TECHNOLOGICAL AND ECONOMIC DEVELOPMENT OF ECONOMY
Baltic Journal on Sustainability
2010
16(2): 254–265

AUTOMATION OF UPDATE OF DIGITAL NATIONAL GEO-REFERENCE DATABASES

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Received 16 June 2009; accepted 27 April 2010

Abstract. Unified geo-reference data model is a very important part of national geographic information management. It has been developed within the project of Lithuanian geographic information infrastructure in 2006–2008. This model allows automated integration of large scale (mainly municipality) geo-reference data into the unified national geo-reference database. It is based on unique object identifiers across all geo-reference databases and on standard update and harmonisation procedures. The common stages of harmonisation of geo-reference databases at different scales include: implementation of a unique identifier of geographic objects across all databases concerned; definition of the life cycle of the objects; definition of cohesion boundary and of the harmonisation points along the boundary; maintenance of the local database and automatic update of the national database using special service. When implemented, such model will significantly facilitate maintenance of national geo-reference database and in five years from full implementation will have a significant economic effect.

Keywords: geo-reference base data, feature, geographic data model, update service, harmonisation, efficiency.

Reference to this paper should be made as follows: Stankevičius, Ž.; Beconytė, G.; Kalantaitė, A. 2010. Automation of update of digital national geo-reference databases, *Technological and Economic Development of Economy* 16(2): 254–265.

ISSN 1392-8619 print/ISSN 1822-3613 online
doi: 10.3846/tede.2010.16
http://www.tede.vgtu.lt

1. Introduction

Intense recent development of spatial data infrastructures worldwide has led to new possibilities of geographic data management and attempts to improve information sharing. It has become evident that consistent and unified geographic information systems at national and municipal level have to be developed in order to achieve efficiency of geographic data exchange and to fully benefit from the exchange, i.e., to re-use collected data for various purposes instead of collecting them many times (Mardal and Lillethun 2005; Morales 2006).

Lithuanian geographic information policy is a part of the national information society oriented strategy. The 60 municipalities in Lithuania perform many functions that use official geographic data. The major part of such data are used as reference base for general, detailed and special physical planning as well as for monitoring of territorial development. Large scale geographic data collected at municipality are also important for decision making in the field of construction, development of urban infrastructure, economy and tourism, environmental and cultural heritage protection etc. Unfortunately, wide use of data is still hindered by lack of interoperability among datasets that are maintained by different organisations. Organisational problems and models of efficient horizontal (between different thematic datasets) and vertical (between local, national and regional datasets) data exchange are often mentioned in various studies (Quak and de Vries 2006; Bulens *et al.* 2007) but rarely analysed scientifically, mostly because these investigations are rather recent and time is needed to make conclusions about sustainability and expansibility of any proposed model.

We have developed an exchange model based on several unpublished studies performed in Lithuania (Feasibili ... 2004; LGII informacinė sistema … 2007; a study of municipal capabilities and expectations from national spatial data infrastructure performed in 2009, etc.). Two methodological principles were followed:

a) Avoiding any duplication of efforts collecting large scale geographic information;
b) Minimising interventions into existing municipal models for handling geographic information.

The main target groups of this field are urban development administrators, planners, politicians and all society that benefits from timely delivery of accurate and up-to-date geographic information.

The paper introduces the data harmonisation solution that would support unified geographic data collection and integration at municipal and national level. It is a strategically important step towards efficiency of national topographic cartography.

2. Evaluation of foreign experience

Information systems that assure consistent geographic data accumulation and management are intensely developed in national and municipal mapping organisations of some European countries since about 1995–2000. Significant achievements in this field have been demonstrated in 2005–2007 in Norway, Germany, the Netherlands and the United Kingdom (OS MasterMap ... 2004; Mardal and Lillethun 2005; Morales 2006). Large amount and integration of different scales are characteristic to spatial data infrastructures in these countries.

