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Efficient management of urban development process by integrating topographic and planning information and real estate registration

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ABSTRACT

In the developed countries the most accurate and reliable spatial data at the scales from 1:500 till 1:1000 is extensively used. The spatial data is useful in the various fields of business undertakings. Also it is applied for planning new territories, in designing or carrying out construction works, maintaining private properties. Thus, the same spatial object should be inscribed into separate information systems or registries. The same spatial objects are repeated and reiterated, unreasonable costs are incurred for their storage, the customers find it complicated to determine and select the best and appropriate spatial data required just for their own needs. This article suggests the solution of the problem. The idea to compose and develop the special information system in which the topographic and infrastructural information are merged and coordinated subsequently, have been introduced. Also modern methods for spatial data acquisition, storage, upgrading, adjustment and updating have been suggested and presented. The distribution model for data storage, data provision to the customers and service activities is defined. Available electronic services based on spatial data are described as advantageous for implementation on topographic maps, for inspection and monitoring of construction projects, for the issue of permits of excavation works and for the other activities.

INTRODUCTION

There is a lack in the public spatial information data sets about the positions of the elements of the underground engineering infrastructure. Meanwhile, almost all the available geospatial information on the engineering infrastructure is spread out in public institutions. This, made us to state that, curious situation causes different kinds of damages. For example, 326 to 764 cases were registered per year from 2004–2012, when the under ground electrical cables were damaged during land excavation work (Statistics electrical incidents in Alberta, Canada 2012). Due to the inadequate scope, errors and uneven structure of the topographic maps stored at the municipalities, the following difficulties constantly appear:

- The specialists of the municipality are not able to use the most relevant topographic data and cannot make their decisions efficiently;
- Experts, dealing with the projects on territorial planning and construction work, are unable to apply topographic data for strategic projects and to make alternative decisions;
- Land surveyors do not have possibilities to determine

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the special terms and conditions for land and forest usage precisely;
- The preparation of the construction projects takes longer time, therefore the possibility to make mistakes significantly increases, and that could lead to an unexpected additional expenses during the process of construction;
- Investors and enterprises are not able to have an independent evaluation of the existing engineering infrastructure;
- Frequent damages of the underground network occur during carrying out the excavation work;
- It is rather complicated to eliminate damages of the underground infrastructure.

Due to these reasons, the financially strong enterprises developed the autonomous infrastructure data storage systems. Nowadays it is even worse, as information about infrastructure objects (mainly engineering networks) is stored or duplicated at private databases and could not be accessible for public usage. Among these enterprises are the following (or similar):

- A group of enterprises operating the engineering infrastructure networks;
- Municipalities;
- Railway companies;
- Real estate cadastre data handling companies.

The spatial databases of these enterprises mostly differ one from another, are not complete or fully reliable. In most cases, data of the geodetic control/as-built surveys, performed by small municipal enterprises engaged in construction, could be lost. Or the geodetic control/as-built surveys, performed by a private operator engaged in construction of the networks, in most cases are not accessible for planers and designers. The objects of engineering infrastructure (networks, streets/roads) entered to the cadastral databases lose part of the information acquired by the geodetic control/as-built surveys.

DESCRIPTION OF THE PROBLEM

In many Eastern European countries the classification of pipelines, cables and networks used to be and remained under the outdated approach, that is, the paper map version had to contain all the available information required for designing. The topographic maps compiled within the period of 1960–2000 contained all the accessible parametric information on the infrastructure networks. It was practically impossible to obtain quickly any additional information at the operating enterprises.

Thus, the system mentioned above was based on the insignificant diversity of the network types, the non-existence of the computer technology and a small amount of the codified parametric information on the networks at the operating enterprises (the files were stored at the enterprises, approximate schemes were compiled).

Meanwhile, together with the spread of computer technologies, enterprises methodically initiated the storage of parametric information about the infrastructure networks. The amount of parametric information is significantly bigger compared to amount of information presented on the conventional topographical plans. The majority of the parametric information is useful for designing or it is necessary for enterprises responsible for the maintenance of the networks (for example, in such cases as specified voltage, pressure or isolation of the main waterways and pipelines).

