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Review / Pregledni znanstveni članak

As-Built Assessment Survey Workflow – Problems and Challenges

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ABSTRACT. The purpose of this paper is to present the range of surveying works carried out during geodetic as-built inventory of buildings and utility infrastructure. The theoretical part of this essay complies grounds for legal basis on territory of Poland, which are core part of geodetic and cartographic studies. Moreover, the phases of geodetic as-built inventory are being discussed, in the light of applicable rules. Particular attention is being paid to the topic of situational and height measurements. The paper discusses methods of measurement used, precision groups and objects subjected to inventory measurement are being listed. The practical part of this paper regards surveying as-built inventory of single-family house. In this study we discuss the consequential procedures that contractors need to follow during the construction process, this includes preliminary actions, field work, and individual elaboration of the findings. Post-completion documentation, gathered in the form of technical frame, after obtaining a positive verification test result was included in the Head Office of Geodesy and Cartography.

Keywords: building, inventory survey, as-built survey, Real Time Kinematic.

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1. Introduction

The participation of a surveyor is necessary in the implementation of any construction investment that requires a building permit in Poland (Mierzejowska 2017). To prepare a construction design, it is necessary to prepare an up-to-date map for design purposes (Kampczyk 2015). In the next stage, the land surveyor is responsible for the delineation of objects in the field and geodetic supervision over the implementation of works. After the construction is completed, it is necessary to carry out a geodetic as-built inventory to obtain an occupancy permit (Dybeł and Kampczyk 2018). As-built measurement is carried out to present the actual condition of the facility and to collect the necessary data to update the Terrain Information System databases (Grochowska 2014, Lewińska and Pargiela 2018). It is the basis for confirming the compliance of the building location with the plot or area development plan (Przewięźlikowska and Krzyżek 2016). The opinion issued by the surveyor carries effects in the subsequent stages of the investment and construction process.

Compared to Poland Turkey is located in an earthquake higher risk zone, so building inspection is important issue and the building inspection law, which came into force all over the country as of January 1, 2011, is one of the most important legal regulations related to the construction phase of buildings (Meydan Yıldız 2019). Geomatics engineers in Turkey carry out as-built assessment workflow instruments at construction applications. This process starts by the geomatics engineer who is authorized during the application of the building. The control and registration processes of the completed building are carried out by a different surveying engineer under the control of the building inspection company. Building application processes are carried out on the GRS 80 (Geodetic Reference System 1980) ellipsoid in the ITRF 96 (International Terrestrial Reference Frame 1996) coordinate system.

During 2020–2021, Ukraine underwent deregulation reform regarding the rules of operation in the construction market (Ivanchenko 2021, Turovets 2021). The reorganization of the State Architectural and Construction Inspectorate has not been completed due to the COVID-19 pandemic. In view of these processes, the example of Polish legislative and technical regulation discussed in this article should be disseminated in Ukraine.

The most important set of regulations covering issues in the field of geodesy and cartography is regulated by the Geodesic and Cartographic Law Act (GCL) (Noszczyk 2018). It includes issues related to the national information system about the area, organization, and tasks of the geodetic and cartographic service. This act covers issues related to the performance of geodetic and cartographic works, keeping records of land and buildings, and an integrated real estate information system. The issues of soil science classification of land, geodetic records of utilities networks and coordination of the location of these networks are discussed. The Act contains information on the state geodetic and cartographic resource, professional qualifications in the field of geodesy and cartography as well as records of towns, streets, and addresses. The act (Kończak 2022) regulates the design, construction, maintenance and demolition of buildings. It also covers issues related to the role of a surveyor during

the implementation of a construction investment. This act imposes the obligation to carry out geodetic as-built measurements and defines the objects that are subject to them. In accordance to the (Kruk 2011), an inventory map is an element necessary to notify about the completion of the construction of a facility or an application for granting an occupancy permit. The legal basis for making geodetic measurements is the regulation (Cienciala and Florek-Paszowski 2019). It includes regulations that define the elements to be measured, the required accuracy, and the methodology for setting up the measurement matrix. The regulation regulates issues related to the method of preparation, development, and transfer of results, in the form of a technical survey, to the state geodetic and cartographic resource. It is required that all geodetic and cartographic works be carried out in accordance with the national spatial reference system specified in (Doskocz and Rejchel 2016). The adopted coordinate system is physically implemented by geodetic networks, the division of which, as well as the conditions of establishment and maintenance, are defined in the regulation (Alsabry et al. 2017). The as-built geodetic inventory involves the need to update databases that are regulated in Poland by (MRPiT 2021b, MRPiT 2021a).

