DIGITAL CARTOGRAPHIC DATA AS A COMPONENT OF THE NATIONAL SPATIAL DATA INFRASTRUCTURE

Sonja Dimova, Elizabeta Dukadinovska-Anastasovska [1]

Abstract

The acquisition of the cartographic data in every country requires large amount of funds. If the acquisition procedures are not inter-coordinated, the funds required for the realization of the procedures are significantly multiplied, resulting in heterogeneous and inconsistent cartographic data, which are sometimes not usable. Also, one should have in mind the fact that the institutions are not so inclined to share the spatial data created by them and are using them for their purposes only.

The overcoming of the mentioned problems and the reduction of the funds for acquisition of the cartographic data is possible through establishment of National Spatial Data Infrastructure as a summary of measures, norms, specifications and services which have the objective to enable improved collection, administration, share and use of the geo-referenced spatial data. The generally accepted NSDI concept indicates that the NSDI and the digital cartographic data are interconnected i.e. the digital cartographic data are an integral part of the NSDI.

Having in mind the above stated as well as the fact that in the past years the production of the digital cartographic data in scale of 1:25000 is performed according the standardized procedures within the Agency for Real Estate Cadastre – AREC, these cartographic data will be the leading element i.e. will be first as part of our NSDI. The cartographic data may be used as "basic data" i.e. as a template used to upgrade the thematic spatial data sets, creating multipurpose cartographic products. In this order, the digital cartographic data as a component of the NSDI will enable easy access for all interested subjects for various purposes and needs. With this, the AREC will contribute towards increase of the economic development, reduction of the double expenditures and will enable multiuse of the cartographic data.

Key words: digital cartographic data, NSDI, INSPIRE, UML, data model, metadata, accuracy

1. INTRODUCTION

The positive trend of development of the NSDI points out the fact that the number of countries which focus towards establishment of a standardized infrastructure of spatial data on a national level – NSDI (National Spatial Data Infrastructure) is increasing i.e. activities are undertaken for the purpose of enabling qualitative collection, administration, exchange, share and use of geo-referenced spatial data. In addition to the above is the mission of the INSPIRE directive having the objective to expand the development of the European infrastructure of spatial data via collaboration in the area of geographic data, including the cartographic, cadastre and land data.

The generally accepted concept of establishing NSDI points out its interconnectivity with the digital cartographic data i.e. to the fact that large part of the spatial data in the NSDI is comprised of cartographic data. These data are considered to be one of the most important components in the process of: management, production of development studies, planning projects, economic and social development, and analysis of the level of dissemination of the spatial occurrences and their interconnections and other.

When it comes to cartographic data, until 2006 in Macedonia were used analogue (graphic) data contained on the topographic maps, produced by the Military-geographic institute in Belgrade whose contents date since 1972. Having in

[1] PhD Sonja Dimova, Agency for real estate cadastre, Trifun Hadzijanev street No 4, 1000 Skopje, Republic of Macedonia, tel. +38923171945, fax. +38923171668, e-mail: sonja.dimova@katastar.gov.mk

B.Sc, Elizabeta Dukadinovska-Anastasovska, Agency for real estate cadastre, Trifun Hadzijanev street No 4, 1000 Skopje,Republic of Macedonia, tel.+38923204843, fax.+38923171668, e-mail: elizabetadukadinovska@yahoo.com

mind the period when they have been made, as well as the fact that in the past no attention has been placed to the maintenance and the updating of these cartographic data, it can be said that they are outdated and do not represent the actual condition on the field, above all the graphic part and the update of the topographic maps which are one of the most significant characteristics upon which the users constantly insist.

To overcome the condition of outdated data in the topographic maps in scale of 1:25000, the Agency for Real Estate Cadastre – AREC in 2004 has initiated the production of new digital topographic maps. The digital cartographic data comprised in the new maps as well as the methodology used to produce them have raised the modern cartography one notch higher, providing an environment where one is not limited only to the topographic characteristics of the territory but is also able to enter the area of information systems. This means that in today's conditions, the production of the topographic maps cannot be viewed solely from the modeling of the spatial data, but it needs to include the standard procedures for acquisition and processing of the data as well as the national infrastructures of spatial data.

