Строительные материалы и изделия
Construction Materials and Products

journal homepage: https://bstu-journals.ru

ISSN
2618-7183

DOI: 10.58224/2618-7183-2024-7-6-9

Development of a method to identify the need for capital repairs and renovation of administrative buildings

Lapidus A.A. [1], **Topchiy D.V.** [1], **Kuzmina T.K.*** [1], **Bolshakova P.V.** [1], **Ganzen E.V.** [1]

[1] Moscow State University of Civil Engineering (National Research University), Russia

Abstract. Identification of needs for production resources during repairs, restoration and reconstruction strongly relies on administrative and engineering solutions. The scope of problems, addressed by these projects, encompasses limited production and non-production resources, as well as unpredictable external risks, or ambiguous initial information about construction facilities. Today all available decision-making principles, underlying the long-term planning of capital repairs and reconstruction of civil buildings, disregard a great number of production-related and administrative factors. Advanced design software and applications, developed on the basis of various mathematical principles, used to describe construction technologies and processes, facilitate decision making by specialists responsible for the implementation of such projects. In this case, principal factors include optimal labour costs and guaranteed quality. The article outlines basic decision-making principles underlying a program of capital repairs or reconstruction of civil buildings in operation. These principles are based on computing the potential of administrative and engineering solutions. Scientific research, conducted in the process of drafting this article, encompasses the analysis of various production-related factors characteristic of production processes, including capital repairs and reconstruction. These factors are represented as a system of linguistic data flow that specifies term sets and membership functions for each condition. Most significant factors are the technical condition of permanent buildings and structures, the attitude of consumers to the subject of the study, and its operation period starting upon completion of earlier repair or reconstruction, as well as the serviceability of internal and external engineering systems. As a result of scientific research, the authors developed and tested a new method used to identify the need for construction and installation work performed within the framework of capital repairs or renovation. The novel method includes specific requirements that apply to the scope of work and the sequence of its implementation.

Keywords: capital repairs, reconstruction, administrative buildings, decision-making method, administrative and engineering solutions

*Corresponding author E-mail: KuzminaTK@gic.mgsu.ru

Received July 25, 2024; Received in revised form October 8, 2024; Accepted November 19, 2024

Please cite this article as: Lapidus A.A., Topchiy D.V., Kuzmina T.K., Bolshakova P.V., Ganzen E.V. Development of a method to identify the need for capital repairs and renovation of administrative buildings. Construction Materials and Products. 2024. 7 (6). 9. DOI: 10.58224/2618-7183-2024-7-6-9

1. INTRODUCTION

Higher living standards, coupled with a good quality of life, is a strategically important task of any state, focused on the interests of its citizens, maintenance of comfortable living standards and natural development of the country as a whole.

In recent years, greater attention is drawn to high-quality design of new residential construction projects to ensure comfortable, safe and environmentally friendly occupancy. Working environments are equally important, as 90% of the population has an 8-hour five-day workweek. Therefore, a person spends half of his or her life at work.

A survey conducted among students of industry-specific educational institutions shows that a working environment is the most important factor determining the choice of future professions, while salary is the second important factor.

Comfortable workplaces, meeting the most recent standards, is an equally important task for any state, given that 70-75% of workplaces are located in administrative buildings.

Existing administrative buildings are not only physically obsolete in terms of design, they cannot satisfy the need for high-quality living. An equally important fact is that the majority of administrative buildings, located in historic city centers, are items of cultural heritage. Hence, capital repairs or reconstruction can extend the service life of buildings, make them more lucrative for the population, preserve the external architectural character of historic centers and increase the investment attractiveness of underdeveloped areas.

Undoubtedly, the main determinants of capital repairs or reconstruction are the funding and the technical condition of administrative buildings. However, no state can pay for simultaneous capital repairs or reconstruction of all administrative buildings that need it.

Consequently, a research-based approach to identifying the need for capital repairs or reconstruction of administrative buildings is relevant at all times.

The analysis of the technical condition of buildings suggests that they age and deteriorate simultaneously. Hence, the reasons for and the frequency of capital repairs or reconstruction demonstrate an evident dependence [1, 2].

Over time, all buildings are subjected to physical and moral deterioration and if capital repairs or reconstruction is not performed in time, the remaining service life of a building becomes shorter, buildings become unable to perform their functions, their operation becomes less safe, and lives of occupants are placed under a threat.

Regular inspections are carried out in the course of the building operation. Inspection results serve as the basis for an inspection certificate that has a list of defects, subsequently used to justify the need for capital repairs or reconstruction.

In addition, capital repairs or reconstruction of buildings can be implemented to change the building function, increase its capacity, improve the building infrastructure by installing advanced items of equipment and upgrading the building to meet the requirements of revised regulations and modern standards.