This type of research has already been carried out in various fields. They were about accuracy issues (Kala 2009, Usmani et al. 2020, Karabin et al. 2021), generation automatic models (Tang et al. 2010, Son et al. 2015, Shrestha and Jeong 2017), comparison of image-mased and manual field survey methods (Klein et al. 2011, Klein et al. 2012, Taha and Ibrahim 2021) or as-built 3D (Bhatla et al. 2012, Prokop et al. 2021) and BIM (*Building Information Modeling*) models (Lin et al. 2018, Dore and Murphy 2014, Jung et al. 2018, Uchański and Karsznia 2018, Jírová and Pešík 2021).

The purpose of this work is to discuss the as-built geodetic inventory of a single-family building utilities. The study presents issues related to the practical implementation of the order under the supervision of an authorized surveyor. The scope of work includes field measurements, compilation of the results in an intimate manner, preparation of as-built documentation and completion of the technical report. The various stages of implementation will be described, starting from the moment of receiving the investor's order to submitting the documentation in the form of a technical survey at the geodesy and cartographic documentation centre.

2. Methods

The as-built geodetic inventory of buildings is subject to the obligation of the contractor of the works to be notified in advance. The contractor may be an entrepreneur, an organizational unit, as well as a person with professional qualifications in the field of geodesy and cartography. Geodetic works may be reported before or after their commencement, not later than within 5 working days. The application is tantamount to an application for access to a copy of the necessary materials of the resource that can be used only for the implementation of one purpose of the surveying work. Geodetic measurement is preceded

by a field interview, performed to become familiar with the area of study and to locate and evaluate the existing control network. The content of the existing basic map with the actual state in the field is controlled, all changes are marked in red. The head of geodetic works decides about the necessity to conduct a field interview. One of the stages of the as-built inventory is the taking of situational and height measurements aimed at collecting current data on the spatial distribution of the elements of the development of the area covered by the construction intention.

As-built geodetic measurements are divided into current and final. The scope of current measurements concerns, among others, cables, and underground utilities, which will be buried or hidden. They must be performed when the items are exposed and unambiguously identified. Final as-built surveys include new build and any vertical changes due to construction work. They are performed after the completion of the works.

Due to the continuous technological progress, contractors give up the use of the existing, time-consuming measurement methods in favour of techniques that are beneficial in terms of effectiveness, enabling quick execution of the order. Real-time kinematic (RTK) positioning measurement is currently the most modern technology in the world, allowing to obtain accuracy of the order of centimetres (Krasuski and Bakula 2021, Teunissen et al. 2014). The main advantage of this type of measurement is independence from existing matrices, which significantly shortens the implementation time. The use of this method is limited in places with an obscured horizon, and the unfavourable location of the satellites causes the suspension of the measurement until their geometry changes. An alternative to satellite measurements is tachometry. The polar method enables measurements in built-up and wooded areas, while achieving the highest precision results. The integration of both measurement methods makes it possible to dispense with time-consuming polygonization and ensure independence from satellite visibility. Table 1 contains accuracy of methods used for inventory based on the existing literature sources. As practice shows during the measurement, accuracy results were obtained which were within the values assumed in Table 1 as well as the legally defined maximum measurement errors of the as-built building inventory.

Table 1. *RTK vs tacheometry accuracy (Luo et al. 2016, Chekole 2014).*

Method/Component	Horizontal accuracy	Vertical accuracy
Tacheometry	2 mm + 2D ppm + determination accuracy of the center	
RTK	2–3 cm	5 cm

All construction objects that require a building permit are subject to the as-built surveying inventory. However, there is a requirement to carry out an inventory for objects that only require a construction notification, they are (Alsabry et al. 2017):

- ✓ detached single-family residential buildings whose impact area is entirely located on the one building site or building sites which they were designed;
- ✓ networks:
 - power cable (including rated voltage not higher than 1 kV),
 - water pipe,
 - sewage,
 - thermal,
 - gas (with an operating pressure <0.5 MPa),
- ✓ buildings of transformer stations and container transformer stations with a building area of up to 35 m²;
- ✓ objects located in closed areas;
- ✓ cable drainage;
- ✓ ports: electricity, water, sewage, gas, thermal, telecommunications;
- ✓ telecommunications cable lines;
- ✓ electric vehicle charging points.

