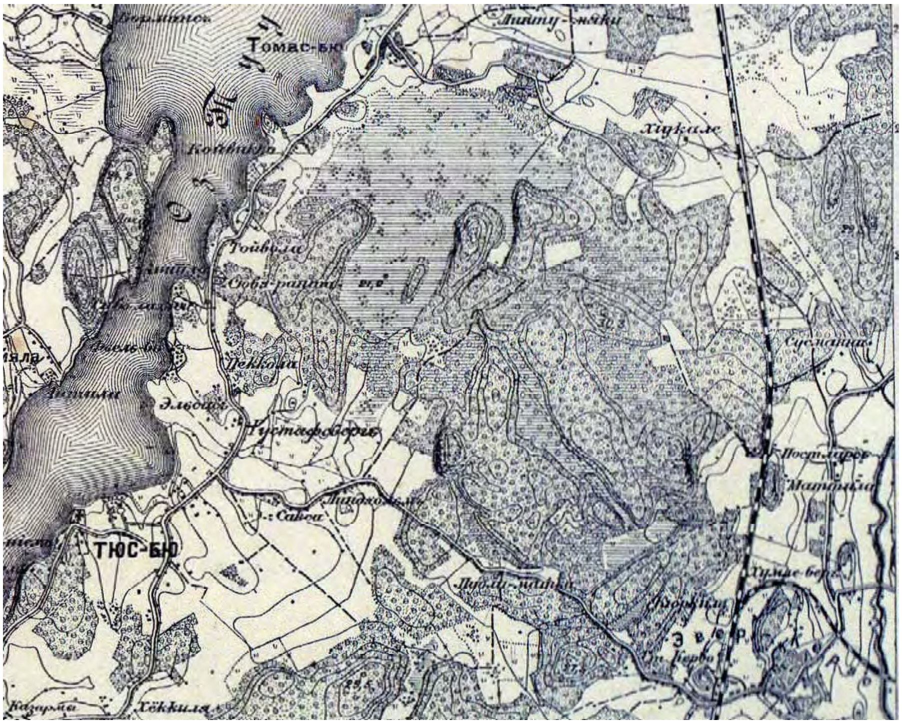

Figure 2.4 Russian topographic map 1:42 000 from Tuusula[30] (Original: the NLS)

National Land Survey of Finland did not play a major role in topographic mapping in the 19th Century. Land surveying was organized using a model from Sweden. In 1840, the Senate in Finland requested the Head Survey Office (Päämaanmittauskonttori) to make a proposal for making geographical maps in Finland. This request was based on the suggestion from the Russian army (Jaakkola, 1983). In 1872, the first general map over Finland was completed by the National Land Survey at a scale of 1:400 000 based on an astronomical-geodetic base consisting of 30 sheets. The source material was jurisdictional maps 1:100 000 that were downsized. The update process was quite laborious, only 2500 km^2 were updated annually, so the revision cycle for the whole country would have been 150 years (Gustafsson, 1933b).

[30] Map sheet no VII-29 1871

The land surveying maps had been a basis for making the parish maps 1:20 000.[31] This work was reinitialised in 1899 based on a triangulated network. Starting in 1916, the projection of polyhedron was used. Annually about 6000 km^2 was compiled covering approximately two map sheets of jurisdictional map 1:100 000. The parish maps were used to compile the jurisdictional maps (NLS, 1923). In 1913, the name of the jurisdictional map was changed to economic map, based on the model from Sweden. This map was printed in colour and it had a great importance because it covered large areas especially in Eastern Finland and Lapland, where there were no other maps available at larger scales (Kajamaa, 1966).

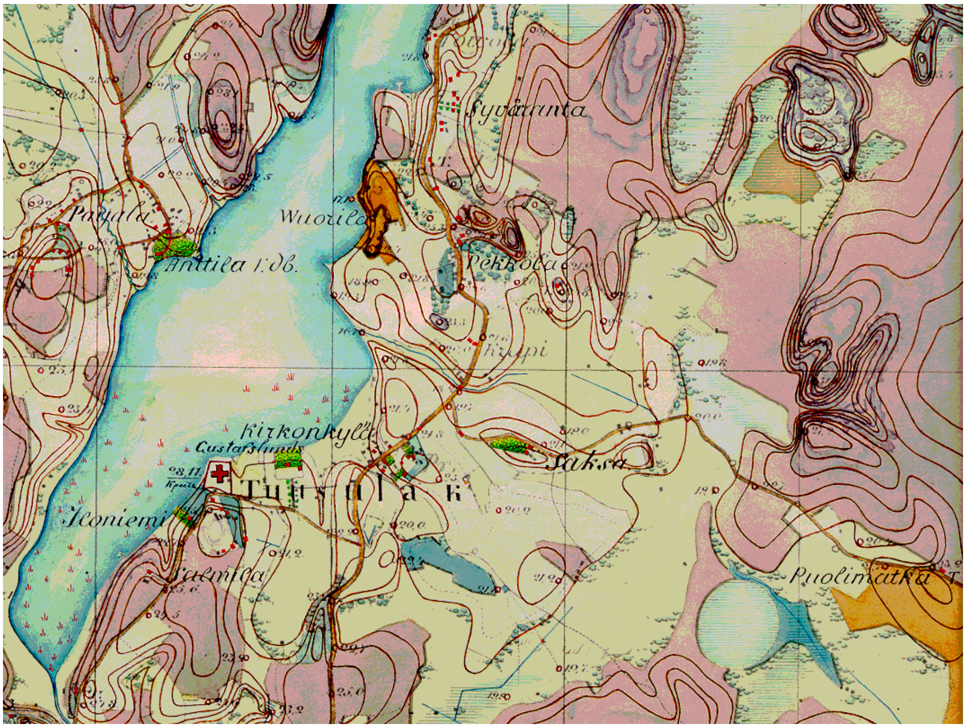

Figure 2.5 Hand-coloured map 1:21 000 with Finnish place names based on Russian topographic map (original: the NLS)

[31] Parish maps were compled by constructing a framework of degrees on tracing cloth, on which all the fixed points were drawn. All available material was then fitted in with the aid of these fixed points. Then, 12-15 copies were constructed from the original and some of them were hand-coloured based on orders of customers (Haataja and Renqvist, 1929). For a production guideline see NLS (1928).

At the beginning of independency, Finland had topographic maps at a scale 1:21 000 and 1:42 000 made by Russian topographers. These maps were reprinted with Finnish place names 1:42 000 (See Figure 2.6).

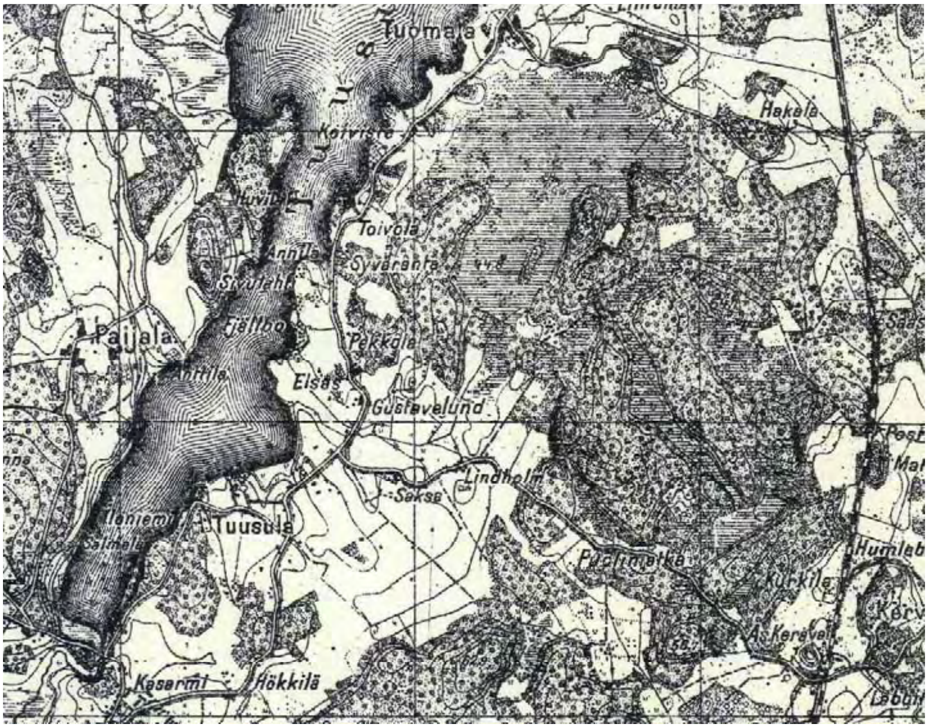

Figure 2.6 Printed topographic map 1:42 000 with Finnish place names[32] (original: the NLS)

In Southern Finland, Finnish topographic maps with a scale 1:50 000 were compiled using Russian topographic maps 1:42 000. The work was initiated by the military mapping organization under the General Staff and it was continued by the National Land Survey (NLS, 1923, Gustafsson, 1932). A debate about organizing the mapping activities in Finland was commenced after the independency. In 1919, the National Land Survey was given the task of organizing topographic mapping. It was realized, when combining the civilian and military requirements, it would be more economical to produce topographic maps. The National Land Survey sent its geographers and engineers abroad to gain knowledge of topographic mapping. Again Germany and France were used as a benchmark. Visits

[32] Map sheet no.1320

were made to Scandinavia, Bavaria, Prussia, France and Potsdam (Gustafsson, 1926; Rehn, 1928). In 1919, Onni Lehtinen studied mapping in Prussia for one year, Rainesalo studied the process in France in 1921 also one year, Ilmari Laukkanen was partly in Prussia and partly in Bavaria, while Jäämaa visited the geodetic institute in Potsdam for six months in 1922. Rafael E. Rehn visited France again in 1926 (NLS, 1923; Rehn, 1928). Based on these benchmarking visits, a committee was nominated that made a proposal in 1923 for the organization of national mapping in Finland (NLS, 1923). The committee proposed that the parish map should be renewed, giving up hand colouring and replacing it with symbols. For topographic maps, they suggested continuing the 1:50 000 maps based on a request from the army (see Figure 2.7). For the larger scale, they proposed 1:20 000 based on the European examples instead of 1:21 000 (see Figures 2.8, 2.10 and 2.11). The parish map already had been made at a scale of 1:20 000 (see Figure 2.9). In Northern Finland, the suggested scales were 1:50 000 and 1:100 000. The method recognition meant updating the Russian topographic maps.

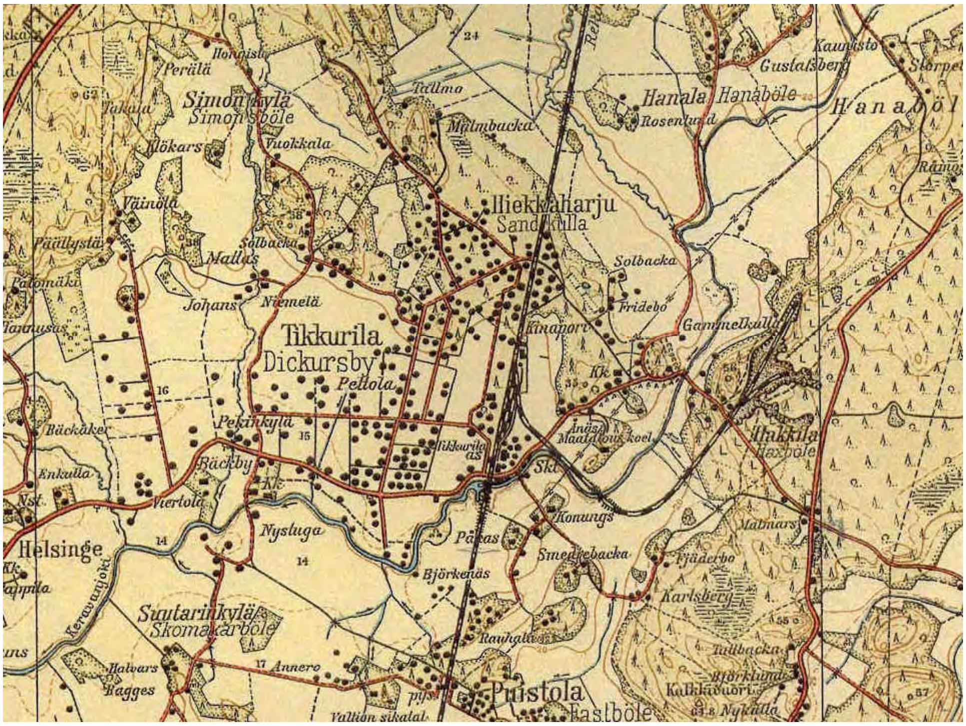

Figure 2.7 Topographic map 1:50 000 from 1937 (Original: the NLS)

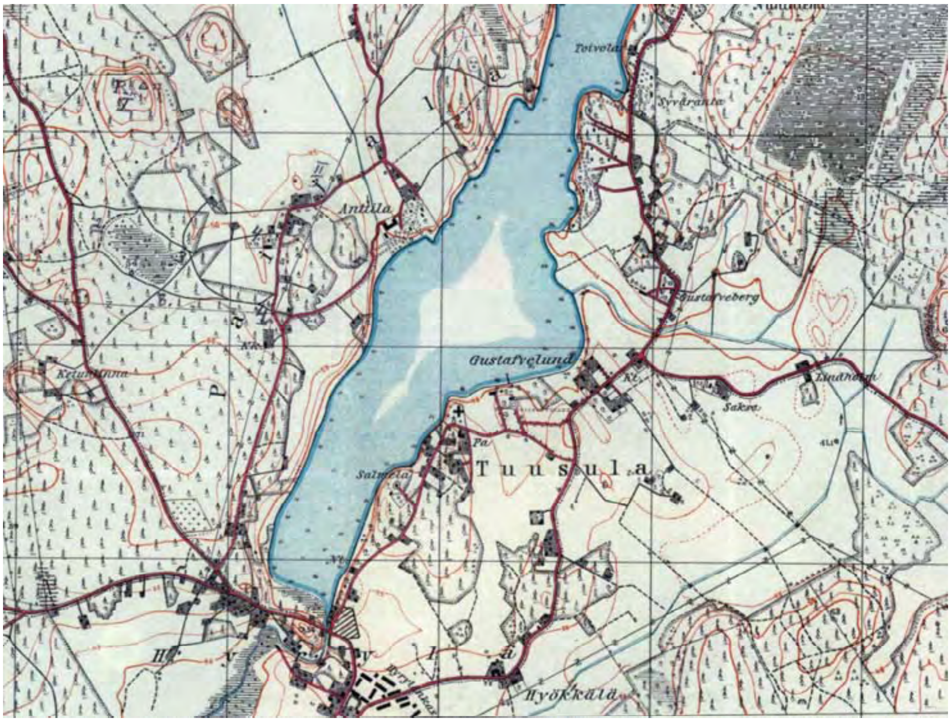

Figure 2.8 Topographic map 1:20 000 from 1928 (Original: the NLS)

In 1939, Mauno Kajamaa made a proposal to combine the parish and topographic map (Kajamaa, 1949). A committee was formed to investigate the proposal and to make further recommendations. The committee made a proposal on renewing the map sheet system, which was approved in 1940. In 1943, Mauno Kajamaa suggested in his doctoral theses (Kajamaa, 1943) the idea of a basic map and made several suggestions on the production process. The second world war interrupted the work of the committee, but, just after the war in 1945, a new committee with two members was formed. The committee made a suggestion on the rationalization of national mapping (Kajamaa & Rehn, 1947).

After a debate, the Department of National Mapping commissioned a new committee to prepare guidance for a basic map. The documentation was approved in 1948 (NLS, 1948, 1948b) and production of the map was begun. At the same time in Sweden, a different solution was adopted. The economic map 1:10 000 had an aerial photograph in the background, and a topographic map was made at a scale of 1:50 000. The topographic map did not represent cadastral boundaries because of the smaller scale.

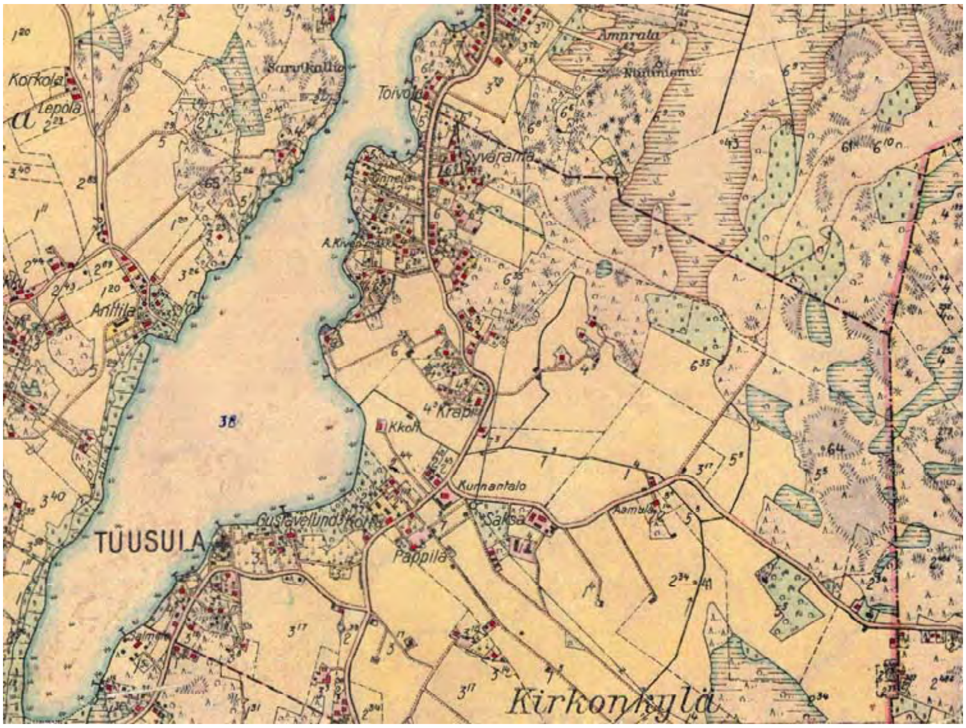

Figure 2.9 A parish map 1:20 000 from 1933 (Original: the NLS)

The basic map 1:20 000 was a revolutionary product (see Figures 2.12, 2.13, 2.14 and 2.15). It represented topographic features with cadastral boundaries having a register number. The production process was based on mapping in the terrain using aerial photographs. This was also a foundation for the cadastral register map. At first, three different versions of a printed map were planned. A economic version without contour lines, topographic version without cadastral boundaries and a combined version. This concept was soon abandoned (Lyytikäinen, 1983).

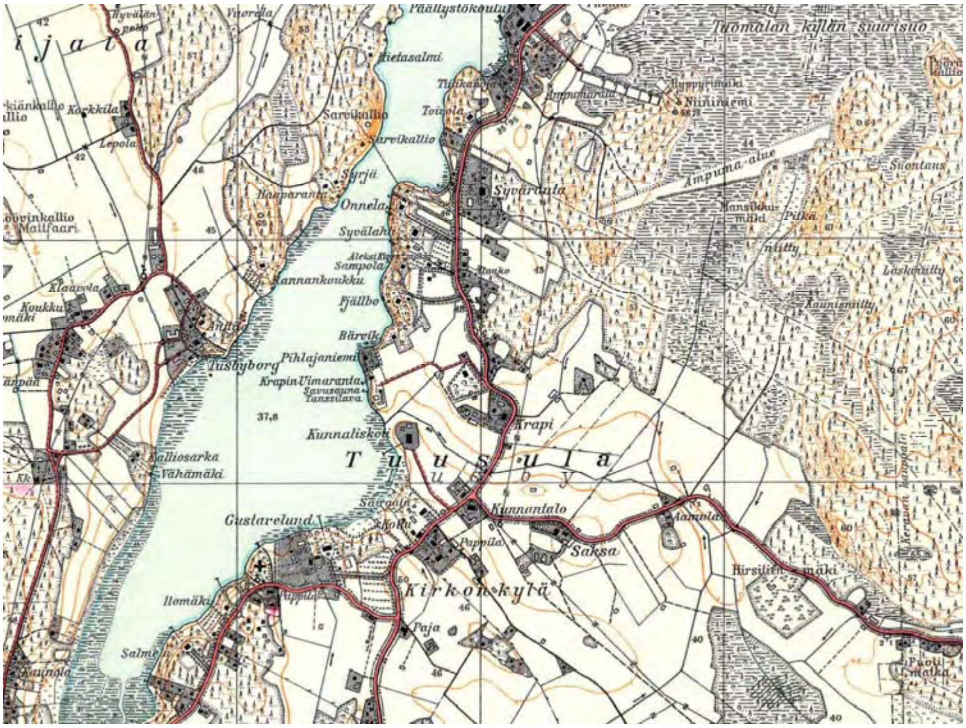

Figure 2.10 Topographic map 1:20 000 from 1937 (Original: the NLS)

In the 1970s, there was a suggestion to construct more accurate maps at a scale of 1:4 000 or 1:5 000 (NLS, 1977). It was suggested to divide the production process between several organizations. The National Land Survey should have collected benchmarks, real estate boundaries, roads, buildings and water framework. Some other features should have been collected by municipalities, for example contour lines and fields. The main production duties should have divided between the NLS, municipalities and the Finnish Road Administration. Updating was suggested to be continuous for real estate boundaries, roads and buildings. Alternatively, the committee suggested that the map could be constructed of an aerial photograph. In 1979, the NLS began the production of the ground map, which consisted of cadastral boundaries on the orthorectified photograph at a scale of 1:5 000.

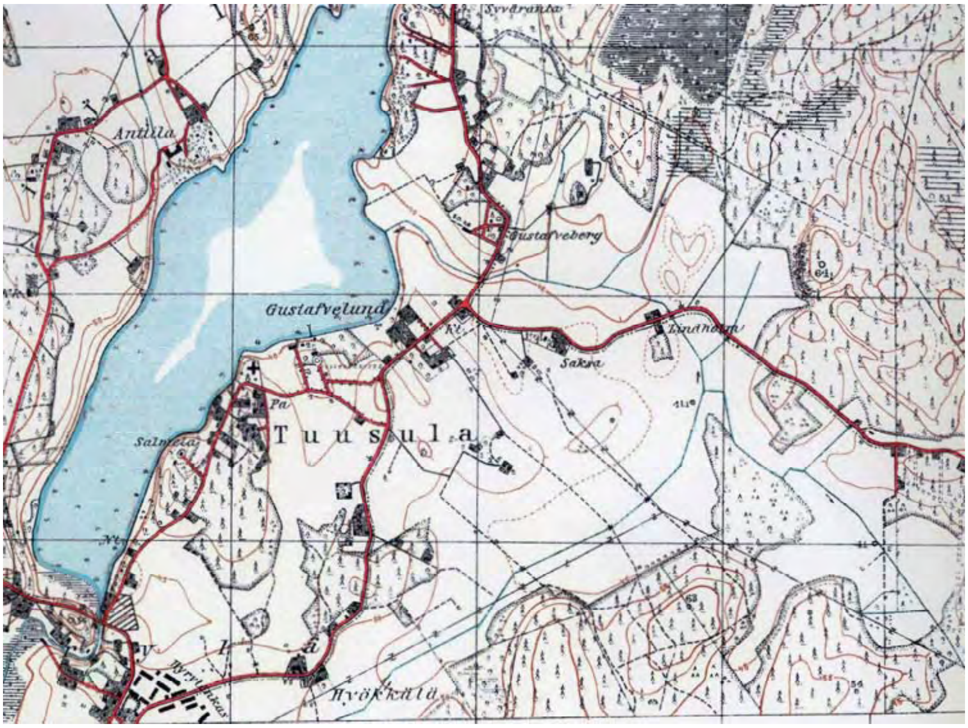

Figure 2.11 Topographic map 1:20 000 from 1941 (Original: the NLS)

The first mapping round of the basic map was completed in 1975. This meant that the mapping of Finland in this medium scale lasted about 25 years. The updating process had been initiated in 1957. The ground map[33] production, which was started in 1979, can be regarded as an improvement of quality in the basic map production. The accuracy level was more suitable for populated areas. In the end of 1990s, the graphical production of the ground map elements was dropped and the process was merged with the topographic database production.

In 1987, the advisory committee for national mapping organized a seminar on the future of national mapping. The updating process was foreseen as being based on the decentralized model and the joint-use of geographic information would be increased (Rainio, 1988). In the seminar, Professor Kirsi Makkonen described the future map: "The map will meet the user requirements actively and with intelligence. Based on the user's answers to questions, required information will be searched from different databases and information will be processed to meet the

[33] The term ground map (pohjakartta in Finnish) is used to separate this map for municipality basemaps

user requirement and a printout will be produced for the user." (Makkonen, 1988).

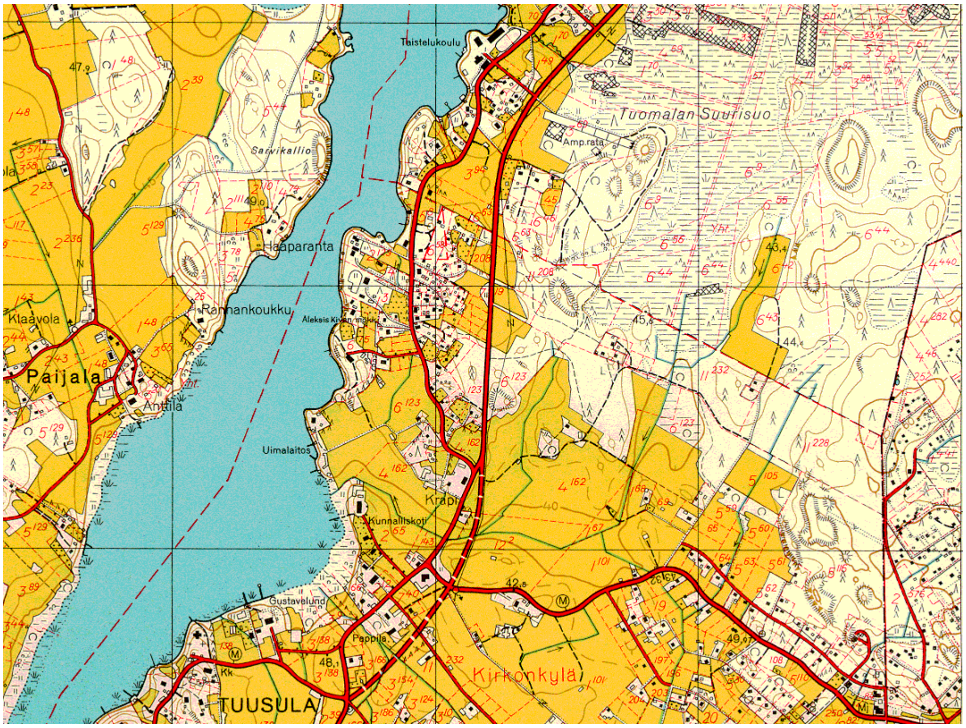

Figure 2.12 A basic map 1:20 000 from 1958 (Original: the NLS)

In 1987, the NLS published a plan for national mapping 1987-2000 known as "*Kartta2000*" (Map2000). According to the plan, production processes would have been transformed to digital, rationalizing some products and dividing production duties. The goal was to start producing the ground and basic map in one process starting in 1989. The printing elements of the basic map were planned to be digitises, including contour lines, fields, waters and roads, during the period of 1988-1992. Product rationalization included a new topographic map of 1:50 000 to replace maps with a scale of 1:50 000 and 1:100 000. Existing materials and remote sensing was planned to be utilized as sources for the new topographic map. Joint use of geographic information was foreseen to diminish duplication of information collection.

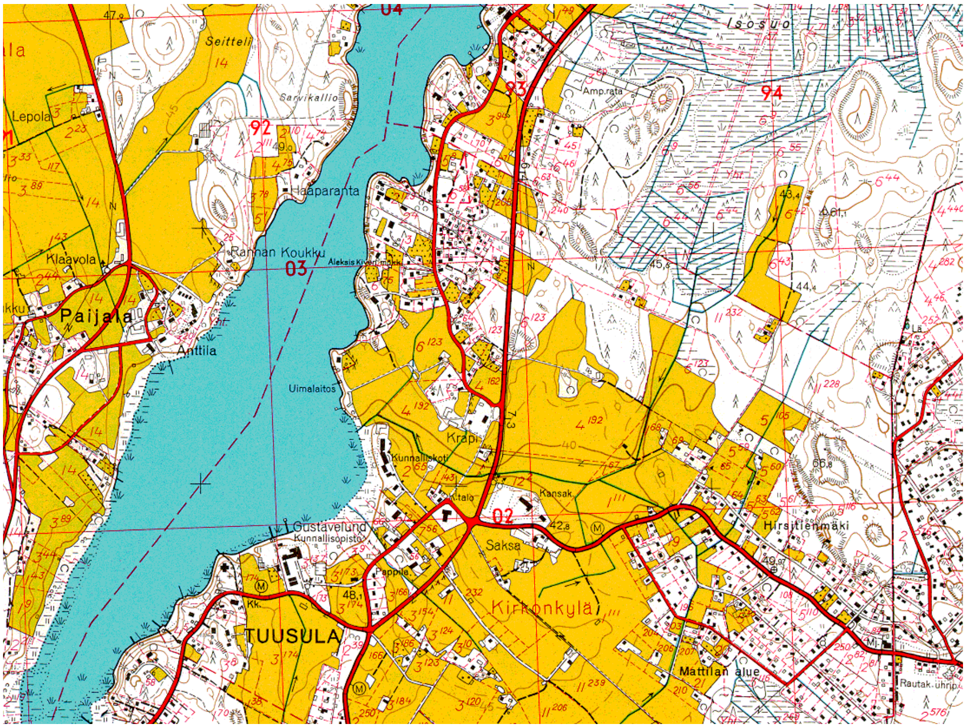

Figure 2.13 A basic map 1:20 000 from 1969 (Original: the NLS)

Although the plan was never actually implemented, some of the elements have been realised surprisingly well. The joint production of the ground map 1:5 000 and basic map 1:20 000 was never realised before 1992, but the principle to use the ground maps both in the basic map and cadastral map was realised. The plan suggested prioritising of mapping based on three classes. In Class I, comprising of areas with high land use, the mapping scale was set to 1:5 000. About 15,000 km^2 would be remapped and most of the areas would have been updated using the existing basic map (about 150,000 km^2). In Class II, comprising forest areas, the scale was set to 1:10 000. Minor parts of the area in Class II (about 15,000 km^2) would have been remapped, while most of the area would have been updated (about 175,000 km^2). Class III comprised Lapland, where topographic map 1:20 000 would have been updated. Graphical map was perceived the end product and goal for the production. Digital production was based on the idea of digitising cartographic elements. The production of 1:50 000 was started based on the plan, but this was already changed in 1995 after the introduction of the Topographic Database. The joint-use of geographic information was not realized. The digital map automation had led to development of an in-house GIS system “Fingis” (also Maagis) in the 1980s, which was used for the digitising of graphical elements. This development was ended in 1997, when the development of new production system for the Topographic Database was initiated.

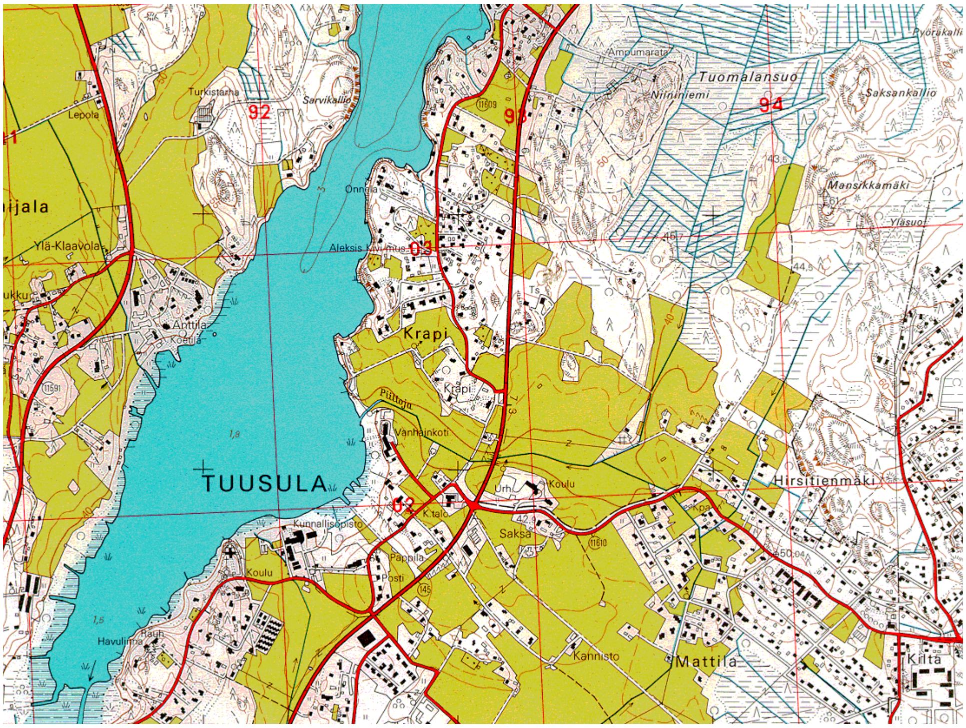

Figure 2.14 A basic map 1:20 000 from 1978 (Original: the NLS)

The development of a digital basic map was begun at the beginning of 1990s. After some investigations, Matti Jaakkola, a surveyor counsellor, nominated a working group to develop a digital basic map. The working group developed a feature catalogue for the Topographic Database, quality model, presentation model and product model. At first the target was to produce a basic map using computers, but it was soon realized that it included the creation of a topographic database and its production process. The term “Topographic Database” was approved in 1992. The quality model of the Topographic Database (NLS, 1995) was completed in 1993 describing the terminology, quality requirements and quality assurance and control methods. The feature catalogue was published in 1993 after circulation of the proposal to 40 organizations and some 46 local organizations for comments. The production started in 1992 and it was completed in 2001 (see Figure 2.16). Now the production process was based on two accuracy levels. At Level A, the production was based on digital photogrammetry using aerial photographs in 1:31 000 or 1:16 000. The process included field checking and correction in the workstation after that. The database was still based on map sheets in 1:10 000. The logical consistency between the bordering maps was checked, but there were still many limitations in the data model. At Level B, the old basic map was digitised manually with a digitising table. This process included a field check also.

