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# Stocktaking methods of facilities in a state of ruin

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**Abstract:** The stocktaking is the basic form of presenting and protecting the object of the historic ruin. It also allows to monitor the behavior state and the degradation progress of an object. Objects in ruin are very specific because they usually do not have elements typical for an existing building. This means that in the case of ruins, methods of stocktaking taken in the same way as in the case of traditional facilities will be insufficient. Elements of objects in ruin often have complicated and diverse geometry, difficult and not completely secure access to all elements. The article presents methods that can be helpful in the stocktaking of such objects. Each method describes the necessary equipment and instruments, the method of taking measurements, accuracy, advantages, and limitations. The paper also presents examples of application for selected methods.

**Keywords:** stocktaking, ruin, monument, photography, 3D scanning, photogrammetry.

## 1. Introduction

The measuring-drawing stocktaking is the most popular, and at the same time the basic form of documentation of monuments.In the case of absence of precise data about the objects in ruin, it is necessary to create their exact stocktaking. Performing measuring documentation precedes activities that involve protection, research, and works on the site. The stocktaking systematically performed also allows to monitor the state of preservation and the extent of the ruin damage.

The stocktaking consists mainly in preparing measuring drawings and describing the current state of the object. It begins with an accurate vision in the field. Only later the stocktaking measurements can be performed. The study must be prepared in an accurate manner, it should take into account all visible deformations, transformations, scratches, cracks, and sometimes transformations of the object over the years and visible details. Its task is to accurately reproduce the actual spatial layout and determination of the technical and functional structure of the ruin.

The stocktaking consists of the following parts:
- situational plan,
- horizontal cross-sections – projections of all floors,
- vertical cross-sections with elevation views,
- detailed drawing documentation of historical details,
- photographic documentation,
- graphic damage documentation,

– technical description containing basic information about the facility,
– description of materials from which individual building elements were made.

At present, despite the huge number of standards (about 40 standards) and regulations (about 5 legal acts) that regulate technical drawing documentation, a lack of a single, detailed standard of the stocktaking is noticeable. Completely different than in the case of the project documentation, architectural and conservation studies, or conservation inspections – the measuring-drawing stocktaking is not included in the quality control. This situation means that the documentation prepared may be incomplete or may have many shortcomings and measurement deficiencies.

## 2. The stocktaking methods

The accuracy of the stocktaking measurements and the way they are presented depends on the purpose of which the later stocktaking should serve. Depending on the required accuracy, it is possible to choose a measuring variant from several different methods.

The equipment used during the stocktaking makes it possible to obtain measurements of different accuracy. The smallest accuracy in units of measurement has photographic documentation. This is due to the scattered scale of different parts of the image caused by the perspective. The photogrammetry is an alternative to the photographic documentation. The most traditional measurement method is a manual measurement supplemented sometimes with geodetic methods (in the case of complex geometry of objects). The use of manual measurement does not require any special skills or expensive equipment.

The most accurate but also the most expensive method is undoubtedly the 3D laser scanning. The laser scanning requires vast knowledge and skills of both the scanner operator and the person working later with the generated cloud of points.

Methods supplementing the stocktaking will include photographs taken bydrones and spherical cameras. With the help of a drone, it is possible to take pictures of building fragments that are not available without the use of specialized equipment, e.g., roofs, chimneys.

### 2.1. Traditional measuring techniques

The basic method of performing the stocktaking is the traditional manual measurement. This is the oldest, easiest and most time sufficient way of performing measurements for most of the ruins. The accuracy scale is significant for creating the object documentation. For making traditional measurements, tapes, scoops, and laser rangefinders are used. The information obtained should be converted into the drawing documentation by using traditional and computer methods.

As already mentioned, the stocktaking begins with a field vision, then a measuring sketch is prepared. To create horizontal projections, measurements are taken from all the walls of the rooms and their elements, including details. Measurements should be performed at one height. To avoid measurement errors, the so-called „string record" should be used, that is, successively read dimensions from the characteristic points on the wall. It should be remembered that the long walls should be measured twice and the floor level relative to the reference point adopted for the given object or its fragment should be given. The thickness of the walls should be measured in places where the full dimension can be obtained directly or it can be made in sections [15].In rooms of irregular shape, diagonals should be measured. This allows you to specify a more accurate room geometry.