For construction objects that require only notification, the architectural and construction administration authority may also impose the obligation to perform an as-built geodetic inventory. The characteristic points of the above-mentioned objects are subject to direct measurements, which are necessary to update the main map and compare the shape and location with the plot development plan. An important element is the simultaneous collection of additional information related to the attributes of objects. They are necessary for the preparation of geodetic documentation to update the databases of geodetic and cartographic resources. All objects subject to the obligation to carry out the as-built geodetic inventory should be in accordance with the plot or area development plan. The as-built inventory map is attached with the remaining documentation to the notification of construction completion. The investor is obliged to attach geodetic documentation, including the results of the as-built geodetic inventory, including a map, and information on the compliance of the location of the building with the plot or area development plan or deviations from this project to the notice of completion of the construction work or the application for an occupancy permit, by a person with appropriate professional qualifications in the field of geodesy and cartography.

After completing the results of the work in the form of a technical report, the contractor is obliged to submit it to the territorially competent centre for geodetic and cartographic documentation. Data used to update the resource databases shall be prepared in the GML (Geography Markup Language) format. It contains both modified objects with the original identifiers and new objects that receive the identifiers given by the contractor (Cieniła and Florek-Paszowski 2019).

As a result of the work carried out, a map of the as-built geodetic inventory is prepared. The document is a fragment of the basic map showing the invest-

ment area, supplemented with newly created elements, marked in accordance with the applicable symbols (MRPiT 2021b). The inventory map should be provided with an official clause, which confirms the acceptance of data sets or documents on the basis of which the map was drawn up to the state geodetic and cartographic resource, or a declaration of the contractor of geodetic works on obtaining a positive verification result.

3. Results

The practical part is an inventory of a single-family building with an external water supply system, sanitary sewage system, a septic tank for liquid waste and a cable supply line. The investment area is located within Rogozno, which is part of the Leczynski district in the Lubelskie Voivodeship. The building has one overground storey with an attic and permanently connected objects: a veranda and a terrace (Fig. 1).

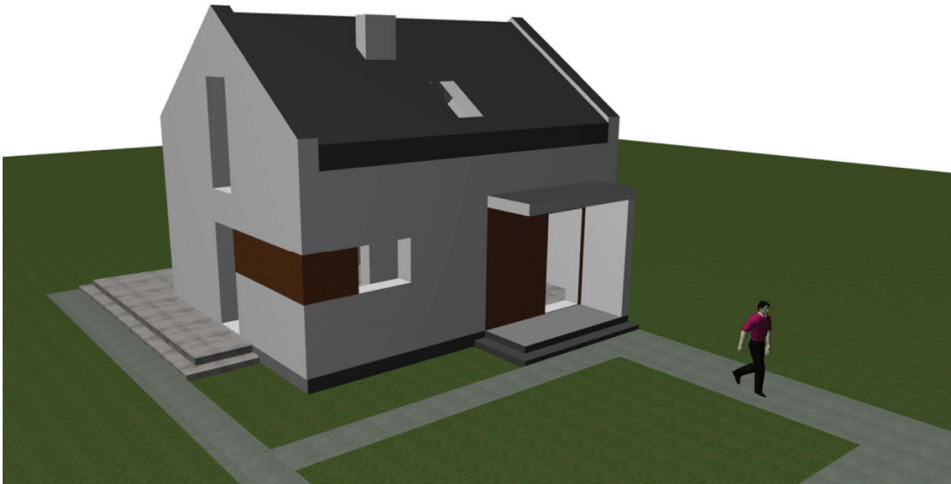


Fig. 1. Visualization of a future building being object of research.

The plot is partially developed and has access to utilities such as electricity and water supply. Access to the property is provided from the existing road with a hardened surface, adjacent to the east (Fig. 2). The plot with an area of 0.2000 ha (yellow line, Fig. 2) is tree-free, rectangular in shape with a flat configuration, the average terrain elevation is 172 m above sea level.



Fig. 2. Registration plot nr 604/2, state of z 27.10.2020 (GUGiK 2022).

Based on the application, an individual work ID was given, and the following materials were obtained: basic map and a cadastral map in vector form; a list of coordinates and heights of the detailed horizontal network points and copies of the descriptive data of the land and building register database. Before starting the measurement, the documents downloaded from local geodetic documentation centre were analysed in terms of completeness, timeliness, and suitability for use.

Then, the basic map was compared with the actual state in the field. The changes that have occurred are marked in red on the copy of the main map. A new residential building, water supply and sanitary sewage systems, a drainless tank for liquid waste and a cable supply line are visible. Based on the list of coordinates of the existing detailed network, points of the geodetic network were found, and a control measurement was performed with the use of a GNSS receiver, using the RTK technique. The measured coordinates were compared with the data of the local geodetic documentation centre resource and it was found that they meet the requirements of.

