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CARTOGRAPHIC INFORMATION MODELING

Textbook

Can be used as teaching material for the Vilnius University courses **Advanced thematic mapping** and **Cartographic information management**.

Centre for Cartography at the Faculty of Natural Sciences
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Preface

The book analyses theoretical problems of cartography that become pressing in the modern cartographic production practice. Continuous increase of the need for cartographic information and up-to-date data, of diversity and complexity of modern cartographic products and growth of users' requirements create inauspicious business environment because of which the quality of the products is often insufficient. For instance, thematic atlases are now published within months, whereas just a few decades ago such atlases had been designed by large teams for several years. The trend of low quality cartographic products is observed in Lithuania as well as worldwide. Therefore it is necessary to look for new methods that allow assuring high quality within a relatively short time span and without significant increase of costs, especially when cartographic communication quality (efficient and convenient transfer of information to the user) is concerned.

Some such methods were developed and tested by the author during implementation of thematic maps and atlases' projects. They are described within a consistent framework of cartographic information management and delivery. The presented approach differs from the classical cartographic design paradigm by treating cartography as an information science and a map as an informational model of a particular universe of discourse. Map design and implementation stages are separated. General system engineering methods and principles, such as requirement engineering, life cycle modeling and task breakdowns that are briefly discussed in the book, can be successfully applied at the implementation stage. Design stage solutions have much bigger impact on cartographic quality. The book provides recommendations on application of semantic modeling for cartographic visualisation and for objective evaluation of communicative quality. Proposed models can be also used for identification and evasion of possible design errors. Three different design paradigms are proposed for specific types of maps. Cartographic stylistics, extended concept of map language and multi-level cartographic communication model problems are introduced as a part of the single design framework. The book can be used by academics and postgraduate students as a supplementary training material.

This work aims to generalise author's scientific ideas and experience of 15 years research encompassing intersection of two fields: cartography and informatics. Some consistent materials on specific issues of theoretical cartography are presented that have been basically ignored in cartographic study materials and textbooks and generally underrepresented in research papers.

The text is largely based on completely original author's research that includes semantic modeling for cartographic design, dual model for cartographic transcription, and paradigms of cartographic design. It is unique in a way how different issues of geographic/cartographic information management are linked in the context of cartographic design.

The first and the largest chapter describes specific issues of requirement engineering for cartographic products, such as types and characteristics of requirements, principles of requirement specification and requirements-constraints balance. It introduces to the reader the life cycle of a cartographic product. It is followed by the chapter devoted to the semantic modeling for cartographic design, described with examples, discussing its possibilities and benefits. New philosophy of cartographic visualisation is introduced to replace the classical conception based on the system of "graphic variables" developed by J. Bertin in 1967. The two themes are linked in the third chapter that discusses other important methods of cartographic information management: breakdown of projects into stages and life cycle modeling, paradigms and principles of cartographic design illustrated by thematic map samples.

The conceptual model for cartographic visualisation, developed by the author, is introduced in the fourth chapter. The model is compared with the classical model and arguments provided concerning its efficiency. Finally, all the above described models are linked to the concept of map language. A new general model of cartographic communication is introduced.

In addition, map stylistics is briefly discussed as a closing issue. Map style is treated as an organising framework for all cartographic expression devices and defines the factors and parameters that form and influence map style. Several particular modern map styles are outlined within a general model.

The main target group of this book consists of cartographers of different specializations, PhD and postgraduate students interested in specific issues of cartographic visualisation. The book contains some practical recommendations (outcomes of scientific investigations that have been tested in practice) that can be used by middle level non-academic cartographers – designers of thematic maps and atlases.

The author is a member of the Commission for Theoretical Cartography of the International Cartographic Association since 2003, a vice-chair of the Commission since 2007. Recently she is Associate Professor at Vilnius University.

1 Requirement engineering in thematic cartography

1.1 Systems engineering and requirement specification

It is not objectively possible to make an ideal cartographic product. However, a careful design is very important for better quality of the map in all its meanings. That's why the design stage should not only be separated, but also deserves a special attention in thematic cartography. Requirement engineering is necessary part of the whole information engineering in thematic cartography, especially for complex projects such as national atlas, regional and thematic atlases, various spatial information projects.

Systems engineering is an interdisciplinary field of engineering that focuses on the development and organization of complex artificial systems. Systems engineering is defined a branch of engineering whose responsibility is creating and executing an interdisciplinary process to ensure that customer and stakeholders needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a systems entire life cycle, from development to operation to disposal. The systems engineering process usually comprises the following tasks:

- State the problem,
- Investigate alternatives,
- Model the system,
- Integrate the components,
- Implement the system / create the product,
- Assess performance / quality,
- Re-evaluate.

The cartographic systems engineering process is not sequential: the tasks are performed in a parallel and iterative manner. Requirement engineering is one of the most important tasks of the *modeling* stage.

In this chapter we will analyze the concept of requirement for thematic cartography products, such as map series, atlases or separate maps. National atlas of the country is a good example of the most complex cartographic products that cannot practically be designed without special methods of information management. National atlas of Lithuania has been compiled by the Centre for Cartography at Vilnius University since 1998. Methods and tools for analysis of the domain of discourse are subject to system analysis and engineering (Borgida, 1986) that have been applied by Lithuanian cartographers for the last several years. The specification of an atlas is a document, in which the atlas and its desired features are described. Atlases consist of maps that represent different fields of knowledge that actually are specific models of real (perceived) world. A *database* that lies behind every modern map is thus also a model of some aspect of the reality. Such thematic field/aspect is called *domain of discourse* (or sometimes *universe of discourse*) and contains the set of entities that a map model is based on. Each entity in such model is represented by a name and has some human-readable description of its meaning.

Specification is a result of detail analysis of users' needs in a specific domain of discourse. Such analysis for a complex atlas can become rather problematic, considering that requirements to maps and atlas can be discovered and changed anytime within the cycle of its development.

It is common to apply the methods of conceptual modeling for specification of any complex system (Booch, 1994), i.e., to define semantic objects (entities), which represent all things of significance (real objects, concepts, ideas) in the domain of discourse, and relationships with that entities. This is the way to decompose the complex system into relatively simple parts. Analysis of such parts, their qualities and relationships enables to discover the qualities of the whole system and choose right way to prepare the specification.

1.2 Concept of a requirement in thematic mapping

In engineering, a *requirement* is a singular documented need of what a particular product or service should be or do. It is most commonly used in a formal sense in systems engineering or software engineering. It is a statement that identifies a necessary attribute, capability, characteristic, or quality of a system in order for it to have value and utility to a user. In the classical engineering approach, sets of requirements are used as inputs into the design stages of product development. Requirements show what elements are necessary for the particular project.

A *system requirements specification* (abbreviation *SRS* is common in software engineering) is a document where the requirements of a system are listed.

A cartographic requirement is a desired quality of a cartographic object or process defined in specification, contract, standard or another document. It is a formal description of what must be the result of system processes, and what is the way to assess the quality of the result (the method of requirement verification).

Verification is a quality assurance process that is used to evaluate whether or not a product, service, or system complies with a regulation, specification, or conditions imposed at the start of a development phase. Verification can be in development, scale-up, or production. This is often an internal process.

Validation is the process of establishing documented evidence that provides a high degree of assurance that a product, service, or system accomplishes its intended requirements. This often involves acceptance and suitability with external customers.

It is sometimes said that validation ensures that 'you built the right thing' and verification ensures that 'you built it right'. 'Building the right thing' refers back to the users' needs; while 'building it right' checks that the documented development process was followed. In some contexts, it is required to have written requirements for both as well as formal procedures or protocols for determining compliance.

Specifying requirements, for which a method of verification and/or validation cannot be defined, does not make much sense, moreover, it is likely to become a source of potential conflicts at review or delivery stages. Examples of requirements are shown in Table 1-1.

Table 1-1: Examples of requirements

No	**Requirement**	**Method of verification**
xx	'The elements of general geographic map are represented in separate layers'	Review
xx	'Dot marker layers representing settlements must be designed over hydrography layers'	Review
xx	'Each page of the digital atlas must contain a hyperlink to the front page'	Testing
xx	'The spelling of geographical names in the Atlas must be approved by State Committee for National language'	Detail checking Quality assurance
--	'The Atlas must be informative'	This requirement cannot be verified, therefore specifying it makes no sense.

There are different ways to specify requirements: simple description, links to the source of a requirement, example, pattern or set of rules that the final product must match.

As long as requirements for thematic maps and information systems are very specific, requirement engineering, including specification, classification, analysis and assessment must eventually become a part of thematic cartography science.

1.3 Principles of requirement engineering

Requirements describe the features and limitations of the system. They are designed to identify business problems and propose solutions and to connect between the business side of an enterprise and the information technology department or external service providers.

The requirements development phase may have been preceded by a feasibility study, or a conceptual analysis phase of the project. The requirements phase may be broken down into four phases:

- requirements elicitation (gathering the requirements from stakeholders),
- analysis (checking for consistency and completeness),
- specification (documenting the requirements)
- Verification (making sure the specified requirements are correct).

The first stage in requirement engineering for a thematic atlas must start with identification of mission, objectives and strategy of the project. It gives the idea about the real need for such product or system and its success factors. For example, the mission of the information system for the National atlas of Lithuania is to organize and support the life cycle of the National atlas as of the most complex cartographic issue, representing basically all information about the state. The mission is decomposed into *objectives*, that define the most general requirements for the structure and contents of the product, describe, by whom, in what context and what ways the product or its structural parts would be used. The results of such primary analysis can be represented as a contextual chart, also showing system relationships with external entities and expected profit and use of the system (Figure 1-1).

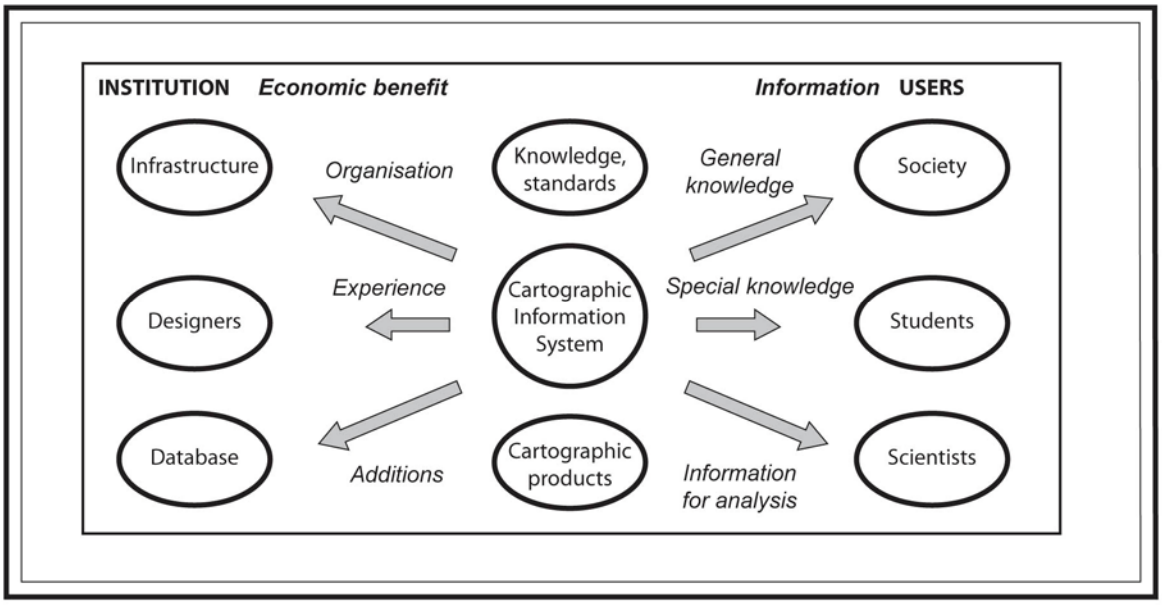


Figure 1-1: Example of a contextual diagram

Objectives are further decomposed into the *functions* and *tasks* of the information system of the Atlas, specifying expected results for each task, delivery terms and methods of their quality assessment.

Next step is *decomposing* the system into structural parts and defining requirements to those parts separately. Starting with the highest level of abstraction, the set of requirements is designed using 'top-down' strategy until the system is decomposed into elementary parts, for which strict, detail, monosemantic and uniform requirements can be set and verified. General requirements at higher levels of abstraction are sums of corresponding requirements at the lower level. This is the way how technological requirements (how to design the product) are derived from abstract project requirements (what product have to be designed).

Every requirement must have a reference to its source and specify all components to whose it applies as it is shown in Table 1-2 (interrelation matrix). The source can be the more abstract requirements, or external sources, such as standards, laws etc.

Table 1-2: Matrix of interrelations between the requirements

Requirement	**Derived from**	**Applies to components**	**Method of approval**
No 1	No1 No2 No 3	Nr X	Quality assessment
No 2	<document ref.>	…	…
No 3	No 1	…	…
…	…	…	…
No m	No 1 No 15	…	…
…	…	…	…

It does not mean that a full requirement set must be developed for every structural part or component at every level; it might be very complicated to specify detail requirements for some components of the cartographic issue (maps, texts), especially their contents vs. form or structure. The need for specifying formal requirements must be determined for each component of the Atlas. Developing formal requirements for a specific thematic map requires specific knowledge or deep and therefore resource-consuming analysis of the map subject (domain of discourse).

An objective method of verification must be specified for every formal requirement in order to be able to check whether the product matches this requirement in any stage of a project. All formal requirements must be documented for the same reason, specifying their number in the set, description, status, entities which they apply to and the author of the requirement. Requirements can be specified also using etalons, collections of representing examples, or system models carrying them through to the design of the corresponding components.

Informal requirements must not be registered in official specification; they can only be described in a document which has a status of informal suggestion or comment to the contract.

Every specified requirement must be possible to put into practice, integrated (not conflicting with any other requirements), significant, monosemantic and verifiable. In ideal system all requirements can be identified by name or number and related with specific objects monosemantically. The consistency of requirement set can be controlled using traceability (location) matrices like one of the Table 1-3.

Table 1-3: Requirement traceability matrix

Components	**System requirements**								
	Nr 1	Nr 2	….	…	…	…	…	…	Nr n
Nr 1	✓	✓	✓			✓	✓		
Nr 2		✓	✓						✓
…	…	…	…	…	…	…	…	…	…
Nr m	✓	✓				✓	✓		✓

The traceability matrix is a cross matrix that traces the requirements through each stage of the requirements gathering process. High level concepts are matched to scope items which will map to individual requirements etc. At the end of a project, this matrix should also show the reason that any stated requirements may not have been delivered.

Requirement analysis is based on building the tree of derived requirements, so it enables to determine which abstract requirement is the source of every specific requirement for the component and what way the requirement was derived from the more abstract one. That is the way to discover incorrect, conflicting requirements (e.g., conventional sign system designed for the Atlas might be not compatible with such system developed earlier for geological maps or not match a general standard of cartographic design).

A well prepared strategy of analysis stage and thorough requirement engineering are important success factors for the company.

1.4 Classification of requirements in information system

Requirements are typically placed into these categories:

Business requirements constitute a specification of simply what the business wants. This is usually expressed in terms of broad outcomes the business requires, rather than specific functions the system may perform. Specific design elements are usually outside the scope of this document, although design standards may be referenced.

Functional requirements describe what the system, process, or product/service must do in order to fulfil the business requirement(s). Business requirement often can be broken up into many functional requirements.

Report specifications are reporting requirements.

Non-functional requirements are the ones that act to constrain the solution. They cannot be met by a specific function, e.g. performance, scalability, security and usability requirements. Non-functional requirements are sometimes known as constraints or quality requirements. They can be further classified.

Requirements can be grouped by their status.

Obligatory requirements. The system or object cannot be created in the way corresponding to the mission and objectives of the project unless obligatory requirements are put into practice. Example of such requirement at highest abstraction level is: ‘Maps are the main components of the Atlas’. Violation of this requirement could result in publishing a photo album or just a book.

Optional requirements. Such requirements are designed to improve the quality of the product, make its design easier and simpler etc. Violation of such requirements does not corrupt the system.

For optional requirements it makes sense to determine the level of importance – taking into account all consequences of its violation. For example, the requirement that all maps showing average air temperatures in ‘Climate’ part must be of same scale and format is more important, than the requirement to design them one of standard scales; compiling maps of unusual scale violates standardisation of the Atlas (making it more difficult to compare such maps with other thematic maps in the Atlas). However, the situation would be even worse, if maps representing the same phenomena are of different, even standard, scales, or located on different pages. In the second case, not only standardisation, but also unification, and user comfort principles of system design are violated.

If all requirements cannot be matched for some reason, those of less importance are given away first. Same requirement can have different weight in different context, e.g., in scientific map accuracy and reliability of information is prior to visual expression, while it is vice versa for educational or, especially, for advertising map.

Additional requirements. They are requirements to expand the systems structure or contents, e.g., to compile extra maps besides the first contract. Such requirements usually are discovered in late design stage.

Formal requirements must be described in a standard order, e.g.:

< Number; object to which the requirement applies; importance (does not have to be formal); the way to put it into practice, the method of verification >.

In principle most of the requirements can be discovered and changed during all the life cycle of the project.

Permanent requirements are set before the design stage and never change until the product is delivered. Temporary requirements usually are determined anytime to simplify the processes of design or compilation for some period, taking in account that they will be changed sometimes later on according to specific rules. Implementation of temporary requirements therefore is less important.

A set of interrelated and integrated requirements consists of requirements for the final product (map, atlas etc.) and project requirements which describe how the product must be created. Some set of requirements is also designed for the project information and support system itself.

Project requirements. These requirements describe the way system or product must be designed; they are usually specified in contract.

Technological requirements define what methods and tools must be used for design, how everything must be documented, what technical resources, software and methods are used to compile maps, what are expected file formats and media for digital maps – so it is basically requirements for design and implementation stages.

Quality assurance requirements determine the ways to plan and control quality of products and procedures to eliminate errors.

Configuration management requirements define methods used for system configuration management.

Finance management requirements describe budget of the project, labour costs, responsibility for unexpected expenses, possible bonuses, accounting procedure. It makes sense to have separate budget for the project even if all the work is performed in a single institution.

Task management requirements describe the stages and functions of the project life cycle, checkpoints, terms of delivery etc.

Delivery requirements describe, what intermediate and final products are created during system life cycle, to whom, when and how they have to be delivered, procedures of delivery and presentation, risks and responsibility, structure, contents, form of all required documents.

Approbation and conflict resolution requirements define the procedures of approbation, criteria for quality assessment, who, when and how must to solve different types of conflicts.

Product requirements (for map, atlas etc.) describe the desired features of the object regardless of how it is created. Such requirements set limitations to possible project decisions. Besides general Atlas' requirements, every component is described in detail by separate set of requirements. Requirements for separate maps are specific to their domain of discourse and related to geographical information of the mapped territory. They can be grouped into those, describing form of maps (e.g., cartographic generalization, layer structure etc.) and specific requirements for the thematic maps contents.

Requirements for thematic map can be semantic (describe presented information), syntactic (describe the structure and presentation form of the information) and quality (general and specific requirements for products quality).

Quality requirements are especially important. General quality requirements are related with accuracy, reliability, consistency of cartographic information.

- *Correctness requirements* describe, for example, to what extent map contents, representations and structure of an atlas match particular standards, specifications or other regulations.

- *Accuracy requirements* define map resolution and allowed maximal errors for different objects of the map.
- *Integrity requirements*, e.g., that all sources of information must be specified (assuring that all information is legally used).
- *Particularity requirements*, e.g., national Atlas must represent more than single sphere of activity and all regions of the state.
- *Efficiency requirements*, e.g., desired balance between complexity and ease of perception.
- *Unity requirements* set the level, methods and ways of standardisation.
- *Changeability requirements* basically say that labour costs for updating information for re-use must be minimized.
- Requirements for stand-alone components, which are designed to be repeatedly published in other issues or separately.

1.5 General requirements for thematic cartography projects

The most general requirements for cartographic products, such as maps and atlases, describe the same crucial aspects: goal and objectives of the project, target groups, size and layout or media, geographic extent, principal and supplementary components, language, mathematical-cartographic and general reference base, thematic contents, implementation, management and costs.

Some of the above mentioned requirement groups are discussed in the sub-chapters. Extracts from the Feasibility study for the *Atlas of the Baltic Sea Region* serve as examples of typical requirements for thematic atlas.

1.5.1 Objectives and target groups of the project

The goal of the cartographic project may be representing different aspects of life in the form of a map or geographic atlas (a collection of maps) featuring important aspects of the chosen region (target territory): nature, culture, society, and economy.

Typically, the following general tasks or a subset of them must be performed:

1. Choice of the co-operation scenario for the project.
2. Design of information system and business model of the map/atlas.
3. Design of thematic GIS database.
4. Selection, analysis and synthesis of geographic data.
5. Cartographic visualization of geographic data (design of maps).
6. Collection of additional non-geographic information.
7. Design and publishing of the product.
8. Maintenance and development of the information system for new cartographic information products.

As a source of integrated information on the target territory map or atlas may be of interest for different professional, social, demographic and regional groups of users. It is often difficult to clearly distinguish between these groups because their needs and spheres of interest overlap. Still, there are three major target groups of complex thematic atlases with their specific preferences:

1. Spatial planners and decision makers;
2. Business, Education and Research institutions;
3. Individual users.

For *spatial decision makers*, especially at governmental institutions and regional organizations, multi-aspect geographic integration of information is important. Spatial relationships, patterns and prognoses, derived from the best available data, can be effectively visualized in order to facilitate the process of spatial thinking. It is often much more important to show the region as a seamless entity instead of minutely representing its territorial or thematic components.

For *education* and *general scientific* information purposes thematic atlases must serve as sources of up-to-date and reliable synthetic information on the region. Some themes, such as historical relationships, political situation, social and cultural tension, security, information society etc., are of interest for this large group of users, however, still underrepresented in the existing information sources.

For the *individual users*, variety of thematic information on the region, affordability and visual attractiveness of the product play the most important role.

1.5.2 Component and geographic extent requirements

Considering preferences of the above described common target groups, **maps** should comprise at least 70% of the thematic atlas, explanatory texts and graphics (including place name index) – about 15%, illustrations (photographs, drawings) – another 15% of the atlas contents.

Each part (and major themes within the larger parts) often starts with a comment of 1–2 pages of the atlas, written by an expert on the subject matter. Brief textual comments may follow each map. Illustrations, charts and other supplementary materials can be placed either next to the relevant map or on a separate page.

Geographic extent of the target territory can be described by a bounding box in geographic coordinates or/and by listing territories that fall into the extent.

> *Example:* The extent from roughly 48°N to 68°N latitude and from 6°E to 37°E longitude is recommended for the maps of the Baltic Sea region. This rectangle contains eastern Norway, all of Denmark, Germany northeast of Frankfurt, all of Poland, Ukraine north of Lviv-Kiev-Charkiv and Russia west of Tver and southwest of Murmansk.

For the regional or country atlases **territorial components**, different from the target territory, can be specified. They are represented on different maps of the atlas.

Example: Territories to be represented in the Atlas

1. The Baltic Sea region
2. Larger geographic context:
    a. World;
    b. Europe.
3. States and parts of the Baltic Sea region at larger scale:
    a. Country maps:
        i. Countries that border on the sea (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden);
        ii. Countries that are in the drainage basin but do not border on the sea (Belarus, Czech Republic, Norway, Slovakia, Ukraine)
    b. Baltic Sea basin.
    c. Cities:
        i. Capital cities that are in the drainage basin;
        ii. Some of major coastal cities and ports (Baltiysk, Copenhagen, Gdańsk, Gdynia, Hanko, Helsinki, Kaliningrad, Kiel, Klaipėda, Lübeck, Malmö, Riga, Rostock, Stockholm, St.Petersburg, Świnoujście, Szczecin, Tallinn, Turku, Ventspils);
    d. Islands and archipelagoes (Archipelago Sea, Åland Islands, Bornholm, Gotland, Hailuoto, Hiiumaa, Kotlin, Muhu, Öland, Rügen, Saaremaa, Stockholm archipelago, Usedom, Valassaaret, Wolin).
4. Areas and/or objects of specific interest within the theme (heritage sites, characteristic territorial structures etc.).

1.5.3 Mathematical-cartographic base

Datum. It is recommended to use same datum for all atlas maps except maybe for the maps of individual countries. De-facto world standard for datum is **WGS_1984** (World Geodetic System). Also, WGS_1984 is convenient to use with the GPS measurements.

Parameters of GCS WGS_1984 are:

Spheroid: WGS_1984
Semi major Axis: 6378137,0
Semi minor Axis: 6356752.3
Inverse Flattening: 298.3

Datum for maps of each individual country can be adopted from respective country datum.

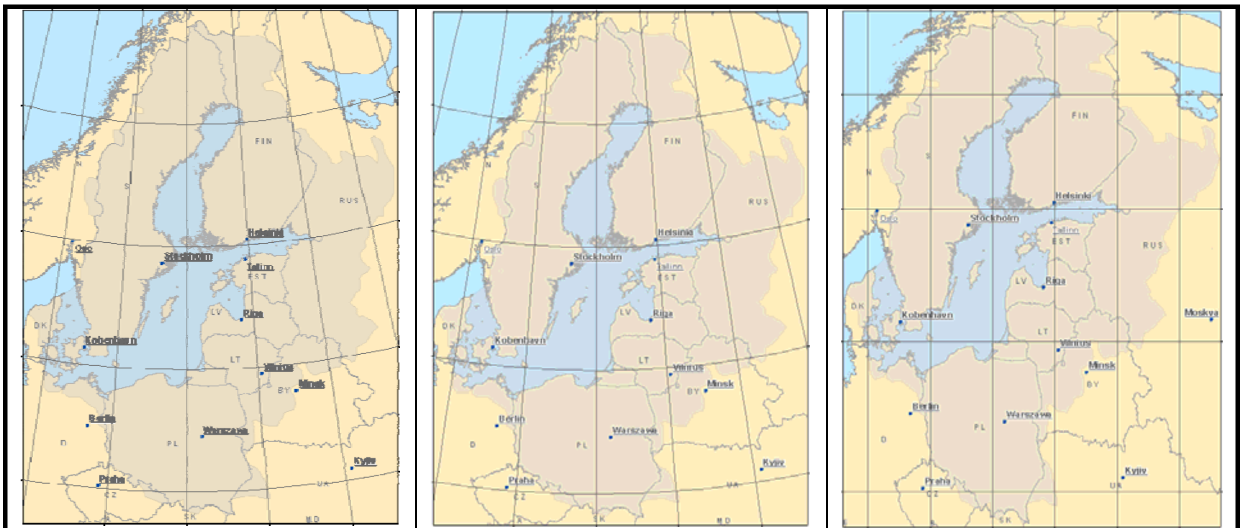
Projection. General requirements related to projections and scales of maps in a typical thematic atlas are:

1. the maps of the same area must be constructed with the same projection;
2. the maps of the same area must have the same standard parallels and should be based on the same ellipsoid reference datum;
3. the most of maps of the same area must be at the same (reference) scale;
4. not more than 4 different scales should be used for maps of the same area. The following alternative scales are recommended: 200%, 50% and 25 or 15% of the reference scale;
5. the total number of map scales used in the atlas should be minimized.

Projection and its parameters are chosen based on comparison of different projection models. Visual analysis of appearance of shapes of the whole area and of individual countries (familiarity of country's shapes to an ordinary user), minimization of distance distortions within mapping area and other considerations are used for selection of projection.

For the world maps, **Robinson projection** is often chosen. This projection's primary purpose is to create visually appealing maps of the entire world. It is a compromise projection; it does not eliminate any type of distortion, but it keeps the levels of all types of distortion relatively low over most of the map. Robinson called this the orthophanic projection, which means 'right appearing', and this can be main purpose of the World overview maps in the atlas.

Some 'good' examples of analyzed projections for the Atlas of the Baltic Sea Region are shown in the figure below.



Albers Equal Area Conic Central Meridian: 20,0	Lambert Conformal Conic Central Meridian: 20,0	Cylindrical Equal Area Central Meridian: 0,0

Standard Parallel 1: 56,0 Standard Parallel 2: 62,0 Latitude Of Origin: 40,0 Original scale: 1: 6 000 000	Standard Parallel 1: 56,0 Standard Parallel 2: 62,0 Latitude Of Origin: 40,0 Original scale: 1: 6 000 000	Standard Parallel: 60,0 Original scale: 1: 6 000 000

Figure 1-2: Possible cartographic projections for the Baltic Sea region (darker brown on the map)

Scale. The set of main scales used in the atlas must be specified. It is a good practice to describe the links between the scales and size of map frames (or pages) and between the scales and the territories.

Example: The BSR optimally fits into portrait orientated standard A3 page (29.7 x 42 cm) at scale 1: 6 000 000. This scale is thus recommended to use for the most of maps of the region. For the same reason, scale 1: 4 500 000 is recommended for the Baltic Sea basin. Scales of Europe and World maps on one page are correspondingly 1: 16 000 000 and 1: 70 000 000.

The table shows main projections, which should be used for the other territories mapped in the Atlas of the Baltic Sea Region, and basic scales for the maps to fit into one page.

