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DISSERTATION

Concept and implementation of Croatian Topographic Information System

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Univ.Prof. Dipl.-Ing. Dr.techn. Norbert Pfeifer
Institut für Photogrammetrie und Fernerkundung (E122)
Technische Universität Wien

eingereicht an der Technischen Universität Wien
Fakultät für Mathematik und Geoinformation

von

Dipl.-Ing. Zvonko Biljecki

Matr.Nr.: 9527591
Kajfešov brijeg 4, HR-10000 Zagreb

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Zusammenfassung

Motiv und Ziel dieser Doktorarbeit ist das Konzept und die Implementierung eines topographischen Informationssystems aus Sicht des aktuellen technologischen Standes der Photogrammetrie als Wissenschaft.
TIS kann defniert werden (K. Kraus, Photogrammetrie, Band 3, Wien ,2000) als computerbasiertes System mit Datenverbindung zur Landschaft welche: erfasst und weiterverarbeitet, gespeichert und reorganisiert, modelliert und analysiert, sowie alphanumerisch und grafisch dargestellt wurde. TIS stellt sich, wie andere Informationssysteme, zusammen aus Datenbank und Anwendugssoftware.
In der Praxis wird mit übernommenen veralteten Implementierungen, in Form von vorhandenen Plänen aus Papier und unvollständigen digitalen Datensätzen mit heterogener Qualität, gearbeitet. Hier wird eine neue Herangehensweise erforscht und vorgeschlagen, die eine optimale Methode des Errichtens eines landesweiten digitalen topographischen Infromationssystems darstellt, beginnend mit einem Entwurf. Diese Untersuchung wurde im Zusammenhang des Errichtens eines Informationssystems der Republik Kroatien erstellt.
Die Anwendung hochentwickelter Technologien, des konzeptionellen Modellierens, der Normierung und der formalen Spezifikation von geometrischen und topologischen Darstellungen, beruhend auf dem Konzept einfacher und erfolgreicher Entwicklungen und Errungenschaften topografischer Informationssysteme, begleitet unter Berücksichtigung von Benutzerbedürfnissen, sind die grundlegenden Eigenschaften angewandter Methoden und Vorgehensweisen zur Lösung der beabsichtigten Aufgabe.
Diese Aufgabe beinhaltet das Erstellen des Konzepts eines topografischen Informationssystems sowie dessen Einführung, welche neben ihrem wissenschaftlichen Bestandteil ausdrücklich gekennzeichnet ist durch strenge organisatorische und praktische Aspekte. Die wissenschaftliche Komponente beinhaltet GML und objektorientiere Herangehensweise im Modellieren der Daten und der funktional orientierten Modellierungsmethode der realen Welt. Den Beweggrund hierzu liefert der Autor, der unterstützt wird von einer Vielzahl von Benutzern aus der höchsten staatlichen geodätischen Behörde, die zuständig ist für die Verwaltung und Fortführung geodätischer und raumbezogender Systeme im Sinne der Gesetzgebung zur hoheitlichen Vermes-

sung und Verwaltung des Liegenschaftswesens. Dies war der erste Schritt zur Implemnetierung der Idee des Verfassers bezugnehmend auf das Einrichten eines modernen Geoinformationssystems.
Die folgenden Aktionen stellen nur die bedeutendsten verwirklichten Schritte zur Implementierung dieses topografischen Informationssystems dar, welche die umfangeichsten staatlichen Aktivitäten innerhalb der nationalen Infrastruktur räumlicher Daten der letzten zehn Jahren waren. Die vertragliche Vereinbarung umfasst Maßnahmen am „Erstellen eines topografischen Informationssystems der Republik Kroatien – CROTIS“, Aufstellen eines Teams zur Implementierung dieses topografischen Informationssystems mit angemessener Ausbildung und entsprechendem Expertenwissen, Erstellen eines Datenmodells in Zusammenarbeit der Endanwender, Erfassung der Daten bezüglich des erstellten konzeptionellen Modells und Etablierung einer topografischen Datenbank in Begleitung von hunderten bereits eingeführter neuer Projekte mit Blick auf die Aktivitäten bezüglich des Erstellens des CROTIS / STOKIS.
Das konzeptionelle Modellieren basiert auf die Anwendung der *Abstraktion*, d.h. auf der Grundlage der Methode, welche durch die Schwerpunktbildung entsteht, also des Erkennens von Ähnlichkeiten zwischen Objekten der realen Welt unter vorläufiger Vernachlässigung ihrer Unterschiede. Die Abstraktion wird verwendet, um das Abbild der realen Welt, der Objekte und ihren Verbindungen, zu zerlegen in eine *Hierarchie von Abstraktionen*, d.h. in die Kombination von Aggregationen und Generalisierungen.
Sowie andere Geoinformationssysteme anderer Europäischer Staaten, berücksichtigt auch das Kroatische topographische Informationssystem ISO Standards als priorisierende Verpflichtung. Ziel ist es, Standards und Grundregeln für das Modellieren eines grafischen und alphanumerischen Kenzeichensystems herzustellen, welches für das Definieren, Strukturieren, Ersetzen, Kodieren, Umwandeln und Übertragen räumlicher Daten bestimmt ist. Geometrische und alfanumerische Daten bilden ein komplexes System, das in einer klaren und einfachen Art und Weise die Geometrie und die Topologie der geografischen Objekte darstellt. Die Komplexität ist bestimmt, definiert und abgeglichen mit den Anforderungen und Anwendungen der Benutzer. Die geoinformatisch funktioanl orientierte Vorgehensweise in CROTIS beschleunigt den Prozess der Umwandlung der Realität in die gewünschte Informationsform, und liefert ein gesamtheitliche Abbildung des erstellten Datenmodells in Form einer strukturierten Basis. Dieses Projekt gibt einen Überblick einer neuen Vorgehensweise zur räumlichen Informationsdarstellung und Verwaltung. Die Einrichtung eines funktionalen, nichtanalogen kartografischen Betriebes, ist die grundlegende Eigenschaft dieses neuen Konzeptes.
Traditonelle analoge kartografische Vorgehensweisen können in der Darstellung der Realität nicht die Erwartungen moderner Geoinformationssysteme und Standards erfüllen. Luftbilder mit klassischer Darstellung der Topo-

grafie liefern entweder unzureichende oder überflüssige Daten in Anbetracht aller Grundlagen und Standards der kartografischen Darstellung mit ausschließlichen Bezug auf analoge Objektdarstellungen. Außer dem ist ihre Struktur meistens ungeeignet um als integrierte Daten oder Basisdaten eines GIS weiterverabeitet zu werden.
Funktional orientierte Abbildungen steigern, unter Berücksichtigung des konzeptionellen Modells, das Qualitätsniveau der Daten erheblich. Die Realität in all ihrer Komlexität kann nur unter Erkennung dieser Vielschichtigkeit in einem befriedigenden Maße dargestellt und informationsbezogen verarbeitet werden. Der grundlegende Leitfaden zur funktional orientierten Modellierung ist hervorzuheben. Dieser gibt der Darstellung und Erfassung der Daten und höheres Gewicht mit größerem Einfluss in der räumlichen Erschließung. Hauptverkehrsstraßen, sonstige Kommunikationswege, Gebäude und ihre grundlegenden Ansätze, sind wesentliche Objektklassen zur räumlichen Wirkungsweise.
Gegenwärtig ist CROTIS modernisiert und abgestimmt mit den aktuellsten ISO und OGC Standards um Prozeduren zur Distribution topografischer Daten, zum Zweck der Speicherung und des Datenaustausches, zu entwickeln, in welchen GML (Geography Markup Language) benutzt wird.
Ein neue Herangehensweise des Datenmodellierens, ein neues Schema für den Datenaustausch und ein neuer Datenkatalog, wurden mit dieser Untersuchung herbeigeführt. Das Modelieren wurde zum Zweck der Verbesserung des Datenmodells gemäß den Standards getätigt, welche Methoden und Eigenschaften zur Ansicht der Objektmodelle und Objektmerkmale liefern. UML (Unified Modelling Language) wurde zur formalen Beschreibung des Datenbestandes benutzt. Das logische Datenmodell in UML ermöglicht die Implementierung eines GIS einschließlich der Datenbank. Die automatische Generierung eines GML Anwendungsschemas wurde aus dem UML heraus entwickelt. Die Datenbeschreibung ist im Datenkatalog beinhaltet, welche automatisch aus dem Datenmodell resultiert. Dies ist die ursprüngliche und einzige Lösung.
Das grundlegende Prinzip im Erstellen von CROTIS ist funktional orientiertes konzeptionelles Modellieren und formales Spezifizieren geometrischen und topologischen Modellierens auf konzetioneller Ebene, das eine leichtere und erfolgreichere Entwicklung und Realisierung komplexer Geoinformationssysteme unterstützt. Diese wissenschaftlichen Vorgehensweisen wurden jüngst innerhalb einiger Workshops getestet und überprüft, welche organisiert wurden mit mehr als 30 der wichtigsten Nutzer. Diese Vorgehensweise, sowie die vollständige Kompatibilität mit ISO Standards, liefert eine vollständige und rasche Integration des Kroatischen Geoinforamtionssystems, als eine der wichtigsten Schnittstelle des NSDI, in Europäische (INSPIRE) und globale räumliche Dateninfrastrukturen.
„Die geoinformatische Vorgehensweise im Erstellen der Realität mit reduzierter Quantität weniger bedeutender Daten, mit gleichzeitiger Betonung

ihrer funktionalen Notwendigkeit, begleitend durch die Nutzung objektorientierter Systeme und moderner informatischer Infrastruktur" entspricht den Merkmalen von CROTIS.

Abstract

The concept and implementation of topographic information systems, as a photogrammetric state of art discipline, is the fundamental frame of reference, motif and goal of this doctoral thesis.
TIS can be defined (K.Kraus, Photogrammetrie, BAND 3, Vienna, 2000.) as a computer-system with data connected to the landscape which have been: captured and processed, stored and reorganised, modelled and analysed, presented alphanumerically and graphically. TIS, as any other information system consists of data bank and aplication software.
The existing practice is battling with legacy system implementations, in the form of existing paper maps and incomplete digital datasets with heterogeneous quality. A new approach is suggested and investigated in this work. Which is an optimal method of building country-wide digital topographic information system, starting from a scratch. The research has been embedded in the context of creation of Topographic Information System for the Republic of Croatia. The application of high technology, conceptual modelling, standardisation and formal specification of geometric and topological modelling on the conceptual level conditioning easier and more successful development and achievement of topographic information system accompanied by full respect of user needs are the basic characteristics of applied methodology and approach in solving the intended task.
The task that involves creating the concept of topographic information system and initiating its establishment is characterised by an expressively strong organisational and practical aspect besides its scientific components which are included in work. The scientific component encompasses GML and object oriented approach in data modelling and functionally oriented modelling methodology of real world. The motivation is coming from the author and is being supported by the highest state authority competent for the organisation and functioning of geodetic and spatial data system of State Geodetic Administration (SGA) defined by the law of ”state survey and real estate cadastre” , as well as coming from the majority of users. This was the first step towards the implementation of the author’s idea referring to the establishment of modern geoinformation system.
The following actions are only the most significant realised steps toward the implementation of this topographic information system, being the largest

state activity within the scope of National Spatial Data Infrastructure in the last ten years - to contract for the works on the "Creation of Topographic Information System of the Republic of Croatia - CROTIS" , to form a team to work on the implementation of the topographic information system providing proper education and informing for experts, creating a data model in collaboration with the users, organisation of data gathering according to the created conceptual model and establishing a topographic data base accompanied by the initiation of about hundreds new projects within the scope of activities connected with the creation of CROTIS / STOKIS.
The conceptual modelling is based on using abstraction, i.e. on the basis of methodology established by concentration applied in recognising the similarities among objects of the real world and temporary neglecting of differences among them. The abstraction is used to decompose the model of the real world, objects and connections among them, in the hierarchy of abstractions, i.e. into the combination of aggregations and generalisations. As well as the other European geoinformation systems, the Croatian Topographic Information System respects and observes the standards by ISO (International Standard Organisation) being one of the priorities among obligations. The aim is to establish standards and principles for modelling of graphic and alphanumeric code system intended for defining, structuring, replacing, coding, transformation and transfer of spatial data.
Geometric and alphanumeric data create a complex system representing in a clear and simple manner the geometry and topology of geographic objects. The complexity is established, defined and harmonised with the needs and applications of users.Geoinformatically functionally oriented approach in CROTIS accelerates the process of transforming the reality into the desired information from, and provides complete projection of created data model into the structured base. The work gives an outline of a new approach in spatial data representation and management. The establishment of a functional, and not analogous and cartographic model, is the basic characteristic of this new conceptual approach.
Traditional analogous and cartographic approach in presenting the reality cannot meet the demands of modern geoinformation system and standards. "Aerial view" with classical presentation of the Earth's topography gives either insufficient or too much data considering all principles and standards of cartographic presentation dealing exclusively with analogous object presentation, and its structure is mostly not suitable to be accepted and processed as an integral or basic data of geoinformation system.
Functionally oriented modelling raises considerably the level and quality of data respecting thereby conceptual modelling. The reality in all its complexity can be presented and processed informatically in a satisfactory way only by recognising this complexity.
The basic guideline of functionally oriented modelling is to emphasise, give more weight to presentation and gathering of data having greater importance

in exploitation of space. The main roads, other communication routes, built objects and their basic approaches and their classification are essential object classes for the functioning of space.
Currently, CROTIS is modernized and synchronized with the latest ISO and OGC standards in order to develop procedures for topographic data storing, exchange and distribution by using GML (Geography Markup Language). New data model approach, new schema for the data exchange and new data catalogue have been encompassed within the research. The modeling was done for the purpose of data model improvement according to standards which provide the methods and properties for display of model objects and model attributes. UML (Unified Modelling Language) is used for the formal description of the data. Logical data model in UML enables the implementation of GIS including the database as well. The automatic generation of GML application schema was developed from UML. Data description is contained in the data catalogue which resulted automatically from data model. This is original and unique solution.
The fundamental principIe in the creation of CROTIS is functionally oriented conceptual modelling and formal specification of geometric and topological modelling at the conceptual level providing easier and more successful development and realisation of complex geoinformation system. Theses scientific approaches have been tested and approved throughout some recent workshops organised with more than thirty most important users. This approach, but also complete compatibility with ISO standards provide full and rapid integration of Croatian Topographic Information System as the most important part of NSDI into European (INSPIRE) and global data spatial systems.
"The geoinformation approach in creating the reality with reduced quantity of less important data, and with emphasizing at the same time functionally essential ones, accompanied by the usage of object-oriented systems and modern informatic infrastructure" is equally significant characteristic of the CROTIS.

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List of Abbreviations

CEN	Comité Européen de Normalisation
CGI	Croatian Geodetic Institute
CRONO GIP	Croatian-Norwegian Geoinformation Project
CROTIS	Croatian Topographic Information System
DCM	Digital cartographic model
DTM	Digital terrain model
EP	European Parliament
EU	European Union
GEOPS	Geodetic Spatial System of Republic of Croatia
GI	Geo-Information
GML	Geography Markup Language
INSPIRE	The INfrastructure for SPatial InfoRmation in the European Community
ISO/TC211	Technical Committee 211 Geographic Information/Geomatics
ISO	International Standardisation Organisation
LPIS	Land Parcel Identification System
LSSREC	Law for State Surveying and Real Estate Cadastre
NSDI	National Spatial Data Infrastructure
OASIS	Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium
OMG	Object Management Group
SGA	State Geodetic Administration of Republic of Croatia
STOKIS	Official Topographic and Cartographic Information System
TDB	Topographic Database
TIS 25	Topographic Information System 1:25000
TIS	Topographic Information System
UML	Unified Modelling Language
W3C	The World Wide Web Consortium
WS-I	Web Services Interoperability Organisation
XML	eXtensible Markup Language

Chapter 1

Introduction

The concept and implementation of topographic information system, as a important part of photogrammetry, of the Republic of Croatia is the fundamental frame of reference, motif and goal of this doctoral thesis. The application of high technology, conceptual modelling, standardisation and formal specification of geometric and topological modelling on the conceptual level conditioning easier and more successful development and achievement of topographic information system accompanied by full respect of users needs are the basic characteristics of applied methodology and approach in solving the intended task.

1.1 Task and approach

The task that involves creating the concept of topographic information system and initiating its establishment is characterised by an expressively strong organisational and practical aspect besides its scientific component which are included. Scientific component encompasses GML and object oriented approach in data modelling and functional oriented modelling methodology of real world. The motivation is coming from the author and is being supported given by the highest state authority competent for the organisation and functioning of geodetic and spatial data system of State Geodetic Administration (SGA) defined by the law of “state survey and real estate cadastre”, as well as coming from the majority of users. This was the first step towards the implementation of the author idea referring to the establishment of modern geoinformation system.
The following actions are only the most significant realised steps toward the implementation of this topographic information system, being the largest state activity within the scope of National Spatial Data Infrastructure in the last ten years - to contract for the works on the ”Creation of Topographic and Information System of the Republic of Croatia - CROTIS”, to form a team to work on the implementation of the topographic information

system providing proper education and informing for experts, creating a data model in collaboration with the users, organisation of data gathering according to the created conceptual model and establishing a topographic data base accompanied by the initiation of about hundreds new projects within the scope of activities connected with the creation of CROTIS / STOKIS.

1.2 Motivation

The fact that there has been no topographic and geoinformation system and that the entire geodetic spatial system of the Republic of Croatia has been disrupted, especially on maps at medium and small scales, has lead to the works on creating modern topographic and cartographic information system.
At the moment it gained its independence Croatia was left not only without fair draughts, but also without equipment and professional potentials for the production of state maps at medium and smaller scales. The production of topographic maps in these scales was under the competence of military institutions of the former state, and their usage for civil purposes was strictly limited.
In order to find efficient and economically most acceptable solutions there was the top professional and scientific potential provided in the country and from abroad, and it lead to the initiation of the "Study on replacing reproduction original and reconstruction of topographic map contents" (Biljecki et al. 1995).
In the work on the Study there were researches and activities carried out on the theoretical basis, as well as on practical models. The fundamental strategy from the project on reconstructing the geodetic spatial system GEOPS was considered in it, and there was also a correspondence with the projects from the same scientific area achieved (STOKIS).
The Study gives the answers to the essential questions in connection with the replacement of fair draught and updating of topographic map contents, with accuracy control on existing maps, the possibility of their full or partial usage, production of brand new topographic maps on the basis of direct photogrammetric mapping, *integration of basic data into Topographic Information System 1:25000 of the Republic of Croatia.* The possibility of producing new topographic maps on the basis of existing resources, expenses and users needs. The creation of a practical model, the topographic map 1:25000 (Figure 1.1 Rakov Potok) by applying the technology of analytical photogrammetry and partly by taking over the results of photogrammetric mapping for the purpose of producing DSMC (Digital State Map of Croatia) at the scale of 1:5000 has initiated the idea to author of making a concept of topographic information system of the Republic of Croatia and its estab-

lishment at the entire state territory. Graphically structured data of high accuracy and quality, gathered by means of direct photogrammetric mapping in 3D as the result of creating a "practical model" of the Study, and in accordance with increasingly large demands posed by users in the field of spatial data in digital form have been a basic motif in initiating on CROTIS.

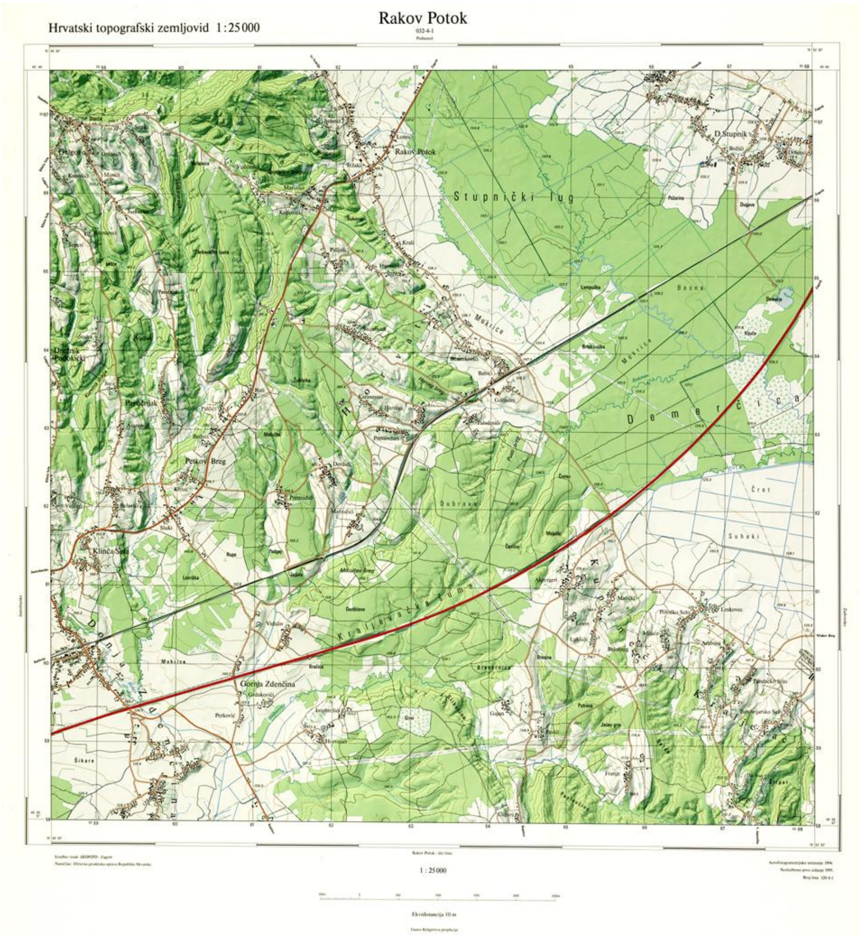

Figure 1.1: Rakov potok, first Croatian topographic map at scale 1:25000

1.3 Concept of CROTIS

Obvious need to create basic national topographic information system has created wide agreement and interest for urgent establishment of CROTIS. The goal of this concept to make flexible, widely usable, centralised, simple spatial information system of high quality that would be based on modern methods of gathering, processing, maintenance, manipulation and exchange of data.

The basic concept of CROTIS involves modelling of the Earth's surface and pointing out functional importance of certain object types using the latest information infrastructure for the production of object-oriented database. The basic principles and topics that are handled and analysed within the scope of the work involve development management, establishment and modelling of Topographic Information System accompanied by standardisation and specific needs of users, production of a system and a strategy.

1.4 Participants

The development of CROTIS (Creation of TIS 25 of the Republic of Croatia, later called CROTIS) was agreed upon in 1996 between the firm Geofoto d.o.o. Zagreb as a contractor and the State Geodetic Administration of the Republic of Croatia as orderer (Contract of 20th June 1996, class: 930-01/06-01/37; reg. no. 541-08/2-96-1) reference to "idea solution" and leadership of author of thesis.

The Croatian Topographic Information System was made within the frame of the work on standards in the field of topographic, photogrammetric and cartographic subsystem to be used in establishing and organising of topographic database. The standards of CROTIS are the basic document by means of which the manner of gathering, processing, presenting and exchange of topographic data is standardised, as well as the production of topographic database and establishment of topographic information system of the Republic of Croatia.

The data model was made through an intensive collaboration with possible users of topographic database. The participation of users has got an official character by means of correspondent questionnaire referring to the remarks made with regards to the suggested data model that has been previously explained in a number of informative lectures and direct contacts with all interested users.

The contact has been made with over 150 most important users: administrative institutions, public enterprises, joint-stock companies, private firms, scientific and educational institutions.

Exactly the collaboration on interactive modelling with the users has reached a high level taking into consideration the users demands and needs limited with the competence of the State Geodetic Administration referring to the contents and cost of spatial data.

1.5 Organisation of data model design

Maximal participation of users and recognition of their needs with respect to the contents, accuracy, classification, attributing, exchange and quality of data accompanied by interactive modelling are the basic characteristics

of CROTIS data model design organisation.
The increased engagement of the experts from the State Geodetic Administration on the design of the data model who are contacting the spatial data users daily has proved itself as especially constructive, being in the function of conceptual modelling according to the "functionally oriented modelling" principles.
The author and his contractor firm Geofoto - Zagreb with its experts and a to a lesser extent the experts from the Institute for Photogrammetry d.d. Zagreb actively and professionally engaged in gathering, processing, presenting of topographic data have produced the basic data model.
After making the first version of the data model, one started with gathering the data by applying analytical photogrammetry, with their topological processing and producing state maps as one of the possibilities to use CROTIS data.
MAPPING CATALOGUES being completely conformable to the data model has been made for the purpose of photogrammetric mapping which provided standardised data gathering according to the CROTIS data model.
The procedures of data gathering and processing according to the CROTIS model have influenced directly the acquisition of new knowledge and experiences indispensable for interactive modelling that has lasted for over three years in the function of the planned concept and establishment of topographic information system.

1.6 Creation of topographic database

The production of the data model has created the conditions for standardised gathering and processing of topographic data.
The author of the concept CROTIS initiated the Cyclical photogrammetric flights of the Republic of Croatia which provided aerial photographs of the entire state territory at the approximate scale of 1:20000.
At the beginning of 1997 the first works on gathering and processing of data according to the CROTIS model were agreed with geodetic firms. During only three years the territory of over 20% of the country was covered with the data defined by means of the above-mentioned work. The territories of the most intensive exploitation were involved in the operations, and they make more than 60% of Croatian economic resources.
On September 6th 2000 CROTIS was officially presented to geodetic experts and scientists together with so far obtained results in its creation, and on December 15th to wider Croatian public as well.
The Book of Ordinances ((National Gazzette 1999)) about topographic survey and state map production is used to full extent and refers to the contents, standards and instructions from the concept CROTIS.
The Program of State Survey and Real Estate Cadastre for the period 2001

- 2005 (National Gazzette 2001) planned the creation of CROTIS for the whole state area.
Just few small parts of Croatian territory are not covered with CROTIS data yet.

1.7 Overview of thesis

This doctoral thesis has been described in twelve chapters that are thematically and conceptually connected. The first chapter ≪Introduction≫ describes in short the motif, goals, participants, data model production organisation and topographic data production. Important connections with previous projects and their contents are described in the chapter No. 2. History. Chapter 3, Theory and principles of conceptual modelling, Chapter 4. together with the Analysis of the existing national topographic information systems (Chapter 5) make separate unity of general information and a good introduction into the Chapter 6 "Concept of Croatian topographic information system - CROTIS" in which the principles, standards, criteria and organisational and implementation features of the system are described in details. This is at the same time the most extensive and the most significant chapter of the doctoral thesis offering the most articulate picture of the work.
Scientific components of the thesis are described in Chapter 7. First, the automatic generating of GML documentation and its testing is described, and then its functionally oriented modelling has been applied.
Functionally oriented modelling has been tested in several workshops in various time periods.
Along with the creation of concepts, modelling the topographic information system, I have initiated and conducted other projects that have already been completed or are being processed now and that are very important for the implementation of CROTIS, which is described in Chapter 9.
CROTIS being the basis of the Croatian NSDI and INSPIRE, the principles, vision, directives and the future, as well as their comparison have been highlighted in Chapter 10.
Croatian Topographic Information System is the basis of all other national information systems that the location of information is very important for. Thus, in chapter 11 there are two presently most important Information System in Croatia described that are based on CROTIS.
The work ends with a long conclusion (Chapter 12) that offers apart from the author's observations also the future work, alternative solution, practical contribution, and author's own real contribution, as well as the part taken over from the "others".

Chapter 2

Connection of CROTIS to previous projects

There are three significant projects that have influenced the initiation of the CROTIS concept, providing also through their implementation the need for it and announcing certain guidelines for it, as well as for the creation and establishment of TDB (Topographic Database). "GEOPS RH" 1994 (Geodetic Spatial System of the Republic of Croatia) as the roof project for basic principals and presumptions of geodetic spatial system, "STOKIS - conceptual project" and the "Study about replacement of reproduction sources and renewal of topographic map contents".

2.1 GEOPS RH

Regarding the state of cartographic activity and of existing topographic maps, Croatia has found itself in a very complex position after becoming independent. Adequate attention has been paid to this problem and in the strategy of renewing geodetic spatial system of the Republic of Croatia. Thus, the activities A.8. and A.9. have been indicated already in the specification of the project GEOPS already (SGA 1993), in the items 4.12 i.e. 4.13, they define essential tasks in this field:

- the activity A.8. includes the foundation of cartographic institution in Croatia, being of high priority order;
- the activity A.9. includes the replacement of unavailable reproduction sources with the new ones, also being of high priority order.

Within the frame of the later activity, the project GEOPS foresees the creation of reproduction sources and the renewal of topographic map contents at the scale of 1:25000 and 1:200,000, production of a digital terrain model having sufficient quality, as well as the completion of the production and maintenance of the state base map at the scale of 1:5000. There is also the establishment of topographic and cartographic databases for topographic maps at the scale of 1:25000 and 1:200,000 foreseen.

2.2 STOKIS – conceptual project

On the basis of tasks and legal authorities referring to gathering, maintenance and distribution of topical information about land surface topography, the State Geodetic Administration has initiated the work on necessary project documentation needed for the establishment and creation of Official Topographic and Cartographic Information System (STOKIS) of the Republic of Croatia. In February 1995 the "Conceptual Project STOKIS" was made within the frame of these activities.
The goal of the conceptual project (Kovačević 1995) was to define fundamental guidelines, strategy for the production and development of STOKIS on the basis of the experiences coming from the world and from Croatia in the field of cartography and geoinformation systems. The need itself to create a primary model of STOKIS, topographic information system, was partly indicated in the conceptual project STOKIS.

2.2.1 Basic conception of STOKIS organisation and creation

In the work on the conceptual project STOKIS there have been the experiences used coming form the Federal Republic of Germany, as well as the solution applied in German information system ATKIS. The conception of ATKIS has been used to a great extent as the basis for STOKIS that has been necessarily adjusted to the existing situation and specific conditions in the Republic of Croatia.
STOKIS is based on a model theory of modern cartography. According to this theory the earth's surface, i.e. landscape with its topographic features and thematic contents is an original. Topographic survey provides - as a primary model - a topographic terrain model. Cartographic processing of the topographic model provides a secondary, cartographic model. In the process of creating and processing both models we use methods of generalisation that help in the realisation of various degrees of model precision. Both topographic and cartographic models can further be used in the production of tertiary models in which the users of STOKIS model connect and enter their own professional data (Kovačević et al. 1995).
The basic concept of STOKIS is shown on figure 2.1.

2.2.2 Creation of information system

Unlike topographic map that incorporates only secondary cartographic models, STOKIS consists of primary and secondary digital terrain models. The

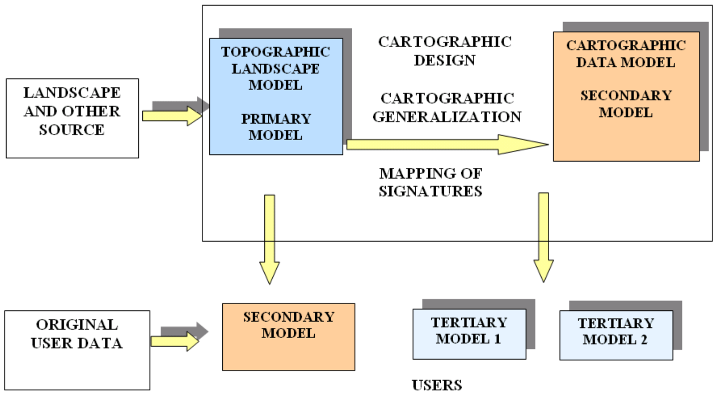

Figure 2.1: STOKIS concept

primary terrain model is created by means of structuring, i.e. logical dividing of three-dimensional earth's surface presentation into topographic objects and parts of objects. According to their shape, position and topological relations, the objects are classified into object classes. Attributes are attached to objects, they are edited catalogue-like and thus edited saved. Such a procedures of topographic modelling results in digital terrain model, abbreviated DTM, as a primary model of STOKIS. In accordance with geometric and positional accuracy of digital data, degree of generalisation and logical structuring of the terrain it is possible to realise digital topographic models of various information densities.
For the purpose of forming secondary cartographic terrain models a digital topographic model is used as a primary model. Cartographic symbols are attached to topographic objects contained in digital topographic model. In this work the procedures of map generalisation are used. Such cartographic modelling results in digital cartographic model, abbreviated DCM, as a secondary model of STOKIS. The intention is to attach different digital cartographic models to different digital topographic models in order to enable the connection of each digital topographic model with more different digital cartographic models.
In order to classify objects into object classes, the catalogues of object classes have to be made, abbreviated STOKIS-KO, and in order to attach a proper cartographic symbols to each object class, a catalogue of symbols is made, STOKIS-KS.
Topographic data with all its geometric and attribute characteristics, gathered and classified by means of object class catalogue, are saved entirely as digital topographic models into the data bank of topograpchic data model. The topographic data bank enables, if necessary, the retrieval of single objects or objects defined by certain criteria. These objects are then processed in the sense of cartographic procedures using the catalogue of symbols. In

this process an adequate cartographic symbols is attached to each object, depending on the object class that the object belongs to, and to its attributes. Thus created digital data are saved completely as digital cartographic model into the DCM data bank. On the basis of one digital topographic model the application of different catalogues of symbols can produce several various cartographic models. The data from DCM data bank can be taken and used for the purpose of graphic preparation and printing of various map publications in analogue form. The users can be offered digital extracts from digital topographic model and digital cartographic model that can be used independently or in connection with the users own professional data. Apart from digital data, users can have also analogous cartographic products at their disposal.