The Ordnance Survey (OS) mapping agency in the *United Kingdom* is the best example of geographic data harmonisation in Europe. Its experience in reference base data management sums up to almost thirty years and has resulted in both efficiency and logical consistency of the cartographic databases. The national OS MasterMap spatial data infrastructure (SDI) encompasses over 450 billions of reference base geographic objects (features), with unique identifier assigned to each of them. That allows linking all MasterMap datasets together and connecting any third party datasets that match the MasterMap data model.

The OS MasterMap model encompasses exchange of geographic data between surveyors and national databases, i.e. automated integration of official high quality data at large scale into the national reference base. National reference database is thus continuously updated without violation of quality requirements. Integral multiscale database can be used as reference base or for spatial analysis.

Norway has a well developed national SDI supported by the Norwegian national mapping agency. Most of agency functions are centralised and large scale topographic mapping (so called Economic Maps) is traditionally performed by local mapping agencies that are in each of the 17 counties.

Integration program for geo-reference base data is in process of implementation since 1992. The 430 municipalities of Norway are extremely diverse in terms of size, population (200 to 500 000 inhabitants), cultural specifics and capacity of geographic data management. Therefore geographic data policies are not homogeneous across the country. Traditionally, urban areas are covered by geo-reference base data at scales 1:500, 1:1000 and 1:2000. Other areas are mapped according to national GEOVEKST programme that is a series of individual geographic data projects for particular territories. The GEOVEKST forum is responsible for co-ordination of geo-reference base updates. Every year update plans are developed that match the actual needs of the forum partners while the stakeholders take part in their financing.

In *Germany*, ATKIS (Authoritative Topographic-Cartographic Information System) is developed since 1980. Official ATKIS topographic-cartographic information system encompasses realty cadastre data at scales 1:500–1:2000 (Authoritative Real Estate Cadastre Information System – ALKIS) and topographic data at scales 1:25000–1:1000000 (AdV 1988). ATKIS databases are supported and developed by local mapping agencies that are co-ordinated by the federal Committee of German local mapping agencies AdV. Data integration between different scales is efficiently supported by organisational measures but not fully automated.

Sweden does not have a single national SDI. Nevertheless, there exist separate well developed information systems of various national and municipal agencies that have their own Internet portals for data access. Some of such systems, such as Land Data Bank System, encompass different datasets with a certain level of integration, based on uniform development vision, standards and co-operation.

Such situation is satisfactory for the Swedish society, however, integration into European spatial data infrastructures, especially forced by the INSPIRE directive (INSPIRE 2009), demands a single geographic information portal and harmonised national data.

3. State of the art in Lithuania

Digital geo-reference databases and digital mapping technology prevail in Lithuania since around 1994. A large part of early digital datasets has been created for particular narrow purposes, such as mapping at various scales (Stankevičius and Paršeliūnas 2005). Such datasets are not interoperable, partially duplicate each other, cannot be easily re-used, linking of various national datasets is very complicated if at all possible.

Comparison of geo-reference data policy and system in Lithuania and abroad reveals, how important is consistent approach to national geo-reference base data and uniform digital mapping processes. The countries described in Chapter 2 have advanced methodology of data harmonisation that allows linking diverse geographic data, such as urban infrastructure, cadastral, statistical and other data to the geo-reference base data that comes from a single source. As it is requested by INSPIRE, spatial data are collected once, maintained at the primary organisation and flexibly re-used for different purposes.

In Lithuania there have been no significant changes in geo-reference base management from 1994 until establishment of the national geographic information infrastructure (LGII) in 2008. National geographic databases are still incompatible, data duplicated due to orientation to mapping at different scales, harmonisation not planned (Pubellier 2005; LGII ... 2007; Beconytė *et al.* 2007, 2008). Analysis performed on municipality spatial data (Stankevičius 2008) show that only big city municipalities have their own information systems that, however, differ in structure and processes of maintenance. Important geographic data sets (Kaklauskas *et al.* 2006; Kolk 2004; Melnikas 2005; Turskis *et al.* 2006; Zavadskas and Antucheviciene 2006; Jakimavičius and Burinskienė 2009a, b) cannot be linked and used together with national geo-reference base data.