The measurement matrix was designed with the minimum length of the sides in mind and ensuring mutual visibility. The points were marked with the use of wooden stakes with the centre point, marked with geodesic paint. Then, two independent measurements of the warp points were performed using the GNSS method, using the RTK technique. In reference to the newly designed points of the measurement network, the measurement with the polar method was started, for which the South NTS-365R total station with a prism was used. The subject of the tacheometric measurement were the corners of the ground floor of the building, the front ends of which were measured with a ribbon tape for additional control. Next, the field details were measured using the RTK technique, the location of the inlets and outlets of connections, axes of underground pipes, upper parts of pipes, cable breakpoints and overground elements of underground utilities were determined. Measurements were made:

drainless tank for liquid waste; sanitary sewage system, water supply system and cable supply line. Elements of the utilities network were measured in an open trench, in accordance with the requirement contained in the Construction Law Act (Kruk 2011). The depths of the well and the tank for liquid waste were determined with the use of a levelling rod, and the lengths of the cables were checked with roulette.

During the works, a field sketch was prepared at the same time, showing the investment elements to be measured, the location of pickets and the numbering of the network points. After the field works were completed, the measurement results were compiled at a camera. As a result of comparing the coordinates from two measurements of the measurement network, it was found that the obtained differences did not exceed 0.05 m, which is in accordance with the standard (Cienciała and Florek-Paszkowski 2019).

Next, the coordinates of the stations from the tacheometric measurement were calculated. Based on the sketch, the data were mapped, while checking their correctness with the measures measured with the ribbon tape. The area of new use and the built-up area, determined by the building contour, were calculated. The compliance of the distribution of the measured elements with the spatial development plan for plot 604/2 was checked, no deviations were found.

A list of changes to registration data has been prepared for a residential building. The information on the current state was supplemented since the extract from the register of buildings and the new state, determined based on the performed geodetic works. The following attributes of the object are tabulated, such as: location, identifier, type, function and class of the building, number of storeys, surface area, address, sequence number and number of rooms. Attribute tables were prepared for each of the revealed wires to update the utilities networks database.

The technical report contains information on the goal, manager, and contractor of works, and the starting and ending dates for their implementation. The materials obtained from the resource, which were used during the surveying work, were listed. The technologies and measurement methods used are described, as well as the course of the activities carried out. The databases that were completed and the names and formats of the files transferred were specified. The documentation was created because of the as-built inventory and was completed in the form of a technical survey. The prepared materials were sent to the appropriate district centre for geodetic and cartographic documentation.

The results of the works were marked on the as-built inventory map of a residential building, along with a cable power line, external water supply and sanitary sewage system, and a septic tank for liquid waste. The document was drawn up in accordance with the applicable symbols, contained in (MRPiT 2021b). The map shows the current distribution of objects in the area that is the subject of the study (Fig. 3). Marking of inventoried objects on the map: building – black bold line, utilities network: water – blue, sewerage – brown, electricity – red, telecommunications – orange.

