JOURNAL OF APPLIED ENGINEERING SCIENCES
ISSN: 2247-3769 / e-ISSN: 2284-7197
sciendo
VOL. 13(26), ISSUE 1/2023
ART.NO. 360, pp.73-82

PROBLEMS OF AS-BUILT INVENTORIES OF COMMERCIAL SERVICE FACILITIES

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Received: 15.02.2023 / Accepted: 20.02.2023 / Revised: 17.03.2023 / Available online: 31.05.2023

DOI: 10.2478/jaes-2023-0010

KEY WORDS: Building, Inventory Survey, As-Built Survey, Geodesy

ABSTRACT:

Paper concerns problems of as-built geodetic inventory of a commercial-service facility with connections (water, sanitary, rainwater drainage, electricity and telecommunications). The facility has a built-up area of more than 3,700 m2 and is located on two registered lands. The inventory was carried out using a GNSS receiver, tacheometer and leveller, and using methods: indentation, orthogonal and geometric levelling. The paper also compares the inventory of the selected building with that of a single-family house. The main differences include, first and foremost, the timing of the survey, the technique, the equipment used and the labour costs.

1.INTRODUCTION

One of the final stages of the construction process is to proceed with the as-built surveying of the building (Kampczyk 2015). This stage obligatorily requires the measurement of completed construction works. As-built geodetic inventory of construction works should be understood as a set of measurement activities aimed at collecting up-to-date data on the spatial arrangement of the elements of land development covered by the construction project and drawing up geodetic documentation containing the results of these measurements, including a map (Sejm 1994b). Thanks to the as-built inventory, we obtain information about the above-ground, aboveground and underground construction objects, concerning the horizontal and vertical location, allowing us to determine the coordinates and heights in the state spatial reference system (Grochowska 2014). This information will allow changes to be made to the databases of land registers and buildings, land development networks and the database of topographic objects (Jagielski 2020; Son, Bosché, and Kim 2015). In recent years, RTK (Real Time Kinematic) GNSS measurements in inventory surveys have become increasingly popular in favour of total station (tacheometry) surveys (Muszyński and Rybak 2017). Static measurements are also being used to establish survey matrices, under conditions that make it impossible to initialize RTK measurements (Maciuk 2018; Lewicka et al. 2021).

The main purpose of the as-built inventory is to confirm the construction of a building on the ground in accordance with the arrangement of the elements on the plot or land development plan (Grochulska-Salak 2018).

According to the Building Act, the surveyor is obliged to include information on the conformity of the location of the object in accordance with the plot development project based on the measurements carried out (Sejm 1994a).

The result of this conformity assessment is influenced by the measurement of the length, the determination of the point location, the measurement tools used, the measurement method, the scale and the quality of the plot development project map. There are cases where it is difficult to determine discrepancies between the site and the development design, and it has therefore been suggested that an acceptable area range should be plotted in the development area. This extent would take into account the development conditions, the building lines not exceeding/obligatory, the minimum distances to other objects of neighbouring properties and neighbouring buildings (Makinde et al. 2021). This would facilitate future assessment of the location of the site in accordance with the design (Przewięźlikowska and Krzyżek 2016). Objects marked out by a surveyor with appropriate equipment that meets the requirements in terms of obtaining the imposed accuracy by the building or surveying law, during the inventory there are no problems concerning the compliance of the object's location with the design (Kruk 2011). If non-compliance with the building design is found, the district building inspector is obliged to issue a negative decision on the permission to use the building (Kończak 2022).

Inventory measurements require direct contact between the surveyor and the object being measured. The exception is the taking of measurements of underground covered utility conduits. For the majority of cases, these measurements take place after backfilling in an excavation, which makes it impossible to correctly locate the conduit and results in "gross" discrepancies with the design (Kruk 2011).