Table 1-4: Projections and scales for different territories

Layer / **Extent**	**Projection**	**General reference data / DB scale**	**Main map scale**	**Smallest map scale**	**Largest map scale**	**Number of different scales**
World	Robinson	1: 50 Mio	1: 70 Mio	-	-	**1**
Europe	Albers Equal Area Conic	1: 1 Mio	1: 16 Mio	1: 8 Mio	-	**2**
BSR	Albers Equal Area Conic	1: 1 Mio	1: 6 Mio	1: 25 Mio	1: 3 Mio	**4**
Country maps	National projections	1: 1 Mio	-	1: 4 Mio		**2–4**
City maps	Planar	1: 50 000	1:100 000	1:500 000	1: 50 000	**4**
Islands and archipelagos	Albers Equal Area Conic / Planar	1:100 000	1: 500000	1:500 000	1: 50 000	**4**
Other	**Albers Equal Area Conic / Planar**	**1: 1 Mio/ 1: 50 000**	**various**	**1: 8 Mio**	**1: 50 000**	

The following table shows the size of main map frames for the given scales (fitting into one page.

Table 1-5: Size of the main map frames according to given map scales

Area / 1 page	**Width, cm**	**Height, cm**	**Orientation**	**Scale**
A3 (Atlas page size)	29,7	42,0	Portrait	-
Baltic Sea Region	28,0	38,7	Portrait	**1: 6 000 000**
Baltic Sea basin	28,0	35,0	Portrait	**1: 4 500 000**
Europe	37,4	27,8	Landscape	**1: 16 000 000**
World	**40,3**	**23,8**	**Landscape**	**1: 70 000 000**

The next figure shows the views of the World, Europe and Baltic Sea basin at chosen projections and projection parameters.

World	**Europe**	**Baltic Sea basin**

		
Robinson False Easting: 0,0 False Northing: 0,0 Central Meridian: 20,0 Original scale: 1: 70 000 000	Albers Equal Area Conic False Easting: 0,0 False Northing: 0,0 Central Meridian: 30,0 Standard Parallel 1: 43,0 Standard Parallel 2: 62,0 Latitude Of Origin: 30,0 Original scale: 1: 16 000 000	Albers Equal Area Conic False Easting: 0,0 False Northing: 0,0 Central Meridian: 20,0 Standard Parallel 1: 58,0 Standard Parallel 2: 62,0 Latitude Of Origin: 40,0 Original scale: 1: 4 500 000

Figure 1-3: Examples of cartographic projections recommended for the World, Europe and Baltic Sea basin

Graticule grid must also be specified.

> *Example:* Five degree intervals of meridians and parallels grid lines are proposed to use for the maps of BSR, Baltic Sea and ten degree intervals for Europe. For the world maps, this interval should be thirty degree for meridians and parallels.

1.5.4 General reference base

Generalization. Representation of the reference geographic data will differ in the maps at different scales and themes. There can be several generalisation levels for each data **layer** (a geographic data set that represents a specific type of feature, e.g., hydrography or vegetation layer) at each **scale**. Most often two or three generalisation levels are sufficient:

I. **Maximum detail** (reference information load is larger than required considering the map scale). Such reference base layers will be used for thematic maps, showing detailed thematic information on the corresponding topographic feature, for example, maximum detail (corresponding to the double reference scale) hydrography layers for Hydrography theme maps;

II. **Average/proportional** (reference information load adequate to the map scale). Such reference base layers will be used for all general maps and for thematic maps, showing thematic information relevant to the corresponding topographic feature, for example, average generalization of settlement and roads layers for maps, representing socio-economic information;

III. **Minimum detail** (reference information load minimized leaving only the major features). Such reference base layers will be used for specific thematic maps, representing phenomena weakly associated to the corresponding topographic feature, for example, minimum detail settlement layers for maps on climate.

I	*II*	***III***

<table>
<tr><td>(maximum detail)</td><td>(proportional level of detail)</td><td>(minimum detail)</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Capitals, large, medium and small cities, European Highway system and major country roads</td><td>Capitals, large, medium and small cities, European Highway system</td><td>Capitals and large cities only, no roads.</td></tr>
</table>

Figure 1-4: Examples of different generalization levels
Settlement and road layers for the Atlas of the Baltic Sea Region

The actual generalizations are designed during the design stage, considering several factors: map scale, thematic map context, density of the respective objects within the mapping area, etc. Therefore the level of generalization can vary within same map and will depend on the actual density of the mapped features. For example, selection criteria of population places will be different in countries with a high population density (e.g. Denmark) compared to countries with a low population density (e.g. Norway).

Data themes (layers). The contents of the reference base map must be specified. In the following table generalisation levels of the basic topographic information layers for different territories and thematic parts represented in a typical regional atlas are summarized. Country atlases often use the same or similar reference base layers.

Table 1-6: Data layers and anticipatory generalization levels for different themes
(for the Atlas of the Baltic Sea Region)

Layer / **Extent / *Theme***	**Relief**	**Hydro-graphy**	**Settle-ments**	**Admin. boun-daries**	**Roads**	**Forests**
World						
Nature	II	II	III	–	–	**–**
Socio-cultural, political, economic	–	–	II	II	–	**–**
Europe						
Nature	II	II	III	–	–	**–**
Socio-cultural, political, economic	–	III	II	II	–	**–**
Region (main theme)						
Geodetic-cartographic base	–	III	III	II	–	**–**
General physical map	II	II	III	III	–	**II**
General political map	–	III	II	I	III	**–**

History of the region	–	III	II	II	–	**–**
Geology and surface	– / I	II	III	–	–	**–**
Climate	–	III	III	–	–	**–**
Hydrography	– / III	I	III	–	–	**–**
Biota	–	II	III	–	–	**I**
Research and development	–	III	III	II	–	**–**
Landscapes	– / III	II	III	–	– / III	**– / II**
Physical infrastructure	–	III	II / I	II	I	**–**
People, society and culture	–	III	III / II	II	–	**–**
Economy	–	III	II	II	–	**–**
Politics	–	III	III	III / I	–	**–**
Country maps	–	II	II	II	II	**III**
City maps	–	II	n/a	n/a	I	**–**
Islands and archipelagos	**II**	**II**	**II**	**II**	**II**	**II**

In all thematic maps, synthesis of information and territorial generalization must be given priority to precise details.

1.5.5 Thematic contents of the atlas

Typically, the atlas should start with general and some thematic maps of the larger geographic context in order to give the reader an understanding about the situation of the target territory within that context. Then there follow several thematic parts traditionally devoted for nature, culture and society of the target territory.

The below described general thematic structure of a complex regional or country atlas is just one of several possible. It can be revised and changed as the result of a detailed analysis and during the implementation of the project, also abridged or extended subject to the resources actually available.

Example of thematic contents of an atlas:

THE TARGET TERRITORY IN A LARGER CONTEXT
Geographic environment:
Physical map of the world. The target territory should be highlighted,
Political map of the world. The target territory should be highlighted,
Physical map of the larger region,
Political map of the larger region.
General maps:
Geodetic-cartographic background,
Physical map,
Satellite view,
Administrative division map,
Country maps (optional),
Subdivisions of the target territory, islands and archipelagos,
City plans (optional),
General zoning.

THE TARGET TERRITORY ON MAPS
History of cartographic representation of the target territory,
Cartographic/GIS coverage of the target territory.

NATURE AND LANDSCAPES
History of the nature:
Geological history,
Paleo-environmental and paleogeographic maps.
Geology and surface:

Geology and tectonics,
Mineral resources,
Underground water,
Relief and Digital terrain model,
Geomorphology,
Geochemical map,
Soils.
Climate:
Main climate influencing factors,
Termics and dynamics,
Bioclimatic maps,
Climatic changes in the future.
Hydrography:
Surface water and seas,
Hydrology,
Hydrogeology,
Ground and surface water resources.
Biota:
Flora and fungi,
Forests,
Fauna,
Exclusive species and habitats,
Biodiversity and biological resources.
Landscapes:
Land cover diversity,
Natural landscapes,
Natural disaster risk,
Anthropogenic landscapes,
Landscape types and framework structures,
Recreational potential of the region.
Environmental protection:
Environmental hazards,
Protected areas and sites,
Environmental policy and initiatives.

PHYSICAL INFRASTRUCTURE
Settlements:
History of inhabitation,
Territorial structures,
Urbanization and rural communities.
Transport:
Transport network,
Roads,
Railways,
Pipelines,
Navigable transport,
Air transport,
Electric transport,
Major energy plants,
Tele-communication.
Public utilities:
Passengers' transport
Goods' transport
Natural gas and coal delivery
Water supply

Waste-water management
Waste management
Power service
Communication service

PEOPLE, SOCIETY AND CULTURE
History of people:
Ancient tribes,
Archaeological exploration,
Population changes,
Movers and shakers of history.
Demographic characteristics:
Population density,
Population distribution,
Population change,
Natural population change,
Age and gender structure,
Families,
Migration.
Ethno cultural characteristics:
Ethnicity,
Nationality,
Languages,
Religions,
Ethnology.
Health and social characteristics:
Health preconditions,
Morbidity and mortality,
Education,
Diversity and social contrasts.
"Soft" / social infrastructure:
Social welfare,
Housing,
Public health service,
Education and science,
Legal systems and public safety,
Communication, trade, financial and daily living needs infrastructure.
Arts, culture and tourism:
Fine arts, music and theatre, museums,
Cultural world heritage,
Tourist attractions,
Leisure.
Information society:
Media,
Radio and television broadcasts,
Internet and e-services,
Information society.
Quality of life

ECONOMY
History of economy
General indicators:
Labour market,
Economic indicators.
Agriculture and food industry:

Agricultural development history,
Agricultural activity preconditions,
Major agricultural commodities and producers,
Branches of agriculture,
Food consumption,
Fibre consumption.
Industry:
History of industrial development,
Industry factor conditions,
Related and supporting industries,
Resource-reliant communities,
Renewable energy,
Mining,
Manufacturing industries and trades,
Consumption.
Service Industries:
The market place and commercial activity,
Specialization in commercial services,
Specialization in public services (public administration and health and education services),
Trade, Export/Import,
Tourism.

POLITICS
History of political relationships:
States territoriality,
Prehistoric times and early history,
Modern period,
The World Wars and the Interwar Period,
The contemporary period, geographical distributions of the joint transnational projects, network of cooperating organizations and institutions.
National services:
Defence,
Human rights,
Political regimes, parties and preferences,
Conflicts.

The maps may be supplemented with texts, illustrations, graphs and charts that also have to be specified.

1.5.6 Language requirements

Language requirements may be specifically considered for national or multi-lingual atlases. The digital database of texts and place names in that case must be organized in a way allowing quick and efficient translations to other languages in case of such need.

> *Example:* Original forms and characters from national alphabets must be used uniformly and consistently for the names of cities, administrative units and local geographic features. Traditionally widely used English versions of some place names may be shown in parentheses below or next to the original form. The rest of place names must be in English, except for the maps of the Toponymy theme.

The place name index is normally placed at the end of the atlas. It must include versions of the major place names in national languages.

1.6 Implementation requirements

1.6.1 Project activities

The work breakdown structure must be specified as a hierarchical description of all the work that must be done to achieve the project goal. It has been used to estimate the duration of the project, determine the required resources, schedule the work and provide better management control. The top-down approach (see Chapter 4.4) should be used to identify project activities.

The main project activities are:

- A.I. Design of the information system and business model.
- A.II. Creation of the GIS database.
- A.III. Detailed design of the cartographic product
- A.IV. Creation of the non-geographic database.
- A.V. Design of maps.
- A.VI. Design and publishing of printed or digital edition.
- A.VII. Project management and co-ordination

A.I. Design of the information system

This activity is planned for development of methodological base and model of the ABSR information system. This also means creation of the necessary organizational structure and physical framework for collection and maintenance of thematic cartographic/GIS data. It can be broken into the following activities (sub-tasks):

1. Analysis of information and specific users' needs.
2. Detailed specification and design of the information system.
3. Preparation of business model.
4. Design of the databases.
5. Implementation and delivery of the information system.
6. Development of overall project methodology.

A.II. Creation of the GIS database.

This activity will create the geographic information sets or links to existing GIS databases, providing geographic data necessary for the maps. It can be broken into the following activities (sub-tasks):

1. Acquisition of geographic data (incl. purchasing, digitizing, linking to external sources).
2. Harmonization of geographic data.
3. Preparation of general reference datasets.
4. Preparation of thematic datasets.
5. Integration of geographic and statistical data.
6. Spatial analysis and synthesis of data.
7. Creation of views and visualization schemes
8. Application development

A.III. Detailed design of the product (atlas, map or map series)

This activity will create the uniform framework for all components of the Atlas. It can be broken into the following activities (sub-tasks):

1. Detailed specification of the contents.
2. Specification of the layout.
3. Design of basic system of signs.
4. Graphic design.

A.IV. Creation of non-geographic database

This activity will create the non-geographic information components of the database and link them together. This activity includes choosing and purchasing or creation of necessary components. It can be broken into the following activities (sub-tasks):

1. Preparation of raster and non-geographic vector images.
2. Preparation of texts.
3. Preparation of numeric data.
4. Preparation of metadata.

A.V. Design of maps

This is the major, the most heterogeneous and the most resource-consuming activity in the project. It will create all maps of the Atlas. It intertwines with the A.II–A.IV activities and can be split into sub-tasks in several ways. The following breakdown is made in order to simplify the cost estimation:

1. Design of the reference-base maps.
2. Design of the general maps for the Atlas. This activity will create maps, which do not contain specific thematic information.
3. Design of the thematic maps. Thematic maps represent specific geographic phenomena, which require deep study, for the target and related territories. This activity can be split into 6 largely successive tasks:
    a. Collection and processing of thematic data;
    b. Preparing a draft thematic map;
    c. Revision of supplementary map information;
    d. Revision of the draft;
    e. Cartographic visualisation;
    f. Revision of the cartographic visualisation.
4. Revision and integration of maps within the themes

A.VI. Final design and publishing

This activity is planned for integration of all Atlas components, final stylistic and technical revisions and publishing of printed edition. It has two sub-tasks:

1. Preparation for publishing.
2. Publishing.

A.VII. Project management and co-ordination

This is the main general activity of the project, which is necessary to assure smooth and uninterrupted implementation of the project tasks. Efficient organization model, which has been used and answered the purpose in large IT projects, is proposed to guarantee efficient project management. The management activity can be broken into the following activities (sub-tasks):

1. Development of project organizational and support structure.
2. Assignment and management of responsibilities.
3. Monitoring project activities and management of changes.
4. Quality assurance.
5. Documentation.

1.6.2 Project deliverables

The deliverables of the project are usually listed in a form of tables where they are linked to the objectives, activities and tasks of the project. General task breakdown and deliverables for a complex cartographic project are shown in the tables below.

Table 1-7: Project objectives, related activities and deliverables

No.	Objective	Activities orientated to the objective	Deliverables
1.	Creation and maintenance of a permanent information system and digital database of the target territory	A.I., A.II., A.IV.	**A functioning digital cartographic information system for the target territory.**
2.	**Creation and making available to public a collection of maps, compiled from the database and representing the target territory in the best way in given circumstances.**	**A.III., A.V., A.VI.**	**Published cartographic product**

Table 1-8: Project activities, aims and deliverables

No.	Activity	Aim of the activity	Deliverables
A.I.	**Design of the information system (IS)**		
1.	Analysis of information and specific users' needs.	Finding out all factors that might impact on structure, form and feasibility of the Atlas IS	**Report on availability of information, SWOT analysis.**
2.	Detailed specification and design of the information system.	Design of the IS components (hardware, DBMS, other software, network, human resources etc.)	**Specifications of all IS components**
3.	Preparation of business model	Ensuring support and sustainable development of the product information system	**Business model, long-term financing and administration plan**
4.	Design of the databases.	Design of database structures to store the data and data flows, considering partitioning, distribution, security issues	**Specification of all necessary datasets, data models and classifications, database structures, test datasets**
5.	Implementation and delivery of the information system.	Integration of all IS components into a fully functional system	**Functioning information system, detailed technological schemes**
6.	Development of overall project methodology.	Providing reasoning of solutions, instructions and knowledge, necessary for further development	**Model of the IS maintenance and development**
A.II.	**Creation of the GIS database**		
1.	Acquisition of initial geographic data	Collecting all necessary data from external sources, cleanup and update	**Structured geo-raster, GIS and statistical data**
2.	Harmonization of geographic data	Making GIS data fully available and interoperable (conversion to a single schema, generalization).	**Seamless and consistent GIS database, metadata**
3.	Preparation of general reference datasets.	Designing alternative reference datasets (different scales and levels of detail).	**Consistent general reference base layers (alternatives).**
4.	Preparation of thematic datasets.	Adjusting thematic data from different sources to	**Consistent thematic layers.**

		corresponding reference datasets	
5.	Integration of geographic and statistical data.	Linking statistical data with geographic information	**Attribute data for geographic objects**
6.	Spatial analysis and synthesis of data.	Production of new data and scientific knowledge	**Derived / cumulative geographic data, models**
7.	Creation of views and visualization schemes	Cartographic visualization according to chosen schemes	**Map layouts, schemes, patterns, conventional signs**
8.	Application development	Automation of complex data operations	**GIS applications**
A.III.	**Detailed design**		
1.	Detailed specification of the contents	Preparing list and specifications of all the components (maps, texts, illustrations and other objects)	**List of the components with brief descriptions and basic requirements**
2.	Specification of the Atlas layout.	Preparing the graphic layout according to the specification of the contents	**Layout, typographic design**
3.	Design of basic system of signs	Designing conventional signs for major groups of maps, obeying the rules of cartosemiotics	**Conventional signs for basic geographic features and for the groups of other entities used in several maps, colour schemes**
4.	Graphic design	Designing and professionally preparing all supplementary graphic components of the Atlas	**Cover design, title pages, decorative graphic elements, illustrations, specified paper type, binding style etc.**
A.IV.	**Creation of the non-geographic database**		
1.	Preparation of raster and non-geographic vector images	Collecting and processing of the supplementary images, graphic editing and enhancement	**Raster maps, charts, diagrams, illustrations ready to use**
2.	Preparation of texts	Collecting and processing of the texts, reviewing, style editing	**Explanatory and other texts, index of geographic names**
3.	Preparation of numeric data	Collecting, processing and verification of numeric data, establishing and managing links with external data sources	**Consistent multiple-use numeric data**
4.	Preparation of metadata	Providing standardised information about the data, stored in all Atlas databases	**ISO-compliant metadata on both GIS and non-geographic data**
A.V.	**Design of maps**		
1.	Design of the reference-base maps	Adjusting database information and transforming it into reference-base maps required for Atlas maps at different scales	**Complete reference-base maps**
2.	Design of the general maps	Selecting information layers to supplement reference base maps, integrating, performing cartographic visualisation	**Complete general maps**
3.	Design of the thematic maps	Preparing thematic map using given reference-base	**Complete thematic maps**

3. a.	Collection and processing of thematic data	Revising the database information, collecting thematic data from other sources, integrating viewpoints	**Specifications of thematic information to be represented on the maps**
3. b.	Preparing a draft thematic map	Choosing visualisation methods, revising map scale and supplementary information, drafting the cartographic representation	**Draft thematic maps for revisions**
3. c.	Revision of supplementary map information;	Revising and, if necessary, re-designing the components (texts, illustrations etc.), which supplement map information	**Revised supplementary components**
3. d.	Revision of the draft	Revising and commenting on the draft by the specialists (can have several iterations)	**Approved draft maps, revised databases**
3. e.	Cartographic visualisation	Representing thematic information using given draft and reference-base, designing specific conventional signs	**Thematic maps**
3. f.	Revision of the cartographic visualisation	Revising and commenting on the cartographic visualisation by the specialists (can have several iterations)	**Approved thematic map, revised conventional sign system**
4.	Revision and integration of maps within the themes	Revising all maps, common supplementary components and the final layout within the theme	**Complete visualisation of theme information, revised and approved theme layout**
A.VI.	**Final design and publishing**		
1.	Preparation for publishing	Physically integrating all graphic components, preparing the Atlas for publishing	**Product ready for publishing (camera ready)**
2.	Publishing	Technical editing, publishing.	**Published product**
A.VII.	**Project management and co-ordination**		
1.	Development of. project organizational and support structure	Preparing project plans, forming project team, creating project infrastructure, assuring availability of necessary resources	**Approved project plans, project team, allotted project resources**
2.	Assignment and management of responsibilities	Selecting best specialists for particular tasks, optimizing performance of project tasks and use of human resources	**Assigned tasks and responsibilities, minimized project costs**
3.	Monitoring project activities and management of changes	Continuous evaluating of the project progress, solving problems, making and co-ordinating necessary changes	**Efficient performance, monitoring reports**
4.	Quality assurance.	Evaluating of the project results, solving problems	**Project results, delivered in time, matching their specifications and other quality requirements**
5.	**Documentation.**	**Preparing project reports and other documents**	**Full project documentation**

1.6.3 Project schedule

Duration of the project should be estimated from the start of implementation, either assuming that all necessary hardware, software and human resources are available or planning necessary purchases, installation and training. In case of sufficient financing and efficient management and avoiding unpredictable holdbacks, it is possible to keep up with the initial plan. However, time reserve of 5 to 25% of the estimated duration has to be planned; especially in the cases when supreme cartographic quality is to be sought. The bigger are the project risks and uncertainty level, the larger time reserve is necessary.

Several risk factors must be taken into account and adequate prevention measures planned:

- Complexity of thematic information and need for synthetic maps,
- Diversity of the target territory,
- Problem of different viewpoints on historical events and relationships,
- Management problem.

Whereas the general (A.I–A.IV, A.VI, A.VII) and also largely A.V activities can be fairly planned and managed, successful implementation of A.V.3 – Design of thematic maps, namely A.V.3 a–c, depends on several human factors that have to be taken into account before planning project human resources:

- Competence of the theme editors and their ability to select and manage the best possible authors for specific thematic fields;
- Availability of sufficient number of competent map authors or/and consultants from each field;
- Ability of the individual map authors to work together efficiently and bridge possible gaps between existing scientific viewpoints on some thematic issues;
- Efficient management considering possibly large number of involved authors and consultants from different fields, countries and institutions.

Project milestones

Several project milestones (control points) must be planned during the implementation time. A milestone is a scheduled event signifying the completion of a major deliverable or a set of related deliverables. A milestone has zero duration and there is no task associated with a milestone except evaluation and approbation procedures determined by the project management team. Not all project activities end at the milestones, for they may include time for corrections and other changes.

The following table shows an example of how project timetable and milestones may be arranged for some general activities.

Table 1-9: Example of the timetable of a project

	Year I												**Year II …**				
Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	…
Activity																	
A.I. Design of the information system																	
Detailed specification and design of the information system.																	
Preparation of business model.																	
Design of the databases.																	
Implementation and delivery																	
Development of overall project methodology.																	
A.II. Creation of the GIS database																	

Acquisition of geographic data																	
Preparation of general reference datasets.																	
Preparation of thematic datasets.																	
Integration of geographic and statistical data.																	
Spatial analysis and synthesis of data.																	
Creation of visualization schemes																	
A.VII. Project management and co-ordination																	
1. Development of project organizational and support structure.																	
2. Assignment and management of responsibilities.																	
3. Monitoring project activities and management of changes.																	
4. Quality assurance.																	
5. Documentation.																	
Major milestones																	

1.6.4 Technology

Cartographic information system typically includes the following components:

1. Hardware:
   a. DB and application servers,
   b. Workstations,
   c. Peripheral devices (scanners, digitizers, printers and special devices).
2. Communications (Intranet, Internet, telephone/fax);
3. Software:
   a. Database management system;
   b. GIS software;
   c. Specialized cartographic and graphic design software;
   d. Project resource management and document management software;
   e. Communication software.

It must be assured that all necessary components are available and properly integrated in order to guarantee successful implementation of the project activities.

Several workstations, differing in capacity and configuration, may be necessary for implementation of different project activities:

1. administration,
2. statistical data processing,
3. GIS / geographic data processing and conversion,
4. (Carto) graphic design (capable for processing also large raster images).

The requirement specification should include a general scheme of technologies used by the project activities.

1.6.5 Project team and organizational structure

Due to vast scope and complexity of some projects, the team must be organized as a hierarchical flexible structure, able to efficiently manage external information sources. Principal model of a complex organizational structure is depicted in Figure 1-5.

A. Project steering committee is an optional external structure that should be formed for very heterogeneous before the inception stage with a purpose to assure necessary political support for project activities and to achieve the best representation of the region in terms of different viewpoints and preferences of the interested parties. It should consist of representatives of each interested institution, most likely representing also the main data providers or other stakeholders.

B. External information sources play a significant role in any project. Usually, large investments have been already made into collection on geographic data, and most of them are distributed, therefore, establishing links with the most reliable data providers is sometimes much more important than collecting of data itself. Secondly, it may prove impossible to have all necessary specialists of thematic fields in a project team. Authors of the most of synthetic thematic maps of narrow fields of expertise, such as, for example, geology, landscapes, marine hydrology, economics, demography, history – come mainly from academic and research institutions and do a very little part of the project work each (e.g., activity A.V.3).

I. Project management level is the top internal project organizational level that consists of two blocks: Project management team and Editorial Board.

Project management team is fully responsible for successful implementation of the project tasks. Chief project manager, project co-ordinator and project administrator undertake general management tasks. Project secretary is optional, but desired, as a team member, fully responsible for project documentation. Several **chief specialists** (e.g., cartographer and data analyst) co-ordinate and report on work of corresponding groups of the Implementation team.

Editorial Board is responsible for quality of the cartographic product in terms of meeting the users' expectations, geographic correctness and cartographic communication. It should supervise the A.II–A.VI activities, evaluate and approve their results. The Editorial Board should have one **scientific supervisor** (preferably a person with significant academic experience and broad geographic knowledge, able to assure that the product remains consistent at any diversity of represented information). For atlases or map series, there must be **theme editors** for each major theme, responsible for the activities **A.II.4–5**, **A.III.1–2, and A.V.4** as well as for selection of the map authors and for revisions of the maps of corresponding theme. They report to the scientific supervisor on the project progress and quality concerning the corresponding theme. The number of theme editors may vary. Minimally, there should be separate supervisors for nature, society and culture, economics and politics and history themes. A larger number would be not efficient for consultants in narrow fields can be hired for a short period. Cartographer and redactor (copy editor) should also be in the Editorial Board as independent specialists responsible for quality assurance. Part of the permanent Editorial Board members may belong to external organizations, so it is not fully internal structure. Therefore its members have to be carefully selected based on personal qualification and responsibility criteria seeking to avoid management problems.

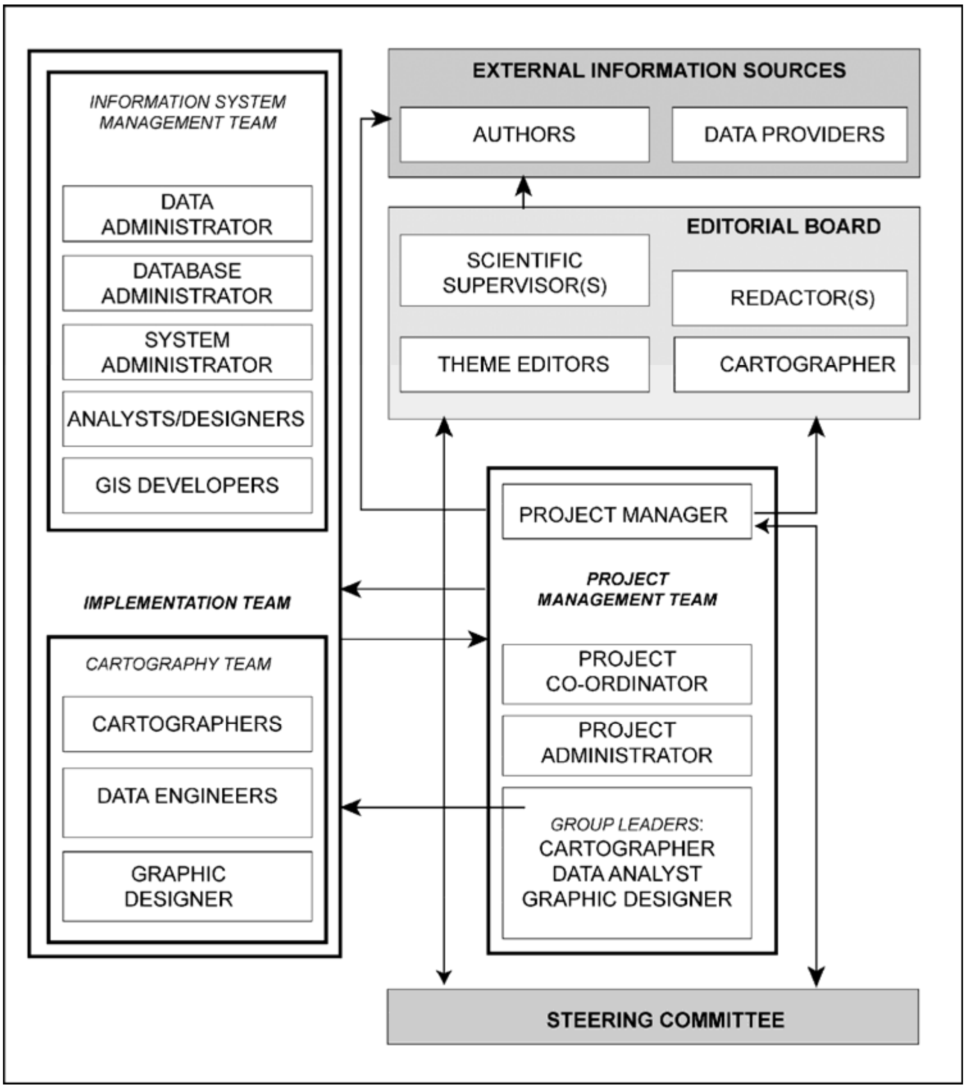


Figure 1-5: Organizational structure of a large cartographic project

II. Implementation level also consists of two blocks: Information system management team and Cartography team. Implementation level services may be provided by different cartography/GIS companies, preferably, jointly by a GIS company and a thematic cartography institution. Long and successful working experience, as well as academic links, is crucial for the project success.