The LGII project introduced technological and methodological changes in geo-reference base data management in Lithuania. Unified Geo-reference Data Model (UGDM) has been developed in the framework of the project (Stankevičius 2008). Implementation of the model has two stages: onetime geo-reference base conversion to a single unified multi-scale geo-reference database (UGDB) and establishment of consistent UGDB update procedures from larger scale datasets.

4. General principles of national geo-reference database update using local data

The main principles of UGDB update from local large scale datasets are as follows:

1. Geographically distributed UGDB, automatically updated from large scale (local, municipal) geo-reference base datasets.
2. Municipalities maintain standardised large scale geo-reference databases (MGDB) for their territory.
3. To support data consistency, unique identifier (top-id) is implemented across all geo-reference databases at all levels.
4. Municipal geo-reference data feed national UGDB via a special automated update service (AUS) that makes data transfer at regularly or by specific criteria.

5. The update is based on tracking of changes of feature life cycle (Stankevičius 2008). The life cycle according to UGDM involves unique identifier, versioning and temporal attributes.

5. Stages of integration of geo-reference base data

Information system for update of national geo-reference base consists of two core components (Fig. 1):

a) national multiscale geo-reference database (cadastre), maintained by national level manager, and
b) municipal large scale geo-reference databases, each maintained at corresponding municipality, using the same basic data model to support automated exchange with national level.

Once integration procedures are performed, all databases can function independently. National database is updated from municipal database regularly or on demand. The actual changes in municipal database are recognized by automated procedure and transferred to the national database thus avoiding excessive replications.

Process of integration of national and local geo-reference base data consists of the following steps.

0. Preparation. Unique identifier is implemented across all the geo-reference databases. The prefix of the identifier identifies local dataset.
1. The harmonisation boundary with local geo-reference database is defined, minimizing splitting or duplicating the features. The MGDB and UGDB features are split along the boundary (no intersections allowed). Buffer zone is drawn along the boundary.