2. THE ROLE OF AREC IN THE ESTABLISHMENT OF THE NSDI

The role of the Agency for Real Estate Cadastre (AREC) in the establishment of the National Spatial Data Infrastructure (NSDI) emerges from the Law on Real Estate Cadastre, enacted in 2008. The Law defines the AREC as an institution established to perform works related to the establishment and maintenance of the real estate cadastre, the management of the geodetic-cadastre information system – GCIS and the establishment and maintenance of the public access to the NSDI.

In compliance to the stated legal regulative, the NSDI includes the establishment of:

- Content of metadata
- Summary of spatial data
- Maintenance of the spatial data
- Networking technology
- Contracts for share, access and use of spatial data
- Coordination and supervision mechanisms
- Procedures.

The content of some articles in the chapter for the NSDI includes the types of data out of which the NSDI will be created, and in light of the previously stated, the NSDI is comprised of spatial data administered in electronic form which refer to the entire territory of Republic of Macedonia and under the authority of:

- The state administration bodies;
- The local self-government units
- Public authorities
- Natural persons and legal entities responsible for the management of the spatial data
- Natural persons and legal entities which use the data and the services from the NSDI and provide services based on spatial data;

Part of the NSDI will also be the spatial geo-referenced data referring to:

- Real estate cadastre
- Hydrography
- Roads
- Protected areas, national parks and cultural historic monuments
- Spatial planning
- Environmental protection
- Geo-referenced statistical data
- Other

The finding, the review and the use of the spatial data is enabled by the metadata. The metadata comprise information for:

- Spatial data (content description);
- Synchronization of data with the prescribed standards and normative;
- Rules for use of data and services resulting from them;
- Data quality;
- State administration bodies, local self-government units, public enterprises, public authorities, persons responsible for establishment, maintenance, distribution and management of the spatial data;
- Data for which the access is limited and the reasons for the limitation.

Besides the above mentioned provisions from the Law on REC which regulate the content of the NSDI and the metadata, the Law also stipulates the obligation of AREC for establishment and maintenance of the public access to metadata on the internet via a geo-portal, in a way which will enable the NSDI subjects to interactively maintain the information.

Having in mind the previously said, with the objective to improve the legal regulative in the NSDI part, it is needed to supplement the regulative with new articles which will define and precisely elaborate the working bodies of the NSDI (the committee and members), their authorizations, services, networking and similar.

3. CHARACTERISTICS OF THE DIGITAL CARTOGRAPHIC DATA AS NSDI COMPONENT

The characteristics of the cartographic data in scale of 1:25000, which result from the manner of organizing the data in the digital topographic map, produced on the basis of the standards for object modeling as well as the accuracy by which the spatial data are positioned on the map, will enable fast integration of these data in the NSDI.

3.1. Organization of the data in the digital topographic map – UML data model

For effective management, processing, presentation and storage of the cartographic data, one must create a topographic data model, defined as organized mass of data which will represent a basis for all activities related to the space.

In the cartography, subject of presentation is the real world which by its essence is really complex, and for those reasons it is presented with a certain degree of generalization. Such generalization of the real world represents its model. The data model is a set of constructions which serve for description and presentation of the selected types from the real world with the assistance of a computer.

The modeling, a procedure used to create the model is the basis for shaping the system and actually it is a scientific method based on: construction, ranking and use of the model, which will assist us in creating better presentation of a certain phenomenon. Having in mind the shape of the replication, the models are divided into: graphic, abstract, mathematical and descriptive models. From a formal logic point of view, the modeling is a process of replication of the original into a model, in which exists a relation between: the original, the model and the modeling subject.

The data model for the digital topographic map for scale of 1:25000 describes the structure and the content of the fundamental data which is to be comprised of. Actually, it represents a model according to which the digital topographic maps will be part of the NSDI. The creation of the conceptual model is performed with application of object modeling due to its adaptability towards complex structures as well as due to its compatibility with the world standards. The conceptual model of the topographic data for scale of 1:25000 includes organization of the data and manner of their presentation.

