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Research paper

Concept of using the BIM technology to support the defect management process

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Abstract: Hundreds or even thousands of defects can be found during the building acceptance, hence the need for solutions which will facilitate the defect management, including identification, costing and repair. The aim of the paper is to present the possible use of BIM to support the defect management process during the acceptance of apartments in multifamily residential buildings. The paper presents a concept of quality control support application called MWBIM (Map of Knowledge BIM) which will collect data about discovered construction defects, their recording and servicing with the BIM technology. MWBIM will run based on Building Information Modelling (BIM), Augmented Reality (AR), Case-Based Reasoning (CBR) and maps of knowledge. There are three phases in the operation of the application: preparatory phase (planning the order of acceptance meetings and elements to be checked), acceptance phase (data collection and assigning them to the building information model) and the reporting phase (reports generation, assigning defects to contractors, follow-up of repair status). The intended uses of the application are mainly personnel involved in the acceptance of apartments.

Keywords: Building Information Modelling; Augmented Reality; Case-Based Reasoning; construction defects; defect management; developer

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1. Introduction

The information technologies are becoming increasingly popular in various fields of life. It is hard to imagine life without smartphones and computers which make everyday life easier for us. The continuous growth of IT has also affected the construction, changing the approach to actions and processes taking place during construction projects. One of the building lifecycle stages is acceptance. Hundreds or even thousands of defects can be found during the building acceptance [1], hence the need for solutions which will facilitate the defect management, including identification, costing and repair. The aim of the paper is to present the possible use of BIM (Building Information Modelling) to support the defect management process during the acceptance of apartments in multifamily residential buildings.

2. BIM - Building Information Modelling

Some twenty years ago, designers still mainly used drawing boards, graphos pens, tracing paper, slide rules, rapidographs, and drawing talents and graphical abilities did matter. The building designs required a capability of a precise use of drawing tools and the revision process was painstaking and time-consuming. New systems and solutions appeared with time to replace the traditional drawing techniques – development of software and computers allowed a quicker and easier designing and facilitated making design changes.

Until the 1970s, the designers made their drawings manually. Thanks to a rapid development of IT and growing requirements of the construction sector, mechanical and electrical engineering, CAD (Computer Aided Design) was developed in the 1980s. In 1975, Charles M. Eastman [2] formulated a term which is a concept of BIM as we know it. Eastman defined "Building Description System" as designing through an interactive defining of elements. According to the definition, all plans, elevations and sections should come from one source, and a modification of the arrangement of elements in any drawing should update the remaining drawings, so the drawings from the same arrangement of elements would be coherent. In his concept, Eastman proposed cost estimation and preparation of bills of materials by means of automatically generated reports based on the descriptions directly connected with the elements which would result in one integrated database for visual and quantitative analyses. The first documented use of the term "Building Modelling" appeared in a 1986 paper by Robert Aish [3]. Aish described what we now know as BIM and is implementation technology, presenting a few main assumptions such as 3D modelling, automatic drawing extraction, intelligent parametric components, relational databases, construction time schedules. In 1992, G. A. van Nederveen and F. P. Tolman used the term "Model Building Information" for the first time [4]. Jerry Laiserin contributed significantly to popularise the term BIM (Building Information Modelling) – in the early 21st century, the great analysts popularised the acronym BIM. Laiserin's publications [5,6] set the mark at which the term "Building Information Modelling" entered a widespread use. According to the author, "Building Information" implies the design, structure and behaviour of a building, whilst "Modelling" is associated with a mathematical or digital description of objects or systems. As BIM was developed, so was the design supporting software. Laiserin, along with the largest software suppliers such as Autodesk, Graphisoft and Bentley Systems, put the term BIM to a widespread use as a systemised potential of the design supporting software in the construction sector. Consequently, many authors of books and papers consider Laiserin the father of BIM, emphasising his significant contribution in implementation and popularisation of the term. The Building Information Modelling has becoming widely used in architecture, engineering and construction in recent years and the BIM has changed the process of design and construction of building facilities. During the last decade, the largest number of BIM-related studies has been in the US, China and the UK [7]. According to O. Kapliński [8], the integrated BIM process and the Building Information Modelling can be considered a trend affecting the construction sector since 2016.

The review of publications on BIM indicates the abundance and diversity of the BIM descriptions. The acronym BIM should read "Building Information Modelling", but BIM solutions currently apply to buildings as well as to infrastructure facilities. BIM is defined as a cumulative representation of functional building features in digital format, which combines technology, methodology and cooperation. It allows collecting, from all project participants, information that is necessary for planning, designing, analyses, construction, maintenance and demolition of a building [9]. According to "BIM Healthy Start", the BIM is [9]:

- IT solutions for designing, visualisation, analyses and cooperation, allowing better decisions to be made;
- A tool for automatic generation of e.g. drawings, analyses, reports, schedules;
- Support for the construction project participants that allows co-sharing of tasks and project information from various locations worldwide.

The US National Institute of Building Sciences defines BIM as a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception to demolition or reconstruction.

The Building Smart organisation [10,11] considers BIM as a model, modelling and construction project management. BIM as modelling (Building Information Modelling) is a process that involves generation and use of facility data. BIM allows the project participants to have an easy and simultaneous access to information. BIM as a model (Building Information Model) is a digital description of building functionalities and physical properties which is a source of building knowledge and data. BIM as management (Building Information Management) involves the control and organisation of construction projects by the use of information implemented in the Building Information Model in order to exchange information about assets during the project cycle.