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The obligation to notify objects for pre-covering measurement is the responsibility of the site manager, or, if there is no manager, of the developer (Dybeł and Kampczyk 2018). The accuracy of the as-built measurements carried out should meet the accuracy requirements for situational and altimetric measurements laid down in the Regulation on the technical standards for carrying out situational and altimetric surveying and for developing and transferring the results of such measurements to the state geodetic and cartographic resource, for objects included in the various groups of situational details (Minister Rozwoju 2020). After the measurements, the surveyor prepares the documentation necessary to update the state resource and the graphical distribution of the buildings in the field in the form of a map. The update also relates to the land use on which the development was created. During the inventory activities, the surveyor determines the extent of the land use according to the land use and on the basis of the decision on exclusion from agricultural production attached to the project. The area of amended use usually differs from the area excluded from agricultural production. This is mainly due to the lack of control of the relevant bodies over the implementation of the investment process (Gałuszka and Paweł 2011). Finally, surveyor completes the documentation of these activities as a technical report and submits it to the documentation centre for amendments to the relevant resource databases.

2. METHODS

The object which is the subject of the analysis of the as-built survey inventory documentation is a commercial and service building with the following connections: water, rainwater and sanitary sewage system, electricity, the construction of which was completed in 2019. The building is located on two plots of land located within Miechów in the Miechów-city cadastral unit. Due to its construction, it consists of two one-storey non-terraced buildings, with a total built-up area of 3702 m^2 (Figure 1).



Figure 1. Current status of the site under study

These are commercial and retail buildings, and it is interesting to note that due to its location, it is situated on two parcels of land classified as other built-up areas, designated respectively by land use symbol *Bi*, which means “other built-up areas” (Attachment 1). It can be categorised as one of the building structures with the largest built-up area located in the area. Due to the specific nature of the type of buildings (size, scale of the project, etc.) put into operation, the vast majority of them are single-family houses, and at most a few percent of the projects are larger buildings (hereinafter referred to as surface buildings). The main difference between the construction process of a single-family house and a superficial building is the duration of construction and thus the time required for surveying, which is related to the surface area of the building and the duration of the individual construction stages. The difference can be seen in the length of the connections: in the case of an area building, the connections are characterised by long stretches of mains with different diameters and parameters, which are connected to each other and a large number of connections to the building, whereas in the case of a single-family dwelling, the connections are relatively shorter and usually connect the building to the mains at a single point of connection. For single-family dwellings, it is very rare to measure connections in the trench than for surface buildings. The greater number of corners and recesses of the building results in the use of appropriate object measurement methods to correctly reflect the building contour. When analysing compliance with the plot or land development plan, the measurement of a commercial and service building is better than that of a residential building, because when constructing larger surface structures, the surveyor is more likely to be involved in the project process and verify progress on an ongoing basis, whereas when constructing a single-family house, the surveyor's duties start with the delineation of the building in the field and later end with the inventory measurement.

3. RESULTS

The first stage of work after receiving the data from the surveying centre is to analyse it for completeness and suitability. At a further stage, an appropriate measurement method is selected for each element to be inventoried. In the object under analysis, the following items were inventoried (Table 1):

No.	Element	Measurement method
1	Building	GNSS, linear section
2	Water and sewer connection	GNSS, levelling, geometrical levelling
3	Electricity connection	GNSS, direct measurement
4	Telecommunications connection	GNSS, direct measurement
5	Landscaping, e.g., pavement	GNSS, direct measurement

Table 1. Elements inventoried and the method of measurement used

The GNSS technique can be used not only in as-build inventory but also in a in a very large variety of research fields from geodesy (Nistor, Suba, and Buda 2020; Nistor and Buda 2016) or atmospheric science (Sorin Nistor, Suba, and Buda 2020a; S. Nistor and Buda 2015).