In compliance to the theory for object modeling and the standard for object based modeling ISO19100 (Object Based Modeling), as well as the stages during the forming of the spatial data model, a conceptual model is formed in function of the production of the digital topographic map in scale of 1:25000.

The basic idea during the creation of the model was how to design one topographic model which will be comprehensive, complete, accurate and adaptable to all eventual needs of the different possible users. During this process a big role was played by the findings from the performed analysis of the content of the current topographic maps in scale of 1:25000, taking in consideration the new technology to be used for production of the maps.

For easier orientation in this set of data, the object approach has been applied and used to select the relevant objects, to assign names and then to group them in specific classes of specific and abstract sets. Actually, the conceptual model allows us to create the model of the real world and illustrate the same through the graphic shape. This is the method used to produce the model of the digital topographic map in which the selected objects and their relations are identified. The conceptual UML (*Unified Modeling Language*) scheme for the Topographic Data Model (TDM) in scale of 1:25000 is shown in *figure 1*.

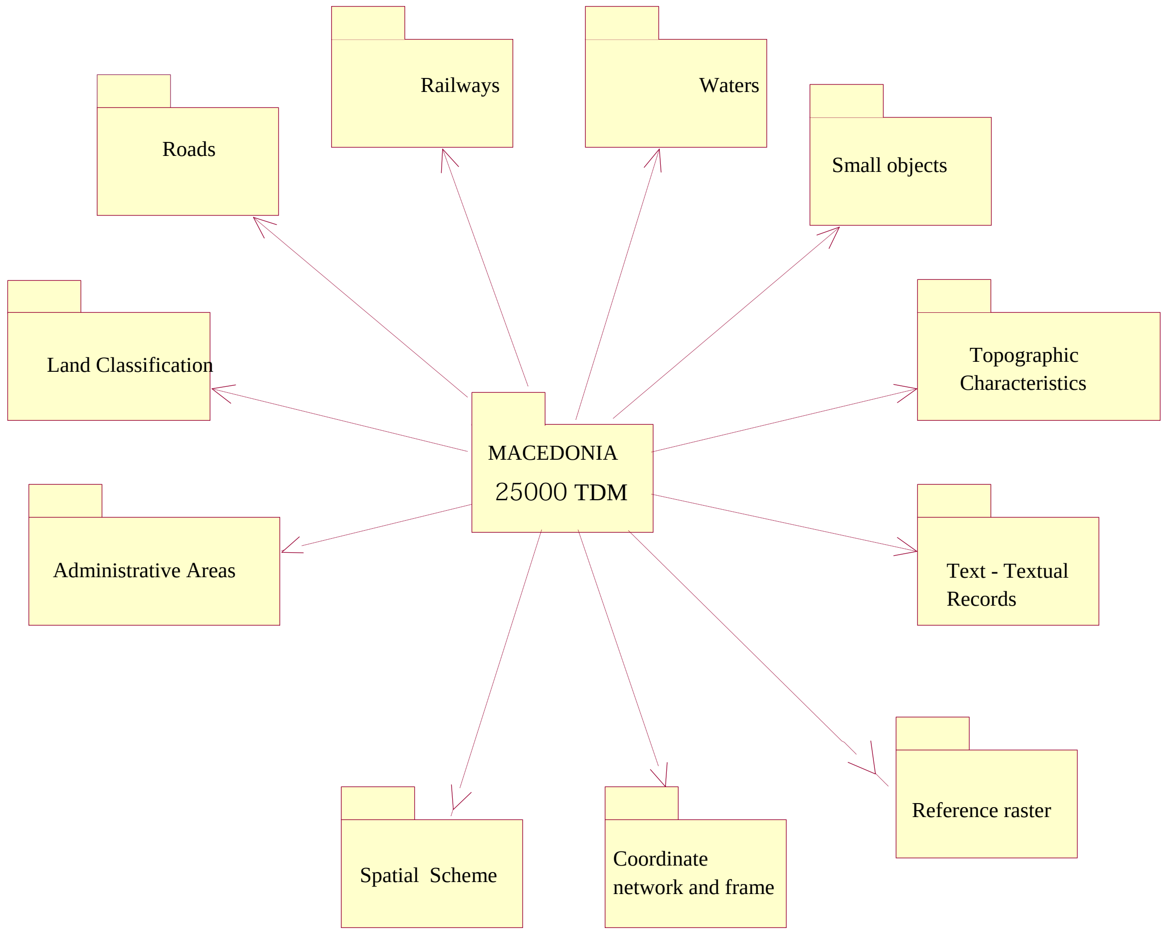


Figure 1: *Conceptual scheme for the topographic data model in scale of 1:25000, produced with application of UML*

The classification of the data occurs as a result to the logical grouping of the objects comprised in the map depending on the geometry, the category, the type and the feature of each object. As we can see from the conceptual scheme, the topographic data model (*figure 1*) is comprised of eleven packages such as:

- ✓ Administrative areas
- ✓ Land classification
