Methodology of creating the new generation of official topographic maps in Poland

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1. Abstract

Poland's role on the international stage and the position of the Polish economy in the international market, especially in the European Union, is increasingly dependent on the level of access to information, including the spatial information. Providing access to spatial information contained in a structure of topographic objects database (BDOT) and developing a new generation of topographic maps in scales: 1:10 000, 1:25 000, 1:50 000, 1:100 000, 1: 250 000, 1: 500 000 and 1: 1 000 000, was the key activity in the past few years in Poland.

In accordance with the Act of 17th May 1989 – the Geodetic and Cartographic Law, (Journal of Laws, 2010.193.1287), one of the fundamental tasks of the Polish Service of Geodesy and Cartography is publishing the official maps and creating national topographic maps.

The Surveyor General of Poland establishes, maintains and provides the standard cartographic studies – topographic maps in scales of: 1:25 000, 1:50 000, 1:100 000, while the marshals of voivodeships in consultation with the Surveyor General of Poland establish, maintain and make available standard cartographic studies - topographic maps in the scale of 1:10 000. Based on Art. §19.1 point 9 of the Geodetic and Cartographic Law, in the Regulation of 2011 the Minister responsible for public administration described the scope of information collected in the topographic objects database and general geographic objects database, the organization, procedures and technical standards for creating, updating and sharing these databases, as well as creating of topographic maps.

For cartographic visualizations, the newly developed database of standardized symbols for standard studies is used. It was published in the form of

seven annexes to the Regulation, which includes over 600 symbols with new color schemes, and a new design of typefaces (fonts) for geographical names and other descriptions on the maps.

The purpose of building the Polish topographic objects database along with the database management system is to acquire a full nationwide coverage and consistent current information about the topographic objects and their attributes. By the end of 2013, thanks to the funding of 85% refund from the EU budget, Poland will have one of the newest, most technologically advanced databases of topographic objects in Europe, which will be also used to create topographic maps of new generation for the entire country. An important element of a new generation of maps will also be shaded relief, developed on the basis of DEM of high accuracy.

Keywords:

geospatial standards, NSDI, topographic data base, topographic maps

2. The concept of the Topographic Objects Database

The Topographic Objects Database, which has been created in Poland, consists of two topographic components (TOPO10 and TOPO250) and seven cartographic components (Fig. 1). At present, the most precise information level concerning topographic description of the terrain is represented by the topographic objects database (BDOT), with the DLM10 component (called BDOT10k); its level of details corresponds to contemporary, civilian topographic maps at the scale of 1:10 000. This component remains the basic source of spatial data for developing the entire scale series of new generation of topographic maps.

Due to the crucial role of the official topographic database, being the reference canvas for development of the spatial data infrastructure, the correctness of cartographic modelling in the BDOT database is of key importance (Fig. 1).

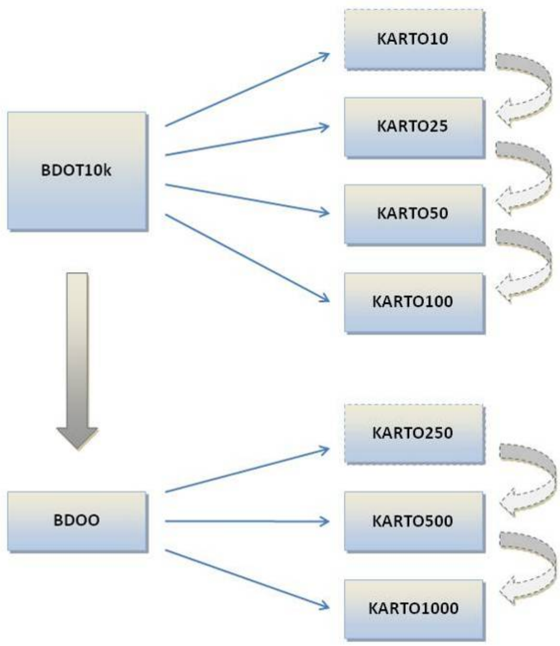

Fig. 1. The structure of the topographic objects database in Poland

The correctly created topographic database is the basic data source for arbitrarily defined spatial analyses and cartographic thematic works. The BDOT structure refers to the concept of multirepresentation databases (MRDB), and contains both two integrated DLM topographic components, specified as BDOT10k (DLM10) and BDOO (DLM250), as well as a series of derivative cartographic models, corresponding to topographic and general maps at the scales from 1: 10 000 up to 1: 1 000 000.