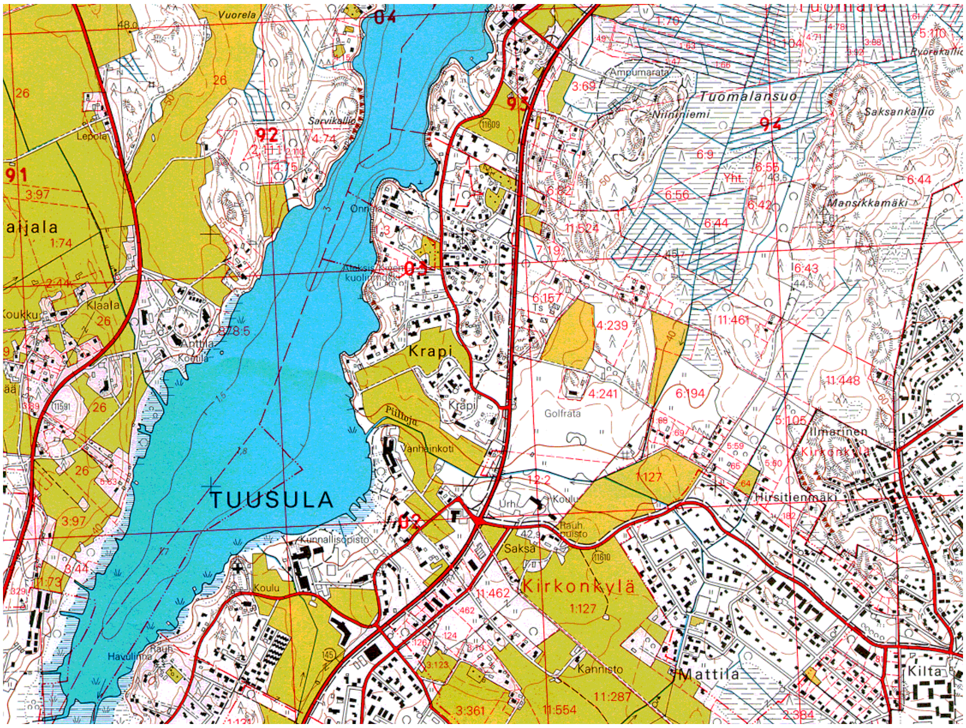

Figure 2.15 A basic map 1:20 000 from 1991 (Original: the NLS)

In 1998, the NLS decided to start the development of a new production system based on the same technology already used in the cadastral map and land surveying process. The new system was completed in 2000 and updating of the topographic database is now based on this. At the same time, the updating process was changed suitable for digital workstations. Also, the NLS was given the responsibility of making topographic mapping in the Northern Lapland, where the Topographic Service had made topographic maps earlier. However, the feature catalogue and quality model was not changed in this context. At the beginning of 2005, the NLS begun to investigate renewal of the feature catalogue and the data model. At the moment the user requirement study is available (NLS, 2005).

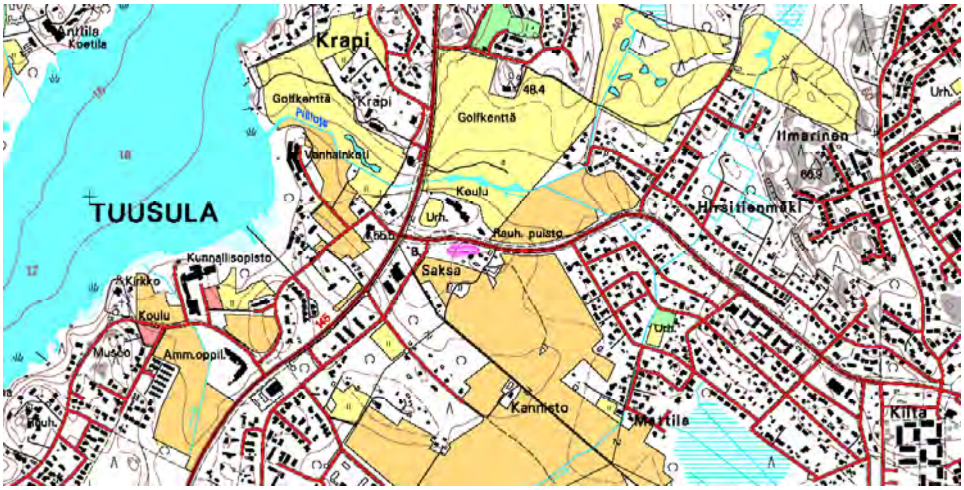

Figure 2.16 A printout from the Topographic Database[34] (October 10th, 2005)

Finnish topographic mapping has some special characteristics compared to European mapping. The topographic mapping of Finland was initiated rather early in Europe, because the country was interesting from the military viewpoint. However, large areas of the country didn't have a large or middle scale map before the basic mapping in 1947-1977. Finland is a rather large country and the mapping of the whole country has required a lot of resources in the analogue mapping age. Topographic mapping has always been regarded to be at a high level of excellence, especially that of the Russian topographic maps and the Basic Map. Even in the digital production period, the NLS had invested in quality management and development of a quality model. Combing the cadastral information with topographic data has a long tradition in Finland. The Basic map has had the cadastral boundaries from 1947. The cartographic appearance of the Basic Map has some national characteristics: Forest information is not represented by colour (as an area), individual buildings are represented in the topographic map (not in cadastre).

[34] Topographic Database does not contain cadastral borders. In the Basic Map 1:20 000 the cadastral borders are included.

2.3.2 Development of Topographic Base Information

The previous chapter considered the development of topographic mapping. Mapping of countries was accelerated during the wars of Napoleon (1799-1815). At the beginning of the 20th century, the invention of the Stereocomparator (1900) and Stereoautograph (1909) and the development of aerial photogrammetry during the first world war (1914-1918), led to the development of production processes in topographic mapping. The invention of astralon (1937) also enhanced map printing. The digital revolution in the mapping can be considered to have started in the 1960s. First, GIS systems and the Military Global Positioning System were developed in the 1960s. Automated map production was introduced in national mapping agencies in the 1970s, and the first civilian remote sensing system, Landsat, was launched in the early 1970s. First high-resolution satellite, Ikonos, was launched in 1999. Laser scanning technology will be utilized also to national mapping. Now, at the beginning of the 21st century, the standardization of geographic information, implementation of SDIs and new object-relational databases mean that topographic information should be integrated with other datasets. Data collection and especially accurate data collection does not require a huge investments if you only require local information. GPS systems will be integrated into other devices such as mobile phones, which means location will come one of the attributes in every day life. As the use of topographic information increases, the next shift will probably be the consumer market. The satellite imagery is now available for everyone, from, for example, GoogleEarth). The Internet will offer every one access to information.

2.3.3 The Concept of Master Database in Topographic Base Information

Traditionally the production processes inside the NMAs have included the production of several scales of topographic information. The manual or semi-automated generalisation of the small-scale dataset from the most accurate database has been quite laborious. In the automated mapping age, the generalisation problem meant that it was easier to update a generalized product than to introduce changes from the more accurate database. The concept of having a master database and several generalized datasets that are linked with it, was first described in the late 1980s in the research initiative of the National Centre for Geographic Information Analysis (NCGIA) 1988-1990 (Buttenfield, 1993). In research, the concept of Multiple Representation Databases (MRDB) has been studied by several authors (e.g. Buttenfield, 1995; Kilpeläinen & Sarjakoski, 1995, Kilpeläinen, 1997; Kilpeläinen, 2000; and Harrie, 2001). Especially topographic datasets are considered by Kilpeläinen and Sarjakoski (1995), Kilpeläinen (1997) and Dunkars (2004). Most of research is concentrated at the data management level.

National Land Survey of Finland adopted the concept of the master dataset at beginning of 1992, when the Topographic Database was introduced (with a scale of 1:5 000/1:10 000). The Topographic Map Database 1:50 000 has been produced using the Topographic Database since 1995. The conceptual models of other small-scale databases were developed based on this idea, and production of the 1:100 000 map database was started in 1996.

2.3.4 History of specifications of topographic base information and basemaps

Basemaps[35] in towns have their roots in the late 19th century when the first city plans 'asemakartat' were constructed. According to the circular letter of the National Land Survey of Finland (December 20th, 1888), town maps should contain measures and areas of real estate properties, roads and marketplaces. All public buildings made of stone or wood, monuments and other significant objects should be presented on the map. In the 1920s, new regulations were planned, because there were no qualifications for personnel or a geodetic base. The National Board of Survey issued technical guidance in 1930 for the geodetic works (Publication 18) and in the Town Plan Act (1931) the board obtained the right to control the work. According to law, a town plan should be based on maps. In 1936, the NLS issued more accurate guidelines for surveying for town plans (Publication 28). Those were updated twice, in 1945 and 1951. In 1959, the Building Act replaced the Town Plan Act and, in 1960, a decree on surveying for town plans and basemaps was issued (NLS, 1983b). The interior ministry issued detailed guidelines in 1960, published by the NLS in three parts 1:500 – 1:2000, 1:4 000 – 1:5 000 and 1:10 000 – 1:20 000. Harmonization of symbology and presentation between different series was emphasized in the guidelines (Kärkkäinen, 1970). This can be considered the first harmonization of the national and municipality maps series in Finland.

Followed by the developments in technology, new surveying guidelines were issued in 1983 (Publication 49). According to the guideline, the basemap should be constructed using the principles of a general topographic map; positional and map accuracy should follow the map scale and characteristics of features presented in the map.

In 1989, The Association of Finnish Towns, which later merged with the Association of Finnish Local and Regional Authorities (AFLRA), began to construct a guideline to harmonize terminology in topographic data and to harmonize clas-

[35] Kantakartta (in Finnish)

sification codes. The first version, which was named "*Classification of topographic data*"[36], was issued in 1992; the present version (2.3) is from 2002.

In 1993, the NLS appointed a working group to develop a data model for basemaps[37]. Classification principles adopted in the work were: to fulfil general principles of a basemap, to use closed polygons for cadastral boundaries, presenting features as lines, points and symbols, and to use closed polygons only when objects would be presented using raster in the map, no networks, and classification features as visible and non-visible when needed (NLS, 1993). The NLS issued a guideline "*Basemap for town and building plans*" in 1996. In the guideline, there was a table showing corresponding classes in the data catalogue for municipality data issued by the AFLRA. In 1993, the NLS issued a revised guideline for surveying basemaps. However, there were no new demands for the content of digital basemaps.

The first guidelines for the basic map were issued in 1948. As explained earlier, three different versions of the basic map were planned. Soon, other versions were abandoned and all basic maps were published with real estate boundaries and contour lines. In 1960, the guidelines were published in the same series as basemaps (NLS, 1983; Niemelä 1984, 1998:60).

Fieldwork for the basic map was completed in 1975. For the first time, the full coverage of the country was reached, when the last sheets were printed in 1997. Revision work had been initiated in 1957.

At the end of the 1980s, experiments of automated basic map production were begun and in 1991 a development-working group was appointed. In 1993, first data catalogue for the Topographic Database (TDB) was issued. This was the first time when there was a different production goal. Basic Map was considered as one of the products that was derived from the TDB. The data catalogue had some characteristics of the map product, note, for example, the use of cartographic features, but there was also clear evidence of modelling real-word features, for example, building geometry, and the use of other datasets as source, for example, the classification of buildings according to the Population Register's building classes and road classes according to classes used in the Road Administration.

In 1997, the first version of the object-oriented data model was developed, but it was not implemented. It defined logical groups for feature classes, topological relationships between features and other dependencies. However, multiple resolution data were not considered (Salo-Merta, 1997).

[36] Maastotietojen luokittelu (in Finnish)
[37] Karttakohdemalli (in Finnish)

In 2000, the TDB and production environment was transformed into a new GIS and physical data model, now supporting object-orientation. This enabled improvements in the logical consistency.

Figure 2.17 illustrates the history of the development of specifications in the national and municipal topographic data production. The first specification covering digital datasets were issued by the Association of Finnish Towns in 1992 and by the NLS in 1993. Connections between the guidelines are illustrated in the Figure 2.17. Especially interesting is the connection between the two models for the municipality data. In the guideline "*Basemap for the town and building plans*", no numerical classification is presented; on the other hand, it describes the relation to real-word features including attribute information and gives guidance for selecting features in the field. The AFLRA's data catalogue gives numerical classification, but the connection to real-world features is not so clearly described and selection criteria are missing. An interesting question is also why the harmonized concept of topographic maps that was established in 1960 was abandoned later. Did the customer's requirements change, or was it related more to changes in production organizations?

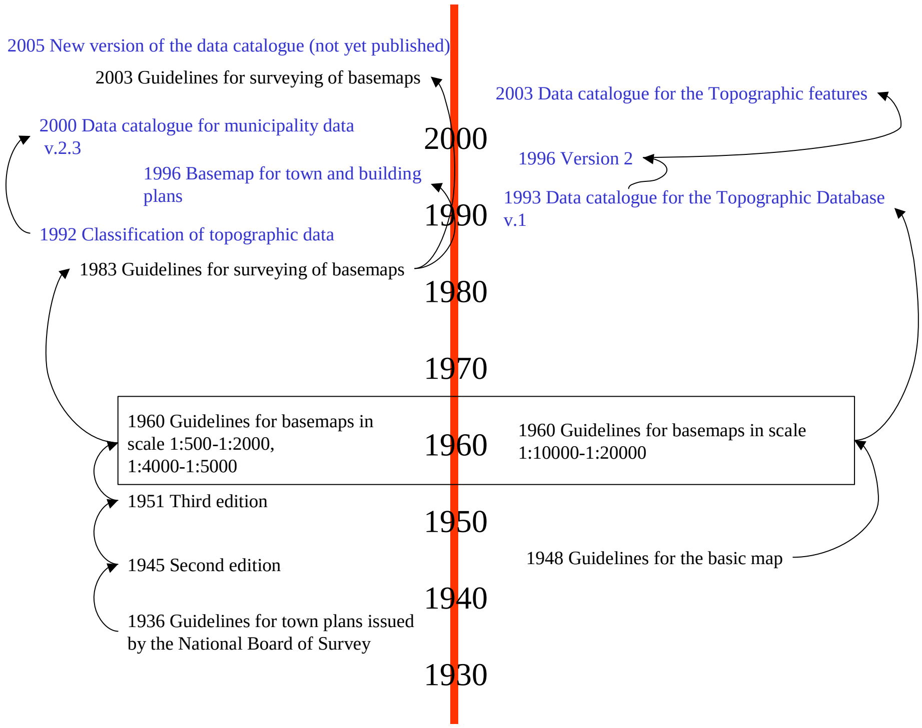

Figure 2.17 Published specification of basemaps (in municipalities) and topographic base information (in the NLS)

2.4 Spatial Data Infrastructures

2.4.1 Development of Spatial Data Infrastructures

The term Spatial Data Infrastructure is described in the SDI cookbook (Nebert, 2004) as "*the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data*." The Federal Geographic Data Committee (FGDC) describes the national SDI as "*the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data*. The NSDI is an umbrella under which organizations and technology interact to foster activities for using, managing, and producing geographic data" (FGDC, 2005). The development of national spatial data infrastructures has its beginning in the US with President Clinton's Executive order (EO) in 1994. In this order, all future federal geographic information collection, storage and reporting was required to adhere to the information standards of the Federal Geographic Data Committee (FGDC). The rationale is stated in the Executive order: "geographic information is critical to promote economic development, improve our stewardship of national resources and protect the environment" (The White House, 1994). Generally, national SDI development can be perceived to protect the large investments in geographic information in the public sector. The reasons why there is now a significant interest in developing SDIs in many countries include:

- the existence of large geographic datasets that are not utilized fully (note: NMCAs spend about one milliard Euros for the maintenance of map-related datasets)
- the same geographic data is collected by many organizations
- the need to discover available datasets (through metadata)
- the need to increase the availability of datasets
- the need to promote the use of datasets

The FGDC describes the benefits of an SDI to organizations in terms of it enabling the following (FGDC, 2005):

- money to be saves by sharing the costs of data production and reducing duplicative efforts,
- faster and easier development of applications through the use of existing data or data development standards,
- improvement of customer satisfaction through better data, faster response, and improved operations,
- provision of better data for decision making,

- saving of development effort by using framework data standards and standardized data, guidelines, and tools,
- utilization of data produced by others more quickly through the use of common formats and access methods,
- resolution of problems created by conflicting data,
- redirection of resources associated with duplicate data production and maintenance to your primary business activities,
- performance of analyses, decision making, and operations in cross-jurisdictional areas,
- reduction of the load from data requests by providing direct access to your data through the framework,
- attraction of clients who need data that are registered to the framework,
- expansion of market potential and program funding through recognition and credibility as a framework participant, and
- provision of consolidated direction to vendors regarding needed technical features.

Masser (2005) summarizes the four key concepts underpinning all SDIs: 1) maximizing the use of geographic information, 2) co-ordinated action required from governments, 3) SDIs must be user driven and support to decision making, 4) Implementation involves technical, institutional, policy and resource aspects.

The components of SDI usually are considered to be administration and technology. Administration includes organizations and people, policy or strategy. Technology includes the concept of core/reference/framework/fundamental datasets, technical standards and access network (Figure 2.18).

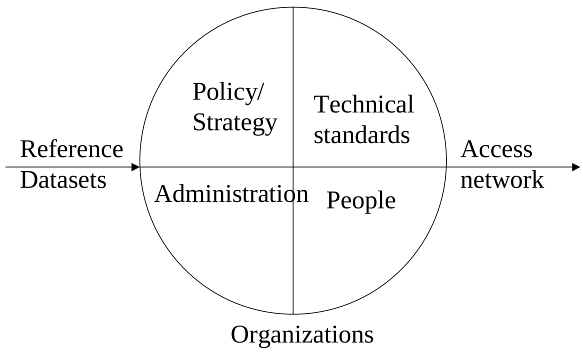

Figure 2.18 Components of SDI

Smith and Rhind (1999) discuss the nature of reference datasets, using term *framework data*, and especially its subset the topographic template. Rhind (1999) further elaborates geospatial data policies. He concludes that there are huge variations in the national policies. He stresses two particular problems that are generic to most national geospatial data policies: how user needs are considered in creation and provision of geospatial data, and how to ensure that organizations bearing the costs also reap tangible benefits.

Masser (2005) and Rajabifard et al. (2003) argue that second generation of SDIs began around 2000. Table 2.1 summarizes the current trends in SDI development according to Masser (2005) and Rahabifard et al. (2003). It can be noted that these findings support the arguments of this dissertation from the process point of view. However, the role of quality management and harmonization have not been identified.

Table 2.1 Current trends in SDI development (redrawn from Masser [2005])

Major trends	Consequences
From a product to a process model	From data producers to data users
	From database creation to data sharing
	From centralized to decentralized structures
From formulation to implementation	From coordination to governance From single-level to multilevel participation From existing to new organizational structures

Masser further argues that, while more than half the world's countries claim that they are involved in some form of SDI development, level of implementation differs greatly in countries. Also, Crompvoets (2006) has studied the worldwide development of national spatial data clearinghouses, and he concludes that a downward trend observed between 2000 and 2002 in the use, management and content of national clearinghouses continued in 2005 might be based on dissatisfaction of the spatial data community with functional capabilities and the piecemeal funding of the majority of clearinghouses.

2.4.2 European Spatial Data Infrastructure

There have been several research programmes funded by the Community that has promoted the use of GI (IMPACT, INFO2000, eContent). In 1994 the pan-European association EUROGI (the European Umbrella Organization for Geographic Information) was formed. In 1995, the European Commission's Information Market directorate published a draft paper "*GI2000: Towards a European Policy Framework for Geographic Information*" (European Commission, 1998), inspired probably by the President Clinton's EO published in 1994. Unfortunately, the resignation of the Commission stopped the process in 1999. After that, some projects were initiated to investigate user requirements and new strategy (ETeMII, GINIE). At the same time, the use of geographic information in the form of, for example, administrative boundaries SABE dataset, increased inside the Commission. Monitoring the common agricultural subsidies, using orthophotogrammetry and satellite images and also some new legislation, the Water Framework Directive, for example, exerted pressure to start the process again (Longhorn, 2004).

In 2001, the European Commission initiated the development of ESDI (INSPIRE). In 2002, the INSPIRE expert group established a number of working groups to develop the initiative further. After this the commission published a draft Directive for the ESDI in 2004 named INSPIRE (European Commission, 2004). It has now entered into a co-decision legislative process, where the Commission interacts with Council and European Parliament. An INSPIRE work programme for defining and preparing the detailed Implementing Rules (IR) was published in April 2005. The drafting teams have now been appointed for the development of IRs.

The proposed Directive creates a legal framework for the establishment and operation of an SDI in Europe. INSPIRE focuses on environmental policy, but there is an intension to extend it to other sectors such as agriculture, transport and energy. It is also intended that the monitoring and improvement of the state of environment should be implemented. The goal is not to have all data at the same harmonization level; therefore, three priority levels have been set. INSPIRE annexes (Annexes I-III) list 31 spatial data themes. For the Annex I themes implementing rules should be adopted within 2 years of INSPIRE coming into force, and Annex II/III themes within 5 years.

The proposed INSPIRE directive is not the only actor in the European Spatial Data Infrastructure (ESDI). EuroGeographics has initiated a Eurospec programme[38] (Luzet, Land and van der Vegt, 2004), which is a contribution for harmonising European NMCA datasets for the INSPIRE but probably at an even more detailed level. The community has other major initiatives such as Global Monitoring for Environmental and Security[39] (GMES) that aims to provide different services for Europe related to risk management of, for example, floods, fires, subsidence, landslides), air pollution, land cover state and changes, forest monitoring, food security, global change issues, maritime security including transport and coastal security and ice-monitoring, humanitarian aid and marine and coastal environment. One of the key aims of GMES is to establish consistent reference-map information from local to European scales. One of the projects is aiming to provide land cover information from Europe, based on satellite data acquisition covering all EU members. The land cover data would have a resolution of 100-500 m and 10 m in 500 urban areas with more than 100 000 inhabitants. The evaluated cost of the data acquisition is 30-40 million Euros annually (GMES, 2005). Galileo Joint Undertaking[40] is a joint initiative of the EC and the European Space Agency (ESA) to provide Europe with its own independent global civilian controlled satellite navigation system. When fully deployed, Galileo will consist of a constellation of 30 satellites.

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[38] http://www.eurogeographics.org
[39] http://www.gmes.info
[40] http://www.galileoju.com

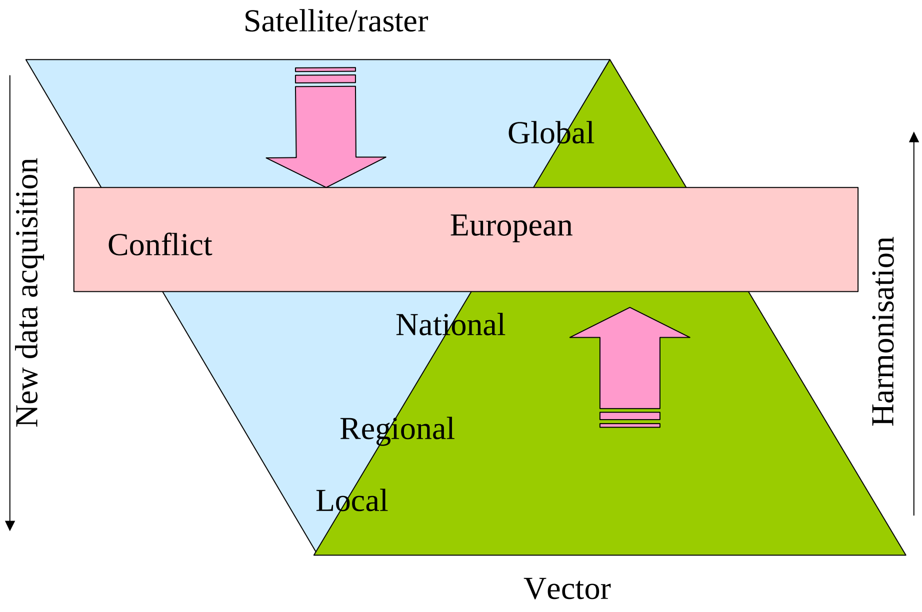

Figure 2.19 Double pyramid paradigm in Europe

Figure 2.19 illustrates the double pyramid paradigm, which seems to take place in Europe. One the other hand, the INSPIRE directive will rely on the existing datasets from the member states. However, harmonization will be a key issue in combing the different data themes. INPSIRE has not recognized the importance of topographic datasets in the harmonization challenge. On the other hand, initiatives like GMES will try to provide similar type of information based on satellite images, using a five year updating cycle – which is actually typical for the topographic datasets). GMES fails to recognize or mention any national datasets in the programme. Some efforts to combine the two different approaches exist nationally. In Great Britain, model generalization has been applied to Ordnance Survey's MasterMap to reduce resolution so that it can be used together with satellite images and thereby improve the accuracy of land cover maps (Wevers, 2005). Also in Finland the Topographic Database has been utilized in the production of the land cover classification (See Paper IV).

2.4.3 Finnish National Spatial Data Infrastructure

In 1985, The Ministry of Agriculture appointed the LIS (Land Information System) project to develop the joint-use of geographic information based on the initiative of the Advisory Committee for National Mapping. The steering tiative of the Advisory Committee for National Mapping. The steering committee of the LIS-project appointed 8 working groups, which made suggestions for development of data transfer and to support shared use. Project (Rainio, 1988) published several governmental recommendations, now public administration recommendations, describing message-based data transfer based on the EDIFACT standard. The project introduced the term "joint-use"[41] of geographic information, which is used in Finland in the context of promoting use of geographic information and diminishing duplicate production of data. The author would like to suggest the replacement of this term by *supporting interoperability and harmonization of geographic information*[42]. The NLS developed a directory service for geographic information and programme for data format transformation. The work can be considered as a basis for a national spatial data infrastructure. The mission to promote joint use of geographic information was added to the duties of the NLS by law. The NLS organized a special unit for this work and people were recruited. The NLS started the annual fair of geographic information and geographic information magazine (Positio). At that time, Finland was one of the first countries that developed a directory service and MEGRIN (now EuroGeographics), for example, used this solution to provide European metadata service (GDDD). In 1990, Mäkinen proposed the development of a core warehouse in middle-scales that would incorporate several different national datasets together. At that time only some elements of the basic map were available in digital form together with some areas of cadastral map. However, harmonization and quality control were already recognized as important.

In the middle of 1990's, it was evident that the approach selected in Finland was not selected in standardisation work (CEN) or by the GIS vendors. The development of the Internet had not been anticipated. Also, the content and coverage of digital dataset was not satisfactory and there was no demand in the market to use standardized solutions. There were no international standards, which could have provided a critical mass for success, available.

In municipalities, the Advisory Board for Information Management of Municipal Administration (KATKO) and the Geodetic Institute had developed shared use. The system for joint-use of geographic information in municipalities has been studied by Kosonen and Makkonen (1988). In this study, they suggested an approach for the modelling of geographic information in municipalities, which can be considered one of the basis for current classification of the AFLRA. In 1989, The Association of Finnish Towns, now merged with the AFLRA, developed a recommendation for interchanging the cartographic system with the municipality topographic information system (Suomen Kaupunkiliitto, 1989). In the recommendation, the present situation of the cartographic system, use of maps and user

[41] Paikkatietojen yhteiskäyttö
[42] Paikkatietojen yhteentoimivuuden ja yhdenmukaisuuden lisääminen

requirements were explored. The Topographic Information System was considered as a user interface and graphical indexing of shared use of geographic information in municipalities. A *town was divided to different regions* (A0=a block in the town, A1=city centre, A2=built-up area for small houses, A3=sparsely populated area). Each region had a different positional accuracy requirement. It also described dimension for the database system (3D model to graphical information) and how information should be complied in the terrain. There was no detailed guidance on the content of the data. In 1989, the Association of Finnish Towns, now AFLRA, began to develop concepts for topographic information and to increase uniformity. This process led to the publication of the *Classification of topographic data* (Suomen Kaupunkiliitto, 1992; AFLRA 1996; AFLRA, 2002; AFLRA, 2003) in 1992 and to the latest version in 2002 (see Figure 2.17).

The LIS-project got a successor in 1993, when a collaboration group in joint-use of geographic information (PYRY) was established. Its mission was to promote the shared-use of geographic information based on principles defined in the LIS-project. In practice, the group should have promoted the establishment of geographic information services described in LIS-project. The collaboration group had been appointed for a fixed-period ending in 1996. We can conclude that the activity in the joint-use of geographic information was rather good until the middle of the 1990s. After the PYRY-project, no formal broad-based development was carried out for the next few years. In 1997, the Advisory Committee for Information Management in Public Administration (JUHTA) published together with the NLS the investigation of nationally important geographic information resources and development needs. In 1992, a Register Pool[43] was accomplished for the development of core public registers not restricted to only geographic information (Näräkkä, 2002).

In 2001, the Council of State appointed the Finnish National Council for Geographic Information (NCGI). One of the task was to develop National Geographic Information Strategy. As explained earlier, we can consider the LIS-project and on the other hand the Advisory Board of National Mapping, which worked until 1991, as predecessors of the appointed council. The National Geographic Information Strategy (NCGI, 2004) sets 9 strategic development needs: "(1) Systematic cooperation, (2) Preparation and implementation of common recommendations, (3) Harmonization and improved maintenance of core geographic datasets, (4) Maintenance of metadata and metadata services, (5) Geographic Information services, (6) Principles of use and distribution, (7) User applications, (8) Research and education, (9) Communication."

[43] Rekisteripooli

Chapter 3

Standards in Geographic Information

3.1 Introduction

Standards can be categorized with reference to technology, organizations, data and processes (see Figure 3.1). This categorization has been represented in FGCD Standards reference model (FGDC, 1996), which was based on Information engineering, which is a design and standards development technique, developed by IBM in the late 1970's and early 1980's.

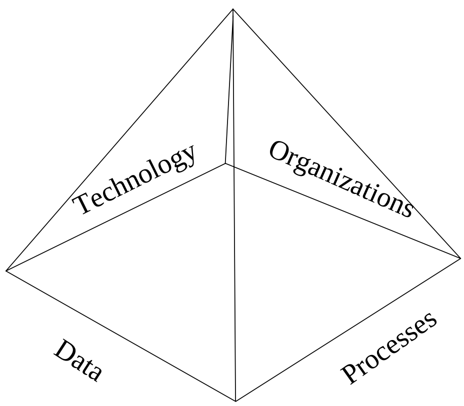

Figure 3.1 Categorization of standards (redrawn from FGDC, 1996)

Data standards describe objects, features or items that are collected, automated, or affected by activities or functions of agencies. Data are organized and managed by institutions. Data standards are semantic definitions that are structured in a model. Processes or functions describe tasks and how information and technology are used to accomplish organizational goals. *Process standards* may also be referred to as service standards. They describe how to do something, procedures to follow, methodologies to apply, procedures to present information, or business process rules to be followed to implement other standards. Process standards are used: (1) to establish a threshold for minimally acceptable data, (2) to determine the best data for an application, or (3) to promote interoperability and broad based use of data (FGDC, 1996).

The organizational component of information engineering consists of the rules for assigning responsibilities and authorities for the people who perform tasks and use technology. These include decisions as to who does which tasks, what data do they need, and what are the attendant skill requirements. *Organizational or institutional standards* are the specifications for communication among communities. These are the human and institutional interactions necessary in relation to carry out data, activity, and technology standards. Ways to organize, communicate, identify responsible parties, and coordinate roles are examples of organizational standards (FGDC, 1996).

Technology includes things like software, hardware, and system protocols. In system design the technology may be specifically described in terms of known application solutions such as computer aided mass appraisal, topologic processing, or coordinate geometry computations. *Technology standards* relate to the tools, environment, and interfaces among systems, and are often known as information technology specifications. They are the tools to produce, manipulate, manage, organize, disseminate, or otherwise implement activity or data standards (FGDC, 1996).