- ✓ Roads
- ✓ Railways
- ✓ Hydrography
- ✓ Small objects
- ✓ Topographic characteristics
- ✓ Text (textual records)
- ✓ Reference raster
- ✓ Coordinate network and frame
- ✓ Spatial scheme

The infrastructure of the topographic data model (*figure 2*) is comprised only of packages whose classes contain data used to load the model.

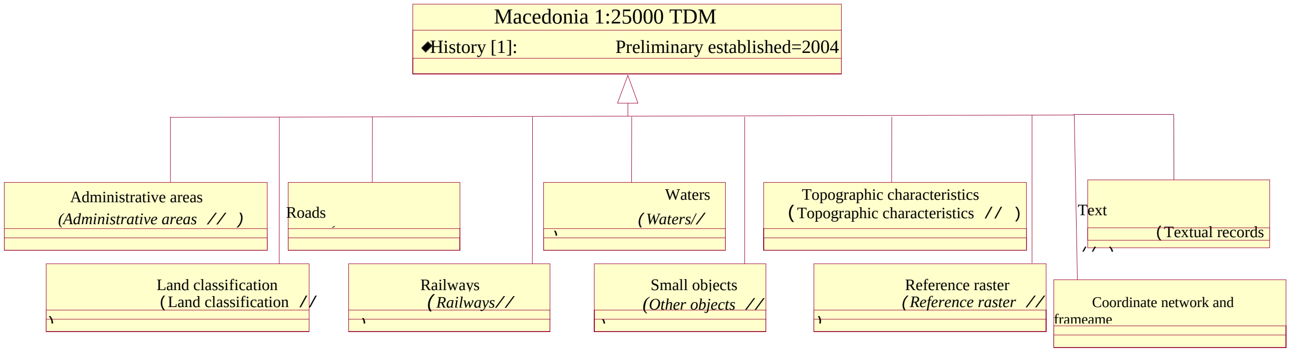


Figure 2: Infrastructure of topographic data model (TDM) in scale of 1:25000

Each of the packages represents one unit comprised of classes, described with certain information i.e. data related to their features and specifics i.e. attributes. The real implemented object analysis during the creation of the TDM is based on the use of the diagrams so the designing of the packages is performed sporadically for each package with UML (*figure* 3), applying the graphic layout of the diagram into classes. With the analytical processing of the diagram we recognize the class of the object and process the diagram into classes. The classes follow the described operations which are conveyed on the objects. The package titled “spatial scheme” is not a part of the infrastructure of the spatial topographic data and due to this it is of informational character only while its elements are used in each package separately.

Figure 3 illustrates in details the UML diagram of the “Hydrography” package, which is comprised of three classes: hydrographic network, point objects and linear objects.

Figure 3: UML diagram of the “hydrography” package

The main characteristic of each class is its name i.e. title while the attributes of each class can be:

- **History** – date of creating the class. The date needs to correspond to the time period of forming the model. There are six fields for the date, out of which, the first four are intended for writing the year, while the remaining two fields are for the month.