Information system management team is responsible for continuous maintenance of the cartographic information system, mainly assuring proper functioning, availability and consistency of the databases. These team members are mainly IT specialists, such as data administrator, database administrator, system administrator, data/GIS analysts, designers and application developers. This team is fully responsible for implementation of activity **A.I** and, mainly, for **A.II** and **A.IV**. It also provides necessary technical support for other project activities.

Cartography team is directly working with maps design. Its members are mainly broad profile cartographers, although additional specialists in narrow fields, such as specialists of thematic fields, photographer, toponymy specialist/interpreter, style editor, etc., would significantly improve the performance. This team is fully responsible for implementation of activities **A.III**, **A.V** and **A.VI**; it is also involved in **A.II** (especially A.II subtasks 3, 4 and7) and **A.IV**. Chief specialists of this team should join project management team as group leaders.

The following table summarizes human resources needed for successful project implementation.

1.6.6 *Project management and co-ordination issues*

The following schemes show the responsibilities for the main project results and documentation.

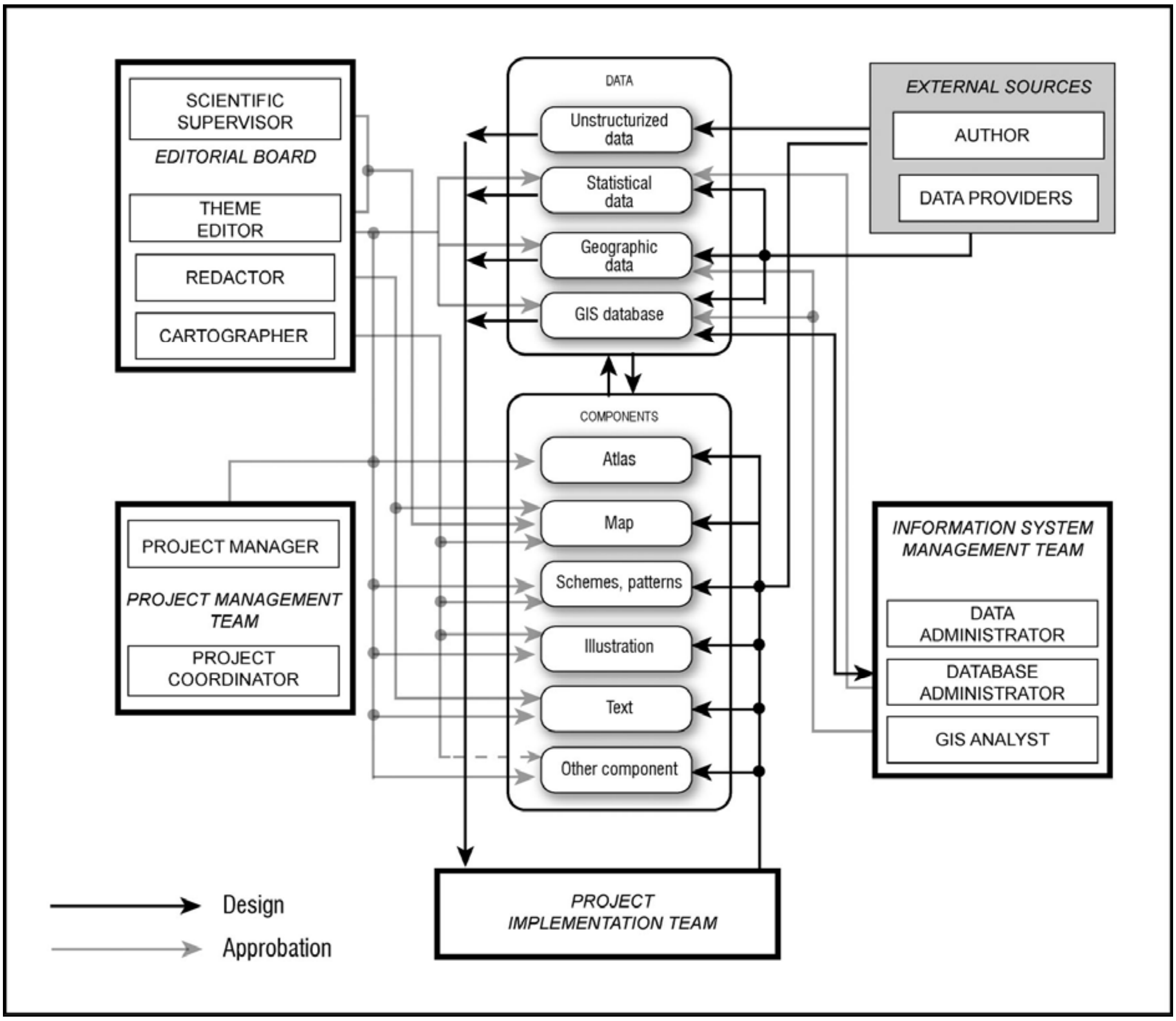


Figure 1-6: General results and responsibilities of a complex cartographic project

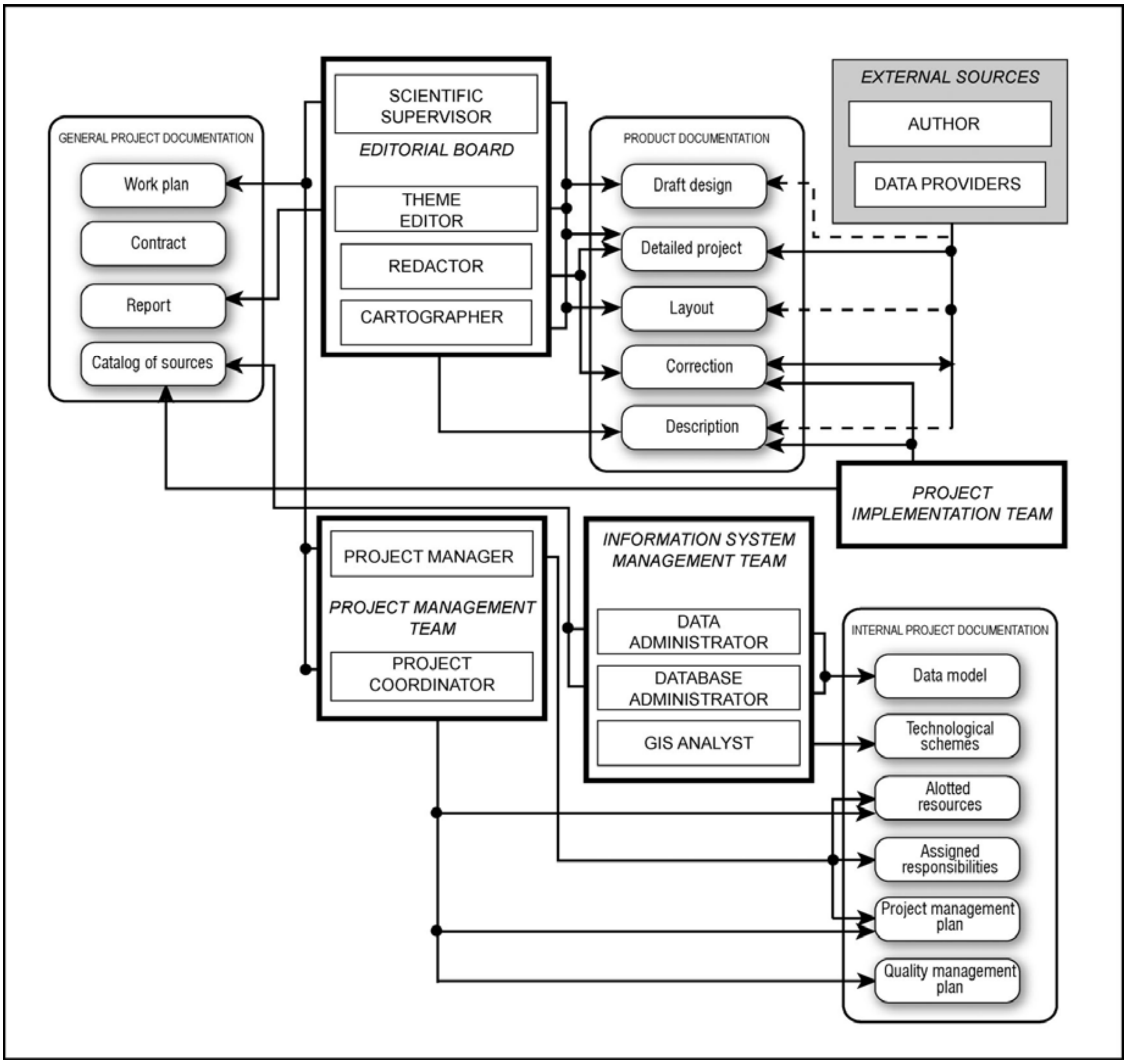


Figure 1-7: General documents of a complex cartographic project

Changes are unavoidable in any project of large scope and duration. Changes can be initiated by the Editorial Board and/or Project management team and involve requirements, results, schedule, project milestones, extent etc. Every change must be considered in all aspects, possible impact of the change evaluated and the change implemented in case of agreement between the contractor and the project team. Some changes may induce revision of the project schedule and timetable. As some changes require larger, than planned, resources, therefore reasonable overhead costs must be reserved (10 to 15% is recommended) and recalculated at the principal milestones.

Quality management is another important issue. It must be carefully planned and performed, considering the ISO 9001:2000 standard.

There are four elements which are central in evaluating the performance of a system. They can be described as follows:

- Well-defined objectives. Monitoring of a system cannot be carried out without a well defined objective;
- Clear strategy. Implementation strategies and assumptions must be outlined in the detailed project plan, as well as ways to attain and satisfy the objectives including institutions, organisations, finances and activities. They have to be assessed as the Project progresses;
- Outcomes (the results of the activities) arising from the objectives and strategies. Indicators should be monitorable and relevant for feedback to objectives and strategies;

- Assessment of performance.

1.7 Quality of the requirements

The main objective of professional cartographer-analyst is to make geographical information available for everyone who is interested. For that, it is necessary to foresee and classify possible users of the cartographic issue, find out their needs and the ways to satisfy their main requirements. It can be done using information engineering techniques, such as requirement engineering which is performed in early stages of the project.

Formal requirements for thematic cartography issues are easier to describe, classify, analyse, assess and put into practice.

There are two main groups of requirements: product requirements which concern quality of the issue itself, and project requirements, which describe the ways the issue must be compiled. Specifying requirement does not make sense unless there is defined some objective way to assess whether this requirement is implemented or not.

The characteristics of good requirements are variously stated by different writers, with each writer generally emphasizing the characteristics most appropriate to his general discussion or the specific technology domain being addressed. However, the following characteristics are generally acknowledged (Table 1-10)

Table 1-10: Desired characteristics of requirements (after Davis, 1993)

Characteristic	Explanation
Cohesive	The requirement addresses one and only one thing.
Complete	The requirement is fully stated in one place with no missing information.
Consistent	The requirement does not contradict any other requirement and is fully consistent with all authoritative external documentation.
Correct	The requirement meets all or part of a business need as authoritatively stated by stakeholders.
Current	The requirement has not been made obsolete by the passage of time.
Externally Observable	The requirement specifies a characteristic of the product that is externally observable or experienced by the user. "Requirements" that specify internal architecture, design, implementation, or testing decisions are properly constraints, and should be clearly articulated in the Constraints section of the Requirements document.
Feasible	The requirement can be implemented within the constraints of the project.
Unambiguous	The requirement is concisely stated without recourse to technical jargon, acronyms (unless defined elsewhere in the Requirements document), or other esoteric verbiage. It expresses objective facts, not subjective opinions. It is subject to one and only one interpretation. Vague subjects, adjectives, prepositions, verbs and subjective phrases are avoided. Negative statements and compound statements are prohibited.
Mandatory	The requirement represents a stakeholder-defined characteristic the absence of which will result in a deficiency that cannot be ameliorated.
Prioritized	An implementation priority must be assigned to each requirement to indicate how essential it is to include it in a particular product release. If all the requirements are regarded as equally important, the project manager is less able to react to new requirements added during development, budget cuts, schedule overruns, or the departure of a team member. Priority is a function of the value provided to the customer, the relative cost of implementation, and the relative technical risk associated with implementation.
Verifiable	The implementation of the requirement can be determined through one of four

	possible methods: inspection, analysis, demonstration, or test.

Requirements generally change with time. Once defined and approved, the requirements should fall under the change control. For many projects, requirements are altered before the system is complete. This is partly due to the complexity of the task and the fact that users do not know what they want before they see it. This characteristic of requirements has led to *requirements management* studies and practices.

During the implementation of a project, requirements can change for different reasons like: ignored users' needs in analysis stage, new needs discovered after analysis stage, changed environment and conditions of the project. Therefore permanent control of all activities and quality assessment of the results is necessary in every complex project. Then it is also easier to foresee and implement changes anytime during the life cycle.

There is no formulaic way to write excellent requirements. It is largely a matter of experience and learning from the requirements problems you have encountered in the past. Nevertheless, there are some common guidelines to keep in mind (after Wiegers, 1999).

- Keep sentences and paragraphs short. Avoid narrative paragraphs that contain multiple requirements. Do not aggregate multiple requirements into a single statement. Never use "and/or" in a requirement statement.
- Use terms consistently and define them in a glossary.
- To see if a requirement statement is sufficiently well defined, assess whether you would need additional clarification to understand the requirement well enough to implement it?
- Write requirements at a consistent level of detail throughout the document
- Avoid stating requirements redundantly. While including the same requirement in multiple places may make the document easier to read, it also makes maintenance of the document more difficult. The multiple instances of the requirement all have to be updated at the same time, lest an inconsistency creep in.

During the implementation of the project, requirements can change for different reasons: ignored users' needs in analysis stage, new needs discovered after the analysis stage, changed environment and conditions of the project. Therefore permanent control of all activities and quality assessment of the results is necessary in every complex project. Then it is also easier to foresee and implement changes anytime during the project life cycle.

2 Application of semantic modeling for cartographic transcription

2.1 New methods and traditional cartography

Cartography, like science in general, has experienced its ups and downs during the complicated historical development of the society. However, it always remained as purely applied science. Theoretical problems of cartography, especially of thematic cartography, were not so much investigated until the independence was restored in 1990.

Since that time the pace of changes in all spheres of life has been accelerating. Global digital revolution coincided with the worldwide-recognized crisis of information management. Suddenly there was a great demand for authoritative and diverse spatial data, new thematic maps and efficient methods for project management. Due to the lack of professional cartographers development of new cartography was mostly influenced by rapid and often uncontrollable implementation of novel digital technologies and by even less controllable growth of informational complexity in this sphere (Barker, 1990, Dodwell, 1992). Emerging problems had to be rapidly solved and it is not a surprise that the most of solutions were provided by specialists of information technology and computer science – from implementing particular software systems for geographic databases and visualization to recommendations concerning project strategy and management. Some of modeling techniques (life-cycle and dataflow modeling, structured diagramming techniques to aid communication and test understanding of analyst and designer, crosschecking of elements of the specification to ensure completeness and consistency, relational design and other) proved to be almost universal and soon attempts were made to apply them in thematic mapping and for cartographic transcription itself.

Such sweeping changes in thematic mapping eventually became the reason of a gap formed between the 'traditional' cartographers with geographic background and the new generation of mapmakers who relied upon modern technology and emphasized effectiveness and profitableness of cartography business as the most straightforward goals. This latter group was often (and justly) accused of amateurishness, ignorance of principles of semantics and aesthetics in cartography and even of geographic illiteracy. The most undesirable outcome of this conflict was formation of a stereotype that related the negative aspects of new cartography with computer and information technologies.

Even now, when professional cartography cannot anymore be imagined separated from digital technology, automation and formal models, this stereotype is very viable. Two typical examples containing opposite evaluations of 'traditional' and 'new' map (provided by 25 cartography and geography students) are presented in Figure 2-1. They show that from new generation of maps only functionality is expected. Unfortunately, there are very many examples among already published maps that back up such division of cartographic production into the two types. As the most of evaluated examples were printed in countries with much longer cartographic tradition, it seems to be something more than just a peculiarity of cartography in Lithuania*.

From the given evaluations conclusion can be drawn, that software and application of formal design methods have no or negative impact on the communicative quality of the production which is closely related with semantics and aesthetics. Evaluations of accuracy, level of detail and usability were not uniform. Does it mean that technology-oriented approach is hardly compatible with human perception?

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* Hereafter we refer to the mass production of thematic maps and atlases as maps of other types (topographic, inventory etc.) due to their limited methods of visualization and correspondence to strict standards rarely become a subject of this kind of discussions.

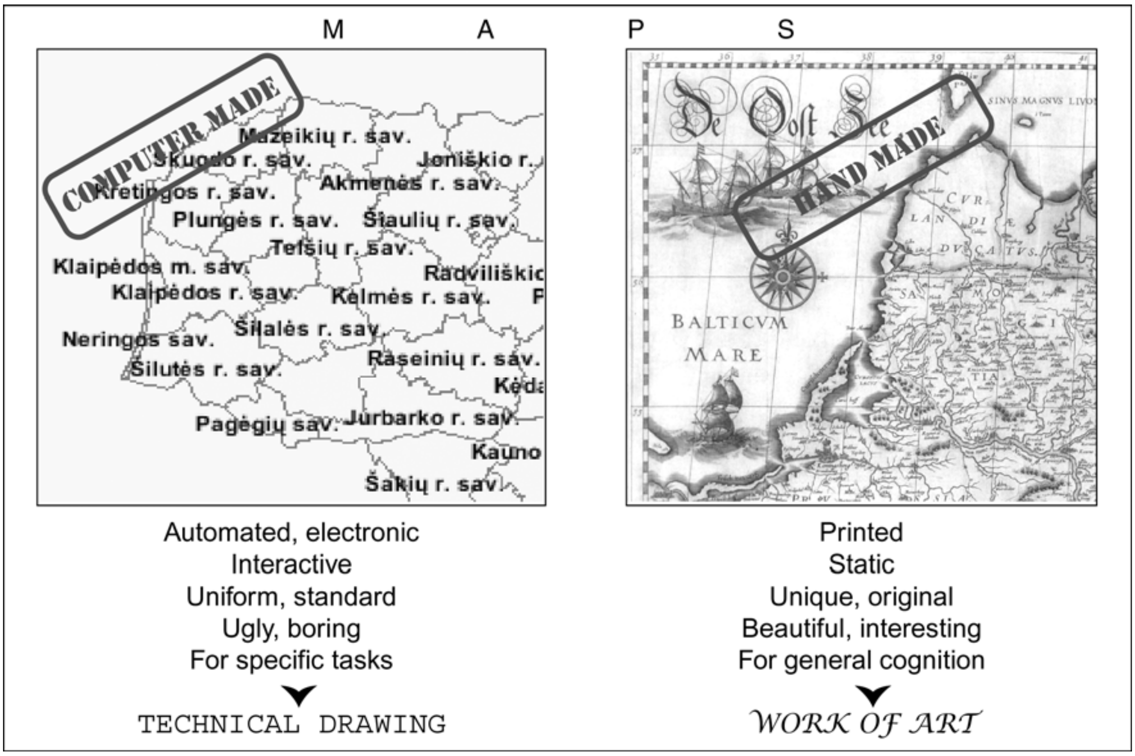

Figure 2-1: Antipodes

However, even the most traditional cartographers seem to not have ready recipes how to attain the desired communicative quality of the map. Besides the basic rules of graphical rendering, personal intuition and experience remain the only means that help to meet the semiotic quality requirements. It is still not clear how better quality of maps must be sought in response to their users and how people without longer experience or special intuition should be taught to avoid semiological errors.

We argue that even semantic correctness and aesthetics of cartographic visualization can be significantly improved applying different commonly used data-modeling techniques, in this chapter namely the entity-relationship modeling, as a part of conceptual modeling for cartographic transcription.

2.2 Semantic modeling technique

Entity-relationship (ER) modeling was one of the first data modeling techniques to be developed (Chen, 1976). It has become very popular, with numerous texts introducing it for the use of systems analysts and computer scientists. This technique is commonly implemented in spatial information systems. Concepts of entity and attribute are described in detail in the book of Laurini and Thompson, 1992. One of the main reasons for using it is that it enforces extreme simplicity. Another reason is that ER is conventionally presented in graphical form, which is considered to improve comprehensibility. It helps to structure information in a most natural way and to easily expand the structure in the future. The fragment of real world is perceived, selected and described in terms of entity, relationship and attribute that correspond to the three basic categories in modern philosophy. For the attributes, their domains (sets of permissible values) are specified.

However, even if this technique among cartographers has been recognized as effective, it is often shunted aside when it comes to visualization unless the latter is automated. One of the main reasons is inertness of thinking that hinders from introducing new approaches in any field. The second one, which is a little more grounded, is that ER technique is apparently resource consuming in early stages of the project while it does not directly yield a cartographic product but an abstract model.

Results of some investigations on effectiveness of ER-modeling for cartographic visualization allow asserting the following:

a) Applying ER-modeling minimum information is lost because attributes are never separated from objects;

b) The technique enables identification of semiological errors at early stages;

c) It follows from this that saving resources for correction and changes compensates the expenditure of labour and other resources for thorough semantic modeling in the stage of analysis*.

In Vilnius University ER-modeling was applied for teaching students to compile thematic maps confined to printed versions without dynamic behaviour or multimedia properties. In this chapter we will illustrate how it works for a single simple historical map though the real power of the method reveals compiling series of maps of different themes or when multidimensional systems of signs are used (e.g., for landscape, complex historical, prognostic maps).

Cartographic transcription using this method consists of five well-defined steps.

1. Data are analysed and the semantic model built representing the selected entities, relationships and attributes out of many provided or available (Figure 2-2, A). Different selection criteria can be applied in this stage depending on the type and purpose of the transcription (map).

2. The model is perfected by elimination of redundant entities and superfluous or unwanted relationships from the graph. Different constraints must be matched in order to confer integrity onto the model.

3. Compound graphical objects (or representational tools for digital maps) are designed in form of a corresponding ER model. ER-model for cartographic signs describes instances of graphical entities which have part of their attributes variable. A monosemantic correspondence between the sets of variable attributes in both models must be preserved. That means, for every attribute of geographic entity one (rarely more than one) attribute of corresponding cartographic sign is assigned, of corresponding type (nominal/ordinal, qualitative/quantitative, discrete/continuous etc., as described hereinafter).

4. One ER model is transformed into another (Figure 2-2, B).

5. The 'cartographic' model is transformed into the legend of the map and used to create the layout (Figure 2-3).

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* Actually it seems that both stages together make up a constant percentage of total expenditure (between 15 and 20%, but this number is still to be verified testing projects under different conditions). It is obvious, that reduction of corrections and changes is always desirable because any changes usually induce other changes thus eventually leading to inconsistency.

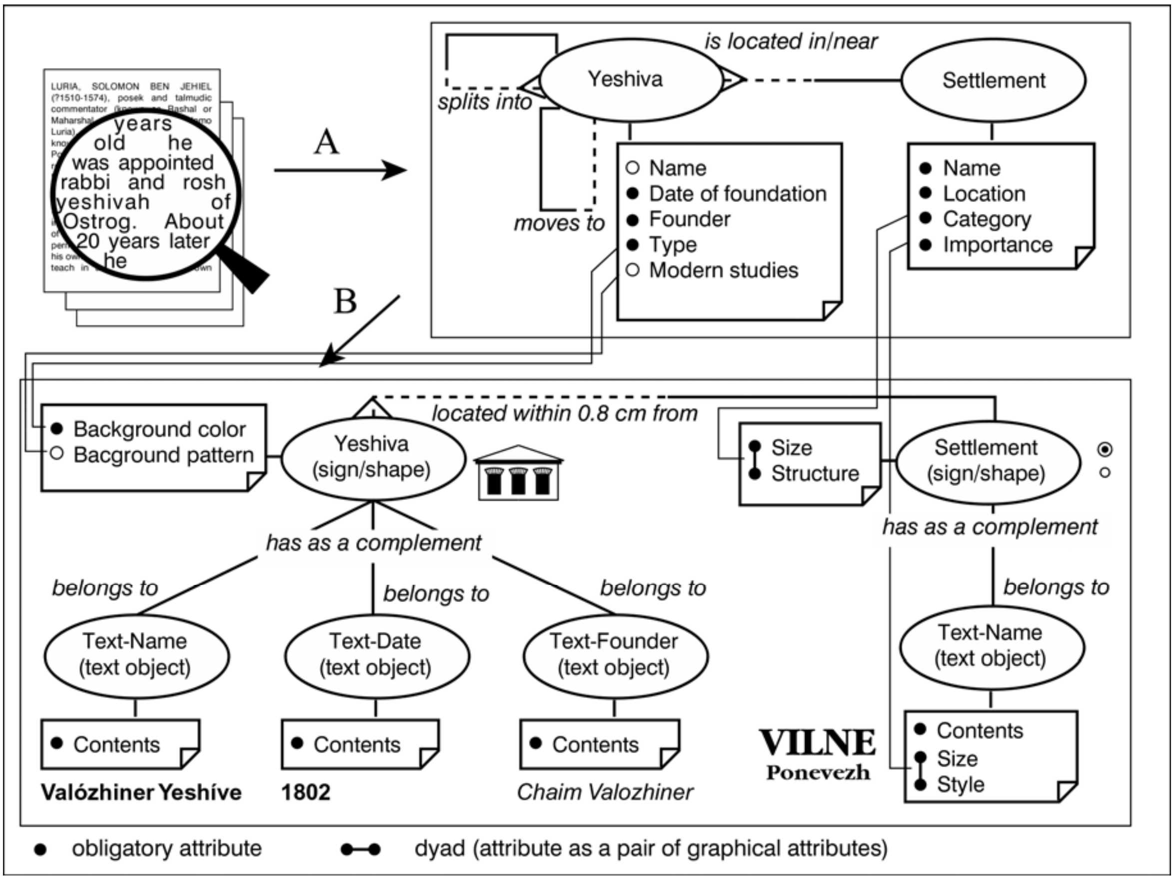

Figure 2-2: Fragments of two ER models for a map
Map of rabbinic academies (yeshivas) in Jewish Lithuania Source: *Lithuanian Jewish Culture, by Dovid Katz, 2004).*

A – building ER model from textual information; B – transforming it into ER model of cartographic signs. In order to simplify the diagram, only three relationships and two entities out of several are shown in this example; attribute domains are left out; only the variable graphical attributes are shown in the 'cartographic' model*. Etalons of cartographic signs/texts are shown next to the corresponding entities in the second model. Attribute of location for settlement dot markers is not specified as it is determined by cartographic projection.

The stages 3–5 make up the visualization part of cartographic transcription. The main designer's decisions here are: choosing fixed and variable attributes of graphical entities by comparison of alternatives reflecting different opportunities or constraints; setting values for the fixed attributes; specifying domains for the variable attributes.

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* The rest of the large number of graphical attributes is fixed thus forming up the distinctive style of the representation.

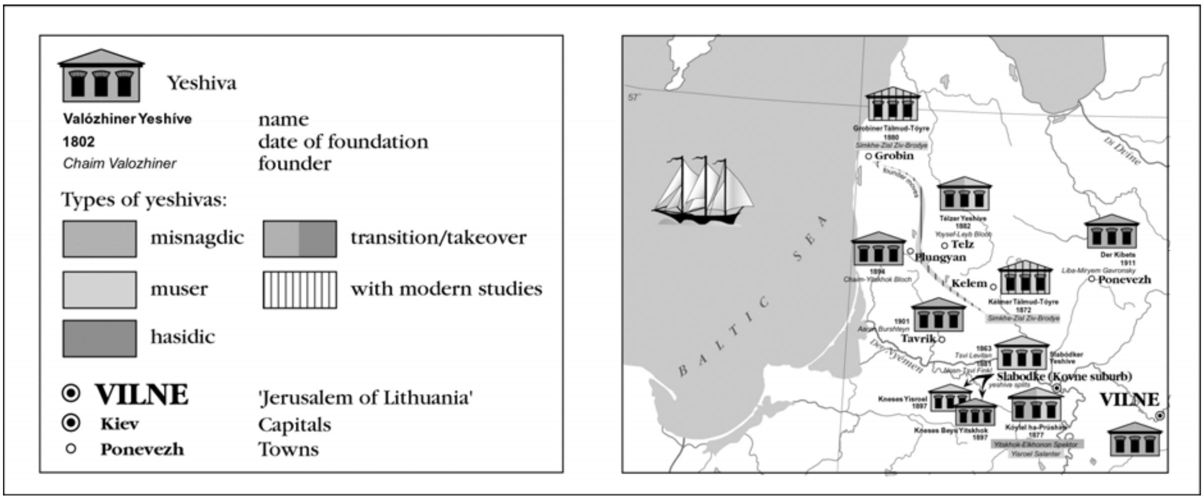


Figure 2-3: The legend and a fragment of the original map.
Data are provided by and used with the permission of Professor Dovid Katz (Vilnius Yiddish Institute, Vilnius, Lithuania).