Based on the aforementioned definitions, we can observe that considering BIM as a technology for computer modelling of buildings seems the most appropriate. The BIM technology is to assist in the development of a digital building model which, in addition to graphics, will include physical and functional properties and parametric rules and relationships between the building elements. In addition, the model can be used at various building lifecycle stages, from the concept, through construction, to use and demolition. Many different types of data can be implemented in the model, e.g. material data, time and technology of installation of a given element, cost data, discovered defects, etc. The principal difference between CAD and BIM is the model geometry: CAD uses lines, circles, simple solids, whereas BIM uses intelligent and parametric objects (e.g. a wall, window, column). CAD facilitates the design process, whilst BIM facilitates the entire process of building development and use.

The next important issue related to the Building Information Models is multidimensionality, which is a clear advantage of the BIM technology. Dimensions from 4D to 7D are generally understood and used in practice. A 4D model is a virtual building model in which each element contains information on the time of construction or installation, and as result the model can be used for the construction planning and management. A 5D model includes the design visualisation, with costs, and allows automatic take-offs and bills of quantities and cost estimate generation. A 6D model takes into account the sustainable development issues, i.e. estimation and optimisation of energy use, building use and demolition costs. A 7D model encompasses management, including integration of operation manuals and procedures with the building elements, planning of modernisation and renovations, inspections and maintenance activities.

3. Maps of knowledge

The aim of author's studies is to integrate the BIM technology and maps of knowledge to develop a tool for predicting the areas that are potentially most susceptible to defects and faults in a real building. The diagnosis and analysis of the knowledge and maps of knowledge allowed the concept of the MWBIM application to be developed.

Davenport and Prusak [12] define knowledge as a combination of data and information with experience, interpretation and inference. According to Baborski [13], "Knowledge is a set of information that allows inference based on premises," while Jemielniak and Koźmiński [14] interpret knowledge as "information combined with experience, interpretation and inference." Hence, knowledge can be defined as an anticipated resource of memorised elements, such as:

- observations and experience;
- impressions and rules of behaviour;
- recommendations, orders and bans;
- knowing the rights and privileges;
- professional skills.

In the literature on the subject matter, knowledge is divided into explicit knowledge and tacit knowledge (implicit knowledge). The latter exists only in the mind of a man who has it, it is a product of experience and is not fully realised ("I know that I know it") and manifests itself only through skilful actions. Unlike tacit knowledge, the explicit or formal knowledge is expressed as characters and written on knowledge carriers.

Knowledge management comprises all processes allowing the use of knowledge to achieve the organisation's objectives [15]. Several stages can be distinguished in the knowledge management process:

- identification of knowledge;
- acquisition of knowledge;
- retention and storage;
- development of knowledge;
- transfer of knowledge;
- use of knowledge.

Maps of knowledge are an important component of the application studied by the author. Two popular definitions of maps of knowledge are given below:

- Map of knowledge is a consciously designed medium that allows communication between those who have the knowledge and those who use it [16].
- Map of knowledge is defined as a graphical representation of knowledge, illustrating the relations between knowledge and its attributes [17,18].

The IT BIM-based model of the map of knowledge will be a tool supporting the prediction of defects in construction projects. The maps of knowledge will be used to present the results of defect prediction at the acceptance stage by means of graphical illustration containing the defects locations in residential buildings, frequency of occurrence, and estimated time and costs of repair. Figure 1 shows a preliminary method of presenting construction defects in apartments similar in terms of shape and layout. Superimposition of 31 apartment plans allowed identification of areas most susceptible to construction defects. The more intensive the colour, the higher the probability of construction defect occurrence.

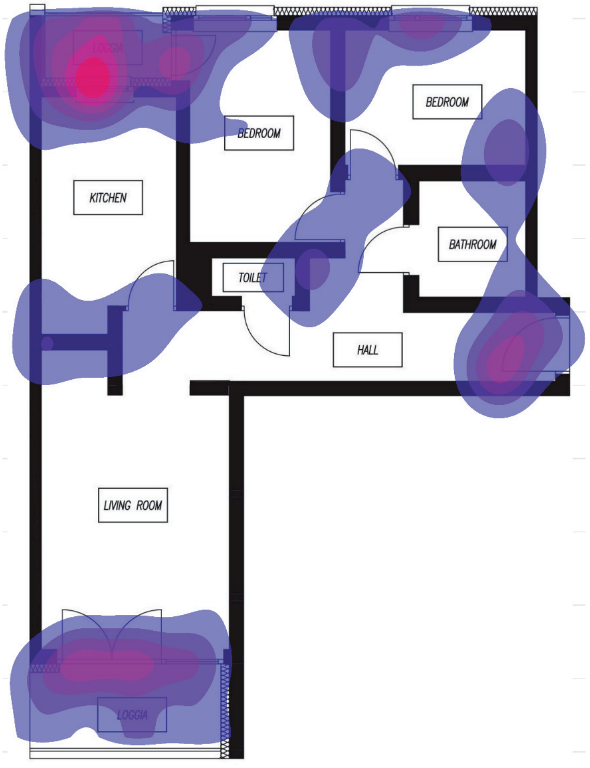

Fig. 1. Presentation of frequency and potential place of occurrence of construction defects

4. Defect management in literature

Many countries in the world lack laws regulating the issues of construction defects. An attempt to regulate these issues has been made in Taiwan where a three-level quality management system TQMS is in force and comprises three phases: quality control (QC, phase one), quality assurance (QA, phase two) and quality audit (phase three). A building contractor is responsible for quality control, owners are responsible for quality assurance, and relevant authorities or the Public Construction Commission (PCC) are responsible for quality audit. The society can play the role of auditors as the defects can be reported via special channels. Pursuant to Taiwanese laws, all project process participants must observe the rules included in the TQMS. Y. Cheng [19] developed a prototype of the applet to the Autodesk Revit software which will help contractors manage the quality of buildings in the first TQMS phase. The developed solution allows the defects and faults to be assigned to individual Building Information Model elements. The author's assumption was to develop a system which will effectively document the defects and faults of the structure and will facilitate their management.