- **Type of element –** during the creation of the topographic data logic model, one needs to define the type of element for each object separately. The element for the object is utilized in the process of editing, when in compliance to the TDM for scale 1:25000 the same is realized completely. The type of the element for all objects in the model, during the acquisition process has a geometric character and can be presented with:

  - Geometric point defined with its rectangular coordinates;
  - Geometric line i.e. open contour comprised of geometric points; and
  - Geometric polygon i.e. closed contour comprised of geometric lines.

  Usually, points are used to present discrete objects with very small dimensions due to which the object cannot be presented or shown with lines or areas in the set scale. Lines are used to show stretched objects which have small width which cannot be shown as area in the adequate scale, while polygons are used to show objects which are big enough and can be shown in the adequate scale.

- **Item –** name of the class, comprised of related objects with common characteristics, which allow uniting the objects.

- **Macedonian name –** textual record for the title in Macedonian language.

- **English name –** textual record for the title in English speaking areas.

- **Code –** code in a form of a full-number record which is unique for each type of object from the model. The code, through the library of graphic symbols of the topographic signs (digital topographic key - *figure* 4), is connected with adequate graphic symbol whose attributes are created through selection of its parameters: level, thickness of the line, type of line, color, type of sign and other. The object attributes connected through its adequate numeric code can be easily processed using a computer. Within one data file, the codes can be repeated depending on the spatial arrangement of the content on the field. The code numeration is made by increasing one point number, starting in the following order:

  - ✓ administrative areas from 1001
  - ✓ land classification from 2001
  - ✓ roads from 3001
  - ✓ railways from 4001
  - ✓ hydrography from 5001
  - ✓ small objects from 6001
  - ✓ topographic characteristics from 7001
  - ✓ text (textual records) from 8001

  This wide gap between numbers is designed with the objective to provide big enough quantity of free codes in the data base. The previously mentioned is useful during the management of the data from the model, especially in the future when the model is to be supplemented with other characteristics. The color range of the classes is selected in a way to adequately represent their nature, so for example the signs for waters are in blue color, vegetation is in green color, railway is in black color, contour lines are in sepia and similar; and

- **Note** – marking element containing textual elaborations and comments related to the class which is elaborated.

For each of the classes in the "hydrography" package, *Figure 4* shows several objects with their characteristics, including the data for their graphic design. Such characteristics are produced for all objects from the topographic model and they comprise the digital topographic key in scale of 1:25.000.

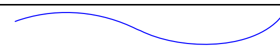
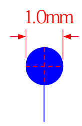
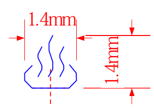
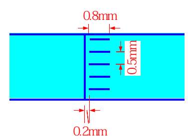
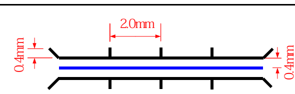
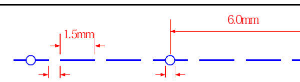
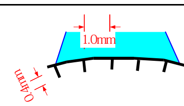
Name of coverage	Name of feature item	Element type	Code of item	graphics	Remarks
streamn (50)	Stream under 5m	line	5001	 e.g. *Biolska r.*	color: blue width: 0.3 Annotation: font:gothic, italic, size: 2mm
	Stream over 5m	line	5002	 e.g. *Crna r.*	color: blue, LightBlue width: 0.3 Annotation: font: gothic, italic, size: 3mm
waterpnt (51)	spring	point	5101		color: blue Annotation: font: gothic, italic, size: 1.5mm
	Source Salutary	point	5102		color: blue width: 0.15 Annotation: font: gothic, italic, size: 1.5mm
waterlin (51)	waterFall	line	5141		color: blue width: 0.3 Annotation: font: gothic, size: 1.5mm
	aquaDuct	line	5142		color: black, blue width: 0.3
	Water pipe line	line	5143		color: blue width: 0.3
	Concrete dam	line	5144		color: black width: 0.6

Figure 4: Excerpt from the digital topographic key in scale of 1: 25.000
(Presentation of the characteristics for several objects from the "hydrography" package)

The described topographic data model for scale of 1:25000 includes a total of 221 objects with the following quantitative schedule: administrative areas – 2; land classification – 41; roads – 42; railways – 22; hydrography – 28; small objects – 48; topographic characteristics – 21 and text (textual records) – 17 objects.