2.2.3 Contents of STOKIS

Digital topographic model of STOKIS contains three-dimensional structure of the earth's surface (topography) in the form of digitally shaped topographic objects. These objects are determined in the state Gauss-Krüger co-ordinate system with regard to their position and height: they do not depend on scale and are not replaced either by conditional or concrete cartographic symbols. Topographic objects are classified into object classes in accordance with their properties, and they are further organised into object groups, and object groups into sever fundamental object entities.

2.2.4 Presumptions and requirements of the conceptual tasks of STOKIS

General requirements

Such a system must be reliable, accurate and topical with regard to its geometry and attributes. Apart from that, it must be widely usable and available to the greatest possible number of users. Because of its complexity and the long time needed for the creation of such a system, as well as because of increasing and constantly urgent demands and needs of users, it is necessary to apply gradual way of creating a system. Such an approach would enable gradual realisation and functioning of parts of the systems as soon as they are finished. Furthermore, the project of the system should cope with the world experiences and standards, and should also foresee the possibilities of being included into appropriate European systems.

Catalogue of object classes of STOKIS (STOKIS-KO)

The terrain structuring is made in the catalogue of object classes (STOKIS-KO). It also involves the classification of topographic objects, which determines also the contents of digital topographic model. STOKIS-KO contains the definition of each object class, encompassing criteria, types of objects and rules for shaping objects and object parts. Apart from that, there are also the instructions contained in the catalogue intended for possible entering of object names, attached attributes, attribute values and references. The main task of the object class catalogues is a terrain classification according to topographic features and states, and hence, establishing the contents of digital topographic model and preparing the fundamental principles for creating topographic data. STOKIS-KO contains topographic objects with topographic and professional information attached to it by means of attributes. Such attribute-like formation enables free selection of topographic objects according to the attributes within object classes, as well as different formation of graphic elements within cartographic object classes.

Implementation project STOKIS

It will be necessary within the scope of implementation project STOKIS to make a more extensive classification of the object class catalogue, to define the rules for formation of objects, and to determine the encompassing criteria, attributes and attribute values for each single object class. An appropriate STOKIS-KO should be made for other selected models as well.

Realisation of STOKIS

The system STOKIS is a very complex system the realisation of which will demand a lot of effort, and intelligent and physical work, regardless of the advance of computer technologies in a few recent years. STOKIS is basically conceived also as a system that will be created in a rather long development process. The purpose of this conceptual project was to define the concept and to set basic guidelines for the organisation and development of this system. The creation of digital topographic model, as well as of the whole system, demands much more extensive and scholarly preparation in the form of implementation project that would first contain the complete catalogues of object classes as the base for the first phase in creating DTM 25, and then also the catalogue of symbols for adequate cartographic models.

2.3 Study about replacement of reproduction sources and renewal of topographic map contents

In the work on the Study, the research and the activities were carried out on the theoretical basis, as well as on practical models. There was the fundamental strategy considered in it taken from the project of reconstructing geodetic spatial system (GEOPS, activities A-9 and A-15), and also the correspondence achieved with the projects from the same scientific and professional area (STOKIS).

The Study (Biljecki at al., 1995) gives the answers to essential questions connected with the replacement of reproduction sources and renewal of the topographic map contents; testing the accuracy of existing maps (printed on paper), possibility of their complete or partial usage, production of completely new topographic maps on the basis of photogrammetric rectification, integration of the basic data into CROTIS (Topographic Information System of the Republic of Croatia), possibility of producing new topographic maps on the basis of the existing resources, expenses etc.

2.3.1 General guidelines and concept

The Study describes the procedure and dynamics in the production of new Croatian topographic map 1:25000. A new map is very important because of the high quality photogrammetric procedure used in gathering the data. Analytical and digital procedures provide three-dimensional presentation, low expenditures in maintaining the map, and direct transfer of data into TIS 25 RH, later called CROTIS.
The Croatian Topographic Map 1:25000 encompasses the most important information on topography of the Earth's surface in digital form. There has been a great effort made to include essential object classes with complete geometric solutions, and partially with attribute description, in this first phase of TIS realisation. The basic data model of TIS 25 will be exchangeable with the available information systems.
Digital Terrain Model (DTM) gives us besides the possibility of height presentation with contours, altitudes and shading, a solid and reliable basis for computerised three-dimensional presentation of the Earth's surface, important and usable for a large number of users: military, geology, hydrology, telecommunication, designing, planning, simulation of catastrophes etc.
DTM has been gathered by means of analytical photogrammetric mapping of high accuracy including all essential relief details.
VEGETATION, COMMUNICATION, WATERS, SINGLE OBJECTS AND LINEAR ELEMENTS are presented and structured considering exclusively modern ways of gathering and processing the data, taking into account especially their economic and high quality integration (objectifying) in TIS 25 RH.
TOPONYMS are presented by means of adequate lettering type depending on the elements and way of their presentation, taking into account aesthetic and information factors of data processing.
WGS 84, at the territory encompassed by the Study there were 17 Global Positioning System (GPS) points measured with their results being included into the procedure of aerotriangulation and data gathering.
CARTOGRAPHIC KEY, a new approach in the production of topographic maps requires the replacement and supplementation of the existing cartographic key, which has been partly done in the Study itself. The complexity

of TIS and new cartographic presentation demands the continuation of the works on the production of new cartographic key for Croatian Topographic Map 1:25000.

2.3.2 Problems and solutions encompassed by the study

- Basic guidelines
- Starting situation
- Overview of cartographic material available in Croatia at the moment
- Croatian Base Map 1:5000
- Detail and general topographic maps
- Quality estimation of topographic maps
- Map accuracy estimation and methods of testing single elements
- Testing the accuracy of the map 1:25000
- Testing the accuracy of the map 1:100000
- Topographic map 1:100000
- Topographic map 1:200000
- Accuracy estimation of a new digital map 1:25000
- Austrian experiences
- Swiss experiences

Defining the needs:

- Selection and recommendation of topographic map scale needed by the Republic of Croatia
- Cyclical aerial photography of the Republic of Croatia
- Digital Terrain Model of the Republic of Croatia
- Digital orthophoto on the basis of cyclical aerial photography and digital terrain model
- Photosketches / photo mosaic / photoplan on the basis of cyclical aerial photography urgently needed
- Geocoded satellite images

- Research and methodology recommendation
- Technical feasibility
- Available resources in Croatia

Control on test tasks:

- Production of digital topographic map 1:25000 from the existing digital map 1:5000
- Usage of completed geodetic documentation
- Possibilities of using digital map 1:5000
- Map generalisation
- Production of digital topographic map 1:25000 from the photomaterial at the scale of 1:9000
- Using the existing topographic map TK 25 in the production of a new Croatian Topographic Map 1:25000
- Accuracy estimation of the scanned TK 25
- Replacement of the contents in raster form
- General about the procedure of transforming graphic patterns into digital form
- Replacement of the contents on raster image

2.3.3 Statements and solutions of the Study serving to the development of CROTIS

Data gathering serving to CROTIS

The data of topographic and cartographic modelling are, as already shown, of high accuracy larger than needed by TK 25, but taking their integration into information systems in account, as well as the fact that they are the basis for establishing TIS 25 RH, the usage of modern data gathering procedures is quite justified, especially because such procedure does not raise the expenses. Photogrammetric mapping and topographic land survey, photogrammetric analytical and digital rectification are basic methods of direct gathering of geometric data for the production of topographic maps. The data structure is adjusted to modern information processing, and to the new cartographic presentation.

Line, point, and arc are the basic and the only graphic elements that are used to present a certain territory by means of modelling and considering

the functionality of single elements. The stated primitive graphic elements are selected in order to achieve as simple, safe and high quality transfer and exchange of data with other information systems as possible.
The basic attributes, types of land coverage, geometry, accuracy, the data about the last updating, identifiers, types of point and line elements are provided and defined in the data catalogues.

Data structure

Digital terrain model is structured in such a way that it enables high quality transfer and exchange of directly measured, but also calculated data about the terrain structure to any other information system and that it is used by available elaboration programs for DTM (SCOP and others). Their exchange format and calculating algorithms were taken in consideration in this respect excluding the possibility of larger information losses that could make a remarkable influence on DTM. Thus structured data make the basis of TIS 25 RH, and are the most important element and starting point for cartographic processing and generalisation.

General aspects

CROTIS being a part of Official Topographic and Cartographic Information System (STOKIS) of the Republic of Croatia was the principal leading idea in the definition and production of topographic map at the scale 1:25000.
CROTIS makes the basis for the production of other topographic maps at smaller scales (TK 100, TK 200, TK 300) that provides reliable and computerised data covering large areas of Croatian state. It will be of great use in reconstruction, planning, military activities, scientific research, education, management and decision making.

Conclusion of the Study

The Study about Replacement of Reproduction Sources and Updating of Topographic Map Contents has given the answers to many unknowns that used to be exposed to photogrammetrists and cartographers in Croatia. Hybrid procedures (replacement of the contents in raster) being the production technology for a new Croatian map 1:25000 are completely rejected, because the price and quality of the results (data) are inappropriate for the integration into TIS 25 RH, but have proved themselves as justified and generally accepted to be used as temporary and quick solution with minimum replacement of the contents, margin and lexical harmonising of names.
The authors proposed (Biljecki et al. 1995) that only a new aerial photography, modern three-dimensional analytical or digital photogrammetric mapping with precisely defined accuracy standards and data structures of graphic geometry model, as well as of alphanumeric data give solid basis

for TIS 25 RH, and hence, also the cartographic model resulting by means of processing and generalisation in high quality computerised topographic map.
The present resources of the Republic of Croatia (its own aerial photography service, modernised photogrammetric firms, possession of appropriate computer equipment, existing cartographic firms, Faculty of Geodesy, State Geodetic Administration) and the knowledge acquired in previous projects, as well as final results of this Study, provide surely undisturbed and much-needed beginning of producing new Croatian topographic maps.

Guidelines for the creation of CROTIS concept and establishment of TDB

Program of activities in 1996:

- Production of 40 - 50 priority sheets of the new Croatian Topographic Map 1:25000
- Production of new cartographic key
- Connecting various cartographic activities in this field, first of all, in civil and military sector
- Production of a new Croatian Topographic Map at the scale of 1:100000 and 1:200000
- Production of new reproduction sources by means of limited replacement (margins and names) and using hybrid method for the entire area of Croatia
- Practical establishment of TIS of the Republic of Croatia and production of priority standards for TIS 25 of the Republic of Croatia.

Chapter 3

History of geoinformation systems

The beginning of geoinformation systems is defined by the production of the first maps containing, apart from topographic, also some other data associated with a certain position on a map, with some co-ordinates in the space.
Today we call such maps, mostly made by means of a computer, thematic maps.

3.1 Historical overview

Historical overview is presented by chronological rations and influence on the GIS development.
In Croatia there is a predecessor of geoinformation system in the form of topographic map sheets at the scale of 1:2880 resulting from the "second Franciscan military land survey" (Lovrić 1988) of the territory of the Hapsburg Monarchy within the frame of which there was also the Kingdom of Croatia (Königreich Kroatien).
The survey was made in the period from 1806 till 1869 by the Headquarters of the Monarchy, i.e. by the Military Geographic Institute from 1839 as it was founded. On the right margin of each sheet there were the data contained about the number of houses, stables, people and horses for all settlements that were presented and named on a map.
A great part of Croatia was a "Military Border" with Ottoman Empire at that time, so the existing men and equipment capacities in the field presented precious data for the Headquarters and military commander of the border.
The historical example for gathering and analysis of geoinformation was the discovery of polluted waters in London in 1854. as the cholera epidemic broke out. Dr. John Snow (Vinten-Johansen P. i dr., 2003.) registered

cholera death casualties on the map locating thus dangerous wells.
In the battle at Yorktown during American revolution, the enemies troop movements were registered on maps, which made a significant change in the warfare manner.
The development of computer technology (especially graphics hardware) and ever growing demands of administrative structures for spatial information have influenced rapid development of geoinformation technologies.
In the sixties of the last century one of the first modern geoinformation systems Canada Geographic Information System (CGIS) was initiated in Canada. The project was initiated for the purpose of analysing the data that were gathered by the institution Canada Land Inventory and of obtaining statistical data on the basis of which the development plans for large areas of Canada were made. The base of the system were seven fundamental layer maps at the scale of 1:50 000 (Tomlinson R. 1998). The main idea was the transfer of maps into computer, entering of other spatial data being the basis of requested computer analysis. CGIS became operative in 1971 and has remained as such till today. During the time in which the system has been developed and used, many innovative solutions have cropped up, with the most important among them being:

- the production of experimental scanner for the transfer of maps into digital form accompanied by the method of vectoring scanned maps
- the production of a data structure system (classification of data into layers), encoding of objects and attribute table concept.

In 1974 there was Harvard Laboratory for Computer Graphics and Spatial Analysis founded with an intention to develop a software to be used in spatial data processing (mapping in vector format and printer output, later on plotter). It was a system for map production without cartographer (SYMAP). A whole program system was developed. The program ODYSSEY (1979) has already got an extensive system for spatial analysis (Coppock, J.T. 2001).
Based on the ideas and techniques of Harvard Laboratory, Jack Dangermond founded in 1969 the Environmental Systems Research Institute (ESRI) and developed the first GIS software for new microcomputers not depending on a platform and operative system. ARC/INFO (1981) saved the data about position and attached attributes separately. The attribute tables can be managed outside of the program (first INFO, later on database), and the objects were saved as a series of arcs (ARC). Originally developed to be applied in forestry it soon became indispensable in the GIS market.
US Bureau for the Census of the late sixties tried in its preparations for census to connect the census with the right geographic position (transformation of street address into co-ordinates and to get the data for a certain census report zones). The report zones were placed hierarchically (a district

within the zone, ...) providing extensive data approach.
Thus defined demands led to the development of GBF - DIME files (Geographic Base File, Dual Independent Map Encoding) that the first census was made with by means of geocoding in 1970. GBF - DIME files as predecessors of TIGER model encoded the segments between junction points/cross sections with defined left and right block using actually the structure of CGIS. On the basis of census the atlases were made in 1970 with computer maps for selected census variables and selected cities. Sophisticated technique was later on used for the production of maps to be sent to market, of statistical maps for PC computers, car navigation system, selection of movement routes, the first aid dispatcher centres, fire departments, police, and all that on the basis of border data banks made by the Bureau for its census.
In Europe there were no significant researches in the field of geoinformation. The tradition and different organisation structure in spatial data processing are the reason for very low activity in this area. More attention was paid to the usage of computer technology in land registry (Austria and Switzerland). The main laboratories for testing new technologies are in England (Ordnance Survey of the United Kingdom) and in France (Institut Géographique National - IGN). In Germany, the independent agencies for map production have founded a syndicate for the estimation of effects caused by the transfer from traditional land registry organisation to the one based on computer technology.
In 1984 the first International Spatial Data Handling Symposium took place.

Chapter 4

Conceptual modeling of geoinformation systems

Database occupies a central position in the topographic information system. The modelling of such a basis must offer to its users all necessary information about the system that has been created according to their requests. In the procedure of modelling a database there are different methods used and it is performed in several phases.

- Phase 1 - Request formulation and analysis, the analysis of object system
- Phase 2 - Conceptual modelling
- Phase 3 - Implementation modelling
- Phase 4 - Physical modelling

Conceptual modelling presents the most important phase in the creation of information systems. Considering the definition itself, the data model must be conceived to enable an effective approach to data, as well as to make adequate operation on these data possible.
Conceptual modelling belongs to the procedure of logical database modelling and is intended for the creation of conceptual data model on the basis of information about the data structure obtained in the phase of request formulation and analysis.
Well modelled conceptual database model must be:

- complete (giving a complete picture of an object),
- natural (objects and their relations presented in the model must correspond to the relations in the real world),
- concise (the structure and contents of the real world are presented with the minimum number of objects and relations among them).

4.1 Theory of modelling

Conceptual modelling is based on using the abstraction, i.e. the methodology of modelling based on recognising the similarities among objects of the real world and on neglecting temporarily the differences among them. The abstraction is used to decompose the real world model, objects and connections between them into abstraction hierarchy, i.e. the combination of aggregations and generalisation.
The method of database abstraction takes the premises as its starting point that the abstraction is the tools by means of which human being understand and conduct a complex system. The abstraction is performed in two ways:

- the abstraction of system status (this procedure results in abstract objects or concepts)
- the abstraction of system transformation (this procedure results in abstract operations).

The procedure of creating a conceptual database model using the method of abstraction starts with defining the abstract objects or concepts. The abstract objects are in certain relations with other abstract objects.
Generalisation and aggregation are basic operations used for defining the relations among abstract object. The generalisation is a procedure by means of which a new class at the higher level of abstraction is formed from some class group. The aggregation is a procedure used for defining an object on a higher level of abstraction starting with the group of its components.
Data model as a formal system must contain the following components:

- a group of modelling objects;
- a set of connections among object.

Generally speaking, a model is an abstraction, i.e. a simplified presentation of real world objects and relations among them. Since the world consists of OBJECTS that can be real or abstract, we call them ENTITIES, and since the term entity is not easy to define, we can say that the entity is everything that exists or everything that is possible to be thought about.
The entities as the representatives of the real world have got certain properties. The description of one property consists of the attribute that defines unambiguously the property type and attribute values. Domain is a group of all values that the attribute can acquire. The Entity class implicates a group of entities with the same properties.

4.2 Object-oriented conceptual modelling

Object-oriented models unite data and processing structure and provide faster implementation of certain operations. An object being the basic model concept has got the following characteristics:

- object is a unique phenomenon in space and time and can be uniquely recognized,
- objects have got characteristics, i.e. attributes,
- objects are manipulated by means of attendance method,
- the characteristic of an object is its behaviour and the changing status,
- objects can be classified,
- objects can be composed,
- objects exchange messages.

Class is a description of one or more objects that have got the same group of attributes and equal behaviour description, and an object is class phenomenon. The class correspond to the entity type.
Each object consists of identifiers, attribute list and attendance method.
These models require also object-oriented databases supported by adequate object-oriented database management systems (OO-DBMS). OO-DBMS store objects in object way and search for them in the same way.
The essential difference between object models and relation models is in the attendance method definition. The relation model describes only the data component of the information system, hence, it only works out the data structure. Since it does not describe the processing component of the information system, the relation model does not represent the conceptual description of complete information system. The conceptual object model is most often implemented in object-related system because object-related DBMSs (OR-DBMS) are dominant.

4.3 Standards in geoinformation

The standardisation in geoinformation is necessary for the purpose of establishing a homogeneous system of collecting, creating, maintenance, presentation and exchange of spatial information in digital form among various manufacturers, users, systems and locations. ISO Technical Committee 211 and Open Geospatial Consortium (OGC) have got the leading role in the standardisation in the filed of geoinformation, and technical protocols that are indispensable primarily in geodata exchange are produced in accordance with the standards stipulated by the World Wide Web of the Consortium (W3C). The standards support interoperable solutions enabling the "geographicalisation" of the Internet, wireless and positionally connected services, as well as of the entire informatics.

4.3.1 ISO standards

ISO (International Organization for Standardization) is the international organisation consisting of national bodies intended for passing the standards in various application domains. Technical Committee ISO/TC 211 *Geographic information/Geomatics* is responsible for the standardization in the domain of digital geoinformation (spatial geoinformation). TC211 is entrusted with the production and publication of the whole series of standards related with the objects and phenomena directly or indirectly connected with the position on the Earth (URL 3).
ISO standards that are used in the field of modelling are: ISO/DTS 19103 *Geographic information - Conceptual Schema Language*, ISO/IS 19107 - *Spatial Schema*, ISO/FDIS 19109 *Geographic information - Rules for application schema*, ISO/DIS 19110 G*eographic information - Feature cataloguing methodology.*

ISO/DTS 19103 – Conceptual schema language

This standards deal with conceptual schema language usage for the purpose of model development. The usage of formal conceptual schema language is indispensable for the standardisation in geoinformation because the understandable schemas used as the basis for data exchange etc. are specified in this way.

ISO/IS 19107 – Spatial schema

The purpose of this standard is to produce the conceptual schema of spatial geoinformation characteristics, and especially geometry and topology. Spatial operators consisting of functions and procedures using or creating spatial objects are also a part of the standard.

ISO/FDIS 19109 – Rules for application schema

The purpose of this standard is to set the rules for defining the application schemas, including the classification of geographical objects. The usage of these rules will make it possible for the data and the systems to be exchanged within and through various application fields. The appearance, naming of classes, attributes, attribute values is solved at the application level in order to obtain a model that would provide different further application of modelled data. UML (Unified Modelling Language) is used as the application schema language.

ISO/IS 19110 – Feature cataloguing methodology

The methodology of cataloguing geographic features, their attributes and relations makes the contents of this standard. Among other things, this approach provides a simpler data transfer between different applications through clear and standardized object defining.

ISO/WD 19136 – Geography Markup Language (GML)

GML is the language with XML structure that is coordinated with ISO 19118 standard for transfer and storage of geographic schemas and information, and this standard defines the syntax, mechanisms and rules of XML schema production.

4.3.2 Open Geospatial Consortium

Open Geospatial Consortium (OGC) is the international, non-profitable and open institution with more than 230 firms, government offices, university members participating in a coordinated process of developing public specifications about spatial data. The basic mission of OGC is (URL 4) production and establishment of public, open and free-of-charge specifications of spatial interface acceptable for global usage. Open interface specification provides for data manufacturers, system designers and system integrators to pay more attention to the functionality of their products and services, wasting less resources and efforts on integration and interoperability. OGC addresses the fulfilment of this mission by setting the following goals:

- Formalization of OpenGIS specifications by means of consensus: through its own organisation of the acceptance process to be handled by committees and specifications, the OGC members develop, monitor and publish OpenGIS specifications.

- Organisation of interoperable projects: introduction of pilot projects, studies, test projects aiming to check quickly and efficiently, test and document the specifications that do not depend on single manufacturer, and are developed on the basis of user requests.

- Development of strategic business opportunities: identifying user communities and markets that need open spatial interfaces and including these communities into development and acceptance of OpenGIS specifications.

- Development of strategic standardisation partnerships: OCG coordinates its standards with other IT standards through partnerships and cooperation with other international standardisation efforts.

- Promotion of requests for interoperable products: through its market programs and public relations programs, OGC works on the increasing the acceptance and consciousness of the needs for OpenGIS specifications.

OGC processes two types of specifications: abstract and implementation specifications. The role of abstract specifications is to create and document the conceptual model that offers the basis, i.e. the reference models that individual implementation specifications are made from. This type of specifications coincides in its sense and contents with the ISO standards, and the process of coordinating the conceptual OGC specifications and ISO standards has initiated the adoption of some ISO standards instead of OGC abstract specifications. This process develops in opposite direction as well. Thus, the proposal for Geography Markup Language (GML) implementation specification has become at the same time the proposal for the standard ISO 19136. It can be seen from this example, but also from many other examples in the practice that the work of OGC is respected in the standardisation community, as well as in user community.
GML is the language for marking that respects the standard ISO 19118 Geographic information - Encoding, and respectfully, the XML specification as well, and it is used for transfer and storage of geodata. The language tries to cover spatial and non-spatial characteristics and connections among phenomena. GMS is a dialect of XML with its syntax and grammar being defined through OGC implementation specification.
Basic characteristics of GML are:

- it provides open and neutral environment intended for defining geo-application data schemas,
- makes it possible for the profile to be used that defined the subset of GML schema making the applied schemas simpler,
- it supports the extension of the basic GML schema for specialized domains and user communities,
- it provides the production and maintenance of mutually connected schemas and data subsets,
- it supports the storage and transfer of application schemas and data subsets, and
- it makes the exchange of geo-application schemas and information they describe easier.

GML can serve exclusively as exchange format or as data storage and processing format. GML schema, i.e. application schema or xsd schema for GML documents, determines the allowed structures in GML documents.
In the development of the system GML schema is stipulated for the purpose of easier data exchange and of achieving greater openness of the system for interoperability.
Out of the momentarily actual versions of GML the following should be pointed out:

- GML 2.1.2 - a stable version defining the basic structures, the only version that is supported in commercial tools at the moment,
- GML 3.0 - a more recent version that introduces richer syntax, this version is also an official version at the moment of writing this document,
- GML 3.1 - the two reasons for publishing this version are the following: corrections in the documents of the version 3.0, and the adoption of GML as the encoding schema accepted by ISO.

More recent versions are the subsets of older versions, i.e. the compatibility principle has been retained wherever it has been possible: all tools supporting newer implementations should be capable of working with the older versions as well.

Chapter 5

Existing topographic information systems

The examples of national standards of the U.K., Republic Germany, Switzerland, France and Columbia illustrate the manner in which the topographic data of the stated countries have been structured. The selection of exactly these countries has been made because of the very succesfully designed and implemented topographic information systems.

Over presented national TIS during this work other relevant national and international standards as A2260/A2261, CCOGIF, DIGEST, INTERLIS, etc. have been taken in consideration (K.Kraus, Photogrammetrie, BAND 3, Topographische Informationes Systeme, Vienna, 2000.).

5.1 ATKIS – the authorative topographic - cartographic information system

The official topographic - cartographic information system of the Federal Republic of Germany was made as the result of the research and development of German State Agency for Surveying (AdV) lasting several years in the field of surveying, cartography and automation (URL 1). ATKIS defines state standard in the area of digital topographic databases having three-dimensional structure.

The system and the database are based on modern cartographic model theory.

The concepts according to which ALB, ALK and ATKIS were founded originated in the 1970s and 1980s. These concepts remain the platform on which the relevant geobasis data inventories are created and maintained at the moment. Other extensive digital database inventories have also been created according to the states' specific concepts, e.g. digital orthophotos, raster data of the topographical state maps and digital elevation models.

5.1.1 Data model

Topographic survey creates a primary model or topographic landscape mo-el, in short, the real world with its topographic features and their thematic structure presents the source.
Using the procedure of cartographic processing and standardised process of map generalisation, a primary model is transformed into secondary cartographic model. Tertiary model or to be more exact, thematic model results from the implementation of user-specific original data model or some other derived model (figure 5.1). Topological relations of features, their geometrically defined and positioned three-dimensional structure together with attached attributes, being coded and saved, make a primary landscape model. The process of topographic modelling results in Digital Landscape Model (DLM), and it can have different degree of information quantity depending on the topographic survey accuracy and level of contents, detailing.
Digital Cartographic Model (DCM) is obtained by adding various symbols

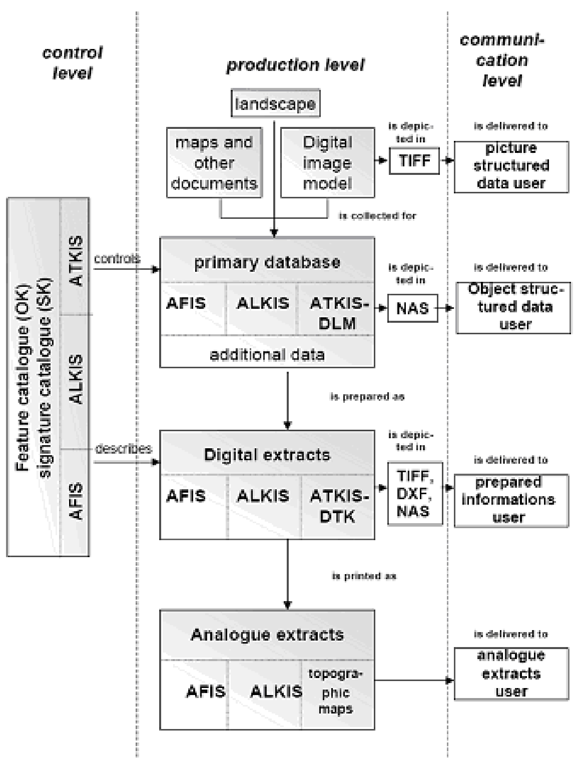

Figure 5.1: Common AFIS-ALKIS-ATKIS Reference model

to the features of DLM, a primary model, following the rules of map generalisation and applying the process of cartographic modelling.
In other to associate the features with object class there is an object cata-

logue (ATKIS - OK) used, and for associating proper cartographic symbols to a certain object type one uses a (ATKIS - OK) catalogue.

5.1.2 Standards

Apart from standard graphically structured exits, the ATKIS data can be transferred through "standardised data base interface" (EDNS) in their geometric, alphanumeric, attribute and topological relations. The possibility of their integration with "European Transfer Format" (ETF) is being researched and developed at the moment.

5.1.3 Development

The future of ATKIS depends directly on the demands of users, but the priority is undoubtedly given to the development of DLM as related to DKM, especially DLM25 (defined by the contents of topographic maps at the scale of 1:25 000), and then DLM 200 and DLM1000. AdV also plans to make independent ATKID data model based on ALK (Automated Cadastral Data Base) data model.

5.1.4 Conclusion

The object-oriented concept of ATKIS enables relatively simple implementation of a complex conceptual data model and defines one of the best and the most developed spatial information systems.
The possibility and the future development of the connection with land registry data is an additional quality, and after introduction of European and world standards, ATKIS has become a complete spatial information system.

5.2 VECTOR25

VECTOR25 is the basis of topographic information system of Switzerland based on the geometry and the contents of a topographic map 1:25 000. Natural and man-made objects are presented in flexible vector format and can make a basis for establishing various thematic geoinformation systems. VECTOR25 describes over 5 million objects through their shape, attributes and topological relations (URL 2).

5.2.1 Data model

Georeferenced vector data about land topography with proper attributes make a high quality base for practical usage and development of multidisciplinary GIS technologies. Thematic object entities (LEVEL 2) structured according to defined criteria of topological relations make basic data model content. In this way there are 140 various classes defined in the data model.

Topology and geometry describe every object class and make a standard data model along with attribute attachment and criteria.

5.2.2 Data quality

Positional accuracy of geometry runs up to 3 - 8 m (referring to the primary data source Topographic map 1:25000), and data relevance lies within the limits of 1- 6 years. Content homogeneity and data consistency are very good. Spatial inquiries and analysis, as well as simulations are enabled by rather free and flexible topology. The criteria referring to minimum and maximum class dimensions have been met. Accompanied by a pretty stable object identification and geometry there has been an undisturbed data transfer provided into other GIS and CAD systems.

5.2.3 Databases – information system

For various disciplines, VECTOR25, databases and information system are of great importance. Spatial and urban planning, defence, tourism, transport and management are the most important areas of applying and using analysis methods, simulations and inquiries provided by means of this topographic information system and databases.
VECTOR25 describes traffic routes, water bodies, land usage and other topographic features with clear topological structure (junction - edge and shape) and classification (140 objects) in the function of spatial analysis and simulations.
Due to a very flexible structure, VECTOR25 and its database can be combined with other sources (e.g. Digital Height Model - DHM25, Pixel maps) which opens the possibility for higher quality analysis and inquiries.
By analysing the contents of the database and detail level one can see that it is more or less in accordance with the contents of the topographic maps at the scale of 1:10 000 - 1:100 000 being thus an ideal reference base for the development and establishment of thematic geoinformation systems. Dynamic classification and possibility of referencing specific attributes with the objects of the base VECTOR25 opens wide application possibilities for various users.

5.2.4 Application – generally

The database VECTOR25 has found wide application, and hereunder there are the most important areas given:

- it makes visual basis for GIS, CAD and navigation systems
- it is used as additional layer for DHM25 in 3D visualisations and analysis

- it serves as the database for planning, analysing, simulation and management
- it is used as reference data for the production of other information systems
- it is used for various publications in analogous and digital form (maps, plans, internet)
- it is used for special products (e.g. multimedia, navigation and geomarketing - CD)

5.2.5 Conclusion

The topographic database VECTOR25 provides optimal geoinformation infrastructure as a primary basis in the production of thematic geoinformation systems. If observed through its contents, detail level and accuracy of answers, it corresponds to detailed general topographic maps, and vector-like structured and topologically edited data provide the possibility of free spatial inquiries and visualisations.
It is important to point out that large usage of TIS (Topographic Information System) data VECTOR25 by users is due to a powerful promotion campaign made by the Federal Office of Topography in Switzerland.

5.3 BD TOPO

French topographic database BD TOPO (La Base de Données Topographiques de l'IGN) was created on the basis of the decision made about its creation in 1982 at the National Geographic Institute of France (IGN).
The basis of BD-TOPO is in the vectored topographic map at the scale of 1:25000 with additional, more accurate photogrammetric and field survey of single elements and objects.
Accuracy and detail level of this database are in accordance with the reference scales of 1:10000 do 1:25000.

5.3.1 Data model

Topographic features are described with two types of information:

- the first information level describes the characteristics of a topographic feature and its connection with the neighbouring one
- geometric level of information locates the objects and its neighbours.

The description level classifies the objects into point, linear and surface objects. An adequate attribute is attached to each single object, and a type

attribute group to a thematic group. The geometric level of information has two concepts: topological and metric. Topographic database contains the information in vector format, and that is, for all objects of point, line and surface type.
The topographic database contains the data of metric accuracy in three dimensions gathered by means of photogrammetric method. The data are gathered by means of photogrammetric mapping on the basis of photography at the scale of 1:30000 and 1:50000.
The mechanism for establishing quality consists of two parts: quality control and providing of quality. Topographic objects are grouped into 5 classes of planimetric accuracy and 16 classes of height accuracy. Apart from the control of geometric accuracy during the production process and completeness of the base BD TOPO, the mechanism of topology and attribute verification has been developed.