The authors [20,21] are working to develop a construction defects management system connected with augmented reality and the Building Information Modelling. They proposed the following technical solution: template for collecting the defect-related information, tools facilitating the search for information, and an AR-based defect control system which is to support the defect management in the field. The tool developed by Park, Lee, Kwon and Wang consists of three stages:

- collection – identification and classification of defects using a template for a standardised and uniform characteristic of defects; the developed template gives accurate information on inter alia defect location and causes, cost impact, repair methods;
- search – an easy and effective search for the defect-related information and defining the relations between information which will be used by the user to understand the problem and search for information in the database without a detailed defect knowledge;
- reuse of information – at this stage the retrieved information should be used to prevent the defects on site using the defect detection by means of BIM and AR (augmented reality).

A wall mock-up and a Building Information Model were made in a laboratory. Compared to the Building Information Model, the mock-up did not have one ventilation duct (pipe), window had different dimensions and was placed at a different distance to the entrance door. The authors tested the operation of AR-related techniques using two methods:

- Using the available database, the Site Manager searches, selects and prepares information on places and types of possible defects and ways to control specific building elements. Then, a

3D geometry and information concerning the material and schedule of making a given element is generated from the Building Information Model. The prepared information is sent to workmen team leaders and the Site Manager or Works Manager. These data are read and expanded by the workmen team leaders to actual places using mobile devices. The Manager can cask for AR images during the performance of the works to make sure that the works are performed correctly and in accordance with the time schedule. Then, the sent AR image is verified by the Manager – they can send to the workmen leaders an immediate warning that the works are not performed correctly and order tasks to prevent an incorrect performance of the works and defects in the building;

- Using the database, the Site Manager searches, selects and prepares information on places and types of possible defects and ways to control specific building elements. Then, a 2D model is generated based on the 3D Building Information Model and is sent to the image matching software. The Manager sends to the workmen leader the camera location when the photographs were taken (height, angle and distance) and asks to send back actual photographs of the building element currently being made. Such photographs are sent to the image matching software where they are compared with a previously made 2D model. Based on the review of comparison results, the Manager decides whether to continue the works or to make corrections.

In [22], the authors developed a model used for cost estimation. Using the replacement of windows in a building as an example, the authors presented the model operation diagram which also can be used to estimate costs of replacing other building elements. The model was based on the BIM and Case-Based Reasoning (CBR). The model core is database in which each case is described by seven attributes: availability of contractors to install an element, installation costs and duration, material, location (e.g. outdoors, indoors, etc.), element size, floor. Based on the CBR algorithm, the model, using the myCBR software, searches for cases that match the new cases. The information necessary to be inputted to the new case will be entered by the user and will be automatically retrieved from the ICF building model. When the closest case is found, the model will generate the estimated windows replacement cost. If the generated cost is acceptable, the process is stopped; if not, the process is repeated with a suitable modification of previous steps.

Mirshokraei, De Gaetani and Migliaccio [23] developed a tool for quality management on site (QA and QC), integrating the Building Information Modelling and the AR. The solution developed by the authors is based on requirements defined by the customer which are used to prepare the specifications by the design team. The quality control plan is generated on the basis of the requirements and their control deadline. Then, the quality information is integrated with the Building Information Model which will be used to verify the requirements on site using the AR. Using the Building Information Model, the controller can determine in advance which elements should be inspected. On site, the inspector can visualise the model with a mobile device and inspect the element using an internet checklist. Based on such checklist, the inspector can decide if a given element conforms to the requirements. If the construction works have not been performed correctly, relevant information is saved in the Building Information Model. Based on the IFC model, the Project Manager can analyse the inspection data in order to assess the project construction quality, review current quality inspections and their effectiveness in minimising the number of defects and faults. In addition, such data can help the Project Manager decide if corrective actions in quality management are necessary.

In [24], the authors presented a system called BIMDM which will be used to exchange information on defects between the participants of the construction process. The defect management procedure developed by the authors includes:

- Identification of defects – identification of new or existing defects;
- Tracking of defects – ensuring that a defect is identified and sent to all people involved in the defect repair;
- Repair of defects – includes the exchange of requests and replies between the participants and tracking the repair status;
- Recording of defects – recording all activities related to the identified defect;
- Closing of defects – the defects are no longer observed.

The proposed solution involves putting the defect information in the Building Information Model to facilitate defect management by the quality control personnel on site. BIMDM allows adding such information as defect type and description, identification date, attachments (e.g. photographs, drawings) and data of personnel who identified the defect and personnel responsible for repair along with the conversation history. The information is added to BIM during a site visit. The Engineer takes a photograph and marks and describes a defect on it. The defect information is assigned to a given element in the Building Information Model using a tablet application. Thanks to the implementation of such data in the Building Information Model, the manager responsible for quality on site can easily check which defects have been found and what their repair status is, and consequently can order corrective actions to prevent similar defects in the future. The defect repair status in BIMDM is defined by the following colour code:

- Green: defect has been repaired and there are no reservations to the way it has been repaired;
- Blue: defect has been repaired and its repair method has to be checked by the Engineer;

- Yellow: defect repair in progress;
- Red: defect repair has not started.

