THE CONCEPT OF A SYSTEM SUPPORTING THE
ACCEPTANCE OF FLATS USING BIM

Krzysztof ZIMA, Cracow University of Technology, Poland, krzysztof.zima@pk.edu.pl;
Ewelina MITERA-KIELBASA, Cracow University of Technology, Poland, e.mitera@pk.edu.pl

ABSTRACT
The aim of the article is to present a system supporting the technical acceptance process of flats in multi-family buildings based on a plugin to IFC viewer and BIM model. A system based on a plugin for a free IFC file viewer - BIMvision was shown. The system is aimed at supporting the identification of defects in individual rooms, assessing their significance along with estimating the time and cost of defect repairs. Then, the plugin allows to collect and add descriptions of the acceptance or non-acceptance of a building element in the IFC file of the building BIM model. The system is based on historical data on the occurrence of construction defects, which facilitates the identification of defects during commissioning. A helpful module is the chatbot module, which suggests where and what defects occur most often after asking a series of questions about the type of object, rooms, their location in the building and etc. The result of the plugin activities is also the planned time of removing defects from the database created as a result of measurements of the time of works on the construction site and the planned cost from the database of costs of removing defects. The article presents the concept of such system along with an explanation of the operation principles all its individual modules.

KEYWORDS
BIM, Construction defects, Cost, Decision support system, IFC, Technical survey.
1. INTRODUCTION

Currently, today's construction companies are required to adapt to the growing expectations of customers and to meet more and more ambitious challenges. In order to meet these expectations, the construction market is undergoing a kind of revolution consisting in the introduction of innovative solutions that will allow the investment to be implemented in a way that allows to achieve the assumed goals in a short time, using the least resources while maintaining the highest quality of implementation. One of the key elements to meet these ambitious requirements is the efficient exchange of information through standardized technical documentation that is available to all participants of the construction process. It must also be able to update data and those involved in investments must be informed about its changes. This is very important because the easy flow of information allows for immediate decision-making and early reaction to possible problems arising during the work.

The article attempts to show the possibilities offered by the use of modern software in defect management at the stage of technical investor acceptance of building using the BIM (Building Information Model). The concept of an advisory system was shown, suggesting to the user the type of defects and the most probable places of its occurrence, as well as calculating the planned costs and time of repairing defects in buildings.

2. MATERIALS AND METHODS

2.1 BIM technology in construction

Contemporary technologies such as e.g. BIM technology develop expeditiously and it is beneficial to continually follow their advancement, in addition to new literature and relevant guidelines (Zima and Mitera-Kiełbasa, 2021). The development of such technologies supporting construction works allows to improve the work of many stakeholders in construction projects. BIM is a technology with great potential to increase the automation of activities performed in architectural, engineering and construction projects. The created virtual model of the facility allows coordinating all industries during the entire life cycle of the building (Leśniak et al., 2021).

The main advantage of BIM is the ability to collect a lot of information in the model, also assigned to specific modeled elements. It allows the use of much of the data needed over the entire life cycle of buildings. These data can be stored in native files or, for example, in an IFC file, but it can also be stored in databases, for example, in the form of CSV files in MS Excel and used in the course of analyzes or in the case of decision support applications operating with the use of the BIM model. Marmo et al. developed a scheme to solve the interoperability problem by mapping IFC to a relational database for maintenance and performance management (Marmo et al., 2020). Similarly, databases can be used to solve other construction issues or to support decision-making based on the use of BIM technology. This applies to both creating simulations of construction works as well as reporting, cost and time analyzes, etc.
BIM has been identified as a crucial lifecycle management technology that may substantially influence the building project's lifecycle (Kaewunruen and Lian, 2019). The use and storage of information in the model gives the advantage that information can be stored throughout the life cycle of buildings and can be used in various phases in decision-making processes. Similarly, (Olanrewaju et al., 2020), after examining the impact of barrier on the development of BIM technology, found that it assists in decision-making across the project lifecycle.

![Image](source: own)

**Figure 1.** An example of the visualization of defects in an apartment of a multi-family flat (source: own)

According to the authors, BIM technology can be used successfully in planning the defect management process. The advantages of such a solution are, first of all, a graphic presentation of construction defects in a 3D model, which facilitates its perception, the possibility of collecting data on defects, automation of calculating the number of defects combined with their quick time-cost analysis, which will be shown later in the article. An additional advantage of using the BIM model is the ability to monitor a technical acceptance processes. A graphic presentation of examples of defects is shown in Fig. 1.

### 2.2 Defects management system

There is no generally accepted and applied definition of a defect in Polish law. In the construction industry, other terms are also sometimes used, such as shortage, non-conformity, deviation, error (Zima and Biel, 2019).

According to PN-EN ISO 9000:2015 (PN-EN ISO 9000, 2015) a defect is a “failure to meet a requirement in relation to the intended or specified use”, and the requirement is understood as a “need or expectation which has been agreed, accepted customarily or is mandatory”. The problem of defect management is an important problem, but also not often discussed in publications.
Some authors are trying to develop a building defect management system based on augmented reality (AR) and building information modelling. They try to gather information about defects, using, for example, databases with tools that make easier searching for information and an AR-based defect control system. For example the tool described in (Park et al., 2013) consists of three stages:

- collection (identification and classification stage with detailed information on causes, defect location, repair methods, costs etc.);
- search (stage of searching for the defect-related information which will be used to understand the problem);
- reuse of information (the stage where the acquired information is used to prevent defects using defect detection with BIM and AR).

In another publication the authors (Kim and Kim, 2019), presented a model for cost estimation in case of defects. The authors described an operation diagram which can be used to cost estimation by the replacement of windows example. The model was based on the BIM model and Case-Based Reasoning method, in which the core of model was database with seven attributes such as: availability of contractors, assembly costs, assembly time, type of material, location, element size, storey. As a result model will generate the estimated cost of windows replacement using historical date and CBR methodology looking for the most similar case for past.

In (Lin et al., 2016), the authors showed a system called “BIMDM.” System is used to exchange information on construction defects between the stakeholders of a construction project. The defect management procedure outlined includes: identifying new defects; Tracking the defect remediation process and recording all actions related to the identified defect and the closure procedure.

The authors (May et al., 2022) showed a system divided into stages of identification, development and evaluation of a defect management prototype using the augmented reality module and BIM models. The Augmented Reality Defect Management System (BIM-ARDM) was developed for building inspection based on BIM. A study was also conducted to evaluate the BIM-ARDM model in comparison with the typical approach used in the defect management control process. The BIM-ARDM system has been shown to be significantly superior to the current approach in terms of usability, workload, efficiency, turnaround time, defect identification, location of building elements and user assistance in the inspection task.

The research conducted so far shows the need to create defect management support systems. Research e.g. (May et al., 2022) also confirms the effectiveness of such systems based on BIM technology, although most of the systems are based on the technical acceptance of construction works supported by AR technology on the construction site. The authors of the article want to present a system for supporting the technical acceptance of apartments based on BIM technology, historical data, extended with cost and time calculations.
3. RESULTS - PROPOSED CONCEPT OF DEFECTS MANAGEMENT DECISION SUPPORT SYSTEM

The concept of the proprietary construction defect management system allows the system to suggest possible defects (type, quantity), time and costs of repair on the basis of a chatbot, i.e. a computer program designed to simulate conversation with user. The system is to enable the classification of defects in terms of their significance and the need to remove them at the stage of investor commissioning, planning the time and costs of removing defects to be removed and supporting the work of the supervision inspector during physical commissioning activities. The system is to use databases containing statistical information on the occurrence of defects, costs and the time of their removal. The scheme of the presented system operation is shown in Fig. 2.

![Functional diagram of the defect management system (source: own)](image)

The decision-making and inspector’s work support system is to be based on the BIM model. The authors choose the existing IFC file viewer made by the polish company Datacomp sp. z o.o. - BIMvision (https://bimvision.eu/) is a free software that allows to view models created in the IFC format, which is the result of exporting data from native applications such as Revit, Vector Works, Allplan or Archicad. The authors of the program give users a special function that allows them to create original plugins for the program. Plugin is an additional module that extends the possibilities of the original application. The application structure consists of two cooperating application layers, the "Presentation layer" and the "Periscence layer". Thanks to this division of responsibilities, it is easier to manage the application and introduce new functionalities to the structure.

The first is the “Presentation layer” created with the use of the MVC (Model-View-Controller) pattern, it is responsible for the exchange of information between the user and the application state. It consists of three forms (Form 1; Form 2; Form 3) that act as a view. Two of them display the already saved data, while the third is used to create new information.
about the completed building approvals. These forms have dependencies passed to the persistence layer and to the API (Application Programming Interface - a set of public methods and interfaces provided to establish clear communication protocols) provided by Datacomp (BIMvision API), which allows interaction with the model saved in IFC format and displayed in BIMvision. In turn, the "Inspector" function is used as a model that feeds the view. It also acts as a controller whose task is to register the plugin the BIMvision software, add buttons in the "Plugins" tab and control the way forms are displayed.

The role of the “Periscence layer” is to manage the CSV file. This layer is responsible for both file creation and read and write operations. Persistence is storing state in a way that allows data to be preserved even after the process that is responsible for its creation is completed. The first class is used as a Data Transfer Object between application layers. They enable the creation of an object by passing the full list of fields or only the identifier of the element retrieved from the IFC model. The first element is used by mapper when reading data from a CSV file. The mapper is used for two-sided mapping of values retrieved from a CSV file. The second is used by the presentation layer when creating a new audit to handle communication between the IFC file and the csv file (csv service). The effect of the actions may be a list of accepted defects or not exported from the model (BIM Model - IFC) to a CSV file. Apart from the listed elements (lists of received and missed defects), the CSV files contain information on defects, 3 databases containing information on the time and cost of removing defects as well as historical data on the types and number of defects occurring during commissioning. Data from Database 1 are used in the system as hints of possible defects during technical acceptance activities. The data contained in Database 3 define the time of defect removal, both in terms of operation and necessary technological breaks. The data from this database is also used to estimate the cost of labor and equipment work in conjunction with the hourly rate stored in Database 3 and equipment labor costs. Database 2 also includes a cost valuation mechanism using cost data on the prices of materials and equipment work. Generally, the output is a unit prices for rectifying defects.

The last element is a chatbot used to communicate with the user. Chatbot asks a series of questions regarding, inter alia, the location of the room, type of room, type of element, etc. suggesting finally what types of defects can be found, their significance, time and cost of removal.

3.1 Significance of the defects

Due to decision-making support, it is necessary to assess and group defects in the proposed system. An odd three-point scale was adopted, grouping the defects into insignificant, significant and unacceptable.

Minor defects are defined as defects that require relatively small and not burdensome interference in individual building elements. These defects do not in any way affect the operation/ use, or the deterioration of the function of the facility. The cost and time of their removal is low.
Significant defects require much more time and a higher cost of their removal, but they do not constitute a categorical obstacle in the possibility of commissioning construction works for use. They allow for the pickup of the apartment, but it is required to remove them after the pickup within the agreed time.

Unacceptable defects are such defects that basically prevent the acceptance of already completed construction works. Failure to accept the works results from the necessity for the construction contractor to carry out very complicated and labour-intensive correction works or defects prevent the proper operation of the facility.

### 3.2 Time and cost of rectifying construction defects

In order to determine the significance of individual defects, but also to plan the time and cost of individual works related to defect removal, an analysis of historical data, estimates of own defect removal costs and measurements of construction works completion time were performed.

**Figure 3. Plastering works** - simple activities in repairing a defect with time and cost analysis (source: own)

Figure 3 shows the time-cost calculations for the defect removal process on the example of plastering works.

For each subsequent simple activity, the cost of performing a given activity was estimated and the times of their execution were measured. For example, for the activity “mixing the
Grout in a bucket with a trowel", the labor cost is € 0.84 and the material cost for the job is € 6.42. In turn, the time needed to complete the work is 10 minutes. The total cost of the repair is € 22.86, the work time is 55 minutes, and the total time, including the necessary technological breaks, is 2 days and 100 minutes. The defect, due to the relatively low cost of works and the short time, was classified as a minor defect of minor importance.

Other works to rectify defects were analyzed in a similar way. The data was saved in csv format as a cost database and separately as a repair time database. The time was determined on the basis of our own experience and normative research conducted during the removal of construction defects in residential premises in multi-family housing. A fragment of the database on repair duration is shown in table 1.

<table>
<thead>
<tr>
<th>Construction works related to the removal of defects</th>
<th>Total repair time</th>
<th>Total repair time without technical breaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of fungus from the wall</td>
<td>15 days 3 hours 45 min.</td>
<td>3 hours 50 min.</td>
</tr>
<tr>
<td>Removal of moisture from the wall</td>
<td>9 days 2 hours 10 min.</td>
<td>2 hours 10 min.</td>
</tr>
<tr>
<td>Removal of plaster chafing</td>
<td>8 days 2 hours 15 min.</td>
<td>2 hours 15 min.</td>
</tr>
<tr>
<td>Removal of floor stains</td>
<td>1 hours 25 min.</td>
<td>1 hours 25 min.</td>
</tr>
<tr>
<td>Repair of a scratched window sill</td>
<td>30 min.</td>
<td>30 min.</td>
</tr>
<tr>
<td>Repair of cracks in the floor</td>
<td>4 hours 45 min.</td>
<td>45 min.</td>
</tr>
</tbody>
</table>

Table 2. A fragment of the database and the cost of construction work when removing construction defects (source: own)

<table>
<thead>
<tr>
<th>Name</th>
<th>Cost</th>
<th>Time [min]</th>
<th>Measurement unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken glass replacement</td>
<td>€ 68.26</td>
<td>45</td>
<td>1 pcs</td>
</tr>
<tr>
<td>Painting correction</td>
<td>€ 25.36</td>
<td>30</td>
<td>1 m²</td>
</tr>
<tr>
<td>Repairing a scratched railing</td>
<td>€ 23.53</td>
<td>30</td>
<td>1 pcs</td>
</tr>
<tr>
<td>Repair scratched flashing</td>
<td>€ 23.53</td>
<td>30</td>
<td>1 pcs</td>
</tr>
<tr>
<td>Repair of scratched woodwork</td>
<td>€ 4.29</td>
<td>30</td>
<td>1 pcs</td>
</tr>
<tr>
<td>Sanding scratched glass</td>
<td>€ 42.99</td>
<td>60</td>
<td>1 pcs</td>
</tr>
<tr>
<td>Repair of a scratched interior window sill</td>
<td>€ 31.70</td>
<td>45</td>
<td>1 pcs</td>
</tr>
<tr>
<td>Repair broken tile</td>
<td>€ 27.50</td>
<td>60</td>
<td>1 m²</td>
</tr>
<tr>
<td>Window joinery adjustment</td>
<td>€ 2.15</td>
<td>15</td>
<td>1 pcs</td>
</tr>
<tr>
<td>Removal of scratches on the ceiling</td>
<td>€ 49.97</td>
<td>150</td>
<td>1 place</td>
</tr>
</tbody>
</table>
The costs result from own estimates and historical data on works related to the removal of construction defects in residential premises in multi-family housing. A fragment of the database on the costs related to the removal of construction defects is shown in table 2.

The costs of building materials are estimated on an ongoing basis based on the market prices of the materials needed.

3.3 Supporting the process of construction acceptance of residential premises

The proposed system for supporting the process of acceptance of residential premises is to estimate the pre-planned time and costs of defect removal depending on the type and number of identified defects. The system is also to advise on an ongoing basis during the acceptance activities where and what defects may occur, and with the use of the BIM model, it is to allow for quick marking of defects, entering a description and their classification. For this purpose, the possibilities offered by the BIMvision browser and the option of making the "Acceptance" plug-in were used. The plugin is still under conceptual work and currently has limited functionality. In order to facilitate the work of the inspector, the plugin is to be equipped with a chatbot module, which is to prompt the inspector where, what defects and about what severity, cost and time of removal may occur. An example of a view in the BIMvision viewer is shown in fig. 4.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Time</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of scratches on the wall</td>
<td>€48.27</td>
<td>130</td>
<td>1 place</td>
</tr>
<tr>
<td>Removal of scratches on the screed</td>
<td>€36.06</td>
<td>45</td>
<td>1 place</td>
</tr>
<tr>
<td>Removing traces of mold</td>
<td>€54.60</td>
<td>230</td>
<td>1 place</td>
</tr>
</tbody>
</table>

Figure 4. An example of the view in the BIM Vision browser for accepting a defect consisting in scratching the glass of a balcony door with a visible chatbot hint system (source: own)
During the acceptance process, a defect was identified (marked with a red border in fig. 4) consisting in scratching the glass of the balcony door. Using the chatbot hints (in fig. 4 in the black box), the inspector gets the cost of the defect equal to € 42.99 and the repair time of 60 minutes. The defect was classified automatically as irrelevant. Following these suggestions, the inspector, for example, decides on the construction acceptance of an element without any comments, counting on the building acceptance of the apartment by customers without indicating such a defect or in the event of its subsequent indication as a defect, the removal of which will not cause problems.

Figure 5. An example of conditional acceptance of a defect consisting in scratching the glass of a balcony door with a visible chatbot hint system (source: own)

In the second presented case, a defect in the horizontal scratching of the wall at the balcony door was identified during the acceptance process. Hints about possible defects are generated by the chatbot question and answer system (a fragment can be seen in Fig. 5). Following the prompts of the chatbot, the inspector identifies defects in the room and decides on the acceptance of the elements. In this case, the acceptance of the element is a conditional check, with the added note - “Horizontal scratch contractile plate by the window. Fix the plaster” and defect was considered significant, requiring action before the lacquer acceptance procedure. The system also suggests the costs and time of defect removal, as in the previous case, as well as the method of repairing the defect.

The defects accepted in the course of inspections, together with the selected repair method, time and repair costs, are finally exported to a spreadsheet, where the costs are summed up and the execution time may be subject to further activities, e.g. related to the creation of a repair schedule.
4. CONCLUSION

The article presents the author's concept of supporting the process of accepting flats in terms of identification of construction defects, automatic estimation of the time and costs of their removal, and marking of approved and unaccepted building elements on the BIM model.

The presented system is designed to facilitate the work of the inspector during the commissioning activities by using a prompting and communication scheme via chatbot, aimed at identifying possible construction defects depending on the type of room, its location, etc. According to the authors, relying on historical data from previous building inspections allows us to draw attention to the most common building failures.

The automatic calculation of repair time and costs is also a very big advantage. This allows you to decide on the significance of the defect, and thus to accept the element for acceptance assuming the acceptance of the apartment by the later tenant (possibly with comments) or its improvement before the acceptance without the risk of rejection of the acceptance of the apartment. In addition, time and cost parameters allow you to plan a cost reserve for the improvement of defects and the schedule of repairing construction defects.

REFERENCES