Current standards in geographic information may be classified as *industry standards*, or de-facto standards and *official standards*, national, regional, or international standards. Examples of industry standards include: Geographic Tag Image File Format (GeoTIFF), which is widely used in the GI community for the interchange of raster images and Geography Markup Language (GML).

Examples of national standards include:

- Amtliches Topographisch-Kartographisches Informationssystem (ATKIS) in Germany, which is a federal standard in Germany developed originally in 1985 to 1989. It is an example of standards based on the object-oriented model for digital landscape maps. Objects in landscape are described using ATKIS object class catalogue.

- INTERLIS Data Exchange Mechanism for LIS in Switzerland. Used within Switzerland since 1991. INTERLIS is a conceptual schema language (CSL). INTERLIS 2 uses object-oriented concepts such as inheritance and polymorphism to refine the language.
- Samordnet Opplegg for Stedfestet Informasion (SOSI) in Norway

Examples of international standards include:

- Geographic Data File (GDF). This standard was developed originally in the EC-sponsored project for European Digital Road Map. Its primary use is in car navigation systems. GDF provides a general data model, which is now compatible with the ISO 19100 geometric model, a feature catalogue for road features, an attribute catalogue, a relationship catalogue, a feature representation scheme, a quality description specification, a global catalogue scheme, logical data structures and media record specifications.
- IHO Transfer Standard for Digital Hydrographic Data (IHO S-57). The standard is commonly used worldwide for the interchange of hydrographic data. It provides an object catalogue.
- Digital Geographic Information Exchange Standards (DIGEST) in NATO. This standard is used in military applications within many NATO countries. Version 2.1 was launched in 2000 and it includes four parts. Part 4 includes the Feature Attribute Coding Catalogue (FACC) Data Dictionary, which is the most-used classification system in topographic information.
- ISO 19100 series.
- OpenGIS specifications.

Salgé (1999) gives another classification of standards: generic (or core) standards and domain specific standards. Generic standards can be divided to process-centric and data-centric.

The following chapter will introduce the ISO 19100 series. OpenGIS specifications have been developed by the Open Geospatial Consortium (OGC), which is an international industry consortium of 310 companies, government agencies and universities. The goal in OpenGIS specifications is to support interoperable solutions related to Internet applications and other GIS and mainstream IT solutions. It has developed the Geography Markup Language (GML) for transferring geographic data between different applications. Web Map Service (WMS) allows a client to overlay map images for display from Internet services supporting the protocol, while Web Feature Service (WFS) allows retrieval of GML data from supporting services. Most of the OpenGIS specifications will also be published in the ISO 19100 series.

3.2 Official Standards in Geographical Information

The European Committee for Standardization (CEN) began the standardization of geographic information at the beginning of the 1990's. Work in the Technical Committee 287 (TC287) resulted eight prestandards and three working group reports. These standards were in force for three years. One of the standards was related to quality (ENV 12656, 1998). The International Organisation for Standardization (ISO) initiated its standardization work on geographic information (ISO 19100 series) in 1996, based on the previous CEN work. This standardization work has now resulted in over 28 published standards and 20 standards begin processed. The work has proven to be quite slow because it is based on voluntary work.

Figure 3.2 illustrates content related standards in the ISO 19100 family. General schemas are related both to imagery (field based data) and vector-based data. Classification principles are given in the ISO 19110 standard (ISO, 2005). ISO 19126 will describe FACC using principles of ISO 19110. Spatial schema is described in the ISO 19107 standard (ISO, 2003c), and spatial referencing using coordinates in ISO 19111 (ISO, 2003d) and identifiers in ISO 19112 (ISO, 2003e). ISO 19127 is a technical specification containing a register of geodetic codes and parameters (ISO, 2005g). Temporal schema is described in ISO 19108 (ISO, 2002c).

Important standards related to quality are ISO 19113 (ISO, 2002b, Godwin, 1997), which describes the quality elements, and ISO 19114 (ISO, 2003) giving the framework for quality evaluation. Technical specification ISO 19138 (ISO, 2006) gives a list of possible quality measures. ISO 19115 (ISO, 2003b) defines metadata elements including quality.

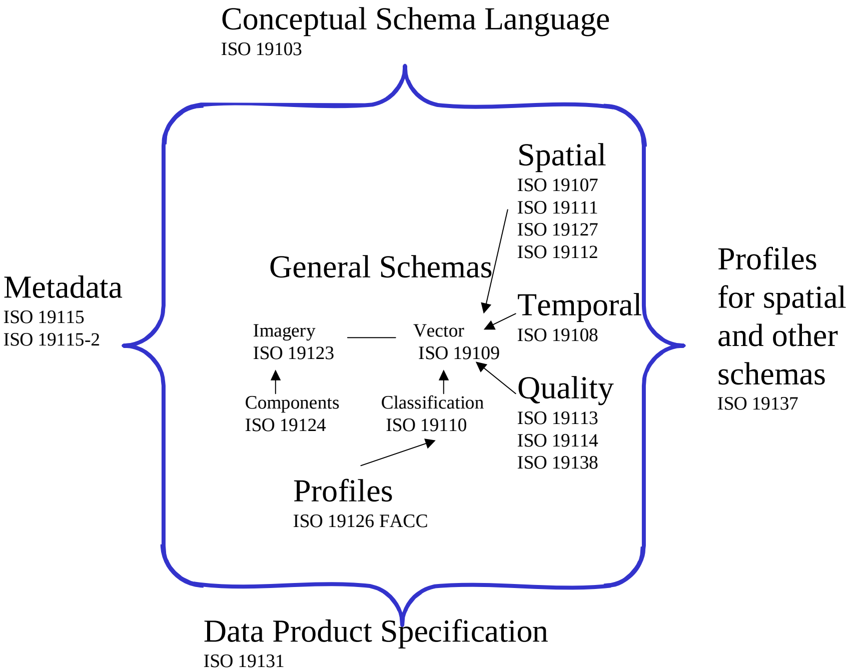

Figure 3.2 Classification of content related ISO 19100 standards (modified from Olaf Ostenssen[44])

Paper III explains the main content of ISO 19113 and ISO 19114 standards. Paper VII the introduces the Geographic Information Quality Management (GIQM) model using the ISO 19100 and other international standards.

If we consider the categorization of standards presented at the beginning of this chapter, ISO 19100 mostly contributes to technology and process categories. Data content specifications will be published as profiles (e.g. IHO, DIGEST). The organizational aspect is currently covered only in the technical report ISO/TR 19122:2004 Qualification and certification of personnel. SDIs are currently handling organizational issues. Some countries have issued legislation for organizing geographic information management. If INSPIRE is accepted, there will probably be more examples of national legislation in the future. Implementation of standards have proven to be very difficult and time consuming. Implementation specifications that would guide organizations in the process should be developed. Currently, the EuroGeographics Expert Group on Quality is develop-

[44] Source E-mail from Paul C. Smith February 2nd 2005.

ing a guide for implementing quality-related ISO 19100 standards, and ISO TC 211 has formed a focus group on data providers (FGDP)[45] to support the implementation processes. This foucus group have made a survey (FGDP, 2006) to the data providers in order to confirm the requirements, and current state of standardization, of data providers. Most of the respondents (95 %) found that GI standards are important. The reasons reported were:

1. Protection of investments
   - data documentation, data quality
   - avoid duplication
   - independence from industry standards
2. Improve collaboration
   - Within large organisations with many departments
   - Easier to share, exchange, and integrate data
   - Relationship with client becomes easier
3. Customer requirements
4. Legislative requirement
5. Best practice, learn from others
6. Support of research

The standards have so far have had a relatively high impact (in terms of usage) are the metadata standard and the standards for data content, data definitions and classifications of features. Data quality standard was recognized important by most of the respondents.

[45] http://www.isotc211fgdp.info/index.php (accessed, Jan 20th, 2006)

Chapter 4

Quality Management

4.1 Introduction

Quality control became important when the production process evolved. Especially when there was a need to produce quality firearms. The French invented the musket that had *interchangeable parts* in the middle of the 18th century. This was the prerequisite for mass production. Interchangability required the development in measurements, tolerances and dimensioning of the parts. Quality control became critically important for the success of production (Andersson and Tikka, 1997).

At the beginning of the 20th century, Frederik Taylor (1911) developed a production philosophy, *Scientific Management*, for the industrial age, which required the separation of planning and production. Planning and management was the responsibility of managers and engineers, while supervisors and employees produced the products. The production process was rationalized so that even the uneducated workers could be used. The responsibility for quality was given to inspectors, who would remove the defective products. In the 1950s, the number of inspectors could be as high as 10 percent (Andersson & Tikka, 1997). One of the founders of quality management can be considered to be Walter Shewhart (1931), who developed the control chart, which is a key method in statistical quality control. He also defined quality as conformance to specifications, which now is the cornerstone of the philosophy of quality (Lillrank, 1998).

In order to improve the production, separate quality departments were established in companies, leading a situation in which management and employees did not have to care about quality. During the 1950s and 60s, Japan came industrialized and took the lead in the quality movement. W. Edward Deming and Joseph M. Juran developed statistical quality control in Japan in the 1950s. The main focus in their doctrine was, however, related to quality management and quality systems. From Japan, the quality movement spread all over the world.

In considering the development of quality management, several authors should be mentioned. Those authors that are known as ‘quality gurus’ are W. Edwards Deming (1982, 1986), Philip Crosby (1979, 1996), Armand V. Feigenbaum (1986), Kaoru Ishikawa (1985, 1986), Joseph Juran (1970,1988,1992; Juran et al., 1979), John Oakland (1993, 1999), Shiego Shingo (1987) and Genichi Taguchi (1987). Here we consider some of the main teachings relevant to this study.

W. Edward Deming, who developed the Plan-Do-Check-Action (PDCA) cycle, statistical process control (SPC), the fourteen principles for transformation and the seven-point action plan. It is accepted that Deming has probably made the most substantial contribution to quality management. The SPC is a quantitative approach based on the measurement of process performance. A process should reach a stable condition, where its random variations fall within determined upper and lower limits. Measurements are recorded into a control chart. Using statistical analysis the mean value is calculated. Events outside normal variation, which is conventionally limited by three standard deviations (a confidence interval of 99.8%), are considered ‘special’, and should be analysed. Those events that fall within normal variation are considered ‘common’ and should be treated at the system level. Deming (1986) considers that 94% of most troubles and most possibilities belong to the system and should be the responsibility of management. (Beckford, 2002). According to Flood (1993), the principal strengths of Deming’s approach are:

- the systemic logic, particularly the idea of internal customer-supplier relationships,
- management before technology,
- emphasis on management leadership,
- the sound statistical approach,
- awareness of different socio-cultural contexts.

Significant weaknesses are:

- lack of a well-defined methodology,
- the work is not adequately grounded in human relations theory,
- the approach will not help in an organization with a biased power structure.

Armand Feigenbaum (1986) developed the approach to quality known as Total Quality Control (TQC). He assumed a world composed of systems. The organization must take into account the environment and the market. The second assumption was that human relationships are a basic issue in quality achievement sumption was that human relationships are a basic issue in quality achievement (Beckford, 2002). Again Flood (1993) provides a summary of principal strengths:

- it stresses a total or whole approach to quality control,
- it places emphasis on the importance of management,
- socio-technical systems thinking is taken into account,
- participation is promoted.

The principal weaknesses are:

- the work is systemic but not complementary,
- the breadth of management theory is recognized but not unified,
- the political or coercive context is not addressed.

Joseph Juran developed the 'quality trilogy', a three-step process of planning, control and improvement. His first book, *The Quality Control Handbook* (Juran et. al, 1979), published in 1951, is considered to have led to his international pre-eminence in the field of quality. He, as well as Deming, was teaching quality principles in Japan in the 1950s. Juran did not consider that radically changing organizational culture was a requisite. One of leading problems in western organizations was, according Juran, the difference in language inside corporations. The top management is interested on economic results, employees on content, while middle management tries to handle both. The essence of Juran's work concentrates on the quality trilogy:

1. Quality planning, which prepares to fulfil the quality goals.
2. Quality control, which tries to fulfil the quality goals during production.
3. Quality improvement, which tries to achieve a new improvement level in production.

Important in quality planning was customer orientation. The internal and external customer should be described first. According to Juran, it was important to realise what was measured and then set the measures that are reliable and objective.

According to Flood (1993), the strengths of Juran approach are:

- its concentration on genuine issues of management practice,
- the new understanding of the customer that it offers, referring to both internal and external customers,
- its stress on management involvement and commitment.

The main weaknesses are perceived as follows:

- the literature on motivation and leadership is not addressed,
- the contributions of the workers are underrated,
- methods are traditional, failing to address culture and politics.

4.2 Viewpoints to Quality

David Garvin (1988) described quality from different viewpoints. Those were:

- *Transcendent view* defining quality as a synonym of with 'innate excellence' or superlative, as a synonym for high standards and requirements. Quality cannot be exactly defined.
- *Manufacturing-based view*, quality as conformance to specifications, errors in the production.
- *Product-based view*, characteristics of a product describe the quality.
- *Value-based view*, price/quality ratio or benefit to customer determines quality.
- *Competition-based* view, quality vs. competition.
- *User-based view*, quality relates to customer expectations.

Lillrank (1998) has questioned this and according to him the value-based and competition based quality don't belong to other views. Quality, price and segmentation are fundamentally different. He describes quality from four viewpoints that are:

1. *Production centred* perspective focusing on variances in the production process. The most common measure is the number of defects or non-conforming products.
2. *Planning centred perspective* focusing on the characteristics of products.
3. *Customer centred perspective* focusing on the value of products and services to the customer.
4. *System centred perspective* taking into account all stakeholders who are impacted by the organization or its products oriented quality.

The four viewpoints described by Lillrank give a clear framework for understanding different approaches and therefore, the Lillrank's approach is adopted in this dissertation.

4.3 Systems Thinking

System thinking attempts to deal with organizations as 'wholes' rather than parts, hence the expression 'holistic'. It considers the organization as a complex network of elements and relationships, and recognizes the interaction with the environment in which the organization is contained. Theoretical background builds upon the early work of Barnard, Selznick and von Bertalanffy (1969).

Ackoff (1981) explains system thinking (cited from Beckford, 2002): "Suppose we bring one of each of these [types of automobile] … into a large garage and then employ a number of outstanding automotive engineers to determine which one has the best carburettor. When they have done so, we record the result and ask them to do the same for engines. We continue this process until we have covered all the parts required for an automobile. Then we ask the engineers to remove and reassemble these parts. Would we obtain the best possible automobile? Of course not. We would not even obtain an automobile because *the parts would not fit together*. Even if they did, *they would not work well together*. *The performance of a system depends more on how its parts interact than how they act independently of each other*."

Further, Parsons and Smelser (1956) developed four functional imperatives to be fulfilled for a system. The imperatives they identified are adaptation, goal-attainment, integration and latency (pattern maintenance) (AGIL). Adaptation means that the system has to establish relationships between itself and its external environment. In Goal-attainment, goals have to be defined and resources mobilized and managed in pursuit of those goals. In Integration, the system has to have a means of co-ordinating its efforts and in latency, the first three requisites for organizational survival have to be solved with a minimum of strain and tension by ensuring that organizational 'actors' are motivated to act in the appropriate manner. Jackson (1990) has interpreted this differently and described four primary subsystems of an organization: goal, human, technical and managerial (Beckford, 2002).

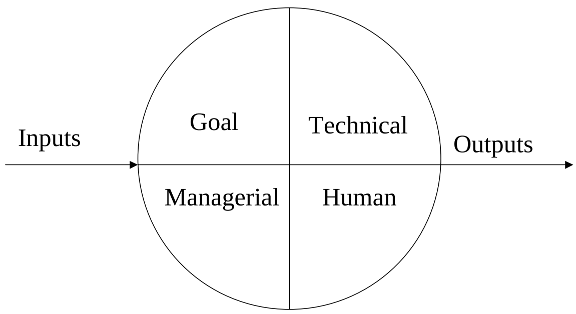

Figure 4.1 The organization as a system (Jackson, 1990, cited from Beckford, 2002)

Comparing Figure 4.1 to the components of a SDI (Figure 2.18), similarities can be noted. The system theory appears to provide a theoretical background for studying SDIs explained in Chapter 2. Even if certain components of a SDI would function perfectly, but, if the components do not work well together, the performance of the system would be poor. It also gives an explanation why quality management is essential to the use of multiple sources for topographic base information production. Quality management should be seen as a holistic approach that covers the all actors in the value chain of reference information.

4.4 Data Quality and Uncertainty in Geographic Information

Already in the 1980's, data quality or error was recognized as an important issue in cartography (e.g. Chrisman, 1982). Goodchild and Gopal edited a book on the accuracy of spatial databases in 1989. At the beginning of 1990, the development of GIS created a need to define data quality in geographic information (e.g. Buttenfield, 1993). In the Spatial Data Transfer Standard (SDTS), five quality elements were described (FGDC, 1991): lineage, positional accuracy, attribute accuracy, completeness, and logical consistency. This was followed by the ICA book on spatial data quality (Guptill & Morrison, 1995) introducing two more elements: Semantic Accuracy and Temporal Accuracy. Goodchild and Jeansoulin edited a book "Data Quality in Geographic Information, From Error to Uncertainty" in 1998, which reflected widening of the concept of data quality. The description of European quality standard had begun at the beginning of the 1990's, which resulted in a prestandard in 1998. When international standardisation was begun in 1996, it was decided to build the ISO 19113 on the existing CEN standard. We can name these efforts as 'truth-in-labelling' and regard them as also based on **the production-centred view of quality.**

Characteristics of data quality in geographic information has been discussed in Paper III. It discusses how quality of geographic information is related to the data specification. Data compilation is carried out according to the data specification, which represents the universe of discourse (see Figure 5.2 and Figure 15.1 in Paper III). Specifications may be poorly described, which may cause difficulties in data compilation and quality reporting. Real-world features have many characteristics, which causes uncertainty either to the conception process (data specification) or to the measurement process. Many natural features are very stable in nature and they do not change very often, but some man-made features are constantly changing. This is even more true with attribute information, for example speed limits. Some features are vague in nature, for example, the border of a coastline. The data compilation process can take two years, for example, from the data capture before the data is published, when the data may therefore be already out of date. There is one clear difference in geographic information compared with other information. It always contains errors or uncertainty. Change from the cartographic paradigm has increased the importance of data quality, because data can be easily transformed and reused as discussed earlier.

Error normally arises from two components: systematic (or bias) and random. Usually, systematic component cannot be completely eliminated and therefore the results presented are estimates with some reliability. In metrology, ***uncertainty of measurement*** is defined (ISO, 1993b) as the "parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand." Measurement uncertainty is estimated using statistical measures and it is represented using standard deviation. However, uncertainty in geographic information relates also to conception process (both user and producer) and analysis and representation of geographic information. For well-defined features, uncertainty is caused by errors and then statistics (probabilility) can be utilized to estimate uncertainty. For poorly defined objects, uncertainty may be caused by vagueness or ambiguity. These types of uncertainties have been discussed, for example, Fisher (1999), Plewe (2002), and Virrantaus and Laine (2003). Uncertainty has been discussed in Paper II. Figure 4 in Paper II illustrates the model of uncertainty or data quality.

Veregin (1998, 1999) describes elements of data quality using three dimensions: space, time and theme. These three dimensions described by Berry (1964) and Sinton (1978) are the basis for all geographical observations. Figure 4.2 represents elements of data quality together with data quality elements described in the ISO 19113 standard. Paper III describes CEN and ISO quality elements in detail and it is not repeated here. Alders (2002) describes the differences between the SDTS (1992), ICA (1996), CEN/TC 287 (1997) and ISO (2001) quality elements. There are some elements that are not described in the current ISO 19113 standard: resolution, meta quality, semantic accuracy and homogeneity. Resolution has been described as a metadata element in ISO 19115 belonging to spatial representation of the dataset. It has been described as the "level of detail expressed as a scale factor or a ground distance". Semantic accuracy, meta quality and homogeneity are described in Paper II.

	where	*when*	*what*
Quality Element	Space	Time	Theme
Accuracy	Positional Accuracy	Temporal Accuracy	Thematic Accuracy
Resolution (precision)	Not defined	Not defined	Not defined
Consistency	Logical consistency, Topological consistency	Not defined	Logical consistency, Conceptual consistency
Completeness	Completeness	Completeness	Completeness

Figure 4.2 ISO quality elements compared with dimensions of quality represented by Veregin, 1998

Veregin and Hargitai (1995) present a geographical model of data quality using the three dimensions: space, time and theme. In Figure 4.3 the spatial dimension defines the horizontal and vertical coordinates (x, y, z) of a location P. The temporal dimension defines the coordinates of P in time (t) and the thematic dimension defines a value for P for some theme or attribute. The quality of P is a point in the three-dimensional space defined by space, time and theme. A volume of uncertainty that contains the true location approximates this point. The volume defines a three-dimensional probability distribution of P. The authors denote that the model suggests that space, time and theme are independent dimensions when in fact they are interdependent.

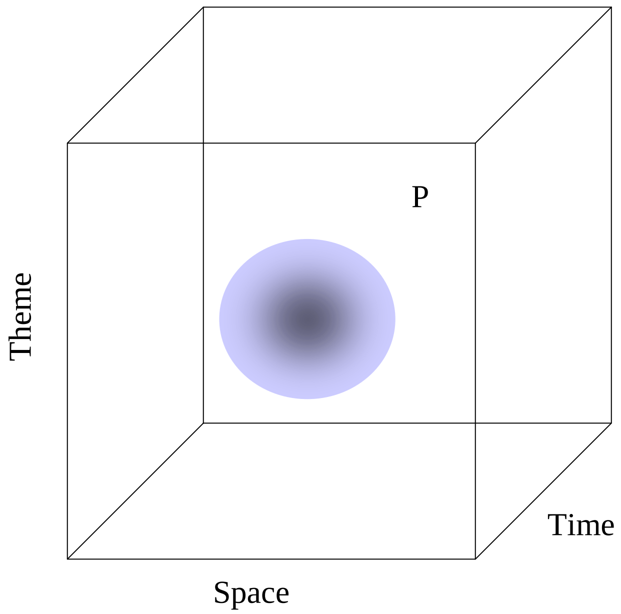

Figure 4.3 Uncertainty in space, time and theme (Veregin and Hargitai, 1995)

The data quality approach taken in respect to the standards has been criticized. Frank (1998) asserts that data quality descriptions should be independent of production methods, operational and quantitative. Most often data quality descriptions are given as lineage, which shifts the burden of the interpretation of the data quality to users. Only some quality descriptions can be derived using standardised procedures and represented as quantified measures (e.g. statistical tests). He proposed a metamodel as a solution, which is based on the observation function resulting in a value and an error related to the value. The function of interest then can provide value and error based on observed value. However, he only provides examples using field-based (vs. object-based) representation and simple functions (calculation or area). Goodchild (2002) has proposed measurement-based GIS as a solution. This provides access to the measurements *m* used to determine the locations of objects, to the function *f*, and to the rules used to determine interpolated positions. Locations might be either stored or derived on the fly from

measurements. He doesn't explain how this could be implemented in reality and no commercial implementation exists today.
Data analysis is often important for the users. These operations cause errors, which can be estimated using error propagation methods (e.g. Veregin, 1989; Heuvelink, 1998, 1999). Rönnbäck (2004) has described methods useful in data quality assessment related to spatial analysis and especially evaluating data usability in the decision-taking phase. Visualization of uncertainty is a method for increasing users' understanding of uncertainty. Several methods for the visualization of uncertainty have been developed (e.g. MacEachren, 1992; Buttenfield, 1993b; McGranaghan, 1993; Monmonier, 1993; Fisher, 1993; Beard and Mackaness, 1993, Buttenfield and Beard, 1994; Beard and Buttenfield, 1999; Drecki, 1999). Ahonen-Rainio has discussed visualization of metadata in her dissertation (2005) and Ahonen-Rainio and Kraak (2005) the use of a sample map in the selection process of geospatial data. MacEachren et al. (2005) have discussed the status in visualization of geospatial information uncertainty and present a comprehensive review of recent efforts. They present a review of typology efforts of uncertainty and suggest a typology, which adds three new elements: credibility, subjectivity and interrelatedness. Those new elements are related to reliability of the information and data usability, which are discussed in the next subchapter.

4.5 Geographic Information Quality

Geographic information quality can be described using quality management viewpoints. The previous chapter gave a review of data quality and uncertainty concepts. Usability is another viewpoint, which has its roots in engineering especially software development (e.g. Nielsen, 1993). Paper V discusses usability and Figure 2 in Paper V illustrates the usability framework presented in the ISO 9241 standard. Possible elements for data usability include (the list, based on Wachowicz and Hunter (2003) and Hunter, Wachowicz and Bregt (2003) is not exhaustive) the following:

1. Marketing: Added Value, Benefits, Costs, Novelty, Services Provided, and Satisfaction
2. Quality: Authoritative, Guarantee Against Error, Integrity, Metadata, Reliability, Validity, and Utility
3. Software and Tools: Human Computer Interaction, Standardisation, Integration, Searchable, and Interface
4. Human Perception - Cognition: Authoritative, Decision Type, Interestingness, Novelty, Popularity, Satisfaction, Trust, User Skill Levels, Familiarity, Interpretation, Visualisation

5. Applications: Aggregation Levels, Type, Exclusiveness, Visualisation, Integration, Decision Type, Use with Models and Algorithms, Availability and Accessibility.

Customer satisfaction surveys will be used for evaluating the finished applications. Quality function deployment, which is a common tool in quality management, might be utilised in transforming the users quality requirements to specifications. This has been discussed by Jahn (2004).
Figure 4.4 illustrates how different approaches of geographic information quality can be categorized using quality management viewpoints. Most of spatial data quality descriptions have been developed to serve the production-oriented approach. Data usability is an important aspect in application and user interface development. Uncertainty analysis is essential when analysing risks (e.g. van Oort, 2006). Rönnbäck (2004) has identified some methods for data usability evaluation. In the system-centred view SDIs and information management are essential. Common quality requirements are needed for harmonization of reference datasets. These will be discussed in Chapter 5. However, all aspects are important in the development of geographic information quality.

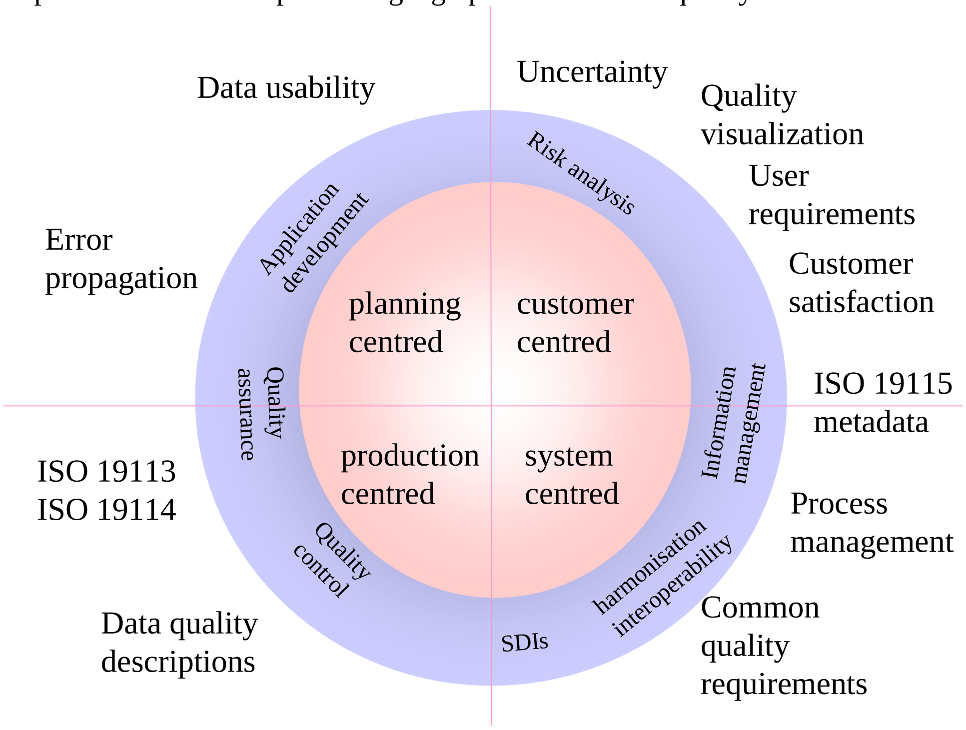

Figure 4.4 Different approaches to geographic information quality from the quality management viewpoint

4.6 Selected Methods

4.6.1 Process Approach

Process-based management has been adopted in the ISO 9000 family of standards. The process management approach is based on the idea that everything we do is based on process. Process is a set of interrelated or interacting activities, which transforms inputs to outputs (ISO 9000:2000). The process approach questions the traditional organizational structures, which have its bases in the scientific management principles, developed by Frederik Taylor (1911). Organizations typically have been divided to different functions or departments, which bring together similar types of knowledge (e.g. production skills). Problems occur when the business process covers many functions, which is a typical case. Figure 4.5 illustrates an organization with functions and business processes.

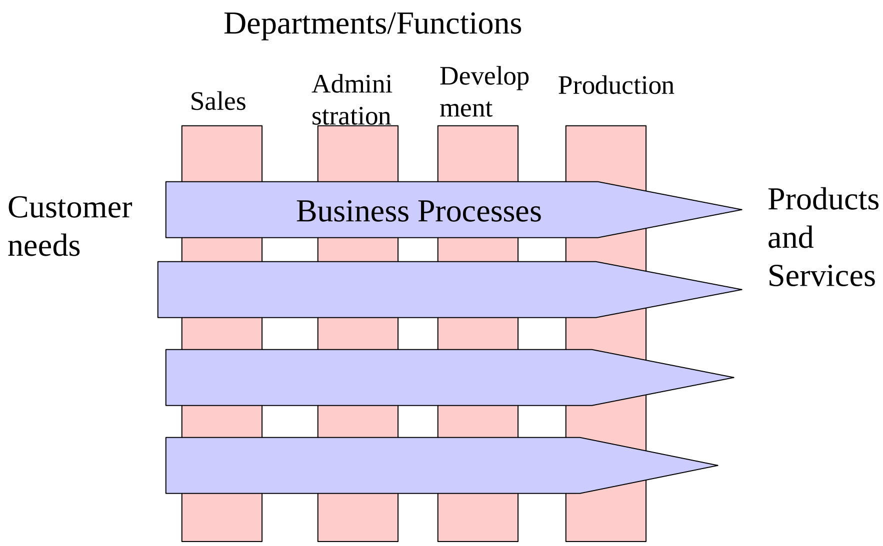

Figure 4.5 Business processes and functions in an organization

An organisation that has embraced the process approach should be able to demonstrate the following characteristics (Hoyle, Thompson, 2002):"

- A clearly defined business planning process
- A business plan that consists of objectives, appropriate measures of success, actions focused on achieving those objectives with the relevant resources and skills provided
- An improvement culture and investment program to support continual improvement objectives
- Measured and monitored performance improvements in financial, environmental, quality, employee and customer satisfaction indicators
- Effective customer and market research processes linked to improvement planning
- Benchmarked performance against appropriate external data
- Awareness of position relative to competitors with known strengths and weaknesses
- Personnel development processes focused on realising full potential
- Effective management of processes: i.e. processes that deliver outcomes which satisfy all the interested parties."

Figure 4.6 presents how ISO 9000:2000 forms a basis for process management and how the EFQM excellence model can be applied in the development.

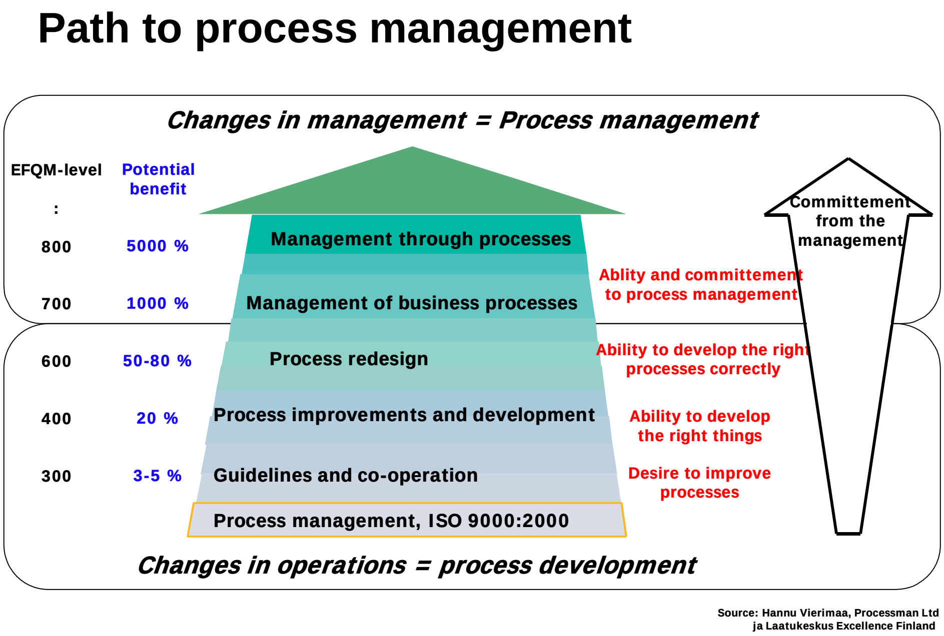

Figure 4.6 Path to process management (translated from Hannu Vierimaa and Laatukeskus Excellence Finland[46])

Hoyle and Thompson (2002) present the way in which they say an organisation should adopt the process approach. The main idea is to change thinking about a QMS or Business Management System (BMS) really means. The BMS is about effective process management with the emphasis on business results, rather than conformity to documented procedures.