M. Salamak and M. Januszka [25] described the use of BIM and AR technologies in inspection of bridges. The authors distinguished three stages of bridge inspection:

- inspection preparation phase with the use of simulator that allows planning further inspection stages and familiarising with the bridge;
- inspection phase in which the application user collects data on the bridge and reviews bridge historical information;
- inspection report preparation phase during which the user prepares the report on the bridge condition.

The designed system is based on the integration of BIM and the Bridge Management System. Such integration allows updating the information on the bridge condition and access to data on the bridge structure and history during all three phases described above. During the bridge inspection, the application will provide a real-time visualisation of selected (e.g. hidden or not visible) bridge elements, including structural elements, equipment items, etc. The inspector will have a decision making support tool at their disposal which after inputting required data will prompt further actions to be taken and allows a classification of the observed damage. In addition, the system will allow assigning the found defects to the Building Information Model in the location conforming to the defect location in the real facility.

J. Ratajczak, M. Riedl and D. T. Matt [26] developed the AR4C application (Augmented Reality for Construction) to improve effectiveness and quality of construction works and exchange information. The solution integrates the Building Information Modelling (BIM), augmented reality (AR) and location-based management system (LBMS). BIM and LBMS were used to provide an interactive 3D model of a building, technical and geometrical data of individual materials and building elements and visualisation of information about planned construction works in specific places on site. The locations in the application are divided into three levels:

- the highest level includes places in which the facility can be built independently, e.g. single buildings;
- the middle level relates to planning the works on individual floors;
- the lowest level is used for planning the tasks on the detailed level.

Two codes are assigned to each construction work: LBS (location-based service – location of construction works) and WBS (work breakdown structure – order of tasks) – they are assigned to individual elements of the Building Information Model. Thanks to the integration of codes and MS

Project schedules, AR4C allows the user to check the tasks lists assigned to individual building elements and their completion status by superimposing the 3D model on the real world using augmented reality. The application can also be used to check the geometrical and technical parameters of individual parts of the building.

In [27], K. Zima and S. Biel used the Case-Based Reasoning (CBR) method for detection and analysis of construction defects. The aim of measurement was to determine the total similarity to the considered problem between the new and the cases included in the Case Database using weighted sums of local similarities and criteria weights as coefficients. The authors presented the use of CBR to detect and analyse construction defects on a specific calculation example. Thanks to the CBR-based solutions, the inspector will receive information about defects they should expect during the acceptance of an apartment, about their location, severity, frequency of occurrence and estimated repair cost. The developed method indicates the elements most susceptible to construction defects, so during the acceptance of an apartment, the inspector should pay particular attention to the indicated places, and in addition they should look into the remaining elements of the apartment because defects not included in the Case Database can also occur. After the acceptance, the inspector should add the new apartment with found defects to the Case Database, and as a result the database will grow and the information about the expected defects during the acceptance of next apartments will be more accurate.

K. Zima and A. Leśniak [28] presented the cost calculation method of construction projects designed in accordance with the idea of sustainable development. The authors used the case-based reasoning to estimate the construction costs of a sports field. In order to estimate the costs using the CBR, created was a database with 143 cases and a list of 16 criteria with weights, e.g. sports field area, area of tracks, ball catching fence, type of sports equipment, construction impact on the environment, etc. Based on the analysis of 15 cases with known construction costs, it was found that the proposed solution is capable of estimating the costs in the initial phase of the project with a 14% accuracy.

5. Defect detection with the use of MWBIM

The objective of the author's research is to develop a quality control supporting application for construction works which will be used in collecting the data on found construction defects, and in recording and use of such data with the use of BIM technology. The application is called MWBIM (Map of knowledge BIM). The name comprises two segments - MW refers to the Map of Knowledge (abbreviation in the Polish language), and BIM to the Building Information Modelling. In addition, the application uses AR (Augmented Reality) and CBR (Case-Base Reasoning). The application will be an extension of BIM Vision – a freeware IFC viewer. The software allows viewing virtual building models created in such CAD tools as Revit, Archicad, Advance, DDS CAD, Tekla, Nemetschek VectorWorks, Bentley, Allplan and others. BIM Vision also allows a visualisation of Building Information Models and has numerous built-in functions and provides an interface for creating extensions which was used to develop MWBIM. The intended users are mainly inspectors involved in acceptance of residential apartments.

The application basis is the Building Information Model. The building models are created in the IFC (Industry Foundation Classes) format – a global, open, neutral standard developed and controlled by buildingSMART, used to describe, make available and exchange information. IPC is a file format created to ensure interoperability in the construction sector. The IFC model can contain the following information [29]:

- building hierarchy (phase, stages, e.g. floor);
- element type (walls, slabs, columns, beams, stairs, etc.);
- geometry (dimensions, element coordinates, volume);
- relationship between individual elements;
- standard and non-standard properties assigned to elements (material, colour, sections, fire protection, weight, etc.).

The model used in MWBIM should be adjusted during the project duration, all design changes should be included regularly. The IFC model accompanies a building during its entire lifecycle, so it is important that during the acceptance and commissioning of the building the developer has the model which conforms to the reality.

