

BIM TECHNOLOGY IN THE PRESERVATION OF HISTORICAL CITY BUILDINGS

Abstract

The article presents new possibilities, which BIM software offers for conservation design, and discusses application of the ArchiCAD software in various preservation related tasks. The use of the Flexijet measurement system in surveys, coupled with the ArchiCAD software, has also been described. Owing to the excellent accuracy of measurements and appropriate software executing surveys, the method makes it possible to obtain a direct rendering of elements of heritage buildings (BIM models). This results in a more accurate assessment of the actual condition of the building and the preservation tasks to be undertaken. Another aspect discussed in the article is the possibility to present and manage subsequent stages of a preservation project. The software allows, in one file, to work on a survey record, various modernization stages (demolitions or additions of new elements) and a final model. The entire process, from a survey to a preservation project, can be based on a parametric BIM model of a building. In addition to a 3D model and standard projections, the BIM model also includes data on the materials, their origin, etc. BIM type computer aided design software has become a sophisticated tool facilitating architectural design and preservation works which may result in better preservation of historical objects within cities.

Keywords: BIM, ArchiCAD, FlexiJet, surveys, virtual model

1. Introduction

The application of BIM (Building Information Modeling) technology based software in preservation of historical buildings has to be considered by firstly analyzing the very software that is used for the computer-aided design in architecture.

Methods for recording engineering objects plans were evolving in parallel with the improvement of tools used for this purpose and carriers of these representations. In architecture, two methods are traditionally used – the sketch and the perspective drawing, and Monge’s projections – plans, elevations and sections. In the past, drawings were produced by hand, nowadays, they are made with the use of the widely understood digital methods. Knowing their potential directly influences the way and the quality of the architectural design.

2. CAD and BIM software

Design of architectural objects is currently based on work with virtual objects and not on the creation of two-dimensional technical drawings. In order for a graphical program to render relevant flat drawings, one has to simply apply a proper method for the creation of projections to three dimensional models. The software itself will create plans, elevations, sections, perspectives and axonometric views, in accordance with the rules of descriptive geometry [4].

In computer-aided architectural design, three main methods for the definition of the form are distinguished:

- digital form definition,
- computerized form finding,
- computational form generation [17].

The considerations presented herein analyze exclusively questions related to the digital form definition method with the use of CAD type (Computer Aided Design) software.

Literature references dedicated to CAD are numerous. They describe how one operates the software to make designs from technical drawing through virtual space modeling to its visualization.

Information on how to work with CAD programs can be found in many textbooks dedicated to this subject, for example: *AutoCAD 2012 i 2012 PL. Ćwiczenia praktyczne* by Mirosław Babiuch [3], *AutoCAD 2013 PL. Pierwsze kroki* by Andrzej Pikoń [26] as well as *Engineering Graphics with AutoCAD 2014* by James Bethune [5]. Visualization software is covered in turn in manuals: *Wizualizacje architektoniczne. 3ds Max 2011 i 3ds Max Design 2011. Szkoła efektu* [24] and *3ds Max 2012. Ćwiczenia praktyczne* [23] by Joanna Pasek, *3ds Max 2012 – Biblia* by Kelly Murdok [19], or *Autodesk 3ds Max 2014. Oficjalny podręcznik* by Randi Derakhshani and Dariush Derakhshani [10].

Introduction to the BIM format and its idea are presented in such works as: *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors* by Chuck Eastman, Paul Teicholz, Rafael Sacks, Katleen Liston [12] and *BIM Content Development: Standards, Strategies, and Best Practices* by Robert Weygant [34].

In our work, we focused on materials dedicated to the ArchiCAD software and the BIM technology implemented within it. Guidance on operation of this particular piece of software is included i.a. in the following publications: *ArchiCAD 10* by Karl Sperbea [31], *ArchiCAD* by Jesse Russell and Ronald Cohn [28], *Началу! ArchiCAD* by Andrej Orlov [22], as well as in *ArchiCAD 17 – Grundkurs by Bernhard Binder* [6] and *ArchiCAD 17: Praxiseinstieg* by Detlef Ridde [27]. BIM technology is described in such references as: *ArchiCAD. Wprowadzenie do projektowania BIM* by Rafał Ślęk [32], *ArchiCAD 17 BIM Modelling*

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und Dokumentation by Bernhard Binde [7], *Building Information Modeling for Construction Using ArchiCAD* by Mohd Shiratuddin, Shane Germany, Tulio Sulbaran [29], as well as *Основы BIM Введение в информационное моделирование зданий* by Vladimir Talapov [33].