The key tasks are:

- System design:
  - Plan for the change: how to convert an organisation with clearly defined goals and getting all people to understand why change is needed
  - Model business: identify core processes that deliver the organization's products

[46] Power-point slide

    - Organize process development teams: appoint process owners or sponsors
    - Analyse business processes: performance indicators
- System construction:
    - Process descriptions, process analysis report, process development plan
    - Process installation
    - Training people, running or prototyping processes, analysing the results
    - Monitoring
    - Process integration
- System validation
    - Process reviews
    - Results

The methodology for implementing a process approach is too well documented for a detail explanation to be needed here. Paastinen (1998) has developed a framework for improving the processes of an organization. Laamanen (2004) has published a guidebook on implementing the process network for an organization. The process approach typically is applied inside an organization. This dissertation applies it in a multiple organization environment with common reference data components.

4.6.2 ISO 9000

The ISO 9000:2000 standard is one of best-known international standards. The first version was published in 1987 based on the British 5750 standard. The British standard has its roots in military standardisation in the late 1950's and 1960s in the United States. The second version of the ISO 9000 was published in 1994, and the third version in 2000. The ISO 9000 family includes several standards:

- ISO 9000:2005 Quality management systems. Fundamentals and vocabulary.
- ISO 9001:2000 Quality management systems. Requirements.
- ISO 9004:2000 Quality management systems. Guidelines for performance improvements.
- ISO 19011:2002 Guidelines for quality and/or environmental management systems auditing.
- ISO 10002:2004 Quality management –Customer satisfaction – Guidelines for complaints handling in organizations.
- ISO 10005:2005 Quality management systems –Guidelines for quality plans.

- ISO 10006:2003 Quality management systems – Guidelines for quality management in projects.
- ISO 10007:2003 Quality management –Guidelines for configuration management
- ISO 10012:2003 Measurement management systems – Requirements for measurement processes and measuring equipment.
- ISO/TR 10013:2001 Guidelines for managing the economics of quality
- ISO 10015:1999 Quality management –Guidelines for training
- ISO/TR 10017:2003 Guidance on statistical techniques for ISO 9001:2000

There are also some guidelines developed for different sectors such as automotive production (ISO/TS 16949:2002), software engineering (ISO 90003:2004), the food and drink industry (ISO 15161:2001), medical devices (ISO 13485:1996, ISO 13488:1996), health-care organizations (International Workshop Agreement, IWA 1), education (IWA 2) and local government (IWA 4). ISO 9001 and ISO 9004 standards should be updated in 2008. The ISO 14000 family concerns environmental management.

Key elements in the ISO 9001:2000 are management responsibility, resource management, process management, measurement and analysis and improvement (see Figure 4.7). It follows the Deming's PDCA-circle as a key principle for improvement. Guidelines for ISO 9000 have been published by several authors (e.g. Hoyle, 2002, 2004, 2005; Carter, 2004).

ISO 9000 has been criticized for being too formal and containing requirements for documenting everything. While there is still a relevant risk in implementing the ISO 9000 quality management system, the present standard does not necessarily mean a bureaucratic 'checklist' approach. Ollila (1995) has found that ISO 9000 certification improved quality as perceived by customers, when he studied thirty-one business-to-business companies.

In this dissertation, the ISO 9000 has been utilised as a framework for the GIQM model presented in Paper VII. This model incorporates the principles of quality management into ISO 19100 standards.

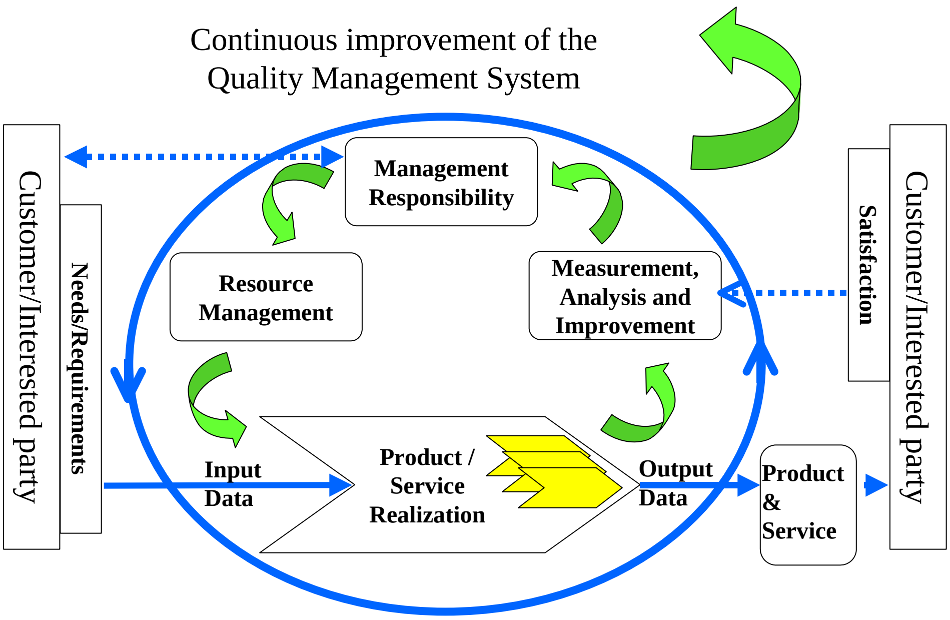

Figure 4.7 ISO 9000 process approach for quality management (modified from ISO 9001:2000)

Chapter 5

Interoperability and Harmonization of Geographic information

Interoperability has been described in the ISO 2382 Information Technology (ISO, 1993) as a “capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.” In GISs, the concept of interoperability has become very important during this decade. Standardization of GI (both ISO and OpenGIS specifications) is based on this concept. Already in 1996, the concept of interoperability was perceived to consist of three dimensions: data interoperability, system interoperability and organizational interoperability (van Oogen and Rowley, 1996, Salgé, 1997). The concept was derived in the EUROGI workshop organized to define a European standardization strategy. Figure 5.1 illustrates the three dimensions.

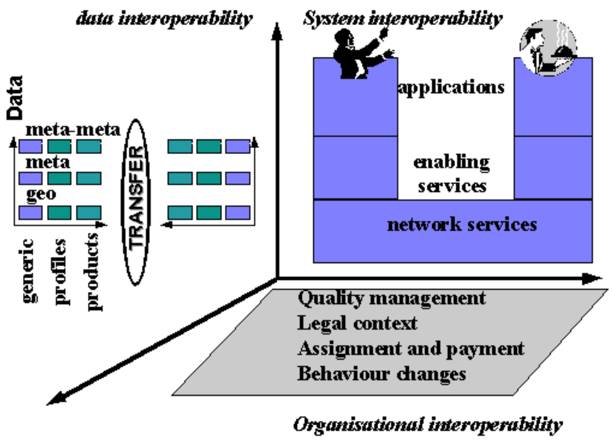

Figure 5.1 Dimensions of interoperability (cited from Salgé, 1997)

Bishr (1997,1998) has described levels of interoperability to cover: network protocols, hardware & operating systems (OSs), spatial data files, DBMS, data model and application semantics. He does not talk about the organizational interoperability, which is one of the key aspects of this dissertation. He claims: "There is no known GIS that provides interoperability at the data model and application semantics levels." However he believes that future generations of interoperable GIS will provide transparent communications at the data model and application semantics level.

Research on integration of databases has been studied in information sciences since the early 1980s (e.g. Batini, Lenzerini and Navathe, 1986). Semantic heterogeneity has been studied by Worboys and Deen (1991), Kashyap and Sheth (1996), Bishr (1997), Bishr (1998), Devogele, Parent and Spaccapietra (1998), Park (2001). Solving semantic heterogeneity can be considered one of the most important aspects in the implementation of SDIs.

Bishr introduces a mechanism for capturing and handling semantic heterogeneity between two heterogeneous data models. Three types of heterogeneity are discussed: ***semantic, schematic and syntactic***. Semantic heterogeneity can be divided into cognitive and naming. Cognitive semantic heterogeneity occurs when the definitions of the real world facts that are shared between two disciplines are different. For example, topographic map can have different meanings in Europe and in America[47]. Naming heterogeneity occurs when real world facts that are semantically alike have different names e.g. watercourse and river. Schematic heterogeneity relates to differences in conceptual models (e.g. differences between entities, attributes, entities versus attributes of difference in representation of equivalent data). Syntactic heterogeneity refers to differences in a logical data model (e.g. relational and feature oriented) or representation of spatial objects in a database (e.g. raster and vector). Bishr proposes that naming semantics can be resolved by developing a thesaurus that has all alternative names of a particular fact. For cognitive semantics he first describes general principles of how real world fact are described using heuristics. *Heuristics* is commons sense knowledge, or rules of thumb, that originate from the expert's past experience. There are three categories of heuristic knowledge: associational, motor skills, and theoretical. Associational knowledge is acquired through observation. Typically it can be expressed as rules (IF-THEN) and expert systems can easily represent this type of knowledge. Motor skills are based on repetition, on the human learning process, for example. Neural networks can be used to emulate this type of knowledge. Theoretical deep knowledge requires going beyond our basic understanding of the domain. Model-based reasoning systems are an example of how

[47] Content of topographic map and detail level may be different.

this type of knowledge can be managed. Bishr then suggests than associational heuristics can be applied for solving cognitive semantics and to store this information to a deductive database.

Devogele, Parent and Spaccapietra (1998) have developed a model for integrating databases of different scales. The methodology is based on: 1) schemas preparation, 2) correspondences investigation and 3) integration. This work has been continued by Badard and Lemarié (1999), Badard (2000) and Braun (2004), which have studied the schema matching for updating information from source database to a target database. Braun (2004) suggests using UML/XML modelling for transformation of schema integration information between models. This approach has some similarities with the ontology approach discussed in the following paragraph. Both try to establish a formal relationship between two schemas using expert knowledge.

The use of ontologies has been studied by Fonseca (2001). In his dissertation, a framework based on ontologies for the integration of geographic information is specified. Figure 5.2 presents two abstraction paradigms for the geographical world. On the left, the abstraction paradigm based on standardization paradigm is illustrated. On the right, the abstraction paradigm is the one presented by Fonseca (2001), and based on the early work of Requicha (1980), and Gomes and Velho (1995). Fonseca explains how the human mind interprets the physical world as a cognitive universe. These images in the cognitive universe are made explicit using logical methods and then we obtain ontologies. They are the formal representations of the logical schemes of the human mind and they exist in the logical universe.

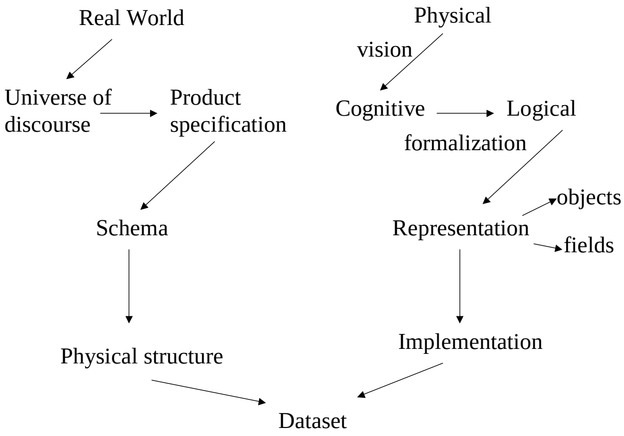

Figure 5.2 The two abstraction paradigms for the geographic world

Fonseca introduces an ontology-driven GIS framework (ODGIS). In this framework the ontology represents concepts in the world. Here the model is not explained further but ontologies are used in the framework to represent the specifications and the classes. In this framework the ontologies are utilized in information integrating through tools. An ontology editor allows users to work on the specifications of ontologies. Users may integrate information through an ontology browser identifying the concepts needed.

Harmonization and schema integration can be perceived to have the same objectives. Harmonization integrates schemas in the same domain e.g. base topographic information. Implementation is executed in changing the schemas in production organizations. If we consider users' options then this is not possible so semi-automated schema integration can be utilized using, for example, ontologies. Both processes require expert knowledge. Ontologies must be developed by experts into ontology translators and in the production environment into product specifications.

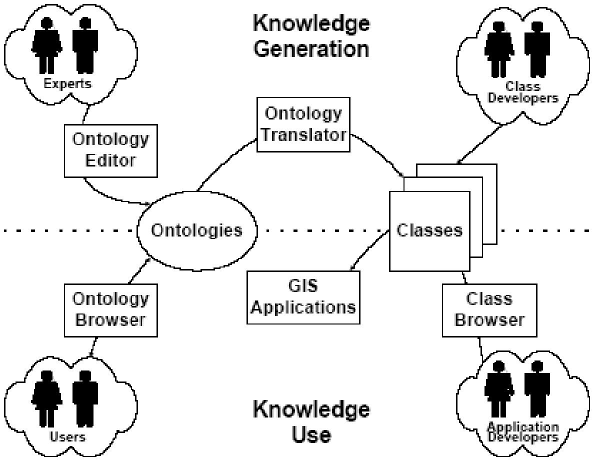

Figure 5.3 ODGIS framework presented by Fonseca (2001)

Harmonization is one of the major challenges in the implementation of SDI and a special challenge for the ESDI. Normally the harmonization process includes describing a common schema with quality requirements. Quality requirements are not commonly described at the moment, while ISO 19113 and ISO 19114 standards can be utilized for the description of the requirements. In this dissertation, a model of how quality requirements should be incorporated in the production processes has been described. Tóth and Nues de Lima (2005) have discussed the importance of quality in the harmonization process in the context of ESDI. They have suggested a conformity-checking procedure as a solution. They do not give an explanation of the model and therefore it is rather difficult to interpret different phases in their model. However, they have discovered that quality requirements are important for the harmonization process.

Chapter 6

Summary of Papers

6.1 Introduction

This chapter presents a summary of the papers, and a discussion of the contribution of each study to the knowledge in the field. Management of topographic information in Finland is addressed in Paper I, Paper IV and Chapter 7. Geographic Information Quality Management is discussed in Papers II, III and VII. User requirements are embraced mainly in Paper V, but also in Papers II, IV, VII and Chapter 7. The European context is described in Paper II, III, V, VI and VII. Paper I introduces a model for topographic information management, which is then reflected in the European situation in Paper II. Proof-of-concept using municipality data is described in Chapter 7, while the state of the art at the European NMCA is presented in Paper VI.

6.2 Paper I: Definition of Basic Topographic Framework for National GI Policy — One Database for All Basic Topographic Data

The objective of this study was to introduce a model of how topographic information management could be based on a multi-producer environment using a database(DB)-driven production paradigm. The paper presents a national Basic Topographic Framework (BTF) that combines all basic topographic datasets into a unified database. The paradigm is based on technical and organizational changes at the NMCAs. A model for the organization of the database-driven paradigm, emphasizing the quality management perspective, is introduced. The main focus for mapping agencies in the new information economy could be as a manager and provider of basic topographic information for several uses. The paper suggests that a mapping agency should develop a strategy for its data production processes, database management, quality management data delivery processes and business processes, and discusses this in connection with the introduction of spatial data infrastructure (SDIs) and standardization. It raises unsolved questions in modelling and user's data quality where standardization fails to give an answer.

Traditionally NMAs have had a control of the data acquisition process inside the organization. This has already changed in many NMAs, where NMA has changed its role from data producer to data subscriber and information managers. The paper suggests that ***Geographic Information Quality Management*** *(*in the paper the term *quality management* is used*)* has a key role when the roles change.

The case study explores how BTF could be implemented in Finland. It identifies several data producers that should co-operate and harmonize their information content with the Topographic Database. In Chapter 7, we explore how municipality data could be part of the Topographic Database.

6.2.1 Contribution to the Study

The paper introduces the ***concept of basic topographic framework*** that is based on the idea of reusing information available in the society and using the most accurate information available. While the idea of joint-use of geographic information is not new, it demonstrates the need to define the content and processes to succeed. In the new national strategy for geographic information (NCGI, 2004), this idea is now accepted. The role of information management at the NMAs is not yet widely accepted. The ***multi-producer database for the national topographic information*** in Finland is not yet reality. In 2005, the new cadastral information management system joined the municipality cadastral information together with the NLS's information. This will emphasize also the need for combining the topographic information, which is currently maintained separately by the NLS and the municipalities. NCGI will start harmonization processes of the many core geographic themes in 2005; the goal is to succeed by 2010.

6.3 Paper II: Framework and Requirements for Management of Topographic Data in Europe

This paper will embrace some of the requirements and introduce a framework for topographic data management based on the analysis of studies into 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.

Most national mapping agencies have separate topographic datasets representing different scales. This reflects the history of how geospatial datasets were created and updated using different data sources and non-synchronized processes. One dataset 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, while propagating the updates would have been problematic.

National Spatial Data Infrastructures (NSDIs) will also play a major role in the development of GI in Europe. They will set the requirements for topographic data producers.

Topographic data have many uses. This paper introduces some user requirement studies indicating topographic data as important reference datasets. Already by 2003, the main actors in GI had recognized the need for harmonization and quality in Finland.

The paper introduces some requirements for the management of topographic information dealing with resolution, data themes and features, data specification, modelling, data catalogues, metadata and data quality, process management, and data access.

A framework for the management of topographic data is presented, and problems related to the present paradigm of producing European-wide datasets, i.e. of the production of a unified generalized dataset, the EuroRegional map, for example, are discussed. Using national, regional or local data directly is another solution, but consistency problems should be solved concerning conceptual models, resolution and data quality. National experiences in providing harmonization data catalogues are discussed. Paper presents an approach for handling some reference data themes in different resolution levels using national databases and virtual datasets for European data.

The paper discusses the possibility of handling reference data as themes instead of a unified database and suggests that resolution or level-of-detail is an important factor in determining how information management should be applied. The need for object-based information management is important for large- and middle-resolution data. In small-scales, the rate of change is not frequent enough to support object-based data management.

6.3.1 Contribution to the Study

This paper introduces a multi-tier framework for handling topographic information at national, European and Global level. It suggests using the framework introduced in Paper I at the national level. Resolution is suggested as one of the factors for determining how information management should be applied. The paper introduces the importance of several factors in the information management. This is further elaborated in Paper VII.

6.4 Paper III: Data Quality and Quality Management – Examples of Quality Evaluation Procedures and Quality Management in European National Mapping Agencies

This paper introduces quality evaluation practices at the European NMAs. It is based on practical experience at the National Land Survey of Finland and knowledge acquired mainly from the EuroGeographics' working group on quality (now Expert Group on Quality). The paper explains the principles of spatial data quality, using concepts in the ISO 19113 and ISO 19114 standards. The concept of data quality is explained using ISO 19113 and compared with the general quality management standard ISO 9000:2000***. The characteristics of data quality are explored.*** Data quality definitions are given using the former European prestandard, which was used to in the development of ISO standards. However, current ISO standards and the European prestandard are not similar, and in some aspects the European prestandard was going further than the ISO. Examples of how quality evaluation is done at three European NMAs (Finland, France and Norway) are presented. The Finnish example gives an idea of how topographic data can be evaluated using ISO 19114 and general sampling procedures (ISO 2859 [1985, 1995, 1999, 2002, 2005d, 2005e] and ISO 3951 [ISO, 2005f]). The process presented is generally valid today, but the introduction of the JAKO system has changed the process somewhat, which is explained in Paper VII. The ***relationships of quality management and quality evaluation are explored.*** Quality requirements based on practical experiences are discussed. Experience in Norway is based on a national standard (SOSI). The emphasis is in logical quality evaluation. In France, three tools are used for quality evaluation: verification of logical consistency, comparing the results with a reference dataset and visual quality control. In conclusion, the paper infers that NMAs in Europe understand the importance of quality, but so far have not really invested in quality evaluation. ***The reasons are that the market has not demanded more and producers have obtained funding from government budgets.***

6.4.1 Contribution to the Study

The paper gives examples of how the NMAs are evaluating quality. It explores the relationship of quality management and quality evaluation, showing that the methods used at the NMAs are different and quality results are not given to customers. Quality standards are not fully implemented. This gives motivation for the study to explore how these standards could be used at the NMAs. Paper VII then presents a model of how quality management and other standards might be utilized.

6.5 Paper IV: The Topographic Database as an Integral Part of the Finnish Spatial Data Infrastructure – Analysis of the Present Situation and Some Possibilities for the Future

In a strategy for national mapping, the Ministry of Agriculture and Forestry has set the goal that the TDB would become one of the main sources for topographic information in Finland. In this paper, the question of whether the TDB is fulfilling the vision of forming the core basic topographic dataset for Finland is explored, together with the question of how it is used, especially with some new products and services. To do this, two examples are looked at. The first is a visualisation example, which simulates the reality using the TDB and some other datasets, and the other is the SLICES land-use dataset. If the TDB is a generic topographic presentation, it should provide a good basis for simulation purposes. The SLICES is one of the first datasets in Finland that is produced by multiple organizations and using multiple source datasets.

For the visualisation, an area in Valkeala was chosen as an example to demonstrate the simulation of reality. The NLS had two areas where the simulation had been calculated. The author visited a semi-randomly chosen site and compared the visualisation with the reality using a 1:5000 print out with a typical cartographic presentation of the basic map. Although the case cannot be used to determine the total quality of the visualisation, it shows that the TDB represents reality quite well. It contains the most important feature types that are required for visualisation. Correct forest classification would have improved the results the most. At the moment the TDB does not have forest data as polygons. Also, this example shows some need for the 3D modelling of feature types, i.e. of buildings and roads.

The accuracy of the TDB is good enough for visualisation application. There is evidence that combining the DEM and the TDB has not been successful in this example. The quality of the DEM needs to be more accurate. Further research is needed to determine whether it is a process problem or related to data quality. The forest classification showed many errors in position and thematic accuracy. Clearly there is a need for improvements in that respect. One solution could be the introduction of borderlines of forests into the TDB and the use of remote sensing for classification. The road and building information need to include some information on the elevation in order to better fit the ground. This could easily be incorporated into the data updating process. Some evidence of a problem relating to the classification of buildings was noticed. Buildings are classified depending on their use, which is not actually noticeable in reality.

For the second study, a visual comparison of the TDB and the SLICES data was carried out. The SLICES project has examples of the dataset on the Internet, and two areas were chosen. Using a colour PDF printout from the TDB, the two datasets were then compared. After visual comparison the results were confirmed on site. The author visited both sites and compared the datasets against the reality.

The SLICES project used the building register as a source for the residential and industrial areas. This is quite a logical choice, because it is the authoritative source for the attribute information on the usage of buildings. On the other hand, the TDB would be quite a logical source for information on the location and extent of buildings. At the moment, there is no connection between these two registers, and this example clearly shows a need for a connection. Also, it seems that the land parcel database of the Ministry of Agriculture and Forestry and the TDB agricultural data should be combined or connected with each other. The land parcel register has the most updated information about actively-used agricultural areas. There may be a similar need with the water register and the TDB. The water register should at least be updated using the TDB. The examples clearly show that there is a need to combine several different data sources in order to make better data products. One possibility for further investigation would be the use of the 1:100 000 small-scale database in the production of the SLICES data. The generalisation level of these products seems to be the same.

The paper examines the quality evaluation of the SLICES land-use datasets (Helminen, Jaakkola and Sarjakoski, 2001). The findings in the quality evaluation report support a connection between the TDB and the building register. In the supporting areas they found that parking places, in particular, were most likely to be missing from the dataset. Again this suggests some needs for improvements in the production process and in the source datasets. In agricultural areas, they found that fields withdrawn from use had the most errors. This again supports the findings suggesting the need for a connection between the TDB and the land parcel register. In water areas, they found the omission error, i.e. the error rate in percentage terms, was 3% or, as they claim, an object accuracy of 97%, and commission error, i.e. error rate in percentage was 2% or, as they claim, a interpretation accuracy of 98%. They found small areas of water and rivers were the most problematic. The visual inspection method used in this study can give an indication of the possible errors. The TDB can be regarded as representing reality quite well. In the quality evaluation of the FGI they visited approximately 15 – 40 pixels in a test area. They do not state the total number inspected at the actual location, but it could be around 6%. This might indicate that the TDB could be used in the future for automatic accuracy assessment. Of course there is still a need for field inspection.

However, some enhancements should be made in the conceptual model and data content. There is a clear need to combine different data sources using, for example, unique identifiers. The BTF model described by the author could be one solution. Organizations should take into consideration a multi-producer model where players are acting in different roles. Quality requirements for a unified database should be set. This means that quality management has a key role in the production processes. Other multi-producer environments, such as the DIGIROAD dataset (2002) and the use of municipal data in the TDB, should also be studied further. By 2003, DIGIROAD will set up a national road and street database covering all vehicle-accessible roads in the country. Cooperation between national agencies and the municipalities should be increased. One interesting concept that should be studied further is the GiMoDig project (Sarjakoski et al., 2002), which explores the possibility of real-time integration and the real-time generalisation of topographic datasets in mobile environments. The examples showed that visual inspection of data quality could be used to identify problem areas. Some ideas for enhancements in the production process of both products were identified. These should be studied more thoroughly.

6.5.1 Contribution to the Study

The conclusions from the SLICES test case suggests that the TDB and the building register, water register and land parcel register should be connected using, for example, unique identifiers. This supports the BTF model presented in Paper I. While SLICES was a consortium of many organizations and the NLS was the producer, it did not use all the best source datasets available. The paper discusses the similarity of the BTF model with the National Map concept in the USA (USGS, 2001). The process roles seem to be close to each other. The main difference is that the National Map consists of several themes, which pick out the most important real-world phenomena for the society. The same approach has been selected in Europe (INSPIRE) and also now in the national geoinformation strategy. The paper then suggests how separate themes could be used in the BTF model. This is further elaborated in Paper II. The BTF would be used as “gluing” the different themes together.

6.6 Paper V: User Requirements for Mobile Topographic Maps

The paper is a user requirement study for GiMoDig project (Geospatial info-mobility service by real-time data integration and generalisation). The report identifies the most common user group for mobile applications utilizing large-scale topographic data in the near future and categorizes user needs. The study is a desktop study based on existing information and knowledge among the participants. The vision in the GiMoDig project was to provide harmonized, European, large-scale topographic datasets to mobile users using real-time integration and real-time generalisation. This enlarges the users of topographic datasets. The investigation showed two different user groups: professional users and consumers. Professional users will first adapt this type of services, but the ***real potential lies in consumers***. The requisite for a GiMoDig type of application is that NMAs ***should upgrade their database technology to object-based and introduce harmonized specifications in Europe***. Situations in which users would need topographic information include safety, emergencies, hiking in the wilderness and other hobbies related to nature. The study also found that most location-based services would benefit topographic datasets if available. The usage areas for topographic information were identified as information services, safety, emergency, restrictions for usage or movement, guidance or navigation, logistics and military.

6.6.1 Contribution to the Study

The study demonstrated the dual role of topographic information in a society. There are general uses and special reasons to use this type of information. ***Connecting the topographic information with other datasets was seen requisite.*** Paper demonstrates ***the importance of user requirement analysis in the design process.*** The study applied general principles a human-centred design approach. Results of this are evident in the model presented in Paper VII. The method of scenario building (Clarke, 1991; Nielsen, 1991) was used in this study. In the research project described in Chapter 7, we planned to use this method in the user interviews but it turned out to be impossible because of the resources and variety of possible scenarios. Nevertheless, we still recommend this method for the requirement analysis of end users.

6.7 Paper VI: European Reference Datasets for European Spatial Data Infrastructure – State of the Art and Development of Common Specifications

This paper gives an overview of the reference datasets in Europe. It is based on *the Report on Reference Datasets and Feature Types* in Europe compiled by EuroGeographics Expert Group on Quality. The report covers 33 European countries and represents datasets from 82 organisations producing 236 datasets.

The state of the art report will ***form the basis for development of common specifications among NMCAs in Europe***. The EuroGeographics programme EuroSpec will facilitate the proposed directive for European Spatial Data Infrastructure (INSPIRE).

In the questionnaire we set out to determine the progress made by NMCAs in achieving interoperability with a question about edge matching, covering technical aspects, content and updating policy. Only a few countries had engaged in cooperation with other countries, and for the most part there were no agreements in place.

Some standards were mentioned. They were, however, mainly national standards or product specifications. It can be concluded that the ***harmonization process has not yet been initiated at the national level among nations, and international standards in geographic information are not yet generally applied***.

Topographic datasets, together with cadastral datasets, were identified as one of the main sources of reference information in Europe. NMCAs in general have an important role in providing reference datasets in Europe. Results suggest that harmonization between countries is required, while most of the feature types were available already at the moment.

Availability was over 60% for all other feature types, aside from addresses with 48% availability. Median availability for a feature type was 82%. We conclude that benchmarks, administrative boundaries and areas, coastlines/shorelines, named locations, roads, addresses and railways typically cover the whole country if available. Update frequency is dependent on the feature type. Addresses were updated continuously by 73% of the countries. The most up-to-date feature types were addresses, administrative boundaries and areas, cadastral parcels, interchanges and roads, and buildings.

6.7.1 Contribution to the Study

Analysis of the questionnaire and results from the GiMoDig (Afflerbach, Illert and Sarjakoski, 2004) project ***support the possibility that a common data model***

for topographic data is feasible at some level. The results of the questionnaire indicated that many countries have similar feature types, but we could not actually compare the semantics or how the feature types actually represent the real world. The questionnaire demonstrated differences in accuracy levels between countries, which might indicate that, if we combine different datasets, the level of detail might be actually different. This has been verified in the GiMoDig project already. Therefore it is ***important to include quality results in the process of harmonization.*** Results indicate that the multi-tier harmonization presented in Paper II might be a possibility.

6.8 Paper VII: Data Quality Management of Reference Datasets —Present Practice in European National Mapping Agencies and a Proposal for a New Approach

This paper introduces a ***model for Geographic Information Quality Management*** that could be utilized for reference datasets. It uses topographic datasets as examples, however, the same principles can be applied to other reference data as well. The model is based on practical experiences developed among national mapping agencies (NMAs) in Europe, as well as standards on quality management (ISO 9000 series), geographic information (ISO 19100) and other international standards.

The Geographic Information Quality Management (GIQM) model includes: (1) Identifying the user requirements, (2) Developing the specifications, setting quality requirements – e.g. conformance levels, (3) Controlling quality during data production, (4) Quality inspection by the producer or the user, (5) Reporting quality results in metadata, (5) Improvement of the model.

A common process for producing geographic datasets is illustrated in Figure 1 in Paper VII. Here we divide geographic datasets into reference datasets and datasets based on user requirements. The latter can either be based on reference datasets or they can georeference them. The quality requirements for reference datasets should therefore be stricter. Quality management procedures are similar in both data-set types.

Process management is especially important for reference datasets because production usually requires the use of many resources. Personnel training and know-how of are vital. Producing geographic data requires human analysis and interpretation and therefore has unique characteristics compared with other types of production. The conception process is quite complex, and automation has not so far been very successful if we consider vector-based datasets. Ensuring the capability of human resources is therefore essential.

Study of the Expert Group on quality has demonstrated the importance of quality management in the production of reference datasets among NMCAs.

The paper introduces how international standards can be applied to fulfil the requirements of the model.

The GIQM model presented sets a framework. Experience from the NMAs in Europe demonstrates that standards can be applied to enable quality results from geographic datasets. However, the paper suggests further research in: common quality evaluation procedures for reference datasets, common data quality measures, harmonized data quality management procedures, and quality reporting to users (metadata).

The paper discusses whether ISO 19100 quality elements actual meets user requirements and suggests they be used as background information needed when something goes wrong in the production process. It suggests using auditing principles for quality evaluation of geographic data to meet the producer's need for quality. The term ***geoaudit*** is suggested for evaluating whether producers' quality specifications are met.

6.8.1 Contribution to the Study

This paper introduces a framework for Geographic Information Quality Management, which can be used in the national BTF presented in Paper I or in the European framework presented in Paper II. The paper has been used for the development of the EuroGeographics Quality Policy (Jakobsson, 2004) and Implementation plan (Jakobsson, 2005c), which describes the principles of how EuroGeographics will manage quality in different projects, products and services especially for the Eurospec programme.

Chapter 7

On Needs for Harmonization and Joint-Use of Topographic Information Produced by the National Land Survey and Municipalities

7.1 Introduction

This chapter will introduce the main results from the research project that studied the possibility of using municipality data for the production of the Topographic Database. The results are published in the report "*On needs for harmonization and joint use of topographic information produced by the National Land Survey and municipalities*", which is published in Finnish in the research notes of the Finnish Geodetic Institute (Jakobsson & Huttunen, 2005).