The BDOO database model, similarly to the BDOT10k database, is compliant with the assumptions of the spatial data topographic model. The thematic scope of the DLM250 component corresponds to the general geographic map at the scale of 1:250 000.

Data stored in BDOT10k and BDOO modules of the reference database allows creating arbitrary thematic products, which utilise the topographic background. This task is convergent with the requirements of commonly created, above-national spatial information infrastructures, including the INSPIRE Directive and the Act on Spatial Information Infrastructure, which implements resolution of this Directive. For more than 30 spatial data themes and 12, so-called, leading bodies, as well as for several dozens of other institutions involved in Inspire implementation, cartography is becoming not only the tool for presenting resulting concepts of the natural environment management, or spatial regularities in population distribution. It is, first of all, the basic source of knowledge about the surrounding space. For cartography, modelling geographic information in the form of functional, reference and thematic databases is of the same importance as visual presentation of such information.

Therefore it may be stated that implementation of INSPIRE ideas influences the development of contemporary cartography, and vice versa, application of cartographic modelling methodology in creating the geoinformation infrastructure results in its increasing functional usefulness and visual perception. The example of such a "positive feedback" is:

1. Utilising the concept of „separating spatial databases from mapping" (Grunrich, 1995) in the topographic database. Distinction of the DLM model (the TOPO component of the database), aiming at spatial analyses, and the DCM model (the KARTO component), to be used for creating map composites, already characterised the TBD, being the pioneering database in Poland. It was the first Polish implementation of this modern solution, which positively influenced the development of both cartography as well as geoinformation. Utilisation of two complementary DLM and DCM models increases the analytical usefulness of the BDOT database, and it simplifies editing the derivative topographic and thematic maps.

2. The subject of research performed by contemporary cartography are the process of geographic information generalisation, which utilise the, so-called, constraint-based modelling and the idea of the MRDB type multirepresentation database. These both ideas were - at least partially - implemented in the process of creation of the BDOT10k and BDOO database structure and in the BDOT database management system. This makes the Polish topographic database one of the most modern geoinformation solutions in the world, what is directly related to the SDI functionality, which utilises the BDOT database as the reference canvas.

3. Development of the continuous at the national level and conceptually coherent topographic databases, with the modern conceptual model, characterised by the high geometric accuracy and timeliness, contributes to the clear consideration of the BDOT as the reference database for all products created by the, so-called, leading bodies in the frames of the SDI developing in Poland. Thus, it contributes to clear consideration of the cartographic modelling methodology as the *de facto* standard with respect to ways of abstracting the geographic space, analysing it and visualising on maps and in web services.

3. Conceptual model of the Topographic Objects Database

Foundations of the assumed conceptual model originate from [Gotlib 2001], and theoretical foundations were presented in [Makowski et al., 2005]. Object classes were distinguished, first of all, basing on consideration of spatial relations existing between topographic objects, which are important for the system being developed [Buczkowski, Gotlib 2000]. It was proposed to group in separate classes objects which may be distinguished basing on their external perception (land cover) and objects which may be distinguished by their functions (land use). Classes, in which objects create network systems and maintain specific mutual spatial relations, were distinguished in a separate group. The next group includes auxiliary topographic data or data being the base for topographic data. Objects which represent the terrain relief were also separated. Classification was constructed in such a way that the database conceptual model may be easily created and then, the database structure may be designed. The objective was not to develop theoretical, scientific classification of topographic objects, but to develop classification which might be practically used and which would allow performing simple spatial analyses and easy data supply for existing and developed GIS systems. As it may be expected, the proposed model is not the only possible topographic data model, but it is characterised by a series of practical advantages. Its most important features, which distinguish this model from previously developed topographic models, include:

1) Implementation of the idea of the landscape model (DLM) by distinguishing (basing on the physiognomic criterion) land cover classes in a way that completely fills the space. For that purpose, such classes as "Built-up areas", "Areas under roads, railway lines or airport" and "Crops on arable lands" were introduced. This approach aims at simplification of data input, as well as of later checking of coherence and completeness of objects which create the land cover. This assumption is also convenient for implementation of all types of spatial analyses. The assumed classification of objects allows creating the continuous "Land cover" layer for at least two levels of details. This allows disseminating land cover data, depending on the users' requirements.

2) Functional separation of lands (the group of ”Land use complexes“ independent from land cover), such as industrial plants, harbours, breeding farms etc., considering that they are not typical topographic distinctions and it is necessary to describe them at various levels of geometric accuracy (starting from approximate up to precise, based on land registration data).

3) Coexistence of objects, which are specific for various, conventional cartographic products (such as 1:10 000 and 1:50 000 topographic maps), e.g. coexistence of the "Built-up areas" class, specific for the model of the 1:50 000 scale topographic map and the "Building" class, specific for the 1:10 000 scale topographic map model.

4) Representation of sections of a carriageway (instead of sections of a road) in the database, as basic elements, which creates the graph of the road network.

5) Representation of both axes of streams as well as areas covered with flowing and stagnant waters, as basic elements which create the graph of the water network. Each water stream is represented in the database at least as a linear object.

Except for the above features of the model, another, unique feature of the BDOT10k/BDOO model should be also mentioned. Besides the representation of the road network by sections of carriageways, also the road axis and road junctions are represented. Such solutions were proposed by a series of publications and expert works [Gotlib and Olszewski 2005, Gotlib 2009a, Gotlib 2009b]. Development of the final BDOT10k/BDOO model also utilises the proposed idea of additional representation of some surface objects by defining and recording their characteristic points in the database (such as main points of localities, bus stations, water harbours or railway stations). Such approach considerably simplifies generation of derivative, generalised databases from the BDOT10k database, including the BDOO component.

4. Rules of development maps of new generation

In Poland the legal act The Law of Geodesy and Cartography was considerably modified within the frames of works concerning the Act on Spatial Information Infrastructure, which is the Polish implementation of the Directive 2007/2/WE of the European Parliament and the Council dated March 14, 2007, which established the spatial information infrastructure in the European Union (INSPIRE). The modified version of the Law of Geodesy and Cartography contains series of delegations to issue administrative acts of the nature of technical standards, and among them – regulations which specified the detailed content of information stored in the topographic objects database (BDOT) and in the general geographic database (BDOO), as well as organisation, modes and technical standards concerning creating and updating of these databases, dissemination of their data, and generating standard cartographic products.

Topographic maps are one of standard types of cartographic products, whose content presents elements of the geographic environment of the Earth surface with their spatial relations. Following the Law of Geodesy and Cartography, one of tasks of the Polish Geodetic and Cartographic Service is to issue official maps, as well as create topographic maps of the country. The Surveyor General of Poland creates, maintains and disseminates standard cartographic products - topographic maps at the scales of: 1:25 000, 1:50 000, 1:100 000, and the heads of sixteen voivodships (provinces) order the creation and disseminate topographic maps for areas of particular provinces. Besides, after agreement with the Surveyor General, they maintain and disseminate standard cartographic products - topographic maps at the scales of 1:10 000. The topographic maps of the new generation will be created basing on appropriate sets of data stored in databases, in the form of six basic graphical layers:

1. A topographic drawing, consisting of selected elements of the topographic objects database, of the level of details which ensures creating standard cartographic products at the scales of 1: 10 000 – 1: 100 000 and the State Register of Basic Geodetic, Gravimetric and Magnetic Controls.