As a result of capital repairs, engineering and economic characteristics of a building remain unchanged, and the same about its service life.

Capital repairs of administrative buildings can be broken down into the two main types:

1. Integrated capital repairs affect structural elements and engineering systems of the entire building and involve suspension of activities in a building.

2. Selective capital repairs involve work performance in parts of a building or a building block without suspending the activity of any institution inside it. It may partially affect structural elements and some engineering systems.

Any work starts with a comprehensive inspection of a building, identification and registration of defects, as well as their effect on operational characteristics [3-5].

Recommendations are drafted upon a comprehensive inspection. They focus on eliminating defects that affect the operational reliability of a building in addition to the analysis of the engineering condition of a building. To get an unbiased assessment of the amount and cost of the work to be performed, it is advisable to develop the engineering part of the project (a project plan), which lists the amount and items of work, the sequence of work items to be performed, the demand for basic machinery, mechanisms and equipment, as well as workforce [6]. The term of work performance must take into account the features of the construction site and logistics arrangements for buildings in restrained urban conditions.

As a rule, buildings with large-scale structural damage are added to the list of structures to be restored. The cost of such work is high, and the project implementation sequence is determined by the priority of tasks if certain restrictions and limits apply. As a result, buildings featuring maximum wear and tear of structures are the first ones to be restored, if their technical condition is close to the emergency condition. However, not a single discovered defect should reduce the operational reliability of individual structures by more than 60%, and its costs should not be comparable with the construction of a new facility. Three project implementation scenarios are developed; they are known are the basic scenario, the supplementary scenario, and the standby scenario. Their development must be completed before the repair and restoration budget is ready.

Modern civil buildings have high-tech engineering equipment and networks that ensure comfort and safety of occupants. Consequently, restoration and construction is of particular importance for these buildings. Making a list of and a budget for administrative and engineering solutions is a highly relevant and important task, if their implementation can reduce the time and cost of work without compromising its quality.

A distinctive feature of such projects is federal funding provided through co-investment programs. This fact should be taken into account when a system of factors, affecting administrative and engineering solutions, is developed for projects that encompass capital repairs and reconstruction of administrative buildings.

Against this background, the federal budget is the only institution guaranteeing performance of obligations. However, current restrictions and rules, as well as the approval process itself, translate into longer approval terms which must necessarily be taken into account when administrative and engineering solutions are devised.

At this stage, it is important to correctly determine the cost of capital repair or reconstruction, as well as the timing of their implementation, in order to avoid future problems caused by the lack of funding.

When a decision is made to implement a capital repair project and the construction facility is added to the “list of direct investments”, tender documents must be drafted to select the design company that will be responsible for the project documentation.

It is also necessary to take into account any potential changes in timing caused by external and internal factors, which are often unpredictable and stochastic in nature. The reason for the extension of terms is the human factor, or incompetent decisions and errors made at the design stage. The unpredictable nature of errors is also characteristic of other processes, in particular, failure of construction equipment, engineering networks, as well as supply of low-quality materials and failure to meet requirements that apply to transportation, storage and use of materials.

In most cases, construction and installation work is performed at the sites of operated administrative buildings. Hence, any work should be performed in compliance with effective in-house regulations, access and control requirements, in-house provisions and corporate instructions. No work should affect any neighboring buildings.

The above scope of problems prevents the application of traditional mid-term scheduling methods. The only solution is the application of probabilistic modeling and neural forecasting [7].

A key task of this research is to develop a mathematical framework based on integral parameters. The framework purpose is to compute the efficiency of a capital repairs and reconstruction project taking into account various production processes [8].

The generalized value of potential effectiveness of administrative and engineering solutions is an adequate value based on the integral characteristic of dynamic construction processes at a construction site. This potential ensures the qualitative and quantitative evaluation of the proposed construction method [9], taking into account several engineering features and construction process arrangements.

Methods that are currently used to manage and streamline construction processes during capital repairs and reconstruction often disregard system interaction between individual processes in time and space [10, 11]. In this regard, the development and computation of the potential of administrative and engineering solutions will be more consistent with real conditions of construction and establish conditions needed to identify the stability of such systems. This potential takes into account dynamic changes and interrelations between individual engineering, administrative and management parameters [12, 13].

Hence, the main task, accompanying the improvement of efficiency of solutions during capital repairs and reconstruction by method of mathematical modeling, is to develop and compute an integral value characterizing the validity of various production factors (Fig. 1).