An intrinsic part of the MWBIM application is the database containing all data from acceptance meetings, both current and previous. The database will include information about the number of accepted apartments (location, floor, shape, area of the apartment and rooms, number of rooms, functionality of rooms, number of windows and doors, presence of garden/loggia/ terrace/ balcony, etc.) and construction defects found during acceptance (location, type, severity, repair costs and duration). In the final stage of the application development, it is planned to build a nationwide database available in the cloud to the MWBIM application. Such database will be created by the users and producers of construction materials and will include information about possible defects repair methods along with the estimated repair cost and time.

MWBIM can become an innovative solution for an AR-based intelligent system supporting the acceptance of residential apartments. The solution will comprise several modules connected with three acceptance phases:

- preparatory phase, during which by means of BIM Vision the user can plan the order of acceptance of apartments and mark the elements or places to which particular attention should be given during the acceptance meetings;
- acceptance phase, during which the inspector collects data using the AR integrated with the database, map of knowledge, CBR, Building Information Model and a decision making support tool;
- reporting phase, during which the user with the assistance of MWBIM prepares the comprehensive report and partial reports.

The MWBIM application algorithm is presented in Figure 2.

During the preparatory phase, the person carrying out the acceptance procedure (further "the inspector") can familiarise themselves with the apartment and perform its initial analysis using the Building Information Model, even before physically entering the building. A three-dimensional building model will allow the MWBIM user to plan the inspection, and to indicate the locations and elements to which the inspector will have to pay particular attention during the acceptance meeting. During a virtual walk, the inspector can use thumbtacks to mark the places they wish to see in the real facility. During the inspection in the building, the AR-based MWBIM application will indicate places which were marked on the Building Information Model. If the inspector has an appointment for acceptance meeting at a specific time and place, they could add information on the meeting date to the thumbtack, so the thumbtacks can play the role of a calendar. At this stage, the inspector can generate preliminary reports – after marking the apartments with thumbtacks, the MWBIM application will use CBR and maps of knowledge to generate a report with information about construction defects that can be found during acceptance meetings, indicating their potential location and severity. The preparatory phase is to make the inspector's work easier and is not necessary for the correct operation of the application.