Digital form definition has its origins in the 1970s, when technical drawings started to be created by application of the vector graphic software. In the eighties, CAD programs were created, replacing the traditional drawing board and the related drawing tools and carriers. These programs are based on vector methods used both in the programming layer and the user interface [20].

The idea of a „virtual drawing board” put emphasis on the development and improvement of the technique of two dimensional drawing, i.e. on the use of flat drawings of projections, elevations and sections. The third dimension was created only as a function of flat drawings. The basis of this approach in the architectural design became the AutoCAD software [20].

The next step in the development of IT technologies, related to architectural design, was made at the end of the 1990s with the introduction of the software for creation of virtual models of built objects. The 3D model became the basis on which flat drawings were created. This concept was implemented by such programs as AutoCAD Architecture by Autodesk, Revit by Charles River Software (renamed to Revit Technology Corporation), or ArchiCAD by Graphisoft [9].

BIM (Building Information Modeling) systems constitute the next stage in the development of computer aided design. Using this technology, a project is created by building a virtual model, which is considered an “initial realization” of the built object that is being designed. BIM uses object logic that considers parametric information assigned to 3D objects, which allows including a complete set of material data on the future investment, sufficient for its realization. It enables a digital record of a built object, including its physical, as well as functional properties. Data recorded in the BIM format are always internally consistent – relevant portions of the documentation contain other interrelated data on the built object. Changes of the BIM model are automatically visible in the entire documentation [29]. This concept appeared in the seventies; however, its introduction into graphical software took place after 1992. It started to become common in 2003 and its popularity has been growing ever since [8]. Popularization of the BIM technology was facilitated i.a. by the introduction of the IFC (Industry Foundation Classes) format [9], which is a platform for data exchange between various types of BIM software and various participants in the design process. IFC is a text format for the data describing the model. It takes into consideration the structure and the properties of the model. As IFC is an independent file format, it is recognized by most BIM applications.

A number of programs for aided design using the BIM technology are currently available. The best-known include: ArchiCAD by Graphisoft, Revit Architecture by Autodesk, ArCADia-Architektura by Polish company INTERsoft [11], Bentley Architecture by Bentley, or IDEA Architecture by 4M Software.

3. ArchiCAD and BIM technology

ArchiCAD is an aided design application developed by the Hungarian company Graphisoft. Since the very beginning, the program has been implementing the BIM idea. Its first version was made in the years 1982/1983 and was based on a concept of creation of a virtual model for producing flat representations – projections, elevations, sections etc. The Virtual Building concept, which to large extent realizes the BIM idea, was introduced into the program already in 1987 [9]. A characteristic feature of this application, since the very beginning, has been the method for creation of the virtual model, which is analogous to the architectural approach towards design and realizations of buildings. The idea behind the program is based on the possibility to draw in a system close to WYSIWYG (What You See Is What You Get), meaning that whatever is being drawn on the screen is going to be published while retaining, at the same time, the working approach characteristic of architects. The process of creation of a body of a building starts with the determination of plans for subsequent floors, within which the architect specifies geometrical parameters of walls, openings etc. as well as their material, cost and other characteristics. This process can be referred to as “initial construction” since we are creating a model of the future building made of objects representing the relevant elements of the final construction (walls, ceilings, balks, etc.). Modifications made to the model and its sections are transferred onto the projection and reversed [1]. On the basis of such a virtual model, both design and technical documentation can be created. Starting with version 9.0, creation of the documentation takes place within the software itself. Earlier the documentation was created in a separate program – PlotMaker. ArchiCAD makes it possible to save the data using the IFC format which enables cooperation with IT systems of other businesses and services involved in the design and realization of an investment [14].

4. Flexijet – surveys of historical buildings using BIM system

The Flexijet system is composed of two elements: hardware, which includes a stand, a head, a laser rangefinder, rangefinder control pads, and software – which manages the measurement (Fig. 1).

