Requirements in thematic cartography

Giedrė Beconytė

Center for Cartography, Vilnius University
E-mail: giedrė.beconyte@gf.vu.lt

INTRODUCTION

Objectively, it is impossible to make an ideal cartographic product. However, a careful design is very important for the quality of the map in all senses. Therefore the stage of design deserves special attention in thematic cartography. Requirement engineering is a necessary part of the whole information engineering in thematic cartography, especially for complex projects such as the National Atlas of Lithuania.

The goal of this article is to describe the concept of requirements for thematic cartography products such as map series, atlases or even separate maps. The most complex cartographic issue is the National Atlas of Lithuania compiled in the Center for Cartography of Vilnius University. Methods and tools for analysis of the application sphere are subject to system analysis and engineering (Borgida, 1986), which has been applied by Lithuanian cartographers over the last few years. The specification of an atlas is a document, in which the atlas and its features are described. The specification is a result of detail analysis of user's needs in a specific sphere of application. Such analysis for a complex atlas can become really problematic, considering that requirements to maps and atlases can be formulated and changed at any time within the cycle of its development.

It is common to apply the methods of conceptual modelling for specification of any complex system (Booch, 1991), *i.e.*, to define semantic objects (entities) that represent all things of significance (real objects, concepts, ideas) in the sphere of application and relationships with those entities. This is the way to split a complex system into relatively simple parts. Analysis of such parts, their qualities and relationships enables to discover the qualities of the whole system and to choose a right way to prepare the specification.

CONCEPT OF REQUIREMENT IN THEMATIC MAPPING

Requirement is a desired quality of an object or process defined in the specification, contract, standard or another document. It is a formal description of what must be the result of system's processes, and what is the way to assess the quality of that result (method of requirement verification). Specifying the requirements for which such method cannot be applied doesn't make much sense, moreover, it is likely to become a source of potential conflicts at the stages of review or delivery. Examples of requirements are shown in Table 1.

There are different ways to specify the requirements: simple description, link to the source of re-

Table 1. **Examples of requirements**
1 lentelė. **Reikalavimų pavyzdžiai**

No **Nr.**	**Requirement** **Reikalavimas**	**Method of verification** **Patikrinimo būdas**
1	2	3
xx	"The elements of the general geographic map are represented in separate layers" „Bendrojo geografinio žemėlapio elementai, vaizduojami atskiruose sluoksniuose“	Review Peržiūra

ISSN 1392–1096. G e o g r a f i j a . 2001. T. 37(2)

Table 1
1 lentelės tęsinys

1	2	3
xx	"Dot marker layers representing settlements must be designed over hydrography layers" „Gyvenviečių sluoksniai, projektuojami virš hidrografijos sluoksnių“	Review Peržiūra
xx	"Every page of the digital Atlas must contain a hyperlink to the front page" „Iš kiekvieno skaitmeninio Atlaso puslapio turi būti galimybė grįžti į titulinį puslapį“	Testing Testavimas
xx	"The spelling of geographical names used in the Atlas must be approved by State Comittee for National Language" „Geografinių vardų rašyba Atlase turi atitikti Valstybinės lietuvių kalbos komisijos patvirtinus sąrašus“	Detail checking Quality assurance Korektūra, kokybės kontrolė
—	"The Atlas must be informative" „Atlasas turi būti informatyvus“	This requirement cannot be verified, therefore specifying it makes no sense Neverifikuojamas reikalavimas, todėl nėra prasmės jo registruoti

quirement, example, pattern or set of rules which the final product must match.

Since requirements for thematic maps and the information system of the National Atlas are very specific, requirement engineering, including specification, classification, analysis and assessment, must become a subject of thematic cartography science (cartology).

PRINCIPLES OF REQUIREMENT ENGINEERING

Requirements describe the features and limitations of the system.

The first stage in requirement engineering for a thematic cartography atlas should start with the identification of the mission, objectives and strategy of the project. It gives the idea of the real need for such product or system and its success factors (Barker, 1990). 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 all basic information about the state. The mission is divided into objectives which also define the most general requirements for the structure and contents of the Atlas, describe by whom, in what context and ways the Atlas or its structural parts will be used. The results of such primary analysis can be represented as a contextual chart, also showing system's relationships with external entities and expected profit and use of the system (Figure).

The objectives are in turn divided into the functions and tasks of the information system of the Atlas, specifying the results expected for each task, delivery terms and the methods of their quality assessment.