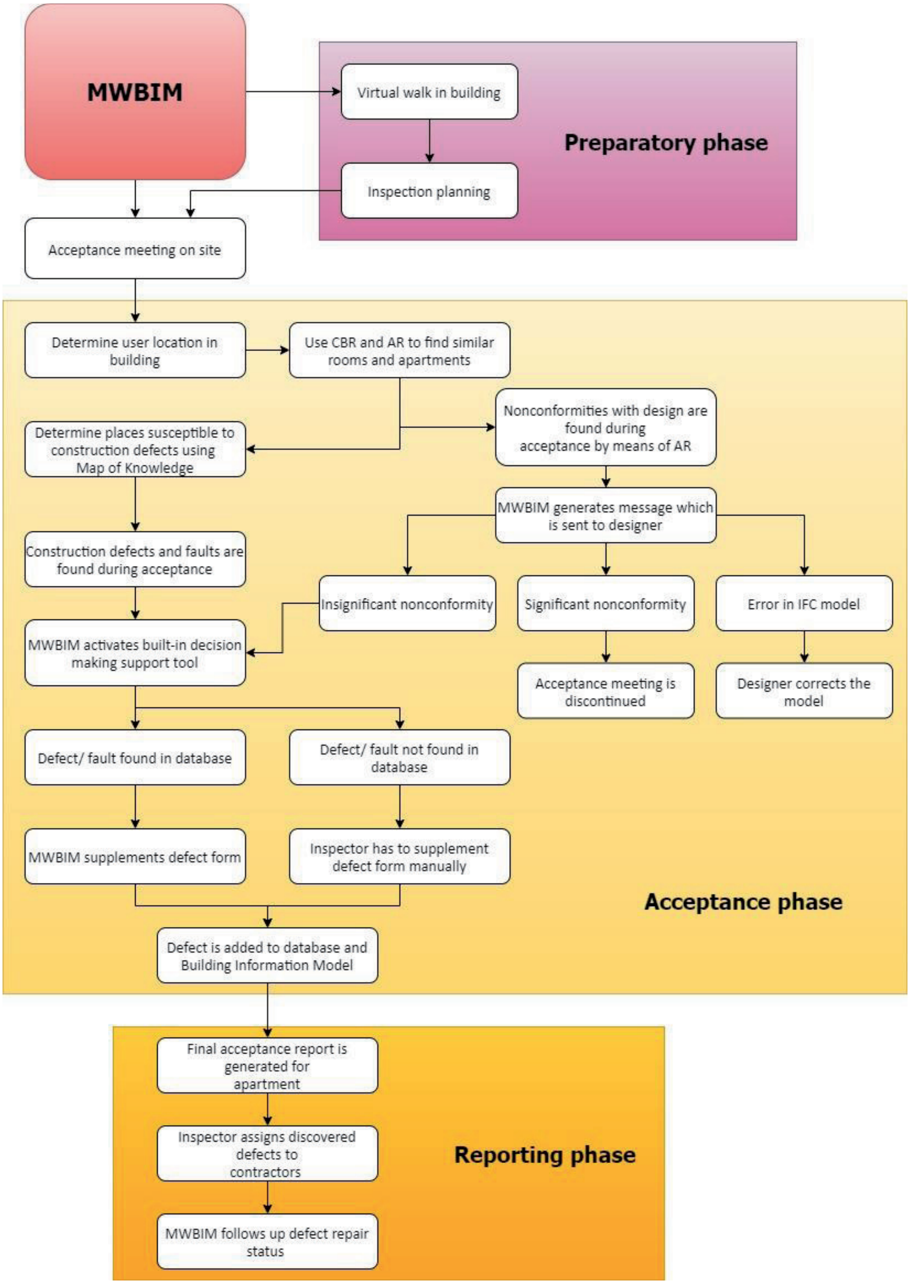

Fig. 2. MWBIM application algorithm

The second stage – the acceptance phase c uses a Human-Machine Interface and an AR-based Graphical User Interface. In the initial phase of MWBIM development, the inspector will use a smartphone to operate the application, and as the application is developed they can use other hardware (e.g. VR goggles) comprising inter alia sensors, an image recording and displaying device, and a positioning system. MWBIM will integrate all elements and modules and collect information necessary for the correct operation of the application. A hybrid positioning system will be responsible for determining the correct location of the inspector in the building – such system will combine global positioning systems (e.g. GPS) and local systems (location indicated by devices installed in the building). If the location is incorrect, the user can modify it manually. After entering the apartment, the inspector will be obligated to make a tour around it, and thanks to the recording of images, AR technology and MWBIM positioning module they will determine the shape and dimensions of all rooms, allowing the extension to find similar cases in the database using the CBR [27]. The real image of the room will be displayed on the smartphone (finally in the VR goggles) and a graphical overlay from the MWBIM extension will be superimposed on the real image. During the inspection of the apartment, based on the maps of knowledge and CBR, the graphical overlay from the MWBIM extension will show the places most susceptible to construction defects, along with descriptions of construction defects that should be expected (e.g. type, severity, estimated repair cost and time). The diagram presented in the article is a fragment of supporting the acceptance process, which is developed by the author as part of a scientific work. The presented diagram is based primarily on the analysis of the frequency of occurrence of construction defects, but the model developed by the author will be extended to include the classification of the significance of defects [1] and the determination of the cost of their repair [30].

The probability of defect occurrence on a given building elements will be marked by the so-called “colour points”) – the more intensive the colour, the higher the probability of defect occurrence in a given place. The presentation of places of potential defect occurrence on the Building Information. Model is shown in Figure 3.

When the user finds a construction defect, the application will assign the photo and the defect form to the location in the Building Information Model which conforms to the location in the real building. Adding construction defects to the building IFC model with the use of BIM Vision is shown in Figure 4.

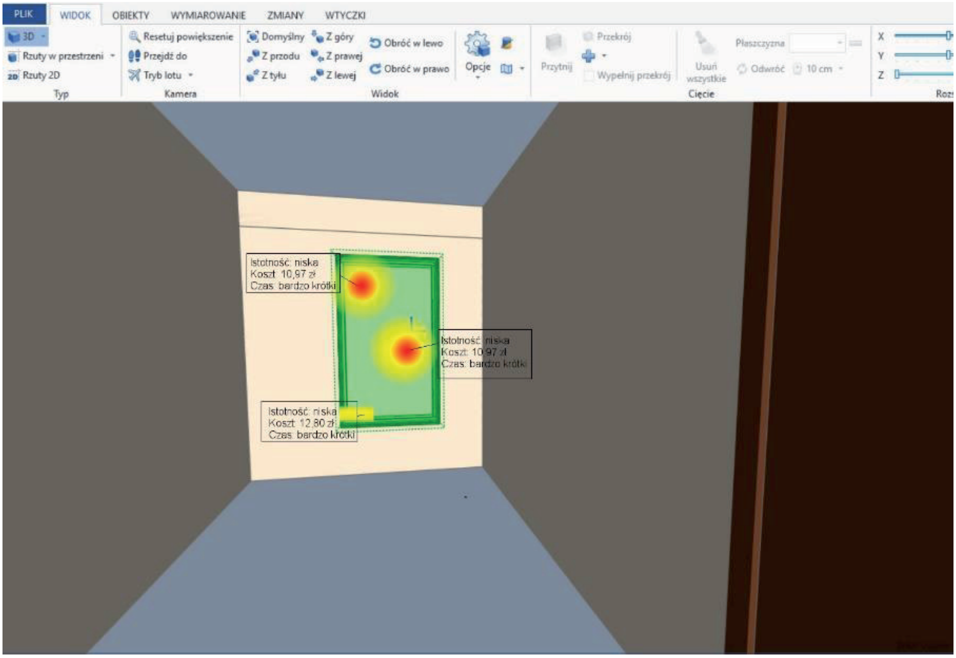

Fig. 3. Presentation of information about potential defects on outside window along with probability of occurrence

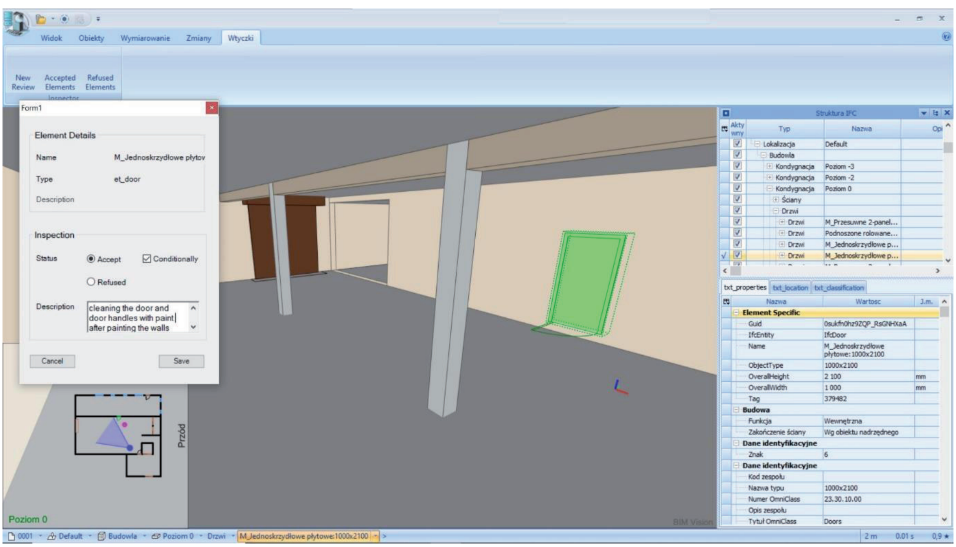

Fig. 4. Adding construction defects to the building IFC model with the use of BIM Vision