It is a big challenge to find out a compromise between designer and the needs of responsible enterprises in terms of the content of the information about engineering networks. For example, in some countries the geodetic technical regulations describe, what information on infrastructure should be acquired by geodetic measurements, but they face the same problem as well. The European Commission directive ‘INSPIRE’ describes the possible structure of the spatial data of engineering networks, where the attributes and classifications could be forecasted (INSPIRE, 2012).

The problem is considered to be a complex one. It is possible to indicate these basic points of the problem:

- The major part of the content of topographic maps (60–80%) deals with engineering infrastructure networks;
- An extensive attributive information is specific for engineering networks;
- The owners of engineering networks are not assigned any definite responsibility for the data and records stored;
- Huge amount of work for editing digital topographic databases is required at the municipalities when integrating new data and records;
- The main customers or users of the data as well as the related public electronic services are not identified.

It is not possible to compile a valuable national spatial data infrastructure (SDI) without the available large scale maps (most accurate and most extensively applied spatial data of topography and infrastructure) and, even more important, without having the accessible strategy of data collection. Other publications indicate, that such data could be used as a part of SDI (Kyrkjeeide and Lillethun, 2004; Van der Molen, 2005; Quak and de Vries, 2006).

Updating the large scale topographic maps during the period to 1992 in Eastern European countries was usually performed by scratching off the changed or extinct elements in the analogue maps and by drawing with an ink the new ones. For example, in Lithuania such maps were stored in the centralized archives of the State Engineering Research Institute (SERI). Generally, the repository and storage of the archives was used, because in cases of necessity it was economically disadvantageous to undertake geodetic measurements of the objects once again, the location of which was already previously determined in the territory; and because it could be rather complicated to identify the spatial position of the underground engineering networks after the trenches were filled up. Approximately in 1992 under the Governmental Order the functions of the owner regarding the National Estate Fund were prescribed to the municipalities, 1:500–1:2000 scale topographic maps were attributed to them as well. In 1992 SERI has been closed and the archives were transferred under the regulation of the administrations of the municipalities. The municipalities acted under its own discretion and competence for eight years. The digital map production technology was rapidly developed during that period.

Some specifications were prepared, where coding structure for large scale topographic maps was described. For example, specifications of the Integrated Geo-Reference Information Systems (InGIS, Lithuania). Nevertheless, the structure of electronic data and technology of spatial data updating was not mentioned in any available document or regulation (Stankevičius and Paršeliūnas, 2005).

The current situation does not allow to modernize processes of plans usage (Stankevičius et al., 2010), to create electronic services, but forces to duplicate the information on the same spatial objects in the databases of different institutions (Stankevičius, 2008).

The know-how technologies of compiling the large scale maps in some countries (Denmark, Holland, Netherland, Norway) revealed, that to achieve this task the financial resources from concerned sectors are needed (Høstmark, 2002; Kok, 2005; Norge digital, 2008). The projects regarding the cooperation of funds are more extensively described in the following publications in Norway (project GEOVEKST) (Mardal and Lillethun, 2005), Netherlands (project GBKN), Denmark (project FOT).

The project in the Netherlands, dated 1968-1975, revealed the chaos in the large scale topographic maps information usage; thus, the problem regarding the territorial planning and the performance of the excavation work was also determined. In 1971 the report was made in the Parliament of Norway on the significance of the databases of the large scale topographic maps, and the conclusion was derived, that there was the demand for the centralized accessible information (established GBKN). During the period of 1992-2001 the Government allocated funds for the municipalities enabling them to participate in the partnership project connecting private and public sectors.

The models of the cost sharing among the partners could be various. The part of the coverage in the partnership is diverse, that is, GEOVEKST and GBKN projects include private enterprises maintaining the networks, FOT project is oriented towards the accumulation of the large scale topographic data and involve the institutions of municipalities, railways, and the cooperation of the institutions responsible for the national topographic and cadastral measurements (Kort og Matrikelstyrelsen, 1995). If compared with the legislation in Lithuania, the biggest difference is that in those projects, as well as in the majority of the other countries, the following requirements are applied, that is, the enterprises maintaining the engineering networks are obliged to accumulate the special data and provide for the enterprises maintaining them (IMKL 2.2 Data Model 2014); partners usually accumulate 1:500–1:2000 scale topographic data (the error on position is allowed up to 3 m in case of the orthophotos, where the objects are in the shade) and topographic data (located on the ground, slopes, trees, fences, electric cables, poles, manholes and similar types, installation cabinets in public places; data are collected for the first time and periodically upgraded by photogrammetric methods according to the centralized notices of the procurements); the accumulated data is reliable and suitable for the usage (for example, GBKN project within the three months period complemented the deficiencies noted); the data is also updated in the various public administrative sectors of the municipality and by applying the compiled technical maps when directly measuring the locality (Specification FOT4 2009). It is also necessary to estimate the fact that in other countries were achieved all requirements mentioned above as the result of the long-lasting partnership processes.