The next step is dividing the system into its structural parts and defining the requirements to each part. Starting with the highest level of abstraction, the set of requirements is designed using the "top-down" strategy until the system is decomposed into its 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 the corresponding require-

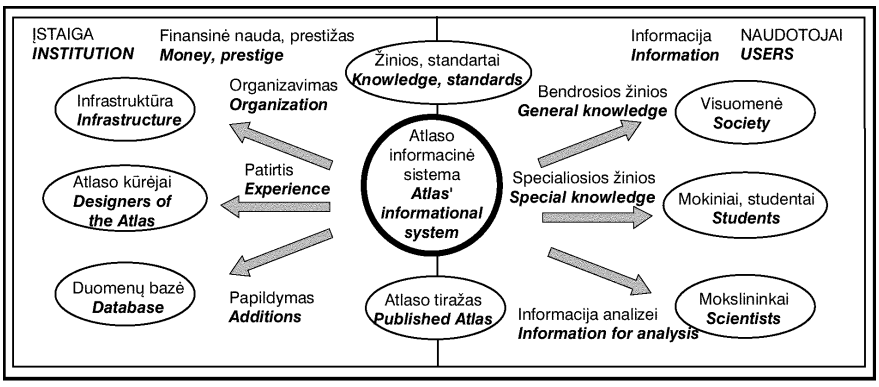

Figure. Example of a contextual diagram
Pav. Kontekstinės diagramos pavyzdys

ments at the lower level. This is the way how technological requirements (*how* to design the product) are derived from abstract project requirements (*what* product has to be designed).

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

me 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 the official specification; they can only be described

Table 2. **Matrix of requirement interrelations**
2 lentelė. **Reikalavimų sąryšio matrica**

Requirement **Reikalavimai**	**Derived from** **Reikalavimai, iš kurių išvestas**	**Applies to components** **Komponentai, kuriuose lokalizuotas**	**Method of approval** **Aprobavimo būdas**
Nr. 1	Nr. 1 Nr. 2 Nr. 3	Nr. X	Quality assessment Vertinimas
Nr. 2	<document ref.> <dokumentas>	…	…
Nr. 3	Nr. 1	…	…
…	…	…	…
Nr. m	Nr. 1 Nr. 15	…	…
…	…	…	…

It doesn't mean that a full set of requirements 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 the structure. The need for specifying the 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's subject (sphere of application).

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 the project. All formal requirements must be documented for the sa-

in a document which has a status of informal suggestion or comment to the contract.

Each specified requirement should be applicable in practice, integrated (not conflicting with any other requirements), significant, monosemantic and verifiable. In an 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 location matrices such as shown in Table 3.

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 in what way the requirement was derived from the more abstract one. That is the way to discover incorrect, conflicting requirements (*e.g*., the system of

Table 3. **Requirement location matrix**
3 lentelė. **Reikalavimų lokalizavimo matrica**

Components **Atlaso komponentai**	**System requirements** **Reikalavimai sistemai**								
	Nr. 1	Nr. 2	….	…	…	…	…	…	Nr. n
Nr. 1	✓	✓	✓			✓	✓		
Nr. 2		✓	✓						✓
…	…	…	…	…	…	…	…	…	…
Nr. m	✓	✓				✓	✓		✓
…	…								

conventional signs designed for the Atlas might be not compatible with such a system developed earlier for geological maps or not match a general standard of cartographic design).

The strategy of the stage of analysis and requirement engineering are important factors of success for the company.

CLASSIFICATION OF REQUIREMENTS IN INFORMATIONAL SYSTEM

Requirements can be grouped by their status.

Obligatory requirements. A system or object cannot be created in the way corresponding to the mission and objectives of the project, unless the obligatory requirements are implemented. An example of such a requirement at the highest level of abstraction 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 simplier, etc. Violation of such requirements doesn't corrupt the system.

For optional requirements it makes sense to determine the level of importance, considering all consequences of its violation. For example, the requirement that all maps showing average air temperatures in "Climate" part must be of the same scale and format is more important than the requirement to design them in one of standard scales; compiling maps of an 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, let them be standard, scales or located in different pages. In the second case, not only the principle of standardisation, but also of unification and user's comfort of systems' design are violated.

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

Additional requirements. These are requirements to expand the system's structure or contents, *e.g*., to compile extra maps to the first contract. Such requirements usually are discovered in a late stage of design.

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

< Number; object to which the requirement applies; importance (doesn't 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 stage of design 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 into account that they can be changed sometimes later on according to specified 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 informational and support system itself of the project.

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

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

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

Configuration management requirements define the methods used for system's configuration management.

Finance management requirements describe the budget of the project, labor costs, responsibility for unexpected expenses, possible bonuses, accounting procedure. It makes sense to have a 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 the system's 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 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 requirements, every component of the Atlas is described in detail by a separate set of requirements. Requirements for separate maps are specific to their sphere of application and related to geographical information of the mapped territory. They can be grouped into those describing the form of maps (*e.g.*, cartographic generalization, layer structure, etc.) and specific requirements for the contents of thematic maps.

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

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

- Accuracy requirements define the 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.*, the National Atlas must represent more than a single sphere of activity and all regions of the state.
- Efficiency requirements, *e.g.*, of balance between complexity and easy perception.
- Unity requirements set the level, methods and ways of standardisation.
- Requirements for stand-alone components, which are designed to be also published in other issues or separately.
- Changeability requirements basically say that labor costs for updating the information for re-use must be minimized.

CONCLUSIONS

The main objective of the professional cartographeranalyst is to make geographical information available for everyone takes interest in it. For that reason, 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 easy to describe, classify, analyse, assess and implement.

There are two main groups of requirements: product requirements which concern the quality of the issue itself, and project requirements which describe the ways the issue must be compiled. Specifying a requirement makes no sense unless there is defined some objective way to assess whether this requirement is implemented or not.