5.3.2 Maintenance of BD TOPO

General principles of maintaining the database are as follows:

- initial data quality cannot be reduced
- maintenance should be realised periodically, every six years
- photography is taken at the approximate scale of 1:50 000
- previous states, before updating the contents, should be saved on magnetic and optical medium.

5.3.3 Conclusion

Three basic tasks given and specified by the conceptual model of topographic and information system BDTOPO are also fulfilled:

1. Updating the contents of topographic maps 1:25000
2. Realisation of the project dealing with the production of maps at the scale of 1:5000 for rural areas
3. Distribution of structured data in topography

The development of multidisciplinary information systems with various data (land registry, topography, pedology, administrative and statistical data) is thus provided accompanied by the clear definition of responsibility over actuality of data (IGN for BD TOPO).

5.4 Ordnance Survey MasterMap®

OS MasterMap is a consistent and maintained framework for the referencing of geographic information in Great Britain. It comprises four separate but complementary layers that provide detailed topographic, cartographic, administrative, address, aerial imagery and road network features positioned on the National Grid (URL 7).
Great Britain was completely remapped between the years 1946 and 1983, and this mapping continues to be updated and upgraded. Since 1946 surveying and mapping techniques have developed and the specifications for capture and maintenance of the mapping have changed to meet new user requirements. Consequently, maps have been produced by a number of different methods, producing a range of accuracies and content within the overall tolerances appropriate to the scale of the published map.
The graphic mapping was digitised from published Ordnance Survey topographic maps created from ground or photogrammetric surveys. Large-scale topographic maps were traditionally published at scales of 1:1250 (urban areas), 1:2500 (rural areas) and 1:10 000 (mountain and moorland areas). These maps were not intended to represent surveys of engineering quality or precision but are a multipurpose series of general topographic maps.
The digitising programme began in 1971, and was aimed at the automation of graphic map production. The increasing demand for digital data in the 1980s led to an acceleration in the digitising programme and coverage of Great Britain was completed in 1995. These digital maps have been constantly revised within a digital environment since their initial capture and are now known as the Land-Line product. In April 2000 Ordnance Survey commenced a programme to convert the unstructured, tile-based data, into an object-based, seamless dataset to form the basis of OS MasterMap. The resultant data was further improved in a manual editing programme finishing in October 2001.
The absolute accuracy of existing data is as shown in the Table 5.4.

The revision activity is split into two processes: continuous revision and cyclic revision. Continuous revision is undertaken for those features of most importance to the majority of customers – mainly urban developments – or where capture is in the national interest. The aim is to capture these features within six months of building being completed on the ground. Cyclic revision is undertaken periodically for changes to the natural environment, which tend to be slower and less evident than additions to the built environment. This information is of use to many customers, with certain areas surveyed purely in the national interest. Capture can be most economically achieved using systematic revision at fixed intervals.
The data is captured and maintained primarily by the following three processes:

Data capture standards (original capture scale)	99% confidence level	Current
Urban (1:1250)	$< \pm$ 1.0 m	$< \pm$ 1.0 m
Rural (1:2500 resurvey or reformed)	$< \pm$ 2.4 m	$< \pm$ 2.5 m
Rural overhaul (1:2500 pre-positional accuracy improvement)	$< \pm$ 5.8 m	$< \pm$ 6.0 m
Mountain and moorland (1:10 000)	$< \pm$ 8.8 m	$< \pm$ 8.0 m

Table 5.1: Absolute accuracy of existing data in Ordnance Survey MasterMap

- continuous revision by network of field offices around the country;
- centralised activity driven by external intelligence sources; and
- cyclic revision by photogrammetric surveys.

5.4.1 Data model

OS MasterMap vector products have a hierarchical structure. The highest level of the structure is the layer. There are currently four layers:

- OS MasterMap Topography Layer
- OS MasterMap Integrated Transport NetworkTM (ITN) Layer
- OS MasterMap Address Layer 2
- OS MasterMap Imagery Layer.

Within each layer can be a series of *themes*. A theme is a fixed set of features that can be collectively selected for supply by users. Within each theme there are features deemed to belong to that theme. A feature can belong to more than one theme. This model is extensible at all levels.

MasterMap Topography Layer includes the following themes: administrative boundaries, buildings, heritage and antiquities, land, rail, roads, tracks and paths, structures, terrain and height, and water.
A theme is created by applying rules based on the attributes of OS MasterMap features. A theme rule can put conditions on more than one feature attribute. A feature is a member of every theme for which it passes the theme rules.
Every *feature* is identified by a TOID®. TOIDs hold no intelligence; they are allocated sequentially as updates are applied to the database. The TOID

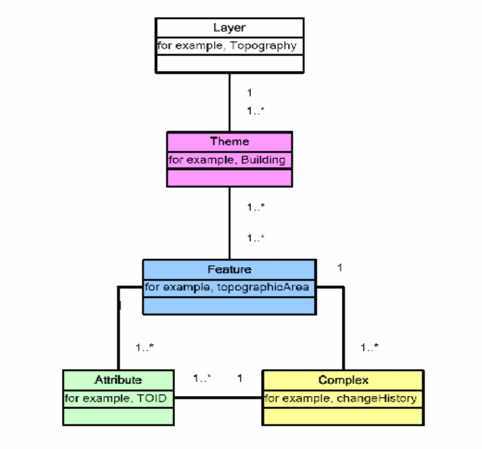

Figure 5.2: OS MasterMap Data Model

will stay the same throughout the life of a feature. As well as ensuring unambiguous identification of features, TOIDs enable full integration across the layers of OS MasterMap. For example, features in the Address and Integrated Transport NetworkTM (ITN) Layers are explicitly linked by TOIDs to the respective building and road carriageway features in the Topography Layer.
The OS MasterMap features are supplied with a version number as a requirement to be able to track the various stages in the life cycle. As the real-world object that feature represents has a life cycle – from creation, through change to deletion – so does the feature. Each feature can have one or more versions of itself that demonstrate change to that feature over time. New versions of features replace existing features. Features that no longer exist can be deleted.

The Topography Layer of OS MasterMap represents real-world objects such as buildings, kerb lines, fences and letter boxes, as well as intangible objects such as county boundaries or the line of mean high water. Real-world objects are represented as a series of area, point, line and text features within OS MasterMap. Ground relief features are only shown where they represent a serious hazard to passage on foot. These are features such as cliffs and man-made embankments and cuttings. Also included within the Topography Layer are non-physical features such as a selection of house numbers and, where numbers have not been allocated, names.

OS MasterMap Topography Layer is created from a master dataset that is refreshed regularly (every six weeks). The Topography Layer works on the principle that custumer takes an initial supply of all data in the area of interest and then update the data by taking change-only update (COU). COU brings delivered database up to date with the most recent OS MasterMap data available from Ordnance Survey. The COU will contain only

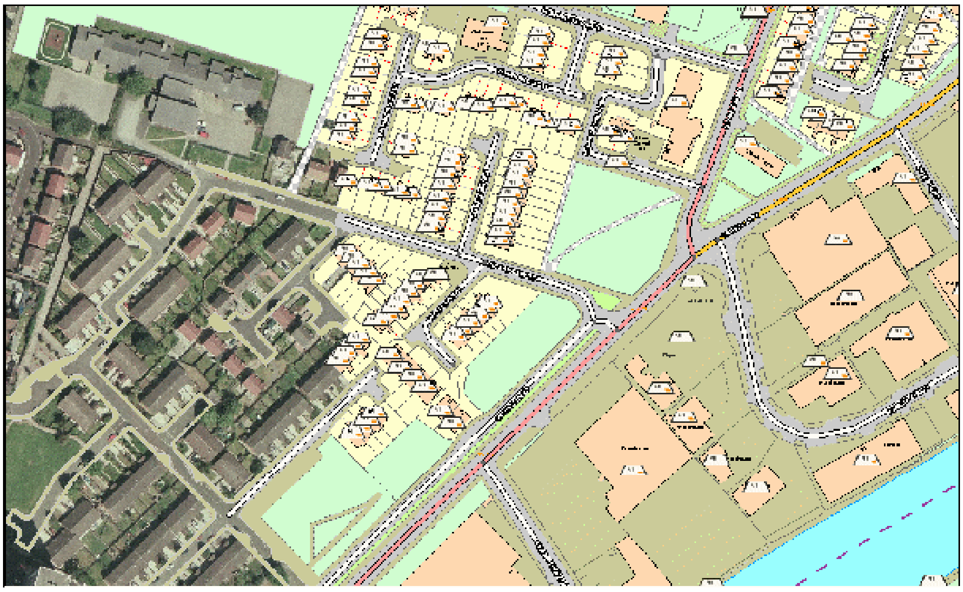

Figure 5.3: All four OS MasterMap layers together

the features that are new or have changed, as well as departed features (information on features that have been moved or deleted). Any feature that is new or changed since the COU date will be supplied with its latest version, and departed features will indicate which features have been moved or deleted since that date.

5.4.2 Standards

The Ordnance Survey follows various standards from the bodies that play a crucial role in geographic information science, the ISO, the International Organisation for Standardisation and OGC, the Open Geospatial Consortium.
OS MasterMap, with the exception of the Imagery Layer, is supplied in compressed GML format, version 2.1.2. GML is a spatially enabled dialect of XML schema.The Imagery Layer is supplied in TIFF, JPEG, MrSID or ECW formats, with imagery metadata in XML.
Ordnance Survey is also involved with the British Standards Institution's (BSI) technical committee – IST/36 – which is responsible for the UK participation in the area of GI in international committees.
BSI is the oldest national standards setting body in the world, including BS 7567 (National Transfer Format) and BS 7666 (Spatial data-sets for geographical referencing).

5.4.3 Digital National Framework

OS MasterMap has been designed to facilitate the adoption of a larger geographic concept called Digital National Framework (DNF). DNF is a model for an industry-standard way of integrating and sharing business and GI from multiple sources. The general principle of DNF is reuse of information: capture once and use many times.
The idea behind DNF is to enable better integration of all kinds of information with location as the common denominator. Within the confines of information technology the best way of achieving this is to link multiple information sources to a definitive location by having a common reference for each geographic feature by giving them all unique identifiers.
Within OS MasterMap Layers there is a set of unique references for geographic features (TOIDs) that are managed and maintained to a consistent, published standard. Each referenced feature may be viewed as a building block for any GI a customer wishes. Ultimately, this has the potential to evolve into a network of information, which, while distributed, when brought together can be used with assurance. Business information can then be shared with the knowledge that all users can have confidence that they are referring to the same location and entity in the real world.

5.4.4 Conclusion

Ordnance Survey continuously implements information technology and innovative ways to strengthen the adoption of interoperable and intelligent geographic information. A key goals which they succesfully reach are understandings of the aims, objectives and applications of their users and customers. The users of the MasterMap are key drivers of further refinement of data. The success of MasterMap lies also on enabled use of digital data within geographical information systems and database systems.

5.5 CO-25

Geographic Institute Codazzi Columbia (IGAC) has used German ATKIS as a data model for the establishment of its geoinformation system taking into consideration specific needs, activity domain and demands of the Institute. Summarising the basic activities and responsibility of the Institute, the information system meets the demands referring to planning, organisation and management in the field of agirculture, cartography, land registry and geography. Coding, manipulating and transfer of data from the real world are defined in the object catalogue CO-25.

5.5.1 Landscape data model

Modelo Digital del Paisaje (MDP), a landscape data model present various objects by means of topography and themes, and geometry, position, attributes and topological relations. In order to simplify the system application logic, a method of classification and cosing according to themes, groups and objects has been applied. The real world is divided into seven basic characteristics and for the detail level there has been the general unique attitude applied. The basic themes are as follows:

- 1000 Control points
- 2000 Land registry
- 3000 Traffic
- 4000 Land usage
- 5000 Water
- 6000 Relief
- 7000 Areas - zones

Themes 1, 2, 3, 4, 5 and 7 are position and two-dimensional, while the theme 6 presents a digital terrain model. The content of database, depending on the scale of reference source, is various, causing thus the difference in the digital terrain model as well (MDP).

5.5.2 Digital cartographic model

Digital Cartographic Model contains graphic presentation of all topographic and thematic objects following the rules of graphic presentation. The digital landscape model is in complete conformity with cartographic model. The Digital Cartographic Model is described in the catalogue of symbols.

5.5.3 Conclusion

An important aspect of development and implementation of Columbian Geographic information System (SIG) is the definition of standards for gathering, processing and exchange of data. Defined in details and implemented data model IGAC makes the presentation of geoinformation possible in a simple form to meet various needs of application.

5.6 General conclusion

Mentioned projects have influence on CROTIS in the way of cataloguing the data, i.e. in making the contents of data catalogue, then form of the classes presentation and big influence has been also made in selecting the standards used for data modeling (as ISO, OGC, CEN, etc.), data catalogue, data exchange solutions.
They haven't had influence on the selection of functionally-oriented modeling and object-oriented modeling, and neither have they given the answer referring to the issues of Land Management.
Presented examples of five national TIS show different approaches and concepts from fully cartography oriented (VECTOR25, TOPO DB) to the real world oriented (ATKIS). From my opinion, generally speaking all presented solutions had to apply more functional and user-oriented approach.

Chapter 6

Concept of Croatian topographic information system – CROTIS

6.1 Introduction

Here are presented principals, fundamental guidelines and scientific approach, briefly, of concept of Croatian topographic information system.

6.1.1 Basic principals of CROTIS concept

The main principals and conceptual model of the CROTIS (Croatian Topographic Information System) are based on the intention to create unique standards compatible to ISO (International Standards Organisation) and CEN (Comite Européen de Normalisation) compatible standards in the field of geoinformation systems. The CROTIS encompasses the standardisation of topographic spatial data giving basic and detailed solutions of topographic information system in the field of data models, their gathering, processing, accuracy, presentation manners, topological relations and their exchange.
By accomplishing and creating of CROTIS, the most essential geospatial information system of Republic of Croatia is established.

6.1.2 Fundamental guidelines

Modelling geodetic and spatial system means of gathering, processing, presenting and maintaining geometric and alphanumeric spatial data in accordance with economic needs and standards within the frame of geoinformation of international (ISO) standardisation organisation, and in accordance with professional and scientific patterns in the field of topographic and land information systems, are the fundamental guidelines of the standards processed in this project. Functionally-oriented modelling accompanied by the observation of patterns in conceptual modelling raises the quality level, utilising value and the reliability of data. Concept of production of topographic database is presented on Figure 6.1. The fundamental guideline of this approach is to point out, give more weight to presenting and gathering the data having great importance for the exploitation and management of space. Functionally less important objects (concrete path between two buildings or family house staircases) do not present object classes of official topographic geoinformation system because their function does not make them essential objects for space management.

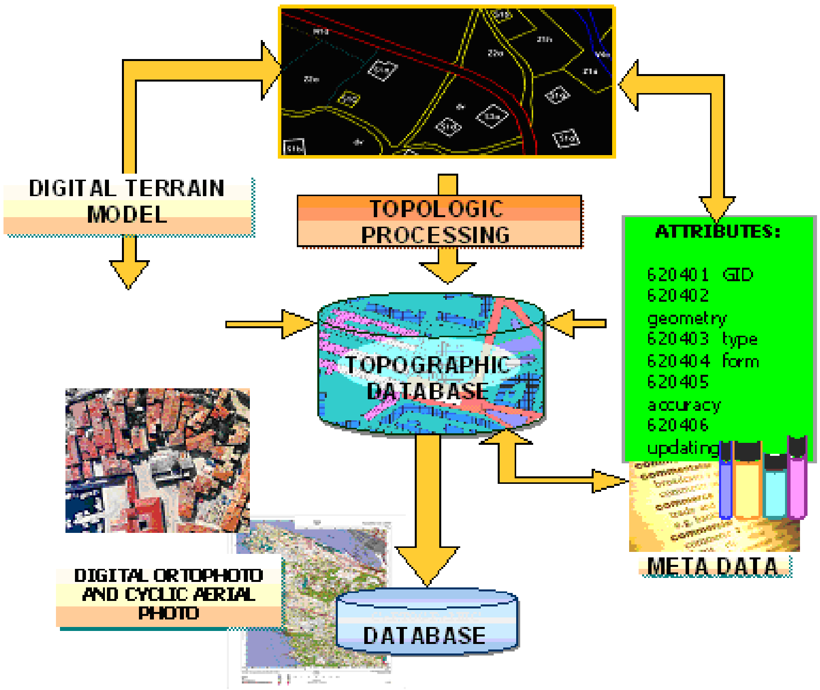

Figure 6.1: Concept of production of topographic database

6.1.3 Contents – CROTIS documents

The principal definition of the CROTIS data model includes the following documents (altogether 5 books), delivered to the SGA:

- Book I : Croatian Topographic Information System (CROTIS) – Conceptual Data Model - Alphanumeric and Graphic Code System
- Book II : Croatian Topographic Information System (CROTIS) – Topological Relations

- Book III : Croatian Topographic Information System (CROTIS) – Exchange Data Structures and exchange Graphic Models
- Book IV : Croatian Topographic Information System (CROTIS) – Object Catalogue
- Book V : Croatian Topographic Information System (CROTIS) – Fundamental principles and object catalogue

The documents deal with the standardisation for graphic and alphanumeric code system. The processed application example of a part of the object catalogues is placed in digital form on CD-ROM, as well as a model, and the library for data exchange.
List of individually processed documents according to the books and entities:

- BOOK I:
  - Fundamental principles and documents
  - Data model - alphanumeric code system
  - Data model - attributes
  - Express data model
  - Graphic code system - data model
  - Selection criteria and the way of presenting classes
  - Photogrammetric plotting catalogues
  - Digital relief model
- BOOK II:
  - Topological relations (in general)
  - Topological primitives
  - Topological relation of object classes
- BOOK III:
  - Data exchange
  - Aplication exchange scheme
  - Colour table
- BOOK IV:
  - Object catalogue
  - Description of all objects classes making the contents of topographic information system
- BOOK V:
  - Summary of books I - III
  - Object catalogue

6.2 Conceptual data model

The conceptual modelling is based on using abstraction, i.e. on the basis of methodology established by the concentration applied in recognising the similarities among objects of the real world and temporary neglecting of differences among them. The abstraction is used to decompose the model of the real world, objects and connections among them, in the *hierarchy of abstractions*, i.e. into the combination of aggregations and generalisations.

6.2.1 General guidelines and scientific approach of functional oriented modelling

As well as the other European geoinformation systems, the Croatian Topographic Information System respects and observes the standards by ISO (International Standard Organisation) being one of the priorities among obligations. The aim is to establish standards and principles for modelling of graphic and alphanumeric code system intended for defining, structuring, replacing, coding, transformation and transfer of spatial data. Geometric and alphanumeric data create a complex system representing in a clear and simple manner the geometry and topology of geographic objects. The complexity is established, defined and harmonised with the needs and applications of users.
Geoinformatically functionally oriented approach in CROTIS accelerates the process of transforming the reality into the desired information from, and provides complete projection of created data model into the structured base. CROTIS gives an outline of a new approach in spatial data representation and management. The establishment of a functional, and not analogous and cartographic model, is the basic characteristic of this new conceptual approach.

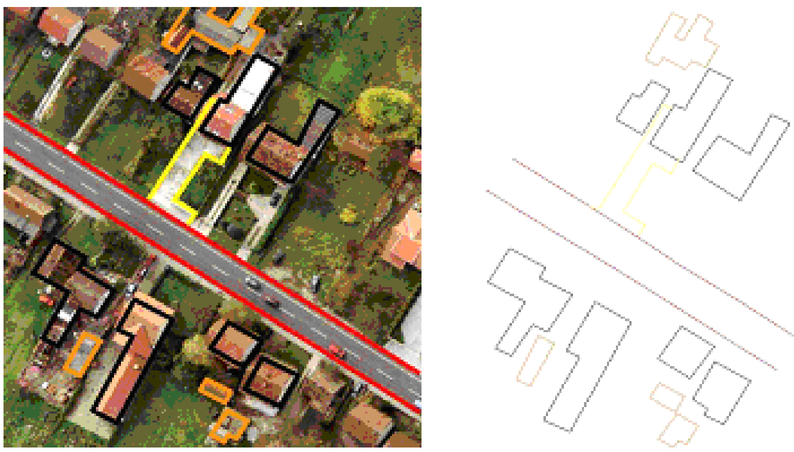

Figure 6.2: Functionally oriented modelling in geoinformation

Traditional analogous and cartographic approach in presenting the reality cannot meet the demands of modern geoinformation system and standards. "Aerial view" with classical presentation of the Earth's topography gives either insufficient or too much data considering all principles and standards of cartographic presentation dealing exclusively with analogous object presentation, and its structure is mostly not suitable to be accepted and processes as an integral or basic data of geoinformation system.
Functionally oriented modelling raises considerably the level and quality of data respecting thereby conceptual modelling. The reality in all its complexity can be presented and processed informatically in a satisfactory way only by recognising this complexity.
The basic guideline of functionally-oriented modelling is to emphasise, give more weight to presentation and gathering of data having greater importance in explotation of real world (Figures 6.2 and 6.3). The main roads, other communication routes, built objects and their basic approaches and their classification are the object classes essential for some region to function. Functionally insignificant objects (concrete pathway between two buildings

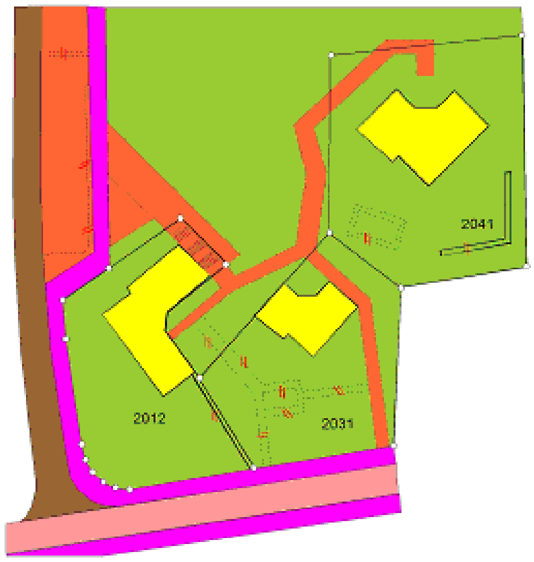

Figure 6.3: Functionally oriented modelling

or family house staircases) are neither gathered nor can make object classes of official geoinformation systems. They can be gathered and presented only if specially requested by users (designing of certain line infrastructures).

6.2.2 Data model – alphanumeric system

This document (Book I) deals with all object classes making the contents of topographic information system.
Model represents the objects of the real world and the relationships among them, i.e. *model is the abstraction of the real world.* Specific, clearly identified item/term is called *object*, and *the class* is a sort or a type of an object. The object can be regarded as an example of the class it belongs to. In the model, being the abstraction of the real world, the item/term representing the class is called *entity.* While the objects of the real world are observed as the instance of classes, the phenomenon of a particular entity is called *instance.*

6.2.3 Classification of objects

Object is the essential concept of a model. The object is considered an entity in the model. The entities have got certain characteristics that are defined by attributes, and the attributes are determined depending on the requests of buyers, on economic needs. By grouping the entities with common characteristics we get entity classes.
The classes of topographic information system are presented in the classification of objects as *object types.* The object type is classified on the basis of common characteristics of the entities it is made of.
In order to make the classification completely determined, the object types are classified into *object groups.* The object groups are gathered into a mutual *object units.* Thus, a complete layout of CROTIS is achieved on the basis of thematic class groupings.
All objects that according to the classification for a certain geoinformation system make its ingredient part are presented in the catalogue of object types (Figure 6.4, page 48).

Geodetic control points

The object unit of geodetic control point is made of the following object groups:

1. positional points
2. leveling points.

The criteria for selecting geodetic control points are not determined. All geodetic points are collected that belong to the object types determined by possible attribute values. It means that all trigonometric points, traverse points and other geodetic control points, as well as all spot heights are presented. The coordinates of geodetic control points are taken over from official records in competent institutions (State Geodetic Administration).

The data stipulated as the attributes of geodetic control points, like: determination method, stabilisation method or status, are taken over from the same sources.

Structures, economic and public objects

The object unit - structure, economic and public objects - is made of the following object groups:

3. residential and public objects
4. economic objects
5. cultural-historical and religious objects
6. objects for special purposes
7. linear objects.

This object unit includes all types of structures, built point-wise objects and linear objects (dam, cutting and wall).
Building is a structure built to stay for a longer period and it is tightly connected with the soil. In a wider sense, it is used for residential purposes, religious ceremonies and economic activity. The criterion for defining and presenting the buildings in CROTIS is their area. The building having the area smaller than the minimum prescribed is not presented. The geometry of buildings is defined on building foundations, which means that smaller or bigger convexities on buildings like balconies, eaves or similar are generally not presented.

Lines

The object unit - lines is intended for storing and presenting the objects needed for the distribution of electric power. The communication objects that are not in the function of navigation and pipelines belong to this group. The object unit – lines is made of the following groups:

8. electric power
9. gas pipeline
10. heating pipeline
11. pipeline
12. water supply
13. telecommunication

Traffic

The object unit - traffic is intended for storing and presentation of all object making the traffic network and a part of its infrastructure, and of the areas intended for air traffic. The object unit - traffic is made of the following object groups:

14. road traffic
15. railway and lane traffic
16. air traffic.

Vegetation and land types

The object unit - vegetation and land types is intended for storing and presentation of all objects that define vegetation coverage, along with natural and man-made object like public and economic areas. This object unit makes the largest part of the area in the sense of land coverage. Together with traffic routes and water streams it defines completely the land coverage in any point of the covered area. The object unit - vegetation and land types contains the following object groups:

17. fertile land (farming and forest land)
18. unfertile land
19. built areas
20. areas of intensive economic activity
21. areas for special purposes (military).

Waters

The object entity - waters is intended for storing and presentation of all waters: nonstagnant water, stagnant water, natural and man-made objects on water streams. The object unit - waters is made of the following groups:

22. land waters
23. sea.

Relief

The object unit ”relief”, as a part of conceptual model of topographic information system CROTIS, contains two object groups: digital relief model and cartographic presentation of “height” (as transitional data). Relief is the only three-dimensional object unit, and because of its specific features, the processing and storage of the data about the height presentation are planned independently from other object units. The height cartographic presentation includes five object types:

24. altitudes
25. contour lines
26. depth
27. depth contours
28. special relief features.

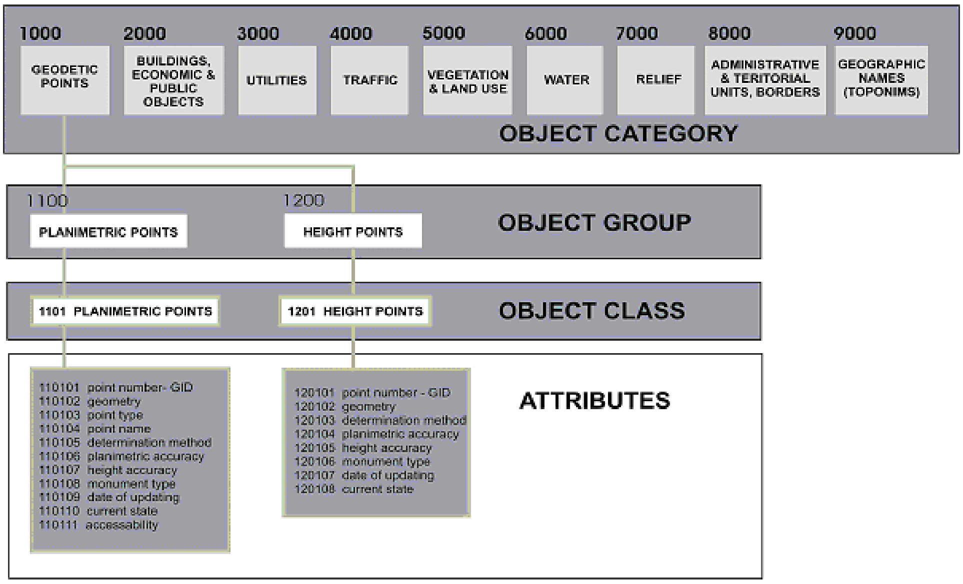

Figure 6.4: Classification of objects

6.2.4 Data model – attributes

In order to describe the conceptual schema (data model) and the catalogue of objects, the formal data description language UML was used. Unified Modelling Language (UML) is a graphical language for object-oriented modelling that makes visualisation, specification, constructing and documenting of program support system possible. UML offers a standardized manner of planning a system, covering conceptual matters like business processes and system function, as well as concrete things that include the classes written in some program language, database schemas and reusable program components.

In Order to model spatial databases UML language is usually used today, as it can be seen from the standards ISO 191xx. The rules that define the method of making the application schema with UML are given in the standard ISO/DIS 19109 Rules for application schema. The basic elements of UML language used in modelling the CROTIS database are explained in this chapter.
The key element of UML used in modelling is the class.
At the foot of the page there is the so called stereotype `<<FeatureType>>`. The stereotype is used for closer description of an individual class in the system. Below the stereotype there is the name of the class.
After the stereotype and class name there comes a part in which there is the list of attributes with the accompanying data types. After the attribute the methods can be stated. In CROTIS model all classes are defined by the name and attributes without methods. The classes that belong to the model can be independent or connected with relations depending on the relationships they have (Figure 6.5). The classes that belong to the model can be

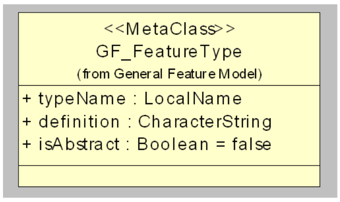

Figure 6.5: Example of the UML class

independent or connected with relation. The classes are connected in the model with the relation of generalisations. The next figure shows the example where the relation of generalisations has been used between two classes (Figure 6.6). Generalisation is the relation where the objects of generalized element or parent can be replaced by the objects of specialized element, i.e. child.
In the above given example the class GM_Curve is a parent, and CestaLine is a child. In other words, the class CestaLine adopts certain characteristics from parents, but it also owns some specific characteristics defined in the class CestaLine. In the given example the abstract class GM_Point is a class defined in accordance with ISO standards.
The model uses three stereotypes `<<FeatureType>>`, `<<Abstract>>`, `<<CodeList>>`. On the basis of these stereotypes the following classes are distinguished:

- those that are realized as objects (feature),
- abstract classes that children inherit the characteristics from, and
- code lists that define the domain of individual attributes.

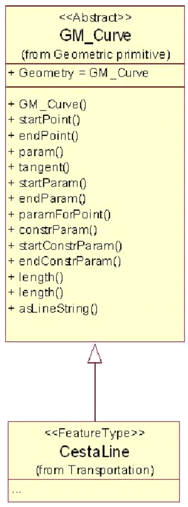

Figure 6.6: The relation of generalisation and abstract class

In the definition of class the attributes were given together with the data type. Simpler types of data are e.g. Integer, CharacterString, etc. but there are also more complex data types that are presented in the given model to the classes with `<<CodeList>>` stereotype. Code list is presented on the figure 6.7.

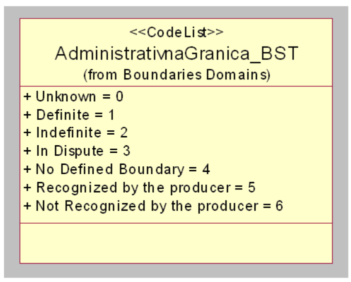

Figure 6.7: Code list

Principles of creating classes according to the standard ISO 19109

Classes Class is the basic unit of geographic features. This standards regulates the rules for creating application schemas, including the rules for creating classes.

Classes and application schema Application schema defines the logical structure of data and can define the operations that can be presented on data, it defines the logical organisation.

General Feature Model It is used for the concept of defining classes and their relationships.
The structure of General Feature Model can be described in the following way:

`GF_FeatureType` `GF_FeatureType` is a meta class that is turned into the class presenting individual object types. Meta class is the class for all instances of this class. It is defined by:

- `typeName` (class name, unique within the entire schema),
- `LocalName` (identifier in the space for object name)
- definition (the definition described by object class)
- `isAbstract` (Boolean attribute, if confirmative, then it is the matter of abstract class)
- `memberOf` (association rule denoting whether the feature class participates in some of the associations)

GF_PropertyType `GF_PropertyType` is a meta class for any class or object class characteristic that describe the characteristics of object class, behaviour and association rules within them. It is defined by:

- `memberName` (behaviour, role)
- `localName` (identifier in the space for object name)
- definition (describes attributes, behaviour or the role of object class)

GF_AttributeType `GF_AttributeType` is the meta class for defining the attribute of feature class. It is defined by:

- `valueType` (attribute type), standard 19103
- `TypeName` (identifies the type of space for local name, it is the subclass of local name)
- `domainOfValues` (description of the set of values)

GF_AssociationRole `GF_AssociationRole` is the meta class for describing the association between object classes

GF_Operation `Gf_Operation` is the meta class for describing the behaviour of object classes in operation conditions.

GF_AssociationType `GF_AssociationType` is the meta class for describing the associations between feature classes.

Attribute

Attributes describe static and non-static characteristics of classes.

atributeOfAttribute `atributeOfAttribute` connects one attribute with another attribute.

GF_SpatialAttributeType `GF_SpatialAttributeType` constitutes the spatial attribute that is used in order to determine spatial characteristics.

Relations between feature classes

Relations describe the connections between classes in detail.

Behaviour of feature classes Behaviour of classes is described in operations that have to

Application schema rules The purpose of application schema is:

- to achieve complete understanding of contents and structure within a detailed application field,
- to provide computer readable schema for the application of automatic mechanisms for data management.