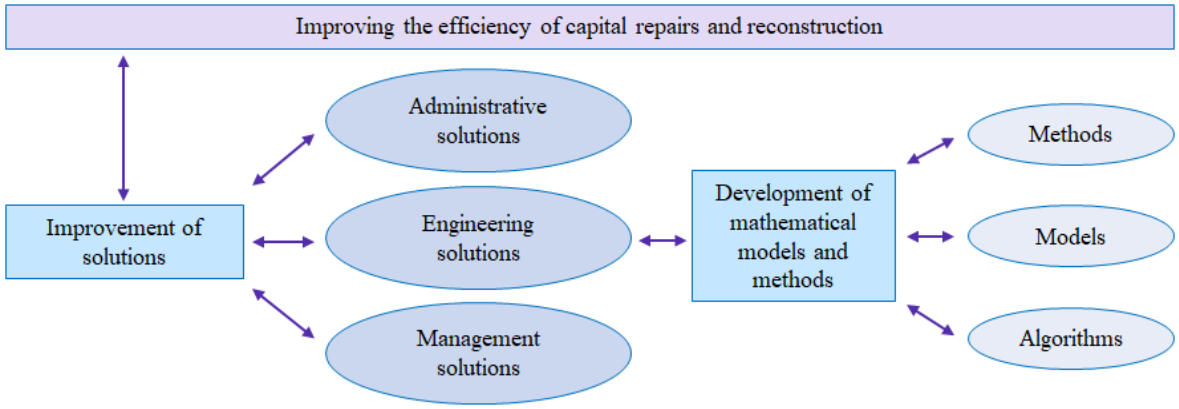


Fig. 1. A block diagram of administrative, engineering and management solutions aimed at improving the efficiency of capital repairs and reconstruction.

Analysis of available scientific research findings, regulatory and engineering documentation, as well as practical arrangements and implementation of capital repairs and reconstruction of administrative buildings shows the absence of research-based methods for evaluating the process of making decisions about capital repairs or reconstruction, taking into account the entire system of impact factors (technical condition, building operation features, building sites, sources and amounts of funding, etc.).

This method can be based on the integral value of potential, taking into account a large number of different administrative and engineering solutions.

It is noteworthy that factors affect the potential at all stages of capital repairs (repair and construction work). Besides, the computed potential varies depending on the effect of factors in the process of the building change.

2. METHODS AND MATERIALS

The method of expert evaluations, system engineering, integral evaluation, statistical evaluation of the questionnaire findings and modeling of the results were used in the study [14].

The comprehensive evaluation of processes that are underway during capital repairs and reconstruction differs the proposed method from earlier techniques describing the state of the company and the work performance methodology [15-18].

The method of expert surveys was applied to study individual factors affecting work performance processes: respondents could rank the effect of on the integral potential.

Without taking into account the practical implementation of such projects, one cannot duly assess the feasibility of construction and installation. Therefore, it is necessary to devise a mathematical

framework describing a systematic approach to computation of the potential used to analyze the available administrative and engineering solutions and design new optimal ones.

The potential of administrative and engineering solutions enables specialists to obtain unbiased information about the quality of proposed administrative and engineering solutions and construction processes themselves, which are negatively affected by both external and internal systems.

The main goal of any capital construction project, including capital repairs or reconstruction, is to boost the efficiency of production facilities, minimize non-production losses, and reduce the time of work. The choice of such administrative and engineering solutions is made on the basis of statistically significant sampling made at real facilities. Such an array of data can only be processed by software packages [19-21]. Correct decision-making about the application of o administrative and engineering solutions is largely predetermined by the quality of incoming information about them (e.g., insufficiency and inaccuracy of initial data).

A system of administrative and engineering solutions for capital repairs or reconstruction must take into account multi-criterial processes, multivariant solutions, rhythm and resistance to external and internal changes, rational planning and use of resources in the process of repair work performance.

The time reserve required for the elimination and timely prevention of adverse effects must be taken into account when the negative impact of external factors on administrative and engineering solutions is evaluated.

This approach will minimize downtime in the course of repair and construction works, streamline work schedules with the help of network models, forecast risks in the course of implementation of capital repairs or reconstruction of administrative buildings using statistical information (prior experience).

In network analysis applied to time intervals processes start early and end late, which contributes to the reliability of processes in terms of technology and arrangement of repair and construction works.

As a result, administrative and engineering solutions change in time under the influence of various resource limits, so it is necessary to ensure their replacement by similar ones, while basic principles of system engineering should remain unchanged [22-25].

Amounts and types of work to be performed during capital repairs or reconstruction of administrative buildings predetermine a set of administrative and engineering solutions, while the performance of such work requires ongoing improvements.

Consequently, identification of the potential of administrative and engineering solutions in the course of capital repairs or reconstruction that meets modern demands, as well as the sustainability and reliability of the system itself during the implementation of such projects is relevant and sought after.