2. A drawing of the terrain relief in the form of contour lines with shading, created on the basis of cartographic elaboration of the digital terrain model, acquired with the use of the laser scanning technology, of the accuracy of at least 4 points per 1 sq.m.

3. Border lines of the administrative division of the country, developed on the basis of the State Register of Borders and Areas of the Units of the Territorial Division of the Country.

4. Location of geographic names, with the use of the State Register of Geographic Names - localities and physiographic units (the register contains about 250 000 names).

5. Cartographic abbreviations for selected topographic objects.

6. Frames, symbols of the map and marginal data.

Cartographic visualisation of topographic objects will use the currently developed and tested database of unified cartographic symbols for standard cartographic products, which cover more than 600 cartographic symbols for topographic and general geographic maps, including the new colour systems for maps. The commonly accessible sets of fonts were assumed for the needs of presentation of geographic names and other descriptions on maps.

The basic assumption of the digital technology of topographic map production is the maximum automation of the editing process and publication of map sheets in the tool environment of geographic information systems (e.g. ArcGIS by ESRI) or cartographic systems (such as Intergraph Digital Cartographic Suite).

At the editing stage two levels of source data processing are distinguished: the cartographic visualisation level and the final presentation level - of the image which is ready for printing or electronic presentation. Thus, the map production process is implemented in two stages; the first stage results in screen presentation, which may serve as the initial image. Such visualisation is the result of utilising the rules of object reclassification, data generalisation and symbolisation, which are described in annexes to the regulations concerning BDOT. The second stage consists of cartographic generalisation, manual graphical editing of the map content and finishing the visualisation to the final form of cartographic presentation as a map sheet including descriptions, names of objects and frames, grids and marginal data, which are required by the technical instruction.

The cartographic visualisation stage, which includes the cartographic projection process, complete symbolisation and partial data generalisation, may be fully automated, i.e. it may be repeatable. Some of editing tasks are left for implementation at the second stage - individually for particular projects. It may be considered that the performed cartographic visualisation is the skeleton of the manuscript map. Editing of the final cartographic image (editing original map for publication) still requires many manual operations. The complete automation of some map editing stages, such as elimination of conflicts between symbols, independently on the applied software, is still not possible.

The second important assumption of the new technology of topographic map production is utilising digital source data, mentioned above, which is stored at the state geodetic and cartographic data resource - first of all, the Topographic Objects Database, but also other data and official registers, such as the State Register of Geographic Names (PRNG), the State Register of Borders (PRG) and the Bank of Geodetic Controls (BOG) etc.

Following provisions of the regulation, standard cartographic products at the scales of: 1:10 000, 1:25 000, 1:50 000, 1:100 000 are produced basing on the BDOT10k resources and products at the scales of: 1:250 000, 1:500 000, 1:1 000 000 – are based on the BDOO (Fig. 1). Apart from the map at the scale of 1:10 000, all derivative products are the subjects of data generalisation and graphical (editing) generalisation. Therefore it is necessary to utilise appropriate algorithms of selection, to perform simplification of shapes of objects, to reclassify (conceptual generalisation) and to aggregate objects.

Independently on the final scale, the technological process of map compilation in a specified map sheet system, basing on the BDOT, consists of the following tasks:

- selection of classes of objects being the BDOT data sets, including limitations of the spatial extension of objects to the limits of a particular project (e.g. a topographic map sheet),
- quantitative generalisation of the map content through automatic selection of attributes,
- quantitative generalisation of the form - simplification of shapes of surface and linear objects (maintaining topological relations),
- qualitative generalisation - modification of the geometric approach to phenomena and content reclassification,
- structuring the hierarchy of layers of the map project - following the pattern of the given GIS application,
- assigning specific or standard cartographic codes to objects (using SQL spatial and attribute queries) and creation of KARTO data files, containing the generalised geometry of objects, referenced to the scale of presentation,
- assigning symbols compliant with pattern symbols, graphical styles and colour palettes to objects, which create the map content,
- implementation of manual editing, consisting of required corrections of geometry of map content elements,
- introduction of dynamic labels containing names and descriptions of objects,
- generation of required descriptions, including possible amendments (basing on labels and content of object attributes),
- elaboration of elements of the map sheet mathematical composition together with marginal information (including explanation of symbols) and its preparation for printing.