2.3 Graphical objects and visual variables

Graphical object is an object designed to represent instances of a geographic entity in the map model or the abstract entity in the map legend.

To avoid confusion employing the term 'visual variable' (after Bertin, 1983) and 'variable attribute' it would be logical to separate graphical objects and their numerous attributes as it is shown in Figure 2-4. As the term 'variable' normally refers to an undefined, unknown value, we argue that it is more logical to treat cartographic sign as an object of particular shape** that has some attributes with no predefined values. Such attributes can be reasonably called visual variables.

Hence graphical objects (cartographic signs) can have two types of attributes. Values to the variable attributes are assigned for visual representation of an instance of geographic entity depending on concrete value of the represented attribute (e. g., colour: red for the type: Hasidic). Assigning values does not require new decisions because all transformations are made during ER-modeling: entity into entity, attribute into attribute, and domain into domain. During this process the domains must be checked for compatibility taking into account the general rules of cartographic visualization.

Another set of attributes is assigned values that do not change for concrete instances, e.g., font, style and colour attributes for place-names: black normal Times New Roman for settlement names and blue italic Arial for river names. These attribute-value pairs together with shapes of the signs make up the design style of the map.

From the point of view of traditional cartographers, semantic modeling suffers from another shortcoming, as though little space is left for the designer's creative work. We argue, that, on the contrary, shifting creativity to the early stage of the design allows improving even esthetical quality of the cartographic representation. For instance, all information can be structured into standard elements or traditional means of cartographic representation and 'new' specific elements, designed taking into account the purpose of the map, which make the map unique. Completely new graphical objects or different attribute values of standard objects help to raise different associations or even emotions (the ship in Figure 2-3).

** I.e., shape never becomes a variable, thus making our model closer to human perception. In fact, an object of different shape is recognized rather as another object than the same object with different shape property.

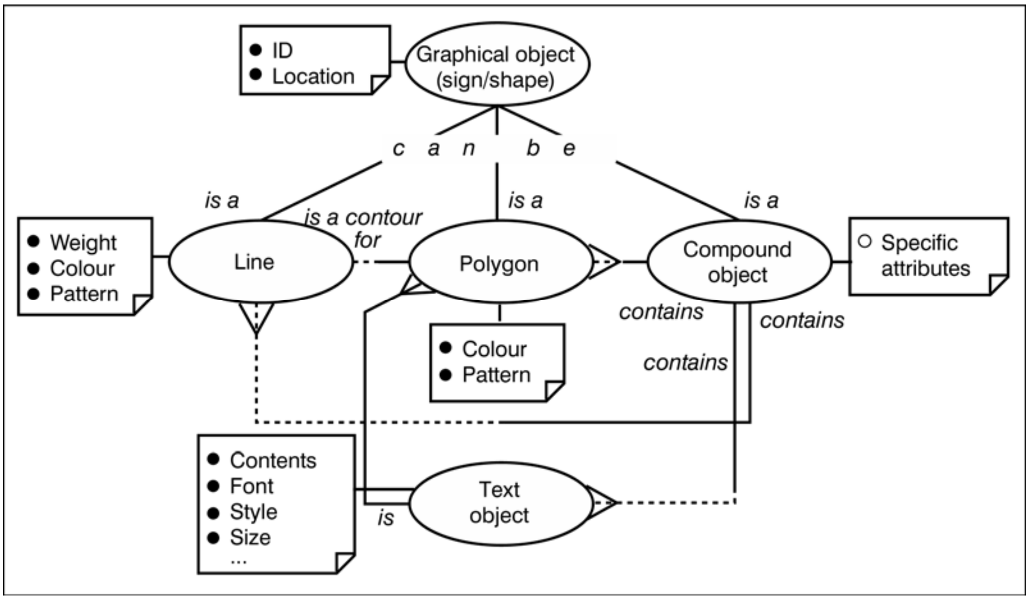


Figure 2-4: Graphical objects and their basic attributes.
All attributes of super type (relationship 'is a – can be') are inherited.

Graphical object can be either a primitive (line or polygon as point is not visible) or combination of primitives. Every compound sign can be formally described though often it is simpler to provide a template. Text object can exist separately, but in the most cases it becomes a part of a compound object. Compound object possesses all attributes of its structural parts and can have its specific attributes as of the whole. In principle, any sign can have not only graphical but also sound, tactile and other kind of attributes.

All cartographic signs have the location attribute that can be either set of co-ordinates (determined by geographic co-ordinates of the represented instance and cartographic projection, e.g., location: 50°20′/25°10′) or refer to another sign (in this case location of the sign is freely chosen within the specified distance from the reference object, e.g., location: Vilnius). Spatial relationships (connectivity, adjacency, containment) of graphical objects are determined by location as well.

It is convenient to translate all nominal attributes into contents of text objects that are parts of the corresponding compound sign. Structural parts of geographic entities are transformed into other structural parts of the sign.

Relationships in the ER-model have properties of cardinality and obligatoriness for the both ends. As they can also have their thematic attributes (e.g., date, density etc.), they are easily translated into graphical objects, e.g., linear pointers or other movement signs (relationship 'moves to' represented by arrow in Figure 2-3). That is convenient for representation of temporal phenomena where the attribute of time is very important. However, some appearing events, like, for example, change of type or change of attributes over time, cannot be effectively transformed into relationships and cartographic image. Such events are usually related with the 'behaviour' of objects.

Other choice for semantic modeling can be the object-oriented paradigm that focuses on objects, classes, behaviour and inheritance. Most of very comprehensive descriptions of a number of object-oriented analysis and design methods are limited to approaches to developing of software systems (Booch, 1994, de Champeaux et. al, 1993). However, application of the paradigm in the field of cartography seems more than natural, especially for interactive cartographic representations. This data-modeling technique is more complex but also more powerful when dealing with electronic, especially interactive cartographic products that compare to software applications in complexity and design.

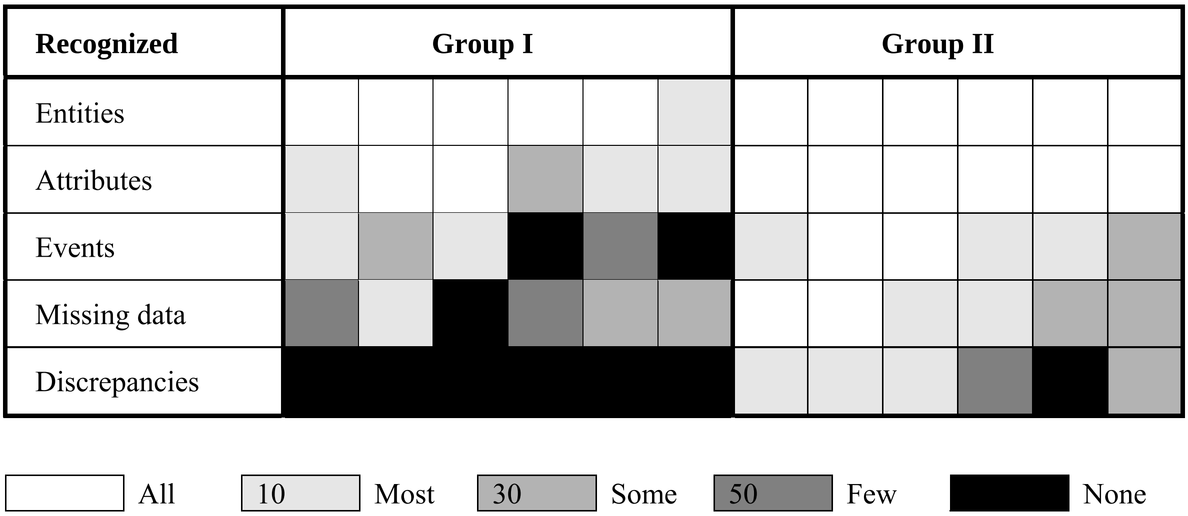
2.4 Effectiveness of the method

Discussing the effectiveness of semantic modeling two aspects must be mentioned: analysis of thematic data and cartographic transcription.

Analysis

It is well known that data for thematic maps often not only are intricate, but also inconsistent, incomplete or vague. It is especially difficult to extract useful information from dozens of pages of textual information, what is often necessary for compiling historical maps. ER modeling helps to elucidate the subject, separate and classify entities, attributes and events (in the most cases they can be graphically rendered as relationships). As it is required to explicitly specify the attributes, much less of potential information is lost and more errors or inadequacies are noticed. If more information is available, the model can be easily expanded preserving its logics.

Table 2-1: Results of data analysis for thematic mapping performed intuitively (group I) and applying ER modeling (group II).



Effectiveness of ER modeling for data analysis can be demonstrated by results of a test. Two groups of students with the same background (geography) were asked to analyze text and build a legend for a complex historical map. That is, they were expected to recognize all objects, their characteristics and events/dependencies that had to be shown on the map. Some data were missing and some errors were made intentionally (mismatching types and dates of events). There were 6 people in each group. The results are presented in Table 3-1 and from our point of view comments are not necessary even taking into account probability of impact of individual differences.

Transcription

Here we will refer to the framework for cartographic visualization suggested by H. Schlichtmann (Schlichtmann, 2003). According to him, there are three general functions related with transcription: signification, clarification and emphasis. Let us see how semantic modeling can help to attain these objectives.

1. Signification. All entities and hierarchies of entities are easily transformed into the graphical model. It guarantees that none of them is omitted. As graphical objects inherit shape and attributes of their super types, risk of semantic errors in visual representation of hierarchies or other complex systems is reduced. Choice of shapes, colours and fonts was also better motivated by the second tested group. Most probably semantic modeling prevents from leaving meaning of visual variables out of account.

2. Clarification. As long as integrity constraints are met, ER approach prevents from excessive use of visual variables unless it is created intentionally in order to emphasize particular entities or to prevent from possible interpretation errors.

3. Emphasis. Some attributes of the graphical object can be employed in many ways to make it stand out*. Usually dyads of variable attributes of the sign are used instead of a single attribute as it is shown in Figure 2-3 (B) – both font size (large) and style (capitals) are employed to emphasize the importance of Vilnius for Lithuanian Jewish culture. ER modeling always guarantees that methods of emphasis are regular and uniform over the entire map or map series.

Semantic modeling is a powerful technique of data analysis and their visual representation. Therefore it facilitates solving two basic problems in thematic cartography: project management and cartographic transcription. However, application of entity-relationship modeling in cartography seems to be not limited to these tasks. There are several more aspects that must be investigated:

1. ER modeling for defining relationships between signs within cartographic syntagmas or even communiqués. Formal description of syntactic and semantic rules of cartographic representation as relationships or object behaviour functions.
2. Usability testing using ER models (e.g., in order to detect situations when the types of entities and relationships between them are not recognized rightly).
3. ER modeling for better aesthetics of the map image.

* Importance of information redundancy for easier decoding is described by J. Fiske (Fiske, 1990).

3 Life cycle in cartography and models of historical map design

In this chapter we will briefly discuss some methods of information management that can be useful seeking better efficiency in process of compiling complex maps on historical events and phenomena. The experience of compiling historical atlases of Lithuania and of the world in Vilnius University allows asserting that popular methods of systems engineering, such as life cycle modeling, paradigms of thematic map design based on different life cycle models and some general principles of design comprise an effective method to minimize the design costs and improve the quality of the final product.

A thematic atlas and even a single map is a complex system in which different information has to be integrated and successfully visually rendered. Maps representing different periods of time and historical phenomena extended over time, such as wars, expansion, administrative and political changes belong to the group of most complex and resource-consuming cartographic products. Whereas modern visualization technologies and electronic representation tools are only been investigated for the purposes of mapping historical phenomena, such production is always in great demand, thus all the problems have to be solved for traditional printed maps time and again, often in conditions of pressing time limitations. It is a very urgent problem in post-soviet countries where the interest of society in historico-geographic maps is induced by prior lack of unbiased information of that type. This chapter is mainly based on the experience of building information systems for several continuous projects of atlases, such as Atlas of History of Lithuania (published in 2001), Atlas of the world history (published in 2003) and map series on Lithuanian Jewish history (published in 2004). Due to the space limitation we will only touch upon the question of project management success factors, leaving aside the problem of product quality, which is, nevertheless, also relevant to the methods of management.

3.1 Process-oriented approach to thematic mapping

The performance of each business function requires knowledge and that knowledge is changed or extended by the performance of the functions. Information systems are developed to manage and control the knowledge the business needs to support decision processes. If information systems within an institution are developed separately, it results in so called 'island systems' such as duplicated data, duplicated efforts to create a product, inaccessible information, a variety of unintegrated technologies and other similar situations that are to be minimized. A common framework allowing the development of integrated information systems as well as choice and flexibility is known as the CASE® Method (Dodwell, 1992) or 'information engineering' approach. Many models used by this method can be easily adapted for similar purposes in thematic cartography. In fact, some aspects of what we know as CASE method today, e.g. workflow diagramming and documentation, were raised to the level of cartographic theory even before the method became popular worldwide.

It is important to conceive the place of cartographic data and cartographic transcription processes within an information system of the institution first of all. Nevertheless, electronic thematic maps are complex enough to be treated as information systems themselves. The *life cycle* model describes the processes (the advantages of a process-centred organizational model have been proven in several studies, e.g. Hammer, 1996) that must be performed to achieve the goals of the information system in some defined order, successive or parallel, connected by the transferred data flows. Regarding the maps, it starts with the idea of doing something and comes to an end when the product is ready for use and distribution.

The essence of the system engineering approach is that the life cycle never ends but repeats itself in an unwinding spiral, whose radius demonstrates the size and complexity of the information system at a given point in time. All the data and knowledge created within the cycle are reused thereby facilitating the processes in the next cycle. However, an information system requires changes in its lifetime resulting from changes in the structure of information, the users' environment or the requirements or expansion to system wide scope. It is highly desirable that the system could develop in this way, growing in size without losing its initial structure for as long as possible. To make this feasible, all incongruities between logical schemes inside the system must be eliminated and even then it is difficult to keep up with the changes resulting from the specifics of cartographic *data* (diverse and often inconsistent) and *tasks* (it is often difficult to separate responsibilities between them even at the highest level of detail).

In our context of cartographic visualization, assuming that the mechanism for obtaining all the necessary data is clear and reliable, the cycle can be imagined as mainly creating and maintaining a database of representations. In this chapter we will try to outline the possible minimal structure of such a database in form of a semantic data model.

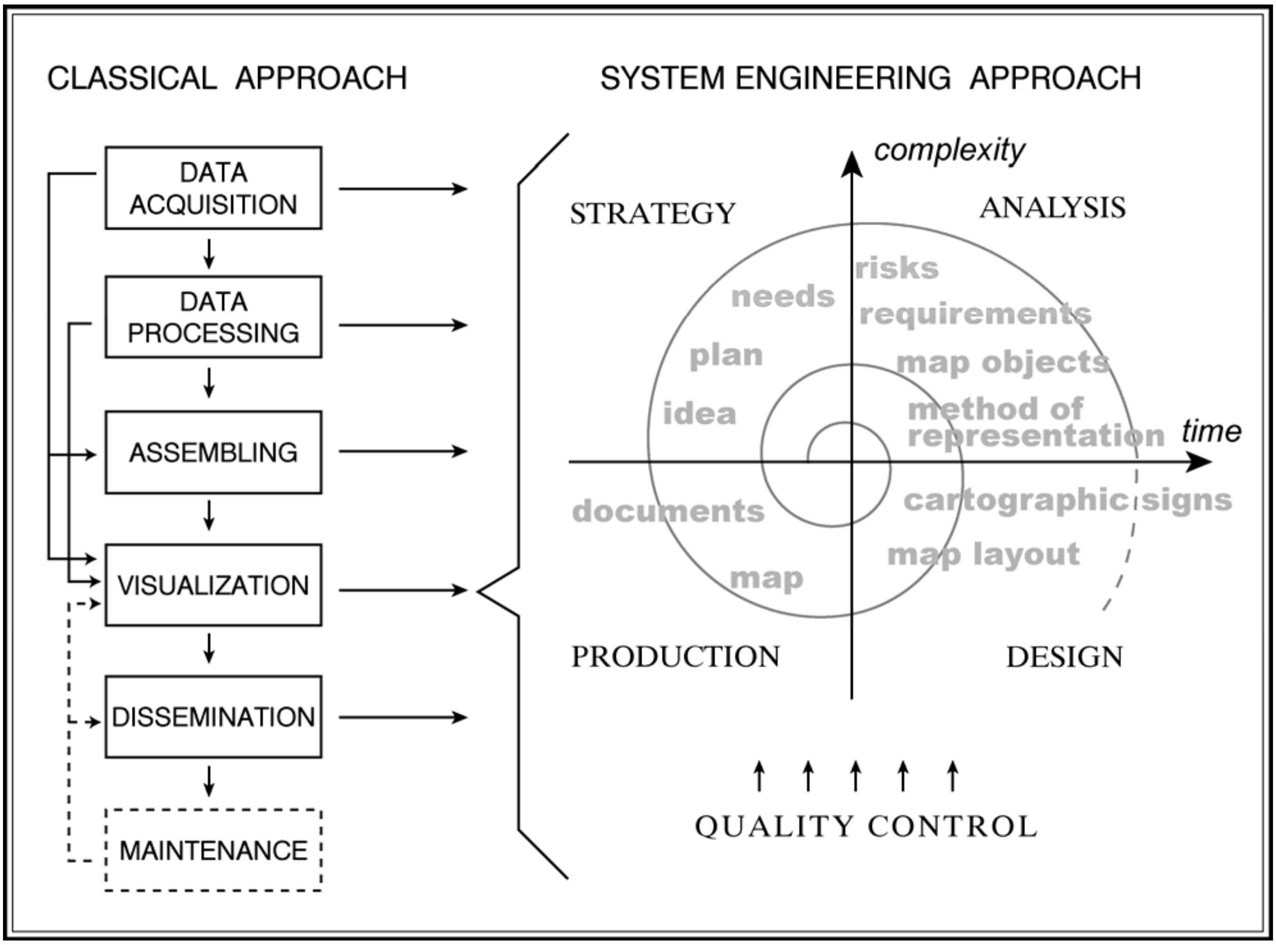


Figure 3-1: Process-oriented approaches to cartography

Figure 3-1 depicts the life cycles of map production where the basic stages are arranged in classical consecutive order and the general spiral life cycle model that must be applied for each of the successive stages.

The aim of the **strategy** study is to produce recommendations and plan for development of the product (data, map or software), ensuring that the problems of 'island systems' are reduced as much as possible. The main objective of the **analysis** stage is to verify and expand the recommendations from the strategy stage in order to create a sound basis for design. In the **design** stage detailed requirements from the analysis stage are taken and carried out. Design alternatives are evaluated against user requirements until an acceptable solution is found. The processes are thereby iterative in this as in all the four stages.

The stage of visualization is the most specific in the classical model. It can be decomposed into many possibly parallel processes that can be arranged and performed in different ways within the strategy, analysis, design and production sectors of the spiral model producing deliverables as shown in Figure 3-1. The processes of design deserve special attention in visualization because the most important decisions about the method of representation, signs and map layout are made in the design stage. Good design is based not only on good project management but on a good conceptual model first of all.

3.2 The specifics of historical map projects

The main reasons why preparation of a map, representing historical data, is resource consuming out of proportion to the quality of the result are as follows.

Specific information. The spatio-temporal information on historical events to be represented in maps requires thorough understanding of it in each particular case, what is not possible without corresponding knowledge. Therefore analysis stage cannot be skipped even if all thematic information is provided by a specialist except extremely rare situations when the specialists possess geographically consistent thematic information. Different viewpoints cause another common problem which requires additional factographic analysis (Einkelstein et al., 1994, Ross, 1980).

The basic geographic features must be represented as they were in the involved period of time while hydrographical network, place-names, network of settlements has changed over time and it is generally impossible to obtain consistent and reliable data from before GIS era. Besides that, such maps vary in scale and territory so it is impractical to store geographic information with temporal attribute for each feature. Usually the geographic data must be transferred from various old maps or traced from textual descriptions and are generally not re-usable.

Specific visualization. Representing complex and diverse spatio-temporal phenomena on a static 2D image cannot be standardized, especially considering the fact that an element of sound emphasis if not suggestion is often desired. Therefore unique, graphically complex and attractive cartographic signs must be used. This requirement basically makes commonly used but graphically not perfect GIS systems inapplicable in the last stage of the map design.

Miscommunication. To create a comprehensive map of some historical period, the knowledge of history and specific thematic fields like ethnology or linguistics, as well as of geography and cartography is required. For it is impossible that all involved specialists have equal skills and similar viewpoints, it is usually difficult for them to understand one another’s needs and requirements.

3.3 The top-down approach

The above mentioned problems is the main reason why communicative and aesthetic quality of maps representing historical data, even of those published in countries with a long cartographic tradition, is often insufficient. There are two main approaches to building systems in general: bottom-up and top-down methods of system design, depicted in Figure 3-1.

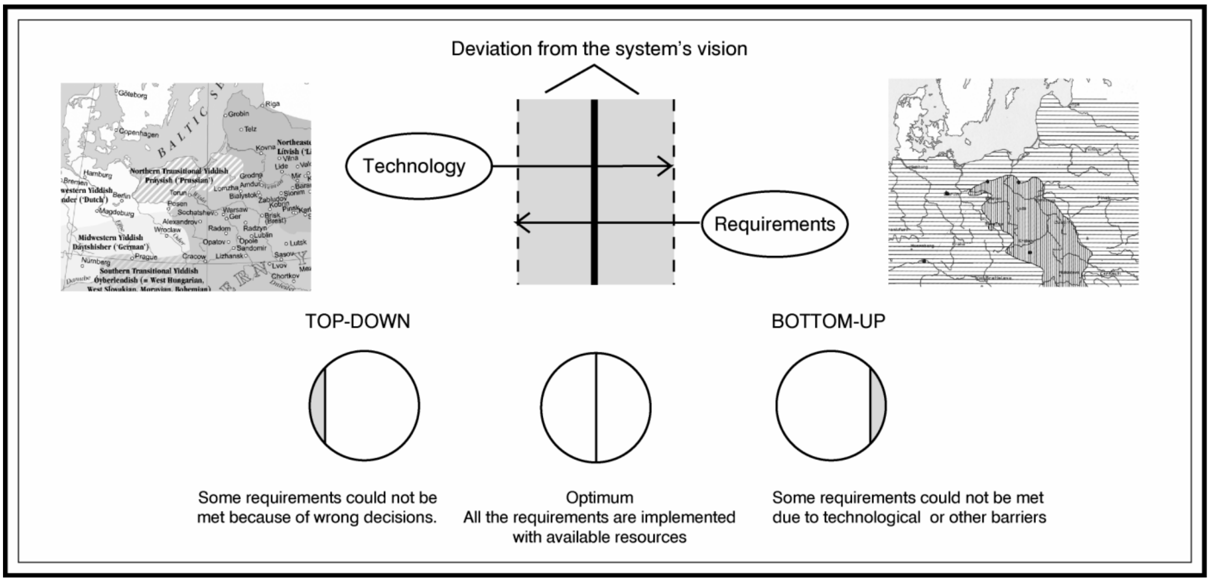


Figure 3-2: Top-down and bottom-up approaches to map design

The *bottom-up* approach in our case manifests in adjusting the specification of a map to the already existing technological facilities and other affordable resources. It means that some requirements from the specification are withdrawn in order to make the project economically feasible in a short time. In the worst case only very basic requirements can be met. It is the case of the map fragment in Figure 3-2 on the right, which is taken from a linguistic atlas (The Language and Culture Atlas of Ashkenazic Jewry (1992) Vol. 1., Max Niemeyer Verlag, Tuebingen). Nevertheless, it is a very common approach for maps representing historical data in the companies which do not specialize in namely this field of thematic mapping.

The *top-down* approach is considered more progressive for it implies orientation to the long term institutional goals. Following this approach all the necessary resources and skills have to be acquired in order to meet all the specified requirements for the particular product and to facilitate similar projects in the future. Diversity of times, scales, territories, themes and emphases in maps and atlases on history requires an unusually complex cartographic information system and a large spatio-temporal database. Sometimes in addition to GIS, graphic design software packages must be purchased. Although the expenditures on system implementation increase many times compared to the first case, the quality of its products is almost always much better (the fragment of map based on the same initial data designed in 2003 for *Lithuanian Jewish Culture* in Figure 3-2 on the left). Moreover, a big part of geographic information is reusable in future projects thus making the costs go down for every next project.

Regardless of which approach is chosen, historical mapping remain problematic because of the above listed problems. Partial solutions to these problems are, however, related with the top-down approach as they employ systems engineering methods (Modell, 1988, Barker, 1990). They are based on

a) paying special attention to particular phases of the life cycle model (assuming that such model is always applied);
b) choosing the most appropriate paradigm for thematic map design and upholding it during the whole life cycle;
c) obeying the relevant general principles of system design, such as unification, decomposition, metaphorization etc.

3.4 Significant stages of map life cycle

A life cycle concept is applicable for continuous projects of both printed and digital map products. The essential phases of classical life cycle model and their main results are depicted in Figure 3-3. Whereas all the phases have to be carefully planned and maintained, some stages of them become more critical when we deal with maps on history.

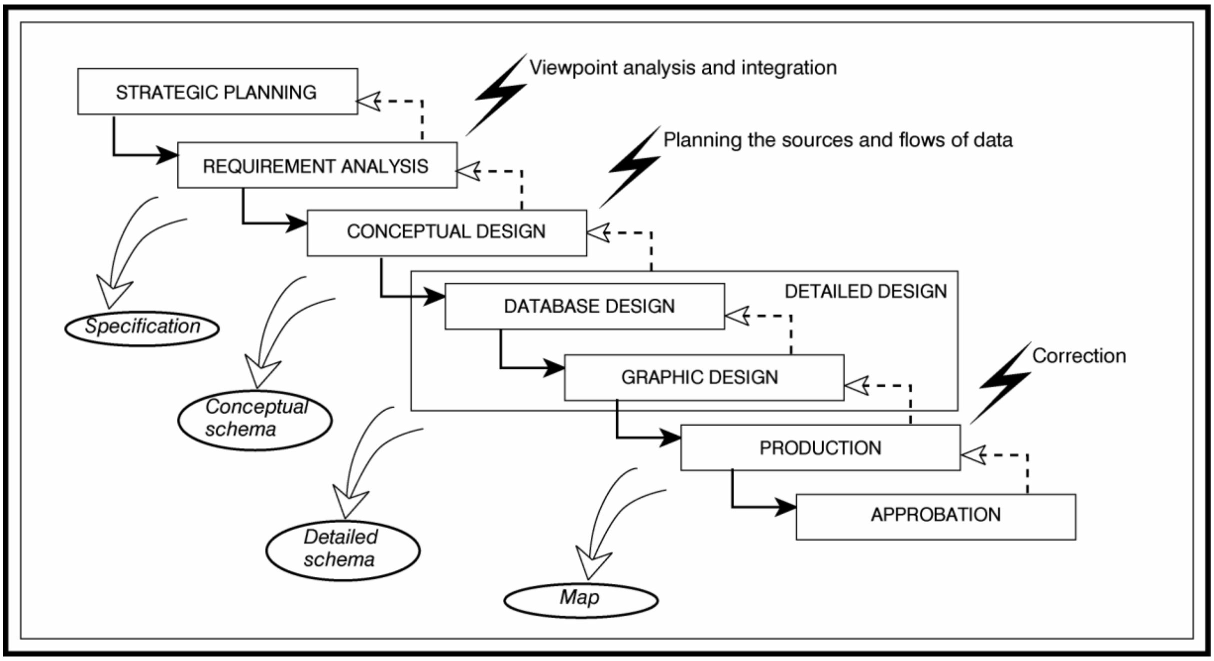


Figure 3-3: Life cycle model and stages of special importance for thematic mapping

Requirement analysis and viewpoint integration. Specification of the requirements to the product is the main result of this phase. It is natural that designing every product we seek for maximal degree of adequacy with the requirements specified. However, historical data are often interpreted differently. Incompatibility of viewpoints, like, which of several sources of data must be trusted, what phenomena must be represented and how, etc., can arise when different contexts and persons are involved. In that case it is essential to not rely on a single opinion or source of information. To integrate different viewpoints, a viewpoint analysis and integration stage must be given special attention in the analysis phase. A possible schema for integrating two different viewpoints is presented in Figure 3-4. The result of integration is usually a compromise, which is not fully acceptable for either of opponents. Still, it largely allows avoiding subjectivity and related problems in the future. On the other hand, differing opinions usually complement one another, thus neither of them should be lightly disposed of.