The National Land Survey's topographic base information has been compiled in digital format since 1992 as the Topographic Database (TDB). Also, most municipality datasets containing topographic information are digital. Until now, there has not been much research on the harmonization of data models and promoting the use of multiple data sources. The Association of Finnish Towns has noted (1992) that joint-use of geographic information is ineffective in a municipality and between other municipalities, governmental and other organisations unless the classification and structure of municipality geographic information is harmonised. This study has examined how close the classifications are in the topographic base information of two producer organizations; the National Land Survey of Finland (NLS) and municipalities in Finland.

The research was carried out in the Finnish Geodetic Institute (FGI) financed by the Ministry of Agriculture, the FGI and the NLS. Researchers were Antti Jakobsson and Harri Huttunen. The project was lead by Professor Tapani Sarjakoski. In the reference group of the project, the representatives were invited from Ministry of Agriculture, the AFLRA, the FGI, the NLS and four municipalities.

The goal for the research was to investigate how the data catalogue of the Topographic Database and the classifications in municipalities could be combined. There was a special interest in studying the feasibility of using municipality data in the production of the TDB (process approach). The study was related to work of the National Council for Geographic Information (NCGI), and especially to the quality management and data quality programme in the National Geographic Information Strategy. Furthermore, the strategy for national mapping (Vertanen and Vajavaara, 2002) set a requirement to investigate the currency of data models and catalogues and development needs related to the joint-use of geographic information, data analysis and revision techniques. The NLS has set a target to renew the data catalogue of the Topographic Database in coming years, and this study gives one perspective to this work. The proposed directive of geographic information (INSPIRE) will describe a common framework for reference datasets, which will change the production of topographic and other reference datasets. The AFLRA began to describe a new data model for municipality datasets after this study and the results were utilized in this work.

The methodology was to analyse current data catalogues, and to evaluate them using a case study. Evaluation was carried out in four selected municipalities representing different types of municipalities. The user requirements were evaluated using a qualitative research method: interviews.

7.2 Methods and Materials

7.2.1 Research into Data Catalogues

Both the NLS and AFLRA have a data catalogue: these were compared in the study. In addition the NLS has published a data catalogue for basemaps. Each municipality has a different adaptation of the general model also. The goal in this study was to develop a connection between these different models. The version of the NLS's data catalogue was dated November, 25th, 2003 and the municipalities' common model was a version 2.3. Figure 7.1 illustrates the models that were compared.

The model or catalogue that a municipality uses for a basemap is dependent on the controller. The NLS is providing this service for those municipalities that have no qualified personnel. At the moment most municipalities are using their own personnel as a controller. The NLS has issued a regulation "*Guidelines for Surveying Basemaps*" (NLS, 2003) based on the Land Use and Building Act, Section 206. However, these guidelines give a lot of freedom to municipalities for defining the content of the basemap. In the Guidelines for Surveying

Basemaps, default specification is the data catalogue for town and building plans (NLS, 1997), but the controller can select other specifications also, such as the AFLRA's data catalogue. Published maps should follow the NLS's guideline.

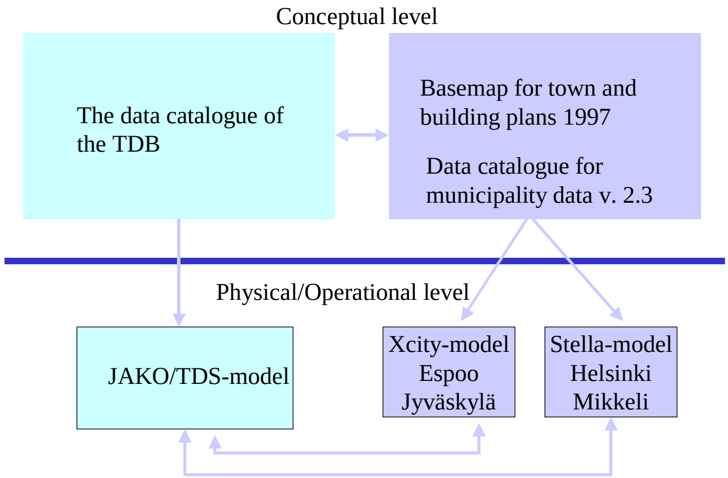

Figure 7.1 Data catalogues used in the analysis

Comparison of data catalogues was based on the assumption that these models are represented the same physical features. Based on the history of these maps, we can confirm this. Figure 7.2 presents the inference technique used in the comparison process. In the first phase, the connection between the models was determined using the name of the feature type, their definitions, attribute information and selection criteria.

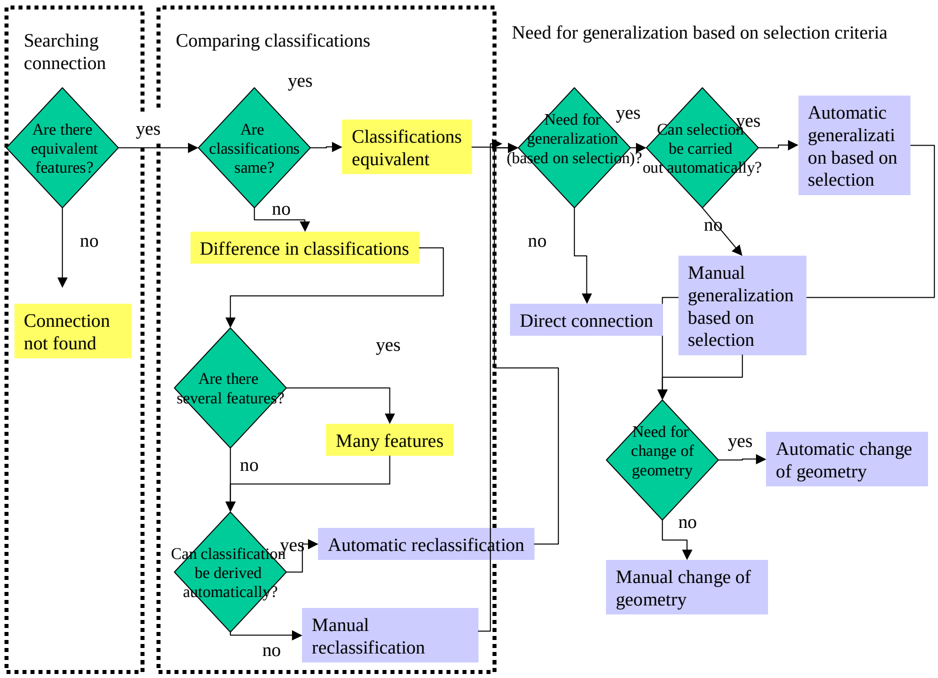

Figure 7.2 Inference technique used in comparison of the data catalogues

Besides comparing the classifications, we deduced whether there was a need for generalisation using the selection criteria described in the data catalogue of the TDB. If criteria were described numerically, generalisation was deduced to be carried out automatically. Finally, the need for change in geometry was deduced. Table 7.1 describes the connection types described.

Table 7.1 Connection types between the data catalogues of the NLS and the AFLRA

Connection type	Description
Direct connection	There is no need for generalisation using selection, or change in geometry. Simplification might be needed.
Automatic / manual generalisation using selection	Classifications are equivalent or connection has been established using reclassification. Selection criteria can be used in generalisation e.g. using minimum size. Manual generalisation might be used when selection criteria are described verbally e.g. using terms like most or minimum importance.
Automatic /manual reclassification	Classification used in the NLS can be derived AFLRA's classification using automatic or manual methods. Manual reclassification means that classification schemas are not interoperable (e.g. no hierarchy) and outside knowledge is required for reclassification.
Automatic /manual change in geometry	Geometry of feature types are changed e.g. polygons are changed to symbols or border lines are changed to centre lines

In the data catalogue of the TDB, all feature classes are divided into feature groups. In the 1996 version there were 12 feature groups (NLS, 1996). In this version, there were 123 feature types divided into over 700 feature classes. A feature type was described using: name of the feature type, definition, method for data compilation, selection criteria, notes, method for digitising, attributes, updating interval, method for updating and method for generalisation. In 2000, a few changes were carried out when the TDB was transformed into Smallworld database. Transportation feature group was divided to three groups: Roads, Railway, Transport network in water. Geographical names, feature notes and cartographic symbols were gathered to own groups. Cadastral boundaries were left out. All together there were now 143 feature types.

In the data catalogue of the AFLRA there were 793 feature classes. The terrain group included 41 classes, flora 22 classes, soil and bedrock 18 classes, elevation 9 classes, watercourses 26 classes, environment monitoring 29 classes, other natural information 1 class, administrative boundaries 26 classes, land-use planning 101 classes, cadastral information 42 classes, built spaces 29 classes, constructions 24 classes, ground transport network 52 classes, railways 31 classes, water transport network 34 classes, air traffic network 57 classes, water system 36 classes, sewer system 42 classes, electric network 30 classes, telecommunications network 25 classes, district heating 21 classes, gas pipes 23 classes, other cables 11 classes, benchmarks and location systems 59 classes, other cultural features 4 classes. Each municipality had its own data catalogue. Helsinki had 279 classes, Mikkeli 425 classes, Jyväskylä 310 classes and Espoo 531 classes. The groupings of classifications were not convergent with each other. Table 7.2 represents the number of classes in the data catalogues grouped into four main groups. The AFLRA especially has many feature classes that municipalities have not realized.

Table 7.2 Feature classes in the data catalogue of the AFLRA and municipalities

Feature group	Helsinki	Mikkeli	Espoo	Jyväskylä	the AFLRA
Terrain	62	58	83	82	108
Roads	11	45	34	29	52
Buildings	69	46	82	90	53
Others	137	276	332	109	580
Summary	279	425	531	310	793

Figure 7.3 illustrates the process of how the comparison between the different data catalogues was carried out. In phase 1, the connection type was derived comparing the NLS's feature type with the equivalent feature type and attributes in the AFLRA. Then in phase 2, the connection type was confirmed or changed comparing the classification used in municipalities; finally the results were evaluated in the field and observations were recorded.

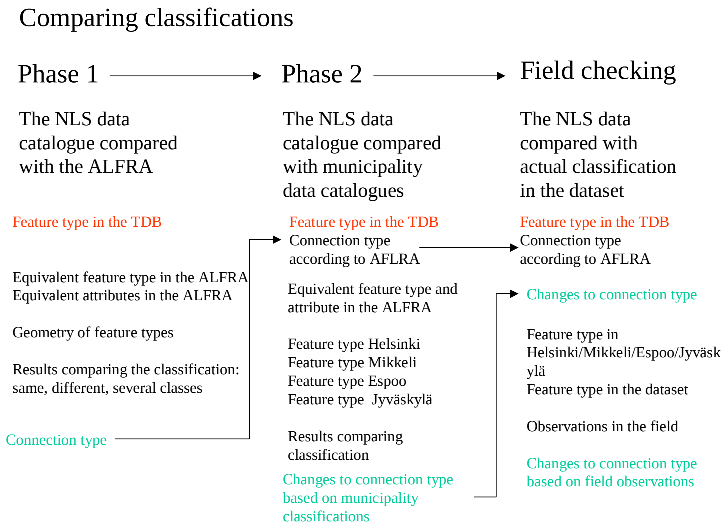

Figure 7.3 Different phases in the comparison process

7.2.2 Case Study in Four Municipalities

In the study, a reference group was formed to monitor the research and to make suggestions for the researchers. Three meetings were held during the project life-cycle. Also researchers interviewed the responsible persons in the municipalities and the district survey offices. For the case study, 5 different areas were selected from 4 municipalities. Selection criteria were that the municipalities would be representing a different type of municipality and also most GIS used in the municipalities (Stella Microstation and Tekla Xcity). Furthermore, the TDB should be rather recent in the selected areas (varied 2000 – 2002) and the accuracy level should be A. Selected areas were about 800 m x 600 m. Figure 7.4 depicts the location of the research areas in Helsinki. The first area, Kamppi, represents the ‘old stone building area in the centre’, while the second area, Mellunmäki, represents a typical suburban area with one-family houses, some old, some new.

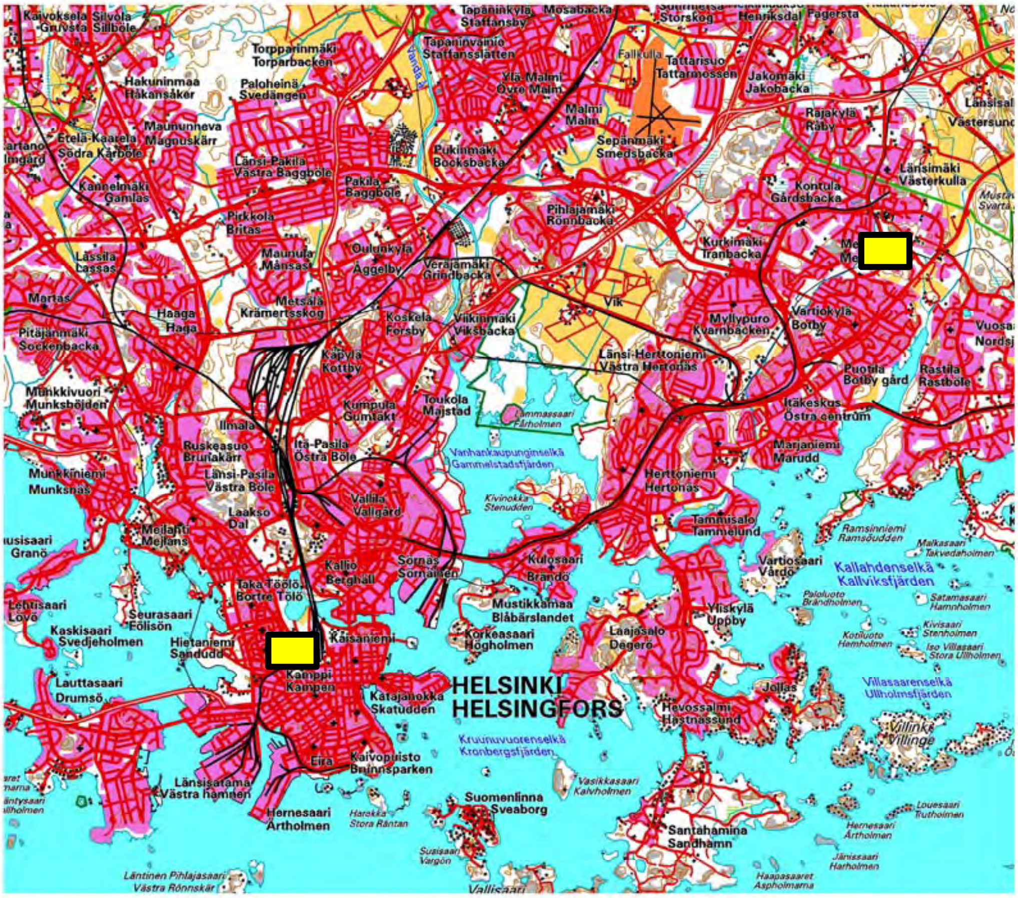

Figure 7.4 Research locations in Helsinki (Kamppi and Mellunmäki)

The third research area located in Olari, Espoo (see Figure 7.5). This area represents a suburb with apartments, row- and one-family houses.

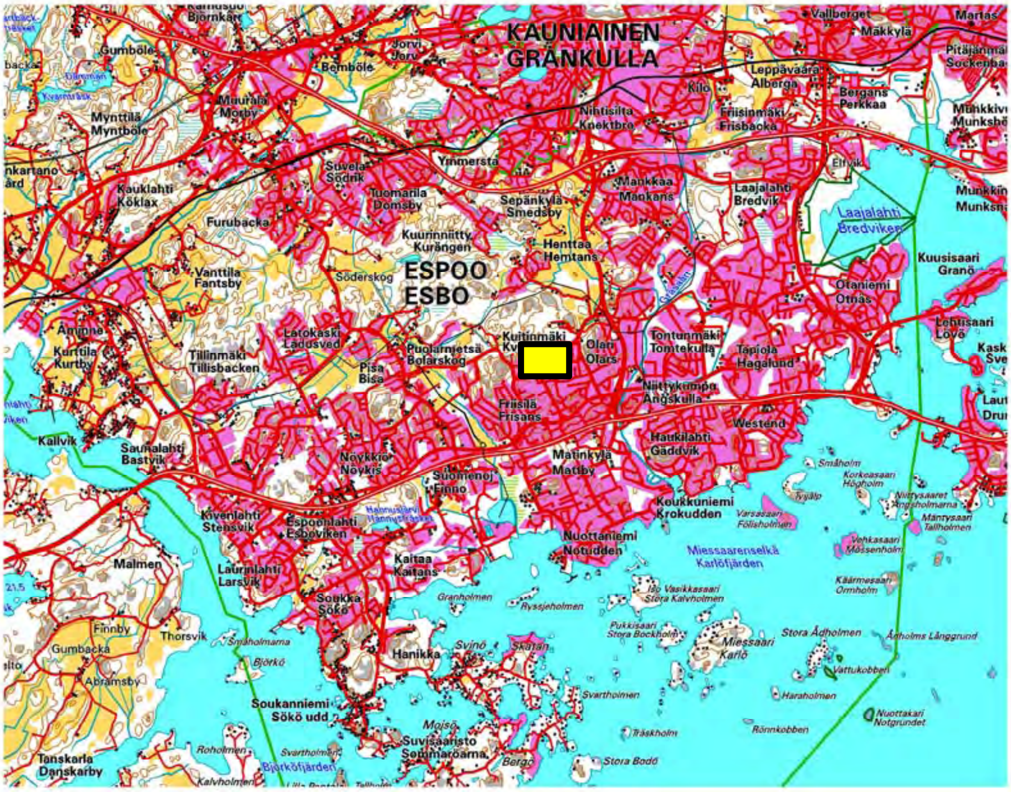

Figure 7.5 Research location in Espoo (Olari)

The fourth area located in Lutakko, Jyväskylä, is a town situated in the middle of Finland and the 9th largest city in Finland (see Figure 7.6). This area represents a new dwelling area located in close connection with the centre of the city. There were no one-family houses and most of the buildings consisted of multi-story apartment houses.

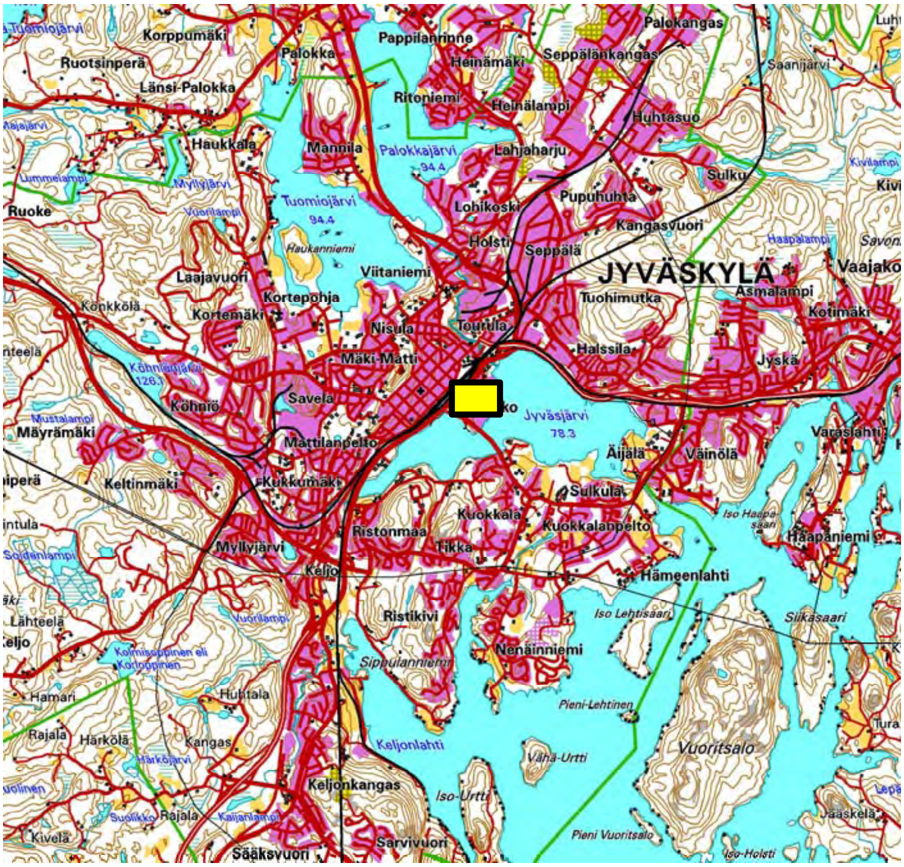

Figure 7.6 Research location in Jyväskylä (Lutakko)

Finally, the fifth area located in Rantakylä, Mikkeli, which is situated in the Eastern Finland (see Figure 7.7). Mikkeli is the 16th largest city in Finland. Rantakylä area represents a typical small-house area close to recreational areas. It also has a small lake and some fields.

We got the basemap data from the municipalities transformed into the national co-ordinate system, KKJ. This data was then also imported to ESRI's Arcview. Then the NLS's data was transferred to the Arcview. The coverage of this data was about 200 meters larger, so we could compare how well the municipality data fitted with the NLS's data. We selected feature types needed to simulate the content of the TDB. In some areas, we tried to build closed polygons from those features, where classification of an area was located in a linear feature (e.g. fields) but mostly we did not change the geometry of the features.

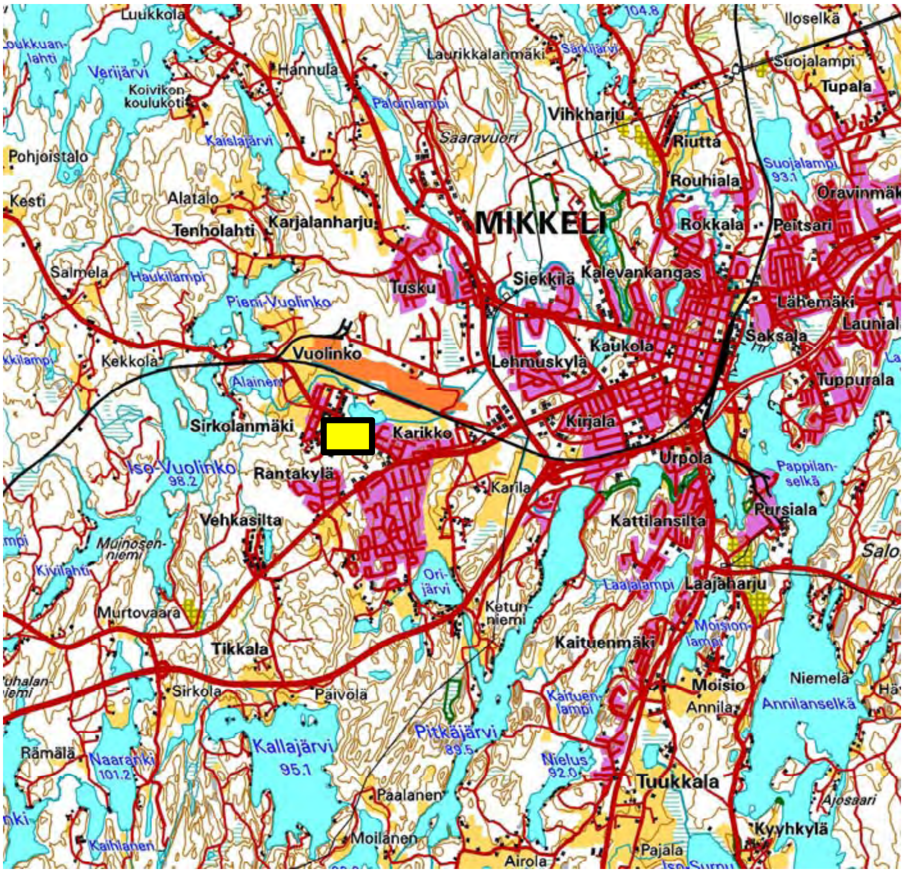

Figure 7.7 Research location in Mikkeli

7.2.3 Questionnaire on the Coverage and Content of Basemaps of Municipalities

At beginning of 2004, we gave a questionnaire to the municipalities. The AFLRA has an annual statistics of the basemap situation but the content and coverage was not satisfactory to our needs. This questionnaire was sent to 150 municipalities. We used the Internet to find out if a municipality had a technical office or some other party responsible for basemaps and only those that had were selected. The number of inhabitants was also used to select the municipalities. The questionnaire was sent by email to the responsible person directly if the name could be found from the Internet. If we did not get a reply, we tried at least twice and sometimes even phoned to get an answer. Overall, we got a response from 135 municipalities (90%).

7.2.4 Questionnaire on the Usage of Municipality Data in the NLS

We carried out a small survey on how municipality data is used at present in the NLS. Questions were sent to the managers of mapping in the district survey offices.

7.2.5 Research on User Requirements

Near the end of the project we carried out a user requirement study using interviews. This study covers only users needs of national topographic data in built-up areas. We used the knowledge of the Sales and Marketing Services of the NLS in the selection process of persons for interviews. We decided to interview resellers of the NLS's datasets and some major clients that we believed to have experience in the built-up areas. A qualitative method was selected because statistical significant results would have been difficult to reach in this type of study. Expert users and resellers were used because end users do not necessarily separate datasets from the application. The initial idea was to use the scenario method in the interviews but we found it too demanding because the potential use situations were so varied. If we would have interviewed end users, then the scenario method might have been the right approach. The questions used can be divided into:

- background questions investigating the experiences of the person and organizations,
- general questions investigating how topographic information is used and in which application areas it would be needed,
- feature type based questions investigating how a certain real-world feature should be modelled. In this part we used pictures from the field and current representations in the TDB and basemaps.

All together, 13 interviews were carried out with 16 interviewees. One interview lasted 1- 3 hours, with 1.5 hours as the average. A printout from the TDB in a scale of 1:10 000 was shown to all interviewees either from Helsinki or Turku region. A simulated version of the TDB from the case studies was also shown.

7.3 Results

7.3.1 Coverage and Content of Digital Basemaps

Coverage of the digital vector-based basemap compared with aimed coverage was rather good. On average there was an about 47 km^2 digital vector-based basemap in a municipality corresponding to 77% of aimed coverage (60 km^2). Median coverage was 28 km^2 corresponding to 92% of aimed median coverage (40 km^2). If we consider only 100 of the largest cities in terms of population, average coverage was 64 km^2 corresponding to 79% of aimed coverage (80 km^2). In sum, there was 6 676 km^2 digital basemap; aimed coverage was 8 158 km^2. If we compare the coverage of the digital basemap to the area of the municipality, average coverage was 6.7% and aimed coverage 8.2%. Table 7.3 represents the results.

Table 7.3 Coverage of the digital vector-based basemap

Order based on population	Municipality	Population 31.12.2003	Coverage of digital vector-based basemap (km²)	Aimed coverage (km²)	Coverage/ aimed coverage (%)	Area of the municipality (km²) source: the NLS 2004	Coverage compared with area (%)	Source date[48] the AFLRA[49]
1.	Helsinki	559185	184.47[50]	184.47	100	184.47	100	20.1.2004
2.	Espoo	224370	256.38	393.33	65	311.9	82	20.1.2004
3.	Tampere	201010	188	188	100	522.69	36	28.1.2004
4.	Vantaa	184187	55[51]	240.84	23	240.84	23	21.1.2004
5.	Turku	175104	238[52]	243.36	98	243.36	98	7.1.2004
6.	Oulu	125951	180[53]	195	92	373.10	48	13.1.2004
7.	Lahti	98294	134.95	134.95	100	134.95	100	13.1.2004
8.	Kuopio	88298	134.095	136.06	99	779.32	17	12.1.2004
9.	Jyväskylä	82451	105.92	105.92	100	105.92	100	the AFLRA
10.	Pori	76233	475	500	95	503.17	94	20.2.2004
11.	Lappeenranta	58923	160	160	100	760.03	21	7.1.2004
12.	Vaasa	56960	37.25	140	27	183.04	20	2.2.2004
13.	Kotka	54629	96	96	100	268.34	36	18.2.2004
14.	Joensuu	52667	50	50	100	81.87	61	7.1.2004
15.	Hämeenlinna	46921	96	96	100	166.62	58	22.1.2004
16.	Mikkeli	46536	93	93	100	1319.01	7	26.1.2004
17.	Porvoo	46231	46	85	54	654.41	7	13.1.2004
18.	Hyvinkää	43179	40	40	100	323.18	12	16.2.2004
19.	Järvenpää	37130	16	40	40	37.46	43	18.2.2004

[48] If no source name, source is the municipality
[49] Source the AFLRA's cadastre and mapping statistics 2002 (AFLRA, 2002b).
[50] Coverage incomplete in the outermost small islands (nearly 100%).
[51] Rest of the town in hybrid form, in sum about 60% in vector form.
[52] Contour lines missing in some border areas.
[53] 1:4000 digital map in scattered settlement areas, but content incomplete.

Order based on population	Municipality	Population 31.12.2003	Coverage of digital vector-based basemap (km²)	Aimed coverage (km²)	Coverage/ aimed coverage (%)	Area of the municipality (km²) source: the NLS 2004	Coverage compared with area (%)	Source date[48] the AFLRA[49]
20.	Rauma	36879	33	40	83	247.08	13	7.1.2004
21.	Lohja	36019	64.3	not set	-	278.46	23	27.1.2004
22.	Nurmijärvi	35914	97.11	97.11	100	362.49	27	3.2.2004
23.	Kokkola	35761	87	87	100	327.52	27	15.1.2004
24.	Kajaani	35725	94	94	100	1157.09	8	26.1.2004
25.	Rovaniemi	35097	67	67	100	94.28	71	19.1.2004
26.	Tuusula	33959	140	219.69	64	219.69	64	7.1.2004
27.	Jyväskylän mlk	33816	100	100	100	449.29	22	20.2.2004
28.	Seinäjoki	31709	109.5[54]	134.47	81	128.9	85	14.1.2004
29.	Kirkkonummi	31701	116	123.5	94	365.01	32	19.1.2004
30.	Kouvola	31367	43.81	43.81	100	43.81	100	20.1.2004
31.	Kerava	31182	30.75	30.75	100	30.75	100	22.1.2004
32.	Imatra	29998	154.81	154.81	100	154.81	100	22.1.2004
33.	Nokia	28099	71.35	91.35	78	289.09	25	7.1.2004
34.	Savonlinna	27544	65	65	100	822.26	8	9.2.2004
35.	Riihimäki	26655	33.5[55]	63.5	53	120.83	28	9.1.2004
36.	Salo	24967	37.5	37.5	100	143.39	26	21.1.2004
37.	Vihti	24967	72	86.5	83	521.97	14	15.1.2004
38.	Kangasala	23442	60	not set	-	355.69	17	12.1.2004
39.	Raisio	23441	46.5[56]	49.5	94	48.89	95	14.1.2004
40.	Kemi	23070	90.71	90.71	100	90.71	100	18.2.2004
41.	Varkaus	22774	72.90[57] (94)	not set	-	86.85	84	12.1.2004
42.	Iisalmi	22664	47	47	100	763.38	6	3.2.2004
43.	Raahe	22596	53.3	53.3	100	527.31	10	17.2.2004
44.	Tornio	22203	40	40	100	118.24	34	15.1.2004
45.	Rovaniemen mlk	21885	145	150	97	7506.45	2	2.2.2004
46.	Hamina	21772	69	69	100	606.98	11	8.1.2004
47.	Ylöjärvi	21698	30[58]	53	57	198.29	15	29.1.2004
48.	Kaarina	21147	50.75	59.7	85	59.7	85	21.1.2004
49	Heinola	20900	35	43	81	680.6	5	12.1.2004
50.	Hollola	20761	71.5	81.5	88	463.12	15	17.2.2004
51.	Valkeakoski	20470	44	88	50	272.96	16	30.1.2004
52.	Kuusankoski	20391	48	48	100	113.94	42	12.1.2004
53.	Siilinjärvi	20124	101.3	121.3	84	402.67	25	29.1.2004
54.	Pietarsaari	19433	67	67	100	88.43	76	13.1.2004
55.	Sipoo	18398	17[59]	73	23	364.1	5	9.1.2004
56.	Forssa	18114	45.24	45.24	100	249.39	18	22.1.2004
57.	Mäntsälä	17481	-	-	-	580.97	0	no answer
58.	Kuusamo	17405	-	-	-	5003.5	0	12.2.2004
59.	Lempäälä	17402	15[60]	70	21	271.65	6	25.2.2004
60.	Anjalankoski	17100	60	60	100	726.14	8	9.1.2004

[54] Area includes watercourses.
[55] The whole town area has been vectorized but not checked.
[56] Aimed coverage will be met by summer 2004, area includes watercourses.
[57] Coverage changed to exclude watercourses (in parentheses reported value).
[58] 1800 ha will be completed in 2005.
[59] In 2004 Söderkulla will be completed (566 ha), 300-500 ha/a during next decade.
[60] In addition there is 1400 ha of incomplete data available.