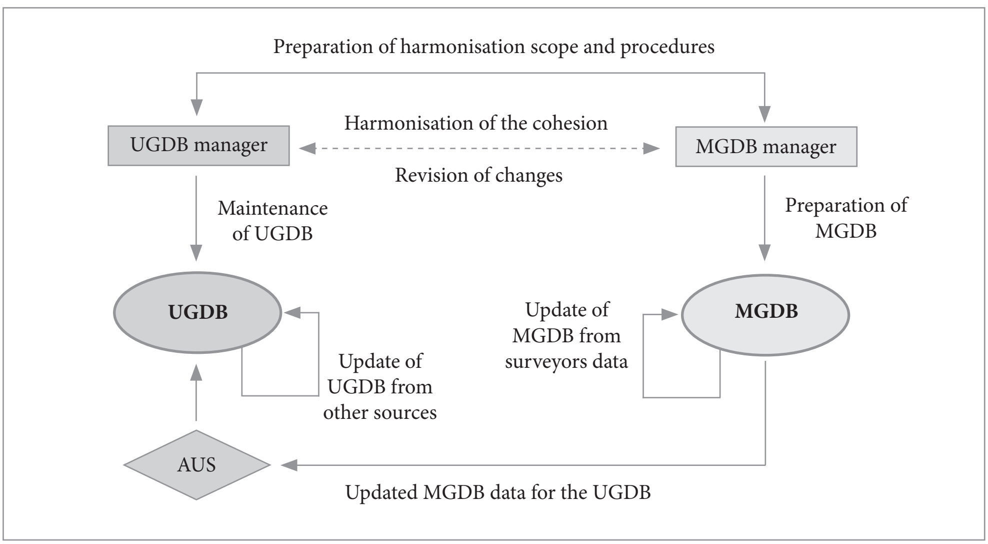

Fig. 1. Integration of municipal georeferential data into UGDB

2. MGDB data extent and feature classes involved in automated update are defined.
3. Harmonisation frequency and procedures are defined.
4. The set of harmonisation points is created in MGDB where MGDB objects intersect or touch the harmonisation boundary (Fig. 2).
5. MGDB is prepared for integration with UGDB. The *Status* attribute of each harmonisation point is set to zero (not revised by the UGDB manager). There is a special attribute field for comments in the case of unusual situation or a problem.
6. The set of harmonisation points is revised by the UGDB manager who ascertains that all harmonisation points connect to the UGDB objects within allowed accuracy and that the attributes of each MGDB and corresponding UGDB object are compatible. The *Status* attribute of each approved harmonisation point is set to 1. In case of errors UGDB manager can add comments to unapproved harmonisation points and create new points for MGDB. The harmonisation cycle is repeated until all harmonisation points are approved.
7. MGDB is maintained in the municipality. The update service AUS informs UGDB manager in case of any change of harmonisation point set. Changed harmonisation points have to be revised and approved by UGDB manager.
8. UGDB is automatically updated from MGDB using AUS.

6. Automated update service

The AUS service is designed to as well ensure interoperability between the municipality geo-reference database MGDB and the surveyors' databases. Mapping software used by surveyors must be compatible with AUS. Exchange is based on five attributes of all geographic objects: unique identifier, object start time, object end time, version number and date of the version.

Firstly, unique identifiers are automatically assigned to all earlier created municipal geo-reference base data. Specific prefix is used for identification of municipality: 'V-' in the case of example in Figure 3, or a numeric code if possible changes of municipality number or names are taken into account.

When new objects are added to the database, automatic AUS procedures fill in the above listed attribute fields (Fig. 4).

The prototype of procedures that select and move information from local surveyors' databases to MGDB (Fig. 5) has been designed during development of Lithuanian geographic information infrastructure.

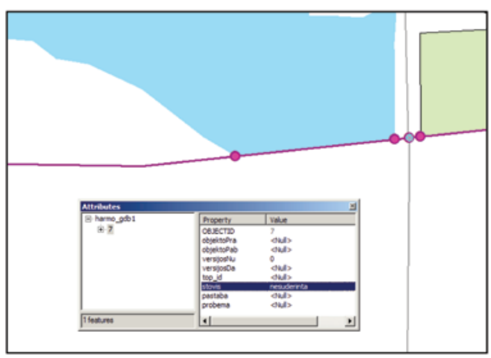

Fig. 2. Cohesion (harmonisation) boundary and harmonisation points of geo-reference databases

Fig. 3. Unique identifiers of features

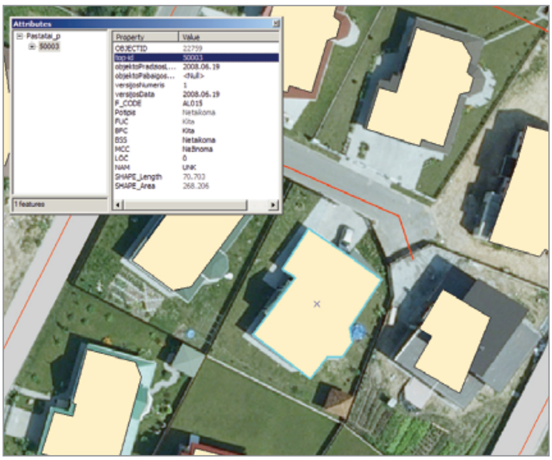

Fig. 4. New record in a local geo-reference database

Figure 6 shows data transformation model used by AUS for update of MGDB. Automatic procedures compare the AUS records with the database and detect objects that have been changed, deleted or newly added in comparison with the last database version. The MGDB objects are then correspondingly changed and the changes recorded.

The AUS software, tools enabling unique identifiers and tracking of objects' life cycle along with full documentation is free of charge and will be distributed to all municipalities. However, full implementation of AUS requires not only technological solutions but also some adjustments of existing legal base: amended regulations of municipal geo-reference base data flows and specifications of geo-reference base data encoding for surveyors and MGDB managers.