Conceptual design. Because of the possible diversity of viewpoints all prospective sources of data must be classified and documented and the schema of data flows thoroughly elaborated, indicating the remit and responsibility of all persons involved. Two phases of design, namely database design independent from graphic design (visualization) must be also foreseen in the conceptual schema in order to prevent modifying geographic data after they are used in the final design.

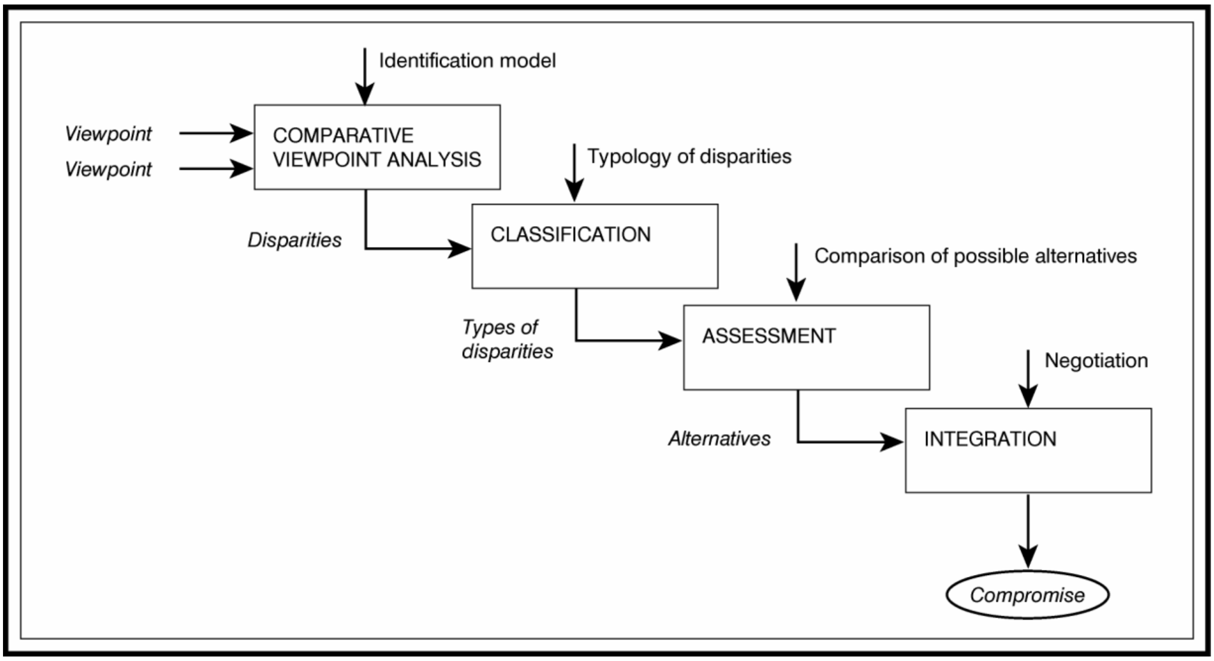


Figure 3-4: Integration of viewpoints

Correction stage. Whereas it is altogether possible to minimize the costs of the correction stage by applying different modeling techniques in earlier phases of the project, it is usually not so with maps on history. The corrections are inevitable and have to be planned as a separate stage of the production phase. Seeking to minimize the costs within this stage a correction procedure and problem solving process processes must be planned.

3.5 Three models of thematic map design

Three different sets of theoretical and methodological principles that can be called paradigms of thematic mapping are figuratively depicted in Figure 3-5. The outlined grey circle pictures an 'ideal' product (assuming that its quality can be satisfactory for both designers and users). The outline of the circle corresponds to the amount of thematic information represented. The grey colour shows the implementation of the product and inadequacy of its version to the ideal. As it can be seen in the figure, in principle the same result can be obtained regardless of which model is chosen. However, the efficiency of work very much depends on the apt choice. Choice of the paradigm and corresponding model depends on the type and complexity of the product and on the relationship between its users and developers.

Framework model is the most generally applied (directly or not) in almost all kinds of thematic mapping whenever series of products with similar structure are designed. It is fully subject to the classical consecutive life cycle model and can be called a manifestation of non-semantically structured approach.

The essence of this model is that the system is always decomposed into components according to some logical schema which is used as a framework to assemble the ready components. Both extent and structure of the system are designated by the specified requirements. The components filling the given structure can be acquired or designed in different ways. It is always possible to measure the deviation of current version from the specification. The manifestation of the framework model is splitting large maps into sheets, objects of the same type into qualitative categories and processing each component separately.

As long as all components of maps, map series or atlas have to be designed and implemented according to same standards and rules accepted within the mapping institution, the structured approach naturally becomes a part of object based or other basic models. For complex thematic maps' systems it can serve as the main paradigm when

a) initial requirements are precisely formulated, comprehensive and largely explicit;

b) there is a sufficient amount of data and schemes that can be reused;

c) the same tasks are pursued by several people.

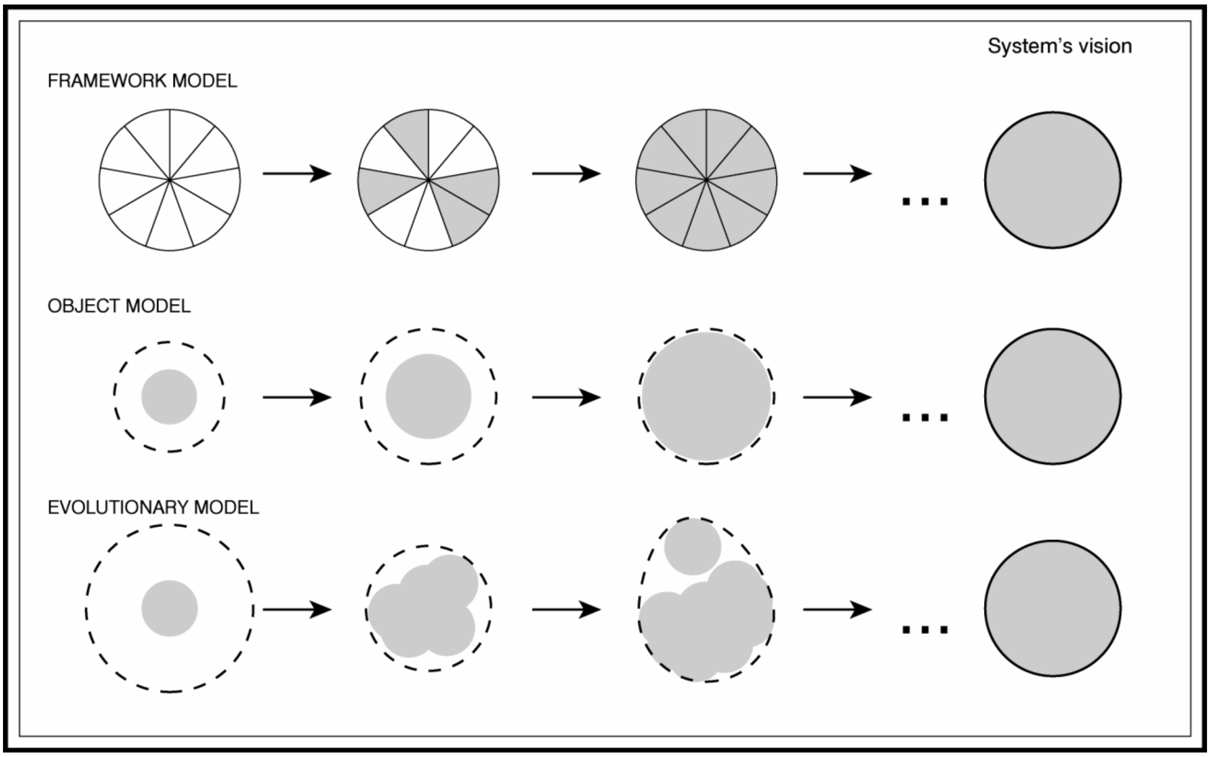


Figure 3-5: Three models of thematic map design

Object-oriented design paradigm embraces an entire spectrum of similar problems and is neither monosemantic nor uniform. In our case it means application of semantic modeling, for instance, entity-relationship modeling, from the conceptual design phase onward. It is also fully compatible with the depicted life cycle model. An object (entity) is an abstraction of a real object, process or phenomenon which contains all information about the object, needed for the design of a model of the application field, and does not contain any superfluous information. It is possible to represent the objects' information in a simple diagram, understandable for everybody including the customers who do not need special knowledge to review and amend the information model in any stage of the project.

According to object approach, the most significant entities and their attributes are integrated by means of relationships into an information model, which is amplified and refined and only then implemented in the database model and in the system of conventional signs. In any stage of the project the difference between the product and its final specification can be measured to a certain extent.

Object model is the best in the case when:

a) it is possible to allot enough resources for the analysis phase in order to formulate a comprehensive initial specification;

b) the requirements formulated by customers are unambiguous, though they can be discrepant;

c) there are many different objects and complex hierarchies of objects to represent;

d) it is likely that the scope of information will be subsequently extended.

Evolutionary model means that the product is designed as serial versions, starting from the draft version which is designed to meet the very general initial requirements. Each version is subjected for review and correction by different specialists (Figure 3-6). With every new version the prior requirements are also revised and new set of more detailed requirements is formulated. The process is repeated until no more essential critique or requirements are issued.

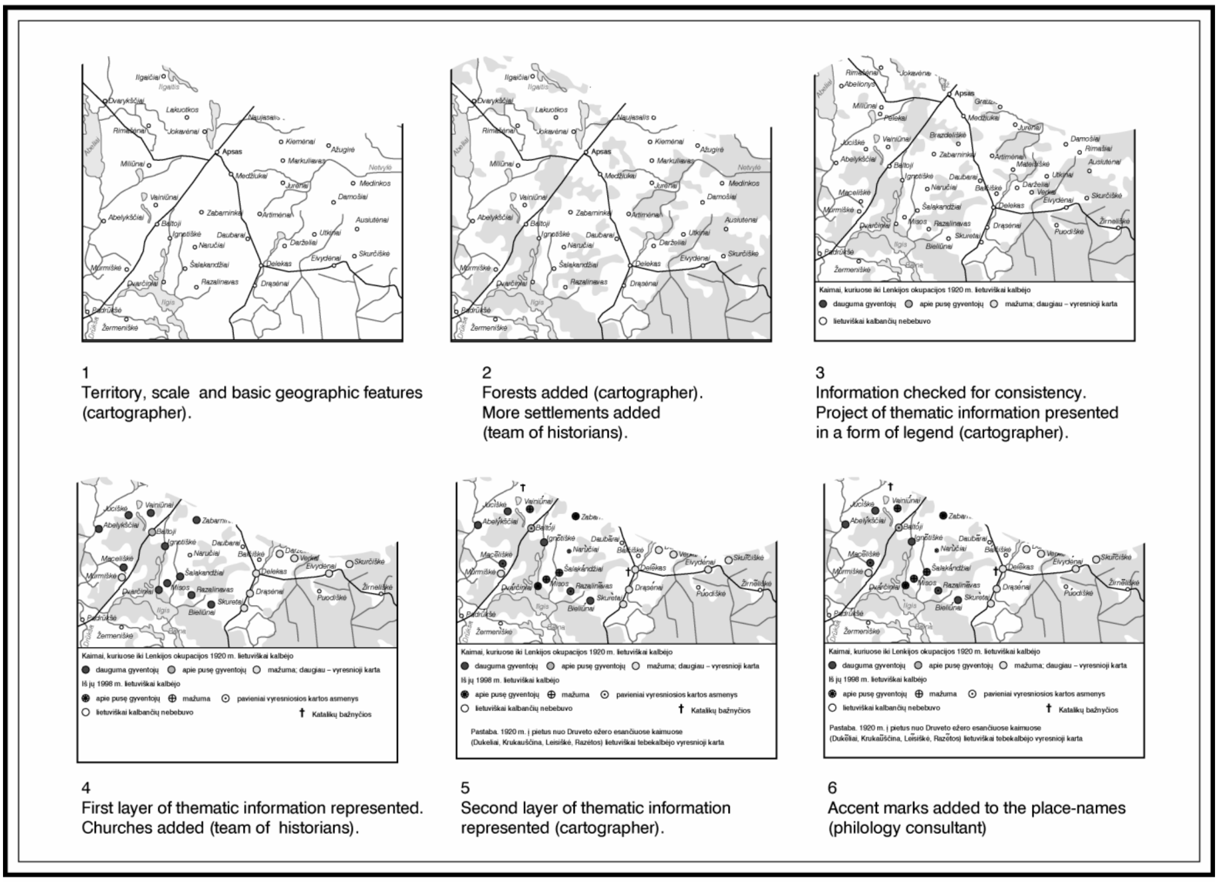


Figure 3-6: Versioning according to evolutionary paradigm

The evolutionary model is a good choice when the time and other resources for analysis stage are limited and the specific requirements for thematic information very abstracted or not clear. Only very general initial requirements are specified, e.g., on mapped territory, scale, format, special conventional signs and other, which are exactly understood and can be approved by both customers and cartographers. Then the full extent and structure of information are unfolded basically step by step. It is difficult to control the changes and almost impossible to measure the difference between current version and the 'ideal' product. On the other hand, this approach is very flexible and leaves more space for alternative solutions. It requires a life cycle model, different from the consecutive model in Figure 3-3.

It is also the most user-oriented model. The customers and the final users of the product can see every improved version, so step by step they start better understanding their own needs and are able to explain them more accurately.

There is a danger that more and more versions will be requested until the limit of time or other project resource is exceeded. Continuous changes can also result in destroying the structure of already created product and further improvement would make no more sense. To avoid that, rigid validation criteria for additional requirements have to be specified before the design stage.

Thus, this model is to be used when:

a) the requirements are non-comprehensive and ambiguous (however, it is desired that they were not conflicting, otherwise they have to be reconciled in repeated viewpoint integration stages what usually makes the evolutionary approach inefficient);

b) thematic information is uncertain and vague;

c) specialists from different fields are involved;

d) communicative quality of the product is of special importance.

A new point of view to information handling in thematic cartography can aid to improve an efficiency of work and quality of the production, especially when complex maps on historical events and phenomena are concerned. It is based on modern methods of systems engineering which proved to be useful designing cartographic information systems in general. If the products of such system are printed maps, these methods only serve the purpose when particular level of complexity is reached. However, considering that modern maps practically do not differ from software products, systems engineering approach seems utterly natural. It provides a solution for the most problems incident to informational and task complexity.

4 Conceptual models for cartographic representation

This topic was inspired by recent discussions of the possibility of a universal map language, a framework for cartographic visualization and a need for a theory of spatial (including cartographic) information in general (Moellering, 2003). Regardless of a vast number of texts devoted to the semiological aspects of map language no system has been created that would describe and explain cartographic signs in all their complexity (Lyutyi, 2002). The decisions about signs in thematic cartography today, like twenty years ago, are mostly based on sets of heuristic recommendations which do not make up a strictly logical system. The more complex the system of signs, the more difficult it becomes to apply the rules. Other than in the simplest cases, it is impossible to limit cartographic design to a single set of rules at all; hence thematic mapping can hardly be subject to automated processing functions. Nor is there an algorithm that could be used to check the symbolization choice for correctness. In order to minimize the gap between theories and practice, we propose to concentrate on developing information models that can easily be tested for their efficiency in thematic cartography.

4.1 The role of conceptual modeling

The process of information modeling for cartographic transcription is depicted in Figure 4-1. It has a clearly defined place in the well-known cartographic communication model developed by L. Ratajski (Ratajski, 1973); however, we will not describe it in this chapter but concentrate on those of its aspects related to the modeling of graphics (or other means of representation) in cartography.

Three levels of modeling must take place between the source and the physical storage of data. A conceptual model (hereinafter CM1) is the result of selection, abstraction and generalization processes applied to the part of the real world from which the data originate. It is a description made in more or less 'human' terms, including objects, relationships or visual variables and can be represented at different levels of abstraction. A good model is a stable representation of real life. Logical modeling is based on a given conceptual model and results in a structure of database objects, e.g. tables in a relational database. A logical model is not required to have the same structure as a conceptual model and usually it does not. A physical model describes how data are stored in memory. All modern user interfaces are based on some conceptual model in order to make working with data more comfortable. Thus both physical and logical models normally are 'hidden' from the user. The upper line in the figure depicts all three levels of modeling for geographic data. Cartographic transcription begins when there is a need to visualize these data, hence to provide a symbolic graphic interface to the data, and that in turn implies design of a specific conceptual model for map symbolism (lower line in the figure). We will call it a conceptual model for map objects (hereinafter CM2).

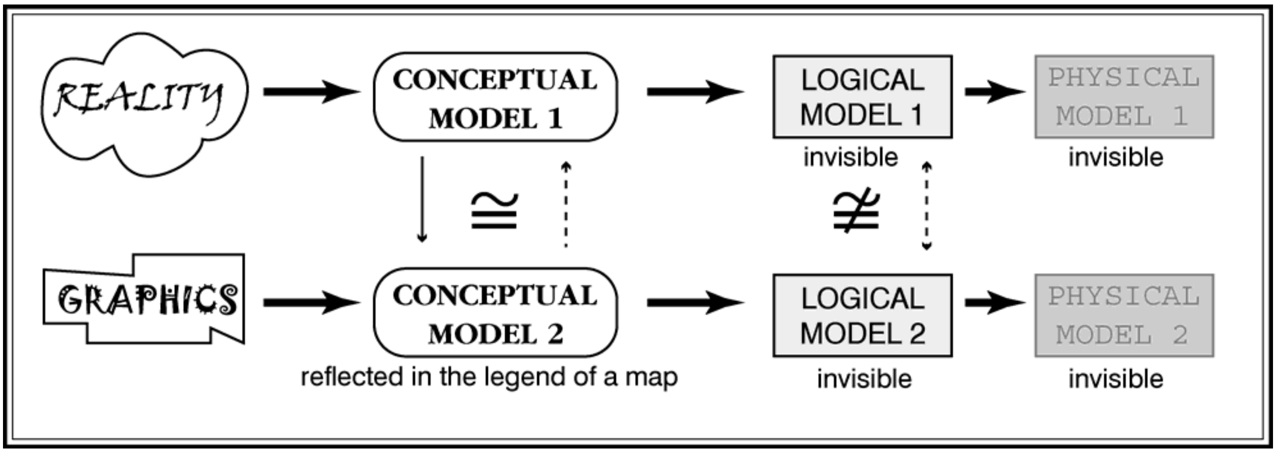


Figure 4-1: Two conceptual models in the process of cartographic transcription

Physical representations of map symbols and map objects are independent of each other. That is not the case at higher levels of abstraction. Logical models are not isomorphic but must be compatible at the database level, i.e. uniformly transformable into each other. The two conceptual models are of the greatest importance in the process of information communication and it is desirable that they be isomorphic because that is the only way to maximize the intersection of 'cartographer's reality' and 'user's reality' reproduced from the map in Ratajski's model (Ratajski, 1973). That is the case because both models are explicitly presented for the user in form of map legend: CM2 as the graphic objects and CM1 as their textual explanations[1]. Thus the user is prompted to think of map information in terms of both of CM1 and CM2 and any little inadequacy between them becomes confusing, hindering the correct interpretation of the information, not to mention discovery of new knowledge. Moreover, it is these terms in which we get feedback from users. Unfortunately, the importance of conceptual modeling is not yet universally recognized.

We cannot expect complete isomorphism between illimitable reality and the limited realm of graphics. That is therefore relegated to the status of a theoretical ideal. In practice CM2 is in some aspects usually less and in others more than CM1[2]. The main task of the cartographer is to ensure that at least all notions of CM1 find their representations in CM2. Considering the diversity of represented information, it is not a simple task.

There are some very general requirements for this twofold conceptual model.

- ALL geographic and graphic entities with all their attributes that are of interest must be represented in the model.
- There must be a possibility to represent all the relationships between the entities.
- The model must be extensible without changing its basic structure.
- A transformation function must be defined between the two CMs at any level of detail.
- The basic rules of cartographic transcription must be obeyed: different objects represented by different signs; an object represented by the same sign in one map; quantitative characteristics represented by quantitatively measured graphic characteristics; hierarchical structure conveyed; general concepts represented by more abstract signs; related objects represented as related etc. (Spiess, 1970).

4.2 Conceptual models of cartographic information

There are many different ways to organize graphics and other information that is used to create a visual representation of spatial data. We will discuss only three general methods that are widely used for map graphics.

4.2.1 'Visual variables' approach.

There is general agreement on the graphic primitives (point, line and area objects for 2D). Variations of such primitives in size, orientation, colour and some other attributes are traditionally called visual variables, introduced, classified and related to characteristics of human perception by

[1] Failing to take conceptual models into account, the building of the legend is quite often referred to as a one of the last processes of the visualization stage, misleadingly suggesting that the legend is an independent part of a map. In fact, the legend as the set of prototypes of cartographic signs must be constructed even before the variable attributes of signs are chosen.

[2] CM2 embracing more than CM1 is not yet the case when new knowledge is produced as a result of 'explorative analysis' but rather related with emphasizing of some entities, attributes or spatial organization. Normally it is not practical to extend CM1 so as to include the notions related with human perception of signs. The influence of conceptual model 'bias' and its effects on knowledge discovery is sometimes discussed as if it were something not under the designer's control. Nevertheless, we do not share this point of view.

Jacques Bertin. After more than thirty years it is still a very popular model among cartographers worldwide. In the context of rapidly developing technologies and the opening of new possibilities for cartographic visualization, a trend to extend Bertin's model is usually still discernible. As a result, the initial structure based on a small number of very simple graphic properties is practically lost. There were attempts to introduce alternative models of map graphics developed from the 'variable's' approach or to integrate this approach into a more universal system of map language (Ratajski, 1976; Pravda, 1977; Lyutyi, 2002), however, they were obviously more complex, less clear and finally remained almost unconsidered (although it is commonly believed in structural complexity of the graphic language).

4.2.2 Extended model of vector graphics

A close relationship between CM2 and interfaces of commonly used graphic design software should be expected. We do not go so far as to suggest that the delineated graphic entities should respond to the state of art in the realm of interfaces because it would not be genuinely compatible with the top-down paradigm, according to which interfaces are subordinated to conceptual models and if needed, must be adjusted to comply with them. However, modern graphic design software systems have been developed for a long time in conditions of continuous competition, they are designed obeying the principle of maximal user comfort and convey commonly accepted classification of geometric objects (described by R. Laurini and D. Thompson, 1992) and also use object models based on human perception. That is why it makes sense to compare those models to what we have to deal with in the course of the process of cartographic transcription.

Taking Adobe Illustrator® as an example we can see how graphic objects and operations are classified in its environment. We observe a coherent hierarchy of graphic objects:

- graphic primitives: points (invisible), lines, areas and text objects
- compound objects, e.g. outlined or hatched areas, graphs etc.
- groups of objects,
- layers
- page/document

There is an evident correlation between this hierarchy and topemes (the first three classes) and assemblages of topemes (the final three) as described by H. Schlichtmann (Schlichtmann, 2003) as structural elements of map symbolism where grouping can become a method to link up the parts of a (possibly spatially disjointed) place.

Most operations can be applied to graphic objects at any level and only some are specific to the particular level, e.g. change of colour, line style and other basic attributes that are applied exclusively to the graphic primitives or change of visibility that is applied to a layer. They roughly correspond to the 'visual variables' though size (scaling) and orientation (rotation) defined by J. Bertin as primary variables fall out of this set, being among the most universal transformations. There are sets of arrangement and alignment operations applicable to several single objects.

4.2.3 Semantic data models.

Two semantic modeling techniques, entity-relationship modeling and the object-oriented approach, originate from information science and are not specifically cartographic. Entity-relationship (ER) modeling was one of the first such techniques to be developed (Chen, 1976). It has become very popular, with numerous texts introducing it for the use in all stages of a system design and especially for the relational database design. It is no wonder that geographic information systems, which as a rule use relational databases, are based on precisely this model. It is based on such real-world concepts as entity, attribute and the relationship between two entities. Application of this data model for cartographic transcription was described earlier, and will not be elaborated in the present chapter.

Another choice for semantic modeling is the object-oriented paradigm (Booch, 1994) that focuses not on relationships but objects, classes, behaviour and inheritance. This data-modeling technique has been developed to describe active, dynamic objects. It is more complex but also more powerful when dealing with electronic, especially interactive cartographic products that compare to software applications in complexity and process of production.

Both entity-relationship and object models are universally used for description of spatial data at the database level.

Table 4-1: Main characteristics of the popular conceptual models
('–' – not present, '+/-' – weak, '+' – present, '++' - strong).

Characteristics	Visual variables	Vector graphics	ER model	Object model
Representation of spatial objects	–	+	+	++
Representation of classified attributes	+	–	++	++
Type/domain control	+/- (indirect)	–	++	++
Means to convey non-spatial relationships	+/- (indirect)	–	++	+/- (hierarchies, methods)
Representation of behaviour	–	–	–	++
Means to reflect context	–	+/- (styles)	–	+/- (polymorphism)
Extensibility (robustness) of the model	+	+	++	++

The characteristics of the described models which are important for assessment of their suitability for managing information in thematic cartography are summarized in Table 4-1. It is obvious that semantic models, though not perfect, have much bigger potential than the other two.

A significant framework recently proposed by H. Schlichtmann blends well with the semantic models as it includes notions of abstract types and instances, hierarchies of types, attributes of different types and functions of the 'expression material'.

4.3 Criticism of the 'visual variables' approach

It is difficult to underestimate Bertin's contribution to cartography and graphic design. He made the first step towards a structured method of (carto)graphic transcription. What is surprising is that during over the next thirty years it was precisely Bertin's system that was extended by different cartographers beyond its initially simple framework without attempts to modify the framework itself. Here we attempt to point out the most common mistakes (that are not necessarily due to any imperfection of Bertin's model).

A general argument against using the term 'variable' to denote the changeable properties of (carto)graphic signs is the direct meaning of this term in mathematics. A variable is an abstract entity of a particular class or type, whose instance is unknown until the variable acquires its value. For example, values '3', '5' or '87' can be assigned to integer variable X. That means that a variable always belongs to specific domain — integer, real or complex numbers, matrices, tables and so forth. Only one value from the corresponding domain can be assigned to it at a time.

Bertin’s ‘visual variables’ are not separate entities, but actually dependent concepts. Indeed, it makes no sense to refer to ‘size’ or even less, ‘orientation’ without some object of which they are attributes. However, in this model variables are treated as something unrelated to any objects, thus making discussions about ‘right choice’ of them quite abstract.

The ‘visual variables’ have no types either. In fact, they should be treated as data types/domains themselves. For example a variable Colour which is from domain {‘Red’, ‘Yellow’, ‘Green’}, could be assigned value ‘Red’ from this domain; a variable RGB Colour which is from RGB domain, could be assigned value (255,255,0) from this domain. No type/domain assignment leads to unnecessary investigations into levels of measurement of all possible kinds of ‘variables’ or even ungrounded conclusions such as ‘using hue for a non-nominally scaled attribute is a poor symbolization choice’ (Robinson et al., 1995). In fact, hue is quantitatively measured by degrees on a colour wheel and in case of relief changes from green through yellow to red often help to easily recognize prevailing type of relief (lowlands, highlands and mountains correspondingly). But in any case, a sound choice of variables does not only depend on type matching, but also on the kind of object to which it is applied (e.g. background colour of a polygon, colour of its contour line or the colour of lettering).

The main consequences of neglecting objects and type control are as follows.

1. The model does not include all possible types of cartographic signs. In fact, only very simple iconic signs can be described in terms of ‘visual variables’ without difficulty. Some categories, like shape, size or orientation, do not apply for signs of area or line dimensionality which represent geographic features. They are, however, fully applicable to other graphic objects of the same class, e.g. pie charts or arrows.
2. All ‘visual variables’ are polymorphic without any possibility for control, e.g. ‘size’ might refer to radius, height, length, thickness, volume, radius of bounding circle, structure {width, height} etc. The same names of different variables imply their inter-comparability, yet it makes no sense to compare values from different logical domains: even though a thickness of a line and a height of a bar are measured in the same units (e.g. points), comparing one to another is meaningless
3. It is not possible to show how different variables are employed for different purposes, e.g. emphasis or clarification.
4. Map designers have to take into account the fact that a single object can not only have several representations that must change with the scale of the map, but sometimes an abstract object (e.g. a town) becomes a set of its components (buildings, streets, squares) when the scale is large enough. There is no place for such an event in the model.

Although the importance of visual perception of relationships rather than of single objects is stressed in Bertin’s study, the relationships are limited to simple hierarchies or sequences. It is obviously not enough considering the fact that more and more complex phenomena are to be represented in maps.

And finally, variations of graphic characteristics are not only dependent on their objects but also invariably take place in some context and must be investigated within that context, as long as pragmatic aspects of cartographic communication are taken into account. Unfortunately, pragmatics is still a weak point in modern cartography.

Comments on particular variables.