TOPOGRAPHIC MAPS USED FOR PLANNING, DESIGNING, CONSTRUCTION AND PROPERTY RECORDING

The technical regulations determining the constructional processes as well as the regulations on preparation of the detailed maps cover the requirement indicating that all maps have to be of a certain period of validity. Thus, there is a tendency to prolong the validation period of the maps (from 1 to 5 years in Lithuania). The extension of the validation of the topographic maps is related to the efforts of project designers to use the same map for the longest possible period of time. The excavation work schedule has to be agreed together with the owners of the underground infrastructure and communication networks.

The constructional processes regarding designing and planning are based on the date when the topographic maps were checked with the operators of the engineering networks; the processes of land use and property registration are based on the archives of the large scale topographic maps. Therefore, in the archives of the municipalities only the fragments of the mutually disintegrated topographic maps are mostly stored, which could not be applied directly in the processes of planning and designing. The material available in the archives is regularly combined into a single set of the spatial objects in the topographic map, the content of which is monitored by the experts of the enterprises maintaining engineering networks; as a result it is used only to solve one task, and after it is lost.

The analysis of the situation implies, that the processes of planning, designing, construction and property registration are not coordinated with the accumulation and presentation of the topographic and infrastructure data used for these processes. Generally speaking, some legal acts specify the order, how topographic maps have to be collected; the other legal acts restrict the usage of the accumulated maps for the infrastructure development. Thus, there is no possibility for the accrued and regularly adjusted topographic maps, developed for the particular area, to be considered as the reliable ones and practically applicable within the unlimited period of time allowing designing and constructing of the infrastructure. The funds invested into the accumulation, administration and adjustment of the topographic maps usually turn to be the unjustified expenditures.

The suitability of the data of the topographic maps in project works is not legalized; the links to the events in the information systems of monitoring of the construction processes are not provided by the information systems (IS); the accumulation of the data of the same objects in the different information systems is duplicated. It predetermines the expansion of the electronic services related to the life event called ‘I create infrastructure’. To be more specific, we do not have the centralized information system, applying the same components and providing the services of the common use of the web.

INFORMATION SYSTEM OF TOPOGRAPHY AND INFRASTRUCTURE

The analysis of situation revealed, that the unanimous and conventionally agreed information system of topography and infrastructure (TIIS) should be created for the upgrading and adjustment of the spatial data functioning under the principles of cooperation. The structure of the spatial data of TIIS has to be organized under the guidance and basis of GIS and it has to be open for the expansion possibilities. Thus, it could open the possibilities for the majority of the enterprises maintaining engineering networks and institutions to apply TIIS. The databases of TIIS could be used in the related IS (when maintaining the engineering networks or registering the objects of real estate).

TIIS would cover the electronic services of topographic maps checking, approval, issue and acceptance, converting of the fragments of the new data, tools of editing and integration. TIIS could be used by applying the common model of databases and processes checking for the related electronic services of permit issuing concerning land excavation work and for electronic services checking the designs of the technical projects. When TIIS is linked with other IS (construction permits IS or the IS of the real estate register or the IS of the operators of the engineering networks), then it is a possibility to organize the observation of the status and conditions of the objects (Figure 1). Thus, the methodology of the building information modelling (BIM) could be implemented. The participants of the constructional process would be able to obtain the latest and most complete (from the point of view of the parameters) information on the infrastructure in one and the same place. The initial information sources should be used to update TIIS, namely topographic maps before designing and before filling up the trenches with communication cables, after the object has been built (Figure 2). Besides that all the spatial objects of the infrastructure are collected irrespectively from the current or future form of ownership. The spatial objects of the infrastructure are given the unique references for the contacts with the departmental information; the information regarding the constructor of the object is also attached.