When performing measurements of the horizontal projections, dimensions are given in the light of all openings and recesses, the height of window sills, and vaults. Door and window openings should be measured both in the light of the opening and the frame. In the direct stocktaking method, it is extremely important to coordinate the projections of all stories with the use of communication divisions and openings. Dimensions should be given only if they have been measured directly and they do not result from calculations.

The facade measurements should be made at the very end, based on projections and designated height of characteristic points. When making the stocktaking drawings of the façade, particular attention should be paid to all kinds of damage, losses, cracks, and secondary materials. It is important to precisely determine their occurrence and describe it accordingly. Both rooms and spaces that are not available for measurement should be marked and described in the drawings, and for elements located at significant heights, the way in which they were drawn is additionally given.

The result of the stocktaking made using the traditional method is the stocktaking note, created during the stay at the facility. It consists of drawings made during measurements together with the dimensions and details drawn. On the basis of the stocktaking note, appropriate documentation of the object is created later.

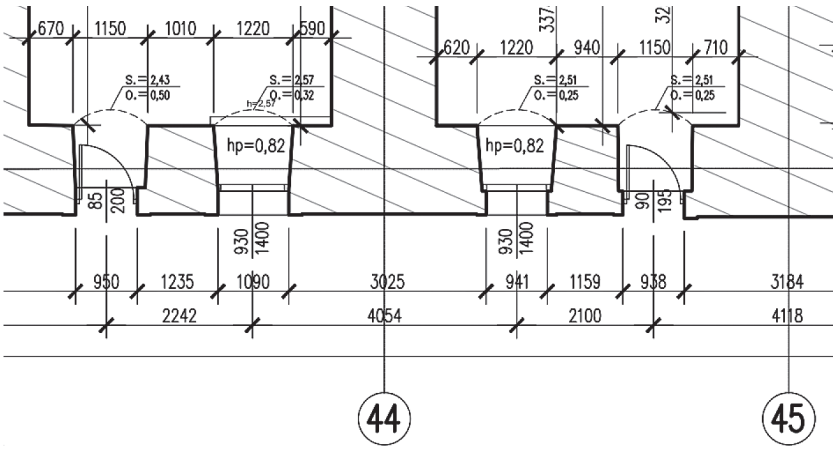


Fig. 1. Fragment of the final stocktaking of the Kłodzko Donjon Fortress – a horizontal cross-section of the "0" storey – the stocktaking made using a computer drawing software.

Photo 1. Traditional measurements of the elevation of the Kłodzko Donjon Fortress


Fig. 2. View of the elevation of the Kłodzko Fortress made after traditional measurements

The traditional method is extremely time-consuming and requires a lot of work, and also does not always give the opportunity to accurately measure all items due to their unavailability. Measurements performed in a manual manner do not give the possibility to map the projection geometry, therefore this method is recommended only for simple objects. There is also a high risk of measuring error by the measuring person. The advantage of the traditional measurement method is the possibility of making a detailed analysis of the structure.

### 2.2. Geodetic method

The geodetic methods are mainly used to measure the geometry of objects and research on deformations and deflections of the object. In the case of the objects stocktaking, this method is time-consuming, therefore, it is recommended to use the geodetic method only to measure complex geometry, difficult access or significant height of objects.

In the case of the technical condition assessment, the geodetic method is used to investigate all kinds of deformations and displacements of elements in the facility. Using the geodetic equipment with very high accuracy, deviations from the vertical or subsidence of building fragments can be estimated. Currently, it is the most commonly used the displacement survey method. An alternative to this method may be the 3D scanning described in the 2.3 paragraph.

Two geodetic methods can be distinguished to assist in the stocktaking. One of them uses a leveler for this purpose, the other uses a tachymeter. The leveler is a geodetic instrument that allows measuring the height difference between terrain ordinates.