6.2.5 Data catalogue

Data Catalogues is a document that offers the classification of objects, attributes and connections between objects for one or more data sets. The catalogue includes similar information that give also UML schemas, but in text form it is less expressive, but more strictly organised. In this way it provides:

- unanimous and consistent object definitions,
- unique way of finding the features,
- consistent definitions of feature characteristics, operations upon features and connections between features.

CROTIS catalogue has been made in accordance with ISO standards 19110 (*Feature cataloguing methodology*) that defines the methodology of making a feature catalogue. This standard specifies the way of organising and presenting a classification to bring it into accordance with standard practice.
The following information elements for data model description have been taken over from the standard ISO 19110:

- at the catalogue level, there has been the catalogue name, application field list, version number, version date and manufacturer information given,
- at the object level for each object from the data set that is described in the catalogue there is object name, object definition, object code, attribute name list, and object name given,
- at the attribute level for each attribute from the data set there is attribute name, attribute definition, attribute data type, measuring unit and domain type given (1 for counted, and 0 for other domains). With counted domain there are the allowed attribute values stated.
- at the attribute value level there are the allowed values and description given.

The standard includes the possibility of additional information elements, primarily the operations and connections between objects that are not given in CROTIS catalogue.

6.2.6 Graphic code system – data model

Under the conceptual view we will understand the user's apprehension of the real worlds in spatial context. This view consists of visual component being the abstraction of symbolisation of reality, and it includes also graphic, textual and imagery elements. The other component is intuitively interpretative and makes the meaning and understanding possible. The conceptual view is unique for every user or group of users. For practical purposes, intended for communication, the conceptual view should be described in semantic form and style. Graphic code system has been made – presented in CROTIS - in digital and analogous form and compatible to the data model.

6.2.7 Selection criteria and the way of presenting classes

The document deals in details with the criteria for selecting classes and with the way of their visual presentation.

6.2.8 Accuracy

The division into accuracy zones, the definition of reliability and references for geometric accuracy in determining object classes are dealt with in details in this document.

6.2.9 Topological relations

The techniques of geometric modelling, developed originally for the purpose of CAD/CAM applications, simulation and robotics, enable the description of information about physical shape of spatial objects. Since there are more techniques of geometric topological modelling, the *boundary-based* representation of spatial objects has been used within the frame of standards. This representation contains the information about surfaces of single objects. The object is represented by the group of single surfaces, and each single surface is described by its own boundaries in form of curves/lines and points.
Very important part of this representation is also the description of connections between each single surface and each of its neighbouring surfaces. The information about the neighbourhood (bordering) make *topology* of a model, and geometric specification of surfaces, curves and points makes *geometry* of a model. Geometric topological model encompasses both geometric and topological information about spatial objects with topological information being the "frame" into which geometric information can be placed. Since it is necessary to have both information types at disposal for the purpose of manipulating with the objects within the frame of topographic information system, i.e. of application development, a modelling has been carried out within the frame of CROTIS resulting in specification of geometric topological types of entity convenient for modelling of the complex spatial objects. In this part of the Work a detailed specification of topological relation operators has been presented over relevant objects defined in CROTIS.

6.3 Data exchange

6.3.1 Fundamental principles

The project determines the manner of data exchange within the scope of topographic subsystem. The contents of CROTIS encompass the process of defining the scheme for data exchange, execution mechanisms and date encoding rules.
The standards define the following:

- the main original objects for explicit geometric and topological representation of geoinformation
- the mechanisms providing the information exchange among users, i.e. information structures

- exchange structure format.

6.3.2 Application schema for data exchange – GML

For the purpose of achieving open data exchange between heterogeneous or homogeneous systems, the application exchange schema has been made.
The application schema has been made according to GML specification and has been made as direct mapping of entities from the database in order to use the possibilities of the tools that support directly the GML specification and provide import and export of data from and into the system.
This chapter explains the basic elements that make GML schema.
Since GML is the dialect of XML, the syntax and language elements are given by XML through the recommendation of World Wide Web Consortium (W3C) (URL 5). The basic elements of the title with explanations are given in the following table (table 6.1).

Explanation	Example
Prologue and definition of document determine the version of xml standard and encoding	<?xml version="1.0" encoding="UTF-8"?>
shema **element** gives *namespace, anotations* and *documentation the elements* directly, and all other elements are contained (dieses element is stretched to the end of the document)	<schema xmlns= "http://www.w3.org/2001/XMLSchema" xmlns:gml= "http://www.opengis.net/gml" xmlns:xlink= "http://www.w3.org/1999/xlink" xmlns:vogis= "http://www.geofoto.hr/crotis" targetNamespace= "http://www.geofoto.hr/crotis" elementFormDefault="qualified">

Table 6.1: GML1

The other elements contained in the schema are explained in the next table (Table 6.2).

6.4 Criteria for "topo" objects

6.4.1 Introduction

The selection criteria and the manner of presenting object classes and their attributes are technical instructions and detailed specification for the establishment and usage of topographic information system of the Republic of

Explanation	**Example**
Import element determines additional schemas that define common elements	<import namespace="http://www.opengis.net/gml" schemaLocation= "http://schemas.opengis.net/ gml/2.1.2/feature.xsd"/>
FeatureCollection declares the basic element being the root of gml document.	<element name="FeatureCollection" type= "crotis:FeatureCollectionType" substitutionGroup="gml:_FeatureCollection"/>
FeatureCollectionType defines the type of the basic collection	<complexType name="FeatureCollectionType"> <complexContent> <extension base="gml:AbstractFeatureCollectionType"> </extension> </complexContent> </complexType>
Class: each class is declared as the element that has got a prescribed type	<element name="CROTIS_BE020_P" type="crotis:CROTIS_BE020_PType" substitutionGroup="gml:_Feature"/>
Each class is defined through the type declared in the element	<complexType name="VOGIS_BE020_PType"> <complexContent> <extension base="gml:AbstractFeatureType"> <sequence> <element ref="gml:pointProperty"/> <element ref="gml:multiPointProperty"/> </choice> </sequence> </extension> </complexContent> </complexType>

Table 6.2: GML2

Croatia (CROTIS). The document deals with the criteria and manner of gathering the data about object types defined by CROTIS, illustrated by general cases presented through examples.

6.4.2 General principles

The criteria and the manner of presenting single object classes are derived from fundamental principles and the concept of CROTIS, and these are to gather, process and present their parts essential for spatial management. The main guideline of functionally oriented modelling is to emphasise, give more weight to gathering and presentation of data having greater importance in spatial management. The main traffic routes, infrastructure in general,

erected objects and their approaches are the most essential object classes for spatial functioning and exploitation.
Functionally less significant objects (concrete path between two buildings or a staircase by the house) are neither gathered nor can make object classes of official geoinformation systems (CROTIS, Topographic Information System, Cartographic Information System). The possibility of their gathering and presentation can be realised only by special requests of users (designing of certain infrastructure lines etc.).
The determination of the detail degree that is defined by these instructions aims to define the manner of gathering and presenting classes more precisely in order to use, maintain and keep data homogeneous in a better way. Nevertheless, too many details have to be avoided.
The basic intention of CROTIS is to be applied in all spheres of spatial data management. It is therefore impossible to foresee all possible applications of this system and specific needs of single users by a data model. CROTIS is conceived as the basic topographic information system of the Republic of Croatia containing the information needed by every user. Such a system serves as the basis for establishing specialised system in any application. The instructions do not present the solution of all cases, and, if all regulations are too extensive, it is not possible to foresee all possible examples. They serve therefore as the model of principles and provide help in making decisions.

6.4.3 Definition of object classes

The Catalogue of Object Classes presents all objects that make an integral part of a certain geoinformation system according to the adequate classification. Obligatory attributes and criteria for their gathering, as well as accuracy and geometric presentation are the essential elements that a creator of computerised reality has to take into consideration permanently. While gathering the data one should also take the principles of functional hierarchy into consideration. Each object class must be defined by means of primitive graphic elements (point, line, surface) and by means of associated code. The object classes defined in such a way and graphically exactly structured are completely conform to topological processing and definition of object classes and their relationship to object oriented databases.

6.4.4 Geometric-topological model

Since we operate with primitive graphic elements (point, line) in data gathering, the boundary-based presentation of spatial objects has been chosen. In order to describe the information on object classes we use surfaces that are described by boundaries defined by means of primitive graphic elements, curves/lines and points. The task of topology is to describe the connections between single surfaces with their neighbours. The information itself about the neighbourhood (boundaries) makes a topological, and geometric definition of surfaces, curves, lines and points makes a geometric model. The geometric-topological model encompasses geometric, as well as topological information about spatial objects with topological information being the "frame" that geometric information can be placed into.

6.4.5 Selection criteria for object classes

Selection criteria for object classes are defined for each object unit separately. The basic selection criteria for an object class are its, over all, functional significance and sometimes its dimensions. If the object class has no relevant function, and the dimensions are smaller than the prescribed minimum, the object is not presented except in special cases described further in the text.
Dots are used for the presentation of objects having dot character. The selection criteria are not referring to the size of an object, but to the affiliation to a certain object class and its importance. The selection criteria for dot objects are determined by the data model itself defining which classes are presented regardless of their dimensions and functionality.
Lines present the objects of line character (e.g. supply liens) and narrow extended objects narrower than the minimum width. The selection criterion is the length of an object. In order to present a certain object of a line character, it has to be larger than the minimum length. The width of a narrow and extended object is not characterised as the criterion for selecting a line object, but it determines its belonging into a certain class. It means that the width of a river, e.g. does not define whether it will be presented or not, but it determines whether it belong to an object class river or to an object class narrow river. The selection criteria have been defined for each of **these object classes and are taken into consideration after the class has been determined that an object belongs to.**
Surfaces are used for the presentation of objects with their area being larger than the minimum area. The basic criterion in selecting such object classes is their area, and in specific cases the width is the selecting criterion. Certain extended object can be of a larger area than the minimum one, however, if it is narrower than the minimum width, it will not be presented. A typical example is the cross-section of power-transmission lines through a forest that can cover a pretty large area, but if it is narrower than the minimum dimensions prescribed by the criteria, it will not be presented, but will be attached to the neighbouring classes of land coverage.

6.4.6 Geometry

Within the contents of these standards there are the definitions of the following geometric entities: points, curves, parts of curves and complex curves outside of the contents of these standards there are all three-dimensional entities.

6.4.7 Topology

Within the contents of these standards there are:

- definition of basic topological entities: node, edge, countenance
- collection of entities forming a loop as topological structure

Outside the contents of these standards there are all three-dimensional topological entities and structures.

6.5 Normative references

6.5.1 Terminology

Within the scope of these standards the following definitions are valid:

application scheme: conceptual scheme for specific application

attribute: essential feature, quality or characteristic of an object

CEN: Comité Européen de Normalization (European Committee for Standardisation)

pure textual encoding: information encoding made by means of code parts for Croatian alphabet based on the group of signs G(02/00) to G(07/14) ISO 8859-1 (Annex CROSCII).

data file exchange: data exchange on the basis of data files usage

dimensions of co-ordinate space: number of parameters for defining the position of points in the co-ordinate system

domain: a collection of values permitted for attribute to have them

external data file: data file the contents of which is not defined by these standards

Euler's equation: the equation that can be used for the checking the topological stability of objects

geometry: measuring spatial aspects of geoinformation

geometric primitive: partial or complete description of spatial appearance of an objects in the sense of co-ordinates and mathematical functions geometric co-ordinate system: global rectangular Cartesian co-ordinate system that all geometry relates to

boundary: closed topological primitive that does not intersect with its own self

graph: collection of nodes $C = \{c_1, c_2, c_3, \ldots, c_n\}$ and collection of edges $R = \{r_1, r_2, r_3, \ldots, r_n\}$; $r_i = \{c_p, c_q\}$; $r_i \in R$; $c_p, c_q \in C$

ISO: International Organisation for Standardisation

isolated node: a node that does not belong to any edge

topographic application scheme: application scheme of topographic subsystem

co-ordinate space: reference system connecting a unique group of n parameters with every point in n-dimensional co-ordinate space

curve: collection of mathematical points in two-dimensional space being the picture of continuous function defined over the real line

sub-collection

list: arranged homogeneous collection of elements

model space: the space with the dimension 2 with geometry defined in it

feature: topological primitive defined by means of one external loop and zero or more internal loops

open curve: a curve with the initial and end points being different

object: individual phenomenon/appearance in the real world

volume of parameters: volume of valid parameter curve values

loop: arranged collection of one or more connected edges that define closed topological entity not intersecting with its own self

connected node: node belonging to one or more edges

spatial view: a collection of samples of geometric and/or topological primitives adjusted to the conceptual scheme

edge: topological primitive connecting two end nodes

sequential data files: data files the elements of which can be accessed only in a sequential manner collection: not arranged collection of various elements

data collection: identified collection of data

> **Remark:** *Data collection represents all entity samples to be exchanged, in accordance with topographic application scheme.*

data exchange: method of exchanging data among users/applications

exchange scheme: conceptual scheme for rules and operators dealing with data exchange

exchange structure: the feature that can be translated by a computer and is used for storage, access, exchange and archiving of data

data type: value domain

topology: discrete spatial aspects of geoinformation

topological primitive: partial or complete description of topological aspects of objects

topological sense: the sense of topological entity derived from the order of its attributes. e.g. topological sense edge $r_i = \{c_p, c_q\}$; it is from the initial node c_p to the node at the end of the edge c_q

closed curve: a curve with its initial and end point being identical.

6.5.2 Data exchange

Standards mentioned before define the entire data structure for the exchange of geoinformation based on data files exchange.
Application scheme makes it possible for a deliverer to define relevant application entities and should be translated into the data language in accordance with the scheme `language`. The application data collection must be transferred into the encoded data collection, together with the data dictionary, in accordance with the scheme `data_encoding`.

6.5.3 Context

Application scheme is a concrete scheme for a definite application. Whenever the types of object defined in the application scheme have spatial characteristics, the presentation of these characteristics is defined in the spatial scheme. Such spatial scheme is an integral part of the application scheme. These standards define the constructions in spatial scheme and the possibilities that can be used for the purpose of application scheme within the frame of CROTIS.

6.5.4 Description of object geometry and topology

In the basis of co-ordinates and mathematical functions, the geometry covers a quantitative description of spatial aspects of an object within the frame of CROTIS. Geometric aspect of information about spatial objects is changed in the process of transforming reference geodetic or co-ordinate system.
Geometry is described by means of primitive objects based on co-ordinate and mathematical function in a selected reference system.

6.6 Different aspects

6.6.1 General aspects

The basic concept and principals of establishing CROTIS are based on technical, financial, institutional and legal factors.
The involvement of all relevant institutions has been realised, especially of the Institute for Physical Planning, Ministry of Defence, State Geodetic Administration and of public enterprises (Forest Research Institute, Croatian Roads, Croatian Waters, Croatian Railroads, Ina - oil industry, Croatian Mine Action Centre, etc.).
Technical possibilities of the contractor and the State Geodetic Administration, the existing data, possible users and their equipment, as well as professional ability are the elements that have been taken into consideration in the creation of the concept and the establishment of TIS.
The establishment of CROTIS is justified by the above mentioned situation with regard to topographic information, untopical topographic maps and non-existence of reproduction originals, as well as by permanent growth of demands posed by users seeking the data on land topography in digital, structured form. The reconstruction of the areas devastated in the war, intensive building of new and the reconstruction of existing routes, foreign investments, legally defined obligation of cities and municipalities to produce (till the end of 2001) spatial and general urban plans (being the greatest acceleration of CROTIS implementation at the time), census, establishment of geoinformation demining system and defining state borders are fundamental demands and needs that do justify and already have justified the establishment of Topographic Information System of the Republic of Croatia.

6.6.2 Political aspects

After acquiring its independence, the Republic of Croatia remained practically without topographic maps and cartography. All resources and original data "became the ownership" of the Military Geographic Institute (VGI) in Belgrade. Only facsimile publications of untopical maps (being of average age between 25 - 40 years) remained in Croatia.

The extraordinary bad situation referring to topographic information of state area has required an urgent solution to be used for the purpose of economy and defence. Management on the state, county, city and municipality level has been unthinkable without high quality topical spatial information. State and regional political and strategic interests presume also the provision of topical information about space, its geometry and other relevant data of real and abstract character. Industry, agriculture, tourism as the basic branches of economic activity look for topical spatial information in topographic data form in the segment of daily needs.
The management of above stated processes is almost impossible or strongly limited without topical topographic base.
The essential political aspect of the Work from its concept to the establishment is expressed by the active involvement of the existing institutions and organisation. The formation of a project group and the work of its members presents the frame through which the State Geodetic Administration, the Faculty of Geodesy, contractors of all works on topographic survey and production of state maps, as well as data users are directly included into the Work.
Provision of financial means has been realised mostly according to the conventional model of financing: the State Geodetic Administration 50%, and local self management (city or municipality) the remaining 50%, except in special cases (due to inopportune planning of works) where the funds could not be provided from the budget of one participator, 100% financing was taken.
Thus, local self-governments have also had more responsible and more constructive relation to the projects, their quality, obligation of staying within schedule, data usage, as well as to the interactive modelling.

6.7 Technical aspects

6.7.1 Existing data, current systems for data gathering

At the time as the concept of the Topographic Information System was created there were only facsimile publication of detailed and general topographic maps available at the territory of Croatia. Professional knowledge, equipment and technology did not exist except in the production of maps at larger scales up to 1:5000. The greatest disadvantage was also the non-existence of the service for aerial photography, and the political circumstances and the war prevented the engagement of foreign operators for aerial photography and processing of photographic material making it one of the biggest problems in the process of providing basic source for data gathering. Analogous technology in the majority of photogrammetric firms was an additional barrier to modern approach and methodology of data gathering.

6.7.2 Users and their specific characteristics

In the attachment there is a list of a part of over 150 potential users with 30 capital ones among them. Their specific characteristics have been taken into consideration in the process of conceptual system modelling. There have been special lectures held and the animation made for the purpose of complete involvement of users. This process is still going on. The involvement of users has been made partly through the structures of the State Geodetic Administration, and mostly by the engagement of the author and the working group of the firm Geofoto.
Some relevant capital users:

- Ministry of Defence and Armed Forces
- Croatian Forests
- Croatian Waters
- INA - Oil Industry
- Croatian Roads
- CROMAC - Croatian Mine Action Center
- HEP - Croatian Electrical Utility Inc.
- Ministry of Environmental Protection, Physical Planning and Construction
- City of Zagreb - City Institute for master and regional planning
- City of Rijeka
- PlinaCRO
- JANAF

Equipment and general situation

The concept of the project CROTIS and providing of governmental and city budget funds has been planned and realised, and now the state and city administration and institutions, as well as a few larger firms dealing with data gathering, processing, maintenance and distribution of topographic data on one hand, and using them on the other, are being equipped.
The essential difference of CROTIS as related to the presented European and world examples of national geoinformation systems is in technical and organisational aspects.
Only private firms have been entrusted with data gathering and their processing. At the moment, all above stated works are carried out by five

largest photogrammetric firms in Croatia, which has been realised on the basis of soliciting for tenders and of standards defined by CROTIS, as well as through single project tasks in the case of specific problems.

Methodology of gathering and processing the data

Almost all data for the production of database and establishment of CROTIS are gathered by means of photogrammetric mapping on analytical systems. Vector defined objects, logically and physically closed forms that are graphically structured and coded on the basis of mapping catalogue (textual identification of object types) make a good basis for completely automated topological processing divided into three phases.
Consistency and quality control of topographic database, and their official verification, is the last and final process in the CROTIS-data processing technology.

Necessary investments

The development of adequate technology accompanied by the existing computer infrastructure, expenses and technical qualifications leads to complete application of OPEN GIS technology, Internet, and to the education of the State Geodetic Administration employees in the field of maintaining and distributing the data, TDB.
For this process it is necessary to make investments for a new computer infrastructure to be installed in the State Geodetic Administration along with the already existing equipment.

6.8 Information and organisation aspects

Closely collaborating with the State Geodetic Administration there have been institution and organisations analysed, and specific measures and mechanism suggested for the co-ordination of activity in direct involvement of users in the project production. Direct agreements referring to cofinancing of the project dealing with the production of digital orthophoto, and with data gathering according to the model CROTIS (HOK 1:5000, TK 1:25000) have essentially influenced the involvement of the majority of subjects, the users into the production of TDB, and partly in the modelling of the entire system. The obligations and responsibilities of firms and contractors are clearly defined by means of agreements and taking over the project documentation. In order to complete all information and organisation tasks the education has been provided by the project group of CROTIS, as well as the technical assistance for a successful implementation of the Work, especially in connection with maintenance and usage of the equipment and data.

6.8.1 Definition of priority and activity

Referring to political and strategic interests of the Republic of Croatia, the priorities and activities for the establishment of CROTIS have been defined. So far reached goals:

- Till the end of the year 2000 all larger and middle urban areas should be covered by digital orthophoto at the reference scale of 1:5000
- In the first two years of the project 1996 - 1998 the areas of two economically the most important counties should be covered with vector data: Zagrebačka and Istarska County (20 % of the territory, and 60 % of economic resources)
- The entire state territory should be surveyed by means of aerial photogrammetry at the approximate scale of 1:20000, and the continuity of new aerial photographs should be provided that are necessary for updating of the contents reaching the quantity of 20% annually
- The topographic database has been made for the limited test area (ISTRIA, 160 km2)
- All gathered data should be topologically processed
- On the basis of TDB the digital vector maps 1:25000 have been produced, accompanied by the necessary map processing and generalisation defined by the temporary cartographic model and cartographic key
- On the basis of TDB the digital vector maps 1:5000 should be produced for all larger urban areas
- Larger part of the state (over 60 %) should be covered with DTM with the accuracy of $rms = \pm 1$m
- Legal and sublegal acts should be made in order to obligate the State Geodetic Administration, users and contractors with respect to realisation of project goals encompassing continuity, quality and official value of CROTIS.

The priorities and activities are planned and executed in five years (2001-2005 defined by the accepted five-year governmental program and by already agreed upon projects):

- To implement CROTIS on the entire state territory
- To produce TDB and generate CDB from it for the entire territory of the Republic of Croatia (altogether 603 sheets TK 25)

- To cover the entire state with DTM having the accuracy of $rms = \pm 1$m
- To cover the entire state with digital orthophoto at the reference scale of 1:5000
- To continue cyclical aerial photography at two levels, at the scales 1:20000 and 1:15000 with premarking of ground control (16°30') points
- To accept new map projection (Gauss Krüger) of one meridian zone
- To provide the maintenance of TDB and establish the mechanism for quality control and data protection
- To establish Topographic Database and Cartographic Database as an integral part of a unique topographic and cartographic information system, STOKIS
- To sign the agreements about joint venture with all capital users of the information system
- To make additional regulation that would regulate the maintenance of database, ownership over data, copyright and data protection

The function, position and responsibility of the State Geodetic Administration are defined by the Law of State Survey and Real Estate Cadastre (National Gazette 1999) and the State Geodetic Administration is already the major initiator and financier of all works connected with the production, maintenance and distribution of TDB data, and of control and insurance of its quality, verification and data protection.

6.8.2 Legal aspects

The support and program orientation of the State Geodetic Administration, and hence of the Government of the Republic of Croatia, is completely provided through so far selected, but also planned budget funds, and by already passed legal acts.
Passed legal acts provide the integrity and complete compatibility of CROTIS and STOKIS. The national importance and priority that have been given to this Work provide a large success perspective.

6.8.3 Financial aspects

For the first expenses assessments in the establishment of CROTIS the following components were taken into consideration:

- Equipment with amortisation and service
- Education and technical assistance (transfer *know how*)

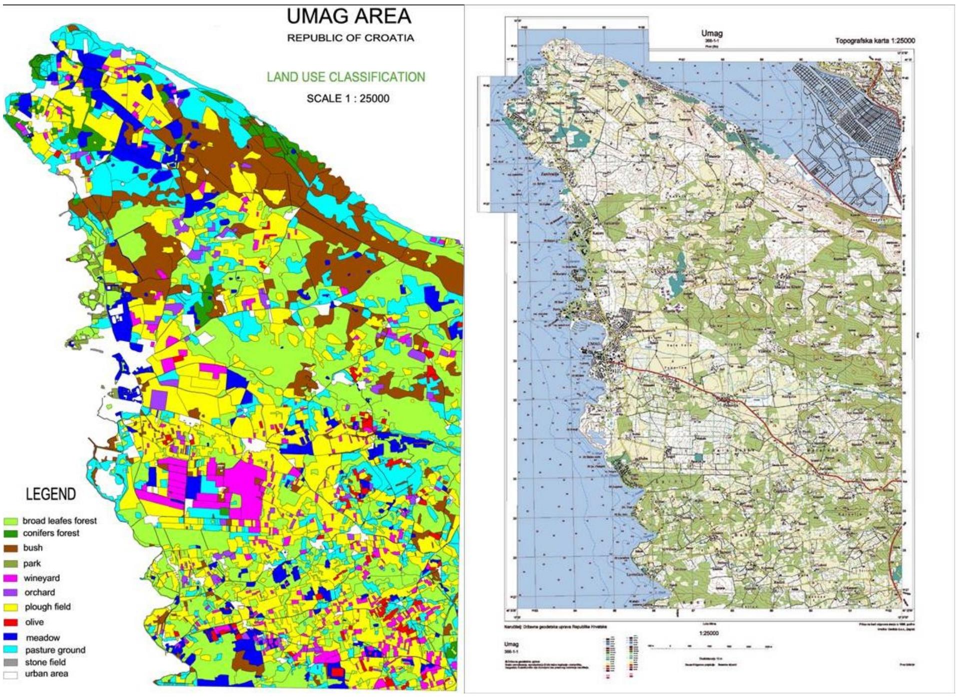

Figure 6.8: From TDB to TK 25

- Management and provision of quality (ISO 9001)
- International assessment of financial and technical aspects
- Department of Croatian (human resources and equipment) and western components (equipment)
- Replacement cost (amortisation) of invested funds into the Work

The principle of cofinancing in the production of TDB according to the agreement with users provides satisfactory financial earnings for a complete realisation of planned programs.
General agreements have been signed with almost all capital users, and the agreements with the majority of Croatian cities.
The agreements are of general character, but they precisely define the obligations and relate mostly to the capital users like Hrvatske vode (Croatian Waters), Hrvatske šume (Croatian Forests), CROMAC and similar, which means those users that are interested in topographic data at the entire state territory. The agreements make it possible for them to use all data without any limitations at any state territory, if they have cofinanced the production of TDB.

6.8.4 Risks

Speaking in realistic terms there is a political risk of temporary standstill or complete interruption of the work, and it relates to possible failure in realising budget payment obligations of the state towards the contractors of CROTIS. At the moment, this risk is minimal due to the so far realised dynamics of implementation, results and importance given to the NSDI, as well as to the generally accepted strategy connected with spatial and general urban planning, and state defence policy.
Larger risk is threatening on the part of larger public enterprises with respect to the income plan in the accepted and executed five-year long program that possibly might not be provided.
Creating larger network and activating so far insufficiently motivated and informed users, which has been specially worked on so far by the structures of the State Geodetic Administration, could eliminate completely the above stated risk, and its consequences could be better amortised.

6.9 Implementation of the concept and management of process

The production of the concept for Topographic Information System of the Republic of Croatia (CROTIS) and its establishment are characterised by a very impressive administrative and organisational tone besides its scientific and professional characteristics. Offering importance to the segment of administration itself - co-ordination and organisation, that it had as an essential segment of realisation, CROTIS has intruded itself as the most important state geoinformation system.
Management of process is the chapter of the dissertation that represents chronologically organisation – administrative and co-ordinate processes and actions of the CROTIS realisation referring to professional and scientific Work parameters.

6.9.1 Conceptual solution, approach philosophy

The goal is to establish a unique, centralised topographic information system compatible with European and world standards in the field of geoinformation. Taking into consideration above all the users needs and specific qualities of Croatia, it is not in the least an easy tasks, having in mind financial and political situation in the country, war devastation and shortage of financial means. The problem of priority, lack of understanding the problems on the part of structure competent for making decisions, and the situation referring to resources and knowledge are the elements equally important for successful implementation of the CROTIS.

Basic idea, philosophy of approach to the production of concept and establishment of CROTIS, is:

> to model a system, function and object oriented, organise data gathering as quickly as possible with the existing resources according to the conceptual model, make "limited" topological processing and produce modern topological digital maps at the scale of 1:25 000 and 1:5000 (TK 25, HOK and DOF5) as a conventional and so far most requested form of taking over and using topographic information by the largest number of users. The second parallel task of the system establishment is to create a topographic database (TDB) for certain priority areas, and to provide its maintenance and data distribution.

6.9.2 "Flow diagram" of the process

Figure 6.9 presents graphically the concept of technical processes in the implementation of the system.

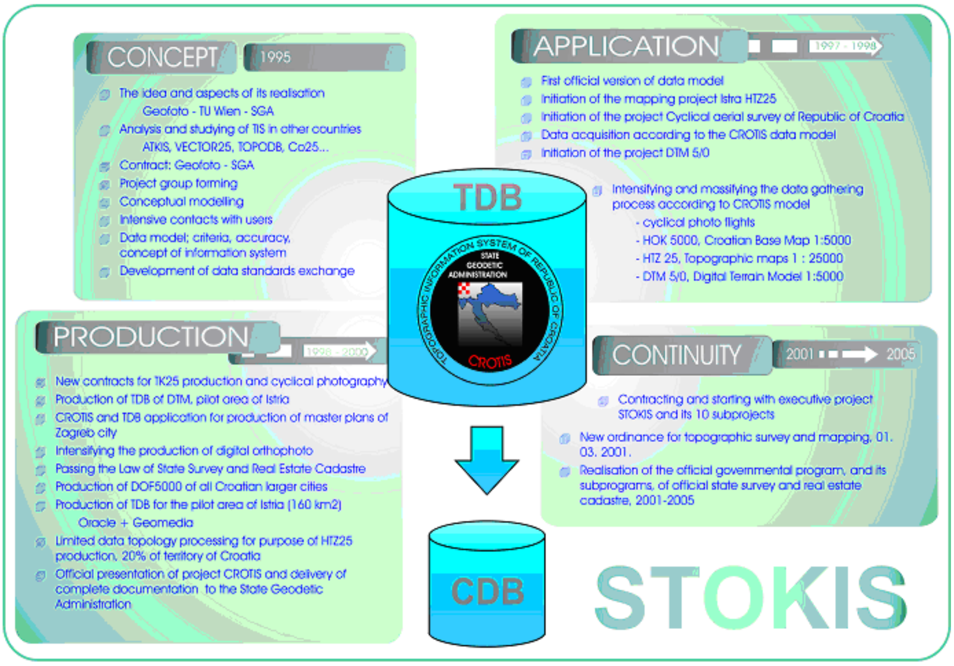

Figure 6.9: Data gathering, creation of TDB and production of topographic maps

6.9.3 Principal phase of CROTIS development

Further in the table there are the principal phases of CROTIS development presented accompanied by the application of multimodular management the basic methodology of which is shown on table 6.3.