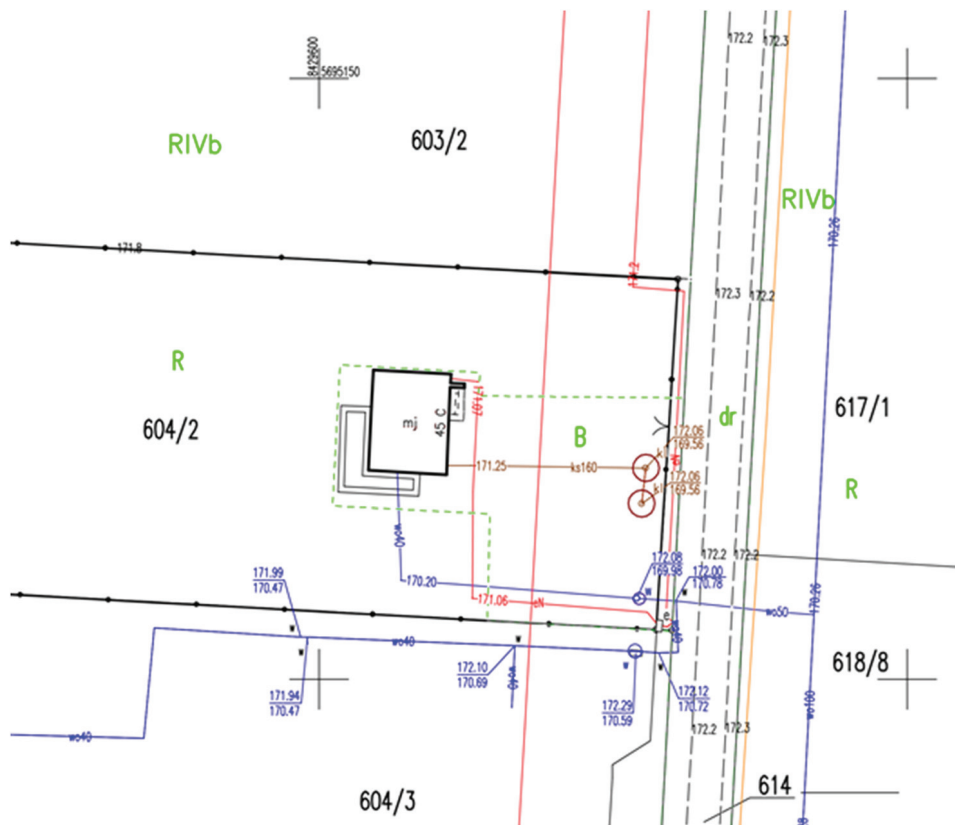


Fig. 3. Map of as-built geodetic inventory.

The map sheet contains information about the compliance of the location of new facilities with the spatial development plan for plot 604/2. The document with the declaration of the contractor of the geodetic works on obtaining a positive result of the verification was handed over to the client.

4. Conclusions

The as-built geodetic inventory is a necessary element to complete the construction investment. At the beginning, the tasks, and the role of a surveyor in various stages of the construction process were described. The contractor must demonstrate knowledge of the currently applicable regulations, industry standards and standards for the performance of geodetic works. The study describes legal acts regulating issues related to the performance of as-built geodetic inventory. Then, the objects subject to inventory measurements and examples of situational and height measurement methods were listed. The

purpose and scope of activities of the surveyor at each stage of the order implementation were presented.

The practical part of the work was the inventory of a single-family building with elements of the utilities network. This paper describes the characteristics of the facility and the location of the property. The body of the building is presented in the form of a self-made visualization. The contracting procedure, divided into preparatory activities, field work, and the compilation of the results, was discussed in detail.

In connection with the implementation of the discussed works, no problems were encountered with the facility itself. The investor informed in advance about the need to carry out a post-completion inventory, thus enabling the measurement of the utilities network in the open excavation. As a result of comparing the location of the measured objects with the plot development plan, no exceptions were found.

The popularization of GNSS measurements using the RTK technique made it the main method used in geodetic handling of investments. The accuracy of RTK measurements may be significantly lower than the geometric or trigonometric levelling, as it does not meet the accuracy criterion (0.02 m). However, in practice, the documentation from the GNSS measurement is accepted in ODGIK, because the survey does not provide information on the method of measuring individual elements.

Spatial databases located in ODGIK are prepared in various height systems. When analysing the materials, it is important to pay attention to the layout of the area in question. In the discussed case, during the preparation of the results of the inventory measurement, the height transformation of the points from the RTK measurement in the Kronsztad'86 system into the Kronsztad'60 system was performed.

The practical part of the work made it possible to get acquainted with the methodological aspects of the profession of a surveyor and the functioning of geodetic and cartographic documentation centres. The final document created because of the work carried out is a map of the geodetic as-built inventory, which was provided to the client. As-built documentation, completed in the form of a technical survey, was included in the state geodetic and cartographic resource after obtaining a positive verification result.

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Tijek postupka procjene izvedbenog stanja izmjere – problemi i izazovi

SAŽETAK. Ovaj članak ima za svrhu prikazati opseg geodetskih radova provedenih na popisu izvedbenih stanja zgrada i komunalne infrastrukture. Teorijski dio ovog rada donosi pravila za pravnu osnovu na teritoriju Poljske, koja su ključni dio geodetskih i kartografskih studija. Povrh toga, razmatraju se faze popisa izvedbenog stanja geodetskih radova s obzirom na važeća pravila. Posebna je pažnja posvećena temi situacijskih i visinskih mjerenja. U radu se razmatraju primijenjene metode mjerenja te su popisane skupine preciznosti i skupine objekata koje su predmet inventarnih mjerenja. Praktični dio ovog rada uzima u obzir izmjeru izvedenog inventara jedne obiteljske kuće. U ovoj studiji razmatramo posljedične postupke koje građevinari moraju slijediti tijekom procesa gradnje, a to uključuje preliminarne radnje, terenski rad i pojedinačnu elaboraciju rezultata. Naknadna dokumentacija prikupljena u obliku tehničkog okvira, nakon dobivanja pozitivnog rezultata testa verifikacije, dostavljena je Glavnom uredu za geodeziju i kartografiju.

Ključne riječi: zgrada, izmjera inventara, izmjera izvedenog stanja, kinematika u stvarnom vremenu.

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