Attachment 1. Cadastral map of the site under consideration

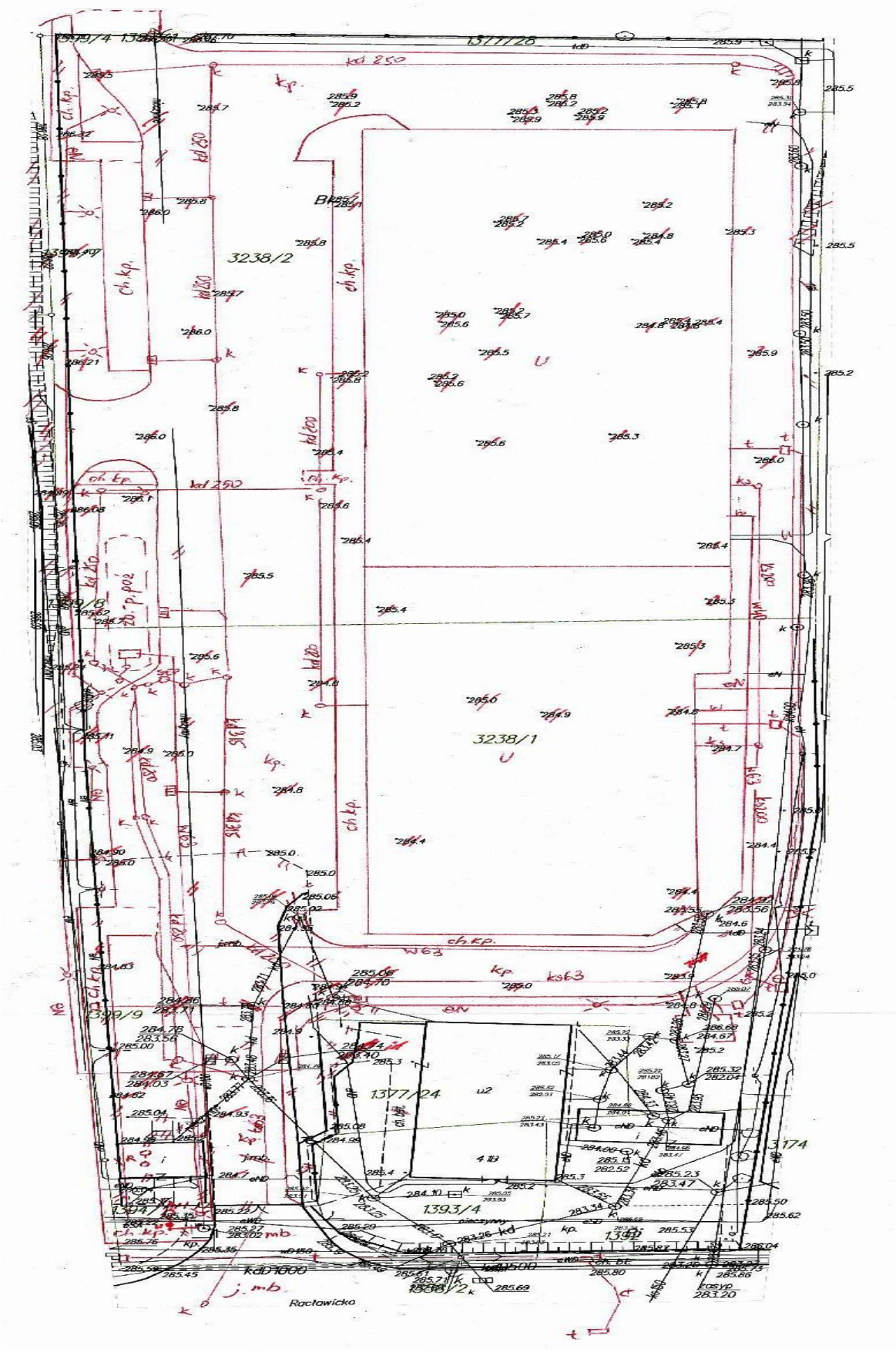
The selected site was measured using the GNSS observation positioning method with a GPS receiver based on the ASG-EUPOS network and a laser rangefinder. Before starting the measurements, a check of the GPS receiver was performed by measuring two points of the geodetic warp with averaging of 30 epochs. The result of the check was positive, with acceptable measurement deviations for the grid points (dx, dy < 0.12 m and dh < 0.09 m), so the work continued (Minister Rozwoju 2020). The measurement of the building was carried out on the basis of the linear indentation method, using a GPS receiver at a suitable distance from the measured object two base points were measured for 30 epochs. Then, by measuring the horizontal distance from the base points to the corner of the building using a laser rangefinder, the geodetic coordinates were determined in the PL-ETRF2000 system in zone 7. This method allows the coordinates of the building corner points to be obtained quickly and easily. The prerequisite for carrying out these measurements is good satellite visibility by the GPS receiver. The location of the building allowed these measurements to be carried out, as neighbouring objects do not interfere with the measurement. The electricity, water sewer and telecommunications connections were also measured using GPS measurements in excavated trenches, while a 4 m pole was used for the measurements. The results from the situational measurements of