Order based on population	Municipality	Population 31.12.2003	Coverage of digital vector-based basemap (km²)	Aimed coverage (km²)	Coverage/ aimed coverage (%)	Area of the municipality (km²) source: the NLS 2004	Coverage compared with area (%)	Source date[48] the AFLRA[49]
61.	Mustasaari	17025	14	37.7	37	828.65	2	20.2.2004
62.	Laukaa	16932	-	-	-	652.14	0	no answer
63.	Haukipudas	16700	40.45	108.69	37	436.59	9	12.1.2004
64.	Uusikaupunki	16412	14.6	20	73	492.93	3	19.1.2004
65.	Janakkala	15517	0	0	-	548.26	0	22.1.2004
66.	Jämsä	15314	13	25	52	1003.98	1	13.1.2004
67.	Vammala	15234	25	52	48	598.72	4	12.1.2004
68.	Lieto	14779	44	44	100	199.19	22	29.1.2004
69.	Nastola	14738	6.8	55	12	325.02	2	13.1.2004
70.	Kauhajoki	14600	36	36	100	1299.78	3	25.2.2004
71.	Tammisaari	14489	45	45	100	721.1	6	10.2.2004
72.	Lieksa	14403	22.7	24.55	92	3424.78	1	3.2.2004
73.	Orimattila	14344	41	45	91	608.93	7	16.2.2004
74.	Pirkkala	14324	8	22	36	81.49	10	17.2.2004
75.	Lapua	14006	27	43.5	62	737.31	4	16.1.2004
76.	Naantali	13705	51.08	51.08	100	51.08	100	24.2.2004
77.	Äänekoski	13696	14	20	70	599.32	2	15.1.2004
78.	Kempele	13644	-	-	-	110.02	-	no data
79.	Ylivieska	13193	21.5	40	54	568.21	4	5.2.2004
80.	Kankaanpää	12784	0[61]	40	0	689.82	0	7.1.2004
81.	Pieksämäki	12521	4	25.1	16	36	11	The AFLRA
82.	Ulvila	12278	30[62]	40	75	137.94	22	29.1.2004
83.	Kontiolahti	12107	8.5	48	18	781.92	1	The AFLRA/ no answer
84.	Parainen	12006	36	70	51	271.6	13	26.1.2004
85.	Ilmajoki	11727	49	49	100	606.24	8	22.1.2004
86.	Liperi	11473	-	-	-	739.76	0	no answer
87.	Nurmo	11450	22	22	100	347.36	6	13.1.2004
88.	Kiiminki	11402	30	38	79	326.81	9	4.2.2004
89.	Keuruu	11393	-	-	-	1260.62	0	no answer
90.	Valkeala	11243	0	11	0	860.93	0	11.2.2004
91.	Leppävirta	11042	11.5	20	58	1139.23	1	8.1.2004
92.	Nivala	10902	13	13	100	529.55	2	14.1.2004
93.	Joutseno	10817	33.7	42	80	310.65	11	29.1.2004
94.	Sotkamo	10724	8.7			2649.69	0	29.1.2004
95.	Kuhmo	10636	25.3	25.3	100	4820.93	1	21.1.2004
96.	Kurikka	10631	11.5	11.5	100	463.05	2	19.1.2004
97.	Maarianhamina	10621	11.6	11.6	100	11.6	100	18.2.2004
98.	Pedersören kunta	10403	14	14	100	790.16	2	3.2.2004
99.	Suomussalmi	10389	23.3	23.3	100	5275.24	0	5.2.2004
100.	Saarijärvi	10208	20.6	28.7	72	887.4	2	19.1.2004
101.	Kitee	10033	0	0	-	864.88	0	3.2.2004
102.	Hämeenkyrö	10012	0	13	0	464.78	0	9.2.2004
103.	Kiuruvesi	9985	13	13	100	1331.04	1	16.1.2004
104.	Hanko	9920	0	66	0	114.47	0	14.1.2004
105.	Paimio	9793	35	35	100	239.32	15	21.1.2004

[61] Buildings and roads mainly in vector form.
[62] New map will be constructed 4000 ha by 2005, incl. old areas.

Order based on population	Municipality	Population 31.12.2003	Coverage of digital vector-based basemap (km²)	Aimed coverage (km²)	Coverage/ aimed coverage (%)	Area of the municipality (km²) source: the NLS 2004	Coverage compared with area (%)	Source date[48] the AFLRA[49]
106.	Kemijärvi	9767	22.72	25.82	88	3502.14	1	9.1.2004
107.	Alavus	9686	23	23	100	790.64	3	21.1.2004
108.	Somero	9682	21	21	100	669.02	3	no answer
109.	Pudasjärvi	9673	14.2	22	65	5646.25	0	9.2.2004
110.	Närpiö	9575	28.96	28.96	100	970.15	3	29.1.2004
111.	Eura	9381	16	16	100	431.41	4	16.2.2004
112.	Halikko	9377	-	-	-	356.79	0	no answer
113.	Sodankylä	9374	0.5	-	-	11773	0	no data
114.	Nurmes	9311	30	30	100	1605.37	2	16.1.2004
115.	Hattula	9198	19	20.5	93	381.49	5	23.1.2004
116.	Huittinen	9103	24.1	24.1	100	390.24	6	19.1.2004
117.	Kalajoki	9091	-	-	-	665.03	0	no answer
118.	Alajärvi	9062	19.2	25.2	76	738.18	3	9.2.2004
119.	Karjaa	9004	10	10	100	197.44	5	14.1.2004
120.	Oulunsalo	8928	-	-	-	80.78	0	ei vastausta
122.	Orivesi	8892	23.28	28.28	82	544.69	4	21.1.2004
123.	Karkkila	8768	28	28	100	242.73	12	22.1.2004
124.	Jalasjärvi	8767	20	20	100	821.56	2	16.2.2004
-	Pieksänmaa	8762	-	-	-	1538.77	0	no data
125.	Kauniainen	8619	5.9	-	-	5.9	100	7.1.2004
126.	Laitila	8589	20	20	100	531.33	4	5.2.2004
127.	Asikkala	8557	4.2	16	26	563.91	1	16.2.2004
128.	Muurame	8513	0	-	-	147.05	0	18.2.2004
129.	Elimäki	8512	-	-	-	383.01	0	no answer
130.	Kokemäki	8462	17.6	22	80	481.07	4	28.1.2004
131.	Toijala	8305	25	25	100	50.88	49	The AFLRA/ no answer
132.	Hausjärvi	8298	-	-	-	355.46	0	no answer
133.	Oulainen	8204	17.23	17.23	100	587.74	3	The AFLRA/ no answer
134.	Haapajärvi	8089	8.5	8.5	100	781.53	1	23.1.2004
135.	Kauhava	8085	0	17.2	0	483.81	0	28.1.2004
136.	Virrat	7986	12.5	19.6	64	1162.72	1	17.2.2004
137.	Muhos	7975	-	-	-	758.81	0	no data
138.	Kristiinankaupunki	7845	16.68	29.48	57	678.27	2	26.1.2004
139.	Outokumpu	7843	0	28.5	0	445.06	0	The AFLRA/ no answer
141.	Suonenjoki	7790	23[63]	33	70	719.57	3	22.1.2004
143.	Harjavalta	7741	37.1	40	93	124.41	30	27.1.2004
144.	Lapinlahti	7625	-	-	-	613.57	0	no data
145.	Ikaalinen	7607	20.55	20.55	100	752.19	3	The AFLRA/ no answer
146.	Viitasaari	7602	20	22	91	1249.43	2	The AFLRA/ no answer
148.	Parkano	7501	0[64]	31	0	855.17	0	21.1.2004
149.	Laihia	7475	0	0		507.34	0	21.1.2004
150.	Uusikaarlepyy	7451	17.94	29	62	723.09	2	2.2.2004

[63] 1000 ha waiting to processed.
[64] Aimed coverage will be completed by 2004.

Order based on population	Municipality	Population 31.12.2003	Coverage of digital vector-based basemap (km²)	Aimed coverage (km²)	Coverage/ aimed coverage (%)	Area of the municipality (km²) source: the NLS 2004	Coverage compared with area (%)	Source date[48] the AFLRA[49]
153.	Loviisa	7372	0	44.45	0	44.45	0	The AFLRA/ no answer
155.	Loimaa	7186	16	21.5	74	47.48	34	26.1.2004
158.	Ähtäri	7001	13	29	45	805.37	2	The AFLRA
160.	Kruunupyy	6799	2.9	14.1	21	713.07	0	19.1.2004
163.	Mänttä	6682	13.2	20	66	64.23	21	26.1.2004
164.	Nilsiä	6633	0	0		709.44	0	23.1.2004
186.	Juankoski	5690	12	16	75	467.37	3	13.1.2004
188.	Pielavesi	5646	-	-	-	1149.76	0	no data
196.	Suolahti	5464	15	15	100	57.87	26	4.2.2004

Figure 7.8 illustrates the coverage of digital vector-based basemaps compared with the area of a municipality. Most of the municipalities will not cover the whole area with basemaps. Coverage of the whole municipality was achieved in 10 towns: Helsinki, Imatra, Jyväskylä, Kauniainen, Kemi, Kerava, Kouvola, Lahti, Maarianhamina and Naantali. Almost the whole area of the municipality (at least 80%) was covered in Espoo, Kaarina, Pori, Raisio and Turku. At least 50% coverage was completed in Hämeenlinna, Joensuu, Oulu, Pietarsaari, Rovaniemi and Tuusula. In 21 municipalities, the coverage was at least 20%. The rest of the municipalities (51) had less than 20% coverage and 12 municipalities did not have a digital vector-based basemap at all.

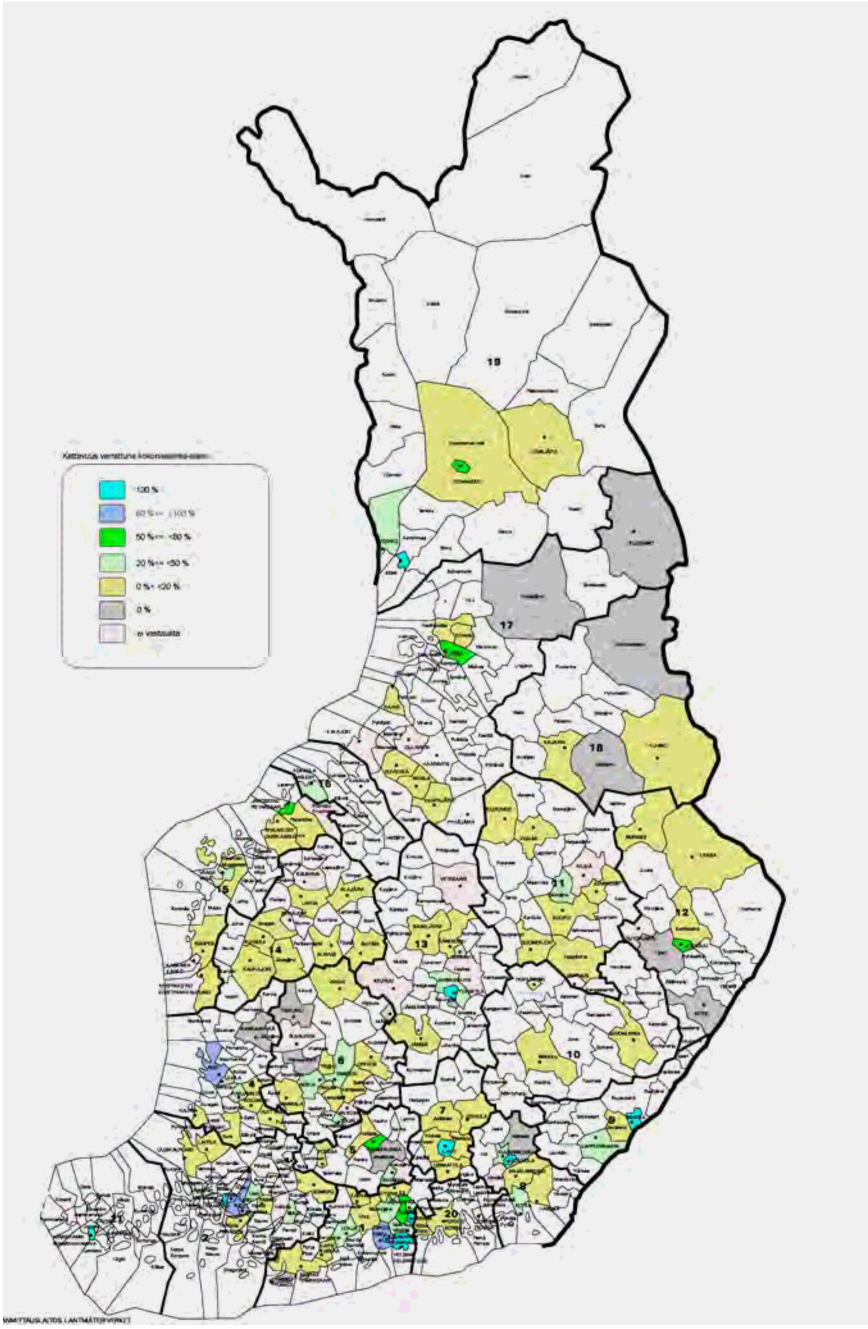

Figure 7.8 Coverage of the digital vector-based basemap compared with area of a municipality

The questionnaire covered all major cities in Finland. Figure 7.9 represents the coverage of digital vector-based basemaps compared with aimed coverage classified by population. We can conclude that middle-size towns have best met the aimed coverage. Most work is yet to commence in small towns and municipalities (less than 20,000 inhabitants). The situation in smaller municipalities seem to be better but probably this due to fact that this questionnaire did not cover all the small municipalities. In the selection process, only the best small municipalities were included in this study.

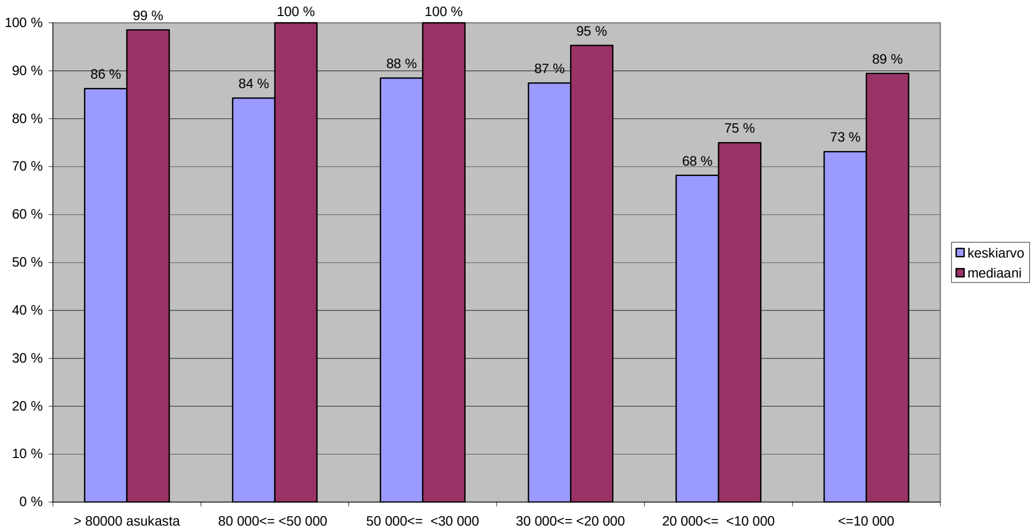

Figure 7.9 Coverage of the digital vector-based basemaps compared with aimed coverage

If we evaluate how large-area basemaps cover in Finland, we can make some estimation based on the results. The questionnaire covered 64-67% of all built-up areas in Finland. According to the Statistics Finland built-up areas covered 2.5% of the area of Finland. Generally, the digital basemaps covered larger areas than those that would be calculated as built-up areas as defined in the statistics. Digital basemaps covered 2.7% of the whole country. In the municipalities not covered by this study the statistical built-up areas covered 2,700 km^2. Most of those built-up areas are probably covered by anolog basemaps. Therefore, we can infer that digital basemaps cover 2.7 – 3.5% of the whole country.

7.3.2 Comparsion of Results Between Data Catalogues

We found an equivalent or derivable connection for 93 feature types of 143 main feature types represented in the data catalogue of the TDB. Table 7.4 represents the connections by main feature types.

Table 7.4 Connections between main feature types in the data catalogues of the NLS and the AFLRA.

Main feature type	Number of connections	Number of main feature types in the data catalogue of the NLS
Roads	1	4
Buildings	17	24
Terrain (including Terrain/1 and Terrain/2)	43	52
Others	32	63
Summary	93	143

Detailed connections between the NLS and the AFLRA data catalogues are included in the research report (Jakobsson & Huttunen, 2005).

Figure 7.10 illustrates the similarity between classifications schemes. When there was an equivalent feature type, the similarity between feature types was studied. As result, three options might be noted. Result “same” denotes that classifications are either the same or it can be directly derived using hierarchy or attribute information. If the classifications are not the same then two different options might follow. If there are several classes representing the same real-world phenomenon, then the result is reported as “several classes”, otherwise there is only one feature type with a “different” classification. There were 93 feature types of 143 feature types in the TDB for which we could find a connection with feature types in the AFLRA data catalogue. Fifty-three feature types had the “same” classification (this equals 38% of all feature types in the TDB), 16 were different and 11 had several corresponding classes in the AFLRA data catalogue. Figure 7.10 represents only the feature type that had an equivalent feature type enabling the comparison with the AFLRA data catalogue to the municipality data catalogues. We can conclude that Mikkeli had most similarity with the AFLRA data catalogue and Helsinki had the least. One of the reasons might originate from their history: the classification system in Helsinki has been developed earlier than the AFLRA’s classification. Mikkeli has relied mostly the version provided by the GIS provider explaining the closeness to the AFLRA. Finally, we can conclude that the classification systems used in the municipalities are not sufficiently compatible, and that this prevents national usage of municipality data. Harmonization between the municipalities is required from a national perspective.

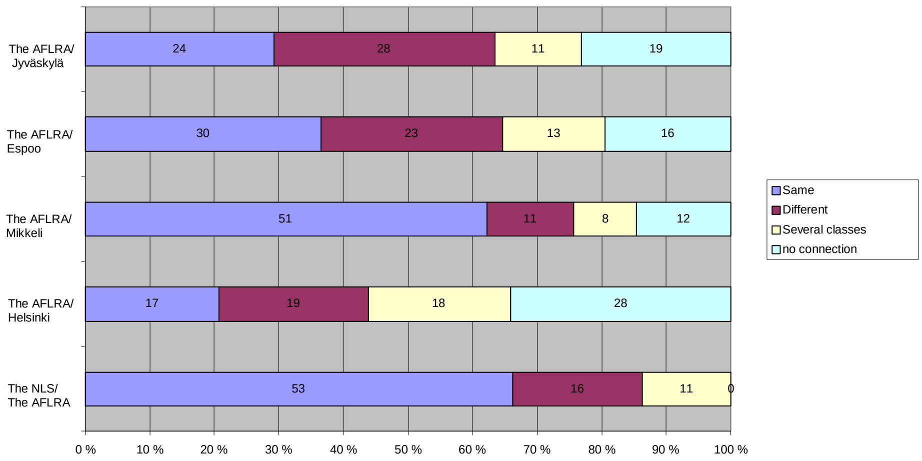

Figure 7.10 Similarity of the classifications

7.3.3 Results in Research Areas

Figure 7.11 presents the TDB in the Olari area and Figure 7.12 the simulated TDB using the Espoo basemap for constructing the TDB. We found a connection between 67 feature types (81%), of which 42 did not exist in the research area and the connection is not validated. No connection was found in 16 classes (19%). If there was a need for generalisation, then manual was the most common type. Detailed results are presented in the report (Jakobsson & Huttunen, 2005).

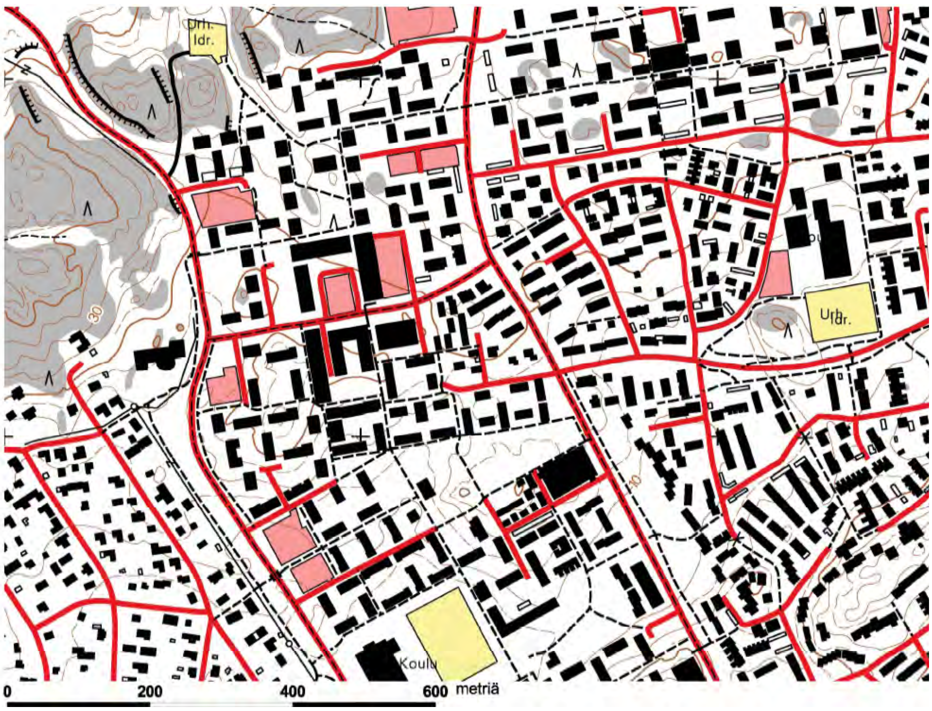

Figure 7.11 A printout of the TDB in Olari

There was a 2 m error in the centre line of the road provided by the Espoo. The reason probably was that this centre line had been digitised from the basemap and doesn't necessarily follow the road borderlines. No walking and cycling paths were found in Olari. The geometry was presented using other feature types e.g. border of pavement etc. Classification used in roads varied so that similar features in the real world had differences in classifications. Buildings were correctly located, but some were not presented as polygons. This turned out to be new buildings that had not completed the inspection process and therefore were not presented with a "raster" area. The building borderlines consisted of many different line classes, which formed a closed polygon. Classification of buildings did not conform to the AFLRA or the NLS classification and we could not use it. Public parking places were not indicated in Espoo. Exposed bedrocks, gravel fields, parks, fields were classified as linear features. Parks will be presented as polygons in the future. We tried to form polygons using these linear features; this turned out to be difficult because of missing parts.

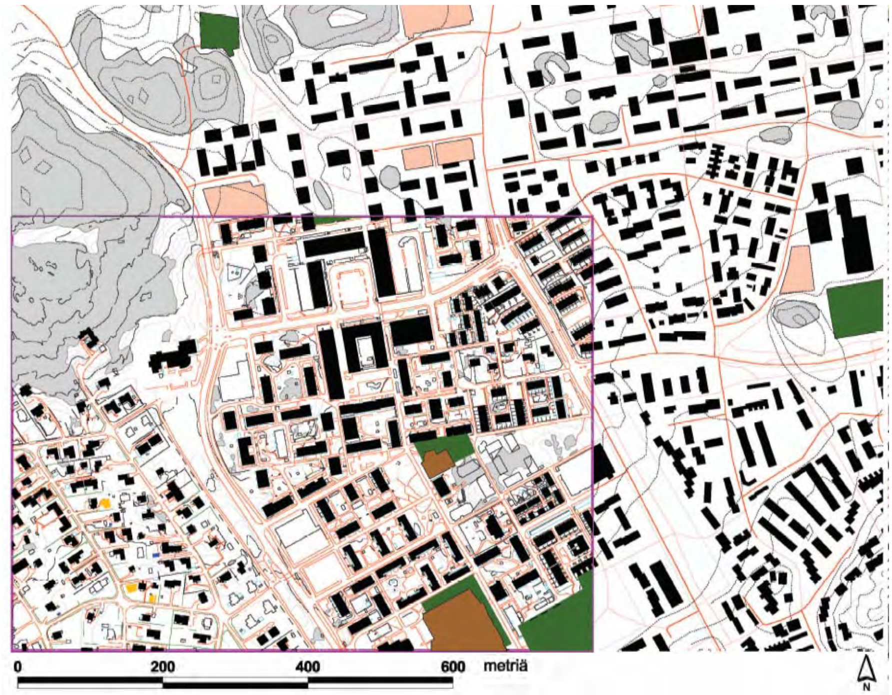

Figure 7.12 Simulated TDB in Olari surrounded by the TDB

Examining the Figure 7.12 we can notice that geometry of building is similar in the simulated and real TDB. The reason was that building information from Espoo has already been utilized in the production of the TDB. Road classification changes from centre line geometry to border lines in the simulated TDB. In the simulated TDB some of details were left intentionally so we could examine the needs of such features in the TDB.

Figure 7.13 presents the TDB in the Kamppi area and 7.15 the TDB in Mellunmäki. Figures 7.14 and 7.16 present the simulated TDB using the Helsinki basemap for constructing the TDB. We found a connection between 54 feature types (68%), of which 27 did not exist in the research area and the connection was not validated. No connection was found in 25 classes (31%). If there was a need for generalisation, then manual was the most common type. Detailed results are presented in the report (Jakobsson & Huttunen, 2005).

Figure 7.13 A printout of the TDB in Kamppi

Walking and cycling paths were modeled as gravel roads when they were not connected with a road; otherwise a road borderline was used. Therefore, it was impossible to indentify walking and cycling paths. Helsinki has decided to model roads as area features, but this was not available when we did the research. Buildings were modeled as area features using some hidden lines if necessary. Green spaces will be modeled as area features in the future, but this has not yet been accomplished. The geometry of water courses had been already been converted to area features in 2004, but this was not the case in the dataset we obtained. Parking places were not modeled as area features, but this work has been started.

Figure 7.14 A simulated TDB in Kamppi

Also in Helsinki, the NLS had used building from the city of Helsinki, which explains the exact matching between the TDB and simulated TDB in Figure 7.14. The rather large white space in the simulated TDB is due to a construction of this area, which is now nearly completed.

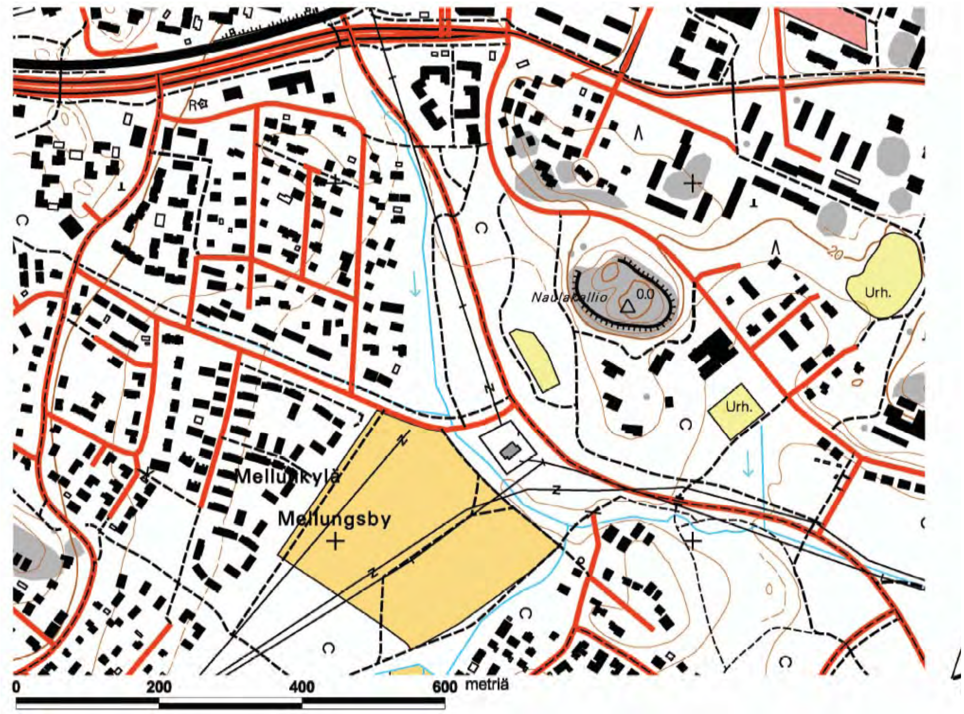

Figure 7.15 A printout of the TDB in Mellunkylä

Also in Mellunkylä the buildings match exactly because the original in both data-sets is the city of Helsinki. However, we found rather many errors the buildings of the TDB in this area, which is explained later.

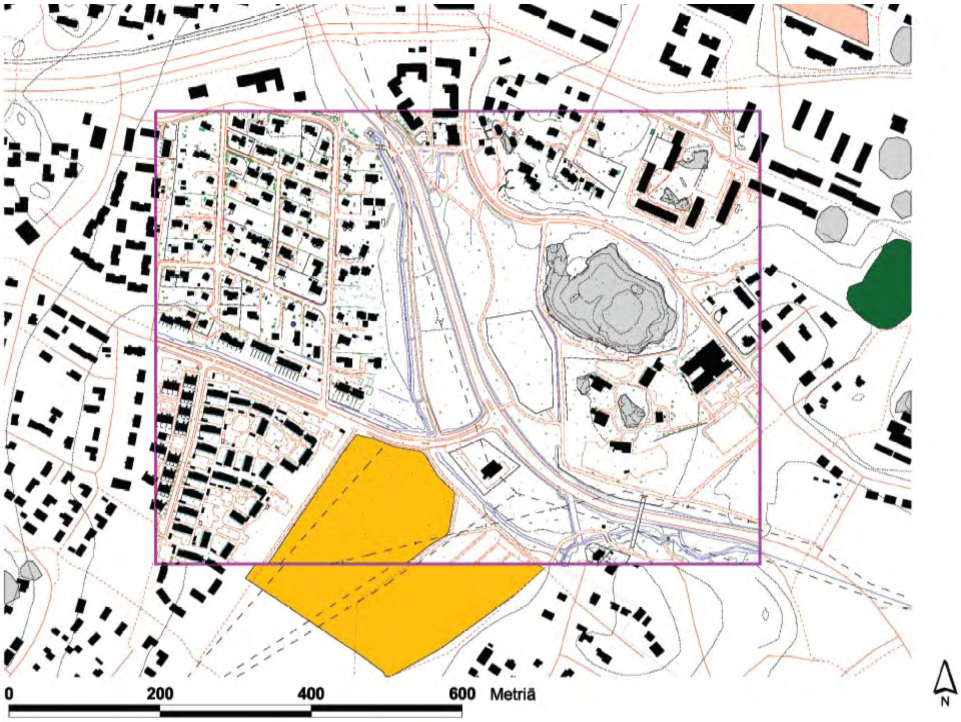

Figure 7.16 A simulated TDB in Mellunkylä

Figure 7.17 presents the TDB in the Lutakko area, while Figure 7.18 presents the simulated TDB using the Jyväskylä basemap for constructing the TDB. We found a connection between 60 feature types (74%), of which 37 did not exist in the research area and the connection was not validated. No connection was found in 21 classes (26%). If there was a need for generalisation, then manual was the most common type. Detailed results are presented in the report (Jakobsson & Huttunen, 2005).

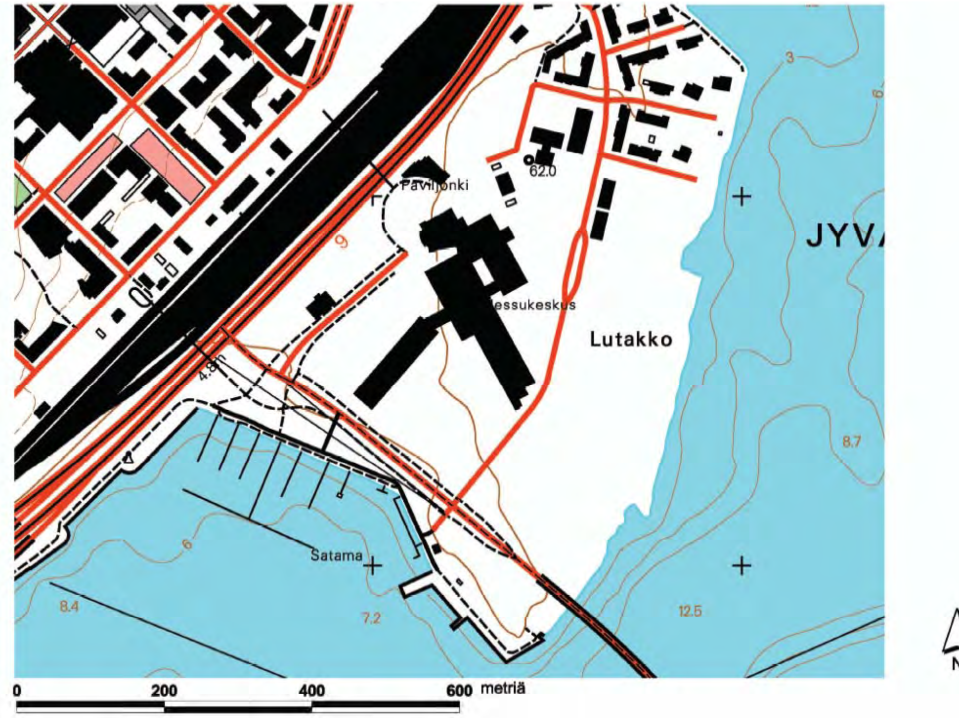

Figure 7.17 A printout of the TDB in Lutakko, Jyväskylä

Also in Jyväskylä the existence of the building identification code was dependent upon completion of the permit process. First, when the construction process begins, the building plan is presented as a separated map and it is transferred to the basemap after the foundation has been completed. Exposed bedrock and watercourses were presented as area features but fields were not. There were lots of slopes identified in the data we got from Jyväskylä, but none in the TDB from the NLS.