The upgrading and adjustment of TIIS is considered to be the constantly ongoing production process for integrating the fragments of the spatial data.

To ensure the financial continuity and vitality it is suggested to establish partnerships in public and private sectors.

The spatial data compiled during the project of cooperation would be useful for:

- Revision of the maps and delivery to the households, businesses, experts and operators of engineering networks;
- Speeding up the approved topographic information for the processes of planning and designing;
- Reducing demand for technical equipment and software for servers and working places;
- Constant and independent (from the particular organization or the owner of the equipment) updating of the spatial data;
- Disappearing demand to duplicate the spatial data in the governmental information systems;
- More accurate decisions of the pre-designing processes, faster processes of planning and designing;
- Ensuring the spatial background regarding the related services of the infrastructure expansion.

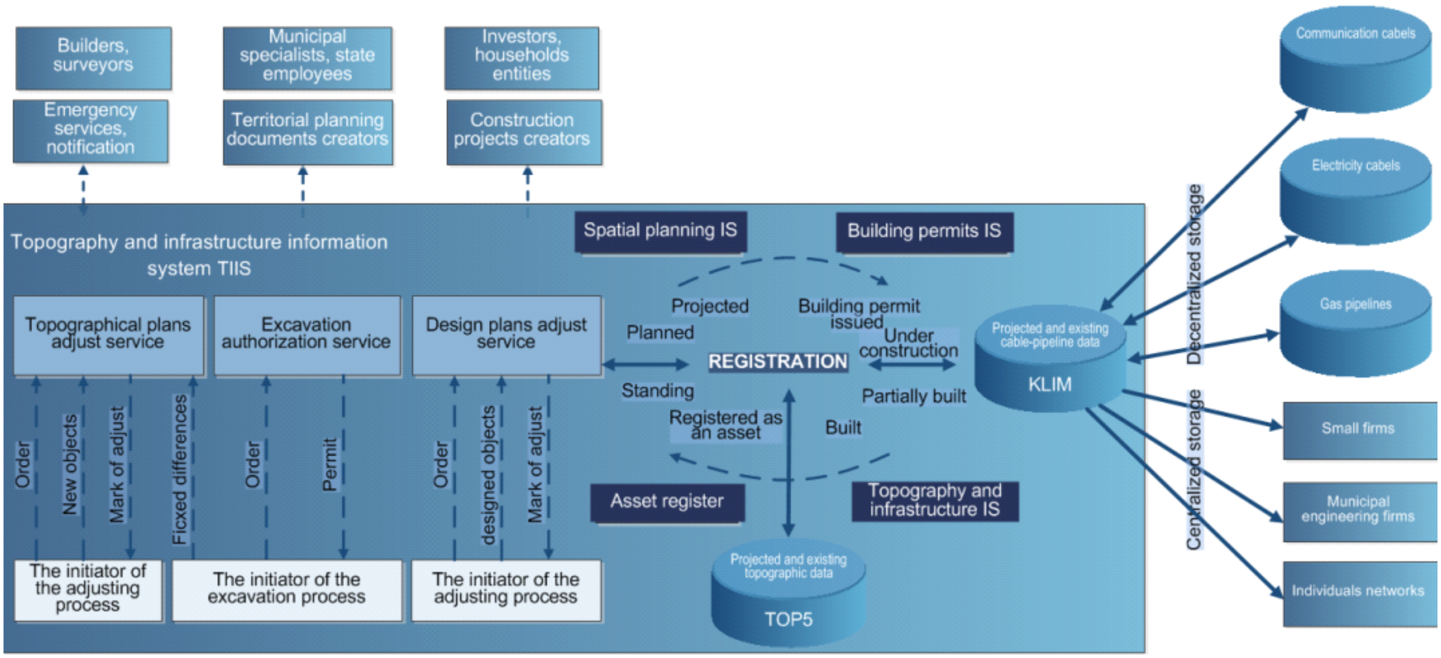

Figure 1. Information system on topography and infrastructure.