the building and the connections were obtained with an accuracy of 0.01 m. The cross-section of the connections did not exceed 0.50 m, so the axis of the pipe or canal was measured. The heights of the rainwater and sanitary sewer technical facilities were determined using the geometric levelling method with reference to the geodetic control points, creating a levelling string. Measurements were taken of the top and bottom of manholes including inlets and outlets. A Leica Sprinter leveller was used for these measurements together with a levelling batten. The results were recorded appropriately in the levelling log with an accuracy of 0.001 m as well as a survey sketch was completed on an ongoing basis. The connections to the building were measured using the classic orthogonal method with a laser rangefinder. The measuring lines formed the corners of the object to be measured, and at the same time a control measurement was carried out on the heads. This was followed by the measurement of all types of pavements, pavements, car parks, and the general technical infrastructure that allows communication and free use of the property. The first document the surveyor prepares after the fieldwork is the GNSS measurement report obtained from the controller, together with a text file with the coordinates. This shows an excerpt from the report containing the results of the measurement made, together with the measurement corrections received. Due to the type of measurements carried out, another log which forms part of the report is the levelling log, which concerned the measurement of sanitary and stormwater drainage connections. This document in paper form was drawn up during the measurement. Once the measurement logs had been compiled, a list of the coordinates of the measured and calculated points proceeded. This list was prepared by means of a table containing the following data: numbers of pickets X and Y coordinates in the 2000 system in zone 7 and height in the PL-KRON86-NH system of the measured situational details with an accuracy of 0.01 m.