Manual editorial corrections are the most time-consuming stage of editing; they include both dislocations and elimination of symbols in order to avoid conflicts, as well as editing names and descriptions. This results in the added value of the graphical image, its readability and uniformity of information transfer are increased. Editorial works are completed by the map frame generation process, introduction of descriptions inside the frame and introduction of marginal information. The final stage consists of rasterisation and preparation of the map sheet for printing or electronic publication.

Concerning the printed versions, it is planned to issue topographic maps at particular scales, considering the demands of wide groups of individual users.

Scale 1:10 000 – the total number of map emblems for Poland 16 191 – it is planned to compile maps for urban agglomerations, including their surroundings, as well as for highly invested areas and for selected touristic areas - about 10 000 emblems developed by heads of provinces. The scheduled period of implementation: 2013 – 2018. The total costs of editorial compilation including printing for 2/3 of Poland is estimated as about 35 million Euros.

Scale 1:25 000 – the total number of map emblems for Poland 3 236 - it is planned to compile maps for urban agglomerations and rural areas (excluding large forest complexes) - about 2 500 emblems developed by the Surveyor General of Poland. The scheduled period of implementation: 2014 – 2019. The total costs of editorial compilation including printing for 3/4 of Poland is estimated as about 10 million Euros.

Scale 1:50 000 - the total number of map emblems for Poland 1 085 - they are developed by the Surveyor General of Poland. The scheduled period of implementation: 2014 – 2019. The total costs of editorial compilation including printing of 1 085 emblems will equal to approximately 5 million Euros.

Scale 1:100 000 – the total number of map emblems for the whole country 286, developed by the Surveyor General of Poland. The schedules period of implementation: 2014 – 2020. The total costs of editorial compilation including printing 286 emblems will equal to approximately 1.5 million Euros.

The total costs of publication of the new generation topographic maps in the printed form, within the period 2011 – 2016 may be estimated as more than 50 million Euros.

The publication module will be utilised for the needs of production of the printed version; this module will be based on commercial applications already existing in other countries, within the frames of development of the national system of management of the integrated topographic objects database. The process of preparing the printed version will be performed within the scope of works ordered in accordance to the public procurement system; geodetic-and-cartographic enterprise will performed works commissioned by the heads of provinces and by the Surveyor General of Poland. Assuming this approach is connected with specification of clear and, at the same time, very high quality standards for commissioned products (topographic maps), in order to maintain the uniform rules of work implementation by all contractors (Fig. 2). In any other case it will not be possible to avoid differences in elaboration of particular lots of topographic maps. Topographic map sheets will be issued in the "PL-UTM" plain co-ordinate system, which is obligatory in Poland for topographic works.