3.2. Mathematical elements

While analyzing them in a mathematical sense, the different types of spatial data produced by AREC, the results are high degree of inter-harmonization of the cartographic data with other geo-referenced spatial data. This is due to the fact that during the production of the geo-spatial data in AREC in which the cartographic data belong, the same mathematical elements are applied *(table 1)*.

Table 1. Characteristics of the cartographic data in AREC

Mathematical characteristics of the cartographic data in AREC	
Scale	**Cadastre maps:** 1:500; 1:1000; 1:2500; 1:5000; 1:10000 **Topographic maps/cartographic data :** 1:25 000;1:50000;1:100000;1:250000;1:1.000.000 **Ortophoto** 1:1000, 1:5000, 1:25000
Cartographic projection	Gauss Kruger projection
Coordinate system	Y- axis, projection of the equator, X-axis, projection of the meridian $\lambda = 21^{o}$
Ellipsoid	Bessel 1841
Horizontal datum	Hermannskogel
Vertical datum	Ortometric heights in relation to the mareograph in Trstu

The form of the geo-referenced spatial data is a pre-condition in order for the same to be part of the NSDI. It should be emphasized that the digital form is the key which the spatial data need to fulfill in order to be integrated in the NSDI. Having in mind the before said, the spatial data which still exist in paper form, including the graphic and alphanumeric data, need to digitalized in order to participate in the NSDI.

Currently in AREC, approximately 30% of the total number of cadastre maps are in digital form produced by means of conversion from analogue into digital form, 90% of the new topographic maps in scale of 1:25000 are directly produced in digital form and the ortophoto products. The remaining part of the cadastre maps as well as the topographic maps in scale smaller than 1:25000 are in analogue (paper form).

When it comes to mathematical elements of the maps, in perspective because of the synchronization with the coordinate systems of the EU member countries, transformation of the data from the current system into the European reference system it is expected. The realization of this activity foremost will be conditioned by performing several analyses which will provide definition of the manner and the time needed for transformation of the spatial data, the time needed for execution of trainings for the users of the spatial data, public awareness campaign on the influence of the new system in practice and similar.

3.3. Metadata

In compliance to the national legislative, the NSDI includes the establishment of the metadata content. The term metadata exists in the last fifteen years, with popularity especially in the World Wide Web – www. The basic postulates of its concept are very close to the people dealing with spatial information.

The metadata in the topographic maps is illustrated with their legend. This means that the information from the legend as information for the publisher, date of publication, type of map, description, spatial references, scale, accuracy and similar represent the metadata.

In the area of geo-referenced spatial information, the metadata will have to answer the questions connected to the information, such as:

- ✓ What type is the data i.e. **what** is the data representing?
  - Name and description of the data set in sense of basic information for the data set and its content.
- ✓ **Who** created the data?
  - Initiator, the data creator.
- ✓ What is the spatial location of the data i.e. **where** is it located?
  - Geographic position based on coordinates, geographic/rectangular and description of the reference system and coordinates for the data set.
- ✓ **Why** is the data created?
  - Reason for collecting the data and who is the user?
- ✓ **When** is the data created?
  - When the data set is created and if it is updated, when is it done?
- ✓ **How** is the data created?

- The manner by which the data is created, the access to the data, information for the quality of the data and the mechanism for its use.

Having in mind the fact that in AREC the metadata production has still not started, AREC has foreseen creation and realization of a model for all types of spatial data in AREC. The spatial data model will include production of the metadata in compliance to the standards and the INSPIRE directive of the European Union. Keeping in mind that the information from the digital topographic map in scale 25000 are produced in accordance with the standards for geospatial data, the logical expectation is that the metadata will first be prepared for the cartographic data.