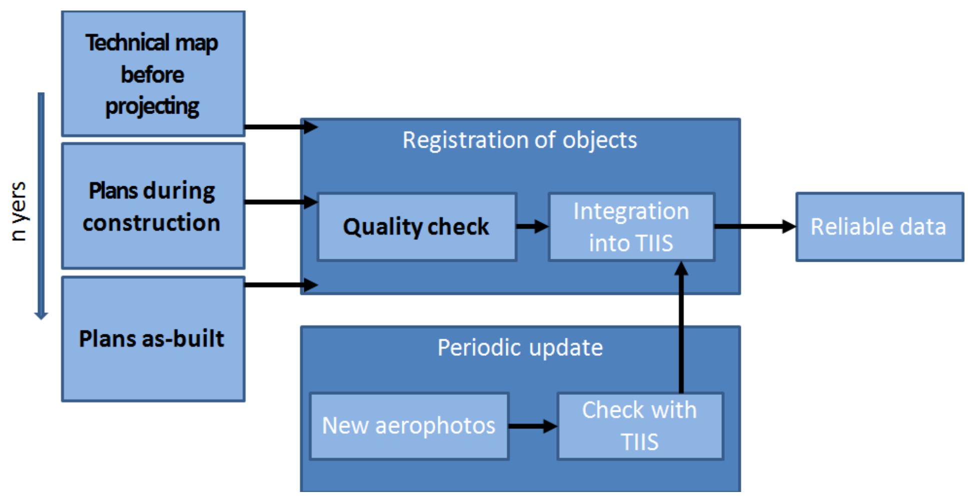

Figure 2. Vitality of TIIS databases–the initial source of information is used.

METHODOLOGY OF THE DATA BASES UPDATING

Updating the data bases at TIIS should be operated under the principles of the decomposed special data, namely when a surveyor at his working place integrates new spatial data into the fragments of the spatial database and when the automatic means and measures register the attribute information of the spatial data as the updating information (CUI); then the public service officers at the enterprises and municipalities review the material on Web, verifying and checking maps by working online; an officer at the TIIS integrates the fragment of the spatial data according to CUI. The major work related to the integration has to be performed at the working place of a surveyor; the employees of the municipality are not obliged for editing procedures on the spatial data adjustment.

The fundamentals for the application of CUI technology are the following: the transfer of the fragment (FSD) of the spatial database to a surveyor and the receiving it

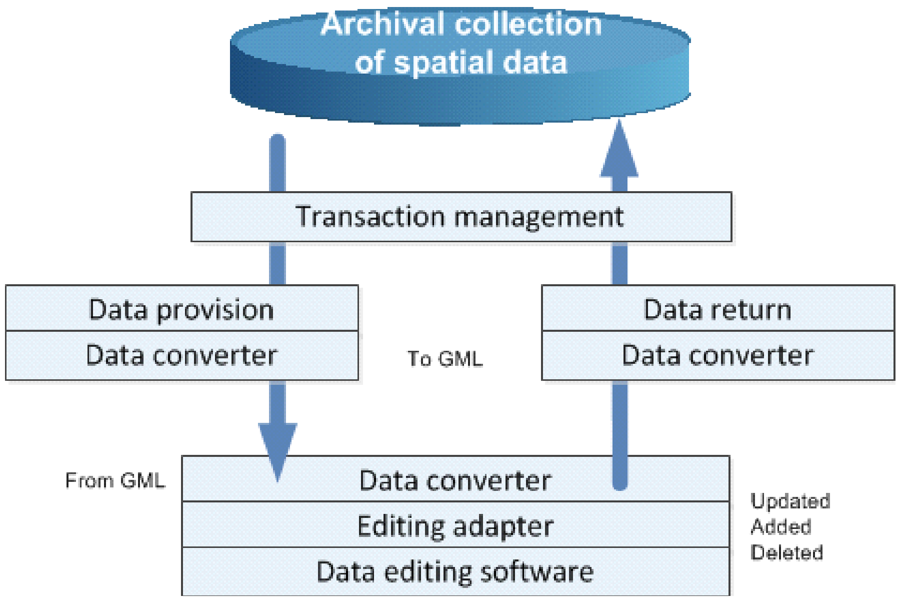

Figure 3. Sequence of adjustment of information change.