Figure 7.18 A simulated TDB in Lutakko, Jyväskylä

Figure 7.19 presents the TDB in the Rantakylä area and Figure 7.20 presents the simulated TDB using the Mikkeli basemap for constructing the TDB. We found a connection between 72 feature types (88%), of which 43 did not exist in the research area and the connection was not validated. No connection was found in 10 classes (12%). If there was a need for generalisation, then manual was the most common type. Detailed results are presented in the report (Jakobsson & Huttunen, 2005). In Jyväskylä, we got the centrelines from the municipality.

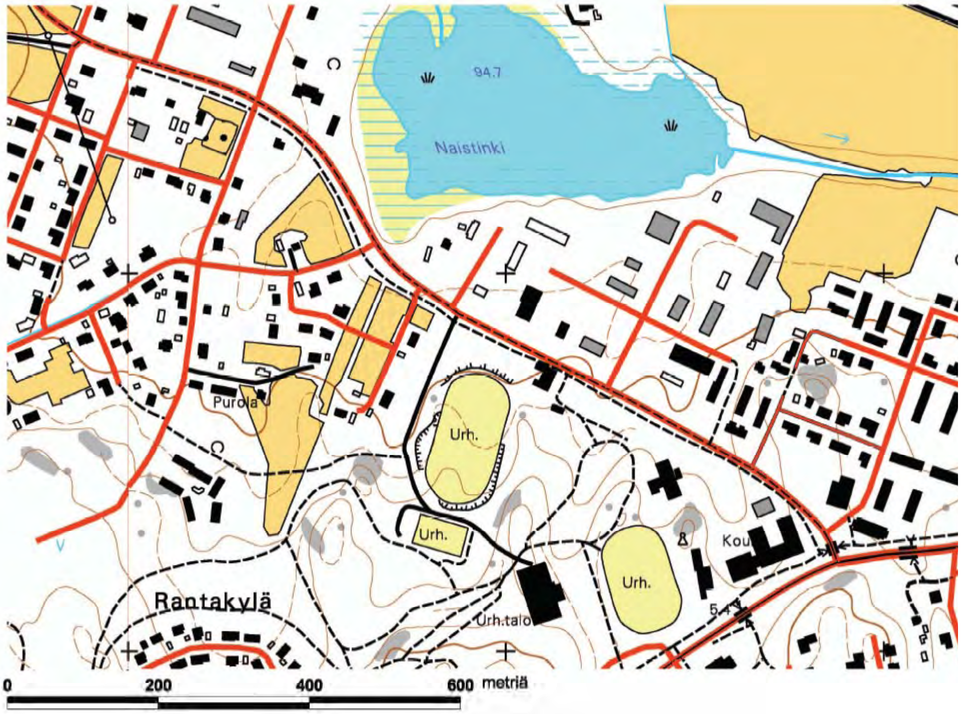

Figure 7.19 A printout of the TDB in Rantakylä, Mikkeli

Roads were presented as borderlines in Mikkeli. We could derive walking paths from the municipality data, but not the cycling paths, which were modelled as gravel roads or road borderlines. Sport fields and recreational areas were modelled as linear features. We tried to use this information, but the results were not satisfactory. Paludified areas were presented as symbols, which cannot be used to form an area feature. Fields were presented as borderlines with symbols inside and we could use them to form area features.

Figure 7.20 A simulated TDB in Rantakylä, Mikkeli

7.3.4 Quality Evaluation Results

After transforming the datasets to Arcview, we visited all research areas and compared the results with reality. An inspection was carried out using printouts so we could not notice all the differences we would have been able to notice if we had digital data in the terrain. In this case, it was not possible to use a field computer in the inspection. We had printouts from both the TDB and municipalities. Usually, only one visit was made but we visited Mellunkylä three times, Kamppi two times and Espoo two times.

Findings were classified as data quality errors, model differences or related to production process. Quality errors were classified using quality elements in the ISO 19113 standard. Model differences were classified as differences in geometry, classification, generalisation, 3D or missing feature type. Some of the findings were related to production processes.

Figure 7.21 represents an example of how findings were recorded. Classification of the findings is identified in the title with some comments from the researchers and in some cases, from the municipalities or the NLS. The municipalities and the NLS had an opportunity to comment on the results.

Figure 7.21 An example of the quality evaluation of the datasets (in Helsinki)

Table 7.5 represent the number of model and process findings in the research areas. The findings verify the findings in the comparison of the classification explained earlier. We can conclude that the most important changes in the classification of the basemaps are: change of geometry in the roads (the present classification used in the TDB can not be derived), classification of walking and cycling paths, collecting all different linear building borderlines to one, classification of parking places, using area features in the terrain features (fields, water courses etc.). Most of the findings were related to a rather “old fashioned” data model, i.e. features were collected for cartographic purposes rather than as real-world features.

Table 7.5 Findings in the research areas

Type of the finding	Number of findings			
	Helsinki[65]	**Espoo**	**Jyväskylä**	**Mikkeli**
Model difference (sum)	8	21	7	12
geometry	1	3	1	5
classification	1	2	1	4
generalisation	4	10	2	1
3D	-	-	1	-
Missing feature type	2	6	2	2
Process (sum)	-	3	-	1

The data quality results are given in Table 7.6. These indicate how the current production processes are functioning.

Table 7.6 Data quality results in research areas

Data quality element	Number of errors							
	Helsinki		**Espoo**		**Jyväskylä**		**Mikkeli**	
	City	**NLS**	**City**	**NLS**	**City**	**NLS**	**City**	**NLS**
Total	**17**	**30**	**16**	**8**	**11**	**23**	**14**	**10**
Completeness	15	19	8	8	9	21	2	9
Positional accuracy	-	6	-	-	1	-	-	1
Thematic accuracy	1	4	-	-	1	1	-	-
Logical consistency	1	1	8	-	1	1	12	-

We can conclude that the quality of the basemaps was rather good based on small number of errors, especially concerning roads and buildings. We cannot derive the results for all basemaps because research areas were very small. Also, a number of findings in Espoo and Helsinki are related to several visits. In addition, in Helsinki we had two areas, which increased the number of findings. If we consider the research areas, Helsinki appeared to have the best quality together with

[65] Helsinki includes two research areas

the NLS data in Espoo. The second-best evaluation gets the data in Mikkeli from the NLS and data in Jyväskylä from the city. Most errors we noted in Jyväskylä and Helsinki from the NLS. The Lutakko area in Jyväskylä had a lot of changes, therefore, most errors consisted of missing buildings. However, data in Helsinki from the NLS was not related to new features and indicated some problems in the updating process.

7.3.5 Usage of Municipality Data in the NLS

The managers of mapping in the district survey offices identified only 15 municipalities, where they had used municipality data. A contract had been entered with 7 municipalities. Usage had been based mainly on barter. Experiences included: two much workload compared with gains, municipality data too expensive (which hinders the usage), if buildings should be updated annually then municipality data would be used more often, no tools in the GIS to use municipality data, municipality data too old, revision process in the municipalities is not working, copyright issues.

7.3.6 Requirements for Harmonization of Topographic Data

In this study, the research questions were: Is there a need for a national topographic database in built-up areas and what users would benefit if the TDB were based on municipality data in built-up areas. Using interviews we examined this need.

Interviewees mentioned the following user requirements for topographic data in built-up areas: estimation of fuel consumption of, for example, forest companies, web services and visualization, planning telecommunication network, delivery of post, for example, waste management, security, fire and rescue services, police, emergency centres, production of geographic information, for example, orthophotos and 3D models, environmental protection, planning of electrical networks, building inspection, road planning, and combining registers.

Some companies emphasized the usefulness of vector-based data over raster-based. They felt that web services need vector-based data, which enables the selection of features and high-speed services. Some governmental agencies used only raster-based data (based on scanned basic maps).

All interviewees were asked whether there was a need for uniform topographic data in the whole country. All agreed, mentioning the following reasons: buildings and roads are important and built-up areas the most important, the need for a national use of data, uniform quality in the whole dataset, similar formats and presentation, analyses covering large areas. Also, it was asked whether there was a need for better accuracy in built-up areas. Some agreed and some were satisfied with the present level of accuracy. Better accuracy was said to be required mainly in planning of electrical networks and waste management.

We investigated opinions related to some national applications. In 2004, the NLS and municipalities were developing a new cadastral data service (UKTJ), which uses both the NLS topographic data and basemaps from 86 municipalities as background map in raster form. The system is now in use, but at that time the interviewees had no clear opinion of whether the cadastral data service would require more harmonized topographic data. DIGIROAD, which is the national road dataset, was also included in the questions. The NLS has provided road geometry for the datasets, while municipalities have supplied some attribute information. Some of the interviewees had a good knowledge of the system and they felt that part of content of the TDB would be useful for DIGIROAD. Land-use information especially would be useful. The third possible national system that would require national topographic data is the planning information system but because development has not been started it was left out this time.

Municipalities felt that there is some need to use the TDB in the production of more generalized products. Also, in regional planning the municipality data is too accurate and detailed to be used. In general planning also, there was a need for common topographic data.

In general, the interviewees were satisfied with the current content of the TDB. There was no indication of useless feature types. Most of the identified needs were related to buildings and road networks. Nearly all were interested in these feature types. The currency of building information was especially emphasized.

It was considered important that buildings and other constructions are presented with rather good accuracy based on corner points. There was no need for generalisation. Elevation information was required. 3D modelling was not required, but some indicated it would be useful. Buildings should contain building identification codes enabling the combination of many attributes. Main entrance to the buildings was seen as important information, together with address information (a building identification code would make this available). Some critical features, for example, the main building in building complexes, and the main church etc., should be presented.

In the elevation model, road elevation should be included and a possible one-meter pixel size in built-up areas.

DIGIROAD satisfies many of requirements concerning roads (although it was not available at that time). The classification of roads in the TDB should be changed enabling generalisation needs based on classes. Road borderlines were important in electrical planning and building inspection, but also centre lines together with intersection areas. Short private roads leading to real properties, which are not presented in the TDB, should be included for route optimisation and delivery purposes. Land use should be complete, especially inside industrial areas and forest.

7.4 Discussion

7.4.1 Compilation of the TDB Using Municipality Data

Results indicate that it would be possible to derive the TDB in built-up areas using municipality data. The digital vector-based basemaps can be estimated to cover 2.7 – 3.7% of the country. These areas include major part of the Finnish infrastructure and majority of people and buildings. Most deficiencies are related to natural features in the basemaps. Quality evaluation indicated that positional accuracy is adequate but improvements are needed in other quality elements. The modelling of basemaps requires further developments enabling economical national usage. Good example is lack of area features for fields, parking places and roads. Some municipalities have a road centreline but accuracy was not the same as in the basemap and in research areas it was even worse that the TDB. Connecting the use of building identification code to inspection process should be reconsidered. Users outside municipality have no possibilities of knowing this. Revision process seem to be functioning in municipalities with population over 20 000 for buildings, roads and cadastral information. The results didn't support the idea that use of municipality data would enable more rich information content in built-up areas. Basemaps are ideal for updating buildings in the TDB because those were most up-to-date beside cadastral information. Current digital basemaps can be considered as map datasets instead of base topographic datasets.

7.4.2 Technical Analysis

Present data models do not support the use of the basemaps for national purposes. The connection between the models is not defined. In this research, the GIS used was not the best choice because we could not use object-based modelling. The selection was made because of available resources. We did not make a transformation of co-ordinate systems because municipalities could deliver data in the national co-ordinate system (KKJ). Most difficulties were related to interpretation of semantic meaning of classification with reality. One real-world feature might be presented using several different classes. Connections between those classes were not indicated and, therefore, giving no support to the decision process. In most cases, we had only the name of the feature class with no description as how it relates to reality. The actual transformation process from municipality to Arcview was rather difficult and time consuming. Because of these difficulties in the data transfer process, we can infer that national usage of municipality data is rather low. The present classification fails to support the national usage and should be harmonized.

7.4.3 Need for Generalisation

In this research, only selection was used for generalisation. A change of geometry would have been used for roads (i.e. borderline to centreline). We examined the possibility of using area presentation in the simulated TDB; the results are presented in Figure 7.22.

We evaluated the need for simplification by comparing dataset sizes. Table 7.7 describes the results of the comparison. At present the size of the TDB equals 1 – 5% of the same basemap. Using selection reduced 40-60% of the size. We can conclude that some simplification is needed if basemaps are used.

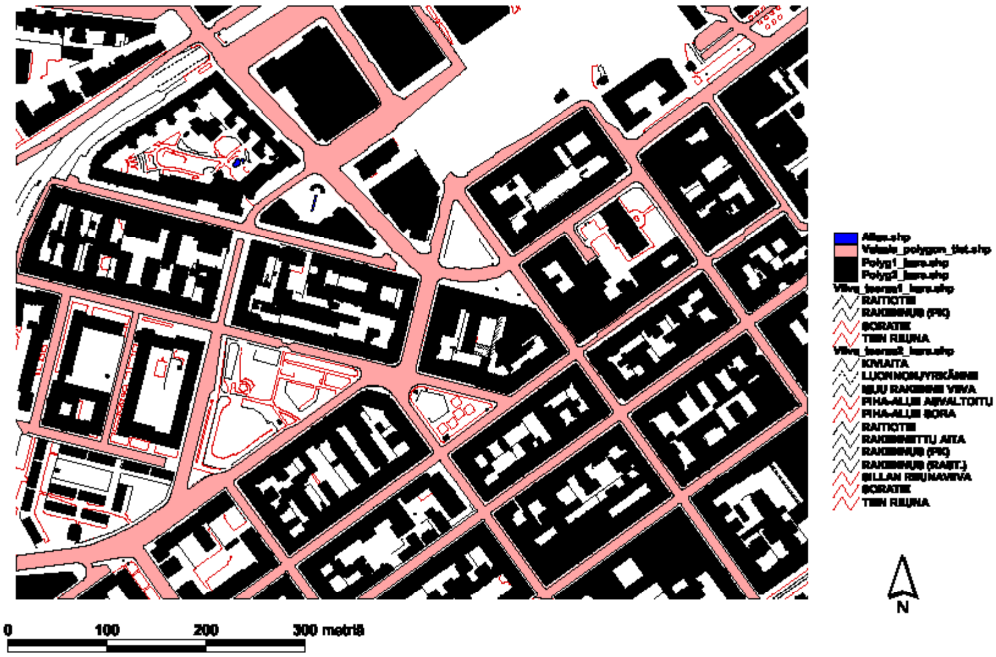

Figure 7.22 Representing roads as areas in Kamppi

Table 7.7 Size of the dataset in research areas

Research area	Size of the basemap (MB)	Size of the TDB (MB)		Size of the simulated TDB	
		(MB)	compared with the basemap (%)	(MB)	compared with basemap(%)
Kamppi	8.37	0.42	5	3.47	41
Mellunkylä	8.92	0.28	3	5.44	60
Rantakylä	3.85	0.20	5	1.47	38
Lutakko	11.6	0.14	1	5.13	44
Olari	44.8	0.38	1	17.0	38

Earlier, Ollila (1996) carried out research into the generalisation of basemaps and concluded that generalisation algorithms could be derived even when data models are the ”worst possible”.

7.4.4 User Requirements

In user-requirement study, we tried to identify the most important feature types and needs for the development of the content. While our study did not indicate any need in the cadastral data system, we still believe that harmonized topographic data would be very useful for this purpose. Also, DIGIROAD, combined with harmonized topographic data, would be very useful, although this study could not indicate this clearly. The scenario method, which could have demonstrated the usefulness of this, might have given different results.

Possible changes for the data model of the TDB in built-up areas include recreational areas and parks. In these areas, more functionality might be presented. It should be considered to complete the network of cycling paths. Now, these are presented completely only outside built-up areas. Separate lanes of roads would be important for navigational applications. Now, railroads have more details compared with roads. In general, representation of the functions is not necessarily included in present models of the NLS and municipalities. A good example of this are service stations, which should be presented, but, because many or even most of them are now only ‘cold’ stations, they are not presented.

7.5 Evaluation of the Study

7.5.1 Questionnaire on the Coverage and Content of Basemaps of Municipalities

We compared results with statistical information of built-up areas (Statistics Finland, 2003). In sum, the 156 municipalities covered in this research had 366 statistical built-up areas according to the Statistics Finland. All together, there were 748 built-up areas in 2000 and we can conclude that this study covered 49% of built-up areas. These 366 statistical built-up areas cover 5085 km^2 with a population of 3,817,423, which equals 89%[66] of the population in 156 municipalities (size of population was 4,292,393 according to Population Register Centre [2003]). In 1996[67], the Statistics Finland announced that 81% of the population lived in built-up areas and the land area of built-up areas was 7,600 km^2 (2.5% of the whole country). In 2000, 83.1% of the population lived in built-up areas, but the land area was not reported in 2000. A statistical built-up area is defined as including at least 200 people, with a maximum of a 200-meter distance of between buildings. This masking does not take into account any administrative boundaries.

Our questionnaire covered 64 – 67% of the area of the built-up areas depending on which municipalities we included in the results. We did not have answers from all 156 municipalities but coverage was gained from 141 municipalities. This research covered all the 100 most populated municipalities in Finland.

Questionnaire was sent to experts in the municipality and therefore the results should present the best available knowledge. In small municipalities, this study represents probably the best municipalities because of the selection process.

[66] Percentage is not accurate because original data is derived from different years and statistical built-up areas include sometimes many municipalities.
[67] Bulleting of the Statistics Finland

Table 7.8 Statistical information of municipalities included in the questionnaire

Included municipalities	Number of built-up areas (Statistics Finland 2003)	Area of built-up areas (Statistics Finland 2003)	Population in built-up areas (Statistics Finland 2003)	Number of built-up areas in this research compared with total number of built-up areas (748) (%)	Area of built-up areas in this research compared with total area of built up area in 1996 (7600 km²) (%)	Population in built-up areas compared with total population of municipalities in 2003 (%)
The whole material 156 municipalities	366	5,085	3,817,423	49%	67 %	89%
Municipalities that answered or coverage gained other wise (141)	336	4,885	3,741,471	45%	64 %	87%

We can compare results with statistics of the AFLRA from 2002 and preliminary results from 2003 (AFLRA, 2002b; AFLRA, 2004). In 2002, the coverage of basemap either in digital or graphic form was 2,623 km^2 with a scale of 1:500 (44 respondents), 2,198 km^2 with a scale of 1:1 000 (63 respondents), 2,988 km^2 with a scale of 1:2 000 (57 respondents), 12,144 km^2 with a scale of 1:4 000 (36 respondents). Correspondingly, in 2003, the coverage was 862 km^2 with a scale of 1:500 (21 respondents), 624 km^2 with a scale of 1:1 000 (16 respondents), 188 km^2 (7 respondents) with a scale of 1:2 000 and 4 km^2 (1 respondent) with scales of 1:4 000 – 1:5 000. The statistics of the AFLRA do not indicate whether the different scales are overlapping (which is the case in some municipalities and with some scales) and the coverage was not satisfactory.

7.5.2 Research on Data Catalogues

Our aim was to carefully select the municipalities for the case study to achieve maximum representativeness. Also in research areas we tried to select different types of built-up areas. The knowledge of Matti Holopainen from the AFLRA was utilized in the selection process. Based on his recommendation, the two main GISs used in municipalities, Xcity and Stella, were chosen as a basis for selecting municipalities for this research. According to the NLS investigation into the development project of the new cadastral data system (UKTJ), which covered 86 municipalities, 27 municipalities uses Xcity (Tekla), 26 Stella (Bentley), 14 ZetMap (VM-Data) and rest systems based on AutoCAD (Fiksu, YTCAD, VidGIS) and Mapinfo. All of the 20 most populated municipalities used either Xcity or Stella. We also tried to use the knowledge of managers in the mapping process in district survey offices, for selecting the research areas, but most recommendations were combined with production needs, which we could not accept. Research areas did not cover small municipalities, which typically use classification system developed by the contractor. However, national interest in the data from small municipalities is not so high. All our research municipalities were among the 16th most populated municipalities and we can conclude that our results represents rather well all the municipalities with at least 50 000 inhabitants. However, it should be noted that all municipalities are individual as the results indicate.

7.5.3 User Requirement Study

We interviewed most significant resellers and customer groups of the NLS. Therefore the results represent quite well the electrical network branch, waste management, municipalities and fire and rescue services. This study did not explore the requirements of end users. According to the user requirement study in the GiMoDig-project (Jakobsson, 2003), usage areas for topographic data can be categorized as: safety and emergency, guidance and navigation, information services, restrictions of use or movement, military, and logistics (see Figure 15 in Paper V). We covered safety and emergency, guidance and navigation and logistics in this study. We could not examine the requirements of citizens in this study or military requirements.

7.6 Recommendations

7.6.1 General Recommendations

We can conclude that basemaps can be utilized for production of the TDB. Data catalogues represent the same real-world features enabling the harmonization. The present classification and data catalogues are not interoperable, and, without changes usage of municipality data will not increase. Harmonization of data catalogues should be considered based on the requirements of the geographic information strategy (NCGI, 2004). According to the implementation programme of the strategy: "The roles of administrative organizations (data custodians) engaged in maintaining core geographic datasets need to be clearly defined in the national legislation and in administrative decisions." (NCGI, 2005:17). Further "the administrative organizations responsible for core datasets should take it upon themselves to ensure that common standards and recommendations are adopted and, equally, that common processes promoting data maintenance and the development of data services are planned and introduced". According to the strategy, the permanent cooperative body (which is now established) "shall ensure that basic geographic data are defined and that the requirements to be fulfilled by these are determined by the end of 2005."

Based on the questionnaire give to the managers of mapping in district survey offices, the present approach based on agreement between the NLS and the AFLRA has not been successful. Municipality data is considered to be too expensive and too laborious to use. In some cases, its being too expensive has hindered its use. The present agreement between the NLS and the AFLRA has not given enough guidance in utilizing the data. At the moment, the use of municipality data requires generalisation based on the agreement, while results of this study do not support this fully, for example, according to the user requirement study buildings should not be generalized. On the other hand, present production guidance and result-based management in the NLS does not require the use of municipality data. One of the major questions is the copyright issue, which currently hinders the usage of municipality data. The NLS delivers all the datasets to customers and there is little use inside of the organisation.

Both basemaps and the TDB are produced on the basis of the requirements of society, and therefore the usage cannot be evaluated based only on market analysis. Municipalities are the most important users of basemaps and we can infer that national usage, at present, is rather small. According the questionnaire, the pricing polices (not presented in this summary) varied in municipalities and some have not set them, while the AFLRA has given a recommendation on pricing. There has been debate on the question of whether municipalities should give information to national government without payment, while the government is charging its services from customers (Holopainen, 1997). A working group in the Ministry of Finance has proposed changing the pricing policy in intragovernmental information sales so that data sales would be based on distributing costs. If this is implemented, then one barrier will be abolished.

We introduce a recommendation on common guidelines, which may postulate development in legislation. Production of topographic data in Finland is already based on legislation, and therefore common usage of this information could be rather naturally being based on legislation. Examples of this already exist in the legislation relating to the population register (buildings), cadastre and roads

(DIGIROAD). In the Geographic Information Strategy, the development of legislation is also considered.

7.6.2 Recommendations for Development of Guidance

At present, guidelines for surveying basemaps fails to set any requirements for common digital data. This can be considered as a deficiency because most municipalities update digital datasets and a common model is required for national usage. This study indicates that the AFLRA's data catalogue is interpreted differently in different municipalities. However, the AFLRA's data catalogue provides a good basis for further development. Guidelines for surveying basemaps should include criteria for digital data. The NLS and the AFLRA should evaluate whether current legislation gives grounds for this.

Development of a common model for topographic base data should be initiated. In Finland, we have had an example of this already in 1960 for graphic topographic data. Common guidelines should cover harmonization needs in Europe (INSPIRE directive), national usage of municipality data, user requirements and users inside municipalities. Guidelines should be based on international standards (e.g. ISO 19100 series and specifications of Open Geospatial Consortium).

Guidelines should contain harmonized classification based on different accuracy and generalisation levels, description of feature types, quality requirements and quality assurance guidelines. Description of feature types should be based representing real-world objects and abandon the cartographic model. Unique identifiers should be introduced for the management of features. Technical specification for data transfer should be included.

A common data model will create the possibility of the national usage of municipality data, which will increase its use. It will also enable common GISs for municipalities and therefore decrease IT costs. Producers will save costs in production because of harmonized specification enables better competition and quality assurance.

7.6.3 Recommendations for the NLS and Municipalities

The NLS and municipalities should consider a common database for topographic base data. This would enable better services for customers and it would support the common cadastral data system and proposed planning database. A common database would probably provide the best solution for the harmonization of national and local datasets and updating. A technical solution might be based on multiple resolution database and unique identifiers. This has been proposed by the author (Jakobsson, 2000; Jakobsson & Salo-Merta, 2001; Jakobsson 2002b) and technical solution has been discussed by Kilpeläinen (1997). In this context, we do not propose a technical solution. One option might be based on distributed databases forming a virtual database. National legislation should be changed to enable a common database.

A common database would not end the updating processes in the NLS. The role of the updating process would change in built-up areas. The NLS should assure quality and perhaps offer some updating services, relating to natural features, for example, or a complete service for the municipality. The updating process could be based on tenders in built-up areas.

7.7 Future Research

Both research and development are required. Future research could be concentrated on technical aspects of a common database, for example, a multiple resolution database, use of unique identifiers in database technology, and semantic modelling. The approach in this study has been the harmonization of data models, which would enable common use. We did not consider technical implementation, but, from the users' point of view, a virtual database should be established. Technically, traditional data warehouse concepts, distributed databases, mediator services and ontology might be applied. These concepts have been studied by Bishr (1997,1998), Devogele et al. (1998), Sarjakoski et al. (2002), Aflerbach et al. (2004) and Jakobsson (2003b).

OWL (Web Ontology Language) and RDF (Resource Description Framework), which have been described by WWW-consortium, are standards based on XML language giving semantic meaning for information. The question of whether these languages could be used for combining datasets should be studied.

In recommendations, we suggested the development of common data catalogues and guidance. The present work of the public administration's recommendations on geographic information is a prerequisite for this.

7.8 Contribution to the Study

The questionnaire to the municipalities demonstrated that ***basemaps in the municipalities are important data sources in built-up areas***. The case study and analysis of the data catalogues in four municipalities suggests that basemaps can be used to compile the TDB supporting the BTF model presented in Paper I. The user requirement study found some need of improvement in the present data catalogues, which can indicate that built-up areas could be more accurately presented than rest of the country. This should be studied further; our results support the idea of using the scenario building method in the user requirement study, which was presented in Paper V. Finally, the analysis of the whole process suggest a need in the handling of the whole process of topographic information management in Finland. The use of municipality data requires ***using the Geographic Information Quality Management principles presented in Paper VII.***

Chapter 8

Summary of Results

Historically topographic maps have had a common background in Europe, which is still evident if we study the results of present topographic datasets produced by the European NMCAs and presented in Paper VI. Finland is no exception. First, the topographic mapping came from two routes: Sweden and Russia, both having the same source: topographic mapping in France and Germany. Second initiation was at the beginning of independency, when topographic mapping was begun by the NLS based on experiences from Scandinavia, Germany and France. The historical background is important if we consider the present effort of building a European Spatial Infrastructure. There is common background for all topographic data now available in Europe. This dissertation is a contribution to building of a ESDI.

The first two papers illustrated the general framework of the study. They introduced a model showing how topographic information management could be based on a multi-producer environment using a DB-driven production paradigm. Paper I presented a national Basic Topographic Framework (BTF) combing all basic topographic datasets into a unified database. It proposed change of the role of the NMCAs from data producers to data managers and supporting the development of the NSDIs. One of the key aspects of this change is the management of information flows; it suggests that general quality management principles might be used for this. Paper I uses Finland as a case study and identifies some datasets that might be used in the production of the TDB.

The second paper studied the management of European topographic information and suggests a multi-tier approach for management of topographic data. The general requirements for this were identified. It suggested the use of resolution or level of details in the process of determining how information management should be applied, and that nationally the BTF model presented in Paper I would be one solution. Virtual datasets at large- or medium-resolution levels might be used to produce European data, because the current production paradigm cannot be utilized economically. In small scales, it would also be possible to produce a database at European level still connected with original datasets.

Paper III provided material for the later papers. The ISO 19113 and ISO 19114 standards were explained together with some examples of current quality evaluation experiences in NMAs. At the moment, three main practices of quality evaluation exists in Europe. Some NMAs evaluate the quality results in reality using field checking (e.g. Finland), some check quality against more detailed data or using imagery (e.g. Germany, France) and some concentrate mostly to logical quality evaluation (e.g. Norway, Denmark).

Paper IV explored the concept of the TDB as a reference dataset in Finland. It demonstrated this with two use cases. The first was a visualization example, which simulated the reality using the TDB, and the second was the SLICES land use dataset. The conclusion from the SLICES test case suggested that the TDB and the building register, water register and land parcel register should be connected using for example unique identifiers. At present, the National Council for Geographic Information is investigating harmonization needs between core datasets in Finland; all these datasets will be considered. The paper discussed the question of whether the concept of a uniform dataset for topographic data should be abandoned because many spatial infrastructures (e.g. INSPIRE) and, for example, the national mapping programme in the USA consider, spatial themes. Using quality evaluation results of the SLICES study, it is clear that the importance of linking all different elements together (e.g. buildings, elevation and land cover) should be taken note of. The paper suggested using the BTF model for providing a framework for theme-based datasets (e.g. Land Parcel Register, DIGIROAD, Building Register in Finland). Paper I, suggested the change of role of the NMCAs to data managers and the utilization of information management principles enabling the development of the NSDIs. Paper IV discussed the roles of the USGS, set in the National Map programme in the USA, which corroborated with the suggested role of NMAs in Paper I. Quality evaluation in this paper was based on visual inspection of data quality in the field, which was utilized also in the research project described in Chapter 7.

The user-requirement study in Paper V demonstrated the need for connecting the topographic information with other datasets. It provided an example of user requirement study for the general framework of Geographic Information Quality Management presented in Paper VII. Practices from usability research may be applied for design process of applications in geographic information. Scenario building method was then suggested in the research project described in Chapter 7 for further elaborating end-user needs.

Paper VI, together with examples from the GiMoDig project, provided proof that a common data model for topographic data was feasible at some level. The importance of quality results in the harmonization process was noted. Results indicated that a multi-tier harmonization presented in Paper II might be a possibility.

Paper VII introduced a framework for Geographic Information Quality Management (GIQM), which can be used in the national BTF presented in Paper I or in the European framework presented in Paper II. This paper has been used for development of the EuroGeographics Quality Policy (Jakobsson, 2004) and Implementation Plan (Jakobsson, 2005c), which describe the principles how EuroGeographics will manage quality in different projects, products and services especially designed for the Eurospec programme.

Finally, the research project described in Chapter 7 explored how the BTF model would be functioning in built-up areas using municipality basemaps. The case study and analysis of the data catalogues in four municipalities suggested that basemaps can be utilised to compile the TDB, which supports the BTF model presented in Paper I. Finally, the analysis of the whole process suggested the need for a better way of handling the whole process of topographic information management in Finland. The use of municipality data requires use of the GIQM principles presented in Paper VII.

Chapter 9

Discussion

9.1 Conclusions and discussion

9.1.1 Role of Quality Management Principles in Topographic Information Management and SDIs

The main argument in this dissertation has been that the information management principles, for example, the principles of quality management, are essential for the implementation of multi-producer datasets. Current interoperability and SDI programmes have not very clearly identified this as a major issue. Most of the efforts have been concentrating on solving the interoperability issues at data or system level. Organizational issues have nearly been ignored. Quality is often regarded as one of the metadata labels, which can be solved by reporting it to the users. However, if users want to combine multiple sources the quality becomes the major role. In Chapter 4, we introduced quality management principles and why quality control became very important in the middle of the 18th century. The invention of interchangeable parts for muskets was one of the reasons. We can consider that geographic information production is stepping into this area, where information can be exchanged and combined very easily. Therefore, the quality management of geographic information could naturally be assumed to have a more important role in future. Figure 4.1 illustrated organization as a system based on Jackson (1990). The components of an SDI, as presented in Figure 2.18 using the principles of system thinking, denotes that system thinking might be applied in the development of SDIs. It would be especially important in the current effort of implementing the ESDI. If we consider the current drafting teams of the INSPIRE directive, the importance of quality is not very evident. Current drafting teams consists of metadata, data specifications, network services, data and service sharing, and monitoring and reporting[68].