Among the tachymeters, instruments without the use of a mirror are often used for measuring distances. Thanks to them it is possible to determine the geometry of the object and to measure the photogrammetric matrix. Therefore, the reflectorless tachymeter can be used to create an architectural stocktaking.

The object stocktaking using a tachymeter is based on measuring angles and distances. The measurement of the length of the section is possible thanks to the precise laser rangefinder, which is built into the device. The distance is determined from the coordinate increments that are between the measuring instrument and the measured point. The tachymeter has the capability to measure selected points, which define the characteristic places on the site.

The tachymeter combined with the appropriate software can significantly speed up the work and, above all, ensure high accuracy of measurements. Measurements taken with a tachymeter will work to create projections, cross-sections, and simple elevations. It is also possible to create a full stocktaking using this instrument, however, a huge downside of this method is the large amount of time which is needed to spend on the site. In this case, the documentation is created on an ongoing basis, it is also possible to correct any errors on an ongoing basis. Before starting work, the cutting planes should be precisely determined. The result of this are drawings created in computer drawing software, directly on the spot.

The advantage of this method is its precision. Using the tachymeter, in contrast to the traditional method, it is possible to make accurate measurements of large objects. Depending on the model of the reflectorless tachymeter, the range of the instrument is up to 2000 m, and the accuracy, depending on the distance, is approximately 2 to 5 mm. The accuracy of the measurements may vary depending on the material from which the beam will be reflected. With smooth materials (e.g., marble) and with a small angle of incidence of the laser beam, the measurement results can significantly differ from the actual state [8].

The tachymetric method itself is time-consuming, so it would be good to combine two methods, both geodetic and manual measurements. Thanks to the tachymeter, it is possible

to obtain wall geometry, while measuring with a ruler or a rangefinder it is possible to place more accurate elements. By combining these two methods, it is possible to accurately replicate the actual appearance of the ruin.

### 2.3. 3D scanning

The laser scanning, from a technical point of view, is one of the most accurate ways to perform the stocktaking measurements. It is made using a laser scanner. It is used mainly for large, complex objects with a special historical value.

Information obtained in digital form during scanning can be stored on external hard drives. Due to the very high resolution and accuracy of scanning, the cloud of points created is a faithful representation of the real state. The information archived in this way can be used later in other, more detailed works than the general stocktaking. The scan made is at the beginning a collection of points needed to create a model and flat figures. It can be used, e.g., during conservation works related to an architectural detail or a detailed assessment of the technical condition of wall damage.

Photo 2. The Leica ScanStation C10 while taking measurements

The principle of operation of the scanning device is based on measuring the distance of the object from the device. The scanner, thanks to the presence of a special optical system, sends laser beams that are reflected from an obstacle. When returning to the photodiode, information about the reflection time are transmitted, which makes it possible to determine the distance of the point from the device. On this basis, it is possible to write the XYZ coordinates for each point, which, when collected together, creates a spatial collection called as the „cloud of points". Such cloud of points is a digital representation of the object covered by the stocktaking. After proper data processing, it is possible to create a 3D model of the object scanned [5].

Measurement of many points and their mutual spatial relations is possible thanks to the scanner's rotation around the axis directed perpendicular to the base plane and simultaneous rotation of the head around the parallel axis.

Additional information provided by the laser is the intensity of the light reflection, which allows for differentiation of elements and surfaces in the object measured. Very helpful

when developing the cloud of points, is the ability to take photos by scanning devices. Photo processing processors and the XYZ coordinates assign the RGB (color) values to the points to give the cloud a realistic texture. In fact, the image that is created from the cloud of points becomes an active and three-dimensional model mapped in a 1:1 scale.

Fig. 3. The cloud of points, which was created as a result of the preparation of spatial data obtained from the Leica C10 scanner – the Janowiec castle

The laser scanners provide the opportunity to obtain much more data in a much smaller time interval than measurements performed in traditional ways. The stocktaking made with the use of the 3D scanning allows to create a detailed study, which is of great importance when working on objects in ruin.