7. Economic impact of the solution

Economic benefit of implemented unified geo-reference base data model is mainly related with reduced labour costs of geo-reference base data managers at both national and municipal levels. It will take much less time to update geo-reference databases, to detect and manage GIS data changes, to data correct errors. Indirectly, automation allows expecting much better data quality and higher level of user satisfaction. The following indices of both national and municipal economic effect of using UGDM and AUS for an average municipality have been defined in LGII development studies and publications (Feasibility ... 2004; Beconytė and Pubellier 2006). They are based on analysis of foreign experience and verified against the results of surveys performed in Lithuania. (ANZLIC ... 1995; INSPIRE – Contribution ... 2003):

- Reduced costs of update and revisions of the national geo-reference database;
- Reduced costs of update and revisions of 60 municipal geo-reference databases due to unified data model and clear data policies. If we expect only 200 working hours saved

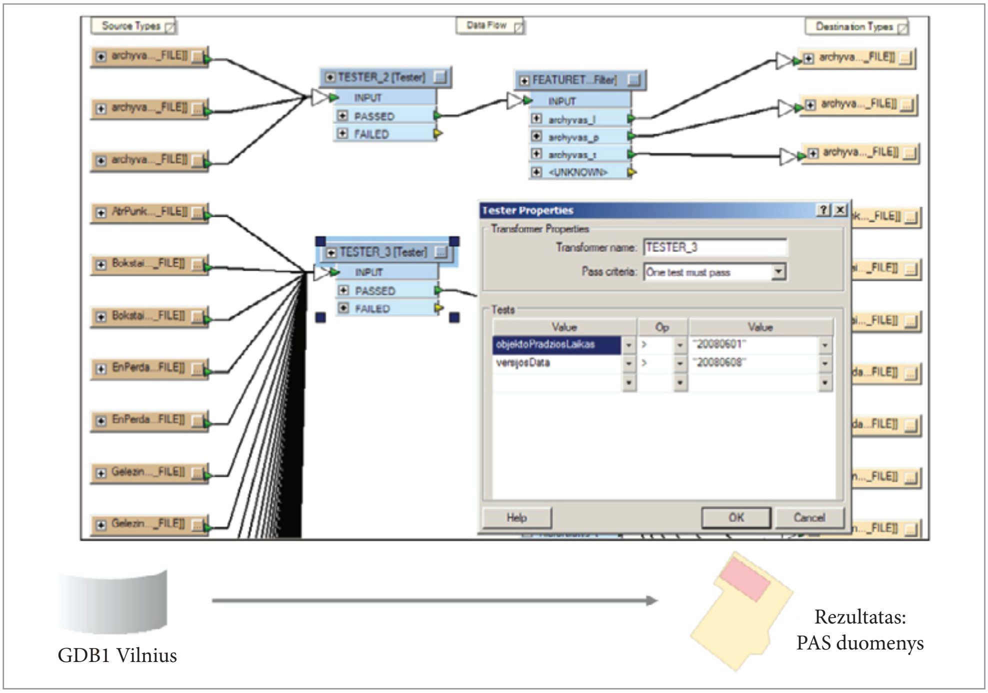

Fig. 5. Automated MGDB update service

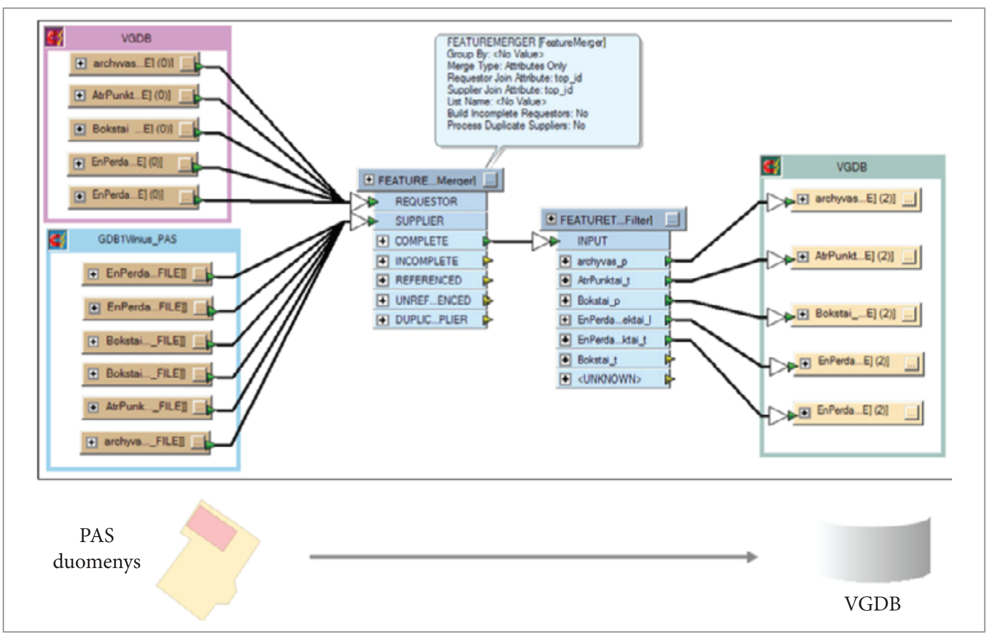

Fig. 6. Update service for municipal geo-reference database (transformation model)

yearly in an average municipality in three years after implementation of UGDM, it already amounts to about 0,3 million Lt for the state (Fig. 7).

- Reduced amount of surveying works due to improved accessibility and quality of geo-reference base data;
- Gained efficiency in public services: reduced labour costs of planners, engineers, constructors and architectors who intensely use geo-reference base data and can easily acquire them up-to-date from municipal or national databases;
- Economic effect due to avoided conflicts and civil court and pre-trial actions caused by misuse of geo-reference data for physical planning.
- Avoided pre-trial actions and civil actions due to incorrect planning decisions, that only can be very roughly estimated based on various studies of other European countries that show relatively big impact of this index for state's economy;

Estimated costs of update of one topographic map sheet at scale 1:10000 that can be saved applying automated update procedures is at least 2500 Lt. Considering the fact that topographic map must be updated every 5 years and that national geo-reference database comprises 2881 map sheet, average yearly economic effect amounts to almost 1,5 million Lt assuming that implementation of all procedures is successful (Fig. 7). It is though obvious, that it cannot be expected immediately after implementation but grows depending of organisational efficiency at the involved parties.

Besides quantified economic effect other positive changes in socio-economic development of Lithuania are expected:

- High quality multi-scale geo-reference base data fit for many purposes thus more widely used for decision making at national level;
- Better decisions and avoided mistakes in fields that require complex geographic analysis of multiple environmental and socio-economic factors, such as sustainable development, resource management, physical planning, environmental protection, crisis management etc.;