During the implementation of the project, requirements can change for different reasons such as ignored user's 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 make changes anytime during the life cycle.

Since requirements in thematic cartography are specific for particular issues and the informational system of the Atlas, their engineering becomes subject to the discipline of cartographical informatics. In the near future it must form a separate branch of cartology.

Gauta 2001 11 14
Parengta 2001 11 16

References

Barker R. (1990). *CASE Method, Tasks and Deliverables*. Addison Wesley.
Booch G. (1991). *Object Oriented Design, with Applications*. Redwood City, Calif.: Benjamin/Cummings.
Borgida A. (1986) *Conceptual Modelling of Information Systems. On Knowledge Base Management Systems*. N. Y.
SPICE Project Organisation: International standard for software process assessment *http://www-sqi.cit.gu.edu.au/spice/*

Giedrė Beconytė

REIKALAVIMAI TEMINEI KARTOGRAFIJAI

S a n t r a u k a

Straipsnyje nagrinėjama, kaip turi būti rengiami ir pateikiami teminės kartografijos leidiniai, kaip pavyzdžiu pasiremiant šiuo metu Kartografijos centre rengiamu Lietuvos nacionaliniu atlasu. Atlaso specifikacija – dokumentas, aprašantis atlasą ir jo pageidaujamas savybes – parengiama išanalizavus atitinkamą sritį. Tokia kompleksinio atlaso analizė gali būti labai sudėtinga, kadangi reikalavimai formuluojami vienas po kito atlaso kūrimo metu.

Reikalavimas – tai objekto ar proceso savybė, numatyta specifikacijoje, sutartyje, standarte ar kitame dokumente. Skirtingai nuo neformalios nuostatos, kuri nurodo, koks turi būti sistemos kūrimo procesų rezultatas, reikalavimas siejamas su tam tikru jo įgyvendinimo laipsnio nustatymu (verifikavimu). Reikalavimas, kurio įgyvendinimo laipsnio nustatyti negalima, neturi prasmės ir yra tik galimų konfliktų šaltinis. Reikalavimų pavyzdžiai surašyti 1 lentelėje. Visi formalūs reikalavimai turi būti dokumen-

tuojami nuorodant jų šaltinį ir autorių bei atlaso komponentą, kuriam jie taikomi (2 lentelė).

Reikalavimus galima pateikti skirtingais būdais: aprašymu, nurodant šaltinį, pateikiant etaloną, pavyzdžių rinkinį arba taisyklę. Kadangi reikalavimai atlaso informacinei sistemai ir kuriamiems teminės kartografijos kūriniams yra specifiniai, jų sudarymo metodus turi nagrinėti teminės kartografijos mokslas. Ateityje kartografinių kūrinių ir sistemų reikalavimų formulavimas, klasifikavimas, specifikavimas, analizė ir vertinimas turėtų susiformuoti kaip atskira šio mokslo šaka.

Kiekvienas dokumentuojamas reikalavimas turi būti įgyvendinamas, integruojamas (suderintas su kitų sistemos objektų reikalavimais), prasmingas, vienareikšmis (svarbu jį tiksliai suformuluoti) ir verifikuojamas (kiekvienam objektui galima nustatyti, ar reikalavimas yra įgyvendinamas). Pageidautina, kad visi reikalavimai vienareikšmiškai būtų identifikuojami ir susieti su konkrečiais objektais. Tam tikslui sudaroma reikalavimų lokalizavimo matrica (3 lentelė).

Pirmasis uždavinys apibrėžiant atlaso, kaip ir bet kokios kuriamos sistemos, reikalavimus yra **koncepcijos** suformulavimas, arba atsakymas į bendriausius klausimus: kam kuriama informacinė sistema, kaip ji atrodys ir kaip bus kuriama. Tada formuluojamas pagrindinis atlaso kūrimo tikslas (**siekis**), iš kurio sprendžiama, ar tikslinga kurti informacinę sistemą ir kokia bus gauta nauda (Barker, 1990). Siekis konkretizuojamas suskaidant jį į **strateginius tikslus**, kurie turi nusakyti bendriausius atlaso struktūros ir turinio poreikius, apibrėžti, **kas, kur ir kaip** naudos jo struktūrines dalis. Šios analizės rezultatus patogu pavaizduoti kontekstine diagrama, kurioje parodoma, su kokiomis išorinėmis esybėmis yra susijusi kuriama sistema ir kokią naudą jos gaus sistemą sukūrus (pav).

Atsižvelgiant į reikalavimų orientaciją (į sistemos savybes ar į jos kūrimo būdą), jie gali būti projekto ir produkto. Reikalavimai projektui nusako, kokiu būdu turi būti kuriama sistema; šie reikalavimai dažniausiai specifikuojami sutartyse. Reikalavimai produktui (atlasui, žemėlapiui…) apibrėžia pageidaujamas paties atlaso savybes nepriklausomai nuo to, kaip jos bus gaunamos. Šie reikalavimai apriboja galimus projektinius sprendimus. Reikalavimai atskiriems atlaso komponentams išskiriami iš bendrųjų reikalavimų.