Figure 9.1 illustrates the potential benefits, which may results in harmonization and introducing information management principles for reference datasets. At Level I, technical interoperability is achieved by using standards like Web Map Service (WMS) or Web Feature Service (WFS). Problems related to content and quality remains. At Level II, the content of reference datasets are harmonized, which enables the combination of local, regional, national, European and global reference datasets. Metadata brings quality information enabling usability analysis. At Level III, compatibility at process level is achieved. Data quality is harmonized and common quality indicators are used. Common pricing and licensing policies will enable easy access to reference datasets. Reference data has been described in legislation giving a clear mandate for the reference data producers. Benefits to society increase from Level I to III because harmonization and process levels will decrease duplicate resources in the maintenance of reference datasets. Integrated maintenance and production processes will encompass many organizations. Productivity and data quality will increase. Benefit to users increase from Level I to III because reference data will be used more, providing new services, which will enable cost savings.

[68] http://www.ec-gis.org/inspire/reports/ir_dt_selection_experts_final_v5.pdf

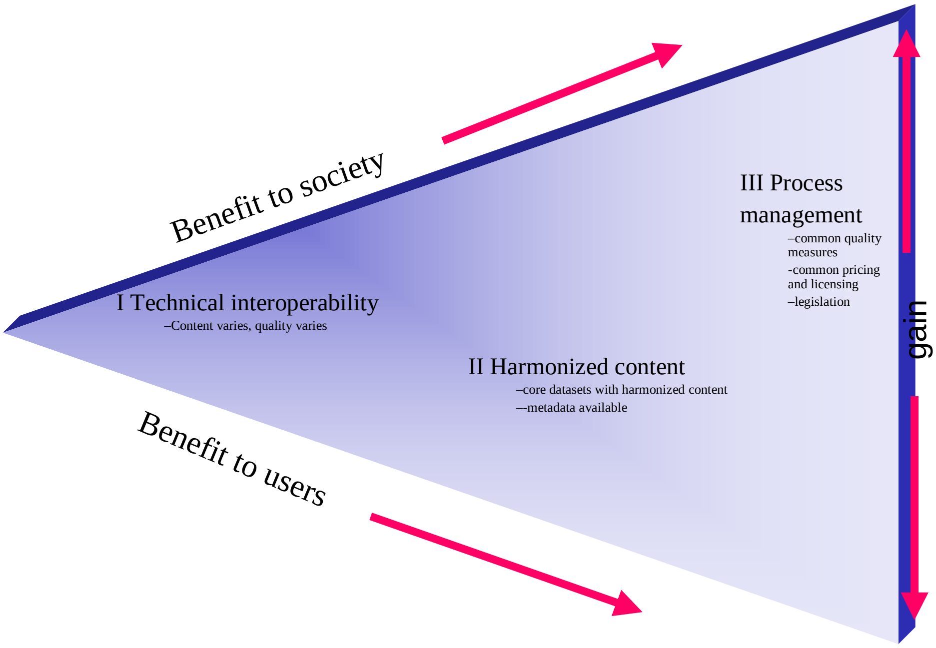

Figure 9.1 Potential gain of proposed Geographic Information Quality Management model to society and users.

A study in the USA (Booz Allen Hamilton, 2005), evaluated two projects: one adopted geospatial interoperability standards and another utilized proprietary standards. The project, which utilized geospatial interoperability standards, had a 119% return on investment (ROI). This can be interpreted as saying that for every euro spent on the investment, 1.19 euro is saved on operational and maintenance costs. Further, the study concludes that standards lower the transactions cost of sharing geospatial data when semantic agreement can be reached between parties. The cost of achieving semantic agreement can be high (especially for data models), but the cost can be recovered in lower operational and maintenance costs. Figure 9.2 illustrates how total risk-adjusted cost was estimated to behave for both projects in the study.

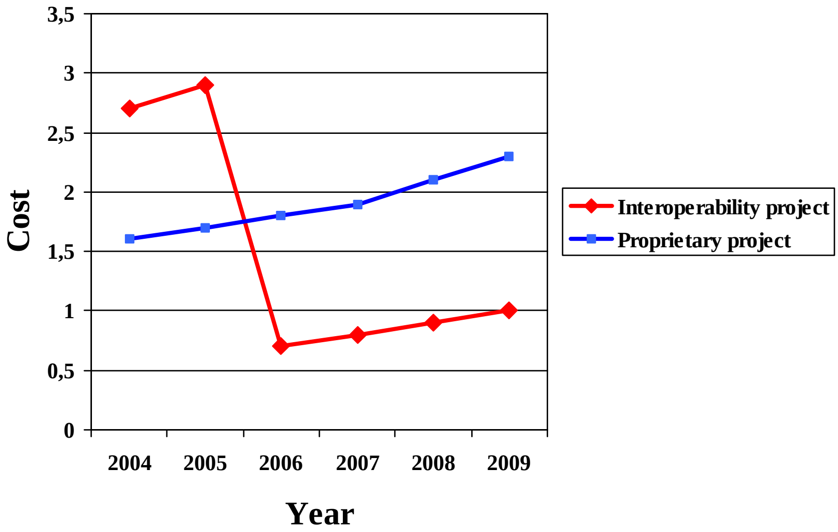

Figure 9.2 Comparison of risk-adjusted costs in two different projects (re-drawn from (Booz Allen Hamilton, 2005)[69]

9.1.2 GIQM model compared with some other quality models

This chapter will compare the GIQM with some other quality models. Onstein (2004) has described a model for geographical information based on communication process. His model is based on communication models of Shannon & Weaver and Roman Jakobson described in Stubkjær (1990). In his model, two parties are involved in the communication: an addresser and an addressee. The addressee is divided into two parts: a technical addressee, typically a computer, and a social addressee. Between those parties two boxes communicate geographic information: the specification part of the message and the feature part of the message. Both messages contain a context, a message, a language and a channel part. He then presents a model how quality assessments of geographical data can be divided into two levels. This model is presented in Figure 9.3. He has developed the figure using Figure 1 from Veregin (1999) and Figure 1 from Jacobi (1999). The quality model is based on work Lindland, Sindre and Sølvberg (1994) and Krogstie and Sølvberg (1999), which discusses quality of conceptual models.

[69] Note: numbers in this Figure are only indicative, see the original report for an accurate presentation.

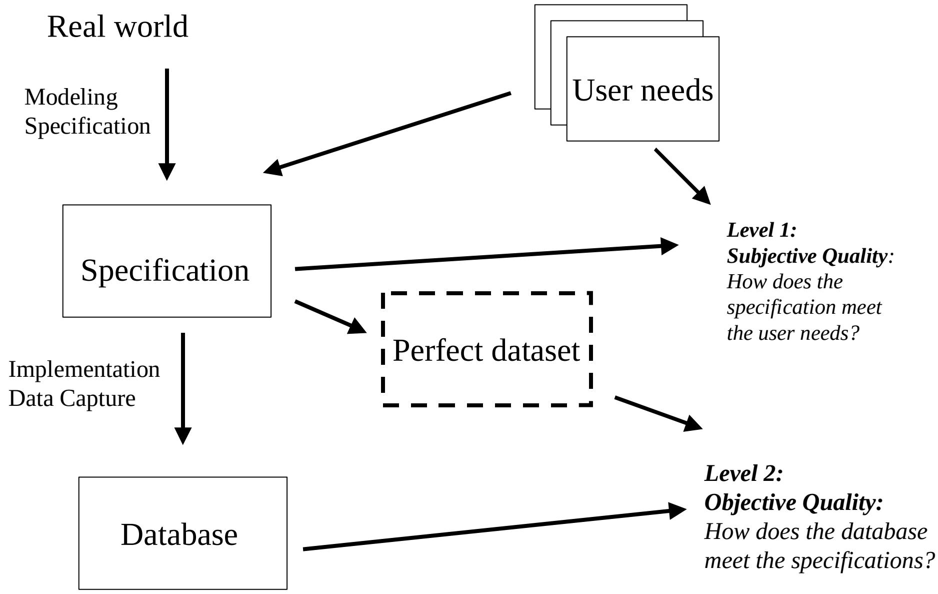

Figure 9.3 The two levels of quality assessment of geographical data (redrawn from Onstein [2004])

While Onstein argues that the model he presents is a new one, it can been seen a continuum of data quality approaches described in Chapter 4.4. In fact, the concept described in the Figure are based on the same principles described in ISO 19113 standard (see Figure 15.1 in Paper III). Further he discusses the need for product specifications, conceptual modelling, data documentation and quality assessment. Here we can note some similarities with the GIQM presented in this dissertation. The GIQM model is based on the existing international standards and a process approach. Onstein assumes that the user requirements should be evaluated against existing datasets, which is often the only possible solution. In the GIQM model the user requirements should be taken into account before the specification process, which is the option available for data producers. In the GIQM the quality requirements have an important role. All data producers should set the requirements in the specifications. This is especially important for reference data producers in multi-producer environment.

Another model discussed here is the EuroRoadS Quality Model (Kauffmann & Wiltschko, 2006). It is targeted for multi-producer environment, which is similar to the GIQM. Figure 9.4 illustrates the structure of the EuroRoadS quality model.

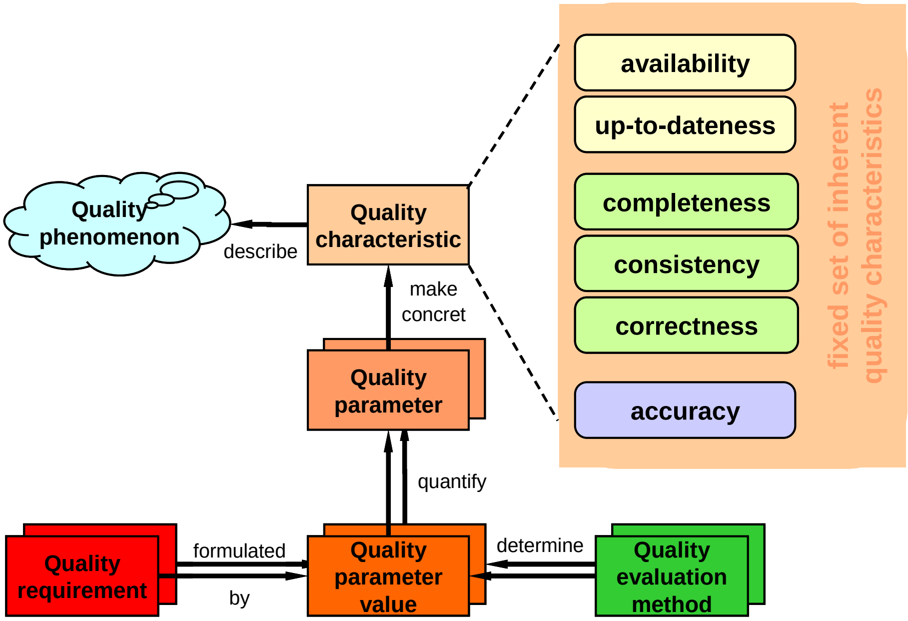

Figure 9.4 Structure of the EuroRoadS quality model (Kaufmann & Wiltschko [2006])

Again the model described follows the principles of ISO 19113 and ISO 19114 standards. In the EuroRoadS quality model some of quality characteristics are different compared with the standard quality elements but it is irrelevant for this discussion. In the EuroRoadS quality model ISO 9000 approach is adopted, which is similar to the GIQM. They introduce some quality control methods such as a cause and effect diagram and FMEA (failure mode and effect analysis), which may be applied during data production. They apply process approach by introducing a PDCA-cycle (see Chapter 4.1).

The model assumes uniform quality measures for data providers, application data providers and service providers. This is very useful but may be unrealistic in reality, if there are many different user applications, which is the typical situation for reference data providers. Error propagation and simulation has been applied to determine how different phases in the information management process affect to reliability of information. This approach is very useful for testing how quality control should be implemented in the production processes. The main difference between the EuroRoadS Quality Model and the GIQM is that the latter concentrates on reference data providers, while the EuroRoadS model assumes that quality measures are available from data providers, and applies these in an application environment. Therefore it does not discuss how user requirements should be taken into account. The benefits of the GIQM model include the application of the process approach. All phases of the data production process are included from analysis of user requirements to provision of data to users. However, both the GIQM and the EuroRoadS Quality Model are not designed to analyse usability from the users aspect.

9.1.3 Role of Quality Management in Geographic Information Standards

Current quality standards of ISO 19113 and ISO 19114 consider quality mainly from the producer’s side and as being related to geographic data. The quality elements described do not necessarily comply with user’s expectations. Most users recognize quality in connection with application and sometimes it is difficult to separate data and application quality. Data quality is an important factor from the quality assurance viewpoint and especially important when different datasets are combined. One of the problems in the process is that quality has also different representations and measures. Research has been mostly concentrating in the integration of schemas; however, quality information should also be considered in the harmonization process.

The GIQM model presented in this dissertation is an example of how organizational issues should be taken into account in the future. Quality management gives a framework that should be incorporated in geographic information standards. Currently, the ISO 19100 series do not cover organizational issues very well. We have noted this already earlier in this dissertation. Implementation specifications should be developed in future to guide organizations through the process.

9.1.4 Use of the GIQM Model in the European context

The GIQM model described in Paper VII has been applied in the context of European reference information management. This has been described by the author (Jakobsson, 2004, 2005c), in the EuroGeographics Quality Policy and Quality Implementation Plan (QIP). Figure 9.5 depicts how GIQM may be applied in a multi-producer environment for provision of reference information in Europe. Service providers and EuroGeographics have a major role in the specification of European quality requirements. NMCAs will take care of quality control during production and evaluation of quality results after the production. Production should be based on best practices among NMCAs. Quality will be assured in data delivery, which includes the possibility of auditing quality results and process either by EuroGeographics or using external auditors.

The QIP describes how this model could be implemented. The implementation of quality management practices (e.g. ISO 9000) and common processes among members are recommended. ISO 19100 quality standards should be adopted in NMCAs together with common specifications, for example, the common quality model. At the moment, the QIP has not been evaluated in practice. However, our findings in the context of using municipality data (Chapter 7) indicate that a com-

common model is required. Another quality model described for European use has been developed in the EuroRoadS project (Wiltschko, 2005; Kauffmann & Wiltschko, 2006) discussed earlier. As noted this model has many similar features with the GIQM model and both models should be utilized in future development.

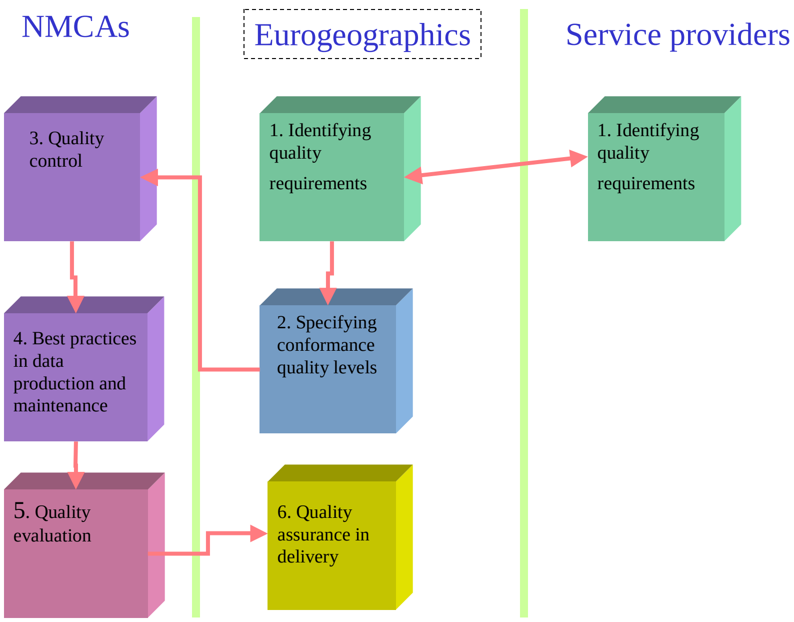

Figure 9.5 Building blocks of quality in distributed data production and delivery (modified from Jakobsson, 2004)

Important phase in the GIQM is the setting a conformance quality levels, which in practice denotes that a common quality model for reference datasets should be developed. This model also assumes that quality management and data quality has a key role in the data production process for the European reference datasets. Alternatively, we could assume that no cooperation between the different data producers will take place, ending up with differences in specifications and data quality. This is rather close to the present situation. Chapter 5 discusses some alternative solutions, which may provide some answers, if we end up with this scenario.

9.1.5 Harmonization in the context of SDIs

In Finland, the GIQM model has been applied for development of the harmonisation guideline of core datasets (Jakobsson, Saarikoski, Lehto and Holopainen, 2006). This guideline can also be addressed as a reference model of the NSDI.

This reference model describes quality management requirements for core datasets as including:

1. Common quality measures should be described using standard measures.
2. Quality requirements should be described using common quality measures based on user requirements.
3. Production processes should be documented and recorded results of quality control should be available.
4. Quality evaluation of results should be conducted by independent evaluators.
5. Both management of core datasets and production methods should be audited.
6. Quality measures should be reported in metadata.

Common quality measures should be described using ISO 19100 quality standard and they should guarantee that quality results are comparable. Quality requirements should be described for core datasets, because quality results that are reported usually contain these values. Quality evaluation can then be utilized to report whether conformance quality levels have been met. Quality control is important during production because of long-standing processes and considerable costs related to the process. Therefore, if quality evaluation indicates that results are not acceptable, producers cannot reject the whole dataset. The auditing of production processes and management of core datasets can be initiated by the subscriber, which, in most cases of core datasets are the ministries or other public agencies.

9.1.6 Use of Basemaps as Source for the TDB

Most of the conclusions related to using the basemaps have been presented as recommendations in the summary of Chapter 7 and not repeated here. Based on the results of this dissertation it can be concluded that topographic information is essential for the building process of SDIs both nationally and in Europe. This study raises some challenges for the NMCAs in Europe and especially for the development of the NSDI and management of topographic data in Finland. Results indicate that harmonization of reference datasets is of essentially importance.

If basemaps and the TDB were integrated to Level III (see Figure 9.1), we could conceive some approximate cost savings and productive increase. Most of the infrastructure of Finland is located in built-up areas and we can assume that most of the changes will be located in these areas. The NLS has planned to spend about 15 million Euros for the maintenance of the TDB annually, which would currently mean an updating period of 5 - 10 years. Annual updating includes roads now, and buildings in the future. We can assume that the municipalities spend about 30 million Euros on the maintenance process of basemaps, although no real statistics are available. If we assume that the maintenance of the built-up areas would cost 5 - 20% of the annual costs in the NLS and data assurance and other maintenance cost in the integrated process would decrease costs 50% then annual savings would be 2.5 –10 % (0.4 – 1.5 million Euros). Implementation of harmonized specification in municipalities and in the NLS should be taken into account, but IT-systems will have to be updated in any case at least every 10 years so we can assume that most costs would be related in co-ordination. In the end, the quality of the national topographic dataset would be increased with more detailed and up-to-date content. In some applications, for example, unique building information from local to national or even to European level is essential; this cannot be achieved without integration. This would also enable the introduction of nearly real-time building information and addresses, which are the most important feature types for many services. A similar estimation could be made for the Land Parcel Register and Building Register. Cost savings in the production process is probably the least important factor if we evaluate the total benefits for the society. New applications built on the basis of the integrated and harmonized core datasets will enable cost savings and new services for the Finnish economy and ensure its the competitiveness in the future.

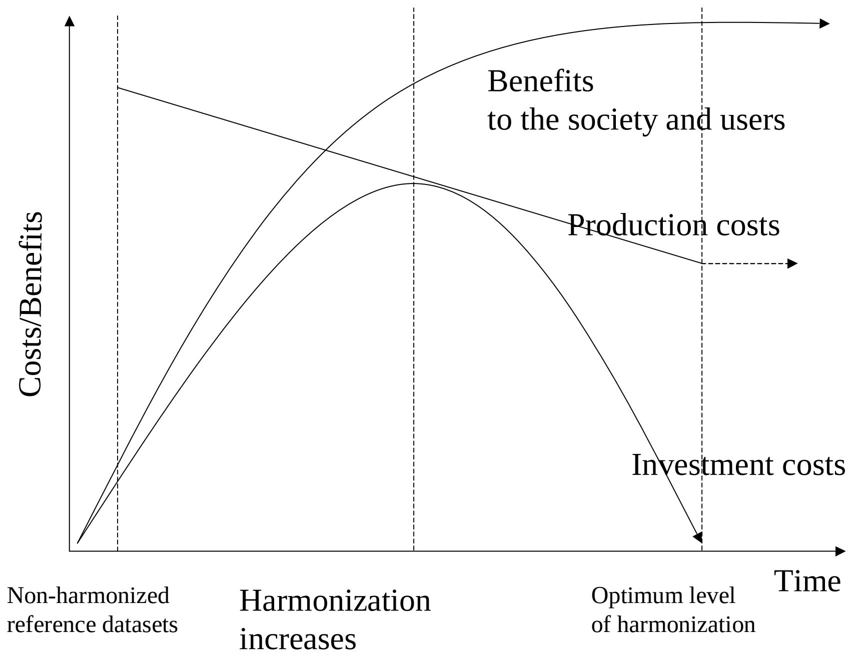

Figure 9.6 Potential costs and benefits of harmonization

Figure 9.6 illustrates how harmonization of reference datasets might increase benefits of users and society in the long term but also mean some investment costs for producers in the short term. In order to get results some investments are needed. Figure is only an approximation and it should not be used to quantification of costs or benefits.

9.1.7 Experiences of Using Municipality Datasets in Sweden and Denmark

Scandinavian countries are also utilized municipality datasets. In Sweden, the Lantmäteriet has introduced a programme for utilization of building and other municipality information in the topographic, cadastral and property data (Wasström, 2005). Feature types included are buildings, addresses, other constructions, for example, recreational, and communication, for example, bicycle paths). The information provision process includes a separate activity, which has the task of making agreements with municipalities. The National Land Survey of Sweden (Lantmäteriet) has set levels of cooperation to three levels. For address and building information, a special application is used by the municipalities to report data. At the first level, municipalities update feature types using the application. At the second level, the register is complete and quality assured, and, at the third level, address information including entrance addresses and buildings, is delivered with geometry according to the specification of the Lantmäteriet, including information needed for property taxation. For other topography data, municipalities deliver analogue or digital data at level 1. At the level 2, they deliver digital data using their own specification, while, at level three, the specification of the Lantmäteriet is utilized (Wasström, 2005b) Table 9.1 describes the agreements that have been made by 27.9.2005. Payment levels are calculated from the total sales of basic data (national cadastral and topographic data) and criteria includes level of cooperation, sales, number of inhabitants and agreed basic amount.

Table 9.1 Cooperation agreements with municipalities and the Lantmäteriet on use of municipality data

Level of Agreement	**Number of municipalities /Payment level**					
	Addresses		**Buildings**		**Topography**	
1	104	2,5%	146	2%	111	1%
2	89	4,5%	56	3%	91	2%
3	15	6%	7	5%	1	3%

The processes the Lantmäteriet utilizes include: receiving information, controlling and modification of the received data (visual inspection), controlling and evaluating the data against Lantmäteriet's data, and communicating the evaluation results. If the first evaluation is favourable, the Lantmäteriet will make an agreement, and then update the topographic data using municipality data.

Experiences include: better understanding the building process of the NSDI, improvement quality of topographic data, improved specification and use of a periodic updating process for quality control. Improvement needs include: difficulties when the definition process of feature types is unclear, quality expressed in different ways, conflict between the two updating processes (based on cooperation and internal updating process). According to Wasström (2005, 2005b), the current experience in the Lantmäteriet indicates that there is a need for common detailed definitions, which should be of a national standard, quality requirements for the municipalities are needed, better definition of the total process and goals and a pilot project to create routines and useful tools. Future plans include the use of national conceptual data models based on Swedish and international standards in the exchange process, common information provision process for all feature types inside Lantmäteriet, use of unique identifiers for features.

The vision is that the Lantmäteriet will have basic geographic data available in such a way that there is no need for others to have copies of the same features. The NSDI should provide a flexible technical solution for provision independency of the physical storage of data. The Swedish Association of Local Authorities and Regions[70] (SALAR) and the Lantmäteriet have made an agreement with common vision "Lantmäteriet and all Swedish municipalities create a common network to support the nation with geographic information". The common vision stretches so that the information provision process covers all organizations involved and so that information is perceived as a common resource. Based on the agreement with the SALAR, the Lantmäteriet leads and coordinates the network. It has been recognized that EU directives and governmental deciding what kind of information will be included in the cooperation; otherwise the each member will make a decision based on market grounds. The aim is that information should be well defined and based on standards.

It can be concluded that the Lantmäteriet and Swedish municipalities have recognised the importance of information provision to all users including national users. At the moment, 290 municipalities exist in Sweden, and the cooperation has been initiated with around 200 municipalities, which is a remarkable. We can infer that the Swedish approach has started on the traditional one-way usage of information in the production process, which may lead to the development of a common data model in future. At the moment there is a conflict in two updating processes in built-up areas. The use of unique identifiers in future might solve this. The Swedish case demonstrates the need for information management of the integrated process and need for harmonization.

In Denmark, the municipalities and the Kort & Matrikelstyrelsen (KMS) had already in 1997 set a goal to develop a data catalogue in common with the technical map produced by the municipalities and the topographic map produced by the KMS. Figure 9.7 depicts the goal of the common catalogue (FOT) and the

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[70] http://www.skl.se/ (accessed, May 4th, 2006).

copyright agreement between municipalities and the KMS. At that time the focus was map-based. In 2002, the development focus was changed into information management and the development of an object-based data catalogue. In 2003, a common specification was published by the Spatial Data Service Community[71]. The Spatial Data Service Community is lead by the KMS; and representatives in this community represent other ministries and local government in Denmark. The specification describes buildings, watercourses, traffic related features, and administrative boundaries. The idea in the development of the specification was to select the feature types that have many users or are regarded as a reference feature for other features, feature types used as identifiers in official registers, feature types having a lot of changes, feature types used in many authorities, common feature types, and those regarded as administrative boundaries (Spatial Data Service Community, 2003). The specification included 17 feature types of the 22 candidates and it included unique identifiers (see Figure 9.8).

Today Denmark is divided into 13 regions and 271 local municipalities (authorities). In June 2004, the Danish government (the Liberal Party and the Conservative Party) and the Danish People's Party came to an agreement about the reform of the framework for public tasks and public service. The counties will be dissolved and five elected regions will be established. Larger and more sustainable municipalities will be given the responsibility of handling most of the citizen-related tasks[72]. At the moment the regions have been using topographic data from the KMS. The new municipalities will take the responsibilities of the regions and of present municipalities (Hartmann, 2004).

[71] http://www.xyz-geodata.dk/ (accessed, May 4th, 2006).
[72] http://www.arf.dk/ (accessed May 4th, 2006).

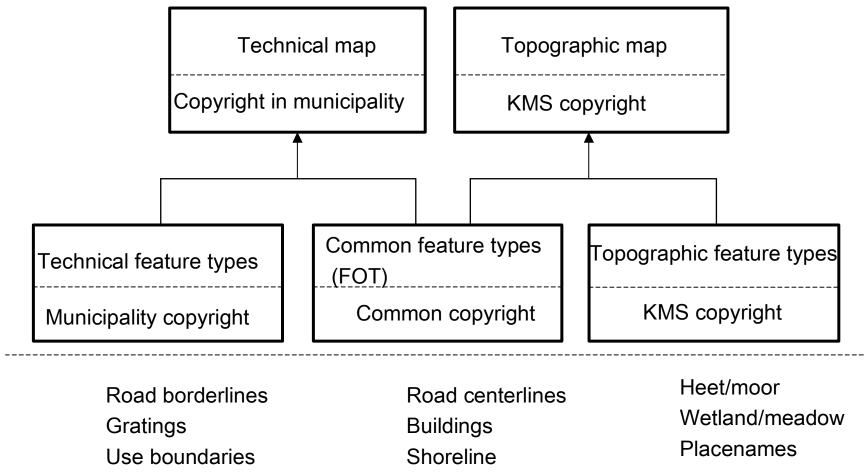

Figure 9.7 Goal for common data catalogue in 1997 (translated from the Hartmann, 2004)

The Spatial Data Service Community has decided to form a project organization for the implementation of the FOT concept in 2005. The FOT specification version 3 (Spatial Data Service Community, 2005) has now been published and comments from different organizations are waited. The specification includes the UML-model and metadata according to ISO 19115. The specification is an example of harmonization of specifications between municipalities, regions and the KMS. The new version incorporates the Top10DK and technical maps to a common database (TopTK). This specification now includes more feature groups and the division of feature types are changed. Feature types are divided into two main groups: multiple sector data and sector data. Feature groups include buildings, settlements, traffic, technical, nature, watercourses, administrative and others. Specification also includes orthophoto, which is produced from the same aerial pictures used to produce or maintain the data. The new version includes some natural feature types, forests, for example.

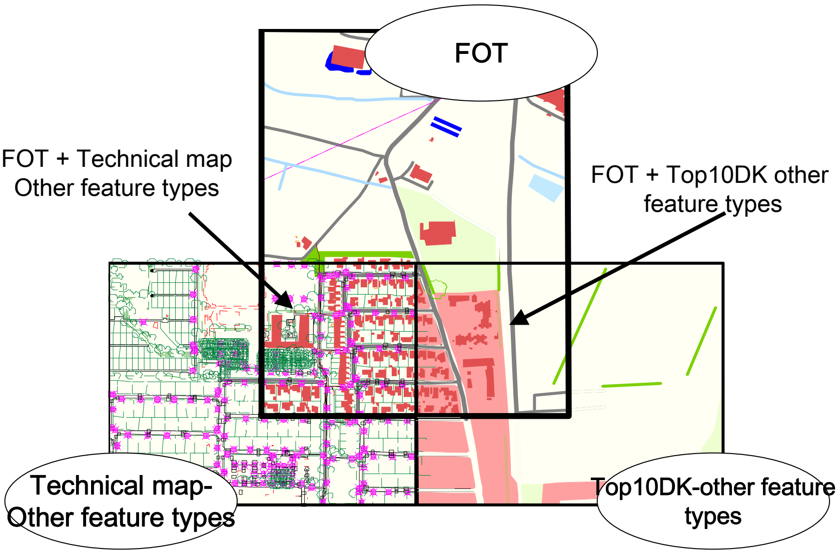

Figure 9.8 Illustration of common feature types in FOT (translated from Andersson, 2005)

The idea now is to combine the municipality data and the TOP10DK to form a common database (TOPTK). All the municipalities in Denmark belong to Kommunernes Landsforening, KL[73] and the association has decided on behalf of the municipalities to join the common geodata infrastructure (Gottlieb, 2005). It is suggested that the KMS will hold the common database (Jönnson, 2005). Maintenance will be based on continuous and periodic photogrammetric updating. In practice the municipalities will stop to administer their own database; instead all updating will commence on the common database. Users in municipalities will use data using standards (WMS/WFS). The financing of the system will be based on sales of the data. Some municipalities are required to update the data before it is incorporated into a common database. Municipalities have to pay for the use of data instead of updating costs. The system should be realised before 2007 (Jönnson, 2005). The FOT version will be finalised in March 2006 and the KMS will initiate test production in a small area in 2006. At the moment, a revision cycle suggested is three years, which means that it would take until 2009-2010 for all technical maps to have been transformed to a new specification and no longer need to be updated (Gottlieb, 2005).

[73] http://www.kl.dk (accessed May 4th, 2006).

The Danish experience clearly indicates that a common specification for base topographic data is required; it therefore supports the main conclusions of this study.

9.2 Future Research and Development

9.2.1 Implementation of the Multisource Topographic Database

The technical development of the multisource Topographic Database should be initiated. However, a common vision of the new multisource topographic database is required before technical development can be started. Experiences in other Nordic countries might be utilized. Both in Sweden and Denmark, a common agreement between national organizations and municipalities has been established. We recommended starting with a common specification work and then continuing with technical implementation.

The Finnish National Council for Geographic Information should also investigate other possibilities for harmonization and the integration of reference datasets. If INSPIRE legislation were to be adopted, there would be a need for legislation regarding reference datasets in Finland. In legislation, harmonization should be required of the data producers.

We identified some research needs related to the development of the multisource Topographic Database. These included use of unique identifiers, ontology, use of semantic languages, and the implementation of multiple resolution databases.

This study did not explore economic consequences in production organizations or user benefits from the economic viewpoint. This should be studied further.

9.2.2 Development of Quality Related Standards

This study applied quality management principles to geographic information management. Currently, the ISO 19100 quality related standards do not clearly take this approach. Implementation guidelines for production organizations should be developed to support acceptance of standards. Paper VII suggested to implement geoauditing procedures for geographic information. This would be useful from a subscriber point-of-view and also from a end user aspects. Some research in this field has already been conducted by Gerval et al. (2006). Quality accreditation of subcontractors and internal processes might also be utilised or even standardized. Ordnance Survey in Great Britain has introduced this in their processes (Cowell, 2006).

9.2.3 Development of SDIs

Quality management principles are not commonly applied in the development of SDIs. The proposed model of GIQM could be applied in the development of

European and National Infrastructures. A working group should be introduced into the INSPIRE process, in particular, to promote quality management and data quality. The GIQM principles could be applied to other data themes as well. However, some data themes might require slightly different approaches (e.g. cadastral information and orthoimagery).

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