The large laser range, depending on the model, enables efficient measurement of large-scale objects. This is a significant asset when making the stocktaking of large assumptions or hard-to-reach due to their location and building area. The density of points acquired facilitates detailed mapping of the wall structure and the geometry of spatial elements. Creation of the cloud of points for the entire facility is possible thanks to combining individual sets with defined field targets or common points determined during processing with dedicated computer software.

The same problem applies to the aforementioned stocktaking methods, the information obtained from laser scanning has to be prepared and presented in the form of technical drawings. However, the probability of making a mistake when mapping geometry or the thickness of building partitions is extremely small.

The main advantage of using the laser scanners is the ratio of working time to accuracy achieved of the mapping of important object parameters. The scanner is so accurate device that it is able to catch anomalies that are not observable with the naked eye. Thanks to this, it is possible to make many useful analyzes and capture places where damage and deformation occur. It is worth remembering, however, that the laser beam is not always able to reach any place and can be reflected from an accidental element.

Due to the accuracy of the 3D scanner, this method is very useful in the process of documenting an object in ruin. The information that can be received through scanning gives the opportunity to use it for various purposes, including design. The ability of changes monitoring

is valuable in the case of objects in ruin, which is why it is important to perform a scan in the largest possible concentration of the cloud of points.

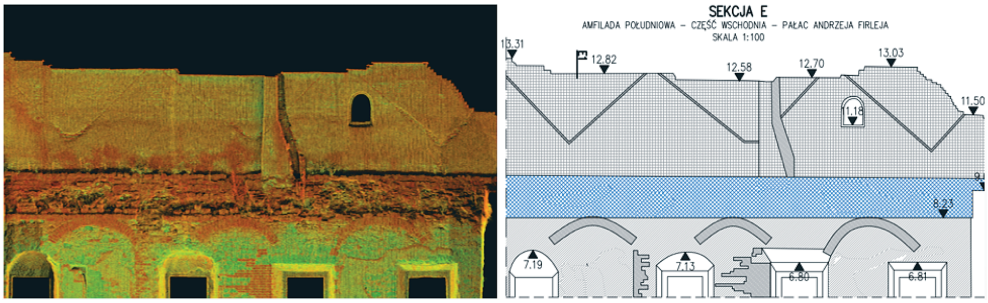


Fig. 3A. View of the facade of the Janowiec castle developed on the basis of a 3D scan

## 2.4. Photographic documentation (traditional, spherical, using a drone)

The photographic documentation is an indispensable element for conducting a detailed analysis of the facility and complementary material for the drawing documentation.

The pictures should be taken in the best possible resolution and quality. The photographic documentation should also be made using the photogrammetric stocktaking, as a supplement to the measurement information.

Photographic documentation should consist of:

– a list of photos,
– a list of pictures numbered and described in detail,
– a graphic presentation of the plan of photographic positions.

The photo catalog should include photographs made in such a way as to show the general characteristics of the shape, its location in space, all elevations and details. The order of photos should ensure easy orientation in the facility and allow quick location of the photo in the documentation [16].

There are three basic photo sets:

I – photographs showing the object with the surroundings; including full frames, without cutting the object, showing the context, general characteristics of the solid, its embedding in space, full facades,
II – photographs showing certain elements of the object, i.e., the entire window or door element
III – photographs showing close-ups related to the detail, i.e., cracks, discolorations, damage, etc.

Depending on the devices used, the photographic stocktaking can be divided into: traditional photography, spherical photography, and drone photography.

### 2.4.1. Traditional photography

The traditional photography is made using various types of cameras. The equipment used for taking pictures is selected depending on the user's skills and preferences.

The photographic documentation should present the whole object and its parts, details, characteristic elements, elevations, and elements of architectural decor. Photographs should be taken from characteristic viewpoints to enable the display of the whole object or its fragments.

Photos of the façade, characteristic elements, openings, materials, and wall damage should be made in a similar way to the orthogonal one, in order to avoid distortions of the object. Photographs of details should be made with a clear comparative scale.