Besides location, six primary ‘visual variables’ (size, orientation, shape, hue, brightness and grain) were defined by J. Bertin, and later on the set was extended and systematized (Robinson et al., 1995), with six counting as primary (size, orientation, shape, and colour as value, hue and chroma) and three as secondary (pattern as arrangement, texture and orientation).

Location. The location attribute of a cartographic sign is usually determined by geographic coordinates of the represented object; however, position can vary if location is specified as a *reference* to some geographic object, for instance, an icon sign can be placed on either side of a city dot marker or aligned with other signs in a group.

Shape. The notion of shape is so closely related to the object itself, that naturally a question arises as to whether two objects of the same shape are really different objects, and if so, whether there are identical objects in a map at all. In fact, an object of a different shape is perceived as another object rather than as the same object with a different shape property. There could be an argument on whether non-uniform scaling produces a different shape or not. What is really variable about shape can be graphic resolution, fuzziness (both introduced by A. MacEachren as separate variables, MacEachren, 1992) and style of drawing (rounded corners or other artistic stylizations) as shown in Figure 4-2.

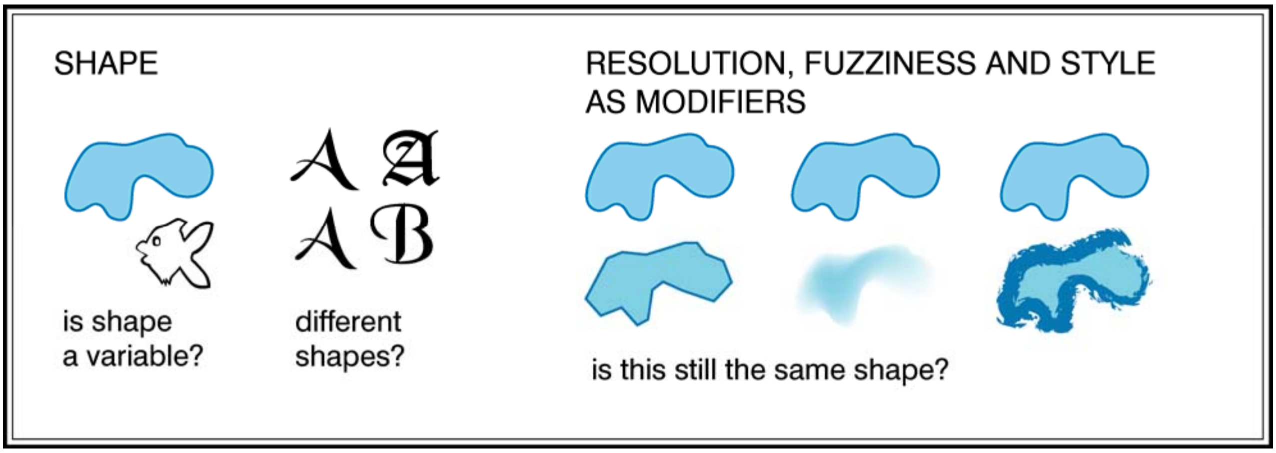


Figure 4-2: Shape as independent 'variable'

Orientation. There are two ways to organize signs with different orientation:

a) isolated signs far away from each other in the map,

b) visually separable groups of signs with different orientation.

In the first case there is a probability that the map reader will not notice this difference and perceive them as the same sign. In the second, if objects are visually expressive, an opposite orientation of objects within a group often implies variously moving directions; if they are abstract geometric shapes or patterns, they are normally perceived as different shapes (Figure 4-3). Considering that, it is difficult to understand why such importance was given to this variable.

Size. The only result of treating size as an independent variable without any implications about its measurement can be a naive recommendation like 'The larger a sign, the more important it is thought to be' (Robinson et al., 1995). Some aspects related to size are depicted in Figure 4-3.

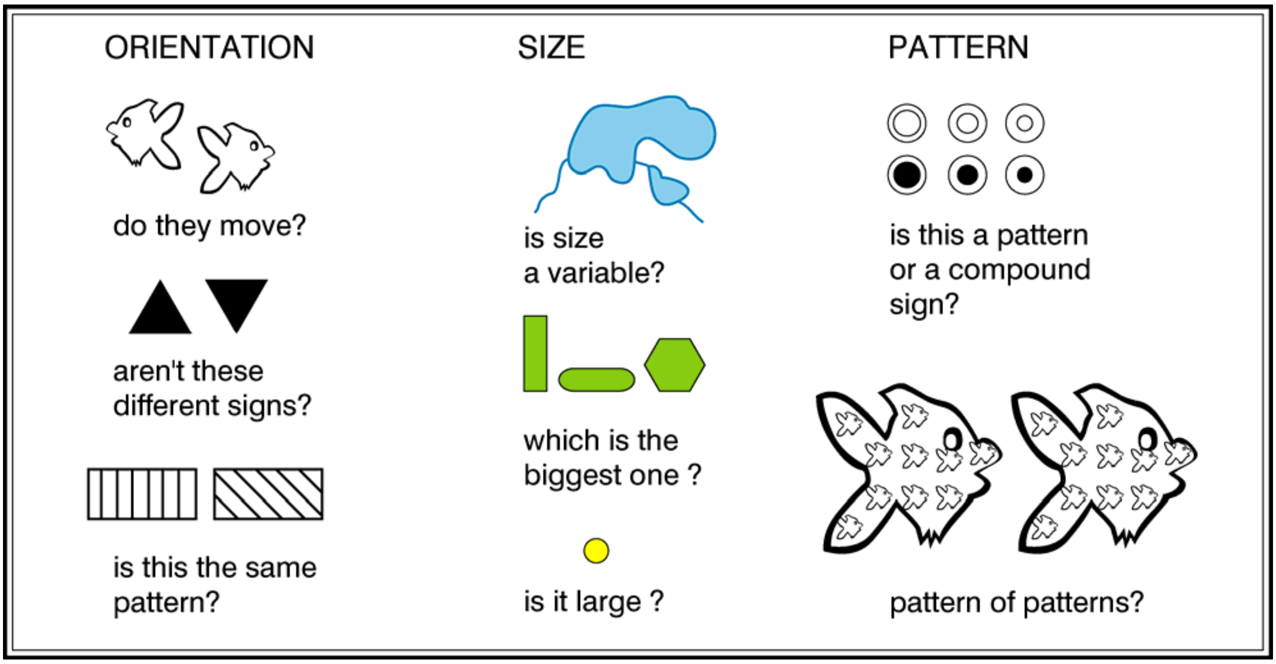


Figure 4-3: More problems with the 'visual variables'

Colour. Colour as we perceive it is made up of three components: hue, which is the main one, brightness/intensity and chroma/saturation. Each of them can be employed to represent some characteristics of the represented object, yet none can exist without the other two. Thus colour is a structure of at least three components (maybe four if not the 'humane' HSB but, for instance, the CMYK model is used) and different colours differ in values of at least one of their components. In fact colour is closest to a separate, though abstract entity. We can imagine it as a painted rectangle or an electromagnetic wave.

Texture (pattern). It is considered to be a secondary variable, most likely because it is so difficult to provide a formal description of it. Actually, in black-and-white images patterns completely replace colours with all three of their components (shape of the repeated element as hue; size of the repeated element as brightness; density as saturation), all preserving the levels of measurement (Figure 4-4).

The problem is that it is quite difficult to tell background patterns apart from compound shapes (Figure 4-3). It is impossible to formally define the difference between a single pattern and several patterns laid over each other. Finally, it is obvious that a pattern can have an infinite number of diverse graphic properties notwithstanding that infinity is not something we want to deal with making use of any semantic model. Perhaps the most natural way to describe pattern would be a recursively defined structure: systematically arranged elementary objects or patterns.

Sets of haptic, sonic, temporal and other 'variables' were added by numerous researchers (DiBiase, Vasconcellos, Krygier) mainly in the last decade of the century (MacEachren and Taylor, 1994) and some of different types have yet to be added as they become practical thanks to new technologies. As long as their usage is clear, new variables/properties can be discussed within Bertin's framework or without any framework at all. It becomes more problematic when some spatial **relationships**, such as arrangement or density (MacEachren, 1995) are misinterpreted as types of Bertin's variables which are **attributes**, thus mixing up the very basic philosophic categories and rendering the whole model even more inconsistent. The same kind of mistake is made by introducing characteristics of dynamic **behaviour** in the set. In the latter case, there are no limits for complexity raising questions, if, e.g. temporal variation of colour in brightness is just one more variable? Is variation in both colour and size a variable of the same type or a variable of some other type? Is the frequency of these variations another variable? Are this frequency and the frequency of a sound two different variables? And finally, can we call a model, in which an unlimited number of types occur, a structured approach at all?

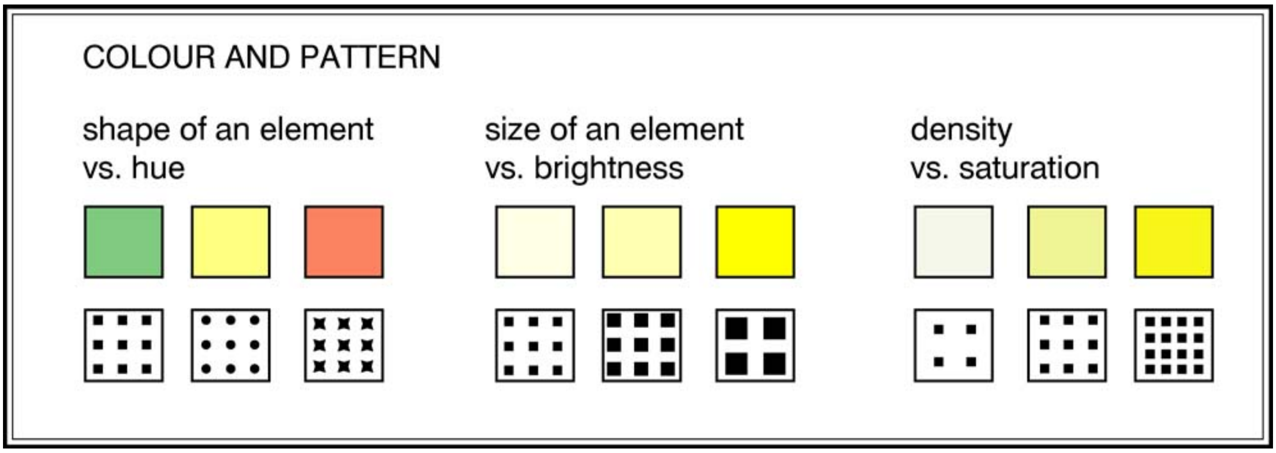


Figure 4-4: Replacement of colour components by patterns

Bertin's model has not become obsolete or too limited simply as a consequence of the new technologies. Concepts of relationship, change, behaviour, sound or touch have always existed as universal and do not depend on technology any more than technology provides better tools to employ them in cartography.

4.4 Proposed outline of a model of map graphics

It is not possible to introduce some elaborated model in which all aspects of cartographic signs would be given appropriate formalism. That does not yet exist. We are merely trying to demonstrate the need for a new model and provide a first tentative framework for its development. Other paradigms can be applied as long as the model is equally practical for cartographers, information scientists and geographers. Considering the growing importance of the map user we would argue that it must in the first instance be convenient for that user.

CM1 can be a simple object model where every object has a name as a non-obligatory attribute. Objects in CM2 are pairs of graphic signs (point-, line- or area-emphasized) with lettering as non-obligatory component[3]. A graphic sign is an object designed to represent instances of a geographic entity in the map model or an abstract entity in a map legend. It can be assigned different methods of behaviour (playing sound or video are only two examples of such methods; complex animation by contrast, comprises a set of methods). Methods and attributes should never be confused, e.g. the *PlaySound* method which is the same for different objects can use some attribute information which is a particular sound record, but that is different for different objects. To avoid confusion with the pure object model, we propose a dual object model in which CM2 objects are the 'sign-lettering' dyads.

The shape of a graphic object is determined either by geographic coordinates or is that which we identify with the cartographic sign itself. Graphic objects are either primitives (lines or areas) or compound signs which are combinations of the primitives. Shapes of particular components of compound signs can represent **super types** of the represented object in some hierarchy. Consistency of identifying objects with shapes is fully preserved in this case, for objects inherit elements of their shape from their 'parents' (the variable attributes of lettering can represent super types as well).

[3] The symbolization potential of a map lettering is quite often unaccounted for. Consideration of how to represent the relationship between an object and its name by the structure of a graphic dyad, and the question of which properties of a text could effectively be made variable would require a separate study.

Orientation, if used for semantic binding at all, should represent the concept of 'direction' as it is perceived in the real world.

Attributes and methods of CM2 objects are of two types. One set of attributes comprises pre-assigned values that do not change in concrete instances. Other attributes must be allowed to vary in values and assigned values for visual representation of an instance of geographic entity that depends on the values of the corresponding attributes of that entity. A monosemantic correspondence between the sets of variable attributes in both models must be preserved. During this process all the **domains** must be checked for compatibility taking into account the general rules of cartographic transcription and the purpose of visualization. This is a much more flexible path to proper symbolization. Polymorphism can transpire in so far as different properties or methods can have the same name; however, in this case, objects are responsible for correctness of operations and type control.

The number of fixed attributes exhibits the graphic complexity of a sign which is not semantically bound. It allows the cartographer to decide for or against this extra complexity in different contexts. Fixed attribute-value pairs together with shapes of signs also make up the design style of the map.

The structure of compound objects can be not only designed for better symbolization but can also imitate a real structure (a most natural example is a pie or bar chart showing population by age or nationality).

Behaviour methods of cartographic objects can be used for three main purposes:

a) as interfaces to object data providing additional information that is not normally visible (audible, tangible etc.) or linking to other objects — this is the main usage of interaction methods;

b) as imitations or symbols of real behaviour of the represented object — changing to representations with scale in interactive maps; moving, varying in size or other temporal behaviour in animated maps;

c) as a method of emphasis — periodic variations of some attributes in order to attract attention (like blinking) — quite derided for permanent emphasis but useful when some event related to the object occurs.

A (**visual) variable** according to the logics of this model is an unknown cartographic sign of particular type, e.g., TownIcon_X can be assigned a value of 'Capital_World_5M' which in our case is a dot marker or 'Capital_Lithuania_50K' which is a shaded area. More strictly, cartographic signs must be treated as vectors in an n-dimensional space where n is the number of all attributes. All possible values of vectors with the same set of m variable attributes form a cluster in that space and different operations are possible with such clusters. Thus it becomes possible to define graphic equivalents for single 'words' and 'phrases' and the idea of creating some universal 'map algebra'/map language seems more practical. The number of variable attributes (so called attribute depth) can be measured as the potential information load (or semantic complexity) of a sign. It also becomes possible to compare all the values of such attributes of two signs and to measure the difference between them. It is a kind of semantic 'distance' at least as a vector in multidimensional space, and in some cases as a single numeric value.

It must be said that although this approach is not particularly compatible with the field data models (e.g. DEM) it can still be useful because the data set of a physically continuous field is never actually continuous. It is rather semantically organized into intervals, or structured in some other way to consist of what can be treated as separate entities unless the whole field is rendered in a single graphic object.

4.5 Summary

In summary, all the models used during the life cycle of a map, atlas or an entire cartographic production company must be linked up to each other and intrinsically coherent in order to improve the efficiency of performance and quality of the expected result. Special attention must be paid to the stages of analysis and design in the aforementioned life cycle and particularly to conceptual modeling. A well-structured approach in these stages is essential for a sound cartographic transcription which eventually results in improved usability of the map. Unfortunately, information concerning the methodology of representation is often treated separately from the information to be represented.

In pursuit of efficiency the conceptual model of map graphics must be designed as a framework, as close as possible, if not completely isomorphic to, the model of information to be rendered visually. The commonly used system of 'visual variables' does not comply with this requirement; however. Other simple and elegant modeling techniques can be applied in order to develop such a framework, encompassing the 'visual variables' as well.

An object model is taken as a basis for the proposed twofold conceptual model in which the representation model is linked and subordinated to that of the spatial data. An entity-relationship model is more suitable for static representations, while the actual object model is perfect for dynamic, interactive images and multimedia attributes. Irrespective of which of the two techniques is actually used, the main features in outline are as follows.

- The cartographic sign as a representation of a spatial entity with lettering as a representation of its attribute(s) from a textual domain.
- There are two sets of attributes for each primitive or compound graphic object: fixed and variable. Variable attributes are the designer's choice as long as their domains match the number and domains of the attributes of the represented spatial entity. They roughly correspond to the 'visual variables'; however, some of the initial 'variables' are used for different purposes.
- Similarly the fixed attributes can be assigned different representation functions.
- Type control is explicit.
- The concept of inheritance is employed to convey hierarchies.

This model can easily be mapped onto the structure of a relational or object database of representations. Database management concepts, such as consistency, normalization and so forth can be considered in terms of the model.

5 Language oriented approach to general models of cartographic representation

5.1 Cartographic representation in modern context

The last four decades have seen extensive efforts in development of spatial modeling concepts and theory. Different and highly automated visualizations of spatial data are now possible, up to photorealistic dynamic representations. However, cartography nowadays also faces a risk of being replaced by automated visualization of geospatial data. Instead of some universal principles of cartographic design, map makers are offered sets of standard visualization tools, which come with all GIS packages and are easy to use. Some of them even have underlying theories; that implies that the outcome will be correct in terms of perception, interpretation and usability. In this chapter, we point out the differences between communication of spatially referenced data and cartographic representation, examine the models of transformation between the two sets of data, and identify the points where information is lost or distorted in the process.

Development of GIS and other information, design and publishing technologies during the past several decades have made an essential impact on cartography. Irrespective of the long tradition of this discipline, its concepts and theory have to be revised against what computerization, spatial modeling concepts and visualization technologies have already brought to cartography. Even though it is almost impossible to imagine modern mapping without GIS technologies, there is a significant difference between the processes that create geographic database and retrieve information from such database and the processes that create and retrieve information from a map. As the processes of both categories usually intertwine when maps are created, it is natural that concepts and stereotypes migrate from one field into another.

Unfortunately, judging by quality of common printed and electronic maps, it can be stated that the existing theories of cartographic representation are still insufficiently integrated (or too weak to be integrated) into rapidly developing theory of spatial modeling and technology of spatial information management. Thus even though need for maps was one of the main factors that stimulated the development of geographic information technologies, at this stage development of geographic databases and analytical functionality is still given priority to the problem of quality of maps produced. More than that, scientific research in modern cartography is also more oriented into effectiveness and improvement of methods of maps' production and use, thus overshadowing the fundamental research. For that reason many cartographic works published demonstrate a lack of uniform methodological background that should have been used to compile them or in the worst case are simple graphical reports generated from one or another geographic information database.

On the other hand, impact of geographic information technologies on methodology of traditional cartography positively manifests in new concepts, models and methods of information management in cartography. Of course, this impact has positive and negative sides. Hereunder we discuss only methodological issues, while the benefits from GI and IT technologies to the performance of the standard mapping tasks do not need to be advocated.

Positive impact:

- A single GIS database containing all necessary data and formal data structures beyond the map image require much better understanding of the represented information. Reassessment of information described in terms of classes, attributes, domains etc. helps to avoid (though not completely eliminate) some common errors (e.g., inconsistency of attribute information, classification errors, missing symbols in the legends, etc.).
- Enforced need and provided possibilities to apply system-engineering methods (due to the large amounts of diverse cartographically represented geographic data and variety of their formats and sources). Different models have been developed to tackle the complexity problem and most of them can be successfully applied for management of cartographic information.

Use of such models makes modern cartography more systematic and facilitates understanding the process of mapping itself. Some applications of modeling techniques (life cycle and dataflow modeling, structured diagramming techniques, quality evaluation schemes and other) for cartographic transcription have been discussed in several previous works (Bertin, 1983, Dumbliauskienė and Kavaliauskas, 2004).

- Concept of meta information (data about the data) can effectively be applied to describe different semantic aspects of cartographic sign systems.
- Growing demand for cartographic production is related with spread of geographic information systems. As people know that it is easy to compile a map (not necessarily a good quality map) as geographic data are available, they want to see more information presented in a convenient form of maps. Naturally, demand for maps motivates more intense theoretical research in cartography.

Negative impact is mostly related with transference of GIS technology stereotypes into cartography:

- Sometimes mapping is equated to automated creation of a map from geographic database (whatever results in producing a map, is mapping). Instead of principles of cartographic design, map makers are merely offered sets of standard visualization tools which come with all GIS packages and are easy to use. Use of such tools indirectly implies that the outcome will be correct in terms of perception, interpretation and usability. It is not surprising that cartography now faces a risk of being expelled from the domain of geo-spatial information sciences at all. Fortunately, more and more GIS users and distributors understand, that cartography cannot be replaced by just automated visualization of geographic data: '… *extracting a map report from an information system is not mapping, just as formatting and printing a document is not writing. (…) While some mapping capabilities are available in many geospatial technologies, great mapping is an art unto itself.'* (Mann, 2003).
- The problem of quality in technological context is often deescalated to problem of accuracy and topological consistency of data. As theoretical problem, efficiency is usually given priority. Dependence on limitations of particular technology is often perceived as natural and inevitable (people first think of whether it is technically possible/easy to do what they would like to).

There is still no completely consistent theory of spatial data or spatial models that would effectively combine the two aspects of spatial information management: data (information, knowledge) management and cartographic representation in respect of the underlying theories of both disciplines – geographic information science and cartography. We assume that geographic and cartographic information flows do not have to be examined after the same model. Neither mechanical merging of two different schemes is acceptable for it usually results in some parts of either scheme underestimated. Thus, the classical communication schemes, which have been commonly accepted by cartographers first and by GI scientists later, must be revised. Comprehensive models of transformation between spatially related data and their cartographic representation would be a significant input into such theory, assuming that human visual perception and cognition issues are considered. We believe it is possible to combine the two models of information communication and merge the information systems (that of geographic data management and thematic mapping), which in terms of their functions are the implementations of the communication models.

Before the two models can be successfully merged, it is necessary to point out the major differences in the communication of data, possible collisions of goals at different stages, points where information is at the biggest risk of distortion or misinterpretation. It is also important to show how different information is communicated between different levels. Hereunder we attempt to unify approaches of language, modeling and communication comparing the two schemas of geographic information communication (encoding and retrieval) and models (formal and informal) used at different levels of abstraction and at different stages of communication.

A general scheme of both geographic and cartographic information modeling (an extension to the famous Ratajski's model (Ratajski, 1976) should allow more systematic approach to cartographic design, and facilitate understanding of geographic data communication to cartographers as well as that of cartographic information communication to developers of geographic information systems. It would also be useful as a framework to identify possible problem areas and weaknesses and to plan the data flows without mixing up data- and representation-related tasks.

5.2 Map language in the communication process

As we have stressed before, a need for methodological background for cartographic works and fundamental research in cartography, map language must be mentioned as it plays an important role for understanding cartographic information communication and may be considered one of the keystones in development of cartographic theory.

5.2.1 Brief overview of the previous research

The concept of a map language has been intensely developed during the 7th–9th decades of the 20th century. Map language has been in one or another way represented in different theoretical schemas of cartology/cartographic communication/metacartography: as a mean of the cartographic communication (Kolačny 1969, Ratajski, 1976), as an instrument for cartographic modeling (Aslanikashvili, 1974), as a tool for cartographic cognition (Berlyant, 1978) etc. Maps were perceived as communicative devices and compared to written texts in some natural language as they similarly express mental concepts. Different researchers investigated into various aspects or elements of map language: semiology of graphics (Bertin, 1983), morphology and syntax (Ratajski, 1976), hierarchy of its structural parts (Pravda, 1977).

J. Ramirez pointed out the limitations of digital maps from the viewpoint of visualization and described an extended representation model for geospatial information as a framework for future (multiple source, quality, and media) mapping. Even though such approach seems innovative and promising integration of both cartographic theory and geographic data models, it still needs to be developed from implementation-oriented to more general. The author has also made attempts to present the fundamentals of a more general cartographic theory, combining existing theories of cartography and the more modern ones of geospatial data. Cartographic language, which appears to be a central component in this general theory, is presented as a set of formal structures.

H. Schlichtmann during the past two decades has touched upon different aspects of cartographic language constructing a coherent framework for thematic mapping (oriented to cartographic visualization). The framework for cartographic visualization revealing the three general functions related with transcription: signification, clarification and emphasis appears a major input into cartographic theory (Schlichtmann, 2003). A. Liutyi in his exhaustive study on map language ('Map language: its essence, system and functions' (Liutyi, 2002) summarized the results of the previous research and presented a consistent theory of map language as of an objective phenomenon. He brought forward the importance of research into map language as a setoff to the prevailing paradigm of cartography as an applied science. Liutyi also pointed out the dualism of map language, i.e., two subsets, one of which describes location of the objects in space. Such approach implies that cartographic information models cannot be treated as parts of geographic data models, i.e., cartographic signs are much more than just additional attributes of represented geographic objects.

It is evident that the research into cartography, exhaustive in particular aspects and revealing diversity of viewpoints, has not yet resulted in integration of the two major trends – cartography as visualization science and geospatial information science. Concept of spatial communication language for describing spatial data/information/knowledge at different levels of spatial representation may become the connecting element, as it is essential in the both theories.

5.2.2 *Languages of spatial communication*

In the process of spatial information communication, we deal with different basic types of languages (there is some overlap in the following classification):

1. Natural languages, such as spoken/written, visual or gesture language. They objectively exist as they have formed historically, in order to satisfy human need to express and share the mental concepts, images and ideas. It is possible to translate the 'texts' from one natural language into another as long as there are common concepts beyond. However, as the laws of such languages are not completely known (they develop), lots of information is lost or distorted in the process of translation. It is even impossible to translate a text from one spoken language into another without any changes in meaning, leave alone visual rendering of a written text or vice versa. Research into natural languages is basically oriented into finding out the existing laws and using them to improve communication.
2. Formal (or partially formal) languages, which are based on limited standards or other artificial rules, but have potential to develop depending on the phenomenon, for description of which they are used (mathematics, music, high level semantic models, and symbols). Bertin's system of graphic variables can be examined as a subset of some formal map language.
3. Artificial languages, such as computer languages (computer simulation of human language e.g. output of a machine translation system), standards and data transfer protocols. They are created on purpose, as more or less flexible standards used to describe the concepts of a particular field. Generally, translations without information loss are expected to be possible between artificial languages, as long as they are based on the same object model and standards. Thus, the process of translation can be automated. Research in artificial languages is always engineering-oriented (standards, methods, efficiency, data loss, application of the constructed rules, and technical quality are the major issues).

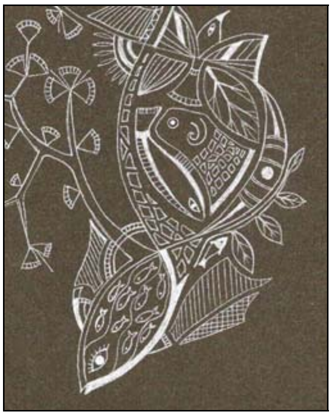


Figure 5-1: Graphical language – a fragment of a drawing

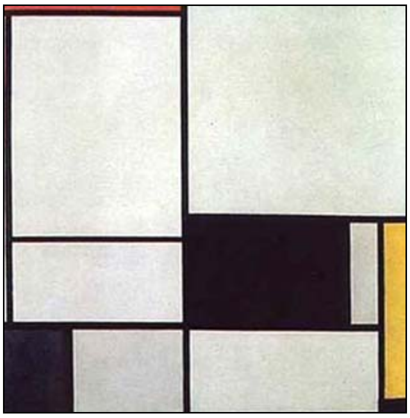


Figure 5-2: Graphical language – 'Composition No.2' by P. Mondrian

```
Unit:=wdCharacter, Count:=1
Extend:=wdExtend
 With Options
    .DefaultBorderLineStyle
= wdLineStyleSingle
    .DefaultBorderLineWidth
= wdLineWidth300pt
    .DefaultBorderColor =
wdColorRed
 End With
    Selection.EndKey
Unit:=wdLine
        Selection.TypeText
           Text:=" "
  ActiveDocument.Tables.Add
   Range:=Selection.Range,
 NumRows:=2, NumColumns:= _5,
```

Figure 5-3: A code in a programming language

The three figures represent the 'texts' in different languages: a natural visual (a fragment of a drawing where the actual meaning of possible symbols are known to the author alone, Figure 5-1); a (maybe) semi-formal visual, for abstractionists often assigned specific meanings to different graphical elements of their paintings (Figure 5-2) and an artificial programming language (Figure 5-3). It is practically impossible to make a translation of drawing in the Figure 5-1 into the language of the painting in Figure 5-2, because underlying concepts are too complex and too different. Even though the code in a programming language may be interpreted as instructions that technically create an image like that in Figure 5-2, such 'translation' cannot be compared with the original neither in semantic richness nor in value.

It is practically impossible to provide a clear set of instructions how to create an abstract painting expressing what is on the author's mind, or even an abstract painting of good quality. It is almost opposite with the third example. As long as meta-information is provided and the syntactic rules of the programming language are obeyed, the piece of code is correct and uniformly interpreted everywhere. Maps find their place somewhere in between, depending on which approach to map language is accepted.