The system is considered to be open because the data can be recorded in DXF, DWG and XML formats, which allows the system to be given a new field of application by using various programs. Currently, it has been adapted to work with the following pieces of software: ArchiCAD, Rhino, Compass CAD10, Scala, PaletteCAD, PythaCAD [13]. In the area of historical building surveys, the systems currently work best with the ArchiCAD software. It takes laser measurements and, based on them, it simultaneously creates standard elements of an ArchiCAD model in BIM technology. The resulting model, thanks to precise measurements, can contain a complete set of data describing in detail the building undergoing the survey. The accuracy

of the measurements is 2 mm, which ensures a tremendous fidelity of the model, which is of particular importance in the case of historical buildings and their documentation. During the measurements, complex objects such as windows, doors, stairs, railing and others can be formed. As these are parametrical objects, the model containing them constitutes an excellent basis for creation of a modernization plan of the measured object. It is an important feature of the Flexijet system as more than 50% of building investments in Poland in urban areas are modernizations, extensions and adaptations. Data contained in the BIM model can be also used for various analyses and simulations [14].

Measurements made with the use of the Flexijet system are similar to standard survey measurements involving laser rangefinders; the main difference resides in the final outcome of the measurement. Measurements made by means of standard rangefinders are a set of points distributed in a space. An actual survey record can be obtained only when they are interpreted and consolidated, which is a time consuming process. In the described system, in turn, elements of the virtual building are created immediately. Hence, the first step during such measurements is to select the piece of the building to be measured and simultaneously created in the ArchiCAD software. The rangefinder is guided onto a point in a space (either manually or using a control pad), the value of the range is measured and the element of a BIM model is being built basing on several (in the case of a wall, at least three) points. Subsequent measurements allow modelling of respective areas. A move between them or a measurement of points not visible for the rangefinder in its current position is realized through finding and fixing three base points, which are visible from both positions. Next, the device is moved to the new position and oriented by localizing the three previously established reference points, which allows continuing measurements and creation of a virtual model.

5. New features of the ArchiCAD software with the BIM technology in preservation of historical buildings in cities

Current potential of the ArchiCAD software makes this application suitable for use in preservation of heritage buildings in cities. The software enables rapid surveys of historical buildings thanks to the connection with the Flexijet system and a tool for reproduction of any kind of architectural elements and details. The Morph tool has been introduced into ArchiCAD version 16. It allows modelling of non-standard objects and their components of complex geometrical shapes. This provides possibilities that were so far unachievable together with the advantages of the BIM technology. In previous versions, such objects could have been created in separate programs and imported into ArchiCAD. However, they were not parametric objects.

The Morph tool provides a full flexibility when defining the form as it operates on the basis of modelling of polyhedrons or of NURBS (Non-Uniform Rational B-Spline) parametric surfaces. In addition, the tool enables for the creation of 3D objects by means of a number of techniques; extraction

and rotation of sections, CSG (Constructive Solid Geometry operations, i.e. creation of solids from objects subjected to Boolean operations – merging, subtracting and portioning), extrusion and skewing of planes, bending and shifting of edges or nodes. Elements can be created based on drawn and transformed outlines of the components of an object or through modifications of spatial BIM elements created with any of the ArchiCAD tools [1]. It is thus an optimal tool for creation of elements meeting the needs of a user. The elements are fully functional BIM components or structures which can be repeatedly utilized in various projects. This is particularly relevant to interior design items such as architectural details or construction elements, models of which are not available in standard libraries or manufacturer materials (Fig. 2, 3).

The survey of a fragment of a Gothic vault in the presbytery of The Dominican Church of the Holy Trinity in Krakow can serve as an example of application of the Morph tool for the restoration of a historical object. The survey was executed by the company BIMPOINT and with the application of the ArchiCAD 17 software [30]. Using the Flexijet system, profiles of the ribs were measured. Based on the measurements, a spatial model of ribs of the