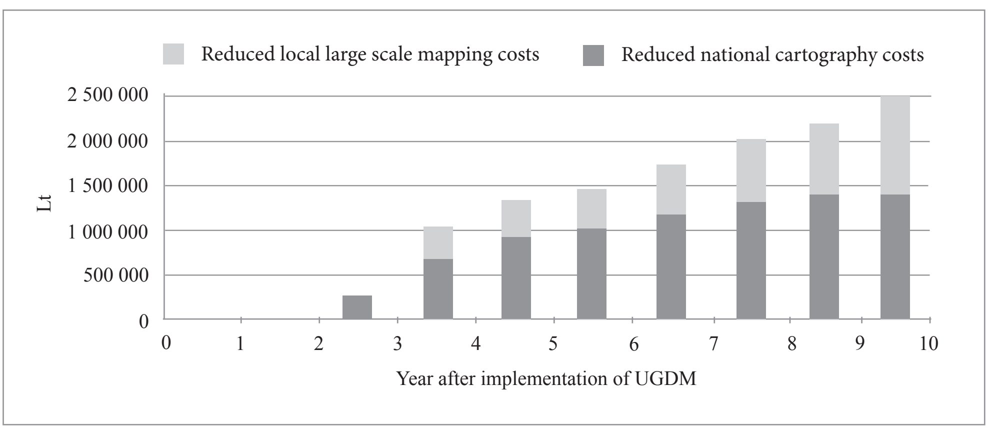

Fig. 7. Estimated economic effect at national level

– Concentration of geographic information and linking to geo-reference databases resulting in more efficient management, more efficient and transparent geographic data policies;
– Implemented modern geographic information and communication technologies, especially at local level; better environment for development of new public services and added value geographic products, integration of various other geographic databases;
– Improved quality of public information and services, increased general capacity in geographic information field.

8. Conclusions

Geographic data, especially large scale national reference base data, are very expensive to collect and maintain, as well as to visualize. Large investments are made every year to keep the most important databases up-to-date. Thus it is very important to efficiently re-use already collected data.

The need for a unified national system of geo-reference base data management becomes pressing. Such system requires automated integration of municipal large scale data into national geo-reference database that is single and multi-scale. Until it is implemented, geo-reference base data collected by municipality administrations are usually isolated, inconsistent and interoperable, therefore difficult to access and use.

The model for harmonisation of geo-reference databases (UGDM) has been proposed and became a base for automated reference databases update technology encompassing two levels:

a) Integration of local surveyors' data into municipal geo-reference database (MGDB);
b) Integration of large scale MGDB data into multi-scale national geo-reference database (UGDB).

It allows state and municipal institutions to efficiently provide the users with up-to-date geo-reference base data for a great variety of purposes such as planning, environmental protection, resource management and emergency actions.

Estimated effect of the described solution is significant for the country. It consists mostly of reduced geo-reference databases maintenance costs and of increase of data availability, quality and efficiency of provision to the users. The data are not duplicated, updates are automated and changes can be tracked at any level. Actual economic effect depends on GIS capacity of a municipality, its urbanisation level and intensity of physical planning.

The model is in the process of implementation that is rather complicated due to need to change existing legal acts. Transfer to the new model can be planned gradually in municipalities; existing business models do not have to be changed immediately. Standard solutions are applicable anytime.

Acknowledgement

This research has used the results of the project „Development of Lithuanian Geographic Information Infrastructure" (LGII, www.geoportal.lt, www.lgii.lt). The LGII infrastructure is managed by the State Enterprise *National Centre of Remote Sensing and Geoinformatics "GIS-Centras"* (Vilnius, Lithuania, www.gis-centras.lt).

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NACIONALINIŲ GEOREFERENCINIŲ DUOMENŲ BAZIŲ ATNAUJINIMO AUTOMATIZAVIMAS

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Santrauka

Lietuvoje atlikta savivaldybėse kaupiamų erdvinių duomenų analizė parodė, kad tik didesnių miestų savivaldybės kaupia erdvinius duomenis, tačiau erdvinių duomenų sandaros skirtingos. Nacionaliniu lygmeniu kuriamos erdvinių duomenų bazės nesuderintos tarpusavyje, dubliuojamas erdvinių duomenų kaupimo procesas, orientuojantis į skirtingų mastelių žemėlapių gamybą. Bendras georeferencinių duomenų modelis (VGDM) apima georeferencinių duomenų konversiją iš įvairių mastelių oficialių geografinių duomenų rinkinių, o ypač iš savivaldybių georeferencinių duomenų rinkinių į bendrą valstybės georeferencinių duomenų bazę (VGDB) ir nuolatines VGDB atnaujinimo procedūras. VGDB atnaujinimo technologijos pagrindas – geoobjektų (vektorinių geografinių duomenų elementų) egzistavimo ciklas ir pokyčių sekimas. Georeferencinių duomenų modelis reiškia, kad yra numatytas kelias pasiekti efektyvią įvairių mastelių oficialių duomenų bazių sąveiką.

Reikšminiai žodžiai: kartografija, GIS, geografinių duomenų modeliai, georeferenciniai duomenys, atnaujinimo servisas, darninimas.

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