So what is the map language? Extending the approach of Liutyi, who proved objectiveness of map language at the highest level, we propose to examine it as a set of models applied at different levels of information communication: from completely natural visual language, which is used to render the mental images, through semantic models (where written language is used as intermediate tool for formalizing the concepts) to data description languages. Such approach allows connecting cartographic and geographic data modeling schemes at least at the lowest level of data description languages (see subchapter 3).

5.2.3 The specifics of map language

The concepts of natural (spoken) language are commonly used for construction of high-level semantic models. Therefore, it seems sensible to look for the structures in the visual map language, which could be mapped into the concepts of natural language. Such elements (syntagmas, sentences, and communiqués) could be translated from one language to the other. As practically all semantic models are based on natural language concepts, a universal scheme of translation would be very helpful for efficient cartographic database creation and for making the automated mapping process more intelligent. At the highest (human) level of abstraction, map language has often been compared to a spoken language. However, it is more an illustrative analogy, used to reveal the objectiveness of visual language, than an essential similarity. Some specifics of map language that distinguish it from other visual and spoken/written languages are discussed below.

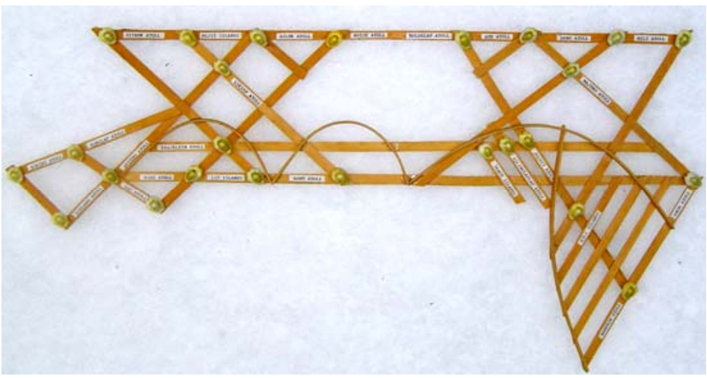


Figure 5-4: Inlay map of Madaba, Yordan, 6–7 centuries BC*

Figure 5-5: Bamboo stick map of the Marshall islands**

Map language is used to describe the same geographic objects and relationships (assuming possibility of the universal spatial object model) using different media and different signs in analogy to alphabet and lexis of a written language. That means, multiple map 'dialects' exist, among which changes of cartographic representation method and media are common. The two very different representations of geographic objects depicted in Figures 5-4 and 5-5 can be interpreted, assuming that

* Source: *Senovės pasaulio paslaptys*. Alma Littera, Vilnius, 2002

** Photo: M. Govorov.

the user has some basic knowledge on what types of geographic objects can be on the map and how different types of objects are represented in each case. Then the translation from one map dialect to another is possible. In the worst case we need to complement the vocabulary so that it includes the words (representations that have to be designed employing the tools and rules of the destination set) to denote the objects that come from the source map.

If we are to agree on overall objectiveness of the map language phenomenon, maps are closer to objects of visual art and their interpretation should be considered a process highly influenced by the specifics of human perception and cognition. On the other hand, if a map is examined as a result of impersonal cartographic transcription, which is true for the map models, described in formal languages (especially geometry), correctness of interpretation is mainly based on quality and coverage of the existing standards (lexis of the formal languages).

Based on Liutyi's statement that map language has been naturally developed to complement spoken language (which is likely to be true), two conclusions can be drawn:

- Map language, as based on spatial perception, is more universal and requires less specific knowledge to understand its different dialects; it is even more powerful communication tool as it was claimed to be;
- Direct translation will never be possible from the natural map language into any formal model, for all the semantic models are based on the concepts of a spoken language. It justifies development of formalized map languages as intermediate systems that prevent loss of information in successive translations all the way down from mental map image to the storage data models. Bertin's graphic variables, object model and various models describing semantic relationships have to be considered as possible frameworks of such intermediate languages.
- Another side of the same, when map images are retrieved from the stored data (formal descriptions); they are interpreted as texts in much higher-level language. It means, additional information can be generated, unanticipated in the formal models. This characteristic is related to the 'knowledge construction' phenomenon.

Dualism is another characteristic of map language that manifests in presence of two subsets of the language: one for registration of the spatial object position, another for rendering of the characteristics of the object (Liutyi, 2002). The two subsets are not completely independent, for instance, real location of the objects determines some characteristics of the signs (size, type, etc.) at particular scale. On the other hand, depending on the specifics of the signs, location of the signs can be adjusted in order to preserve the topological relationships. Difference between spatial and non-spatial may fade in some cases, e.g., arrows in historical maps (the central line may not represent actual path of some movement at all). It means that even though the models of encoding spatial information (information about location) coincide with the models of cartographic information at some parts, they cannot be completely isomorphic. Thus, we will examine cartographic communication process as a series of translations of 'description' of the subject area from the highest level map language through different formal (semantic models, mathematical, computer and other) languages to formal description of data and backward.

5.3 Spatial information communication revisited

5.3.1 Process of cartographic communication

As it was mentioned above, we conceptualize cartographic communication process as a series of translations. The key concept is the ***service model*** of a protocol layer. Layer *n-1* is said to offer ***services*** to layer *n* via a protocol*. In our case, a layer is a 'description' of the subject area on the correspondent level of cartographic (or spatial) representation. A protocol of communication is the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event.

Language vs. protocol:

Language: A system of symbols and rules for expression or communication.

Protocol: A set of rules used to specify the format of an exchange of data.

Our two-way layer model, representing cartographic (spatial) communication process is shown on the Figure 5-6. It starts at ***human mental*** application layer and works its way down towards the ***machine physical*** layer (top-down approach). The retrieval part represents different steps of the reverse process of cartographic communication.

This model has dualistic network nature. From one side, it is an n-tier network model, which transmits author's (cartographer's) information top-down and back. The author's mental map may be distorted during the transmission. From the point of view of the map user, this client/server model provides collection of map (spatial) services. The user can gain new information, distort, or support the encoded vision of mental space. Such layer communication model possesses unique characteristics. It is *distributed* and *heterogeneous***.** Thus, different protocols (languages) have to be used to accomplish different communication tasks. The entities exchanging messages and taking actions are human, hardware or software components of a heterogeneous network. The communication system is very complex.

With layered protocol architecture, each protocol belongs to one of the layers. Several protocols or their combinations can be used within one layer, with the condition that all the protocols belong to the same layer level. For example, the instruments of vector or raster graphics, or a hybrid one can be used as a protocol for the cartographic representations. A protocol in a layer *n* is *distributed* among the entities, which implement that protocol. For example, the software and hardware components can implement the visual graphical display of a map.

Another characteristic of distributed applications is that the cartographic communication layer model contains *connection-oriented services* and *connectionless services* at the same time. What can happen to information as it travels from its source to its destination? The layer *n*-1 might guarantee that the *n*-protocol information unit will arrive without error to the layer *n* in the destination, or it might only guarantee that the *n*-protocol information unit will arrive at the destination without any assurances about the error. Along the path of communication, information can be lost due to different reasons and in different amounts at *each* node. Therefore, the performance at a node can be measured in terms of the probability of information loss. At the level of mental map, the protocol of transfer is very subjective, so information is not only probably lost, but can also be gained as new 'knowledge'. The layer of logical representation can support connection-oriented service: information (data) can be transformed to and retrieved from the conceptual or physical representation levels without any loss. The loss of information can be minimal and estimated at the conceptual representation layer; for example, loss due to spatial or semantic generalization.

The model of communication can be shorter or longer in terms of intermediate nodes (layers). In traditional cartography it has just three layers: reality (A) is transformed by cartographer through his mental model (B) into a map (C) which is read by a user (C') and interpreted in order to build user's mental model (B') of the reality (A)" (Ratajski, 1976). In computer environment, the chain of transformation is longer and may have branches. Now we can analyze the communication layers by examining the correspondent protocols and scenario in which information loss occurs.

5.3.2 Models for encoding the cartographic data

The top (**human mental)** layer of the communication-encoding tree (Figure 5-6) is a protocol that combines natural languages and human protocols of spatial perception and communication. Here we can speak about the inner expression languages.

People use inner languages (semiotic systems) to interpret the geographical space or its existing models – maps, images of the space and measurement results (the map language at the highest abstraction level, discussed above). The images can be combination of the physioplastic ('high grade naturalistic') and ideoplastic (coming rather from the mind) representations. We can see space in our mind as natural photographic images, as abstract symbolic representations (e.g. image of a street map seen before), or as their combinations. Elements of spoken and mime languages can also be used to enrich the inner spatial imaginations. The meta-symbolic insight is therefore an implicit understanding that a symbol not only has meaning but is at the same time an object with a physical presence in the real world.

The next (language) level consists of the **structured representations** of the mental images. People use language(s) to express their interpretations of the mental maps. The concepts can be rendered orally or in written form, as well as using gestures. It has to be mentioned, that not genetic ('innate') factors, but cultural conditioning and training fundamentally determine individual modeling abilities of spatial representations, i.e., people more often draw what they *know*, than what they *see.* The 'fortuitous realism' can be a method of cognition: 'in that the meaning of the scribble is discovered in the course of creating it' (Piaget and Inhelder, 1969).

The spatial representations, both mental and rendered in some structured language, may generate 'multiple representations of similar knowledge'. Karmiloff-Smith (1992) refers to certain brain circuits, which may have been biologically selected, resulting in the mind splitting into separate modules. In time, these modules may have 'co-operated' again resulting. More recently, the cognitive scientist Dan Sperber postulated a module in the mind, which he calls the *module of meta-representation*. Another reason of *meta-representation* is dynamism of thinking. Outcome of mental interpretation is dynamic; the final outcome can be changed with further thought.

The concepts of any *natural* language can be translated into a *formal* language (***semantic formal model***) and backwards. As natural and formal languages are not isomorphic, the loss of information takes place. Several formal languages are used for spatial modeling. Object-oriented notations such as entity-relation, sequence and other diagrams have been implemented in some GIS and mapping packages for descriptions of spatial data structure and behaviour and spatial modeling, according to, for example, Unified Modeling Language specification (UML…, 2005). The mathematical language operates symbols and formulas that are often used for functional modeling of fields and surfaces.

Information transfer between the mental and semantic model of cartographical representation is eventually accompanied by information loss. Information loss and distortions may occur due to cartographic generalization. For example, the geometrical model can be richer before transformation into sign representation, requiring more 'media space.' Symbols' omission or movement can affect geometry. Misinterpretation of the semantic relationships between the objects and the signs is another common problem. Information loss also occurs when the syntax of a formal language is not rich enough to render the map information**.**

The cartographic symbolism can be translated into **conceptual model** of geo- and cartographic database representation (system of signs) and be enriched with additional attributes. Language of vector or/and raster geometry with corresponding tools for description of semantic, topological and behaviour attributes can be used for spatial modeling. Cartographic representation is usually separated from the spatial representation. According to our scheme, cartographic elements can be represented as symbol sets with specific attributes, linked to the corresponding attributes of spatial objects. In more advanced case, cartographic behaviour rules can be enforced to control the rendering order of layers and symbols, text placement, and cartographic zoom-dependent generalization.

Translation from an analogue cartographic representation into a conceptual digital layer is accompanied by spatial information loss due to precision and errors of digitalization or scanning process. Geometry and topology of a feature can be distorted. Iconic view of corresponding analogue and digital signs may be not identical as well as the correspondence between visual variables. Attributive information can be preserved. Information loss control and estimation can be implemented with some level of probability.

The next representation level is **logical model**, which is an intermediate between the conceptual view and the data storage model (e.g. relational, geo-relational structure specific to a particular vendor's format etc.) or computer-readable text formats (e.g. XML (GML) etc.). Exporting conceptual model and UML object model into a logical model may not introduce information loss unless due to incompatibility of standards and data types. The language of relational algebra in mathematical (variables and operators) or graphical forms (table structure and relations), programming and scripting languages (e.g. XML), spatial descriptive and query languages (e.g. SQL) can be used for logical spatial modeling. Symbolization data can be represented as separate computer-readable text structures (e.g. *.lyr*) or are stored as a part of the relational schema together with the spatial data. The formal languages of computer graphics are used to represent the spatial features and the signs in library. Languages of predicate logic and other artificial languages can be used for description of the attributes and behaviour.

Logical model is translated into file organization form and secondary storage format (binary machine opcodes) of **physical layer**. No loss of information occurs unless due to machine errors during data translation into this layer or incompatibility of storage formats. Computer language of the binary system of impulses is used for communication.

5.3.3 Models for retrieval of the cartographic data

Data retrieval process from the **physical** storage through **logical** and **conceptual layers** is relatively safe. Data loss will not occur if fully compatible data formats and interoperable standards are used. Thus, data encoding and retrieval between the physical and logical levels can be controlled. When different data standards are used, they may appear not fully compatible. For example, geometry often can be preserved during transformation between different logical formats and conceptual representations, what is not always true with physical formats (loss of precision can occur). Behaviour information can be lost and the layer organization can be modified during the translation between the physical formats.

Many spatial formats do not contain cartographic information within them at all; therefore cartographic data incompatibility between different logical formats is common. Often information about map representation is stored in separate files (e.g. *.lyr*, *.apr* etc). Translation between different cartographic representations is not fully compatible or not supported (e.g. between *.apr* and *.tab*). Symbol palettes (especially vector graphics) also often are not compatible, even in the software packages of the same vendor (e.g. between *.apr* and *.mxd*).

Retrieved conceptual schema can be considerably altered if transformation of format occurs within the logical layer. Information loss can also occur in the next level of modeling (symbolic representation). It can be due to several reasons – e.g. rasterization and resampling of geometry on a monitor, discrepancy of the colour schemas, dynamic visual generalization, limitations of computer graphic formats (e.g. SVG) etc. In general, the conceptual model can contain more information that it has been retrieved for a view. Visual rendering process is dynamic in terms of recognition of information, encoded in a spatial database. A set of attributes can be visualized in different ways and combined with the results of analysis of the same data.

Several languages can be used for visual cartographic representation. It is often a language of computer graphics, but also it can be written, schemas notations, mathematical and even spoken (e.g. computer sound).

The process of translation information from symbolic representations to **mental images** can be different for analogue and computer maps, although the principles of immediate interpretation may be similar. Computer image can be interactive and richer in terms of its graphic/multimedia expression tool set. Possibility for dynamic interpretation of computer images can be much bigger compared to interpretation of hard copy maps. The final outcome of interpretation of map image may depend not only on user's knowledge, associations, and preferences but also on his computer skills.

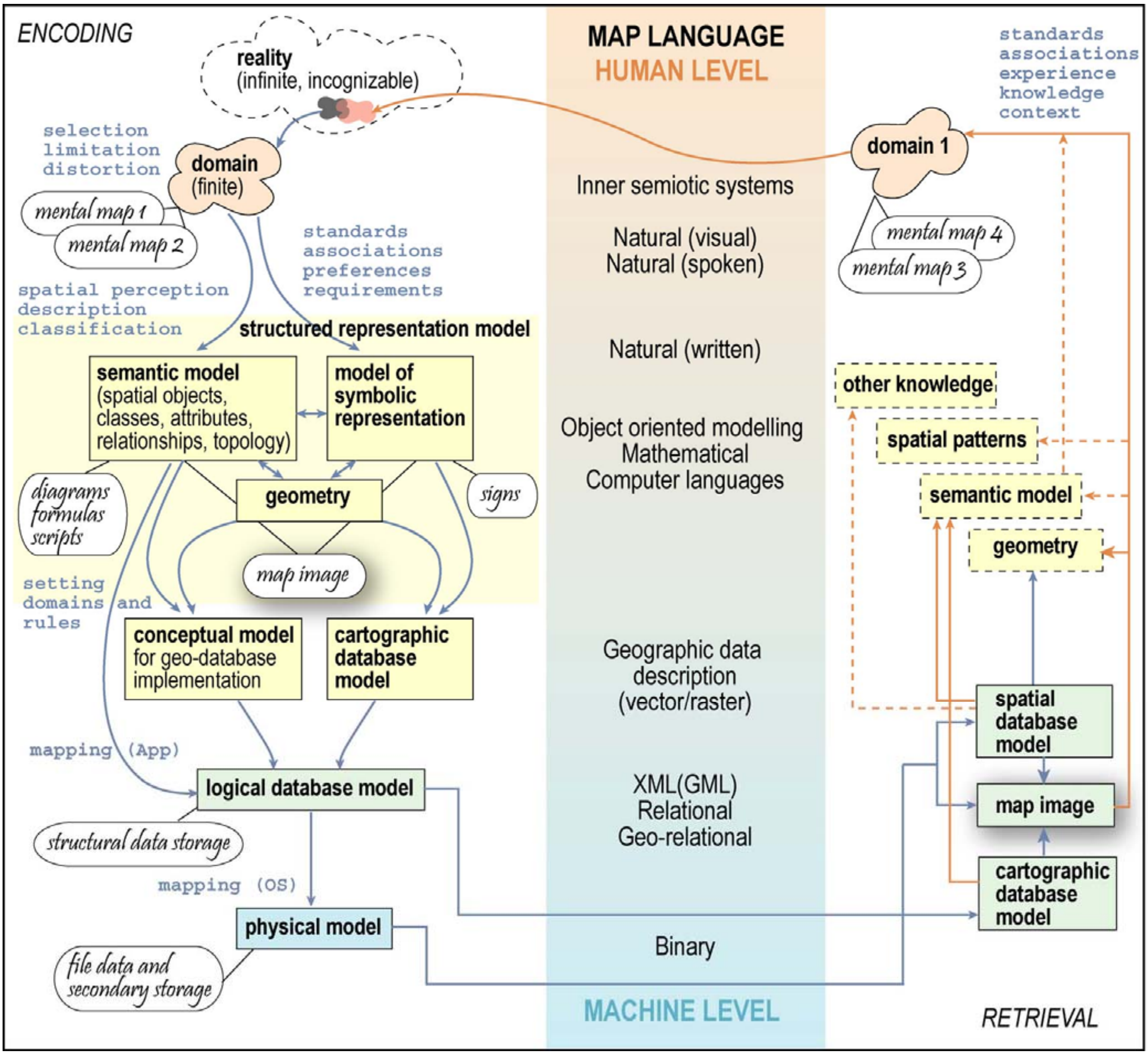


Figure 5-6: Spatial communication scheme

5.4 Conclusions

The language used to represent the spatial knowledge – the 'map language' – can be analysed as a series of communication systems, starting with the language of visual perception as an objectively existing phenomenon that helps us to form mental maps, through equally natural, but better structured spoken/written language, then through semi-formal languages and conceptual and logical schemas, which are already formal languages and closing the set with the Nyerges' 'deep spatial structures' (Nyerges, 1991) close to physical representations. Such approach may prove more efficient than discussions on existence and diversity of different map languages as it can be practically used for construction of spatial information communication models, identifying possible communication problems and for planning the data flows. Such models, in turn, help to unite the geo-database and cartographic communication (neither of them subdued) viewpoints striving for quality, efficiency and innovations.

Rendering of spatial information at different levels (mental, conceptual, logical, and physical) according to this approach can be examined as successive translations from one language to another within the set. Naturally, we strive to minimize the loss of information in the process of each translation. Nevertheless, there is a big gap between formal and natural languages, which is responsible for distortions or loss of information as well as for generation of additional information, which can manifest in useful insights as well as in simple ‘noise’. The commonly accepted spatial information modeling and cartographic information modeling schemes have common parts (at least at data description level); however, they never coincide completely.

The process of map making will always require human intervention – as natural languages require smart interpretation. Therefore, it is impossible to fully standardise the methods or processes of thematic cartography, nor to provide universal rules of information generalization. Conceptual differences between cartographic and geo-database modeling languages do not allow such thing as 100% efficient automated cartography information systems. It is, however, possible to make the cartographic communication from geo-database more efficient due to partial congruity of spatial and cartographic information communication models. The processes of problem solving and the methods of quality improvement can be same or very similar at some stages.

The further research could focus on particular schemes of ‘translation’ between different scales, time sections, purpose (target groups), and methodology allowing to quantify the information loss and thereby to estimate the data quality. Structural analysis of the languages participating in the cartographic communication and equivalence of their structural elements also can be interesting to investigate. Clarification of the concepts of the natural visual (map) language would help to improve the process of geographic information visual encoding and retrieval as human perception and cognition issues are concerned. It would also allow developing the methods of exchange between cartosemiotics, map aesthetics, stylistics and data modeling fields in cartography.

An undivided approach to a map (map as information system itself) has many advantages against splitting it into elements for database purposes. As in natural language good and correct words/phrases are not necessarily combined into what can be called a good sentence (and vice versa), correct use of the elements (e.g., visual variables) one by one does not yet guarantee a quality of the representation.

6 Style in modern cartography

6.1 Manifestation of style in cartography

Almost everybody sufficiently involved in the production or use of maps will agree that the concept of style is in one or another sense applicable to a map. Confusion begins when we try to define what map style really means. Usually style is defined as a specific manner of expression, a quality, that characterizes belonging to a particular period of time, school or group. Such quality is present in different means of communication, such as verbal communication, music and communication related to the sense of sight, to which maps belong as well as paintings. But everything is different when style is mentioned in the IT context. The first association conjured up will likely be Cascading Style Sheets, or, if closer to geographic information and maps as its visualizations, Style Manager or some similar tool of a GIS software. Finally, there is also a common understanding of style as a fashion, usually associated with good taste and refinement. So which of these three meanings are we dealing with in cartography?

In one of his essays Evelyn Waugh has pointed out clarity, elegance and individuality as three essential elements of style and provided the simple definition: 'Style is what makes the piece memorable'. So how many memorable pieces could be found within the stacks of maps, used daily by almost everyone? Perhaps just a few – the historical ones or successful imitations of them, maps with exceptional content and unconventional representations. And in most cases it is only due to uniqueness of the product, but not to exclusive elegance of its design.

We have to admit that elegance is a practically indefinable quality, but it somehow reflects itself in overall harmony of visualization and contents. Due to this quality some old maps look surprisingly modern while most of modern maps do not. This paper reflects an attempt to outline the main parameters that can be used to determine, evaluate and/or implement a consistent map style.

Style in modern cartography can be defined as a loose framework that organizes all cartographic expression devices, is used distinctively and can be identified as belonging to particular region, cartographic edition and/or map producer. It is only possible to speak of style when parameters of such framework can be described and have same or similar values in at least several maps. *Absence of style* in this context means that method of use of different graphic attributes[4] is rather haphazard and vary across the analyzed series of maps.

Style is not only perhaps the most important concept of map aesthetics, but also a factor that significantly impacts on quality of cartographic communication. It is the result of evolution and augmentation of cartographic visualization

The structure of style is rather complex and can be influenced by geographic space, time and culture.

Historical maps usually reflect general art styles of corresponding *epochs*. The traditional (baroque, Renaissance) graphic design styles can be easily identified not only by the graphic devices of the map image, but largely by ornaments, composition and elements of layout. Digital technologies open new graphic and interaction possibilities thus marking a new epoch in cartography. However, not only the mainstream art style, but also prevailing designers' approach to cartographic communication form an epoch-specific styles of maps (Figure 6-1).

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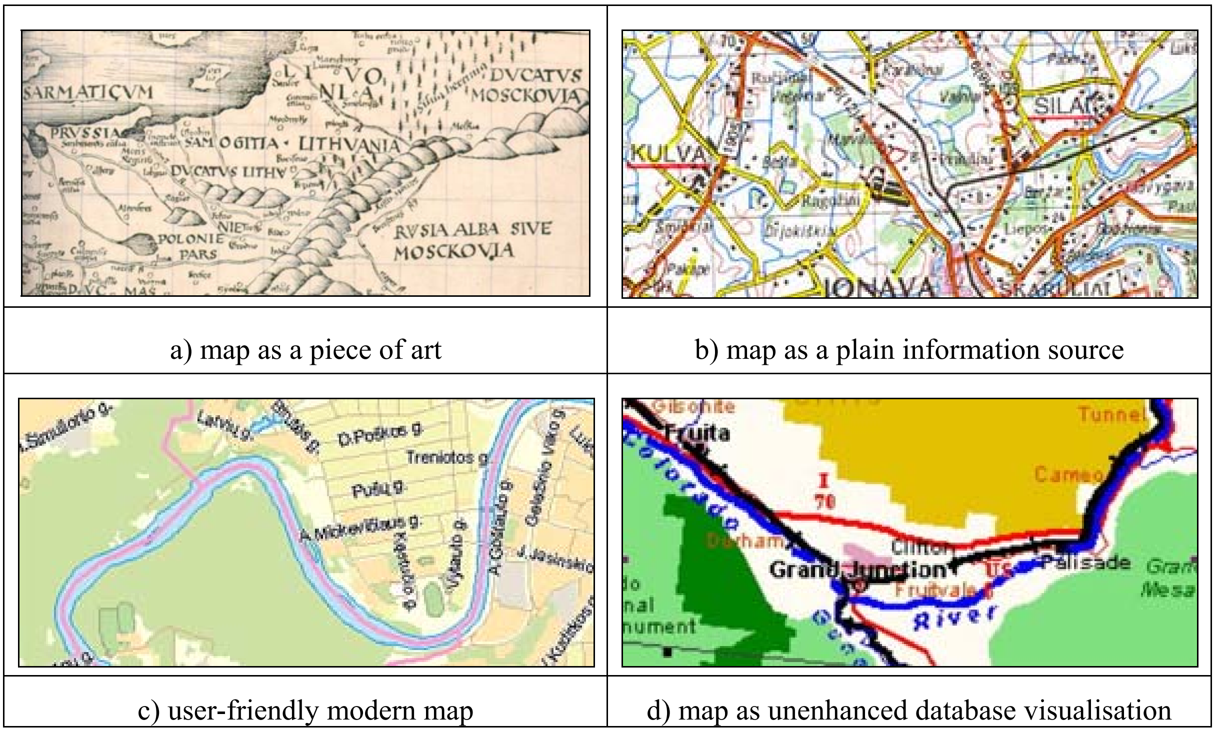
[4] The term 'graphic attributes' in this paper replaces the still more popular term 'graphic variables', which is not precise from the author's point of view. A variable is perceived as an independent object whereas an attribute is a characteristics of some object that cannot exist without the object, which is always the case with graphic 'variables', for example, thickness (of a line) or brightness (of polygon's fill colour).



a) map as a piece of art

b) map as a plain information source

c) user-friendly modern map

d) map as unenhanced database visualisation

Figure 6-1: Reflection of the cartographer–user relationship on the style of a map

Geographically, *national and regional* cultures have to a certain extent made impact on the cartographic representations, especially on the historical ones. Nowadays it is not so easy to identify a map as designed in a particular country or region, but in some cases reasonable assumptions can be made.

Culture of an organization, company or author can form its individual style that reflects its values, goals and other specifics of thinking. It takes a lot of time and efforts to develop a good individual style. That is the reason why smaller cartographic companies often follow or simply imitate[5] style of maps published by the reputed companies.

Importance of style in cartography is hardly disputable. There are three major fields where presence of style improves map quality.

- Identification. Style allows for positive identification of the author and culture.
- Information. A significant part of stylistic devices are not neutral but carry additional social, emotional and aesthetic messages that maps can convey. Besides that, style allows to make assumptions concerning map target group. N the other hand, if the style is actually compatible with perception specifics of the target group, it improves map communication. Whereas reading and interpretation of common map information takes some time, style is evaluated immediately and can give a user a good idea about the value of the map.

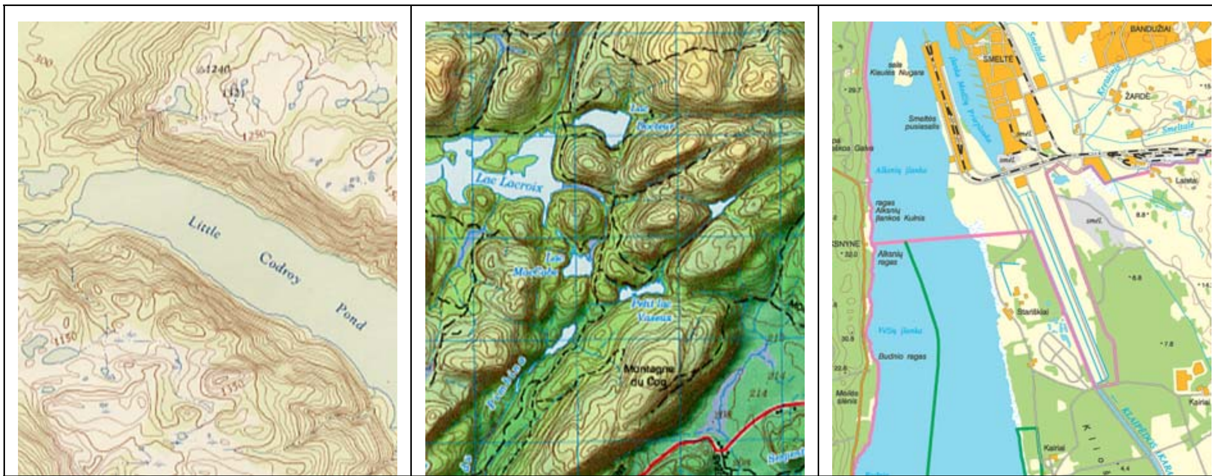
[5] There is a considerable difference between *following the style* (a good practice of accepting some general stylistic framework and developing it to match own vision) and *imitating the style*. Imitating is copying entire sets of values of graphic attributes used by other author that is in principle copyright violation. Unfortunately, we do not know about any practical method to distinguish between deliberate imitation and choice of the same values by coincidence. Choice of particular values, such as green or blue colour, has never been considered as subject to copyright that makes the problem of protection of entire design/style even more difficult.