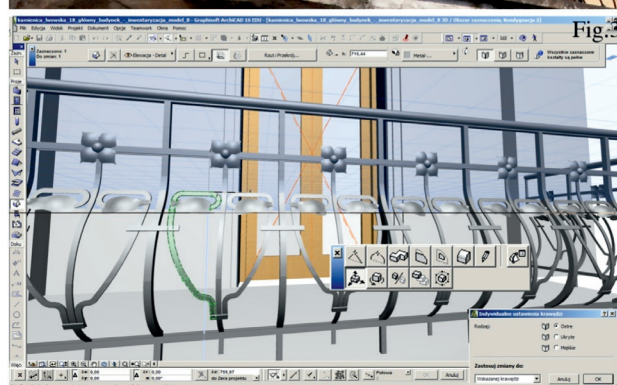
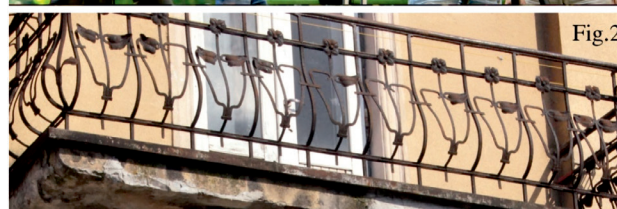
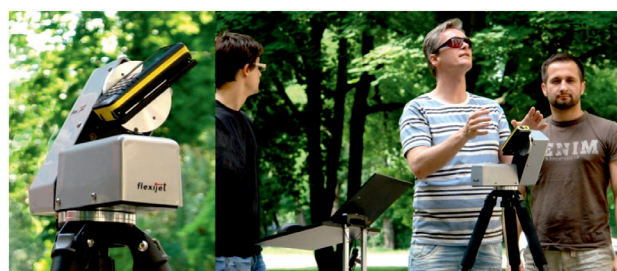


Fig. 1. A view of the Flexijet system during survey measurements of the facade the Palace in Łobzów – photography by Szymon Filipowski, reproduced upon permission

Fig. 2. Photograph of a railing outside of a tenement house in Krakow – author's own work

Fig. 3. View of the user interface with the panel of the MORPH tool and a 3D model of a railing outside a tenement house in Krakow as created with the use of the MORPH tool in ArchiCAD 16 – author's own work

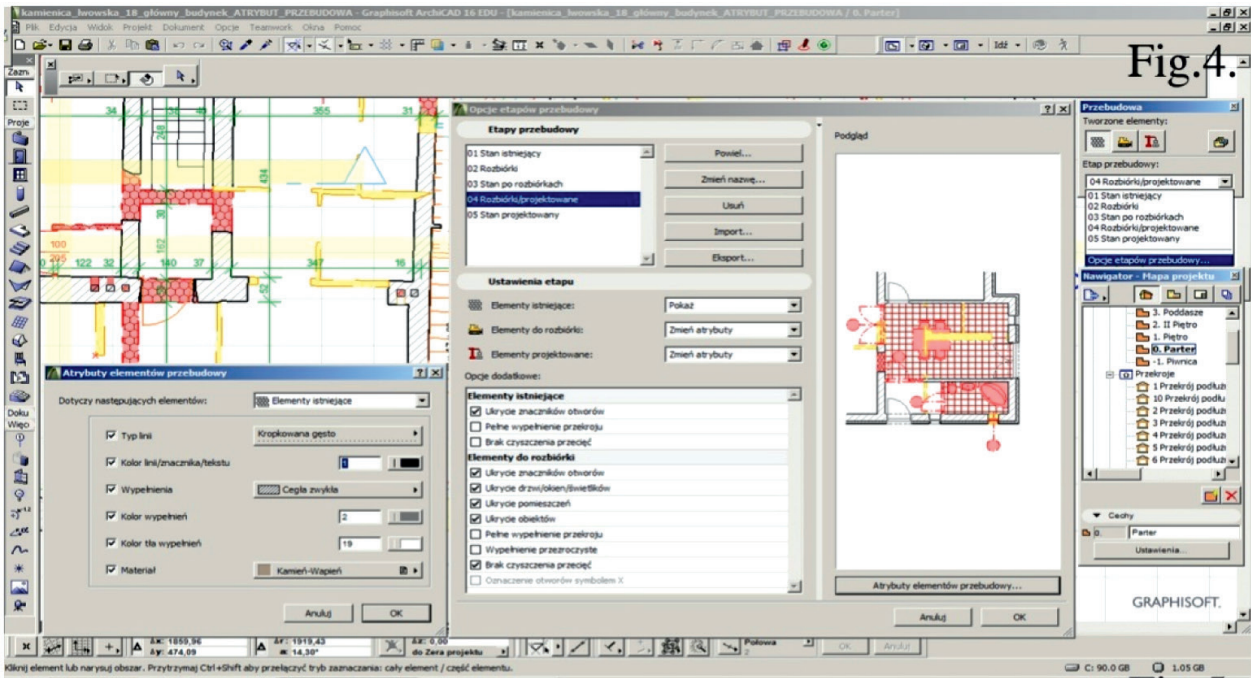


Fig.4.