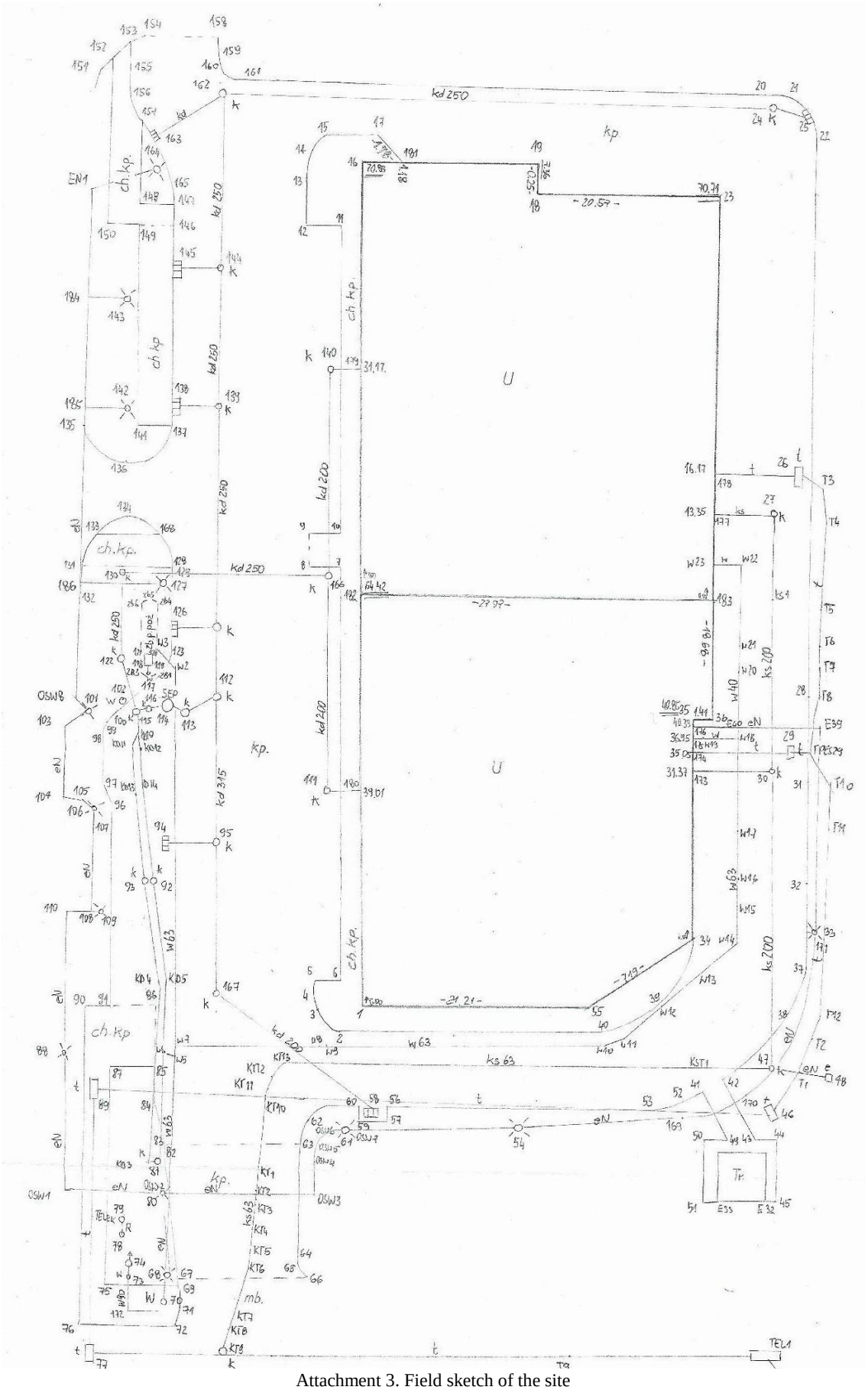
The documents produced on the ground or during the survey are the field survey map and the field sketches. On the basis of these, the survey supervisor maps the building including the connections and the technical infrastructure with the help of a suitable graphics programme. In this case, the surveyor used the EWMAPA geodetic programme. The map of the field survey was prepared on a fragment of a basic map on a scale of 1:500 (Attachment 2).

All field changes have been marked in red. In addition, it contains the title, the stamps of the surveyor and the survey manager, the north arrow, the section number and the date of the interview. Two field sketches were produced for the surveys carried out (Attachment 3) is illustrated by a field sketch created during the survey with a GPS receiver. In addition, a field sketch was made of the inventory of the sanitary and rainwater drainage network (Attachment 4). These documents include: the location of the objects in the field to be measured with the correspondingly assigned pickets, the course of the connections with a description of the type and diameter of the pipe, the control measurements on the building, the measurements obtained from the orthogonal method, the north arrow, the designation of the evidential unit, the precinct and the number of the evidential plot, the designation of the contractor and the person drawing up the sketch, the date of the measurement. The field sketch for the measurement of the sanitary and rainwater drainage system lacks the points of the grid with the direction of measurement used for the work.