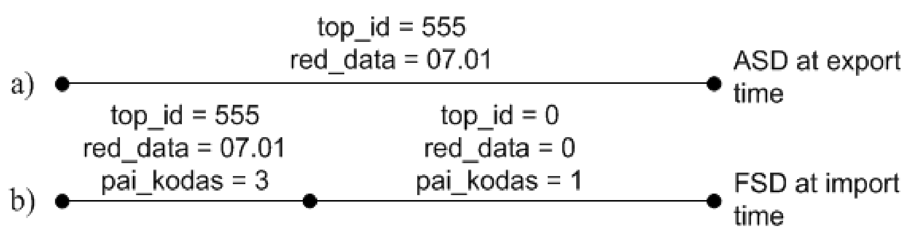

Figure 4. Results of CUI record after CAD function break is used.

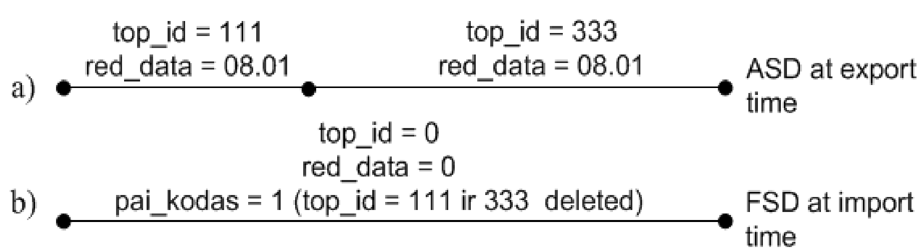

Figure 5. Results of CUI records after CAD function join is used.

from the surveyor has to be made in the open standard language GML; tracing changes update information and recording the attributive data into FSD at the working place of a surveyor. The concept of the applied technology is presented in Figure 3.

The way of spatial data editing is described in Figures 3 to 5. That is the expansion applied at any market by a surveyor of the manufacturing enterprise, which when operating within the environment of the manufacturer, continues the observation of the activities of the surveyor. Hereinafter, the most popular cases of the spatial data editing are presented based on the analysis of the management of the archival spatial database (ArcMap, manufacturer ESRI) and FDS editing (AutoCAD Civil, manufacturer Autodesk).

The spatial data submitted to the surveyor from the

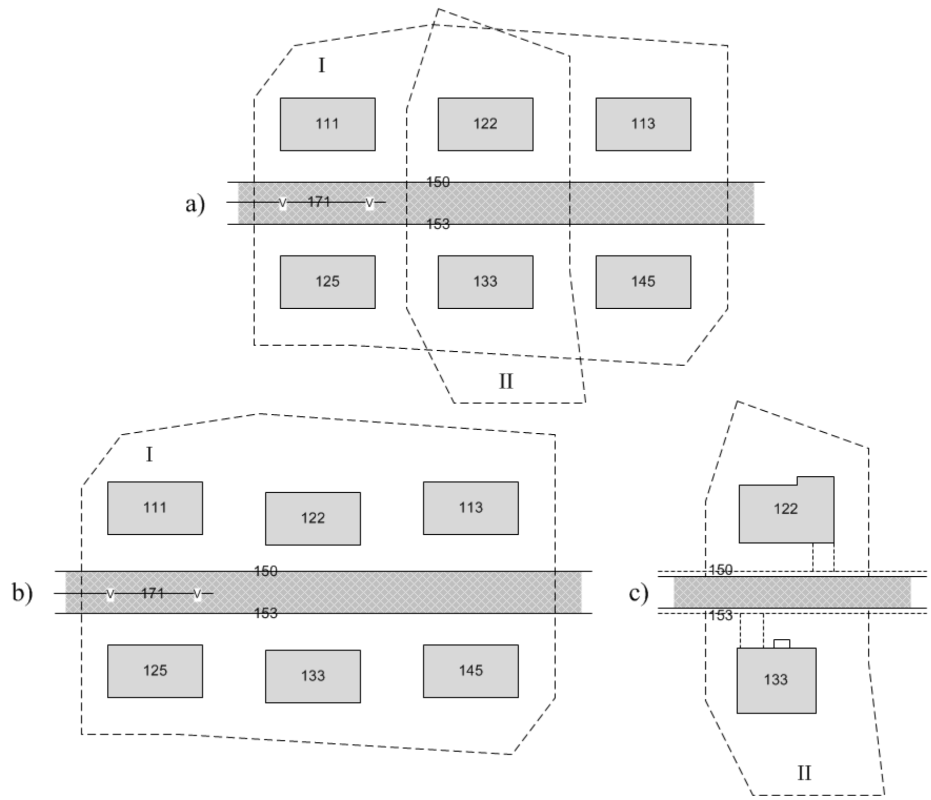

Figure 6. a, Within a similar time from archive database to surveyor I and to surveyor II, the databases FSD are presented; b, The later returned sets of FSD to surveyor I ; c, the previously returned FSD to surveyor II.