3.4. Analysis of the accuracy

The information related to the accuracy of the spatial data positioning will be of great significance to the users of the NSDI data.

According to the International Cartographic Association – ICA 1993, the quality of the spatial data can be observed through the following elements:

- Lineage of the source material;
- Positional accuracy – as measure for horizontal and vertical accuracy of data;
- Attribute accuracy – accuracy of the attributes in thematic, qualitative i.e. descriptive or quantitative i.e. numeric value assigned to the data;
- Completeness – a grade for the degree of data completeness i.e. grade of the existence of the model completeness;
- Logical consistency – inter-compatibility of the data;
- Semantic accuracy – quality of the description of the spatial data;
- Currentness – time based information related to the data collection.

The positioning i.e. the geometric accuracy is one of the elements which define the quality of the spatial data. This information will enable to identify the discrepancy of the spatial data shown on the topographic map from their real/actual position, location on the field.

The examination of the positioning accuracy of certain cartographic data sets in the digital topographic maps in scale of 1:25000 in a certain test area is shown in *table 2*:

Table 2. Outcome from the examination

Type of observation	Empiric dispersion		m	$m_{x,y} = \sqrt{m_y^2 + m_x^2}$	Mid values
	D^*	D			
y-coordinate for houses and buildings	1.30	/	1.14	1.74 m	$m_{x,y} = \frac{\sum_{i=1}^{3} m_i}{3}$ $m_{x.y}$ =1.94 m
x-coordinate for houses and buildings	1.72	/	1.31		
y-coordinate for road network	0.38	/	0.62	0.73 m	
x-coordinate for road network	0.16	/	0.40		
y-coordinate for river network	4.28	/	2.07	3.35 m	
x-coordinate for river network	6.92	/	2.63		
H-coordinate for DTM 12.7%	/	1.71	1.31	$m_H = \frac{\sum_{i=1}^{3} m_i}{3}$ =0.89 m	
H-coordinate for DTM 4.7%	0.79	/	0.89		
H-coordinate for DTM 1.5%	0.22	/	0.47		

The executed examination of the digital cartographic data points out that the analyzed sets of cartographic data have high geometric accuracy amounting to 1.94m per position and 0.89m per height.

4. CONCLUSION

Following the trend in the area of geospatial information in reference to the establishment of the NSDI, the Agency for Real Estate Cadastre – AREC plans in 2010 to start with activities whose realization shall be executed in two stages.

The first stage will be focused towards production of two documents, the Strategy for development of NSDI and Data Model and standards for AREC. The implementation of these documents will be executed during the second stage, during which the AREC Geo-Portal will be established first and then the process will continue with the establishment of the inter-coordination on national level with institutions which will be identified in the NSDI strategy. As a summary of all activities, in 2012 AREC plans to establish the governmental Geo-Portal on a national level i.e. NSDI.

The objective of the NSDI is to be a simple and fast access to spatial data, bigger transparency and cooperation between the NSDI subjects, economic development and opportunity for multi-purpose data use. In that sense, the cartographic data will be able to be used as “basic data” i.e. as template on which the thematic sets of spatial data will be upgraded, creating different types of cartographic products. In such constellation, it has to be emphasized that the cartographic data are one of the components of the NSDI which will enable them to be easily accessible for different purposes to all interested subjects.

Considering the methodology and the standards used to produce the new digital topographic maps in scale of 1:25000 as well as their characteristics, at this point there is a need of creating metadata for the cartographic data which will enable their integration into the NSDI. This is specially due to the fact that the metadata referring to the administrative borderlines, hydrography, roads, cultural-historic monuments, the manner of land use, the heights, the geographic names as well as other data which are part of the digital topographic map in scale 25000 will enable the previously mentioned to be incorporated directly into the NSDI, in compliance to our legislative and according the INSPIRE European directive for spatial data infrastructure.

Opposite to these, the data which still exists in analogue form first needs to be digitalized in compliance to the standards and the model of spatial data and then to produce the metadata and to integrate them in the NSDI.

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