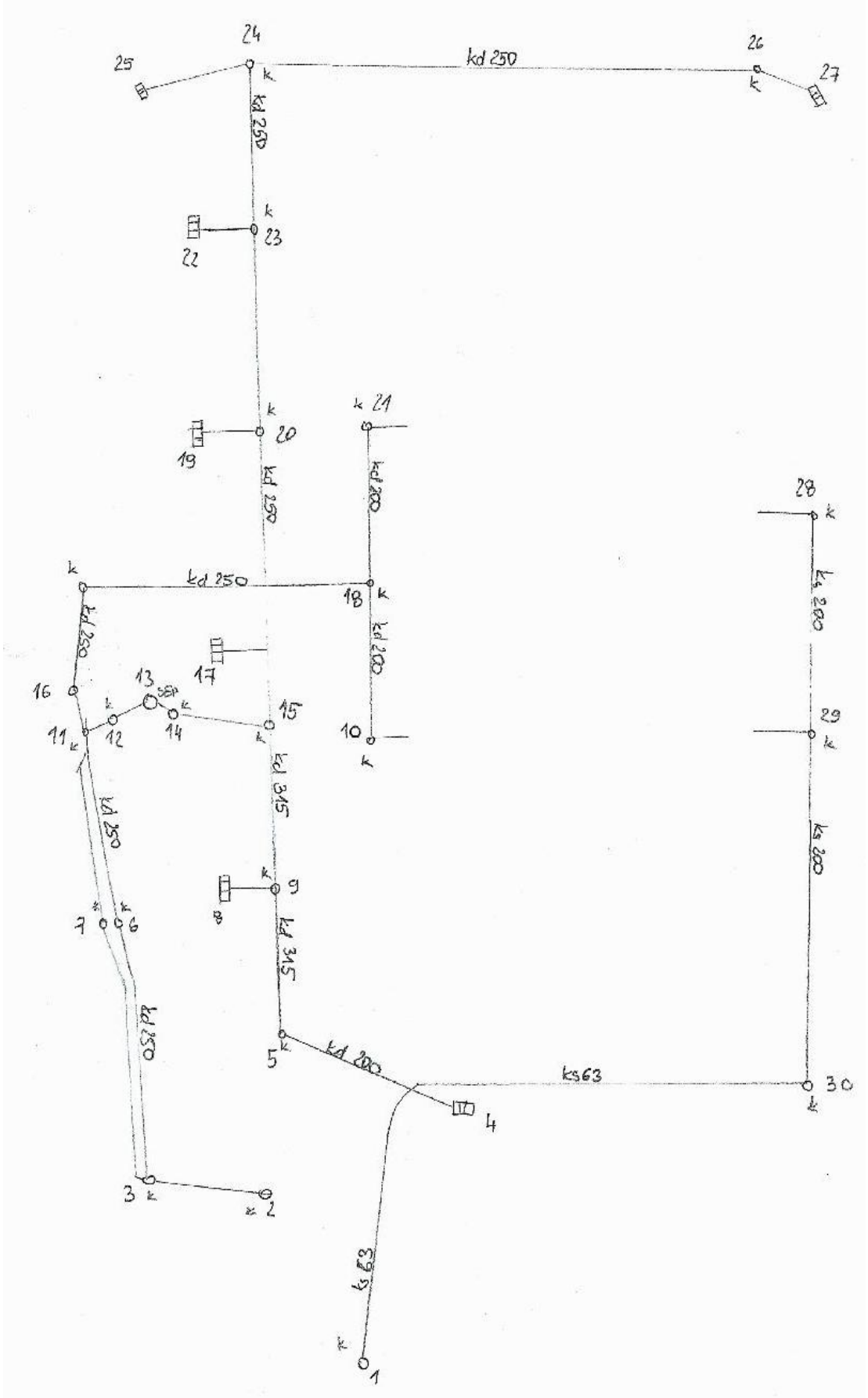
In the course of carrying out the as-built surveying work, the surveyor prepares documents necessary for updating the land and building register. This update consists in separating the land, which is necessary for the use of the facilities located on the plot and providing the registration data of the newly constructed buildings. At this stage of the work, the area of the newly constructed land use is counted and the remaining land use on the plot is accounted for, as well as the built-up area of the constructed building. The calculations were carried out on the basis of the coordinates of the points obtained by measurement in the WinKalk surveying software. In order to transfer the new EGiB data obtained to the resource, so-called lists of changes to the registration data are prepared. These documents introduce changes to the land and building register. In the example given, only the building was subject to updating, as on the plots in the land and building register the use was marked as other built-up areas (Bi), so there was no obligation to make changes. The first document used to update the EGiB of a new site is the list of changes to the registration data. The list contains data on the existing and new status. Information is entered on the identifier of the evidential unit, precinct, plot, building, building type according to the NACE, building class according to the PKOB, main function of the building, date of construction completion, and number of underground and overground storeys of the building, material of external walls, field of construction and usable area of the object. These attributes are determined on the basis of the measurement taken and the information contained in the construction project. In addition, a list of data changes in terms of the numerical description of the building contour is prepared, which includes information on the rectangular X,Y coordinates of the corners of the building object, as well as the designation of the plot of land on which the building is located and the building identifier. Once the above documentation is completed, the surveyor prepares a technical report, in which he describes the course of the work performed and the survey equipment used, which local geodetic documentation centre materials were used in the execution of the work, provides information on the date of commencement and completion of the work, the designation of the contractor and the work manager, the ID of the notified surveying work.
The final stage in the development of the as-built geodetic inventory is the preparation of the as-built inventory map (Attachment 5).The map was prepared on a copy of the principal map updated by measurement at a scale of 1:500. The map features a graphic visualisation of the building object, including connections to water, rainwater and sanitary sewers, electricity and the telecommunications network. In addition, information is provided on the name and identifier of the registration unit, precinct and parcel, map scale, description of the sectional division with a description of the cross grid, date of preparation of the map, contractor /manager of the surveying work with his/her authorisation number. The surveyor shall include on the map information on the conformity of the construction of the building with the plot or land development project. The assessment of the conformity of the location of the built structure with the layout on the development plan is influenced by the error in the location of the boundary points, the error in the measurement and the quality of the materials that the surveyor has in his possession to verify the location. The map prepared and classified in this way by the geodetic documentation centre is handed over to the investor in order to notify the completed construction works and obtain a decision on commissioning of the construction object with the connection.