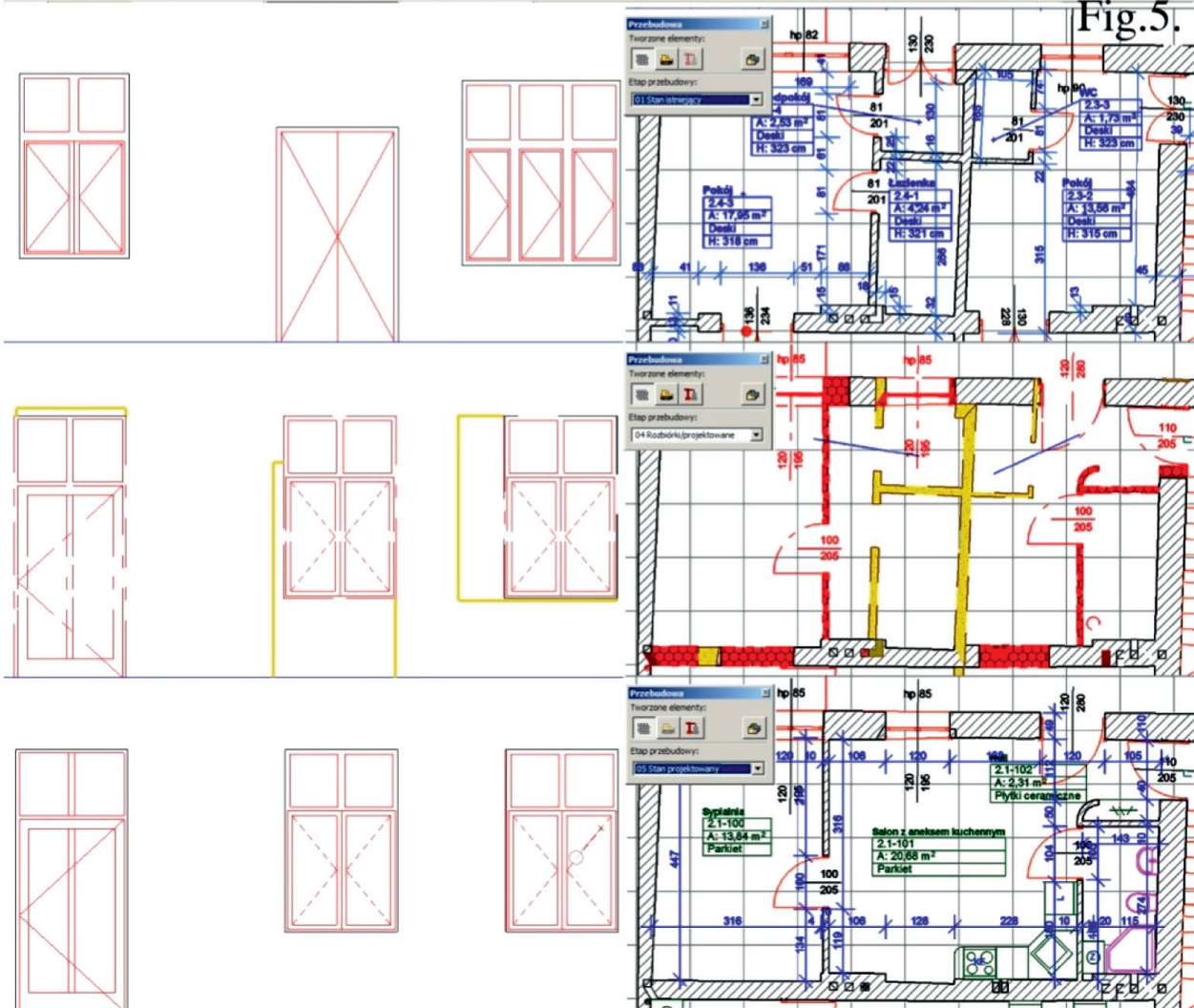


Fig.5.

Fig. 4. View of the ArchiCAD 16 user interface with the panel of the MODERNIZATION tool and a bill of materials – author’s own work

Fig. 5. Section and elevation fragments for a tenement house in Krakow undergoing a modernization with various MODERNIZATION stages indicated – author’s own work

vaulting was created. To create the ribs, first the beam tool was used, and next the elements were converted using the Morph tool which enabled their finishing and optimization.