Based on the materials collected during the inspection (photos, videos, voice notes, etc.), the inspector can complete the form on a mobile device during the acceptance meeting or in the office using a desktop application. The form will be supplemented with assistance of the decision making support tool which after the manual input of basic data will allow the user to classify and evaluate the observed defects, indicating the method and estimated cost and time of the repair. Based on the decision making support tool, the inspector will make a decision if a defect should be considered significant and be included in the acceptance report, or should be considered insignificant and be omitted in the report. If a discovered defect is not found in the database, the user can add the case manually, completing the defect form. When the inspector does not know the data necessary to complete the description, they should add them to the form later and the MWBIM overlay will from time to time prompt the inspector to complete the information and will block the generation of the final acceptance report until the information is supplemented. All defects found will be recorded in the case database, making the CBR indications more accurate and more consistent with reality. The MWBIM application can also help the inspector identify the nonconformities between the model and the building using the overlay that superimposes the IFC model on the real image of the building using the AR technology. The inspector can email the discovered nonconformities, in the form of photos and voice notes, from each apartment, to the designer by means of the MWBIM application with request for clarification.

The final system phase is support in making the acceptance reports, based on the retrieved and collected data. After the acceptance meeting, the user can view the construction defects marked on the IFC model. A photograph and a form will be attached to each defect with the following information:

- defect description;
- element on which the defect occurred;
- location (apartment No., room);
- defect severity suggested by the decision making support tool;
- possible repair method;
- estimated repair cost and duration;
- defect repair priority;
- final repair deadline;
- repair status.

After completing all data, the application user can assign the discovered defects to contractors and monitor the repair progress. A colour code will be used for an easy follow-up of the repair status: green (defect repaired, no reservations concerning the repair), blue (defect repaired, check of repair quality is necessary), yellow (defect repair in progress), red (defect awaiting repair). The MWBIM application can send the partial reports to indicated contractors who can change the repair status on an internet form. The contractor will be obligated to upload a photo on the website to confirm that the defect has been repaired. When the contractor reports the defect as repaired, the MWBIM application will notify the user that the repair status has changed.

6. Summary

The BIM technology has many advantages, however there are still many obstacles to its widespread use during the construction and use of buildings in Poland and abroad. The reasons for that include a general reluctance to change, lack of understanding, antagonisms between trades and process participants, conformism of politicians and officials, necessity to invest in human resources and IT, etc. Nonetheless, the BIM technology is a standard of the future which facilitates cooperation between the construction project participants, gives a broader view of the final project effects by means of 3D visualisation, automates the process of making the design documentation, facilitates searching for errors and collisions in the design, etc.

Construction defects in multifamily residential buildings are a problem that requires a deep analysis. Thousands of defects and faults are discovered during the acceptance of apartments, hence the need to develop tools supporting the identification and control of defects. Thanks to the MWBIM application based on maps of knowledge, augmented reality, case-based reasoning and the BIM technology, a person performing the acceptance will receive information about the defects that can be expected during the apartment acceptance, their potential location, severity, frequency of occurrence and estimated repair cost. The application and the implemented decision making support tool will allow assigning the defects and their descriptions to specific locations in the IFC model of the building for an easier defect management. In addition, the MWBIM application will allow generating reports from acceptance meetings and modification and monitoring of the repair status by contractors which will speed up and simplify the work of both the inspectors and construction contractors.

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Koncepcja wykorzystania technologii BIM do wspomagania procesu zarządzania usterkami

Słowa kluczowe*: Building Information Modeling, Augmented Reality, Case Based Reasoning, zarządzanie, usterki budowlane, zarządzanie usterkami, deweloper*

Streszczenie:

Wprowadzenie

Jednym z etapów cyklu życia budynku jest jego budowa, której zwieńczeniem jest odbiór. Podczas odbioru budynków może być wykryte setki, a nawet tysiące usterek budowlanych, dlatego powstała potrzeba opracowania rozwiązań, które ułatwią zarządzanie nimi, w tym identyfikację, wycenę i naprawę. Celem artykułu jest prezentacja możliwości wykorzystania technologii BIM do wspomagania procesu zarządzania usterkami na etapie odbioru lokali mieszkalnych w wielorodzinnych budynkach mieszkalnych.

Detekcja usterek z wykorzystaniem MWBIM

Celem badań naukowych autora jest opracowanie aplikacji wspomagającej kontrolę jakości wykonanych robót budowlanych, która ma służyć zbieraniu danych o wykrytych usterkach budowlanych, ich rejestracji i obsłudze za pomocą technologii BIM. MWBIM będzie działać w oparciu o modelowanie informacji o budynku (BIM - Building Information Modeling), rozszerzoną rzeczywistość (AR - Augmented Reality), wnioskowanie z przypadków (CBR - Case-Based Reasoning) oraz mapy wiedzy. Nieodłącznym elementem aplikacji MWBIM jest baza danych, w której są zbierane wszystkie dane ze spotkań odbiorowych lokali mieszkalnych, zarówno bieżących jak i odbytych wcześniej. W bazie będą zapisane informacje dotyczące odebranych mieszkań (lokalizacja, piętro, kształt, powierzchnia mieszkania i pokoi, liczba pokoi, funkcjonalność pokoi, liczba okien i drzwi, obecność ogródka/loggi/tarasu/balkonu, itp.) oraz usterek budowlanych, które zostały w nich wykryte (lokalizacja, typ, istotność, koszt i czas naprawy). MWBIM będzie składać się z kilku modułów powiązanych z trzema fazami inspekcji: fazy przygotowania, odbioru i raportowania.

Faza przygotowania

Na etapie przygotowania i planowania spotkań odbiorowych, osoba przeprowadzająca procedurę odbiorową będzie mogła zapoznać się z odbieranym mieszkaniem przy użyciu modelu BIM oraz dokonać jego wstępnej analizy. Model budynku umożliwi użytkownikowi MWBIM zaplanowanie inspekcji, w tym wskazanie lokalizacji i elementów na które inspektor będzie musiał zwrócić uwagę podczas spotkania odbiorowego.

Faza odbioru

W początkowej fazie tworzenia MWBIM inspektor do obsługi aplikacji będzie wykorzystywał smartfon, natomiast wraz z rozwojem aplikacji zostanie wykorzystana ubieralna platforma sprzętowa. Po wejściu do mieszkania inspektor będzie zobligowany obejść mieszkanie, dzięki rejestracji obrazu, technologii AR i modułowi lokalizacji MWBIM określi kształt oraz wymiary wszystkich pomieszczeń, co umożliwi rozszerzeniu znalezienie podobnych przypadków w bazie danych z wykorzystaniem metody CBR. Na urządzeniu inspektorowi będzie wyświetlał się rzeczywisty obraz pomieszczenia, na który będzie nałożona nakładka graficzna z rozszerzenia MWBIM. Podczas inspekcji mieszkania nakładka będzie pokazywać miejsca najbardziej narażone na usterki budowlane, wraz z opisem usterek budowlanych których należy się

spodziewać (m.in. typ, istotność, szacowany czas i koszt naprawy). Prawdopodobieństwo pojawienia się usterek na danym elemencie budynku będzie oznaczone poprzez tzw. „kolorowe punkty” – im większe będzie prawdopodobieństwo wystąpienia usterki w konkretnym miejscu, tym kolor będzie intensywniejszy. Gdy użytkownik wykryje jakąś usterkę budowlaną aplikacja przypisze zdjęcie oraz formularz usterki do lokalizacji w modelu BIM zgodnej z lokalizacją urządzenia. Inspektor będzie miał możliwość uzupełnić formularz podczas spotkania odbiorowego z wykorzystaniem urządzenia mobilnego lub w biurze po wizycie na obiekcie za pomocą aplikacji desktopowej na podstawie materiałów zgromadzonych w trakcie inspekcji. Formularz będzie uzupełniany za pomocą narzędzia wspomagającego podjęcie decyzji, które po wprowadzeniu ręcznie podstawowych danych umożliwi użytkownikowi klasyfikację oraz ocenę zaobserwowanych uszkodzeń wraz ze wskazaniem sposobu oraz orientacyjnego kosztu i czasu potrzebnego na ich naprawę. Na podstawie narzędzia wspomagającego podjęcie decyzji inspektor podejmie decyzję czy defekt uznać za istotny i wpisywać go do protokołu odbiorowego, czy uznać za nieistotny i pominąć usterkę w protokole. W przypadku gdy wykryte uszkodzenie nie zostało znalezione w bazie danych użytkownik będzie miał możliwość dodać przypadek ręcznie, uzupełniając formularz opisujący usterkę.

Faza raportowania

Ostatnią fazą systemu jest wspomaganie w przygotowaniu protokołów ze spotkań odbiorowych, bazując na pozyskanych i zgromadzonych danych. Po spotkaniu użytkownik będzie miał możliwość przeglądnięcia na modelu IFC zaznaczonych usterek budowlanych. Do każdego uszkodzenia będzie załączone zdjęcie oraz formularz opisujący usterkę. Po uzupełnieniu wszystkich danych, użytkownik aplikacji będzie miał możliwość przydzielić wykryte usterki poszczególnym wykonawcom oraz monitorować przebieg ich naprawy.

Podsumowanie

Dzięki aplikacji MWBIM osoba przeprowadzająca odbiór mieszkania otrzyma informacje jakich usterek budowlanych można się spodziewać podczas odbioru mieszkania, jaka jest ich potencjalna lokalizacja, istotność, częstość występowania oraz szacowany koszt ich napraw. Dzięki aplikacji i zaimplementowaniu narzędzia wspomagającego podejmowanie decyzji możliwe będzie przypisanie usterek i ich opisu do konkretnych lokalizacji w modelu IFC obiektu budowlanego, co ułatwi zarządzanie usterkami budowlanymi. Dodatkowo, aplikacja MWBIM pozwoli na generowanie raportów ze spotkań odbiorowych i modyfikowanie oraz monitorowanie statusu naprawy przez wykonawców, co przyspieszy i uprości pracę zarówno inspektorów jak i wykonawców robót budowlanych.

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