### 2.4.2. Spherical photography

It is a modern type of photography. With a view range of 360º horizontally and 180º vertically, it allows to rotate around own axis and document the image down and straight up. It gives the effect of free looking around. In contrast to traditional static photography, which only shows a slice of reality, the spherical photography is not limited by the so-called frame.

The spherical photography is performed using a wide-screen camera, 360º camera, or individual photos can be combined by using computer software. Photographs should be made in such a way as to have control points allowing for the connection of frames. Therefore, it is necessary that each successive overlap in about 20–40%.

Photographs taken by the 360º camera and viewed without using the appropriate software creates a flat image (see Photo 3). The effect of free browsing is possible only with the use of computer software. Photographs are created in a good resolution, which allows for close-ups. By zooming in, the image becomes flat.

The spherical photography is an ideal complementary stocktaking material that also allows to create a virtual walk around the object.

Photo 3. Photograph taken from the 360º camera, flat image view.

### 2.4.3. Photography taken by drone

Unmanned aerial vehicles, i.e., the drones, are remotely controlled by the operator, although there are also models that move completely autonomously. Undoubtedly, they have enormous potential, because they enable to perform many works that are unattainable using traditional methods.

This technology, in the stocktaking of objects in ruin, allows to reach places that are impossible to photograph using traditional photographic documentation methods. Drones allow the whole body to be covered form the top and they are thus helpful in determining the exact shape of the ruin.

Photo 4. A photo of a wall crown made with the help of a drone.

## 2.5. Photogrammetry

The photogrammetry, like traditional photography, consists in taking pictures with the difference that in the pictures presented there are no geometry disturbances caused by the perspective. Thanks to photogrammetry, it is possible to cover difficult-to-access elements with measurements, because image registration takes place without physical contact with the building [1].

The photogrammetry is a technique for making measurements, recreating shapes, sizes and mutual relations between the location of objects in a given area on the basis of photogrammetric photographs called as the photograms. The image recorded using the photogrammetric method reflects much more information than traditional measurements would have. Therefore, this information is an extremely valuable archival material, especially in the case of objects in ruins [20].

To create a photogrammetric study, the object should be photographed from at least two points. This allows for a mathematical reproduction of the position and orientation of each of these photographs in space, and it is also possible to see the image of the object spatially. In connection with the geodetic determination of coordinates of points reproduced in photographs, it is possible to place the received three-dimensional images in space.

The photogrammetry is an accurate technique for making the stocktaking of objects. If the camera is placed at a distance of 20 m from the object, the measurement accuracy will be 1 cm [19]. The measurements accuracy can be increased by putting the camera closer to the object being tested. The effects of the photogrammetric analysis are vector drawings. This method is extremely helpful in the technical documentation of the façade and the external outline of the building. Photogrammetry allows for precise capture of surfaces decorated with details, which makes it useful in the case of historic buildings.

Facade views made on the basis of this method can serve as a basis for creating chronological stratification at further stages of research, while in the case of restoration and conservation works, they can be used in the stocktaking of damages.

Basically, converting a photogrammetry technique into stocktaking drawings is very time-consuming. The pictures should be drawn each time. The stocktaking created in the

photogrammetry method can also function as plans, because their execution is consistent with the scale of the object.

## 3. Summary

Objects in the state of ruin are quite specific when it comes to the stocktaking. Due to a number of limitations such as: difficult and dangerous access, material diversification, geometric diversity, and specific architectural detail, when developing such documentation, it is necessary to use different methods.

The choice of method depends primarily on the purpose of which the inventory is to be used, but also the availability of specialized equipment and economic conditions (some of the above-mentioned methods are expensive). Methods with traditional manual measurements are by far the most commonly used. Technological progress, however, is increasingly displacing such methods and techniques at the expense of digital methods. More and more often, a specialized 3D scanning is used. Scanning offers great detail, allows to make drawings in a much simpler and faster way. Using the appropriate software, it is possible to generate 3D model from the cloud of points. Such models are currently widely used not only in digital processing, but also in 3D printing.

Geodetic, photographic and photogrammetric methods can be used as complementary methods.

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