Surveys of historical buildings are initial stages in the preservation of historical objects as they allow determining both the condition of the object undergoing the survey and the possible conservation works. Application of the BIM technology in this field helps to move more quickly from the survey stage to the design stage as already at the measurement step the preservation data can be assigned to the elements being surveyed, for instance the data on the condition, period, material etc. can be recorded. These data can be recorded as a text but also as a photographic documentation which further facilitates the subsequent design work.

Another element improving architectural design in preservation works, available in ArchiCAD version 15 and higher, is the “RENOVATION” attribute, which is available for all objects being created. This attribute allows the user to manage and visualize the relevant stages of a preservation project; starting with a survey to subsequent transformation phases to the final project. The application makes it possible to assign elements three different attributes – “EXISTING PLAN”, “DEMOLITION PLAN” and “PLANNED STATUS” – while retaining all advantages of the BIM technology (Fig. 4). Such classification allows for the presentation of combinations of various elements, depending on the selected modernization or adaptation stage. Properly defined graphical styles ensure clarity of the created documentation as ArchiCAD allows differentiating the graphical appearance of the subsequent stages of modernization (Fig. 5). It is also possible to define own styles which enables free adaptation of the way of presentation to individual needs. All stages are visible in elevations and sections as well as in project’s 3D View.

At the survey stage, it is possible to introduce data on each of the elements, for instance, on the historical value, which then defines either a need for their preservation, conservation, replacement or even complete removal. Architectural elements which are subject to protection under the provisions of laws on preservation of historical objects can be additionally protected against random classification for disassembly through having them assigned to a closed layer. Normally, objects appointed for demolition are marked in yellow, while walls and planned elements are in red. Such division, as well as the possibility to select a portion of a design to generate bills of materials, allows creating material take offs adapted to any given modernization stage. Speed up retrieval of data on material take offs for each of the stages provides an opportunity for more efficient planning of material procurement in line with the time schedule of the modernization. Numerous lists of elements required for the modernization constitute an additional support for the logistics of the operation. They indicate which of the elements are already present on site (as per the survey data) as well as materials intended for installation or replacement. Based on these sheets, one can

foresee not only the demand for new materials, but also the expected volumes of debris and other wastes which will be generated during each of the modernization stages.

One has to also mention the possibility of the ArchiCAD BIM model to work with programs intended for cost estimations (for instance ZUZIAbim). This facilitates managing financial aspect of an investment. It is possible to add data from material take offs to cost estimations directly from virtual models and hence to make quick estimations of costs at any stage of a project. This translates into quick realization, flexibility to changes and reduced cost for cost estimation preparation.

6. Summary

BIM type computer aided design software has become a sophisticated tool, which facilitates designing in architecture and preservation works. This may result in a better preservation of historical objects within cities. The change of the design tools has also altered the entire design process and the scope of the designer’s work. Application of the BIM technology allows designers to focus on aspects related to the modeling of architecture and the very preservation of historical objects. They have been freed from a number of tasks related to creation and maintenance of documentation. It has also become easier to manage the collaboration between various businesses owing to the possibility of working on a 3D model. The constantly updated virtual model allows preliminary identification of conflicts among discipline specific designs, which in turn, helps to avoid costly reworks during realizations. Introduction of parametrical elements in the BIM technology makes it possible to execute an entire survey of a building in one piece of software, for example in ArchiCAD. The cost of a project may be lowered owing to effectiveness of surveying with the use of the Flexijet system, creation of a project in the ArchiCAD software with the advanced features of the BIM technology, as well as a possibility of cost estimation based on a virtual 3D model. Also, material take offs and work take offs provide a more efficient way of controlling the costs for the entire investment. All the above aspects of the BIM technology were confirmed during works on the project for modernization of a historical tenement house in the centre of the district of Podgórze in Krakow.

In Author’s opinion, sophistication of the BIM technology allows designers not only to fully control the space being designed but also to control other aspects of a realization, for instance, its costs. In preservation works, the economic aspect is a very important factor which might positively influence preservation of heritage fabric. Reduction of investment costs might speed up execution of conservation works and increase their number within the same budget. It is of particular importance in preservation of historical objects in cities with large numbers of such objects such as Krakow or Wroclaw.

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