archival spatial data base should have additional attributive fields of metadata, necessary to continue the observation on the changes:

- TOP_ID (unique number of the spatial data);
- RED_DATA (special data geometry or the date of the last change of the attribute);
- CUI_CODE (the value of the information code for the adjustment of the changes).

Fields TOP_ID and RED_DATA are presented to a surveyor to be registered and filled out. They should not be changed during the editing procedure and has to be transferred to TIIS after renewing the data base of FSD. Field CUI_CODE is presented for a surveyor filled out with values '0' or 'Zero'.

The adapter of editing has to follow the cases of the spatial data editing at the working place of a surveyor and correspondingly fill out the attributes of metadata:

- If a new spatial data is compiled, to the attributive field CUI_CODE is attached value '1' (new), to the fields TOP_ID and RED_DATA are attached values '0' or 'zero';
- If a spatial data is deleted, to the field CUI_CODE value '2' (deleted) is attached, during the moment of export to GML the spatial data is transferred to a separate GML file;
- If geometry or attribute of the spatial data is changed to the attribute field CUI_CODE, value '3'(changed) is attached, for the fields TOP_ID and RED_DATA are saved values which were received from the archival spatial database.

When editing FSD geometry, CAD at the manufacturing enterprise mostly uses break, join, trim, pedit/spline, move, rotate functions. The tests assisted in deriving the conclusion that CAD function break was created in such a way that the primary characteristics of the spatial data are preserved for the certain part of the line, which is closer to the initial point of the line (Figure 4). CAD function join deletes both primary spatial data and compiles the new ones (Figure 5).

However, when several surveyors are editing the geometry of the spatial data within similar period of time and submit it to the archival spatial data base, the conflict situation is formed due to the spatial data sent in between (Figure 6). Here comes the example describing the situation. When from the archival spatial data within a similar period of time there are sent FSD with the unique numbers for both the surveyors, the territories of FSD data bases cross each other. Surveyor II carries out the measurements in the locality; he details the primary spatial data and submits CUI to TIIS (digital archive). For the next period of time surveyor II submits FSD of the overlapping territories, where he does not perform the detoxification of the primary spatial data in a detailed way (cases when spatial data are required for the pre-designing testing, to design the inlet of the engineering networks or where the changes of the objects at the site of measurements do not occur). The automatic procedures of FSD integration into the archival spatial data according to CUI, find the previously submitted spatial data of surveyor II (unique numbers 122, 133, 150, 153), the dates of which are newer than FSD submitted by surveyor I later afterwards. An expert from TIIS would have to solve the conflict between the spatial data versions. After the spatial data of surveyor I is accepted and if the mutual problematic situation of the spatial data is not going to be solved interactively, the more recent spatial data which have been presented in a more detailed way, might be deleted.

The mutual conflict regarding FSD and archival spatial data could be solved by integrating CUI at the TIIS. Thus, there has to be established a manufacturing enterprise which according to the derived logical terms and conditions of monitoring could perform the search of the objects of the conflict between FSD and archival spatial data and could record the description of the found conflicts into the attributive fields. The manufacturing enterprise has to cover the window of conflict visualization and allow the expert from TIIS to select visually the versions of the correct solution.

CONCLUSION

In order to have freely accessible and reliable spatial data, it is necessary to:

- develop the information system of topography and infrastructure (TIIS);
- allocate responsibility when submitting a particular type of objects for the constructional procedures to be performed;
- distribute the financial funds for the maintenance of TIIS among the owners of specialized information systems;
- divide the work regarding the integration of the new data for TIIS when applying updating information;
- determine the communication links of TIIS with the related information systems (IS): IS of construction permits, IS of the real estate register, the IS of roads and railways, the IS of the enterprises keeping the maintenance of the networks;
- develop related electronic services for verification of the topographic maps, design projects, excavation maps at the concerned enterprises.

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