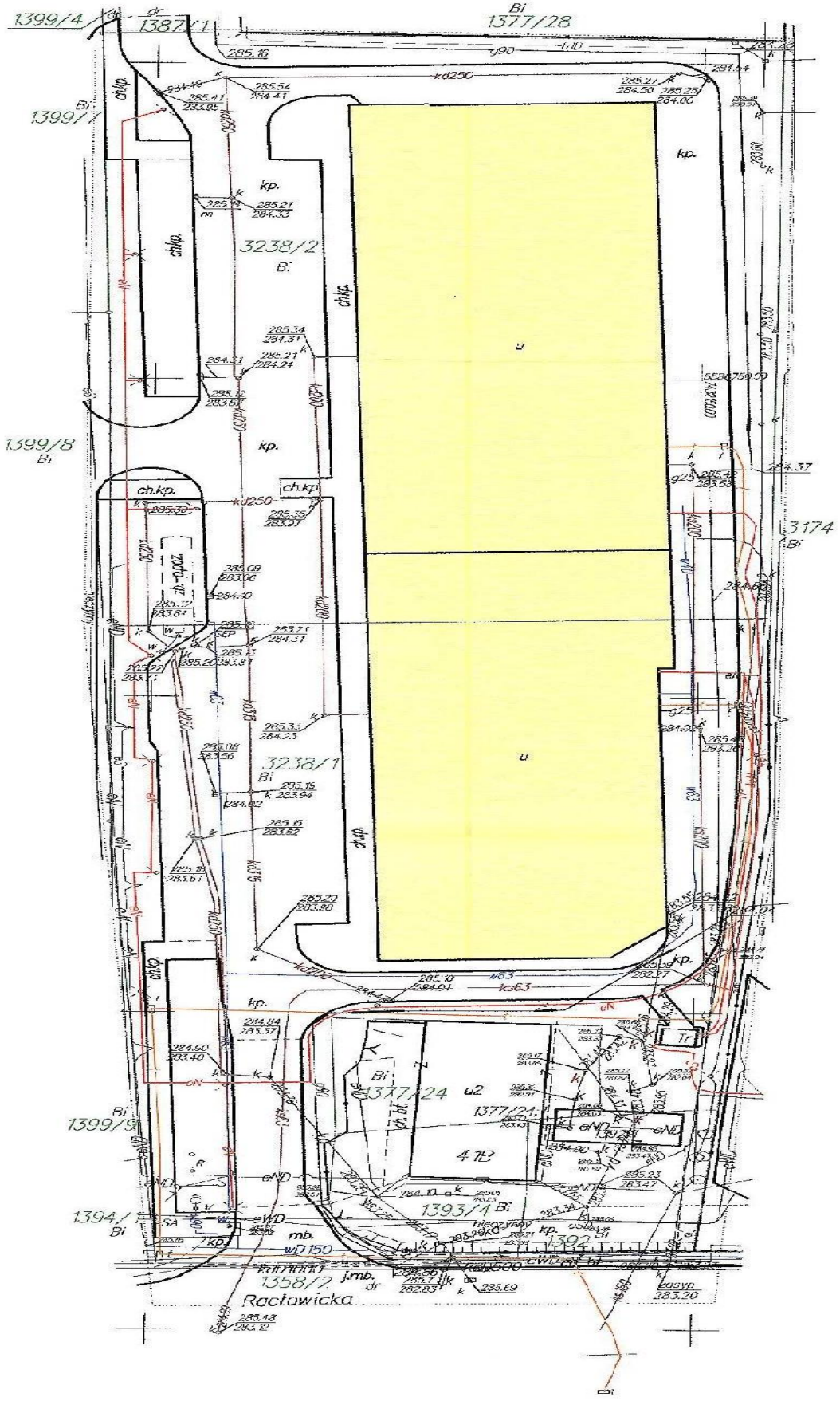
Attachment 2. Basic map from field interview conducted