Table 6.3: Principal phases of CROTIS

Period	Process
1995. October – November	• The idea and the aspects of its realisation
December	• Presentation of conceptual solution to Prof. Dr. Dipl.-Ing. Karl Kraus, TU Vienna, as the mentor on the thesis
1996. January – April	• Analysis and studying of TIS in European countries: – ATKIS, Germany – VECTOR25, Switzerland – BEV - Solution, Austria – CO25, Columbia (Swiss and German solution) – TOPO DB, France
May	• Definition of the project task TIS 25 of the Republic of Croatia
June	• Realisation of the contract between Geofoto and SGA about conceptual model and implementation of TIS

July – September	• Forming a project group • Conceptual modelling of basic object types
October – December	• Intensive campaign for provoking interest and including possible users into the production of data model and system concept
1997. January – February	• Production of the first data model version • Initiation of the project "Production of TK 25 of Istria, 21 sheets" according to the data model CROTIS
February 7th	• Presentation of the concept at the CERCO gathering, Zagreb
June	• Contracting and starting the project ISTRA TK 1:25000 • Initiation of the project Cyclical Photography of the Republic of Croatia, at approximate scale of 1:20000

July	• Initiation of a series of projects on data gathering according to model CROTIS (HOK 1:5000, DOF 1:5000) • Data gathering according to the model CROTIS
October	• Adjustment of the existing and issuing a temporary cartographic key according to the data model CROTIS • Initiation of the project DTM 5/0, digital relief model, covering the entire state with the data about the height presentation on the basis of digitising the contour lines on HOK 1:5000
November – December	• A series of the project concept and model in the country and abroad being the basis for professional and scientific, and public verification of the goals, standards, contents and procedures to be achieved. • Education of experts in SGA and institutions referring to data gathering
1998. January – June	• Intensive interactive modelling with permanent consultation users, performers and administration

July – August	• Production and delivery of the final data model CROTIS to the State Geodetic Administration
September – December	• Intensifying and massifying the data gathering process according to CROTIS, and within the frame of the projects: – Cyclical Photography of the Republic of Croatia 1:20000 – TK 25, Topographic maps 1:25000 – DOF 5, Digital orthophoto 1:5000 – HOK 1:5000, Croatian Base Map 1:5000 – DMR 5/0, Digital Terrain Model 1:5000
1999. January – April	• Production of TDB (topographic database) for the height presentation (DTM) on the system TDM (SCOP) • Topographic Data Management for the pilot area of ISTRIA • Development of exchange application scheme, EXPRESS solution • A series of presentations among the results and initiation of projects

March – April	• Intensifying the production of digital orthophoto as an integral part of CROTIS-a
June – July	• DOF 1:5000 of all larger cities of the Republic of Croatia was produced
September	• New contracting for the production of TK 25 and Cyclical photography for the purpose of establishing CROTIS
October	• Analysis of the results obtained by using TDB CROTIS data for the production of the regional plan and Master plan of the city of Zagreb
November	• New Law of State Survey and Real Estate Cadastre with clearly defined obligation for TDB CROTIS to be created
December	• Initiation of the work on the book of ordinances for topographic survey and production of state maps according to the data model CROTIS
2000. January – May	• Production of TDB for the pilot area of ISTRIA 160 km2 in the base ORACLE with the tools GEOMEDIA

June – August	• Topological data processing of TK 25, 20% area of the Republic of Croatia
September 6th	• Official presentation and delivery of complete documentation of CROTIS in the State Geodetic Administration to the Croatian geodetic public
December 15th	• Public presentation of the model CROTIS to wider administrative, economic, professional and scientific public of the Republic of Croatia • Delivery of data and presentations all over the area of Istria in digital and analogous form made according to the instructions and standards of CROTIS
2001. January – February	• Initiating and contracting of the implementation project STOKIS (Official Topographic and Cartographic Information System), and subprojects of STOKIS as the basis for the continuation of complete establishment of CROTIS

March	• Book of ordinance for topographic survey according to which there is clearly defined permanent obligation of the State Geodetic Administration in the field of gathering, processing, maintenance and distribution of the data from TDB according to the CROTIS data model
2001.-2005.	• Realisation of the official governmental program of state survey and real estate cadastre – *Subprogram B: Creation and completion of basic geodetic state survey bases* – *Subprogram C: Establishment of multipurpose spatial information system intended for the support in spatial management conducted by state authorities and public enterprises* – *Subprogram D: Establishment of information system for gathering, keeping and distribution of state survey and real estate cadastre data*
2002. January	• **On February 1st 2002, the State Geodetic Administration put the topographic data model – CROTIS to official service**

2003.	• Realisation of the Croatian-Norwegian Geoinformation Project (CRONO-GIP) wich resultes with seven Product Specification in geoinformatics domain and with establishment of the Quality Control processes at Croatian Geodetic Institute
2004.	• Start of Military Geoinformation Project, which use the CROTIS products as the basic input for NATO standardised geoinformations
2005.	• Start of Geoinformation project in the Croatian Mine Action Center, firmly based on the CROTIS products and standards
2006.	• 90% of the territory of Croatia is covered by CROTIS data

2007.	• Study of mechanism and implementation of the maintenance procedures for TDB • Geoportal SGA • Develop and implement of model generalisation procedures in function of production of TDB 25, TDB 100, TDB 250 • Distribution rules standardisation
2008.	• INSPIRE harmonisation • Cover entire Croatian territory with CROTIS geodataset • LPIS/IACS integration

Chapter 7

Scientific approach – GML

The Croatian Topographic Information System - CROTIS encompasses the standardization of topographic spatial data. The final goal is setting up a flexible and simple but high-quality geoinformation system based on modern technologies of modeling real world, emphasizing functionally significant objects in management of human environment. The backbone of the system is object-oriented spatial database that is meant to be the basic topographic information system of the Republic of Croatia containing the information that majority of users would need as the basis for creation of specialized information systems.

Currently, CROTIS is modernized and synchronized with the latest ISO and OpenGIS standards in order to develop procedures for topographic data distribution by using GML (Geography Markup Language).

New data model, new schema for the data exchange and new data catalogue have been encompassed within the research. The modeling was done for the purpose of data model improvement according to standards which provide the methods and properties for display of model objects and model attributes.

UML (Unified Modeling Language) is used for the formal description of the data.

Logical data model in UML enables the implementation of GIS including the database as well. The automatic generation of GML application schema was developed from UML, this is my contribution, that I want to talk about now, paper Biljecki et al. (2006): "Production of object-oriented conceptual data model CROTIS" presented by me at conference Map Middle East 2006, Dubai, and Biljecki et al.(2006): "The Adaptation of CROTIS Data Model and Generation of GML Application Schema", KiG, 5, 4-13. Data description is contained in the data catalogue which results automatically from data model.

7.1 CROTIS UML – metamodel

Review of trends in other national topographic standards and their changes conditioned with new norms and regulations, showed that it is necessary to adjust CROTIS to current norms.
While project analysis was related to implementation form, content of the model was not changed, in sense that there was no addition of new objects, classes and attributes.
The first part was UML data model describing classes, attributes and their values.
New CROTIS model was made according to the rules of conceptual schema language and application schema language of UML.
Metamodel is the data model which describes the whole modeling process of CROTIS. It encompasses: Model Layer, Documentation Layer and Compatibility Layer.

- **Model Layer**
  Model Layer contains the packages, classes, attributes and values of attributes. It notes model structure and it is compatibile with UML-metamodel. UML has elements required for the name of classes and attributes of classes. Model Layer is the implementation of UML model. Since UML doesn't have enough information for the generation of specified schemas, it was necessary to add Documentation Layer and Compatibility Layer, Figure 7.1 and Figure 7.2.

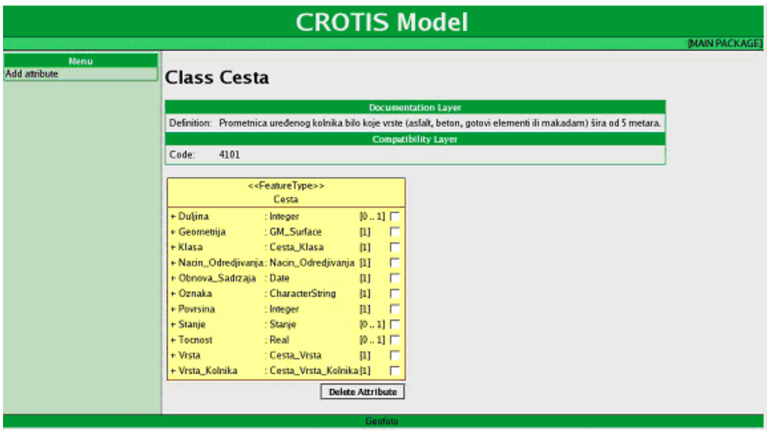

Figure 7.1: Model layer

- **Documentation layer**
  Documentation Layer contains data required for documentation definition. Data Catalogue belongs to Documentation Layer.

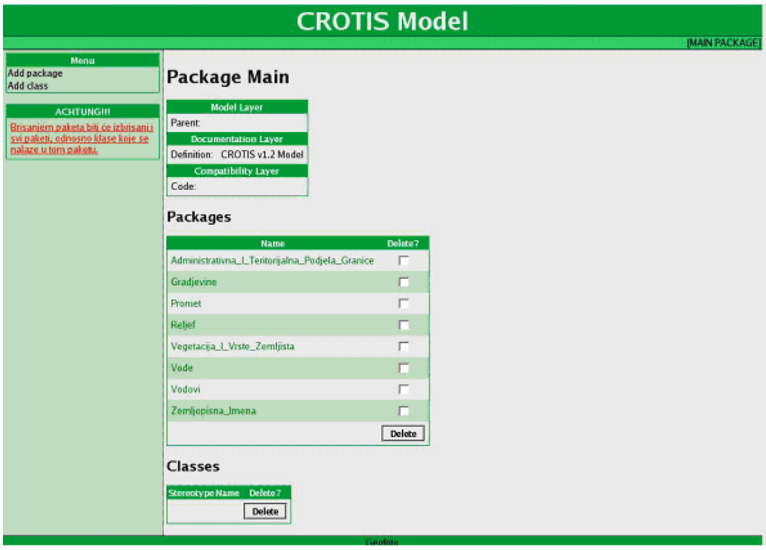

Figure 7.2: Implementation of model

- **Compatibility Layer**
  Compatibility Layer contains data about coding and data required for data mappings, from old to new data model.

GML application schema and data catalogue were generated automaticaly from UML. Since UML does not contain enough information for data generation, some additonal attributes were added to ensure the above mentioned products. This way, all data that are not contained in UML, such as code for compabillity, definition, etc., were added later in UML application in order to get generated products. UML approves object-oriented modeling and possibilities of extensive appliance. The Figure 7.3 shows data flow and method of project execution.

7.2 Processing adaptation of CROTIS data model

7.2.1 The adaptation of model

The analysis of previous CROTIS data model version 1.1 resulted being different from model specified in ISO. The differences between old version and new version of data model are presented on the Figure 7.3.
The data modeling was accomplished through appllication schema prescribed in ISO 19109 standard. Conceptual schema language should contain objects which are described in ISO 19103 standard. Application scheme includes class geometry, which is prescribed with 19107 norm.
New model contains classes described through the class diagrams like Fea-

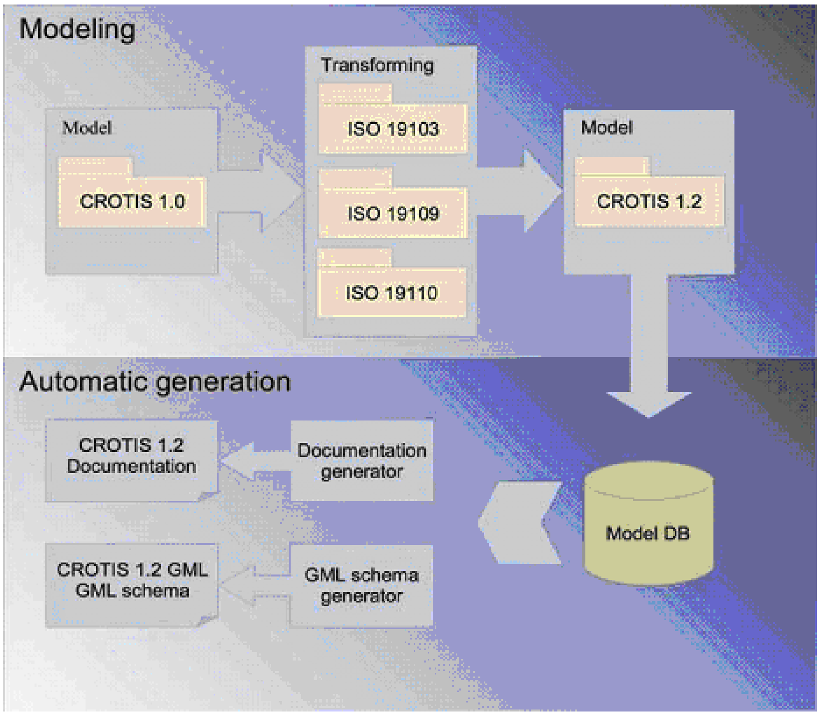

Figure 7.3: Schema of adaptation of CROTIS data model

ture Type. The class has attributes which describe the properties of classes. When several attributes are listed, their values are shown trough Enumeration Class (Figure 7.4).

The previous version of data model was conceived through the following tables:

1. Data model
2. Data model – attributes, figure 7.5

In that case two separate tables show the objects and the properties. Such tabular data model does not allow any kind of automatic generation. The goal is to get a model which enables more than common tables, such as generation of GML.
The purpose of application schema and new modeling is:

- Full understandig of contents and structure inside a very detail application field
- Provide computer visible schema to enable application of automatical process mechanism for data control

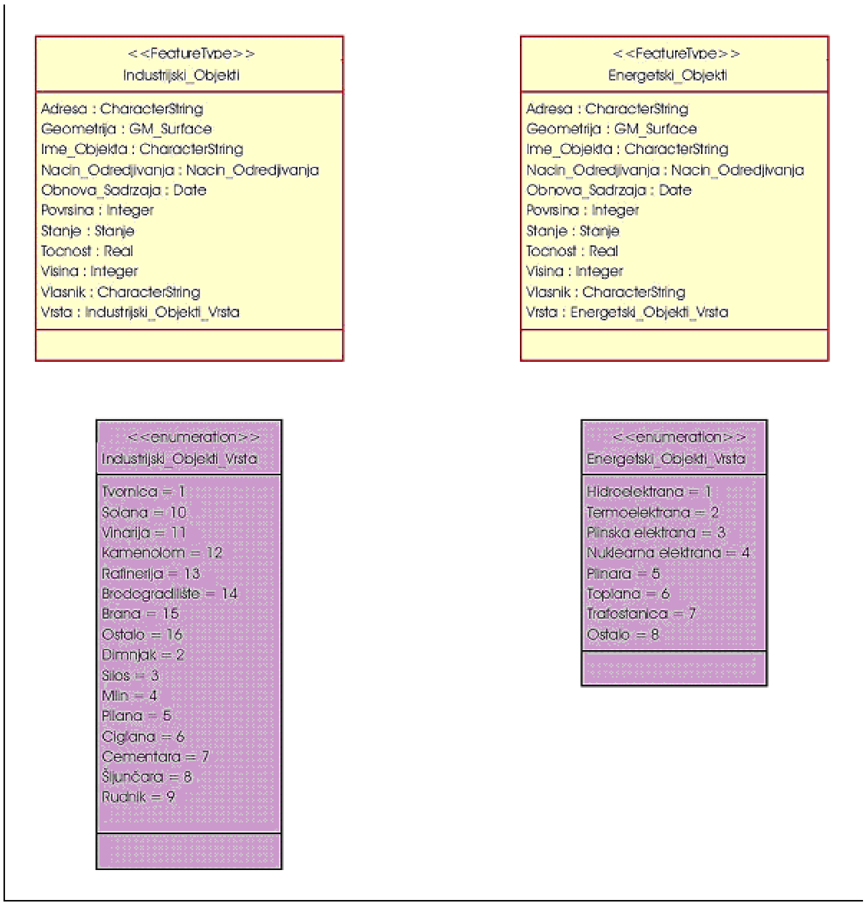

Figure 7.4: UML classes and enumeration classes

7.3 Automatic generation of documentation and GML

7.3.1 Documentation generator

The Data Catalogue presents all objects that make an integral part of a certain topographic geoinformation system according to the adequate classification.

Attribute obligation and criterion for their gathering as accuracy and geometric presentation are the essential elements for creation of computer representation.

The data catalogue is generated automaticaly from data model. The elements needed for the generation of Data Catalogue are contained in Documentation Layer The standard ISO 19110 presents the template for organization of the feature catalogue information according to rules described by

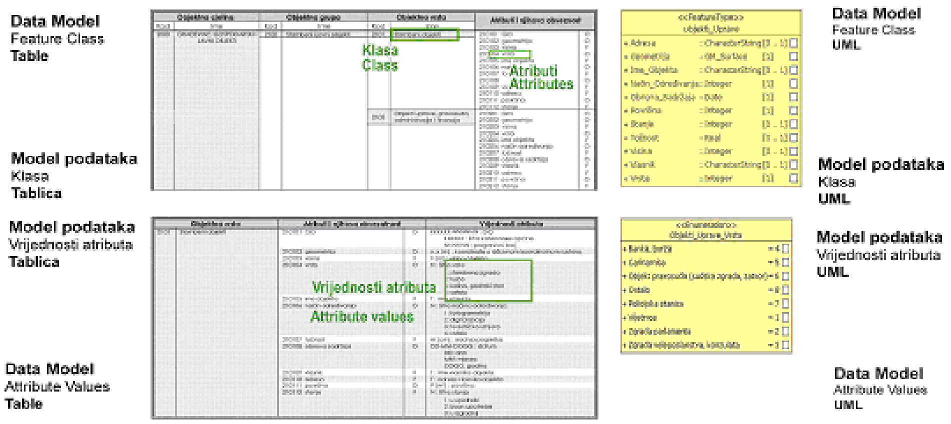

Figure 7.5: Transformation of old data model to new one

standard.
The Figure 7.4 shows the example of the data catalogue and standard ISO 19110. Some elements are mandatory (M), conditional (C) or optional (O) and can be included in the feature catalogue.

7.3.2 GML schema generator

Project *Production of object-oriented conceptual data model and production of GML application schema* determines the manner of data exchange within the topographic information system. The contents of standards include defining the schemes for data exchange, execution mechanisms and data encoding rules.
The standards of OGC define the following items:

- basic source objects for explicit geometric and topological geoinformation presentation
- mechanisms that are used for their exchange among users, i.e. informatical structures
- format of exchange structure.

Implementing mechanisms in previous version of CROTIS were based on EXPRESS language for formal data description (ISO 10303-11:1994), and the data were encoded in accordance with ISO 10303-21:1994 standards for pure text encoding.

In the meantime OpenGIS consortium developed specification for GML and currently ISO is accepting and developing GML as ISO standard.
The Geography Markup Language (GML) is an XML encoding in compliance with ISO 19118 for transport and storage of geographic information,

```
<!-- <<FeatureType>> Energetski_Objekti -->
  <xs:complexType name="Energetski_Objekti_Type">
    <xs:complexContent>
      <xs:extension base="gml:AbstractFeatureType">
        <xs:sequence>
          <xs:element name="Adresa" type="xs:string" minOccurs="0" maxOccurs="1"/>
          <xs:element name="Geometrija" type="gml:SurfacePropertyType" minOccurs="1" maxOccurs="1"/>
          <xs:element name="Ime_Objekta" type="xs:string" minOccurs="0" maxOccurs="1"/>
          <xs:element name="Nacin_Odredjivanja" type="xs:integer" minOccurs="1" maxOccurs="1"/>
          <xs:element name="Obnova_Sadrzaja" type="xs:date" minOccurs="1" maxOccurs="1"/>
          <xs:element name="Povrsina" type="xs:integer" minOccurs="1" maxOccurs="1"/>
          <xs:element name="Stanje" type="xs:integer" minOccurs="0" maxOccurs="1"/>
          <xs:element name="Tocnost" type="xs:decimal" minOccurs="0" maxOccurs="1"/>
          <xs:element name="Visina" type="xs:integer" minOccurs="0" maxOccurs="1"/>
          <xs:element name="Vlasnik" type="xs:string" minOccurs="0" maxOccurs="1"/>
          <xs:element name="Vrsta" type="xs:integer" minOccurs="1" maxOccurs="1"/>
        </xs:sequence>
      </xs:extension>
     </xs:complexContent>
</xs:complexType>
```

Table 7.1: GML example of application schema

modelled according to the conceptual modelling framework used in the ISO 19100 series and including both the spatial and non-spatial properties of geographic features [6].
The specification defines the XML Schema syntax, mechanisms, and conventions.
Example of mapping of Feature class is showed on the following table:

Stereotype (UML)	**XSD element type (GML schema)**
<<FeatureType>>	complexType
<<Enumeration>>	*

*Enumeration classes are transformed as Integers
The example of mapping of attributes from UML to GML is shown on the following table:

UML attribute	**XSD element type (GML schema)**
Date	date
CharacterString	string
Integer	integer
Real	decimal

The example of mapping of geometry data type from UML to GML is shown in the next table:

UML geometry	**GML 2.1.2**	**GML 3.1.1**
GM_Point	`PointPropertyType`	`PointPropertyType`
GM_Curve	`LineStringPropertyType`	`CurvePropertyType`
GM_Surface	`PolygonPropertyType`	`SurfacePropertyType`
GM_MultiSurface	`MultiPolygonPropertyType`	`MultiSurfacePropertyType`

The data from topographic database are presented through the web portal the prototype of which has already been made for different users such as: companies producing topographic maps, land use planning departments of the regional and local communities, private companies producing "derived" maps or databases, hydrography, road and railroad authorities, large state owned and private companies exploiting natural resources, ecology authorities and organisations, tourist and recreational organisation and local authorities, Ministries, Croatian Air Traffic Control, Croatian Waters, municipalities, utility companies, etc. The mentioned users can review the data and download the data sets in GML. For the review of data they need only web browser. Users can get some extra permissions which enables them to download the data, and they cab also get restrictions for data protection. The Figure 6.3 shows the example of topographic database and web application of topographic data CROTIS.

7.4 Testing of data model

Testing of data model is related to:

1. Testing of data catalogue includes:
   (a) comparing of data catalogue with data model
   (b) cheking of all classes, attributes, and attribute values

2. Testing of GML schema:
   Testing is carried out through the establishment of mapserver based on generated GML. XML parser is an application for the validation of GML acording to generated GML schema. Testing is applicable on the data from the topographic database. The town of Pula has been selected for the test area. Input data was exported from Oracle database. Mapping of data from old data model to new data model has been done with the Feature Manipulation Engine (FME) software. The data model is not tested directly, but through the implementation. The first part is related to the checking of the data contents (classes, atrributes, values). On the other part GML is tested.
   New CROTIS data model (classes, attributes, etc.) has been entered and maintened in PostgreSQL database. The interface for certain editing of some parts of the data model contents has been created.

Data catalogue and GML are generated by special generators that have been added to UML.
Therefore, the implementation of metamodel is in PostgreSQL. Source generator reads and transforms products of model from the database.

1. **Data model**
   Data model is in PostgreSQL database. Metamodel is compatible with the simplified UML-metamodel with added specified data which enables more generations (e.g. additions to UML for generating of Documentation and GML). Metamodel is oranizied through the layers and it describes the whole modeling process of CROTIS. It encompasses: Model Layer, Documentation Layer and Compatibility Layer.

   - **Model Layer**
     Model Layer contains the packages, classes, attributes and values of attributes. It notes model structure and it is compatibile with UML-metamodel. UML has elements required for the name of classes and attributes of classes. Model Layer is the implementation of UML model. Since UML doesn't have enough information for the generation a specified schemas, it was necessary to add Documentation Layer and Compatibility Layer.
   - **Documentation Layer**
     Documentation Layer contains data required for documentation definition. Data Catalogue belongs to Documentation Layer.
   - **Compatibility Layer**
     Compatibility Layer contains data about coding and data required for data mappings, from old to new data model.

2. **Client for the modeling**
   This is web application written in PHP. This application stores the design data about data model into the database. For now this application has enough capacity for modeling of CROTIS data model which has considerably easy structure.

3. **Generators**
   The application which reads data model from the database and generates required code (e.g. Documentation generator creates LaTex code, which could be easily transformed to PostScript format or PDF and on the other hand there is GML generator transforming the data model to GML application schema). Immediately, all application are customized for the CROTIS data model 1.2.

7.5 MapServer

The data from topographic database is presented through the web portal the prototype of which has been made for different users such as: companies producing topographic maps, land use planning departments of the regional and local communities, private companies producing "derived" maps or databases, hydrography, road and railroad authorities, large state-owned and private companies exploiting natural resources, ecology authorities and organisations, tourist and recreational organisation and local authorities, Ministries, Croatian Air Traffic Control, Croatian Waters, municipalities, utility companies, etc.
The mentioned users can review the data and download the data sets in GML. For the review of data they need only web browser. Users can get some extra permissions which enables them to download the data, and they also get restrictions for data protection. The Figure 7.6 shows the example of topographic database and web application of topographic data.

The Figure 7.7 shows the FME (Feature Manipulation Engine) in action.

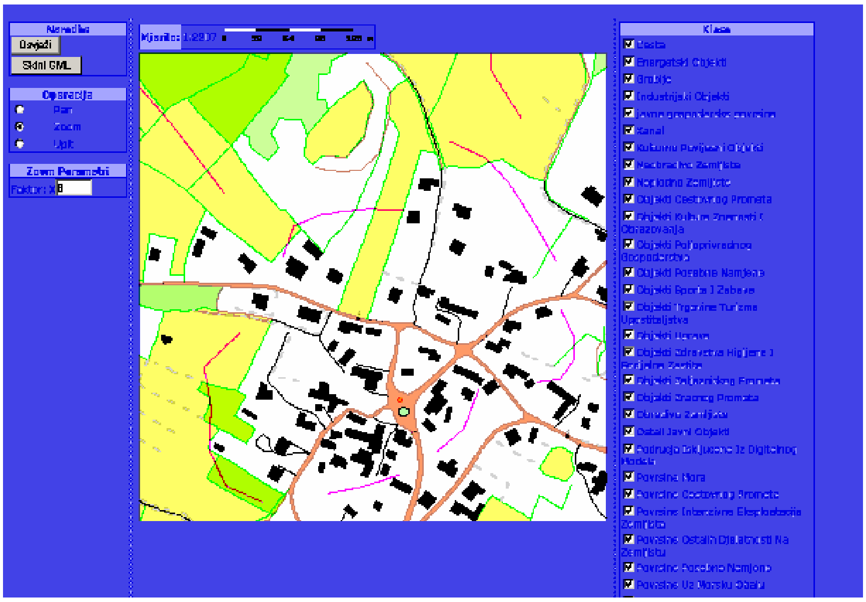

Figure 7.6: MapServer

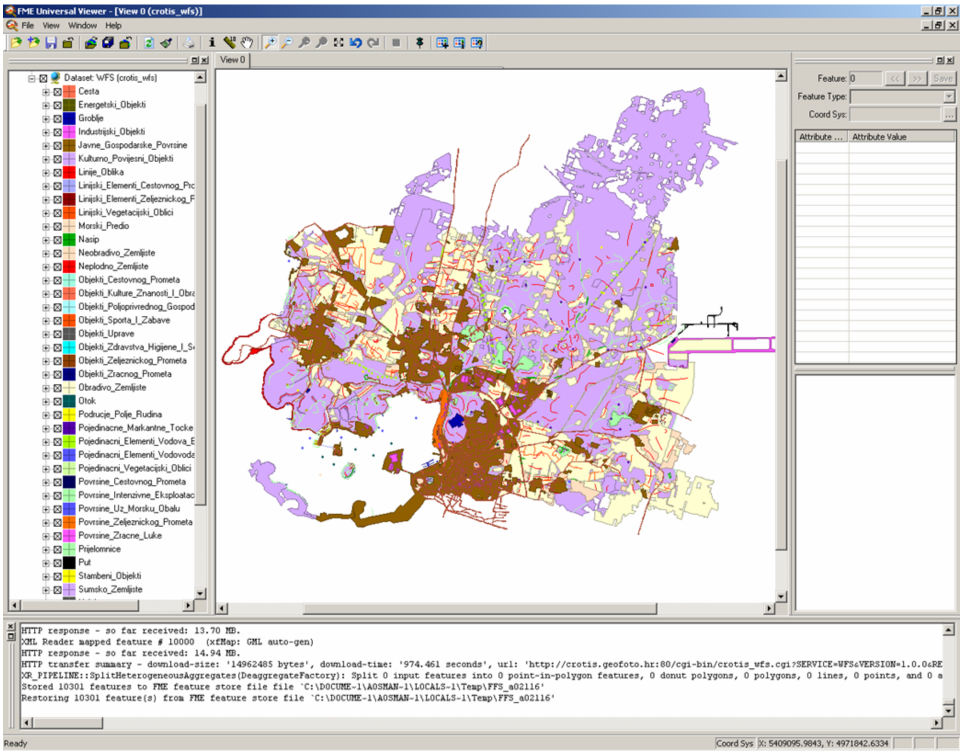

Figure 7.7: Spatial informations in FME Viewer

Chapter 8

Scientific approach – functional oriented modeling, FOM

8.1 Introduction

As mentioned before in *6.2.1 General guidelines and scientific approach of functionally oriented modelling* Geoinformatically functionally oriented approach in CROTIS accelerates the process of transforming the reality into the desired information form, and provides complete projection of created data model into the structured base. CROTIS gives an outline of a new approach in spatial data representation and management. The establishment of a functional, and not analogous and cartographic mode, is the basic characteristic of this new conceptual modeling.
The basic guideline of functionally oriented modelling is to emphasise, give more weight to presentation and gathering of data having greater importance for most of stakeholders in exploitation of real world (Figure 8.1). The main roads, other communication routes, built objects and their basic approaches and their classification are essential object classes for spatial functioning. Traditional analogous and cartographic approach in presenting the reality cannot meet the demands of modern geoinformation system and standards. "Aerial view" with classical presentation of the Earth's topography gives either insufficient or too much data considering all principles and standards of cartographic presentation dealing exclusively with analogous object presentation, and its structure is mostly not suitable to be accepted and processes as an integral or basic data of geoinformation system.
Functionally oriented modelling raises considerably the level and quality of data respecting thereby conceptual modelling. The reality in all its complexity can be presented and processed informatically in a satisfactory way only by recognising this complexity.

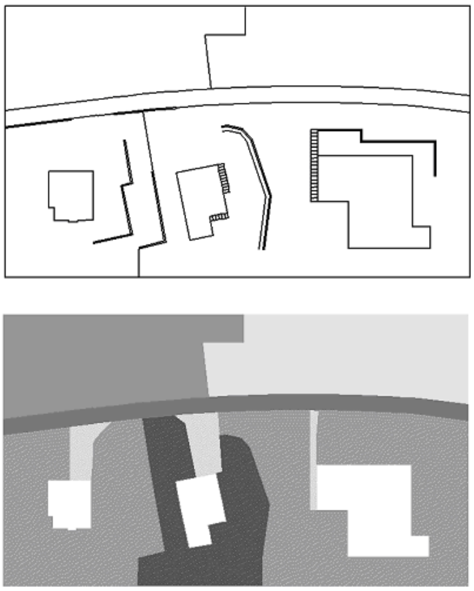

Figure 8.1: Example of differences between cartography and functionally oriented modelling

The basic guideline of functionally oriented modelling is to emphasise, give more weight to presentation and gathering of data having greater importance in explotation of real world (Figures 6.2 and 6.3). The main roads, other communication routes, built objects and their basic approaches and their classification are essential object classes for the functioning of space. Functionally insignificant objects (concrete pathway between two buildings or family house staircases) are neither gathered nor can make object classes of official geoinformation systems. They can be gathered and presented only if specially requested by users (designing of certain line infrastructures).

8.2 Functionally oriented modelling vs. cartographic modelling

Traditional cartographic-topographic approach to the real world modelling implies the concept of the „view from above“ known to everyone and accepted and irreplaceable for a long time, as well as the concept of its presentation in two-dimensional drawing with limited setting off, colour and line type – symbols, traffic route classicisation, object types and other attributes. The length of the real world object, its width and area without more precise and more detailed consideration of its characteristics and the importance for more users with respect to economic, social and political character presents the definition of widely adopted, traditional cartographic approach. Redundant information on one hand that make the process of data gathering, processing, presenting, and later on of map updating are frequently contrary to the lack single objects or the lack of important characteristics on the other hand. Map generalisation the task of which is to present real world in adequate scale and the most authentic way satisfying all map users is simply impossible and not adjusted to the needs of modern times, exploitation, planning and managing the space. Ever growing demands in connection with the quality, quantity and time component of spatial information request different approach. The fundamental approach of functionally oriented modelling preferring unlike ≪vertical≫ point of view and ≪dimensionality≫ the functionality expressed through economic and management importance of objects and their characteristics is called functionally oriented modelling. We are often in situation to hear the term ≪user oriented≫ modelling that differs partly from ≪functionally oriented≫ modelling. Both approaches imply maximum interaction with users and their needs during the process of model and specification production. However, we are often troubled when translating ≪user oriented≫ approach due to insufficient competence of individual or the majority of users, their insufficient education and inexperience, being addicted to previous conventional approaches (maps) in presenting the reality, and inability of coordination, the occupation and complexity of geo-information approach. It is then absolutely good solution "functional oriented" approach with maximum involvement of current or potential users. The approach just used in this work can well be called "functional and user oriented" approach. A series of workshops, information and educational lectures, panels, published professional and scientific works, and large author's consideration of user needs in the process of modelling were not sufficient input and base for defining the contents of the topographic database, their resolution and characteristics. Having in mind the above stated, data model has been made within the period of less than a year using functionally oriented approach and its testing in the workshops with relevant users of spatial data (more than 30 institutions), and producers (providers) of data (six private photogrammetric companies). The results of testing have been processed and presented in the chapters no. 8.4 and 8.5 that indicate clearly that the approach presented has given excellent results. Functionally oriented modelling takes all essential aspects and components of sustainable development and space management into consideration unlike cartographic modelling, which presents today the issue of necessity.

8.3 Implementation of functionally oriented modelling and its practical aspects

The change in the approach of spatial data collecting by operators has been indicated as one of the largest tasks and obstacles in implementing functionally¡ oriented modelling. The change carried out by photogrammetric operators from ≪mapping to modelling≫ has proved to be an important factor that was underestimated in the beginning but later recognized as such. Only until recently used to cartographic way of thinking, photogrammetric operators, and also their management, have produced the greatest ≪resistance≫ in the implementation of the new approach. Real space, the phenomena with space, but also without space components, objects with their characteristics make a complex system of spatial information, and their shaping into unanimous and unique geo-information system, is a very responsible, demanding and difficult work. A lot of time has been invested into the education and training of photogrammetric operators, and other participants in data collection according to new rules. However, only after a unique control system has been established within the system of data producers, and of the quality control system at the state level, there has been a satisfactory, but still not complete harmonization of topographic data and their conformity with the model CROTIS achieved with full implementation of functionally oriented modelling. Known as ≪Croatian model≫, it includes implicitly the State Geodetic Administration as the orderer of topographic databases, photogrammetric firms as data producers, and the Croatian Geodetic Institute in charge of monitoring and controlling the quality of TBP.

Further on, there are some characteristic parallel examples of the relationship reality – functionally oriented modelling presented with the explanations and practical aspects.