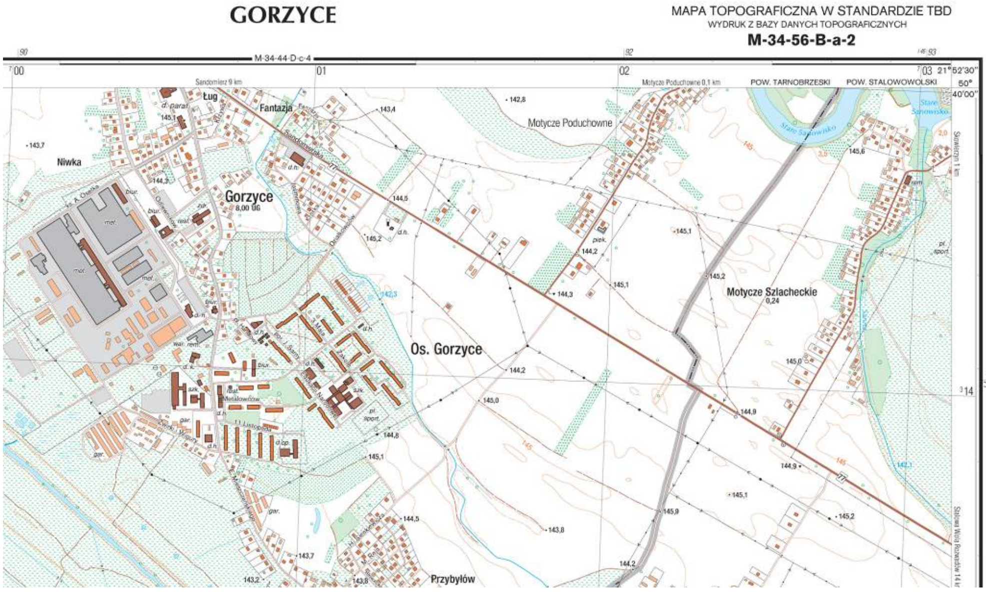

Fig. 2. Topographic map of new generation.

5. Methodology of presenting the terrain relief on maps

In order to achieve the correct cartographic resulting model (both the spatial database and the topographic map), common processing of planimetric and altimetric data is of key importance. This allows obtaining the topologically coherent, derivative element of the source, reference database.

The developed concept is based on the assumption that compilation of cartographically correct maps, which include altimetric information, requires the utilisation of "conventional approaches with the use of new technologies" (Olszewski, 2013). This means the acceptance of several substantial assumptions, which define the general frames of the generalisation process:

Generalisation of altimetric information requires selection of structural forms, which meet specified criteria concerning the size, for the given scale. This results in selection of the following components from the source terrain relief model:

- Structural lines (lines of streams and ridges),

- Characteristic points of specified number,

Basing on selected data, the derivative digital model of the terrain relief is created, which is the source for isolines generation, This approach allows maintaining the topology, modelled in the system. (

Fig. 3).

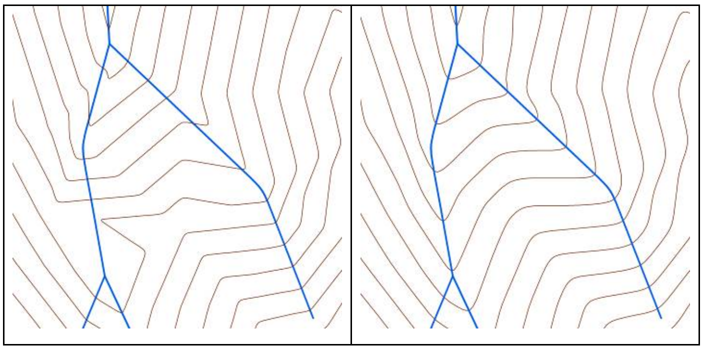

Fig. 3. Contour lines based on the Digital Elevation Model
a. without consideration of water streams, b. with consideration of water streams.

Besides, due to the high morphometric differentiation of the area of Poland it should be assumed that for the considerable part of Poland it is reasonable to amend the contour drawing of the terrain relief on the new generation topographic maps with shaded images (Fig. 4). The proposed approach, which utilises the, so-called, Swiss method for simulating the aerial perspective, as well as the full parametrisability of this method, allows increasing the perceptual values of the topographic map considerably. However, it should be stressed that utilisation of a semi-transparent layer of the "topographic shades" results in the necessity to modify the colour scale prepared for cartographic visualization of planimetric content on the new generation topographic maps.

Fig. 4. A part of the 1:10 000 scale topographic map, generated from the BDOT database
a. without the terrain relief, b. with contour lines and shading.