Attachment 3. Field sketch of the site



Attachment 4. Field sketch of the levelling of the facility's sewage network



Attachment 5. Graphical part of the as-built inventory map

4. SUMMARY AND RESULTS

When carrying out the as-built surveying of a building, there are certain aspects that can be seen to influence the performance of such measurements. Important factors, for the surveyor in this type of task, are the time taken to complete the survey, the survey method, the equipment used and the labour costs. The selected building was characterised by a large building footprint, which made it stand out among other inventory measurements carried out. Despite its volume, it did not require the use of more complicated measurement methods to faithfully reflect the shape of the building in the field. Due to its location, a GPS receiver was used for the measurements, which significantly sped up the measurement time of the building. Compared to single-family houses, GPS receivers are also used to determine the rectangular coordinates of the building corners, whereas in most cases a total station was used. It is much faster to carry out measurements for residential buildings with smaller building areas than for surface buildings. This is primarily due to the area occupied by the constructed building and the number of connections made. In the case of the commercial building in question, measurements were taken for five types of connections (water supply, sanitary and rainwater drainage, telecommunications and electricity), whose total length was approximately 1,400 m, while in the case of the measurement for a single-family house, the number of connections is four (water supply, local sewage, electricity and gas) with a total length of 110 m. Another difference between the surface object inventory and the single-family house inventory is the way in which the connections are measured. In the case of the first inventory, the measurements of connections are carried out in an excavation, whereas in the case of residential buildings, the measurement is usually carried out after the line has been backfilled. The timing of the measurement is also determined by the number of pickets measured. In the case of a surface object measurement, this number is 339 pickets, while for a single-family house it is 95 pickets. The choice of measurement technique is linked to the shape of the building, the more complex the structure, the more measurement methods used and the longer the surveyor's time in the field. Another important issue is the equipment with which he/she will obtain the appropriate measurement accuracy. When surveying a commercial building, the surveyor used several pieces of surveying equipment, including

The surveyor used several pieces of surveying equipment, including a GPS receiver, a leveller, a pole, levelling staff, a tripod, etc. This set-up illustrates that the surveys were carried out in teams of several people, which has an impact on the costs generated, comparing this to the inventory of a single-family house the number of people involved in these activities is considerably less and amounts to a maximum of two people. The costs incurred by the surveyor for the as-built inventory can include the number of field trips to carry out the measurement. The costs are considerably less in the case of smaller developments, e.g., a single-family house, than in the case of a selected surface building, the construction of which is spread over time and each stage requires an inventory measurement. With both inventories, the method of measurement and the equipment used must be well matched to the type of building, so that the measurement time does not take too long and thus generate unnecessary labour costs.

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