Short, functionally inessential attachments:

1. cartographic approach

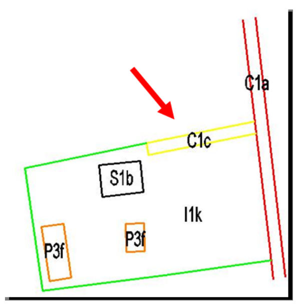

Figure 8.2: Cartographic approach

2. functional approach

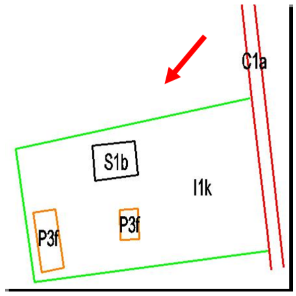

Figure 8.3: Functional approach

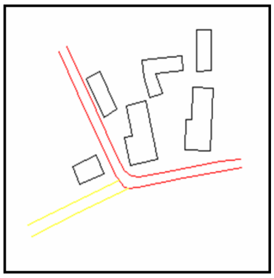

Figure 8.4: Buldings in blocks (cartographically)

8.4 Testing of functionally oriented modeling approach

The testing of functional oriented modeling approach have been realised through two workshops with majority users, more than thirty stakeholders with long term experience:

- 1st workshop, performed in 2002.
- 2nd workshop, performed 5th of April 2007

Main goals of testing have been:

1. Comparing applied approach of functionally oriented modeling with results from 2002
2. Reviseing approach with demand of users based on their experience
3. Getting inputs for data model enhancement
4. Proving the quality of approach

5. Getting general figures of cost benefit of applied proof
6. Getting general figures of approach reference to technology benefits (data capture, model generalization, mapping, data maintenance and data distribution)

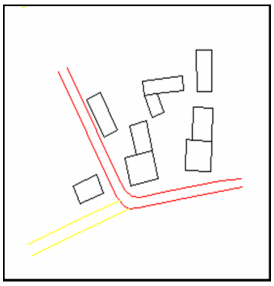

Figure 8.5: Buildings according to purposes and separation within blocks (cartographically)

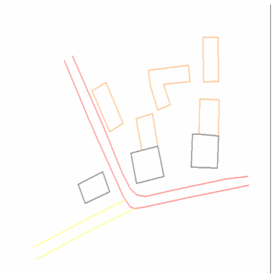

Figure 8.6: Buildings according to purpose (functionally)

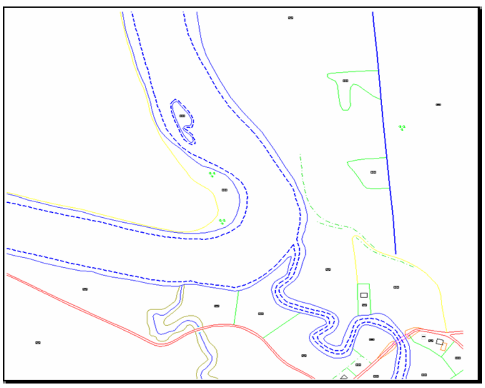

Figure 8.7: River bank and water face (cartographically)

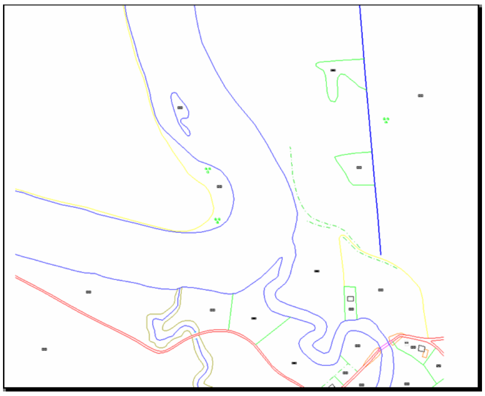

Figure 8.8: River bank (functionally)

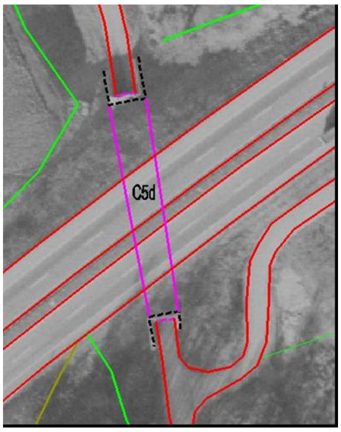

Figure 8.9: Underpass (cartographically)

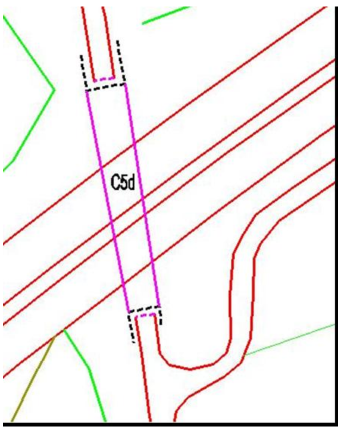

Figure 8.10: Underpass (cartographically)

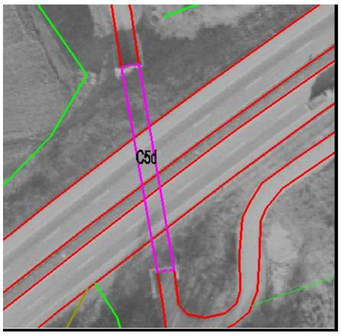

Figure 8.11: Underpass (functionally)

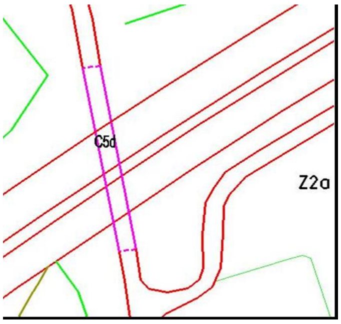

Figure 8.12: Underpass (functionally)

8.5 Users workshop CROTIS-GML – 2007

To achieve the goals mentioned in the chapter 8.4 testing of functionally oriented modeling the users workshop CROTIS-GML was organised on the 5th of April 2007 in the SGA premises. "Capital users" of topographic and cartographic data were present there. About thirty most important users (state and cities institutions) participated in the one-day workshop. After the presentation of Croatian NSDI goals and Geoportal by SGA experts, the CROTIS-GML and CROTIS products have been presented by the author of the thesis as a input for a data model test.
Four group works for "capital users" have been organised using standard questionary form (documented at Geofoto and SGA). Here are presented the final results:

Group work 1 – Theme: existing and new products

Conclusion result A: Users recognized the importance of vector data which are used on daily level. However, the raster data will be used in the future too.

Conclusion result B: Contour lines are still used by most of users for relief presentantion. DTM is welcome in TIN form for the users who are capable of making 3D analysing and presentation. The height of building is demanded in the domain of regional and urban planning, 2.5D

Conclusion result C (data exchange): The users are not yet familiar with technical capabilities in using GML application schema as an exchange format

Conclusion result D (data upload): The direct data access throughout internet is a evident users demand

Conclusion result E (data type): For all categories of users as the most important datasets have been shown Topographic Data Base TBP10 and digital ortophoto DOF5, then the DTM. The minor importance have been shown to the cartographic data

Different datasets: All users showed interest in the possibility to upload different datasets

Group work 2 – Theme: Data quality The work in four groups presented a little bit different results. Before making any conclusion, but also refering to the importance of this matter, there is shown a "adjusted" result of priority of quality elements shown here:

1. Accuracy
2. Accessibility of geodatasets and on time delivery avaliability
3. Resolution - level of details – scale
4. Topology
5. Actuality
6. Level of classification
7. Metadata
8. Completeness

Conclusion of Data quality test: Statistically , the most important are accuracy and data avaliability and on-time delivery. Very low importance has a completeness and Metadata. However, heterogeneous users have given different results. For this reason test results have to be taken with some reserves. It is more realiable to analyse the results by different "homogenous" groups.

Group work 3 – Theme: priorities of quality elements

Conclusion:

- Users of topographic dataset need accuracy better than $rms = \pm 1$m
- The number of requested objects (classification) is under 50, but this means that some objects are not always considered
- Attributes (characteristics) have to be integral part of the classes
- Surface topology has to exist in data model
- Five years up-to-date period mechanism system meets users requirements
- User community wishes to have internet access to geodatasets and to metadata
- Most of users require on-line data delivery

Group work 4 – Theme: Functionally oriented modelling For this work the author has organised an "introduction" presentation with the goal to help users to understand the complexity of different approaches and methodology in data modeling. The cartographic, user-oriented and functionally oriented approach of data modeling has been presented, discussed and verified. Then, using an on going process the users in four homogenous groups have been devided.
The functionally oriented modelling has been tested on over thirty representantive cases in the domain of the most important classes as traffic, transportation, buldings, waters and complex objects. Here are some examples presented that are used for test (Figures 8.2-8.12).

Conclusion of FOM testing: Most or nearly all users test results confirmed that functionally oriented data modelling approach that has been applied and implemented in CROTIS fully meets the requirements (documented at Geofoto and SGA).
Finally, all answers to the questions set for testing have been achieved. The applied FOM approach and conceptual model have been tested in time period of five years. Above presented test results based on users experience and demand respectivelly justified FOM approach.

General Conclusion:
Some realiable inputs (group work 1-3) for data model enhacement (specification and data exchange) have been achieved, as a less resolution needed, higher accuracy is asked very begin of GML application schema usage and

neccessibility of direct access to geodatasets are reality. The proof of data quality and its enhacement has been achieved, too.
General figures of technology benefits and cost benefits have been achieved, too. These components have been proven throughout testing and discussion with users and getting a general input for current works and future development of CROTIS concept and implementation as a model generalisation, data capture, data maintenance and data distribution.

Chapter 9

Executed and current relevant projects

In this chapter there are the most relevant projects, executed or presented within the frame of CROTIS implementation. Their definition and relevancy are coming from the user demand and my proposals.

9.1 STOKIS, implementation project of the official topographic and cartographic information system of the Republic of Croatia (contract of 2nd February 2001)

In the conceptual project STOKIS (Kovačević i dr. 1995) there has been an establishment and designing of the Official Topographic and Cartographic Information System of the Republic of Croatia foreseen for the area of topographic survey and production of state topographic maps.
The projects *Study on the substitution of fair draughts and renewal of topographic map contents*, CROTIS (Topographic Information System of the Republic of Croatia), the production of about 100 sheets of TK 25 (Croatian Topographic Maps) and the creation of a new cartographic key for TK 25 have lead to the establishment of a conceptual topographic (CROTIS, primary) and for the most part cartographic (KM, secondary) model of gathering, processing and partly presenting the topographic information.
The production of new cartographic keys, integration of topographic and cartographic information system, establishment of quality control mechanism and maintenance of topographic and cartographic base are the fundamental goals of the proposed project STOKIS.

9.1.1 Goal of the project

The fundamental goal of the project STOKIS was the establishment of *Official topographic and cartographic information system of the Republic of Croatia* according to the basic principles of the conceptual project STOKIS (altered in its smaller part). The establishment of topographic and cartographic information system encompasses the standardisation in the field of creating, maintaining and distributing the topographic database and state topographic maps.

9.1.2 Contractors of the implementation project

Due to its extraordinary significance and implementation complexity of the project, it has been suggested that a *commission for the realisation of the implementation project STOKIS* should be founded with the proposed experts and scientists officialy leaded by author in it to have such complex activities conducted by a *permanent body* within the State Geodetic Administration.
The task and obligations of the *STOKIS commission* would be: organisation, co-ordination and realisation of all projects and subprojects, control of carried out works, promotion, co-ordination, and administrative and legal activities on the establishment of STOKIS. The fundamental tasks of the project group would be initiation, definition, co-ordination of administrative, scientific, and economic activities.

9.1.3 Planned scope of works

- Instructions, collaboration and participation at the creation of new computerised cartographic keys offered by the Faculty of Geodesy
- Definition outside of the frame topographic map contents
- Determination of signs and names of single topographic map sheets
- Map generalisation, instructions, standardisation
- Map visualisation of topographic map contents
  - colour selection
  - print determination
  - co-riddance networks (projections)
  - test print
- Integration, establishment of full conformity between the data model and CROTIS, and users needs

- Quality control with the creation of mechanism - procedure of data transfer from the status *IN PROJECT* to STOKIS datum
- Selection of new map projection with estimation of possibility for is feasibility with respect to time and economy parameters
- Computerisation of the State Geodetic Administration
- Establishment of topographic database and cartographic database
- Education and promotion of the project within the State Geodetic Administration, and complete involvement of STOKIS users
- Complete establishment of STOKIS
- Creation of a strategy of SGA in the field of topographic and cartographic information system

9.1.4 Basic parameters in the creation of STOKIS of the Republic of Croatia

- Establishment of STOKIS in the function of economic processes and the development of the country
- Integration of STOKIS into the European Topographic and Cartographic Information System (CERCO)
- Momentary circumstances with regard to topographic and cartographic information
- Importance of global and regional political and strategic interests in connection with the topographic and cartographic data
- Involvement of existing institutions and organisations into the creation of STOKIS
- Financial aspects, help from abroad and introduction of Ministry of Defence into the project
- Possible users and their specific characteristics, equipment and general situation
- Human, technical and organisational potentials, operative qualifications and capacities
- Methodology in data gathering and processing, and necessary investments

- Information and organisation aspect, analysis of institutions and organisation in close collaboration with the State Geodetic Administration, making suggestion for specific measures and mechanisms intended for the co-ordination of activity in direct participation of users at the work on the project, defining obligations and

- Responsibilities outside of state firms and consultants, providing education and technical help for a successful implementation of the Project, especially in connection with maintenance and usage of equipment and data.

9.2 Quality control of topographic survey and production of state maps

9.2.1 Goal of the project

The goal of the project is to make a mechanism and procedure for quality control of topographic survey and production of state maps for the purpose of official verification and data transfer from the status *IN PROJECT* to the official datum (STOKIS).

9.2.2 Scope of planned works

- Production of a conceptual mechanism - system of quality control

- Production and description of quality control procedures following single phases of topographic survey

- Preparation of quality control procedures in the production of state maps

- Suggestion for the mechanism of “inner” control

- Data consistency control

- Photogrammetric mapping data control

- Production of a control mechanism for topological data processing

- Creation of procedures for accuracy estimation of object classes geometry

- Quality control of aerial photography

- Creation of control procedures for attribute accuracy and reliability

- Field encoding and planned procedures

9.2.3 Basic parameters of topographic and cartographic base establishment

1. Data model CROTIS
2. Cartographic data model
3. Required geometry accuracy
4. Class selection criteria

9.3 Production of cartographic data model

9.3.1 Goal of the project

The production of cartographic data model that would be in complete conformity with TDB (topographic database) defined by CROTIS, and used for the establishment of cartographic database (CDB) is the fundamental goal of the project (Biljecki 2002).

9.3.2 Scope of works

- Conceptual modelling in the function of establishing a cartographic database, its full conformity with the needs of users.
- Graphic and alphanumeric modelling in accordance with the defined contents of HOK 1:5000, TK25 and other topographic maps at small scales.
- Integration, establishment of full conformity of Cartographic Data Model and Topographic Database defined by the project CROTIS.
- Production of a data model according to ISO (International Standard Organisation) TC 211 (Technical Commission) standards.
- Production of functionally oriented model.

9.3.3 Basic parameters of modeling

1. Production of a model functioning to be used for economic purposes
2. Integration into European Cartographic Information System
3. Financial aspects
4. Possibilities and needs of possible users
5. Possibilities of information infrastructure

9.4 Establishment of topographic and cartographic database

9.4.1 Goal of the project

The goals of the Project are to establish a unique and operative topographic and cartographic database in the State Geodetic Administration in conformity with the data model CROTIS and with the cartographic model accompanied by full application of quality control and protection systems and procedures.

9.4.2 Scope of planned works

- Selection of equipment for establishment, maintenance and distribution of topographic survey data and production of state maps.
- Structuring of database in the State Geodetic Administration according to the model CROTIS and to the cartographic model
- Establishment of data protection mechanism
- Creation of visualisation procedures for topographic and cartographic database
- Production of a unique system and operational level
- Establishment of data distribution procedures
- Optimising the receipt, processing, maintenance and distribution of data
- Organisation and co-ordination among contractors of joint projects

9.4.3 Basic parameters of establishing topographic and cartographic database

1. Momentary situation, strategy, need for cartographic information
2. Integration of bases into the European Topographic and Cartographic Information System
3. Financial aspects
4. Professional, technical and organisational potentials

9.5 Accuracy and quality estimation for DTM 5/0

9.5.1 Introduction

In 1997 the State Geodetic Administration initiated the production of a unique digital terrain model of the Republic of Croatia (hereafter referred to as DMR 5/0) from analogue height terrain presentation given on the State Base Map at the scale of 1:5000. This activity is in accordance with the recommendation from the CONCEPTUAL PROJECT STOKIS (Kovačević i dr. 1995.), passage 8.2. - Preliminary works.
"Instruction for the execution of works on data gathering for the purpose of producing DMR on the basis of HDK 1:5000" (hereafter referred to as: INSTRUCTION) was made by the Institute for Photogrammery d.d. and delivered to the State Geodetic Administration in April 1997.
In the process of establishing DMR according to the INSTRUCTION the height presentation of the terrain on the existing sheets of ODK 1:5000 is transferred from analogous into digital form by digitising the *contour lines, single terrain heights intermediate contour lines, single heights of characteristic terrain points* (peaks, valley bottoms and karst valleys, and similar), *as well as the heights of natural and man-made terrain landmarks* (watersheds, gullies, natural and man-made dams and cuttings, canyons, water flows, coast lines etc.).

9.5.2 Goal of the project

The basic goal of the project is accuracy estimation and quality control of DMR 5/0 being used within the frame of Topographic Information System CROTIS and according to the basic principals of the conceptual project STOKIS.

9.5.3 Purpose of the suggested project dealing with the control of DMR 5/0

Although it is the matter of quality control to be made on completed works invested in the production of DMR 5/0 - the control copy of layered plan from the established DMR 5/0 has to be made for every single processed sheet of ODK 1:5000, and its overlapping with the original analogous contour lines presentation, there are still doubts present that the applied procedure is correct.
In order to confirm or eliminate the justification of such doubts the suggestion has been made for this control project by which a limited number of height points for control would be defined using the method of random selection. The selected points would be determined in terms of height through direct surveying (either in the field or from adequate photographic material

by means of photogrammetric interpretation) and then compared with corresponding data from DMR 5/0, providing thus the conditions for objective estimation of DMR 5/0 data accuracy and quality.

9.5.4 Scope of works

- The selection of 1000 height points to be controlled, with 50% among them on flat, and 50% on hilly (well-indented) land (a certain amount of controlled points will be selected on man-made objects, and the same number on natural or man-made landmarks);
- Taking over height data for control points from DMR 5/0;
- Determination of heights by means of photogrammetric survey from adequate existing photogrammetric material;
- Identification and measurement of heights directly in the field at a smaller number of control points, analysis of control survey data with interpolation accuracy and quality estimation of DMR.

9.6 Computerisation of the State geodetic administration and education of employees

9.6.1 Goal of the project

The basic goal of the suggested project is to furnish, computerise, suggest and organise mutually a professional group of employees in the State Geodetic Administration that would be competent for the receipt, maintenance and distribution of topographic and cartographic data guided by the goals and functions of topographic and cartographic information system.

9.6.2 Scope of planned works

- Selection, testing and delivery of equipment for the establishment, maintenance and distribution of topographic survey data and state maps according to the data model CROTIS / STOKIS.
  Basic criteria to be met by the (software):
  - Complete program equipment is delivered for the operational system Windows NT;
  - Program equipment must enable the work in multi-users environment (1 server + minimum 6 clients) and support the interactions of users with database in long transactions;

  - The equipment must be in accordance with OpenGIS, and the system for database management should be harmonised with OpenGIS Simple Feature Specifications for SQL;
  - Program equipment must support spatial inquiries and analysis in accordance with OpenGIS specification;
  - The possibility of vector and georeferenced raster data processing;
  - Complete topological vector and georeferenced raster data processing;
  - Data exchange with other systems by means of DXF, SCOP-WINPUT and ISO-10303 - 21 format;
  - High degree of protection (unauthorised changes) and data security in the cases of unpredictable standstill of working system (direct system support with *backup* and *recovery*);
  - Providing continuous *support* by telephone connection and direct intervention;
  - Installation of program equipment for two working places on the computers in the State Geodetic Administration;

- Educating the employees from the State Geodetic Administration (2 employees) using the equipment of Geofoto and the equipment of the State Geodetic Administration (after the installation);
  - Education of the professional group from the State Geodetic Administration will be carried out in the field of all activities necessary for receipt, maintenance and distribution of STOKIS data.

9.7 Model generalisation

In order to understand better what model generalization is, one should start from map generalization and its definition. *Map generalization* is the process of map contents simplification adjusted to map scale and /or purpose of map. (Frančula, Kartografska generalizacija, Zagreb, 2000). *Model generalization* relates to the generalization of data model, i.e. Topographical database. It is not burdened with the presentation (symbolisation) on map and with its limited space. The primary goal of map generalization is to reduce the data quantity in accordance with the target scale of topographic base.
Goals of model generalisation are as follows:

- Reduction of data quantity
- Removing of the details irrelevant for target scale
- Data harmonization

Generally speaking, model generalization consists of:

- Selection/elimination of objects
- Changing the type of geometry
- Type classification
- Integration
- Geometric simplification

It is important to mention with model generalisation that *none* of these operations includes shifting of objects, the position of objects remains the same. This is one of larger difference related to map generalisation. Not shifting the objects brings about the situation in which planned, requested (guaranteed) accuracy of the topographic base is preserved.

- Selection/elimination of objects is one of the first actions. The change of the scale itself makes certain objects disappear from the model – they are not of interest to us for the abstraction degree and for what the model is intended for. The selection is made at the level of complete object classes, as well as on the object itself and its selection depends on its attributes, as well as on the conditions set by the data model (geometric conditions and attribute conditions).
- Changing the type of geometry depends on the target model, abstraction degree and presentation conditions. One of more important criteria in changing the type of geometry is also the dimensions of the object itself. The types of geometry changes are: area into point, area into line, line into point. The changes of geometry do not affect the accuracy of database, it continues to remain preserved.
- The type classification is one of optional selections and depends first of all on the data model itself.
- Integration, i.e. joining of neighbouring objects that are identical with respect to their geometric and attribute values in the target data model.
- Integration, i.e. joining of neighbouring objects that are identical with respect to their geometric and attribute values in the target data model.

The above stated actions result in changing geometry and its simplification which leads to the change in topology. The distortion of topology should be repaired to make the base topologically correct, i.e. to make the performance of analyses possible.
Generalised schedule of action in model generalisation is the following:

- control and preparation of original data (TBP10)
- transfer of data into the target model – so called mapping (TBP10 into TB25)
- completing the objects with additional attributes foreseen in the target model
- determination and change of geometry types
- joining the objects of the same attribute values
- simplification of geometry
- solving the conflicts

Successful model generalization cannot be carried out without improved topology. So far gathered experiences indicate the fact that the control and preparation of the existing data is very important in order to carry out model generalization as painless as possible.
In already existing specifications CRONO GIP and CROTIS model one can notice their incompatibility. It is therefore necessary to carry out the mapping process between them in order to get a clear situation with respect to the model and accompanying attributes.
Data quality is one of the most important prerequisites of successful model generalisation performance. Since data are usually collected by various institutions, it is very important that they are collected according to a specific standard, so that the data would be harmonized. The harmonization of data is affected by the time period of their collection as well, if the model has changes in the course of time. The standards should also be adjusted to multi-purpose function so that the data could be used for several purposes including as small additional interaction of users as possible.
Everything mentioned so far relates to model generalisation itself, what makes it what it is, performance schedule, demands with respect to data quality. Before performing the model generalisation itself, it is necessary to define/have:

- model of original topographic base (TBP10)
- model of target topographic base (TBP25)
- conditions for the presentation of objects of the target topographic base (TBP25)
- the rules for mapping from the original model into the target model (TBP10 into TBP25)

Above given four items are inevitable for performing model generalisation. *Why* should we make model generalization and what do we get with it? The answer to this question is given to us by the definition of generalization itself. Generalization makes it possible for us to describe the realities with various degrees of abstraction. Unlike the map generalization, model generalization makes it possible to preserve object position. Thus obtained base can be used for analyses that are appropriate for regional or some higher level, depending on the scale they agree with. These analyses are faster, and the bases are relieved from surplus of details. It can be used as the origin for obtaining various maps (topographic or thematic) and for creating smaller-scale base with higher abstraction degree. Model generalization makes map generalization easier, since the object have already been simplified and reduced to the presentation scale.

9.8 Model generalisation TBP25

Generalization makes it possible to describe the reality with various degrees of abstraction. Model generalisation refers to the generalisation of data models, i.e. the topographic database. Unlike the cartographic generalisation, it is not burdened with the presentation on map (symbolisation) and with limited map space.
The primary goal of model generalisation is the reduction of data quantity adjusted to the target abstraction degree of the topographic base.
The goals of model generalisation are as follows:

- The reduction of data quantity
- Removal of the details irrelevant for the target abstraction degree
- Data harmonisation

Generally speaking, model generalisation consists of:

- Selection/elimination of objects
- Changing the type of geometry
- Type classification
- Integration
- Geometric simplification

It is important to mention with model generalisation that none of these operations includes shifting of objects, the position of objects remains the same. This is the essential difference related to map generalisation. Not shifting the objects brings about the situation in which planned, requested accuracy of the topographic base is preserved.

- Selection/elimination of objects is one of the first actions. The change of the scale itself makes certain objects disappear from the model – they are not of interest to us for the abstraction degree and for what the model is intended for. The selection is made at the level of complete object classes, as well as on the object itself and its selection depends on its attributes, as well as on the conditions set by the data model (geometric conditions and attribute conditions).

- Changing the type of geometry depends on the target model, abstraction degree and presentation conditions. One of more important criteria in changing the type of geometry is also the dimensions of the object itself. The types of geometry changes are: area into point, area into line, line into point. The changes of geometry do not affect the accuracy of database, it continues to remain preserved.

- The type classification is one of optional selections and depends first of all on the data model itself.

- Integration, i.e. joining of neighbouring objects that are identical with respect to their geometric and attribute values in the target data model.

- Geometric simplification depends first of all on the requested accuracy. It must be within the frames of the requested accuracy of the topographic database. We distinguish here the simplification of area and line objects.

The above stated actions result in changing geometry and its simplification which leads to the change in topology. The distortion of topology should be repaired to make the base topologically correct, i.e. to make the performance of analyses possible.
Generalised schedule of action in model generalisation is the following:

- control and preparation of original data (TBP10)

- transfer of data into the target model – so called mapping (TBP10 into TB25)

- completing the objects with additional attributes foreseen in the target model

- determination and change of geometry types

- joining the objects of the same attribute values

- simplification of geometry

- solving the conflicts

Before the model generalisation itself has been carried out, the existing data should be checked. It is necessary to check the congruence of original data with their specifications. Apart from the completeness of attributes, it is also necessary to check topology. Without improved topology there is no possibility to carry out a successful model generalisation.
In already existing models CRONO GIP and CROTIS it has been noticed that they are compatible. It is therefore necessary to make the mapping between them as well in order to get a clear situation with respect to the model and accompanying attributes.
Data quality is one of the basic prerequisites for successful execution of model generalisation. Since data are usually collected by various institutions, it is very important that they are collected according to a specific standard, so that the data would be harmonized. The harmonization of data is affected by the time period of their collection as well, if the model has changes in the course of time.
Before performing the model generalisation itself, it is necessary to define/have:

- model of original topographic base (TBP10)
- model of target topographic base (TBP25)
- conditions for the presentation of objects of the target topographic base (TBP25)
- the rules for mapping from the original model into the target model (TBP10 into TBP25)

Above given four items are inevitable for performing model generalisation and they present also the goal of this project.

Figure 9.1: Model generalisation approach

Figure 9.2: Model generalisation approach example (input)

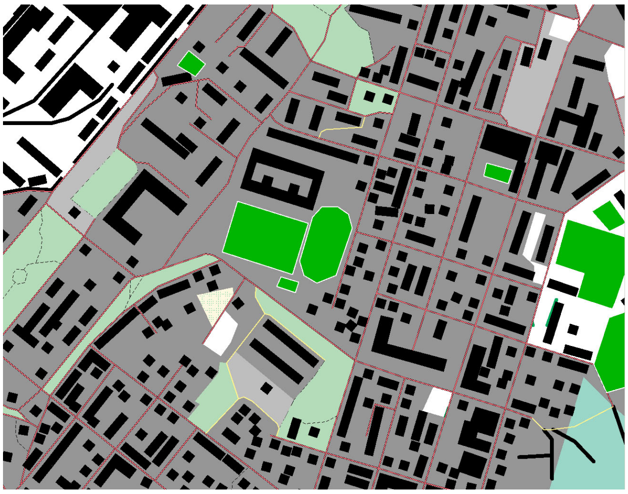

Figure 9.3: Model generalisation approach example (generalized)

Chapter 10

INSPIRE vs. CROTIS-NSDI

10.1 Introduction

In this chapter there is a level of conformity presented between INSPIRE and CROTIS as the most important part of Croatian NSDI. With the new "Low of State Surveying and Real estate Cadastre" which has been approved by Croatian Parliament at 26th of January 2007, articles 11-14 and articles 84-94, then reference to Directives for Topographical surveying from February 2002, CROTIS became fundamental and integral part of Croatian NSDI and INSPIRE.

The initiative and proposal from European Commission for a directive on establishing an Infrastructure for Spatial Information in Europe is named INSPIRE. Initiative aims at making available relevant, harmonized and quality geographic information for the purpose at formulation, implementation, monitoring and evaluation of Community policy-making. The most of INSPIRE directive has become effective in 2007 by the decision and agreement of the European Parliament and the Council.

Parallely, a preliminary working Programme has been agreed upon to start working in advance on the adoption of the directive. In this part of thesis there are the actual status, relation and relevant actions presented refering to the Croatian NSDI represented by CROTIS.

Part of the Chapter 10 (from 10.2 to 10.12) has been adapted from the context of the different INSPIRE documents: INSPIRE directives 2007, draft implementing rules for metadata 2007-02-02, INSPIRE-Enviromental Thematic User Needs 2002-10-02 and INSPIRE-Newsletters 2006-2007. The Figures 10.1 and 10.2, as well as the table 10.1 have been taken over from mentioned documents.

10.2 INSPIRE concept and initiative

The ambitious initiative of INSPIRE was adopted through the "Proposal for a Directive" made by the Commission in July 2004. At that time this was a major milestone for the use of Geographical Information in Europe as a contribution to environmental policy and sustainable development. Naturally, after this first step of co-decision procedure, the Directive has to be implemented in every EU Member State.

INSPIRE concept is meant to create EU Spatial information infrastructure that delivers to the users integrated spatial information services. The concept itself is foreseen to allow users to identify needed datasets and access to the Geo-Information from different and wide-range sources, at global, national, regional and local level, in an interoperable way. The necessity to support the complexity and interactions between human activities and environmental pressures and impacts creates a big need for quality geo-referenced information. At present, there are gaps present in EU in the domain of spatial information, fragmentations of data sets, different specifications and standards, different cartographic projections, datums, lack of harmonization between datasets at different geographical scales and parallel geodata capturing. Then, the not standardized metadata sets make it more difficult in the way geodata are identified and used. These problems have defined themselves the main principals of INSPIRE:

- Data should be collected once and maintained at the level where this can be done most effectively
- It should be possible to combine seamlessly spatial data from different sources and share them among many users and applications
- Spatial data should be collected at one level of government and shared among all levels
- Spatial data needed for good governance should be available under the conditions that are not restricting their extensive use
- It should be easy to discover which spatial data are available, to evaluate their fitness for certain purposes and to know which conditions can be applied for their use
- Geographic data must become easy to understand and interpret because they can be visualized within appropriate context and selected in a user–friendly way

10.3 INSPIRE vision

The coordination and stepwise approach are fundamental principals for the INSPIRE implementation. Gradual harmonization of geodata and information services aiming at the integration of systems and datasets at different levels into a coherent EU spatial data infrastructure is the main vision. It will require the establishment of appropriate coordination mechanisms and common rules for data policies. The initial phase as the first step has to focus on harmonization of documenting existing data sets (metadata) and a mechanism to make this documentation accessible. Furthermore, as the second step, the differences should be resolved concerning an easy access to geodata, then simple analyses with common procedures follows regardless of the fact that they com from different sources as different themes.

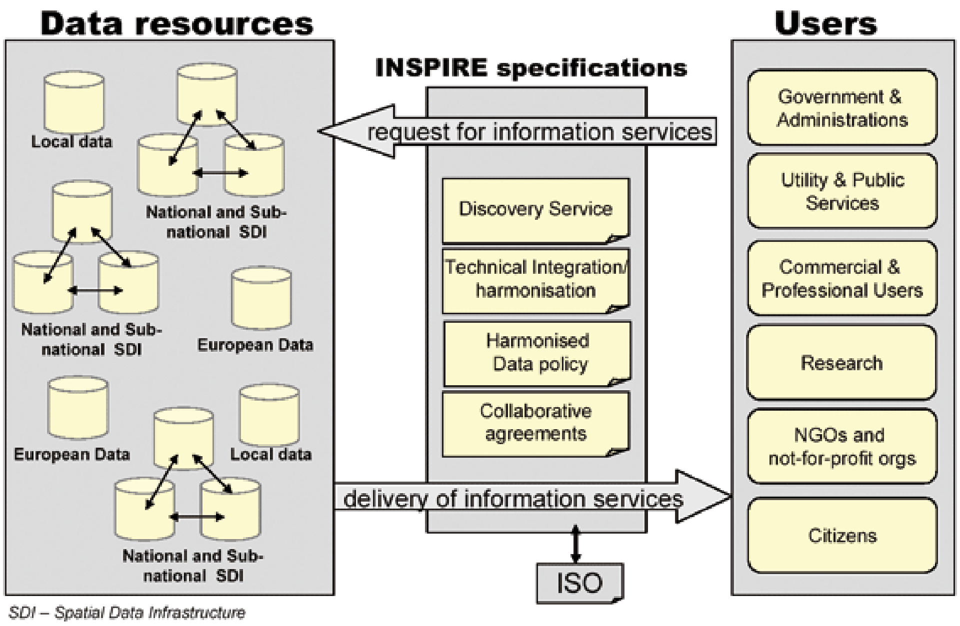

Figure 10.1: Diagrammatic view of the INSPIRE vision

The next, third step foresees absolute standardization of data models in the appropriate domain. The existing geodata are mapped to a common set of models and then advanced data analysis, coordination and visualization are made. As the fourth step and the last one, real time access to actual geodata in the entire EU should be allowed. To achieve this goal, all common models should be completed services and they should provide fully integrated data from various sources and various stages, from the local to the EU level into coherent seamless geodata sets supporting the same standards and protocols. Normally, some of the mentioned steps will be carried out parallely according to priorities, degree of availability and harmonization of existing geodata sets.