6. Conclusions

Comparing to existing civilian, topographic and general maps, the following, important changes were introduced on the newly designed maps:

- the placement of separate symbols of geodetic controls on topographic maps has been eliminated,
- criteria of road classification have been changed; the road class (topographic map) or the road management category (maps at general scales) have become the leading criteria,
- classification of roads and streets has been unified and distinguishing of streets by means of separate symbols has been neglected (scales 1:10 000 – 1:100 000),
- on topographic maps, streets or sections of streets excluded from traffic (pedestrian paths) have been marked by a separate symbol,
- similarly to the map at the scale of 1:10 000, on a map at the scale of 1:25 000, multi-family and one-family apartment houses, as well as outhouses have been distinguished,
- on the map at the scale of 1:25 000, densely built-up areas of one-family houses have been marked,
- apartment houses and outhouses have been marked on the map at the scale of 1:50 000,

- one-family houses, dense areas of multi-family apartment houses and compact areas of multi-family apartment houses have been distinguished on the map at the scale of 1:100 000,
- on general geographic maps, industrial and storage buildings as well as apartment and service facilities have been distinguished, and additionally an administration-and-service centre and shopping has been distinguished on maps at the scale of 1:250 000,
- on maps at the scales of 1:250 000 – 1:1 000 000, all presented localities have been represented by symbols diversified according to the number of inhabitants,
- on general geographic maps, tourist objects have not been presented,
- on general geographic maps, borders of national parks have been introduced; borders of military training areas have been introduced on all maps, excluding the map at the scale of 1:1 000 000,
- on maps at the scales of 1:250 000 – 1:1 000 000, rivers and waterways have been distinguished with a separate symbol.

References

Bertin J (1967) Semiology of Graphics: Diagrams, Networks, Maps. University of Wisconsin Press, 1983 (first published in French in 1967, translated to English by Berg W.J. in 1983)

Carpendale MST (2003) Considering Visual Variables as a Basis for Information Visualisation. Department of Computer Science, The University of Calgary. http://pharos.cpsc.ucalgary.ca/Dienst/UI/2.0/Describe/ncstrl.ucalgary_cs/2001-693-16. Accessed 9 June 2008

Franck G (1998) Ökonomie der Aufmerksamkeit. Carl Hanser Verlag, München

Freitag U (1971) Semiotik und Kartographie. Kartographische Nachrichten 21:171–182

Gotlib D. (2000a): Opracowanie i implementacja modelu pojęciowego wybranych elementów topograficznego systemu informacyjnego. Sprawozdanie z grantu dziekańskiego za rok akademicki 1999/2000. Wydział Geodezji i Kartografii Politechniki Warszawskiej, Warszawa.

Gotlib D. (2000b): Metody tworzenia schematów pojęciowych w systemach informacji przestrzennej. Materiały II Ogólnopolskiego Seminarium Modelowanie danych przestrzennych, Warszawa

Gotlib D., 2003, Baza Danych Topograficznych a produkcja map topograficznych, ”Kartografia i systemy informacji geograficznej”, Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. 13 A, s. 69 – 76, Wrocław

Gotlib D., Iwaniak A., Olszewski R. (2006), Budowa Krajowej Infrastruktury Danych Przestrzennych w Polsce. Harmonizacja baz danych referencyjnych. Wrocław: Wydawnictwo Akademii Rolniczej we Wrocławiu.

Gotlib D., Iwaniak A., Olszewski R. (2007) GIS. Obszary zastosowań, Wydawnictwo Naukowe PWN, Warszawa

Imhof E (1965) Kartographische Geländedarstellung. De Gruyter, Berlin

Makowski A., 2005, System informacji topograficznej kraju. Teoretyczne i metodyczne opracowanie koncepcyjne. Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej

Olszewski R., 2012, The role and place of cartography in the development of the spatial information infrastructure, w: GEOINFORMATICA POLONICA 11: 2012, Polska Akademia Umiejętności – Wydawnictwa, Kraków

Stankiewicz M., 2005: Współczesne rozumienie topografii, W: „System informacji topograficznej kraju" – red. A. Makowski, str. 49 – 56, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa