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Research paper

Supporting the technical management of residential buildings in the process of their exploitation

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Abstract: By analyzing the individual stages of the building's life cycle, it can be easily concluded that the building's exploitation process is the longest and at the same time it is the justification for the construction project related to the construction of this building. In the course of the building's exploitation, various phenomena occur that affect its condition and thus the possibility of unlimited use. These are natural phenomena, as well as phenomena derived from external influences, which often lead to deterioration of the building's condition, or even its degradation. In response to these phenomena, maintenance, renovation and modernization activities are undertaken. Technical management is related to the identification of these phenomena, programming of adequate measures and their implementation. The conducted analysis of the results of the survey in the group of property managers allows to state categorically that the process of technical management is relatively little supported by IT tools and is still based on individual analysis and often intuitive actions. The article presents the possibilities of applying an innovative approach in the acquisition and collection of information about the technical condition of buildings, indicating the legitimacy of standardizing information forms and using them in building a database of cases of the CBR (case based reasoning) inference system .

Keywords: building maintenance, CBR, text mining.

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1. Introduction

The exploitation of the building is the final stage in its life cycle, which justifies the effort made in the investment process. Taking this into account, it is expected that during its operation the building will have the required properties, e.g. in the technical and functional scope. Much attention has been paid to these issues [2, 3, 4, 9, 17, 19, 22, 32, 35, 36]. This shows, inter alia, on the validity of the building operation phase. However, in the course of the conducted analyzes, it was found that the process of technical management of the building is relatively little supported, and that in the process itself, most of the activity is intuitive and does not rely on any systemic approach. It seems that such a model of operation is not effective and in many cases it is possible to obtain better results in management. These conclusions result from observation of practical issues related to the activities of real estate management. The analysis of the literature allows to state that the problem of real estate management is current, including the issue of technical maintenance and the necessary financial outlays is noticeable and represented [6, 7, 12, 28].

In connection with the previous statement, the existing state was analyzed and new possibilities of innovative tools supporting the technical management process were indicated. First, standardization of the technical condition assessment was proposed, which is a key element necessary in the process of technical management. Subsequently, the legitimacy of collecting information about the building and its processing with the use of innovative data analysis techniques was indicated. Ultimately, based on the available data and information, it was proposed to build a supporting system based on inference from cases (CBR), the use of which will support the process of technical management. The engineering problem posed concerns undertaking maintenance and repair activities, and in particular their forecasting, and the construction of a base of cases and models of dependence of parameters describing the technical condition and expenditure on maintenance, preceded by the acquisition of knowledge about the building, constitutes a proposal to solve the problem.

2. Real estate management

Real estate management seems to be a narrow activity focusing on the results of construction production - construction objects, including buildings. It turns out, however, that this activity is complex, multi-faceted and depends on many external and internal factors. Many publications on the subject of property management present various approaches to property management, defining different classifications in management [4, 5, 22, 32]. Śliwiński [32] introduces the division of static

and dynamic real estate management, where he refers to static management as a traditional approach and inadequate to contemporary realities. Indicates that the static approach is limited to administrative, technical and economic activities to maintain the facility in proper condition. He defines the dynamic approach as a contemporary approach focused primarily on innovation and creativity in real estate management, with the focus not only on the real estate itself but also on the user's needs, including adapting to their changing needs. This results in a certain flexibility of management, and the dynamic approach itself equates to the term "facility management".

Bryx [5] defines the property management process as activities that relate to the proper use of the property. Such a definition of management in terms of the classification of approaches to property management presented by Śliwiński places property management as a technical and administrative process. At the same time, Bryx, seeing the problem and the actual essence of management, indicates routine activities:

- of a technical nature - consisting in the use, maintenance and renovation as well as real estate administration,
- of an economic nature - consisting in earning revenues, incurring expenses for maintenance and repair, depreciation of real estate.

Moreover, Bryx points to non-routine activities, which seems to correspond to an element related to the dynamic approach in management. He mentions here the fight for the increase in the value of the property, innovative expansion or restructuring, which may be implied by the needs of the real estate user.

Atkin and Brooks in the comprehensive study "Total facility management" [4] again point to the basics of property management, as well as a number of other management issues such as choosing the right strategy in management, outsourcing, special services and partnership, logistics, ordering, security and health protection, human resources, or information and knowledge management.

Referring to the term of technical management, one should mention a number of actions taken by the manager or, more generally, the decision-maker, aimed at maintaining the proper technical condition of the building allowing for unlimited use. These are, in particular, activities consisting in conducting regular inspections of the building and adequate repairs, renovations and modernizations.

3. Analysis of applied management approaches

Taking into account the previous comments on property management, attention was paid to the ways in which property managers operate in the management of residential buildings. The subject of the study was to identify the approaches used in management, especially in technical management in connection with economic factors, as well as in the field of management support tools. The conducted survey (2018) showed some interesting relationships and facts. The questionnaires in the form of an electronic form were sent to 62 entities operating in the real estate management market - mainly real estate managers, administrators and housing cooperatives from the Greater Poland area (region in central and western Poland). A 79% return was achieved. The cross-section of the surveyed entities from the point of view of the number of residential buildings managed by the entity, as well as the circumstances of managing real estate other than residential real estate is presented in Fig. 1

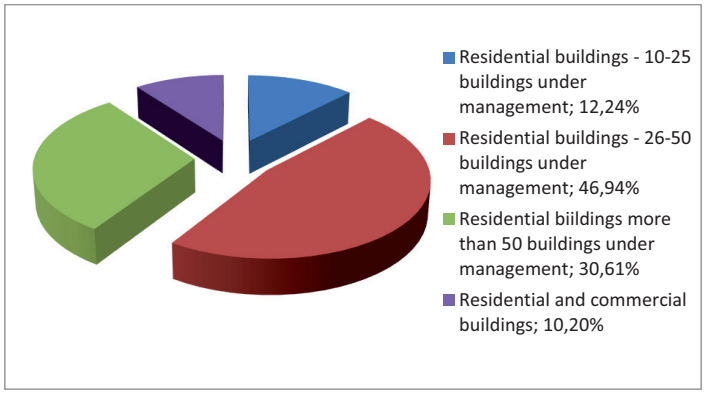


Fig. 1. Classification of the population of the surveyed entities. The largest share of entities managing 26-50 residential buildings

One of the key issues covered by the study was to define the use of management support tools by property managers and their nature, as well as awareness of the potential of innovative tools, where the developing BIM 7D technology was indicated [9, 15, 23, 25, 27, 29, 31, 35].

The results of the study are presented in Figs. 2 and 3. Interesting features include the use of dedicated computer applications supporting financial settlements and, at the same time, low use of management support applications in the technical aspect. The reasons for this phenomenon can be found in the lack of dedicated solutions for generally available IT tools and reducing the technical management issues in existing applications to a relatively low level of advancement (usually noting

an event covered by technical management in the calendar with the introduction of a note, lack of developed databases and knowledge bases). In addition, as a complement to the study, an average level of awareness of the potential for innovative solutions was noted - where BIM 7D technology was indicated. In the author's opinion, any system based on a database and knowledge base that supports management in the technical aspect can be adopted as a solution corresponding to the indicated one.

In order to define the approaches used by managers, it is impossible to present categorical conclusions. A great part (unfortunately) does not apply any systematic approach, and all activities in the field of technical management are carried out only in a situation of ultimate necessity and only with the condition of having appropriate financial resources. The use of such an approach basically leads to a complete reduction of maintenance activities and focusing only on undertaking renovation activities with a significant material scope. Often the scope of these renovation works is so extensive that the funds accumulated are insufficient and the current technical condition is so deteriorated that the implementation of activities other than renovation will not result in any improvement of this condition.

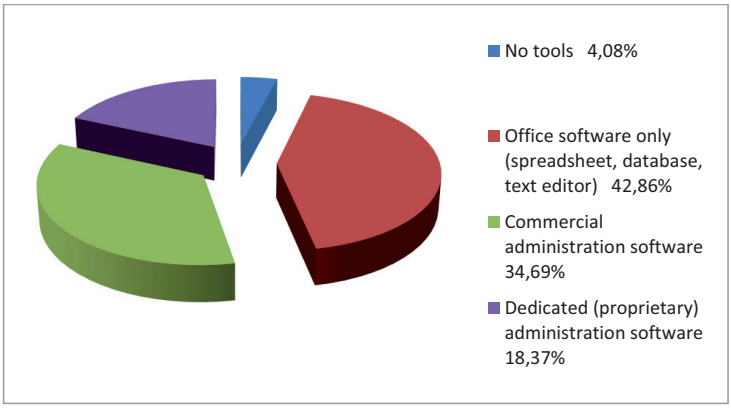


Fig. 2. The use of building management support tools

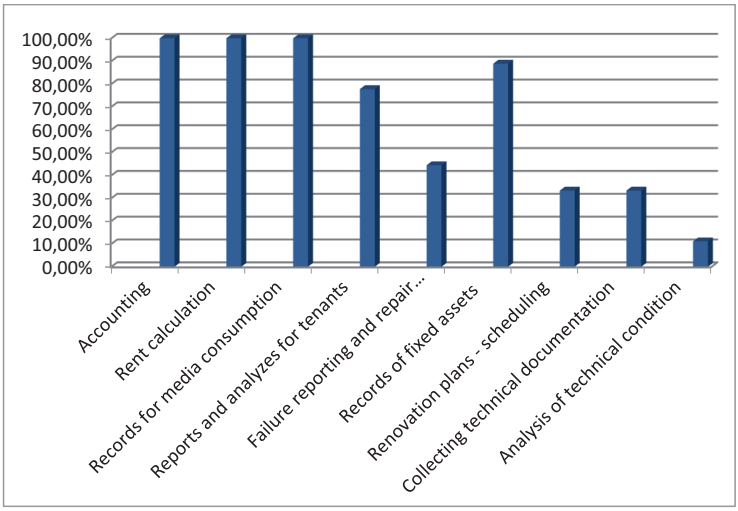


Fig. 3. Functions represented in the used building management tools

In addition to the above-described management method, which can be described as inadequate, managers use an approach consisting in the systematic indexing of renovation rates, which are a component of the rental rate (the rental rate includes a service charge - including administration, ongoing maintenance and indirect costs as well as repair fees) and collecting funds until they are used for renovation works, in connection with the need to perform them. In the meantime, less demanding maintenance works are carried out (e.g. painting works, possibly improving the aesthetics), which, however, as shown by the observations of the managers themselves, often do not bring the desired effect, as a result of which the technical condition of the property deteriorates.

The approach described above is perhaps slightly better than the one described earlier, it is also not the correct approach.

Only a negligible percentage of property managers monitor the technical condition of the property on an ongoing basis and, based on the conducted observations and analyzes of this condition, try to forecast activities and secure them also from the financial side. This mode of operation seems to correspond to the correct approach. The main problem in its application, however, is the manager's imperfect knowledge of the phenomena of technical wear that occur, its possible consequences for the facility, as well as the very issue of forecasting a change in technical condition seems to be based on intuition.

Therefore, it is reasonable to use tools supporting the technical management process.

4. Sources of information about buildings

The key to supporting the technical management of the facility is proper recognition of its current state. In this context, it is possible to mention the sources of information about the building, as it will be the focus of attention. The first sources of information about the building are the observations of the manager or administrator, as well as the record of technical defects - if it is kept. However, the listed sources are imperfect, mainly due to the lack of special knowledge among managers or administrators, as well as due to possible superficial observation. Also, the record of events - faults, failures may not be a categorical source of information about the condition of the building, at best it is a prognostic. A building book is a much better source of information about a building, which is an element required by the applicable law in the country [13, 14, 15, 17]. The book contains entries of authorized persons regarding the inspections and controls performed. As a rule, protocols of performed inspections and technical inspections are an attachment to the construction book. These protocols contain a description of all the signs that allow to state the current technical condition of the building, registered in the course of the visual inspection carried out by a construction engineer. Basic structural elements of the building are assessed: foundations (most often visible foundation walls), external and internal walls, ceilings, partition walls, staircases, window and door woodwork, roof and its covering, as well as devices and installations. A protocol prepared in this way has the character of a qualitative description, where on its basis the engineer controlling the building summarizes and evaluates it through qualitative values according to the adopted scale, e.g. very good, good, satisfactory, bad, very bad condition. It also happens that the rating is represented by a weighted degree of technical wear. Despite the harsh nature of such an assessment, it is usually subjective.

In terms of the development of BIM modeling, its usefulness and use at the stage of building operation can be indicated. This statement is, to a large extent, still of a potential nature, because, as the study shows, objects where BIM 7D has been implemented are rare - they did not occur in the study. In our national reality, the lack of BIM 7D implementation results from a delay in the application of BIM modeling at the design and implementation stage, as well as for other reasons (economic factors, insufficient education and dissemination).

5. Standardization of sources in the process of knowledge acquisition

Research conducted by the author, leading to the construction of a database on residential buildings, indicated one important need - standardization in the form and a dictionary of terms used in technical inspection reports, which is a valuable source of information about the building. The element used in the study was a set of protocols from inspections and inspections of the technical condition of residential buildings in the resources of managers in the city of Poznań and the agglomeration. Protocols from inspections of residential buildings categorized into groups related to the construction technology and the erection period were analyzed. A certain correlation was noticeable here, resulting mainly from the prevalence of certain technologies over time. A group of buildings in traditional technology (tenement houses from 1920-1950), in large-panel technology (apartment blocks from 1960-1990) and buildings in mixed technology (buildings from 1990-2010) were distinguished. It should be noted that the protocols were drawn up over a dozen years by various engineers, hence their different form and description.

In connection with the acquisition of knowledge, among others on the condition of residential buildings, various technical inspection protocols were analyzed. The text mining [13, 16, 17, 20, 21, 26, 33] approach was used in the analysis, due to the fact that the protocols from technical inspections are text documents and, in order to accelerate the analysis of a large number of these protocols, an automated approach to knowledge acquisition was chosen. 64 buildings were analyzed, for which a total of 529 protocols describing the technical condition of buildings in a given period of time were obtained. In accordance with the adopted algorithm of proceeding in the analysis (Fig. 4), protocols were first digitized. For this purpose, the OCR (optical character recognition) technique and methods of scanning documents were used, and in the event of technical problems with full-page scanning, a manual PEN scanner was used. Having analyzed protocols in digital form, the document was divided into sections regarding building data, sections regarding the description of the building condition and an assessment of the technical condition. After that, the algorithm of the text mining method was followed.

The specificity of the Polish language and the multitude of inflectional forms turned out to be a nuisance in the process. The Statistica environment was used in the text mining analysis. This environment does not support the Polish language, which can be described as highly inflectional. The process that occurs in text mining is stemming. This process can be described as the reduction of various forms by "cutting" the existing prefixes and suffixes to the root form representing the word. In a way, the equivalent of the stemming process is lemmatization, i.e. reducing a word in the

analyzed document to its basic form - infinitive or singular denominator. The result of text mining is obtaining a quantitative representation of a text document in the form of a BOW (bag of words) frequency matrix.

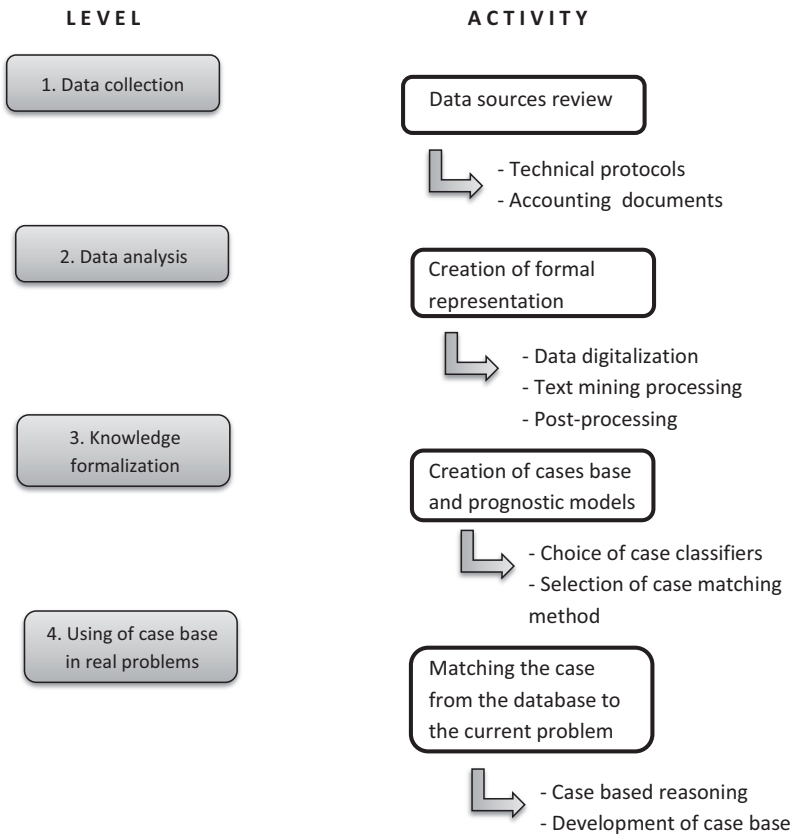


Fig. 4. Own algorithm of conduct in the process of knowledge acquisition and building a management support system

The main problem in the analysis is the dimensionality of the obtained BOW matrix. Its number of columns directly depends on the number of different words in the text document. Failure to carry out the stemming process or similar lemmatization results in the presence in the matrix of columns related to different inflectional forms of the same word and meaning. In addition to increasing the

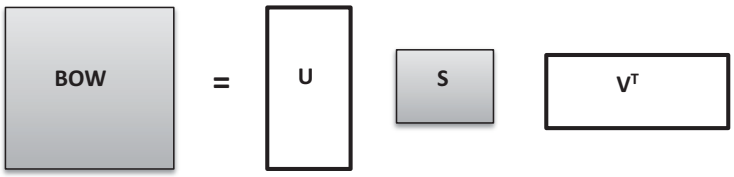
dimensionality of the matrix, this undoubtedly affects the sense and importance of further analysis. By performing the text mining process without stemming processing, the dimensions of the matrix with the number of words exceeding 600 for documents related to one building were obtained. When lemmatization was finally used, at the beginning, the dimension of the matrix was reduced for further analyzes, where the number of words corresponded to an average of 200. It should be noted that it is not just about the reduction of the matrix dimensionality itself. After all, there are known methods that allow for dimensionality reduction (e.g. PCA - principal components analysis, SVD - singular value decomposition). The use of the lemmatization process is primarily determined by the semantic purity of the document. The use of various inflectional forms may not result in a diametrically different interpretation of a quantified text document.

The analyzes carried out many times have shown the need and legitimacy of standardizing the form of the analyzed documents - technical inspection protocols, both in terms of the form and the language used. This is justified by the use of these documents in analyzes for the purposes of data and knowledge acquisition. In the course of the research, it was shown that the application of document form standardization reduces the processing time of the document, in particular its division and the earlier need to review the document itself. The use of standardized terms simplifies and also shortens the analysis of text mining itself, which reduces the initial sets but also the purity of the obtained results.

6. The use of knowledge in the building of the support system

The purpose of the analysis according to the algorithm presented in Fig. 4 was, in the first place, to develop a database of buildings and the subsequent construction of models related to the buildings, the use of which would support the management process in terms of planning the renovation policy and securing the necessary expenditure. The conducted survey research as well as direct observations of management issues indicate the existence of a real problem in the scope of forecasting and securing the necessary expenditure on the required repairs. The analysis of the literature allows to conclude that these issues are noticed and that there are solutions to solve the problem [3, 6, 7, 9, 12, 15, 17, 22, 28]. However, there are no known solutions to the problem of technical management of buildings based on the proposed approach, in particular the use of text data about the technical condition of the building. Also, the analysis of the actual state shows that the solutions proposed earlier are not popular, which results in a problem of a practical nature.

The listed building databases are a direct result of the analyzes carried out in the field of technical condition. A new element in relation to the approaches used in the construction of this type of databases is the inclusion of a variable describing the technical condition in an abstract form for the recipient of the vector. The components of this vector are the transposed values of the frequency matrix, which is the formal form of the text description of the technical condition (BOW matrix). The idea of transformations using singular value decomposition is presented in Fig. 5.



BOW - unconverted frequency matrix (Bag Of Words)
U matrix - terms in the space defined by its components
Matrix V - documents in the space defined by the components
Matrix S - diagonal matrix, the meaning of individual components

Fig. 5. The idea of transforming the distribution according to singular values

At the same time, the base includes the weighted average degree of technical wear determined during the preparation of the building inspection report. If this parameter is missing in the protocol, which is the result of the lack of standardization of post-control protocols, the weighted average degree of technical wear was determined and included in the database.

Apart from the parameter related to the technical condition, the database also takes into account other features. The selection of the features describing the facility resulted from the availability of data that were arbitrarily determined as relevant in the course of the analysis of building documentation. These are mainly features corresponding to the technology of the erected building. Main classes characterizing typical technologies, basically appropriate for the period of building erection, are distinguished here: traditional technology - old buildings, city stones, prefabricated large-panel technology - buildings 30-60 years old, multi-storey, widely represented in urban estates, traditional mixed technology - contemporary buildings up to 30 years, when there are elements of reinforced concrete, prefabricated and traditional construction - mainly in the field of vertical brick partitions. In addition, the database includes a feature such as the age of the building, which is very often related to the technical condition of the building. Other characteristics

describing the building is the ownership structure, where, based on the analysis of the facts, the following classes were distinguished: housing association, housing association and other forms. In addition, information on the share of communal premises, the number of co-owners, or the fact that the building is under the care of the conservator of monuments was included. Apart from the parameters describing the technical condition, the parameters characterizing the expenditure on the maintenance of the building are very important. These are the amounts resulting from the analysis of accounting documentation indicating the previously incurred expenditure on renovation, modernization or ongoing maintenance of the building. Outlays of a different nature, in particular amounts related to taxes or fixed fees, were excluded from the analysis.

The building base created in this way corresponds to the case base in the CBR system, which buildings for the purposes of the system will be defined as representative buildings. Models of the dependence of the age of the building, the technical condition of the building and the expenditure on building maintenance have been developed for the buildings. These models are part of the problem solution because they indicate the maintenance policy and the effect observed over time - the technical condition of the building. In CBR methods, much attention is paid to defining the rules for finding an adequate case [1, 10, 11, 18, 24,30,34, 37]. Examples of searching for similar cases can be found in the literature. One of the most frequently used and at the same time uncomplicated is the algorithm developed by Cortes. It determines the value of the similarity function between the query Q and the case from the base C. The value of the function is the weighted average of the attributes of the compared cases. The method of determining the value of the similarity function is determined by the relationship:

$$SIM(Q,C) = \frac{\sum_{i=1}^{n} w_i sim_i(Q_i,C_i)}{n} \tag{1}$$

where:

Q – means query,,

C – a case saved in the database,

sim(Q,C) – is the value of global similarity between the query and the case,

n – is the number of compared attributes,,

w_i – is the weight of a given attribute,

sim_i – is the similarity value of the i-th attribute.

In the used approach, the rule selecting a case from the database was based on defined and ordered checking criteria. First, the criteria of the so-called input, in particular the technology of the building (this criterion has already been defined as the main classifier dividing the entire population into three groups), area and volume indicators and its age, while the technical condition is the decisive criterion. This criterion was based on the similarity of the technical condition of the building from the database and the analyzed case. Due to the fact that the technical condition is represented by the formal form of a text description, it was possible to apply a number of methods available for quantitative issues. Clustering based on the agglomeration approach using the Ward's method and the Euclidean distance measure according to the general formula was used for the final verification of the cases from the base with the analyzed case:

$$d(x,y) = \sqrt{\sum_{i=1}^{p}(x_i - y_i)^2} \tag{2}$$

An example of an analysis using the adopted agglomeration approach is presented in Fig. 6.

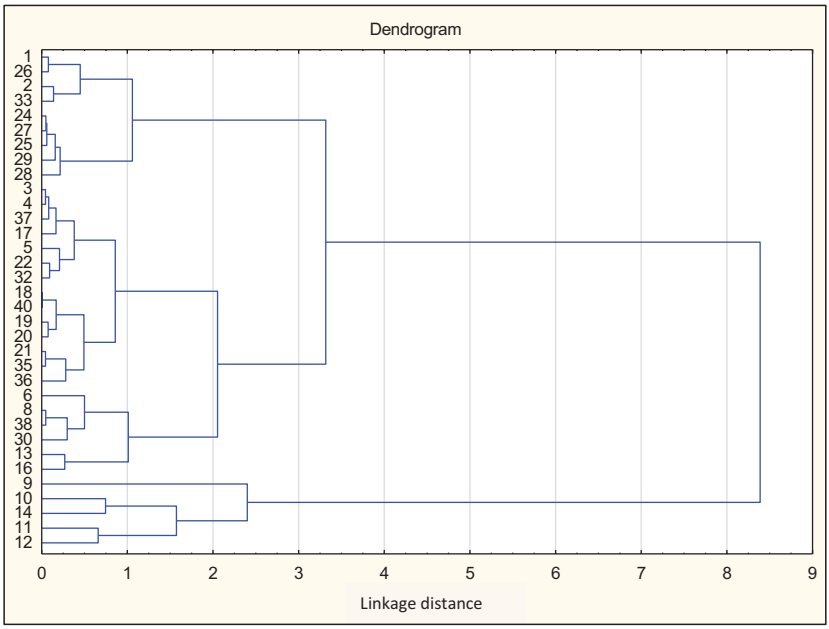


Fig. 6. Dendrogram for the analysis of 40 cases (buildings). The tested feature corresponds to the technical condition of buildings in prefabricated technology. The entered case was marked with the number 1.

In practice, searching the case base consists of introducing the analyzed case represented by a vector describing the technical condition into its resources and then launching the agglomeration algorithm. As a result, it is possible to identify the case from the base closest to the analyzed one and, based on its features, start inference for a new case, in particular by analyzing the technical condition as a variable depending on time and expenditure on building maintenance.

7. Conclusions

The presented issues of analysis of the available sources of information about the technical condition of buildings are aimed at supporting the building management process. Technical management seems to be the primary issue in terms of the usability of the building, its durability and safety. As it results from the analysis of the surveyed respondent, the actual state of technical management indicates a shortage of supporting tools, as well as often an inappropriate approach in management. The use of standardization in the description of the technical condition in connection with the required obligatory inspections and reviews creates an opportunity to create the foundations of a management support system based on the construction of a case base and forecasting models. Thanks to modern techniques of data analysis as part of text mining analysis and by inference from cases, it is feasible to build a supporting tool. The possibility and legitimacy of developing the proposed approach is noticed by building an application dedicated to mobile devices (such as a smartphone, tablet), which would allow, through a standardized form and dictionary, to carry out technical condition checks and, at the same time, to automatically collect data collected in databases used in the application.

References

[1] Agnar, A., Plaza, E., “Case-Based reasoning: Foundational issues, methodological variations, and system approaches”, AI Communications. IOS Press, Vol. 7: 1, pp. 39-59, 1994.
[2] Alshamrani, O.S., Alshibani, A., “Automated decision support system for selecting the envelope and structural systems for educational facilities”, Building and Environment, Vol. 181, 106993, 2020 https://doi.org/10.1016/j.buildenv.2020.106993
[3] Araszkiewicz, K., “Digital Technologies in Facility Management - The state of Practice and Research Challenges”, Procedia Engineering 196, 1034 – 1042, 2017. http://dx.doi.org/10.1016/j.proeng.2017.08.059
[4] Atkin B., ”Total Facility Manahement”, Wiley and Sons, 2015.
[5] Bryx M.,”Podstawy zarządzania nieruchomościami”, Wydawnictwo Poltext, Warszawa 2009
[6] Bucoń R., “Model decyzyjny wyboru wariantów remontu lub przebudowy budynków mieszkalnych” Politechnika Lubelska, 2017.
[7] Bucoń, R., Sobotka A., „Model decyzyjny wyboru rozwiązań remontowych budynków mieszkalnych”. Budownictwo i Inżynieria Środowiska, 59(3), 57-65, 2012

[8] Chen, Q., García de Soto, B., Adey, B.T., "Construction automation: Research areas, industry concerns and suggestions for advancement", Automation in Construction, Vol. 94, 22-38, 2018. http://dx.doi.org/10.1016/j.autcon.2018.05.028

[9] Chen, W., Chen, K., Cheng, J.C.P., Wang, Q., Gan, V.J.L., "BIM-based framework for automatic scheduling of facility maintenance work orders", Automation in Construction, Vol. 91, 15-30, 2018. http://dx.doi.org/10.1016/j.autcon.2018.03.007

[10] Chua, D.K.H., Li, D.Z., Chan, W.T. H., "Case-based reasoning approach in bid decision making", Journal of Construction Engineering and Management 127(1), 2001. http://dx.doi.org/10.1061/(ASCE)0733-9364(2001)127:1(35)

[11] De Mantaras, R.L., Mcsherry, D., Bridge, D., Leake, D., Smyth, B., Craw, S., Faltings, B., Maher, M.L., Cox, M.T., Forbus, K., Keane, M., Aamodt, A., Watsoni, I., "Retrieval, reuse, revision and retention in case-based reasoning", The Knowledge Engineering Review, Vol. 00:0, 1–2. 2005. http://dx.doi.org/10.1017/S0269888906000646

[12] Dębski P., „Prognozowanie wydatków na remonty przy użyciu sztucznych sieci neuronowych", Przegląd Budowlany 10/2001, s. 34–36. 2001.

[13] Gajzler M., "Protocols from periodic inspection of buildings in text mining analysis - advantages and problems of analysis", MATEC Web Conf., Vol. 222, 01004, 2019 http://dx.doi.org/10.1051/matecconf/201822201004

[14] Gajzler M., "Usefulness of Mining Methods in Knowledge Source Analysis in the Construction Industry", Archives of Civil Engineernig, Vol. 62/1, 127-142, 2016. http://dx.doi.org/10.1515/ace-2015-0056

[15] Gouda Mohamed, A., Abdallah, M.R., Marzouk, M., "BIM and semantic web-based maintenance information for existing buildings", Automation in Construction, Vol. 116,103209, 2020 http://dx.doi.org/10.1016/j.autcon.2020.103209

[16] Guerrero, J.I., León, C., Monedero, I., Biscarri, F., Biscarri, J., "Improving Knowledge-Based Systems with statistical techniques, text mining, and neural networks for non-technical loss detection", Knowledge-Based Systems, Vol. 71, 376-388, 2014. http://dx.doi.org/10.1016/j.knosys.2014.08.014

[17] Gunay, H.B., Shen, W., Yang, C., "Text-mining building maintenance work orders for component fault frequency", Building Research and Information , Vol. 47, 518-533, 2019. http://dx.doi.org/10.1080/09613218.2018.1459004

[18] Jiang, Z., Jiang, Y., Wang, Y., Zhang, H., Cao, H., Tian, G.," A hybrid approach of rough set and case-based reasoning to remanufacturing process planning", Journal of Intelligent Manufacturing, 30(1):19-32, 2019. http://dx.doi.org/10.1007/s10845-016-1231-0

[19] Kasprowicz, T., Eksploatacja obiektów budowlanych. Materiały Konferencji Naukowo-Technicznej: Problemy Naukowo-Badawcze Budownictwa. Krynica, 171-178, 2005.

[20] Khadjeh Nassirtoussi, A., Aghabozorgi, S., Ying Wah, T., Ngo, D.C.L., "Text mining for market prediction: A systematic review", Expert Systems with Applications, Vol. 41/16, 7653-7670, 2014. http://dx.doi.org/10.1016/j.eswa.2014.06.009

[21] Kobayashi, V.B., Mol, S.T., Berkers, H.A., Kismihók, G., Den Hartog, D.N., "Text Mining in Organizational Research", Organizational Research Methods, Vol. 21/3, 733-765, 2017. http://dx.doi.org/10.1177/1094428117722619

[22] Langevine R., Allouche M., Abourizk S., "Decision support tool for the maintenance management of buildings", Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montreal–Canada, June 14–16, 2006.

[23] Leite, F., Cho, Y., Behzadan, A.H., Lee, S., Choe, S., Fang, Y., Akhavian, R., Hwang, S., "Visualization, Information Modeling, and Simulation: Grand Challenges in the Construction Industry ",Journal of Computing in Civil Engineering, Vol. 30(6), 04016035-1:30, 2016. http://dx.doi.org/10.1061/(ASCE)CP.1943-5487.0000604

[24] Leśniak A., Zima K., "Cost Calculation of Construction Projects Including Sustainability Factors Using the Case Based Reasoning (CBR) Method", Sustainability, 10(5), 1608, 2018 http://dx.doi.org/10.3390/su10051608

[25] Marmo, R., Polverino, F., Nicolella, M., Tibaut, A., "Building performance and maintenance information model based on IFC schema", Automation in Construction, Vol. 118, 103275, 2020 http://dx.doi.org/10.1016/j.autcon.2020.103275

[26] Martens, D., Provost, F., “Explaining data-driven document classifications”, MIS Quarterly: Management Information Systems, Vol. 38/1, 73-100, 2014. http://dx.doi.org/10.25300/MISQ/2014/38.1.04
[27] Motawa, I., Almarshad, A, “A knowledge-based BIM system for building maintenance”, Automation in Construction, Vol. 29, 173-182, 2013. http://dx.doi.org/10.1016/j.autcon.2012.09.008
[28] Nowogońska B., Skarzyński A., „Programowanie remontów użytkowanych budynków mieszkalnych metodą stosowania wskaźników”, Przegląd budowlany, 3/2006, s. 40–43, 2006
[29] Peng, Y., Lin, J.-R., Zhang, J.-P., Hu, Z.-Z., “A hybrid data mining approach on BIM-based building operation and maintenance”, Building and Environment, Vol. 126, 483-495, 2017. http://dx.doi.org/10.1016/j.buildenv.2017.09.030
[30] Pinto, T., Faia, R., Navarro-Caceres, M., Santos, G., Corchado, J.M., Vale, Z., “Multi-agent-based CBR recommender system for intelligent energy management in buildings”, IEEE Systems Journal, Vol. 13/1, 1084-1095, 2019. http://dx.doi.org/10.1109/JSYST.2018.2876933
[31] Pishdad-Bozorgi, P., Gao, X., Eastman, C., Self, A.P., “Planning and developing facility management-enabled building information model (FM-enabled BIM)“, Automation in Construction, Vol. 87, 22-38, 2018. http://dx.doi.org/10.1016/j.autcon.2017.12.004
[32] Śliwiński A., “Zarządzanie nieruchomościami”, Agencja Wyd. Placet, 2006
[33] Thangaraj, M., Sivakami, M., “Text classification techniques: A literature review”, Interdisciplinary Journal of Information, Knowledge, and Management, Vol. 13, 116-135, 2018. http://dx.doi.org/10.28945/4066
[34] Watson, I., Marir, F., “Case-Based Reasoning: A Review”, Knowledge Engineering Rewiev, Vol. 9/4, 327-354, 1994 http://dx.doi.org/10.1017/S0269888900007098
[35] Yousefli, Z., Nasiri, F., Moselhi, O., “Maintenance workflow management in hospitals: An automated multi-agent facility management system”, Journal of Building Engineering, Vol. 32, 101431, 2020 http://dx.doi.org/10.1016/j.jobe.2020.101431
[36] Zavadskas, E.K., Turskis, Z., Vilutienė, T., Lepkova, N., “Integrated group fuzzy multi-criteria model: Case of facilities management strategy selection“, Expert Systems with Applications,Vol. 82, 317-331, 2017 http://dx.doi.org/10.1016/j.eswa.2017.03.072
[37] Zhao, X., Tan, Y., Shen, L., Zhang, G., Wang, J., “Case-based reasoning approach for supporting building green retrofit decisions”, Building and Environment, Vol.160:106210, 2019. http://dx.doi.org/10.1016/j.buildenv.2019.106210

Wspomaganie zarządzania technicznego budynkami mieszkalnymi w procesie ich eksploatacji

Słowa kluczowe**:** zarządzanie nieruchomościami, CBR, text mining

Streszczenie:

Okres eksploatacji obiektu budowlanego jest docelowo najdłuższym etapem w cyklu życia obiektu, któremu podporządkowane są wszelkie poprzedzające go etapy cyklu życia. Analizując literaturę przedmiotu odnosi się wrażenie, że proporcjonalnie mało uwagi poświęca się zagadnieniom występującym na etapie eksploatacji. Gros uwagi skupione jest na zagadnieniach występujących na etapie projektowania, przygotowania i samej realizacji inwestycji. Poniekąd jest to właściwe, albowiem poprawne zaprojektowanie i zrealizowanie przedsięwzięcia winno skutkować redukcją problemów na etapie eksploatacji. Nie można ich jednak całkowicie wyeliminować, albowiem wynikają również z czynników zewnętrznych jak i naturalnych. Jednocześnie należy zauważyć, że zagadnienia problemowe występujące na etapie eksploatacji mają charakter kompleksowy i obejmują wiele czynników, w tym również pozatechnicznych.

Obserwacje bezpośrednie zagadnień jakie występują na etapie eksploatacji budynków mieszkalnych pozwalają sformułować wniosek o konieczności stałego monitorowania stanu technicznego budynku i w związku z jego zmianą aktywnego działania poprzez planowanie adekwatnej polityki utrzymaniowej i remontowej. Również bezpośrednie

obserwacje pozwalają stwierdzić, że w wielu przypadkach, pomimo zaistnienia potrzeby wdrożenia działań utrzymaniowych i remontowych, ze względów ekonomicznych, te nie są wdrażane. Wynika to z faktu, że wdrożenie działań, w szczególności remontowych, wymaga odpowiednio wczesnego przygotowania i zapewnienia środków finansowych na niezbędne nakłady. W przypadku drastycznego pogorszenia stanu technicznego budynku, częstokroć wysokość niezbędnych nakładów przewyższa możliwości finansowe właścicieli i użytkowników, co w konsekwencji prowadzi do jeszcze większej degradacji stanu technicznego. Z uwagi na to, istotnym jest prognozowanie nakładów finansowych niezbędnych na działania utrzymaniowe i remontowe, których zakres jak i zasadność wynika ze zmian stanu technicznego budynku.

W aspekcie stwierdzonej zasadności prognozowania nakładów finansowych oraz planowania polityki utrzymaniowo-remontowej dokonano analizy stanu faktycznego poprzez badania ankietowe. Na podstawie uzyskanych wyników stwierdzono m.in., że wykorzystanie rozwiązań IT dedykowanych do zarzadzania nieruchomościami obejmuje 53,06% badanych podmiotów – zarządców nieruchomości. Ponadto stwierdzono, że same rozwiązania IT dedykowane dla zarządzania nieruchomościami w marginalny sposób obejmują zagadnienia typowo techniczne, a akcentują zagadnienia administrowania, rozliczania opłat i ich księgowania, czy komunikacji. Co szczególnie mało satysfakcjonujące, w oparciu o wykonane badanie ankietowe, jak również obserwacje bezpośrednie, zauważa się brak wykorzystania zalet BIM w zarządzaniu nieruchomościami. Ma to jednak uzasadnienie w tym, że technologia BIM obecnie upowszechniła się w projektowaniu i w realizacji i w związku z tym dopiero w pewnej perspektywie czasowej zauważalne będzie wykorzystanie BIM w zarządzaniu nieruchomościami, tym bardziej, że już kilka lat temu stworzono podwaliny BIM 7D.

W związku z podjętym celem – budowy narzędzia wspomagającego zarządzanie techniczne budynkami mieszkalnymi zwrócono uwagę na źródła informacji i wiedzy o budynku, w szczególności jego stanie technicznym, a także w dalszych krokach – nakładach finansowych na prowadzone w budynku działania utrzymaniowo-remontowe. Jako istotne źródło informacji o stanie technicznym budynku, ale nie tylko, wskazano książkę obiektu budowlanego oraz zawarte tam protokoły pokontrolne. Problem, który dostrzeżono podczas analizy wymienionych źródeł informacji o budynku, to po pierwsze postać tekstowa dokumentów oraz brak standaryzacji formularzy. O ile niezaprzeczalnie książka obiektu budowlanego oraz protokoły pokontrolne stanowią cenne źródło aktualnych informacji o stanie technicznym budynku, o tyle ich analiza bez narzędzi jest pracochłonna i czasochłonna. Mając to na uwadze wykorzystano w analizie metodę text mining, wielokrotnie opisywaną i sprawdzoną w zastosowaniach. Przy okazji analizy text mining zwrócono uwagę na jej składowy proces określany w języku angielskim mianem stemmingu. Jest to proces, w którym słowa sprowadzane są do postaci rdzeniowej. Ze względu na brak w stosowanym rozwiązaniu narzędzia Statistica Text Miner algorytmu obsługującego język polski, analizę wykonano bez sprowadzenia słów do postaci rdzeniowej, a także poprzez podejście manualne w obróbce tekstu zastosowano lematyzację. Zastosowanie lematyzacji pozwoliło w rezultacie w znaczącym stopniu zredukować wymiarowość wynikowej macierzy BOW (bag of words) nawet o przeszło 60%, która to macierz stanowiła reprezentację formalną dokumentu tekstowego. W kolejnych krokach zastosowano postprocesing poprzez rozkład według wartości osobliwych i w rezultacie poprzez reprezentację wektorową uzyskano reprezentanta stanu technicznego budynku, co obok innych cech takich jak technologia budowy, wiek, powierzchnia użytkowa, liczba kondygnacji, wielkość nakładów na utrzymanie i remont, struktura właścicielska, udział lokali komunalnych w budynku opisywało przypadki budynków zebrane w bazie.

Przeprowadzone analizy dla 64 budynków zrealizowanych w jednej z trzech wyszczególnionych technologii (tradycyjna, wielkopłytowa prefabrykowana, tradycyjna współczesna) dały podstawę do budowy bazy przypadków,

gdzie określone zależności nakładów i stanu technicznego mogą stanowić element pomocny we wnioskowaniu dla nowych przypadków, dla których istotna jest prognoza stanu technicznego i niezbędnych nakładów na jego utrzymanie czy poprawę. Przy tym wskazano na systemy wnioskowania w oparciu o przypadki, gdzie zasadniczym zagadnieniem natury technicznej jest przyjęcie algorytmu dobierającego przypadki z bazy danych. W przyjętym podejściu zastosowano m.in. metodę Warda z miarą odległości euklidesowej. W rezultacie uzyskano dendrogram pozwalający na wskazanie najbardziej zbliżonych do siebie przypadków z punktu widzenia stanu technicznego. Wcześniej jednak dla selekcji przypadków zastosowano kryteria wejściowe, których spełnienie jest niezbędne. Kryteria związane były z uzyskaniem zgodności przypadków w zakresie technologii i przedziału okresu wzniesienia budynku. Wybór najbardziej zbliżonego przypadku z bazy do przypadku nowego pozwolił na prześledzenie zależności nakładów utrzymaniowo-remontowych i stanu technicznego przypadku z bazy i na tej podstawie sformułowanie wniosków dla nowego przypadku.

Zasadniczymi wnioskami wynikającymi z prowadzonych analiz jest zasadność gromadzenia informacji o stanie technicznym budynków oraz innych charakterystykach z nimi związanych w aspekcie zarządzania technicznego budynkiem. Zauważa się korzyści wynikające z stosowania metod zautomatyzowanej akwizycji wiedzy, w szczególności w przypadku tekstowych źródeł informacji i wiedzy, a także stosowania podejść eksploracyjnych w analizie danych. Elementem sprzyjającym rozwojowi podejścia zautomatyzowanego w akwizycji wiedzy jest standaryzacja dokumentów źródłowych jak i ujednolicenie stosowanego w nich słownika. Uzyskanie odpowiednio liczebnej populacji przypadków budynków, dla których możliwym jest określenie podstawowych charakterystyk, a także reprezentacji formalnej stanu technicznego i nakładów na utrzymanie i poprawę tego stanu daje podstawy do budowy bazy przypadków na potrzeby wnioskowania z przypadków.

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