10.4 Users and procedures

In some way users and procedures of Geoinformation data could be the cross–institutions, but the INSPIRE initiative is covering the main Community sectors with a spatial impact such as energy, agriculture, security, transport and overall information needed to support environmental policy. Clearly, the 6th Environmental action Programme highlights the need for better knowledge and some science in environmental policy-making and geoinformation will therefore be increasingly required to achieve this.
Let's start with users, because they are many and various. Most of them are from planning, governing, management, assessment, monitoring and reporting areas, as Governments and Administrators at different levels (EU, National, Regional and Local), utility and public services (transport, health, emergency services and utilities as water, gas, electricity, telecommunications supply. . .), research and development (universities, public and private Institutes, application developers for IT System), commercial and professional end users (tourism, value added resellers, surveyors, property developers and insurance), non–governmental organizations and non–profit organizations.
On the other side, we have private and public sector geodata producers. On the side of public sector there are planning institutions, hydrographic national administrations, national environmental protection agencies, cartographic agencies, land registry and cadastre, military institutions, utilities and other land administration organizations. The private geodata procedures could be engaged by the mentioned public sector or they can offer or sell geodata in the geoinformation market. In some EU countries, the private sector supplies data and services directly to the commercial market. Some spatial information is used internally by public institutions under various types of agreement, as some of them conduct commercial business with the private sector or with general public. The importance is to recognize the difference between sharing and trading of geodata.

10.5 Fundamental approaches

Some very important facts as a funding and pricing influence in most of EU member states the INSPIRE initiative implementation. The way of funding and pricing fundamentally influences users access to geoinformation.
Most of the EU countries launched a NSDI initiatives which should be used as a base for the INSPIRE initiative. Most of working groups, besides these procedures, have been coordinated and reviewed by national expert networks and the INSPIRE expert group. Here are some characteristics of SDI at

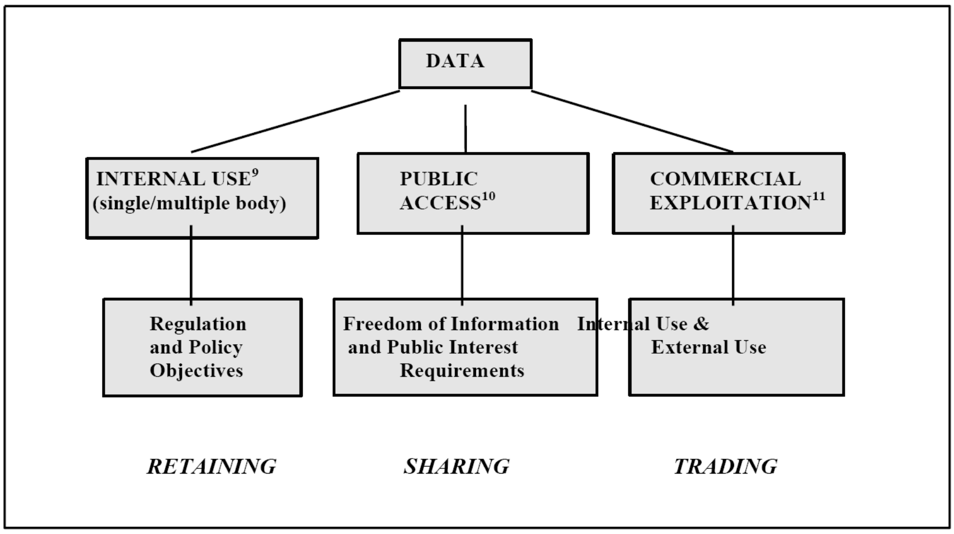

Figure 10.2: Simplified Diagram Illustrating Public Sector Data Uses

the local, regional, national and international levels including existing and foreseen geodata sets:

- user drivers, focusing on the general users needs concerning data content, data access etc.
- multi user (all kinds of users are addressed, from EU policy making, via national and local agencies and companies to individual citizens
- multi level, in the sense that local, regional, national, EU infrastructures need to be linked together
- pan – European, considering the needs both of member states and of accession countries
- building of existing data
- building on existing organizations and active partnership
- combination of EU top–down and active national bottom–up approach
- strong need for harmonization and standardization of data and systems
- a base for multi–sector use (transportation, agriculture, etc.)

As it has been presented, the INSPIRE and EU SDI is a combination of the NSDI of EU Member States. Therefore, the national SDI's are a fundament of INSPIRE, and EU geodataset is a seamless combination of national datasets.

10.6 Organization and implementation

Fundamental conditions for the success of INSPIRE is a requirement for a set up of general management co–ordination bodies at EU and at national level.
SDI establishing is a complex action which involves different issues as policy, legal, technical, cultural, financial and organizational matters. Co–ordination and management at national level is needed to assure the functionality of the national SDI's. Then, data services of EU geodata with the concept of decentralized system of servers located on the Internet which contain metadata is a tool which gives to the community the access to the reference geodata sets. Mentioned datasets are decentralized at national, federal, regional or local level. European SDI is supported, managed, ordered through Commission and other bodies which are also the main users. Similarity is present at national, regional and local level where Environmental Protection Agencies are the main users together with national Mapping Agencies, Cadastral Agencies as it is the case in Croatia.
The implementation is oriented mostly to organizational issues and should be done gradually, because of many reasons as varying situation among different countries; different thematic and reference data components, different scales and resolution (levels of detail), specific standards based on commonly accepted international standards. The most important components and phases of the implementation are:

- settin up of the organizational structures and setting up an implementation project
- education, information (website) and capacity building
- setting up a EU metadata catalogue
- specifications adaptation to ISO standards
- considering the heterogeneous situation in different EU members
- linking to other user initiatives

10.7 Reference data and related metadata

To organize and provide a link between applications and many of different geodata sets it is necessary to define "reference data" concept. The reference data must fulfill few requirements: provide an unambiguous location for user information, enable the merging of data from various sources and provide a context to allow others to better understand theinformation that is being presented. As the issue of reference data should be addressed at all levels in

EU, national, regional and local, the metadata are a part of them, too. The components of reference data are:

1. Geodetic reference data
2. Units of administration
3. Units of property rights (parcels, buildings)
4. Addresses
5. Selected topographic themes (hydrographic, transport, height)
6. Orthoimagery
7. Geographical names

The reference data are complex and for every topic there are recommendations. Here is on overview of the most important, key recommendations:

1. **Geodetic reference data**

   Geodetic datum: ETRS89
   EU height reference for vertical measurements: EVRF 2000
   Ellipsoid: GRS80
   Coordinate reference systems/Projections:

   - Lambert Azimuthal Equal Area (ETRS –LAEA) for statistical analysis and display
   - Lambert Conic Conformal (ETRS – LCC) for conformal pan – European mapping at scales smaller or equal to 1:500000
   - Transverse Mercator (ETRS – TMzn) for conformed pan – European mapping at scales larger than 1:500000

   However, each EU country should provide necessary algorithms to convert coordinates from their national coordinate reference system to ETR89.

2. **Data Quality**

   As data quality should fulfill the requirements of very clear user data specifications, quality control mechanism and procedures, quality insurance must be adapted.

   Technical quality and quality control procedures need a standardized data set specification as product specification. Regardless of the fact that there are ISO standards, product specification are now to be made, INSPIRE defines minimum contest of data specification, object definition, attributes and codes, then the specification should define the accepted range of values for each of the quality elements. INSPIRE is defining the most important quality elements as accuracy (spatial, temporal and thematic), logical consistency and completeness (data, model, attribute and value completeness).

3. **Quality testing**

   Generally, there are two ways to carry out quality testing; one could be done using certain procedures and other should be done by some independent institutions. After conformity testing according to ISO19113, It is necessary to give a report on the deviations and values found.

4. **Quality flagging**

   As many users consider a geodata sets error free, there is a big problem of data quality and decision making based on unknown data set quality. Geographical data should be used with consideration of errors propagation. In the metadata there must be information on some aspects of quality, especially accuracy and completeness. The quality of the reference data should be known and quality principals ISO19113 must be adopted as ISO19114 quality evaluation procedures.

10.8 Maintenance

The actuality of geodata is one of crucial quality elements. However, it is very difficult to manage it because of many different mechanisms and unknowns. Some of the old data are just replaced by a new set without the information about the last change or about features, object, polygons or area of update. Different systems allow the possibility to store the history of data, too. Therefore we can speak about two aspects of maintenance: the management of time and the management of changes. The INSPIRE recommendation is that reference data provide methods and technologies that will permit users to access "change only" updates, but in short term, they shall retain the traditional "snapshot" approach, according to minimum INSPIRE recommended update intervals.

10.9 Interoperability

As the basic principle of INSPIRE to keep the data where they are and to provide access to them there are complex solutions offered for its implementation. In one way, data can be expanded throughout known standardized format (OGC standardization) or in the other way with advanced technical infrastructure for direct access to geodata sets.

10.10 Language and culture

As an EU SDI has to promote and allow the flow of data from all EU countries at all levels, there is an obligation to take into account the different languages and different cultural aspects. Metadata definitions and templates should be made available in any EU language, then feature catalogue and specifications are a more complex issue because of cultural aspects. The concepts of urban area and appropriate object description are various all across EU. Here are the data contents, geographical names and character sets as geodata for which the existing related international standards should be used.

10.11 Resolution scale and implementation priorities

The resolution (scale) is a complex issue with relevant influence of time and cost. Resolution is more appropriate term for reference data description. However, most of users are "scale description" of data, as a long time use. To simplify the relation between scales and resolution, there are some indicative values and ranges presented here:

Geographical level	Resolution range	Scale level	Scale range
EU	> 100 m	Small scale	$< 1:250000$
National	25 m	Medium scale	$1:100000 - 1:250000$
Regional	10 m	Medium scale	$1:25000 - 1:50000$
Local	< 2.5 m	Large scale	$> 1:25000$

Table 10.1: Resolution–scale–implementation

Some important recommendations:

- Primary reference data should be collected and maintained at the largest possible scale, local level
- To define and implement mechanism that allow the updated information to flow from the local to the European level of the reference data

10.12 Metadata

Since metadata should inform users about the existence, accessibility and model of use – distribution, EU members should develop a common metadata profile that follows the guidelines in ISO 19115. On principle, the metadata profile should include a model of metadata and formats for metadata exchange. At the implementation level, metadata should be kept up-to-date. As mentioned before, metadata profile shall cover multilingual aspects, code list etc. Generally, all the reference data should be documented by metadata and three aspects of them must be considered: discovery, access and use.

The preparatory and implementation time schedule

INSPIRE is icluded into the co–decision legislative processing, where the commission interacts with Council and European Parliament to discuss proposal and finalize it. The three phases in the programme are accepted:

1. Preparatory (2005 2006)
2. Transposition (2007 – 2008)
3. Implementation (2009 – 2013)

The key of the preparatory phase is the organization of the participation of stake holders in the preparation of the implementing rules.

The Transposition Phase (2007-2008) is a period of two years in which the EU States should include INSPIRE into their national legislation. The Implementation Phase (2009-2013) refers to the implementation and monitoring of all measures of EU States in accordance with their national legislation conformed to the INSPIRE. The Member States co-ordinated at the community level by the Commission will report on the progress according to the timetable set by INSPIRE.

10.13 CROTIS fulfillment of INSPIRE requirements

The references to general rules for the establishment of an infrastructure for spatial information in Europe are the component elements here which should be included into the infrastructure of Member States:

- Metadata;
- Spatial data sets and spatial data services;
- Network services and technologies;
- Agreements on sharing, access and use;
- Co–ordination and monitoring mechanisms;
- Process and procedures

EU States will adopt some directives, procedures and different measures to have these components adequately placed. More precisely, the Implementing Rules will have to be adopted after the Transposition Phase (2009), two years after their becoming effective. The Republic of Croatia, especially its geodetic and geoinformation society intends implement INSPIRE directives and enviroments standards as a importan part of the negotiation phase of EU integration. Let's give a realistic overview of CROTIS, as a fundament of Croatian NSDI, fulfillment of INSPIRE requirements refering to the component elements content, conformity and time schedule (milestones).

10.13.1 Metadata INSPIRE – CROTIS

In CROTIS, as well as in INSPIRE, there are two kinds of the metadata addressed: Metadata for spatial data and metadata for spatial services. However, it should be taken into consideration that other related existing and emerging standards from ISO, OGC, and CEN will have an important input to the process.

Activity Description (Metadata set)	INSPIRE milestone	CROTIS milestone and comments
Detailed INSPIRE definitions on content and structure of metadata for spatial data	2/2005	4/2005
Survey of existing initiatives and solutions for content and structure of Metadata for spatial data	4/2005	4/2005
Draft implementing rules for metadata for spatial data (including the draft core metadata element set) for overview	6/2005	12/2006
Draft rules for the existence of the INSPIRE core profile	9/2005	12/2006
Final draft Implementing Rules for metadata for spatial data (includes core metadata element set and extension rules) LSSREC Article 87	12/2006	1/2007

Table 10.2: Breakdown and milestones/metadata

The scope of mentioned activities and issues which should be addressed:

- Rules for creation, maintenance and updating of metadata
- Multilingual issues in the creation and maintenance of metadata

- Certification, Quality, Accuracy

General comments of INSPIRE – CROTIS relation:

The general task to make a loop from the metadata stored in a catalogue forms, proposed interfaces OGC catalog Interface (CAT) 2.0 and Encoding OpenGIS Catalogue Services Specification 2.0 –ISO 19115/ISO 19119 Application profile, the accessibility to applications and services via catalogue interfaces is currently solved by the creation of Croatian Geoportal on Internet defined by LSSREC article 87. CROTIS through its conceptual modeling introduced four out of five metadata description main principals through its conceptual modeling:

1. spatial data (description of contents)
2. the conformity of data with the prescribed norms
3. quality and validity of spatial data
4. bodies, public systems, natural persons or legal entities responsible for the establishment, management, maintenance and distribution of spatial data sets and services

The Rules regarding the usage of spatial data sets and services, as the last metadata implementation component, are being partly, but soon to be fully resolved within this year. To conclude with it can be stated that the existing metadata sets, infrastructure, cataloging system and services are highly conformed to INSPIRE implementing Rules on Metadata.

10.13.2 Spatial data specification / harmonization INSPIRE – CROTIS

From the author's point of view this is most demanding part of INSPIRE. In general the INSPIRE plan adoption of Implementing Rules for data specification, harmonization and data exchange is due by 2009 and 2012 at the latest for Annex II and Annex III. The scope of that activity will address the following topics:

- Definition of the basic Conceptual Model for the data themes in the INSPIRE including the definition of:
  - Geometrical, topological and temporal representations
  - Spatial and temporal relations
  - Semantics
  - Unique identifiers

  - Reference to a common reference systems including spatial and temporal reference System as well as multilingual thesauri

- Guidelines on the use of the defined conceptual model and its related methodology to develop spatial data specifications
- Generalization rules to threat different scales
- Encoding (to support exchange of spatial data)

The fundamental conceptual model is a reference point for harmonization of data specification and will give a roadmap for representation of the spatial, topological and temporal characteristics of real world modeled phenomena.

Activity Description (specification/harmonization/exchange)	INSPIRE milestone	CROTIS milestone
Detailed high level INSPIRE requirement on harmonized data specifications and requirement on the arrangements for the exchange of spatial data	3/2005	6/2005
Survey of existing National Conceptual Models and Methodologies used by Member States to develop specifications for Annex Data	6/2005	6/2005
First draft version of the Conceptual Model	12/2005	3/1997
First draft Methodologies to develop specifications for Annex Data	12/2005	7/2002
First draft of implementing rules on the arrangements for the exchange of spatial data	6/2006	6/2006
First version of the Conceptual Models and Methodologies to develop specification for Annex Data	6/2006	6/2006
Reports on the usability of the conceptual model as a basis for Annex I, II, III data specifications	12/2006	5/2007

Table 10.3: Breakdown and milestones/data Specifications, harmonization and data exchange

The different workshops will be organized at the level of EU with the intention to have an overview of existing National Conceptual Models and Methodologies used by Member States to develop specifications. The scope of mentioned activity will be an input for experts in conceptual modeling of geo–information with the experience in SDI development or related interoperable geo–information applications.

General comments on INSPIRE – CROTIS relation:

Definitely, the most advanced part of CROTIS are data specifications, harmonization of products and data exchange. Also, Conceptual model, data specifications and data exchange are fully conforming with ISO-TC211. These facts could be seen from the context of the Table 10.3 and have been reported as a result of several monitoring activities executed by EU consultants.

10.13.3 Network services and interoperability INSPIRE – CROTIS

The main objective of this task is to develop the prototype of the EU Geoportal. It is intended to support the following functionalities of the INSPIRE Network Services:

- Upload services (for metadata and spatial data)
- Discovery services
- Data view services
- Download services
- Transformation services
- "Invoke spatial data services" services

There are the tasks presented above which show that the first task is to create common understanding and definition of functionality of the network services. As the INSPIRE requires accessibility through EU Geoportal, therefore the applications shall enforce the interoperability with a Member States network. Important issues:

- General architectural model
- Security (access to the service and data transfer) when applicable
- Multilingualism as requested by INSPIRE
- Metadata for services
- Compliance with services metadata and impact
- Technical architectures and protocols
- End–user needs

Geospatial standards from W3C, WS – I, OMG, OGC, ISO, OASIS and CEN will have an important input to the process.

Then, the EU Geoportal will be done in close collaboration with National Portal developments.

Activities Description (Network/interoperability)	INSPIRE milestone	CROTIS milestone
Detailed definitions of the INSPIRE Network Services and the EU Geoportal	4/2005	5/2006
Survey on existing initiatives and solutions	6/2005	10/2005
First draft of interface specifications for Network Services and technical specifications of EU Geoportal	12/2005	6/2006
Test report and impact analysis	6/2006	7/2006
Review reports and recommendation	9/2006	7/2006
INSPIRE Network Services draft Implementing Rules	12/2006	12/2006
1st Prototype of the EU Geoportal using the prototypical INSPIRE network services	12/2006	5/2007

Table 10.4: Breakdown and milestones/network – interoperability

In addition, the development of the services and Geoportal prototype will be proved by pilot implementation.

General comments INSPIRE – CROTIS:

The core of the Croatian NSDI is Geoportal in the way of networking and interoperability first at the national and then on EU (INSPIRE) level. The standardization, specification and implementation rules and their adoption within theses directives have reached a sufficiently high level.

10.13.4 Sharing – Monitoring – Coordination – Integration

Furtheron, due to the facts and objectives that are referring only to the INSPIRE initiative, and that there is no opportune report on any relation between INSPIRE – CROTIS, general approach of Data and Services Sharing, Monitoring and reporting and Organizational structures and co–ordination will be explained.

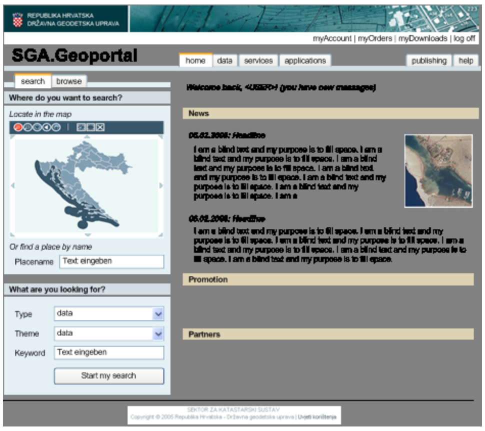

Figure 10.3: Prototype of Croatian Geoportal

The objective for the INSPIRE component element Data and Service Sharing is composed of three parts: Development of data – sharing Implementing Rules governing access and rights of use to spatial data services for Community institutions and bodies available for adoption by 2007, developing Implementing Rules governing third party access to upload services by 2007 and third part are Implementing Rules to increase the potential of reusing the spatial data sets and services by third parties by 2009. With this activity it will be issued:

- Requirements of Community institutions and bodies, requirements of third parties
- Current types of rights, such as rights of ownership, rights of use, copyright
- Types of access, such as retaining, sharing and trading
- Types of use, such as discovering, view, download

Monitoring and reporting as INSPIRE component elements are the activity which propose mechanisms, methodology and indicators by which continuous monitoring of the implementation progress is measurable with respect to the targets set out by INSPIRE, in general this activity addresses:

- what organizational structure is applied to build up and maintain the relevant SDI components
- how quality assurance is organized
- an overview of contributions from the public authorities during the past 3 years

- data on the actual usage of the SDI
- what progress has been made in data – sharing and third party licensing agreements
- figures on tangible costs and benefits in relation to the implementation of INSPIRE

There are three relevant deliverables foreseen: Monitoring indicators, Implementing Rules for Monitoring and Implementing Rules for Reporting.

The last INSPIRE component element Organizational structures and co–ordinations as activity is obliged to define organizational structure that should be in place when INSPIRE will enter into force; define the rules and responsibilities of the components of the proposed organizational structure in accordance with:

- strategic (policy) developments at the Commission level
- co–ordination tasks at the ommunity level, at the national level and at the thematic community level, operational support
- technical development and technological evaluation including progressive standardization
- link with relevant international initiatives
- experience gained during the Preparatory Phase

These activity foresees two deliverables: 1st Proposal for Organizational Structures, roles and responsibilities and Final Organizational structures, roles and responsibilities.

10.13.5 General statement of facts INSPIRE-CROTIS

The national standard which plays and which will play a significant role for INSPIRE Implementation Rules is CROTIS constituting conceptual model, specification and data exchange application schema. ISO and OGC based, CROTIS provides the optimum component elements as fundament for a discussion within the INSPIRE community. The minimum effort would be necessary for harmonization of CROTIS as the main part of Croatian NSDI with INSPIRE directives. With the facts mentioned in the thesis, the predication of INSPIRE implementation in Croatia has become simple, will be adopted within realistic and satisfactory time frame. At the operational level the fundamental and central engine of the technical side of the Croatian NSDI is the National

Geoportal of Croatia. This effort is presented with already mentioned new LSSREC, article 87. CROTIS, as a unique geodata set which covers at the moment nearly the whole territory of Croatia being a very welcome solution for a setup of NSDI. Then, topography is geodata set which can be used by a large number of user communities for a large number of purposes. As it has been presented before in this work, CROTIS dataset is already transferred between major stakeholders.
All works and responsibility for establishment, monitoring and maintenance of Croatian NSDI as a part of INSPIRE initiative is organized through NSDI bodies. Croatian NSDI bodies are the NSDI Council, Committee and working groups. The NSDI Council is responsible for leading the establishment of the NSDI and the coordination of the activities of the NSDI subjects. The NSDI Council is made up of a president and 15 (fifteen) institutional members, appointed and deposed by the Government of the Republic of Croatia.
The NSDI Committee is a permanent executive body for the establishment of NSDI Council. The NSDI Committee is appointed by the NSDI Council,as described in LSSREC from 26th of January 2007, articles 92-94. Author of thesis if a member of Croatian NSDI Council.

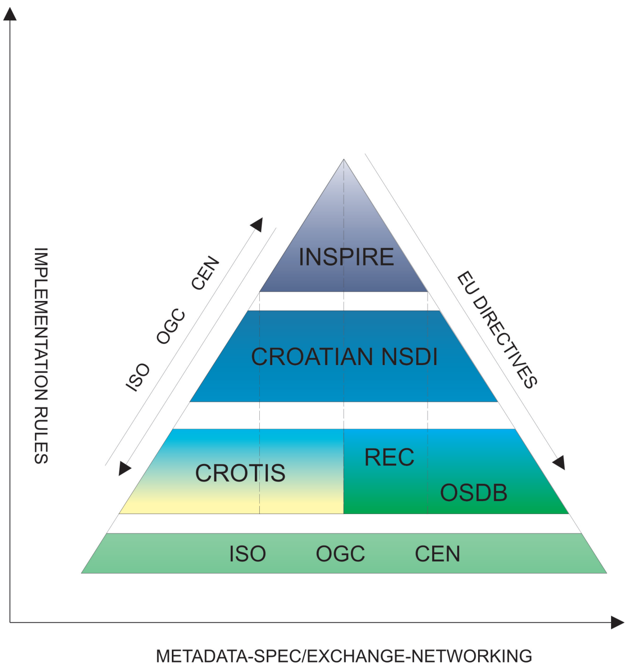

Figure 10.4: INSPIRE-NSDI-CROTIS relation

Chapter 11

CROTIS derived main Geoinformation Systems

In mean time the most important users "capital users" of Topographic Information System CROTIS have been recognize the quality and importance. Here will be mentioned two most relevant users which are strategic partners of SGA and politicaly and economicaly are very important for the entire country.
These are Military Geoinformation System developed for the Ministry of defence[1] and Mine Information System, created for Mine Action Center (demining activities)[2]. Both Geo-Information Systems have been promoted, modeled and leaded by the author of thesis.

11.1 Military Geoinformation System of the Ministry of Defense of the Republic of Croatia

11.1.1 Introduction

With the project ≪Military geoinformation system – VoGIS≫, Ministry of Defense of Republic Croatia began foundation of a unique informatics system for needs of the Ministry of Defense and the Armed Forces; the system that is in accordance with international norms and norms and principles of the other government bodies, and which is tightly connected to the existing geoinformation system of the State Geodetic Administration CROTIS. According to the Preliminary design, the goal of the VoGIS is "implementation of a geoinformation system that will be the basis for development of all further activities in domain of military spatial data, with special emphasis on creation of military cartographic database and military maps, along

[1] presented on FIG 2006, Munich, Germany
[2] presented 2006 on ISPRS, Goa, India

with the fulfillment of the Partnership Goals". The original concept of implementation of modern geoinformation system is described in this chapter, along with solutions for all elements of cartographic production based on topographic and cartographic databases; the concept that have not existed before in Republic Croatia.

11.1.2 Expected project results

By the realization of the project VoGIS the following is established:

- Efficient multi-user geoinformation system that will include all elements necessary to the Ministry of Defense (MD) and the Armed Forces (AF)
- System which is in correlation with other existing geoinformation systems in the Republic of Croatia, firstly with the CROTIS system of the State Geodetic
- Administration.
- System which enables secure bi-directional exchange of digital information with other members of the NATO and the Partnership for Peace, fulfilling in this way the obligations that Croatia has according to the Work plan 0122 of the Partnership for Peace (NATO 2002).

Accomplished results represent broad basis on which, among some others, establishment of unique cartographic information subsystem inside the VoGIS is based, and which got priority in realization.
The entire project VoGIS encompasses more project parts which are carried out through subprojects, in phases. In the first phase of the project the following essential project parts have been accomplished (Biljecki 2005):

- Analyses of the existing system of the Ministry of Defense with definition of detailed requirements for future system
- Description of the entire model of the VoGIS system
- Modeling of basic topographic database according to the object oriented principles, which includes production and description of conceptual data model with usage of the UML, data catalogue and the GML application scheme for data exchange.

In the second phase have been developed concept and implementation of entire topographic-cartographic production process, which has as final goal production of the Military cartographic map 1:50, 000 and the Military operations map 1:250,000. The concept give a technological solution for appending of a military content in the topographic database, model design and catalogues of objects of all necessary databases, methods and procedures of generalization, design of cartographic symbols and rules, index maps, selection of existing and development of necessary standards and production and printing.

11.1.3 Basic realization principles

The realization of the system is weighted with two important factors: time and financial means. Process of geo-informatization of the Croatian army and the Ministry of Defense requires reliable, central topographic database which should include topographic elements for specific subsystems like logistics, aviation, training and other. Therefore, some basic principles were set to ensure quick, rational and modern project implementation:

1. The application of IT technology has to be maximal. All production processes need to be preformed on IT equipment, all products need to be primarily digital, including maps whose analogue form comes out of a digital form. All processes, especially conversion and production processes need to be as automatic as possible.

2. Rationalization when acquiring data. When implementing VoGIS, the principle is used according to which data collected in one institution should be used as many times as possible for needs of a various state institutions. This principle results in rationalization, but also in data quality as each data type needs to be acquired and updated in authorized institution (i.e. profession). Therefore, the basic topographic database of the Ministry of Defense results from the topographic database of the State Geodetic Administration (CROTIS database). The basic database should be used, besides cartography, for solutions of other topographic projects and tasks of the Ministry of Defense.

3. Usage of standards and norms. When classifying and coding a content of a databases it is necessary to use the NATO standards, the ISO norms in modeling and the OGC standards in implementation.

4. Production of military maps needs to be formed in a way that would ensure that map is not produced as isolated product drawn on the computer screen, but map needs to be derived by certain technological procedure from previously made cartographic database.

5. Change of technology in map production may result in change of appearance and map content, while not decreasing its quality and usage.

11.1.4 Implementation concept

Serial production of military maps based on digital technology does not exist in the Republic of Croatia. Moreover, in the Republic of Croatia there is no tradition for production of topographic maps in scale 1:50,000 and 1:250,000, with few exceptions which refer to particular test sheets. In the Republic of Croatia does not exist, as well, tested or in practice confirmed technology for map production based on cartographic databases. And, finally, the Republic of Croatia does not have regulations or technical specifications for production of maps in scale 1:50,000 and 1:250, 000.
Listed facts clearly show the complexity and severity of set goals, as well as responsibility the project team took.
Preliminary project of the Ministry of Defense sets starting and final elements for the project. Starting element of the whole project should be the basic topographic base of the VoGIS system (Digital Landscape Model - DLM) with accuracy +/- 1m that results from over taking and expanding topographic database of the State Geodetic Administration, which is made according to the CROTIS standard. The final products of cartographic component of the system have to be military maps in scale 1:50,000 and 1:250,000 that are in compliance to the NATO standards.
The first problem which author faced was disproportion in scales of the original (1:10,000) and scale of the maps. As very unfavorable ratios 1:5 and 1:25 eliminated direct production of a smaller scale map from a bigger scale map, project team had to find a solution for data "flow" trough a system (trough databases of different scales), while keeping in mind that printed map is actually only a media on which spatial data is shown (Kraak and other 1998).
Considering that a GIS system of the Ministry of Defense had to fulfill several expectations and not only map production, the project team developed a concept which in the center has topographic databases (Digital Landscape Models) and in which databases of smaller scale (i.e. accuracy) develop from bigger scale databases (11.1).
The basic Digital Landscape Model (DLM10), after appending the specific data, becomes a basis from which, with specific generalization procedures, is produced the topographic database (DLM50) of smaller accuracy (planned is +/- 5m) which is used as basis for production of the Cartographic Database (CdB50) of the scale 1:50,000 and as original for the topographic database (DMK250) of accuracy +/- 25m which will be used as original for production of the Cartographic Database (CdB250) in the scale 1:250,000.

Standards

DIGEST standard for coding was used when modeling the DMK10 and other databases. This significantly eased model links (mapping). Topo-

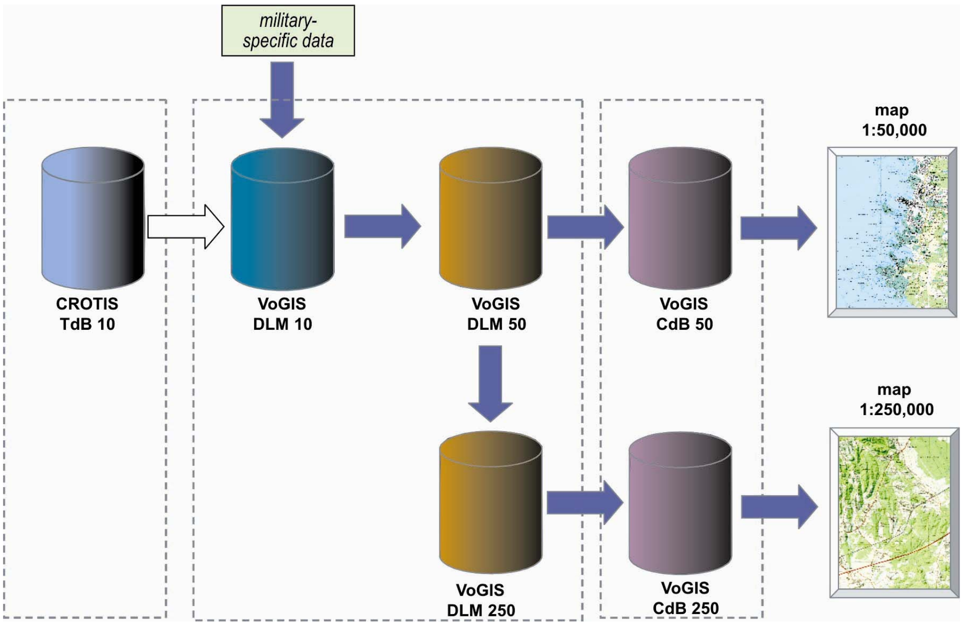

Figure 11.1: The Concept of the Military geoinformation system of the Republic of Croatia

graphic data of accuracy i.e. scales 1:50,000 correspond to the conditions of the NATO alliance for regional level planning and are often issue of exchange. Therefore, there is a condition set that when modeling, the standard Vector Smart Map Level 2 (VMap2) should be used as much as possible.