- Integration. A well thought-out style makes general idea of the map reflect on its every detail thus serving as a strong organizing framework. It guarantees wholeness of the product.

Modern maps, that are designed, stored and often used in digital form, still do not have specific stylistic tradition. In this paper we will not concentrate on digital representations that on one hand surrender to the limitations of various displays, but on the other hand have almost unlimited possibilities of animation, interaction and other qualities. These qualities of digital maps require different approach and new extensions of traditional (if it exists in cartography at all) stylistic analysis. Thus we will concentrate on static representations (printouts or raster images) and try to define the main characteristics that allow for identification of such representation as belonging to one of the general visualization styles.

More formally, style is a *set of parameters*, part of which are determined by the map scale, theme and general purpose whereas the rest of them are subject to the designer's free choice.

The purpose of *cartographic stylistics* is to assure that all elements of visualization consistently *support appropriate perception* of map information by the target group. It is worth mentioning that 'appropriate' does not necessarily mean 'correct' or even 'most efficient', but rather that user's mental image of the map is close to the mental image the cartographer intended to convey. Maps often carry emotional contents. Sometimes they are designed with a purpose to distract attention from particular objects of geographic reality they represent or to create a false impression about the correctly represented phenomena in the other ways. Obviously such differences between represented reality and mental image is normally not the case with topographic maps, charts or other maps whose whose principal purpose is to accurately portray the features of the earth's surface. But regardless of high standardisation such maps can significantly differ (6-2). There is a general trend that more and brighter colors and lighting/shading effects are applied to modern maps. Unfortunately, the older maps, although less eye-catching, often are stylistically more consistent and pleasant to use for a longer time. Apparently importance of style grows in proportion to the diversity of graphic attributes and number of their values applied for cartographic visualization.



a) Canada, 1958	b) Canada, 2002	c) Lithuania, 2005

Figure 6-2: Fragments of 1: 50 000 topographic map sheets

Assuming that divergence of styles directly depends on allowed level of freedom of graphic expression, it can be stated that there are two large groups of maps that require different approach of stylistic analysis.

1. *General reference maps* that provide extensive close-up detail. Accurate and homogeneous representation of real world objects, large scale and high level of standardization are typical for these maps. Topographic maps, charts and some large scale thematic maps (e.g., geological) certainly belong to this group.
2. *Thematic maps* that contain specific information about particular locations and/or spatial patterns. Such maps usually are compiled at smaller scale, do not have strict visualization standards and often contain sets of conspicuous objects (an element of advertising).

It is evident that stylistic elements vary much less and are more difficult to identify within the first group. However, it does not mean that map stylistics should be limited to thematic mapping. As topographic maps utterly and metaphorically represent the state, their stylistic quality is important at national level.

Unfortunately there is a general lack of studies on map stylistics as well as of consistent practical recommendations for improvement of cartographic style. In the best case single chapters or paragraphs by various authors have touched this subject, mainly discussing impact of epoch style on historical maps or impact of modern technology on the modern ones.

Perhaps the most consistent ideas on map stylistics can be found in works of Lithuanian cartographer M. Dumbliauskienė who has examined style as a component of cartographic design within the framework of cartographic communication. Unfortunately, only a small part of this research has been published in English. She has developed a set of purpose-dependent stylistic criteria that can be used for evaluation of communicative quality of individual maps: level of cartographic expression, level of generalization, level of regulation, expressiveness and strength of emotional impact. Even though we do not completely agree with all her ideas, our hereafter presented model is related to at least some of the proposed criteria.

6.2 Factors that influence map style

Maps are products of science, technology and art. The concept of style applies to map design, which is usually associated with the 'artistic' part of this triad. It allows for stylistic analysis of maps as of pieces of art. Nevertheless, map design is closely related and often largely determined by the technology used to make the map and by the specifics of data that are represented on the map.

It is possible to outline some objective factors that restrict use of possible stylistic solutions. For this we will use a simple but comprehensive framework for cartographic visualization that has been suggested by H. Schlichtmann (Schlichtmann, 2003). It is based on three main functions of with cartographic transcription: signification, clarification and emphasis. Signification is about correct visual representation of map informations, especially of hierarchies or other complex systems.

Clarification is about making visualization easy and convenient to use. Emphasis means that a part of map information may serve a background for some objects of particular interest, that are graphically highlighted.

Purpose. Map purpose influences not only the choice of map contents, but also projection, scale, level of generalization and layout. For example, nautical charts are usually designed using Mercator projection that preserves direction and shapes. However, it would not be a good choice for a purpose that includes correct representation of size (e.g., general political map). Metro maps do not require consistent scale and are not split into sheets in contrast to inventory maps. Maps that must first of all convey large volume of precise data necessarily contain many various objects and almost all graphic devices are employed to convey significant information (attributes and relationships), thus leaving no freedom for additional expression and no much space for decorations. On the other hand, maps designed to be specifically noticed or memorised, require expressive design.

There are several general purposes that differently influence map style.

1. <u>Inventory and navigation maps</u>. Due to characteristic standardization and accuracy requirements this purpose allow very little freedom of stylistic expression. Unusual, extravagant graphic solutions are not acceptable. Within this group, signification function prevails.

2. Orientation maps. This is a large group of maps with strong clarification function. Clarity is an important issue. Nowadays, when maps are already so complex and become increasingly interactive, ease of reading is likely the best thing a cartographer can give to the user. It is often said; the better the design, the less it draws attention to the design itself. Clarity means that the map reader can easily move along, picking the information he needs, not bothered by that what he does not want at the moment but having it conveyed when he wants more, avoiding confusion. Decoration and emotional involvement are subordinate to the function, which must dictate the form. Excessive use of graphic devices is not desired unless they are necessary to emphasize particular entities or to prevent from possible interpretation errors.
3. Thematic maps with primary purpose of visual communication. Here emphasis plays an important role and good style means that methods of emphasis are regular and uniform over all the map or map series. More sophisticated graphic solutions are often appropriate. This very large set of maps can be roughly split into three smaller groups corresponding to informing, training and advertising missions. Correspondingly, importance of attractive emphasis is higher for each of these subgroups. Nevertheless, good style always remain functional and this rule should never be forgotten.

Target group. Maps of the same purpose require different style for different audience. Visually impaired people and children are typical examples. While the former need specific color solutions, the latter need decorations, attractive and recognizable objects.

Media. Even though modern publishing and presentation technologies are quite flexible, technological limitations still exist. To make a complex map look aesthetic (and in many cases simply avoiding information loss), black and white, grayscale and color outputs may be designed in different styles. Very small fonts, thin lines or pale subtle colors would not be readable on maps, presented exclusively on computer screen. A map with just a few large objects, that may appear rather stylish on a large screen, would be very inconvenient to use for mobile devices. By the way, not only limitations but also additional space for stylistic variations is due to modern technologies. Three-dimensional, interactive, animated maps require an extended stylistic framework, connecting style of traditional graphic devices with, for example, a style of 3D lighting or a style of map objects behavior.

6.3 Stylistic criteria and parameters

Speaking of different styles we will try to eliminate impact of the factors listed in the previous chapter. Partially for this reason, but also because of unavoidable subjectivity of evaluation, values of stylistic criteria will not be absolute, but relative to two neighbouring reference standards of each purpose-oriented group:

1. ‘minimal map’ as database visualization using common schemes, i.e., stylistically indifferent sample;
2. ‘standard map’ that is designed used minimum graphic enhancement necessary to meet basic criteria of communicative quality, i.e., one step ahead of the ‘minimal’ map.

According to M. Dumbliauskienė, stylistic criteria are: graphic expresiveness, generalisation, standardisation, illustrativeness and strength of emotional impact. Also composition is described as a specific group of criteria that includes scale, proportions, color scheme, accentuation and general layout.

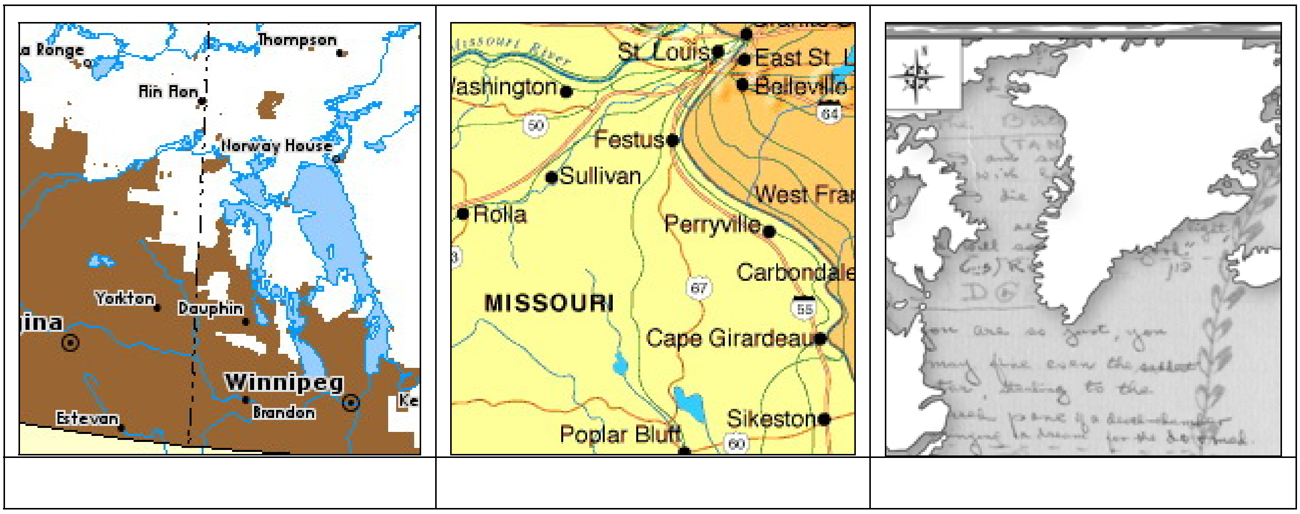
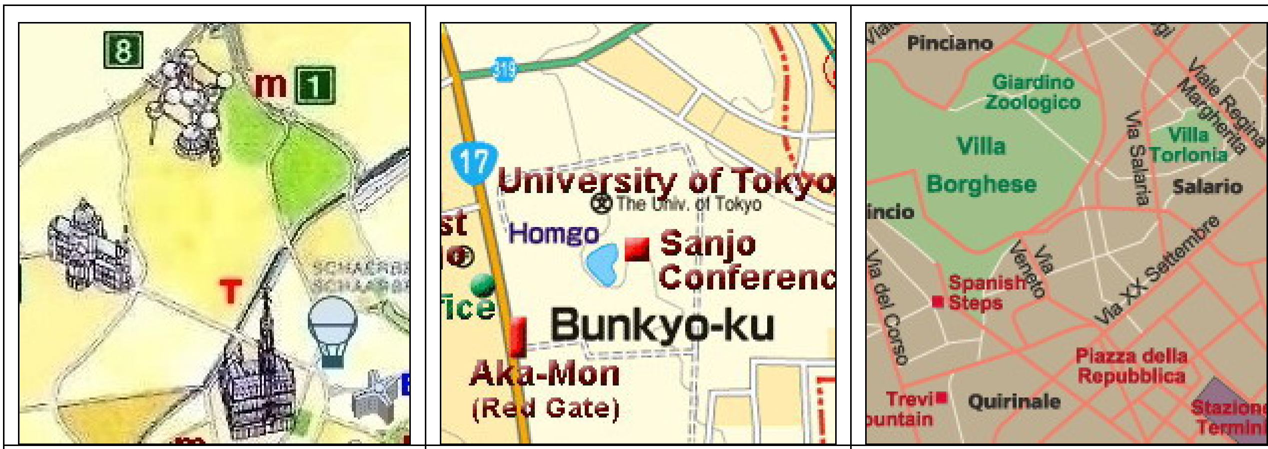


Figure 6-3: ‘Minimal’, ‘standard’ and ‘stylish’ (from the left) map samples

From our point of view, some of these abstract criteria cover same aspects of map stylistics (for example, use of a particular color scheme results in accentuation or deviations from standards) and some, such as ‘emotional impact’ or ‘general layout’ are too abstract to be evaluated. Therefore, identification of map style requires a set of more formal and more independent parameters. We propose only three basic largely independent criteria, that can apply to different map components separately, but, on the other hand, combine composition and other aspects into one system.

1. **Decorativeness.** Roughly speaking, this parameter describes amount of work applied for making map or its component specifically beautiful. Decorativeness manifests in eliminating imperfections of visualisation (for example, hydrography linework is approximated by splines, position of letterings is adjusted manualy, polygons made transparent etc.) and in addition of graphic devices that normally do not convey additional information, except of subjective impressons generated by associations. For example, Greek or baroque patterns can be used for map frames. However, three-dimensional drawings of buildings in city plans or of other spatial structures should be clasified as decorative even though they mainly serve the purpose of clarification. This parameter covers illustrativeness, (partly) standardisation, strength of emotional impact and accentuation from M. Dumbliauskienė’s set.
2. **Expressiveness**. This parameter describes the components that are intentionally designed as conspicuous (not necessarily beautiful). Both graphic expresiveness and strength of emotional impact from the previous set are directly related with this parameter, whereas scale, proportions, color scheme and generalisation largely depend on it. Expressiveness manifest in bright colors, interesting patterns, images, large texts and signs, thick lines, excessive generalisation.
3. **Originality**. Amount of unusual visualisation solutions (they can increase or not increase decorativeness and expressiveness) is strongly related with style. Originality means the degree of deviation from standard visualisation schemes for a particular map type. It can be observed in entire map (e.g., oval layout), its objects (inverse colors, distorted shapes, unexpected fonts, artistic effects) as well as in cartographic base components, such as a grid of unusual map projection, inverse orientation, varying scale. Nevertheless, it is difficult to formalize as graphic solution, once seen or described, loses its uniqueness. Parameter of originality is related with all of the abstract criteria.



a) decorativeness | b) expressiveness | c) originality

Figure 6-4: Samples of street maps with one prevalent stylistic parameter

The criterion of **stylistic consistency** must be added to this system for verification and for identification of the case when emphasis plays a significant role and big differences in parameter values across the components does not mean absence of uniform style. It corresponds to the abstract criterion of accentuation. Strong emphasis is used, for example, in advertising maps and makes it difficult to identify their style. Therefore we exclude this group, as well as maps, designed to meet the needs of specific target groups, from further analysis in this paper. In general, methods and styles of accentuation require a separate analysis.

Inconsistency of manifestations of the first three parameters usually means that the style is not sustained and higher parameter values are sporadical.

The framework connecting these stylistic parameters with standard map components, oriented to classical media (printed or non-interactive screen image) and main indications for each parameter are presented in the table below.

Table 6-1: Stylistic parameters and their indications

Parameters / Components	**Decorativeness**	**Expressiveness**	**Originality**	**Consistency (applies to each parameter)**
Lines	• resembling natural shapes and patterns (associative) • decorated	• generalised • thick • vivid patterns • shadows • artistic effects	• unexpected patterns	• consistent • background/highlights
Colours	• harmonious • nuanced • contrasting	• pronounced • dark • contrasting • discordant	• inverse • unexpected	• consistent • background/highlights
Textures	• transparent • artistic effects	• irregular • rough	• unexpected effects	• consistent • background/highlights
Conventional signs	• associative • decorated	• prominent • sketchy • 3D effects	• unexpected associations	• consistent • background/highlights
Lettering	• decorated	• prominent	• unique fonts	• consistent

Parameters Components	**Decorativeness**	**Expressiveness**	**Originality**	**Consistency (applies to each parameter)**
	• artistic effects	• unusual orientation • 3D effects	• unconventional orientation	• background/highlights
Supplementary components (title, grid, frames, scale, north arrow)	• decorated	• prominent • sketchy	• unconventional • unique	• consistent • background/highlights
Composition	• balanced • decorated	• assymmetric • simplified	• unconventional	• consistent • background/highlights

If consistent use of graphic expression is observed, it is possible to identify the type of map style. The following table shows tentative relationship between possible combinations of ranged parameter values and the strength of stylistic expression.

Table 6-2: Stylistic parameters and stylistic expression of maps

Parameters Visualisation types	**Decorativeness**	**Expressiveness**	**Originality**
Minimal (automated)	None	None/Colors only	None
Standard (regulated)	Low	None	None
	Low	Low/Colors only	None
Conventional style	Low	Moderate	Negligible
	Moderate	Low	Negligible
	Moderate	Moderate	Negligible
	Any	*Any*	Present
Conspicuous style	Low	High	Negligible
	Moderate	High	*Any*
	High	Low	*Any*
	High	Moderate	*Any*
	High	High	*Any*
	Any	*Any*	Definite

'Minimal' maps themselves are not of interest for stylistic analysis. They are identified mainly by absence of any graphic enhancement and inadequate generalisation. Possible presence of expressive details is in this case due to the ready-made visualisation schemes or simply incidental. The only rare case when it is sensible to speak of the 'minimal' style is when it is intentionally applied to invoke 'technocratic' associations.

Presence of even a few components of original design or recognizable decorations and/or accents separates 'standard' maps with little freedom of graphic enhancement from the maps with larger freedom of expression.

For *Standard* visualisations that basically correspond to topographic (inventory) and navigation maps, more ranks or types of manifestation of decorativeness and expressiveness within the *Low* category must be used for identification of their specific style.

Much bigger number of different styles can be detected within the next two groups of maps. *Conventional* and *Conspicuous* style groups are approximately separated by presence of *High* values of either parameter. The main practical difference between these two groups lies in much bigger diversity of clearly different styles among the highly decorative or expressive maps.

Originality is the strongest style-defining criterion. Even though the uniqueness of visualisation is usually achieved by the use of decorative and/or expressive devices, it allows separating out not a group but a particular individual style.

Additional *refining criteria*, such as contrast, harmony, promiscuity etc., must be used for definition of particular styles within a group. Style can be also named after associations it activates: historical, political, social, cultural, emotional etc.

6.4 Modern map styles

In the space fomed by the above mentioned three criteria, it is possible to tentatively identify several common map style types. They are also shown in Figure 6.5.

Table 6-3: Frequent stylistic groups of modern maps

Parameters Style types	**Decorativeness**	**Expressiveness**	**Originality**
Laconic	Low	Low	Present
Constructive	Low to moderate	Low to moderate	Negligible
Expressive	Low to moderate	High	Negligible
Lightsome	Low to moderate	Moderate to high	Present
Aggressive	None to low	Very high	Negligible
Soft / lyric	Moderate	Low	Present
Antique	High	Low to moderate	Present
Luscious	Very high	Moderate to high	Negligible
Extravagant	Low to high	High	Definite
Artistic	*Any*	*Any*	Definite

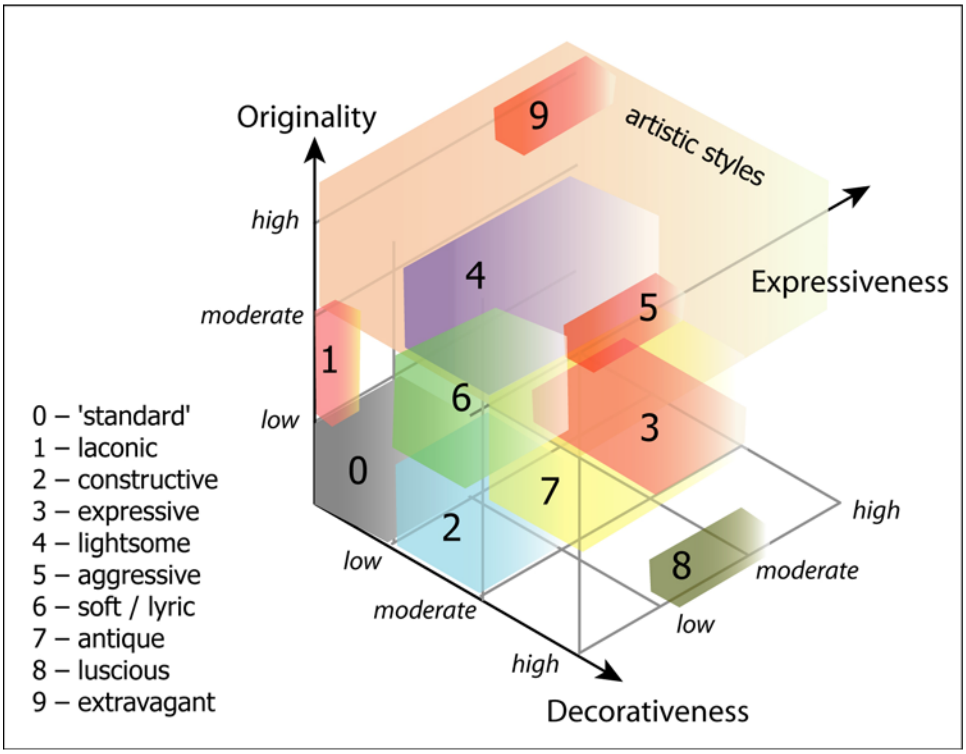
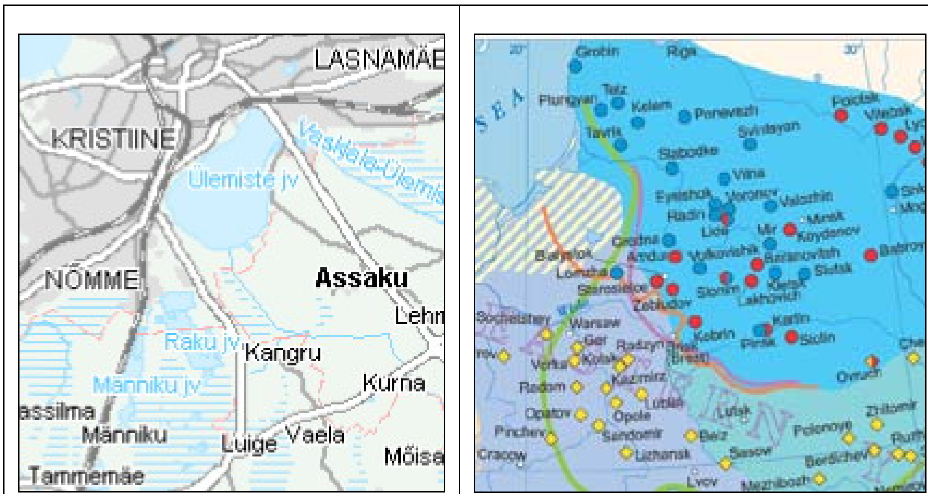


Figure 6-5: Stylistic groups of maps in parameter space

6.4.1 Conventional styles

Laconic style manifests in very simple but to some extent original graphic design along with minimised number of graphic objects and devices without additional geometrical simplification. It suits well to the maps with clearly expressed clarification function.

Constructive style is the most common example of good cartographic design practice. It means harmony between the map contents and graphic design, attractive, balanced and inobtrusive visualisation. It is emotionally neutral or slightly positive.



a) laconic | b) constructive

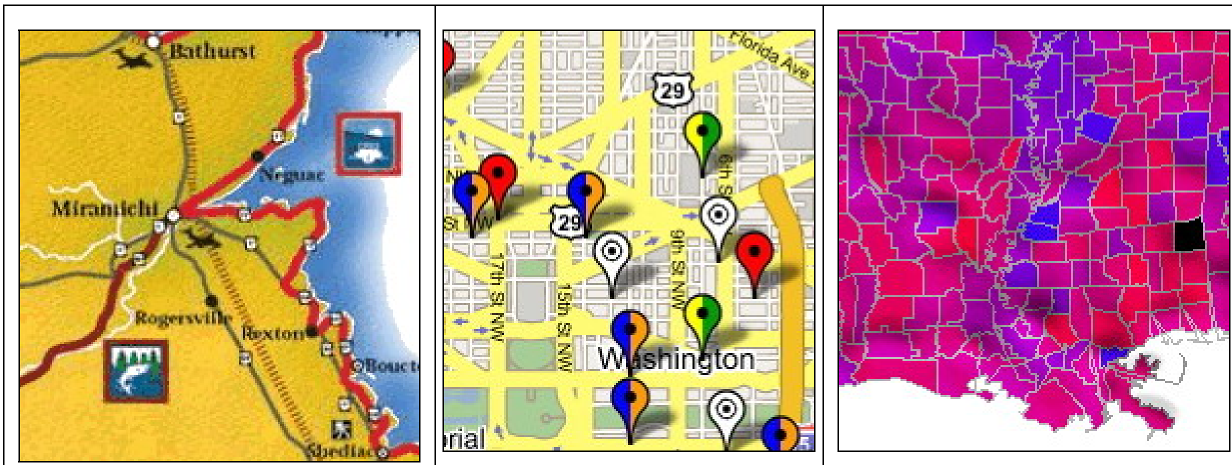
Figure 6-6: Samples of conventional styles

6.4.2 Expressive styles

Expressive style manifests in intense, contrasting colors and sizes of the objects, daring use of patterns and graphic effects such as lighting and shadows, lack of nuances, rhytmical composition. Objects are often stylised or even distorted in order to attract attention and stimulate perception (balanced clarification and emphasis).

Lightsome style is a version of the expressive style, specifically figurative and picturesque. It is elaborated to raise interest, evoke positive emotions and associations, always preserving the function of clarification.

Aggressive style can be seen as the extreme case of expressive style. Dissonant blatant colors immediately attract attention and often boost memorizing map information. Due to simplified, sketchy design and generally negative emotional impact it is rarely applied as a consistent visualisation manner, but often chosen to highlight the parts of advertising maps thus supporting the function of emphasis often at the expense of the clarification and signification.



a) expressive | b) lightsome | c) aggressive

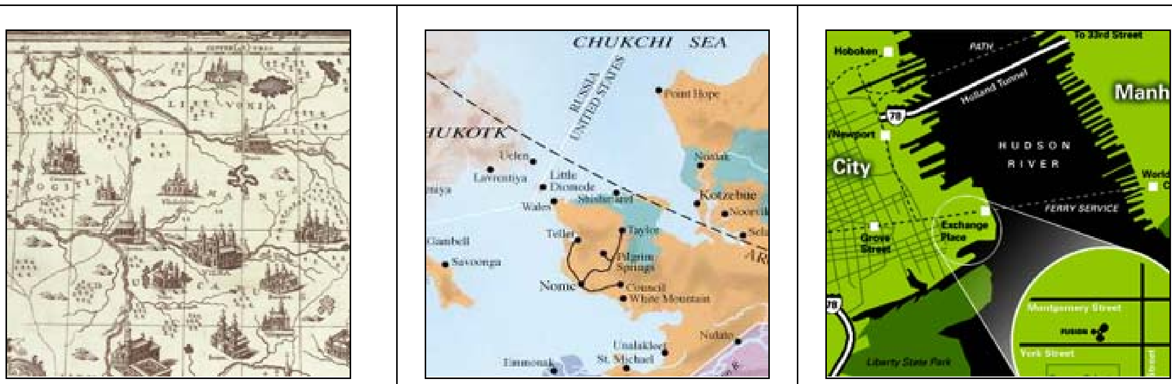
Figure 6-7: Samples of expressive styles

6.4.3 Artistic styles.

In these styles, aesthetic function usually prevails over clarification and signification.

Antique styles, that imitate the design of historical maps of different or mixed epochs, are perhaps best known of the modern artistic styles. They are is distinguished for static drawing-like visualisations, presense of additional drawings, geometric or floral ornaments, limited number of natural pale fill colors, cursive scripts or calligraphic fonts, textures of old parchment paper etc. They are mostly emotionally neutral but invoke associations with the particular period or culture.

Soft/lyric style is formed by subtle aquarelle-like gradations of colors, temperate use of gradients, shadows, elegant fonts and ornaments. Contour lines are very fine or absent as well as unnecessary map objects. For its perfect clarity, this style can be examined as the more sophisticated case of the laconic style.



a) antique	b) soft / lyric	c) extravagant

Figure 6-8: Samples of artistic styles

Luscious style is rather rare and manifests in extensive use of different types of ornaments, mannered fonts, both contrasting colors and nuances, static composition.

Extravagant style is both very expressive and original. It creates strong impression due to unexpected composition, unconventional decorations, unusual, dissonant color schemes and original visualisation manner (for example, mystical, minimalistic, rough).

A great variety of other artistic styles are also characterized by the originality of design, but in a more conventional manner and with different purpose than pure extravagant style. Imitations of modern ink, charcoal, or crayon drawings, paintings may be good examples.

Thus, four major groups of styles can be defined by general degree of graphic enhancement of visualised data: 'minimal' (no enhancement, 'standard' (small-scale enhancement), conventional (moderate enhancement, a few sub-groups) and conspicuous (significant enhancement, a great variety of individual styles). Within the last two groups, some more concrete style types such as laconic, constructive, expressive, lightsome, aggressive, soft, antique, luscious, extravagant and artistic can be defined. They serve as principal reference areas in a hypothetical three-dimensional space of map stylistics.

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