New concept of military topographic-cartographic system of the Ministry of Defense can be seen on the map production concept, too. State Geodetic Administration produces topographic maps for public (civil) usage which leaves for the Ministry of Defense only to produce military topographic maps. Reduced functionality (not in quality) has to be noticeable in the content and visual appearance of maps, as well as in speed and economy of production and easiness of maintenance. Newly produced military maps will not be used by so wide spectrum of people as the maps of the Military Geographic Institute have been used, but only by users inside the Ministry of Defense and the Armed Forces.

The consequence of these principles is elimination of objects insignificant for military needs which brings towards more simple and more readable cartographic display. On the other hand, the cartographic data model encompasses even bigger number of attributes then needed for production of the Military Topographic Map 1:50,000 (MTM50), so that different versions of the maps can be made, applying different cartographic designs with the same data.

When choosing scale for a topographic database that would be used as basis

for production of the map 1:250,00, the main argument was again the NATO standard for exchange and planning at international level, the Vector Smart Map Level 1 (VMap1). For production of the map 1:250,000, the standard JOG-G was defined according to the NATO's requests.
Basic characteristics of the content of the cartographic database, concerning the military character, express the changes developed in the perception of topography because of technology development of the military equipment (e.g. neither hydrography nor vegetation do not represent insuperable barriers in transportation as 20 or 30 years ago).

Data flow trough the system

Two procedures characterize data "flow" trough the system: mapping and generalization. Mapping is procedure which connects all object classes and attributes of an original model to object classes and attributes of a produced model. Mapping is designed with help of the software tools and is executed automatically.
Transformation procedures from DMK10 base to DMK50 base and from DMK50 to DMK250, namely between topographic data in different scales, is preformed with so called model generalization. Model generalization is defined as controlled reduction of data in spatial, thematic and time sense (Weibel 1995), and encompasses following processes:

- Selection of object classes
- Selection of certain objects according to the attributes and appearance context
- Geometry change (areas in lines, areas in points, lines in points)
- Filling blanks that are result of selection (preservation of topology)
- Simplification of networks (roads, waters)
- Geometry smoothness.

In model generalization procedure there is no object movement so that required accuracy of topographic data is not damaged.
Cartographic generalization is conducted when transferring data from topographic to cartographic databases (from DLM50 to CdB50 and from DLM250 to CdB250), and includes:

- application of map specific displays
- movement of objects
- text positioning.

Procedures of model and cartographic generalization are preformed with the GIS program tools, partially automatically. When modeling databases and planning generalization processes; purpose, subject, display, means for display and originals were taken into account (Frančula 2000).
It is important to mention that the implementation concept was presented two times to the experts from Defense Geospatial Intelligence (Great Britain) and National Geospatial-Intelligence Agency (USA) and in both cases had excellent rating.

Map design

According to requirements of the Ministry of Defense, the appearance of the map, i.e. cartographic symbols need to be in accordance with the existing Croatian standard. Cartographic symbols for map 1:50,000 are produced so that they are identical (with few changes because of scale and newly added objects) to cartographic symbols defined with Cartographic Key for the Topographic map in scale 1:25,000 defined by the State Geodetic Administration.
Basic characteristics, i.e. bigger changes comparing to the Croatian standard are visible at following objects:

- Roads: Instead of administrative distribution (state, county....), classification according to surface is used (asphalt, macadam...)
- Inhabited places: shown with grey surface in case of dense inhabited places
- Terrain: shown with combination of contour lines, height points and shadows with less hatching and detail
- Vegetation: NIMA standard symbols are used, as they are more appropriate for map usage when the visibility is decreased
- Toponyms: fonts from NIMA maps are used, as they burden the map significantly less
- Shape of cartographic symbols for dotted objects will be identical to signs of Croatian TM25, but decreased for about 80%

The planned changes in cartographic symbols will be in sake of simplification of map production and will release the map of un-needed details that disturb quick and easy usage of the map.

11.1.5 Map nomenclatures

The project produced also the index map of Military Topographic Map 1:50,000 and Military operation map 1:250,000, that is in accordance with

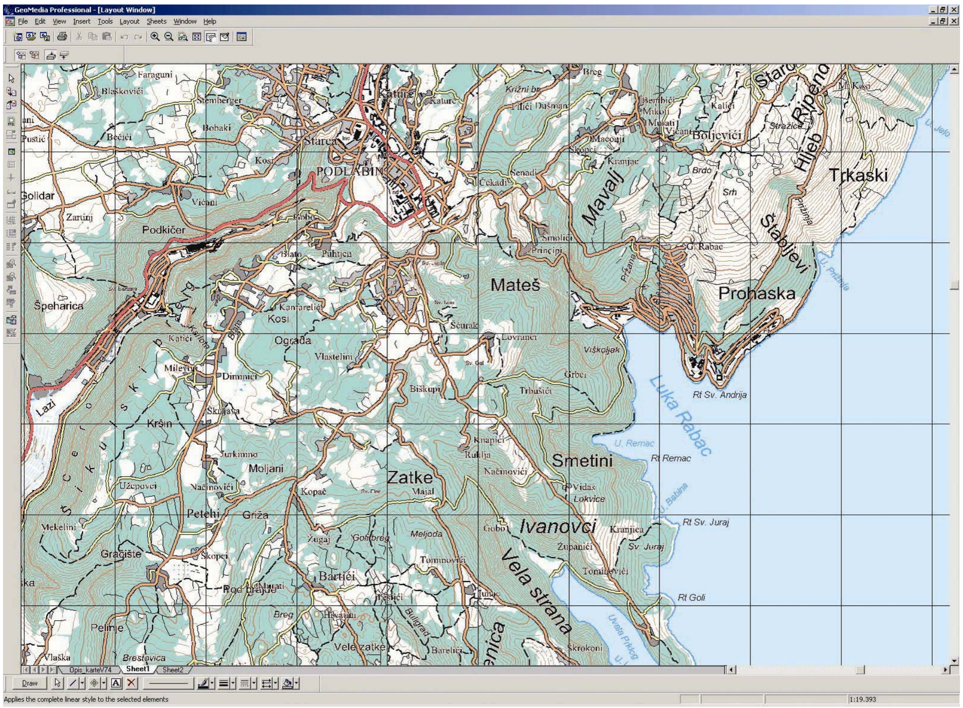

Figure 11.2: Visualization of DMK50

the NATO standards. Sheets 1:250,000 are formed inside one UTM zone with division to 3 columns and 8 rows, while size of one sheet is 2°x1°.
Number of sheets in scale 1:250,000 necessary to display whole territory of the Republic of Croatia is 15. Division to sheets of map 1:50,000 is preformed by division of map 1:250,000. A sheet 1:50,000 is formed inside one of 1:250,000 sheets by dividing in 6 columns and 5 rows, each in size 20' x 12'. Number of sheets in scale 1:50,000 necessary for display of entire territory of Croatia is 179. Number of sheets is possible to decrease with expansion of borders of the neighboring sheets.
When naming the sheets, the principles are firstly set. According to the basic principle, the name of the sheet is given according to the settlement with biggest number of inhabitants. The principles describe procedures when sheets have part of foreign territory on them and when there are no settlements on the maps, etc.

11.1.6 Conclusion

New, original concept of the geoinformation system of the Ministry of Defense is modern, open and standardized system that enables the Ministry to accomplish all set goals, towards its users (the Armed Forces, various Administrations...) and to member states of the NATO alliance and the

Partnership for Peace. System leans on the most modern principles and technological implementations of today's geoinformatics.
Production procedure that this project suggests is introduction of two topographic databases (DLM50 and DLM250). The basic database in scale 1:10,000 that develops from the CROTIS system of the State Geodetic Administration will be the original for production of the topographic data base 1:50,000 which will be the original for the topographic database 1:250,000.
Bases produced this way become secondary products of the VoGIS system, where each database has its own GIS functionality – it is used as a database for a GIS analysis of medium (1:50,000) and large areas (1:250,000). This means that database DLM50 is used for spatial analysis at regional level and DLM250 for analyses on state and interstate level. These databases do not contain smaller and less important objects; have less density of objects and components which enables analysis of bigger surfaces and bigger number of objects. It is important to point out that these two DLM databases are made according to the NATO standards (VMap1 and VMap2).
The basic VoGIS database (DLM10) remains highly-precise detailed database for analysis at local level and, what is most important, the source for all Ministry's geo-topographic products.
The concept of the topographic-cartographic production of the Ministry of Defense is this way accommodated to the state topographic-cartographic system, i.e. leans on and can fulfill the system of the State Geodetic Administration. This way the Ministry of Defense can use all existing resources of the State Geodetic Administration and when planning future activities need to coordinate with the SGA. This way the funds that the Republic of Croatia invested in data, information and knowledge are used in the maximum manner.

11.2 CROMAC GIP

11.2.1 Introduction

The Croatian Mine Action Centre (CROMAC) was established by government decree on 19th February 1998 with the basic task of planning and conducting mine action in the Republic of Croatia. The landmine problem was recognized as a development, ecological and safety problem and one of the impediments to normal life and development. Accordingly, the highest state authorities are involved in the efforts to overcome the problem - the Croatian Parliament and the Government, which appoints the CROMAC Council, a body with the task of coordinating the work of CROMAC. The Croatian Mine Action Centre develops Annual Demining Plan proposals and submits them to the Government for approval. In October 2000 the Croatian Parliament passed the National Mine Action Program, determining the objective: to demine the Croatian territory by the year 2010. The CRO-

MAC collaborates with the Scientific Council - the advisory Body, on the area of testing and implementing of the new technologies (URL1).

11.2.2 Project goals

The goal of the CROMAC Geoinformation Project (GIP) is to develop and establish a new GIS for demining purposes by creating central spatial database with actual and high quality topographic data.
Establishment of such system is prerequisite for speeding up demining process of the mine-contaminated area. It is also necessary to help up in demining organization, plan and management.
Existing Mine Information System (MIS) has to be expanded to provide additional functionality such as:

- high-quality planning, preparation and execution of general and technical investigation
- exclusion from mine suspected area
- humanitarian demining project development
- demining supervision during and at the end of the process with the certification of the demining area.

New updated raster (Figure 11.3) and vector (Figure 11.4) topographic data will provide precise and reliable basis for all demining actions. Using internationally adopted standards for geographic data (ISO, OpenGIS) CROMAC MIS will become open to the wide range of users.

The most important group of users who doesn't have special requests from the MIS except information about the mine-contaminated area, are citizens of the Republic of Croatia. The CROMAC GIP will ensure on-line and printed availability of information about the contaminated area.

Higher-level users are local government, state government, public companies and the private companies. CROMAC will provide to these users different database access permission levels.
The most demanding users are CROMAC employees. Beside regular requests form the system, CROMAC employees are responsible for the whole system who can change and add data in the database.

11.2.3 Project realisation

CROMAC GIP will enable implementation of MIS in the future unique national geoinformation system. Logical solution for the basis of this system is State Geodetic Administration's topographic database developed according to CROTIS standard (Biljecki et al. 2000.). Topographic data also plays important role in CROMAC demining actions.

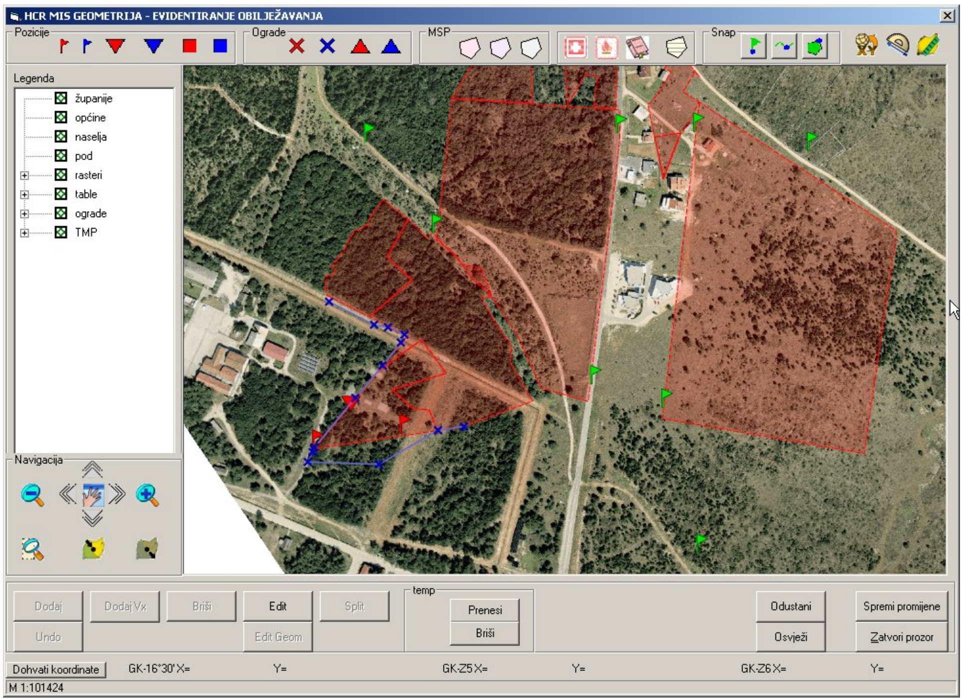

Figure 11.3: CROMAC GIP output

Because of bad broadband Internet connection availability for the realization of the project all of the data have to be installed both in central office and branch offices.
Modeling MIS database according to ISO and OpenGIS specification will assure integration of MIS data with existing geoinformation systems and in the future, when all of the prerequisites will be fulfilled, MIS will become integral part of the National Spatial Data Infrastructure (NSDI). Beside topographic data, new MIS will include data from Register of the Spatial Units, raster data (topographic maps, orthophotos) and the existing CROMAC data. Because of CROMAC GIP complexity the project can be executed in several phases. The steps needed for realization of the whole project are listed in the following list.

CROMAC GIP project realization phases

1. Analysis of existing MIS with accent on content, analysis of human and technical resources of CROMAC
2. Determination of detailed requests and directions on whole system
3. Database modeling and creation of application schema

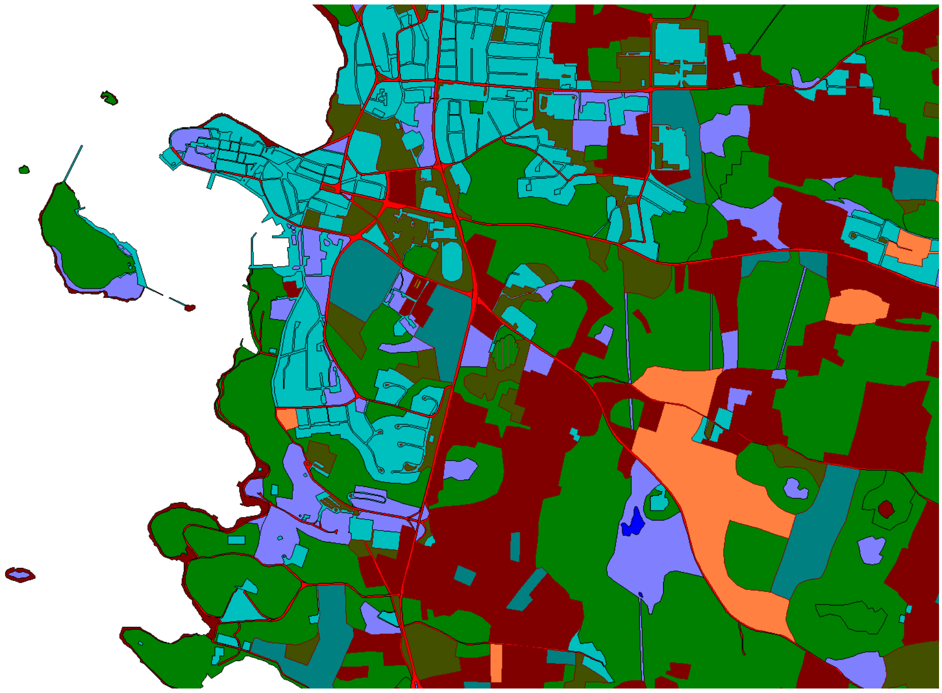

Figure 11.4: Extract from topographic database (Land Use)

4. Creation of specifications and procedures for unification of existing data in MIS and acceptance of data from other sources

5. Collection and editing of data from topographic database, other sources as well as CROMAC data

6. Development of applications according to specific needs, customization of menus and interfaces

7. Education and training

8. Establishment of data quality control sub-system

9. Establishment of maintenance and backup sub-systems

10. Development and establishment of Internet/intranet sub-system

11. Installation of hardware and software, establishment of the full system with all data

Inception study report as a result of two first steps plays important role for the successful database design. Any additional requests and the changes in the database design will jeopardize project realization. For this reason the good cooperation with the CROMAC employees has to be established.

After the database modeling, the application schema for the data exchange will be developed and the data will be integrated into the unique database. Specialized applications for database manipulation will be developed. The type and the number of applications will be determined in cooperation with the CROMAC employees during inception study.
Education and training of the CROMAC employees will follow installation of application and the testing of system. Training will assure that the CROMAC employees successfully manage MIS.
During the project duration, no meter of system testing and installation, the full functionality of the existing system must be guaranteed.
The quality control sub-system, as well as the database maintenance and backup sub-systems will be established.
At the end of the project, Internet / intranet data availability will be solved and some advanced training for the CROMAC employees can be done.

11.2.4 Major phases in project realisation

Database modelling

Before database creation phase it is necessary to define database entities and their relationships. That step is called database modeling and presents the critical step that defines functionality of the whole system. Therefore, the modeling phase must be taken with special care and attention. The role of the user of future system is essential in defining the database model. User must describe its demands in detail so all of them can be in time included into design and project plan. Using ORACLE technology, the new database can unite various data types (new and existing basic data in raster and vector format, attribute data, existing data form Mine Information System - MIS). Database should be materialized in accordance with relevant ISO and OpenGIS standards, accordingly, the

- conceptual data model and
- application schema for data exchange

shell be created and described. The conceptual model should be represented with UML schema according to recommendations of ISO Technical Committee 211 Geographic Information / Geomatics. The following standards must be used in creation of the conceptual model:

- 19103 - Conceptual Schema Language
- 19107 - Spatial Schema
- 19108 - Temporal Schema

- 19115 - Metadata
- 19118 - Encoding
- 19136 - Geography Markup Language (GML)

The application schema for data exchange shall be created with GML modeling language, according to specifications of OpenGIS (OGC 2003).

Specifications and procedures for data collection and management

The database will contain various groups of data related to all Croatian counties that are contaminated with mines and explosives, namely:

- topographic data from Croatian Topographic Information System database (CROTIS)
- data from Croatian Register of Spatial Units
- raster data, included Digital Orthophoto in scale 1:5000 (DOF 5), Topographic map in scale 1:25000 (TK 25) and Croatian Basemap in scale 1:5000 (HOK 5)
- cadastral data and
- data from existing Mine Information System of CROMAC.

After integration of existing data, CROMAC will continue with collection of data through field inspection. Data are collected by mapping the borders of minefield polygons and categorized suspicious areas, based on inherited sketches and records, old minefield maps (if exist), signalized incidents, etc. Collected data can be mapped on digital base maps on the field using the IntelliWhere OnDemand system with integrated GPS device Trimble GeoXT (Figure 11.5) or in the office.

For collection of data, the specifications must be developed that have to be compatible with specifications of Croatian SGA's Products Specifications developed under the CRONO GIP project (Croatian Norwegian Geoinformation Project). Specifications have to be compatible with normative procedures of CROMAC - Standard Operative Procedures (SOP) as well and describe:

- description of technology for data collection,
- description of methodology and criteria for data collection,
- instructions and regulations for data management and
- data quality elements with tolerances.

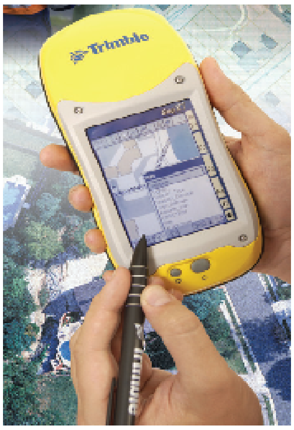

Figure 11.5: Field data collection

Development of specific applications for CROMAC

Significant conformance, improvement of security during upload and editing and effective and efficient operator's work will be obtained by development of specific applications under the GIS software system.
Applications will be developed depending on position in production chain, type of the software (e.g. GeoMedia Professional, GeoMedia, IntelliWhere OnDemand) and user defined needs.
Specific applications can automate creation of reports, instructions and other documentation that is dependent on actual content of database, ensuring correct implementation of prescribed procedures without possibility of omitting any.

Data quality control system

The process of collection, editing, transformation and adjustment of data needed in CROMAC ends with uploading of new information into central database. Homogeneity and consistency of database structure and content must not be disarranged; therefore the implementation of the process of quality control of data prior the upload is a necessity. All data, regardless of source and type must be quality controlled.
Data quality system must be based on ISO standards, namely 19113 and 19114. Standard ISO 19113 – Quality Principles establishes the principles for describing the quality of geographic data and specifies components for reporting quality information. It also provides an approach to organizing information about data quality. This International Standard is applicable to data producers providing quality information to describe and assess how well a dataset meets its mapping of the universe of discourse as specified in the product specification, formal or implied, and to data users attempting

to determine whether or not specific geographic data is of sufficient quality for their particular application (ISO, 2002a). Standard ISO 19114 - Quality evaluation procedures provides a framework of procedures for determining and evaluating quality that is applicable to digital geographic datasets, consistent with the data quality principles defined in ISO 19113 (ISO, 2002b).

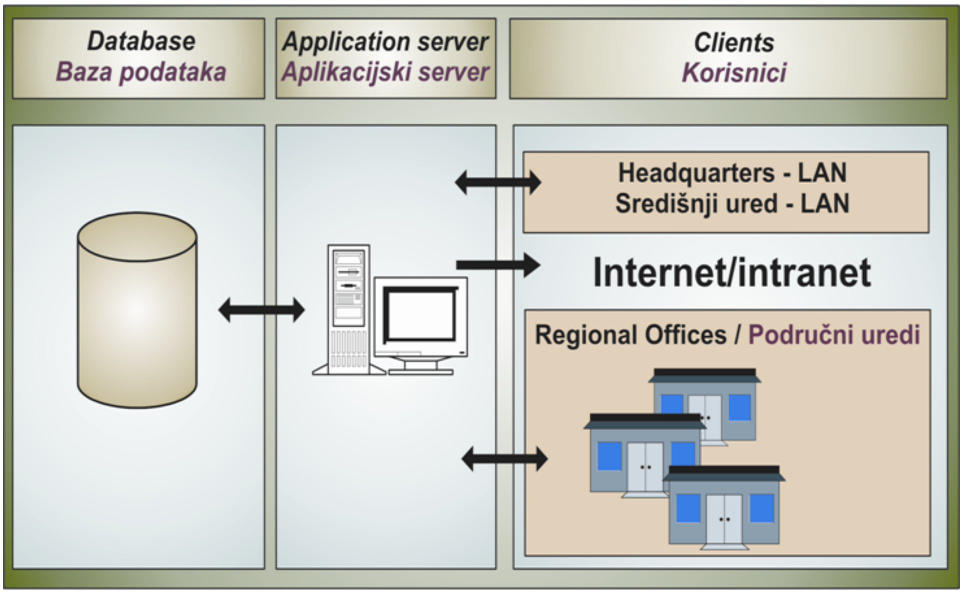

Figure 11.6: Information infrastructure architecture of CROMAC GIP

11.2.5 Conclusion

The creation of the new topographic information system (TIS) in the function of improvement of MIS will considerably help and shorten demining process of the mine-contaminated area. It will provide update and accurate data to the demining companies and also to the all-level system users form the government to the ordinary people who are interested what locations of the country are mine contaminated. GIS structrured data will enable high-level analysis of information from various sources.

Modeling data according to ISO and OpenGIS standards along with the quality control procedure applied to the data captured on the filed will raise the quality of the whole system and will assure that the MIS becomes integral part of the other geoinformation systems and also one level of the NSDI.

Chapter 12

Conclusion

The fundamental principle in the creation of CROTIS is functionally oriented conceptual modelling and formal specification of geometric and topological modelling at the conceptual level providing easier and more successful development and realisation of complex geoinformation system.
This approach, but also complete compatibility with ISO standards provide full and rapid integration of Croatian geoinformation system into European and global systems.
"The geoinformation approach in creating the reality with reduced quantity of less important data, and with emphasizing at the same time functionally essential ones, accompanied by the usage of object-oriented systems and modern informatic infrastructure" is equally significant characteristic of the CROTIS.

The application of high technology, conceptual modelling, standardisation and formal specification of geometric and topological modelling on the conceptual level conditioning easier and more successful development and achievement of topographic information system accompanied by full respect of users needs are the basic characteristics of applied methodology and approach in solving the intended task.
The task that involves creating the concept of topographic information system and initiating its establishment is characterised by an expressively strong organisational and practical aspect besides its scientific components that are included in the work. Scientific component encompasses GML and object-oriented approach in data modelling. The motivation is coming from the author and is being supported by the highest state authority competent for the organisation and functioning of geodetic and spatial system of State Geodetic Administration (SGA) defined by the law of "state survey and real estate cadastre", as well as coming from the majority of users. This was the first step towards the implementation of the author's idea referring to the establishment of modern geoinformation system The following steps are only the most significant realised steps toward the implementation of this

topographic information system, being the largest state activity within the scope of Geodetic Spatial System in the last 10 years – to contract for the works on the “Creation of Topographic Information System of the Republic of Croatia – CROTIS”, to form a team to work on the implementation of the topographic information system providing proper education and informing for experts, creating a data model in collaboration with the users, organisation of data gathering according to the created conceptual model and establishing a topographic data base accompanied by the initiation of about hundreds new projects within the scope of activities connected with the creation of CROTIS/STOKIS.

As well as the other European geoinformation systems, the Croatian Topographic Information System respects and observes the standards by ISO (International Standard Organisation) being one of the priorities among obligations. The aim is to establish standards and principles for modelling of graphic and alphanumeric code system intended for defining, structuring, replacing, coding, transformation and transfer of spatial data. Geometric and alphanumeric data create a complex system representing in a clear and simple manner the geometry and topology of geographic objects. The complexity is established, defined and harmonised with the needs and applications of users.Geoinformatically functionally oriented approach in CROTIS accelerates the process of transforming the reality into the desired information from, and provides complete projection of created data model into the structured base. The project gives an outline of a new approach in spatial data representation and management. The establishment of a functional, and not analogous and cartographic mode, is the basic characteristic of this new conceptual approach. Functionally oriented modelling raises considerably the level and quality of data respecting thereby conceptual modelling. The reality in all its complexity can be presented and processed informatically in a satisfactory way only by recognising this complexity. The basic guideline of functionally oriented modelling is to emphasise, give more weight to presentation and gathering of data having greater importance in exploitation of space.

Currently, CROTIS is modernized and synchronized with the latest ISO and OGC standards in order to develop procedures for topographic data distribution by using GML. New data model, new schema for the data exchange and new data catalogue have been encompassed within the research. The modeling was done for the purpose of data model improvement according to standards which provide the methods and properties for display of model objects and model attributes.UML is used for the formal description of the data. Logical data model in UML enables the implementation of GIS including the database as well. The automatic generation of GML application schema was developed from UML. Data description is contained in the data catalogue resulting automatically from data model. This is original and unique solution.

The fundamental principle in the creation of CROTIS is functionally oriented conceptual modelling and formal specification of geometric and topological modelling at the conceptual level providing easier and more successful development and realisation of complex geoinformation system.This approach, but also complete compatibility with ISO standards provide full and rapid integration of Croatian geoinformation system, NSDI, into European SDI, INSPIRE and global data spatial systems.

12.1 Future work

12.1.1 Next steps in realisation of CROTIS

Future work should be focused on **launch model generalisation** based on the production of object-oriented conceptual data model of topographic database TDB25 according to current ISO standards and defining the rules of mapping TDB10 to TDB25. The model of source topographic database is TDB 10 and the model of target topographic database is TDB25.
The establishment of cartographic database includes object-oriented approach is a next step. After that the distribution is to be organised through:

- statutory system and EU practice, INSPIRE
- web server, web marketing of services, Geo-Portal
- SGA and user agreements
- direct marketing and sales
- legal provision of usage of TDB, copyright

To develop **system maintenance** of topographic database would be the first priority. *System maintenance includes integration with other geo-information systems model specification as well, as defined by developing of technology, developing of standards and changing of user requirements as well.* CROTIS is the most important component of NSDI, and both systems are conform. The conformity with INSPIRE directives and implementation Rules is on very high level.

12.2 Alternative solution

12.2.1 General feedback on concept and implementation of topographic information system of the Republic of Croatia

Regardless of successful conceptual modeling and implementation of this original solution, there are some components, processes and approaches

which could be executed in a different way if it would be done again. With ten years of concept development and its implementation some elements had to be better defined, too.
Most relevant and significant are:

1. More precise and detailed specification of geodata (DTM, TDB, etc...) had to be done at the beginning of data capturing

2. Quality control system had to be developed and implemented before geodata have been captured and processed

3. Updating and maintenance mechanism of TDB had to be developed and implemented at the early stage of CROTIS implementation

4. Distribution of geodata by SGA had to be and have to be much more advanced, efficient and defined, and this ”risk” has been highlighted and strongly recommended by the author of thesis

However, all four “unpleasant” facts and “no success” steps of CROTIS implementation have been significantly influenced by the shortage of financial resources and no understanding from the responsible authorities, never mind my constant attempts and insisting.

12.3 Practical contribution of CROTIS

Very big step in creating Croatian NSDI is the main practical contribution of CROTIS. Data model, specification and data exchange standards are on high level of compatibility to implementation rules and INSPIRE directives. Entire new cartography and CDB for Croatia have been derived from CROTIS data. All major Geographic Information Systems (VoGIS, MIS, etc.) are based on CROTIS.

12.4 My personal contribution

Apart from the fact that the idea about the establishment of Topographic Information System comes from me, the concept of CROTIS (Chapter No. 6), and the scientific approach, automatic generating of GML documentation (Chapter No, 7) and functionally oriented modelling (Chapter No. 8), and their testing are all my direct contribution to this work.
The initiated completed projects and those still being worked on, the organisation and management of model production and the implementation of the entire CROTIS have been run by the author of this thesis.
The basic information about the examples of existing natinal TIS, standards, INSPIRE, and the definitions in TIS and theory of GIS discipline have been taken over from various references and sources.

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Curriculum vitae

Zvonko Biljecki was born on the 15th October 1960 in Derventa, Bosnia and Herzegovina. He graduated from Faculty of Geodesy at University of Zagreb (1984), where he also finished Postgraduate studies in photogrammetry and geoinformation (1986-1988). He did his doctoral studies with professor Karl Kraus as mentor at Vienna University of Technology, Faculty of Mathematics and Geoinformation, Institute for photogrammetry and remote sensing on theme Concept of Croatian Topographic Information System – CROTIS that he completed with professor Norbert Pfeifer on the same Institute. He has taken several informatics and management techniques and strategies courses, image data processing courses and IT courses. His key qualifications are management, photogrammetry and geoinformatics, development and application of quality control systems, modeling and development of databases according to ISO, OGC and CEN standards as well as production and project management. He is a member of numerous professional and institutional bodies; he is a member of Croatian NSDI council (since May 2007), he performs the duty of vice-president of Croatian Cartographic society (since 2001.), and since the year 2000, he is the president of the Croatian photogrammetry, remote sensing and geoinformation society by the Croatian Geodetic Society, then, he is the president of "Council of Project STOKIS".
He is the owner and director of Geofoto company that he established in 1993. In 1984 he began working as surveying expert, and then research assistant and photogrammetry production expert at the Faculty of Geodesy at the University of Zagreb. In 1989 he moved to Lugano, Switzerland, to company Geofoto SA where he worked until 1994 as production engineer in photogrammetry department. In 1994 he was promoted to director of the same company. He remained at this position until 1997 when he returned to Zagreb, to work as an external professor at the Faculty of Geodesy, teaching three classes and as director of the newly established Geofoto in Zagreb. At the University he was co-mentor and supervisor for several graduation theses. He held several public lectures and received two awards from the International Cartographic Association (for the best orientation map in 2001 (Beijing) and for the best photomap of urban area in 1999 (Ottawa)). He

has actively participated at several international conferences and symposiums (Map Middle East, Intergeo, FIG Congresses, ISPRS conferences and symposiums and other). He is the author of many scientific and expert works and has great experience abroad and in Croatia in project leadership for big clients like Ministries, Governments, World Bank project and others.

Most significant scientific publications:

- "Production of object-oriented conceptual data model CROTIS", Map Middle East 2006, Dubai, 2006
- "Mine Information System for the Humanitarian Demining", ITI 2006 Proceedings of the 28th International Conference on Information Technology Interfaces, Cavtat/Dubrovnik, 2006
- "Spatial Information Management of Croatian Ministry of Defense", Shaping the Change, XXIII FIG Congress, Munich, Germany, 2006
- "Geomatic Engineering in Humanitarian Demining", ISPRS Symposium on ≪Geospatial Data bases for Sustainable Development, ISPRS Commission IV, WG IV/5, Goa India, 2006
- "The Adaptation of CROTIS Data Model and Generation of GML Application Schema", 2006
- "Conceptual Solution for the Military Geoinformation System of the Ministry of Defense", 2006