Evaluating the applicability of the Harrington's scale

The Harrington's scale is used to find numerical values of valuation functions of factors.

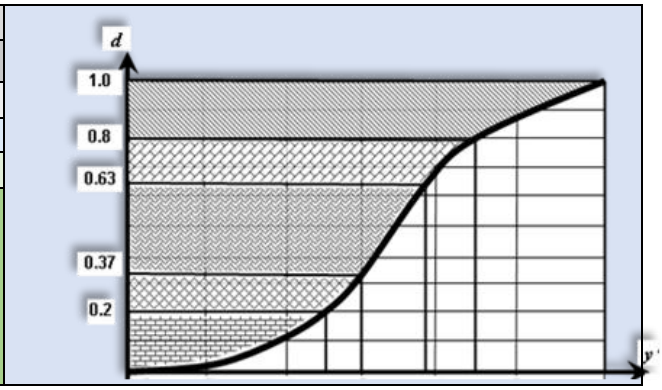
The generalized Harrington's desirability function determines the relationship between the numerical value of the dimensionless scale and the psychological perception of the decision maker regarding this value expressed in fuzzy concepts of desirability (Table 1).

Numerical values presented in Table 1 correspond to points of the curve represented as equation: $d = exp[-exp(-y)]$.

Due to the fact that values of interval boundaries, denoting physical deterioration, are close to the boundary points of the Harrington function, Harrington scale desirability categories are used to construct membership functions for values of linguistic variables.

Table 1. Harrington's desirability scale.

Desirability	Mark d
Very good	1.00–0.80
Good	0.80–0.63
Satisfactory	0.63–0.37
Bad	0.37–0.20
Very bad	0.20–0.00



Selection of factors for determining the integral potential of capital repairs or reconstruction of administrative buildings

The system of factors affecting capital repairs or reconstruction should take into account the features of work at such facilities, for example, the site development density, the access regime, the need for temporary withdrawal of users from a facility, infrastructure in the area of work performance, and other factors.

The following primary goals of repair and restoration must be taken into account in the course of implementation of such projects:

- further safe building operation;
- more comfortable building operation.

Therefore, at the first stage it is necessary to clearly define the criteria and factors affecting the formulation of the need for capital repairs or reconstruction of administrative buildings (Fig. 2).

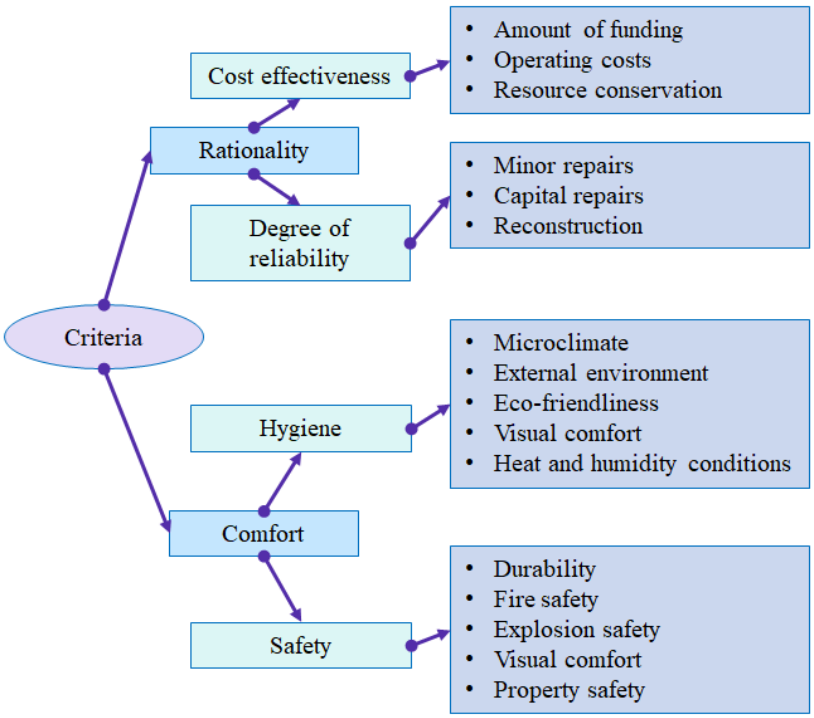


Fig. 2. Factors affecting the formulation of the need for capital repairs or reconstruction of administrative buildings.

At the second stage the integral potential of administrative and engineering solutions (Pcr) is found. The following principal parameters, affecting its value, must be identified:

- technical condition of an administrative building;
- duration of operation of an administrative building;
- building category;
- planned amount of repair and restoration work;
- terms of repair and restoration work;
- quality control of repair and restoration work.

The structure of the integral potential takes into account parameters of design, construction and installation work, as well as project management (Fig. 3).

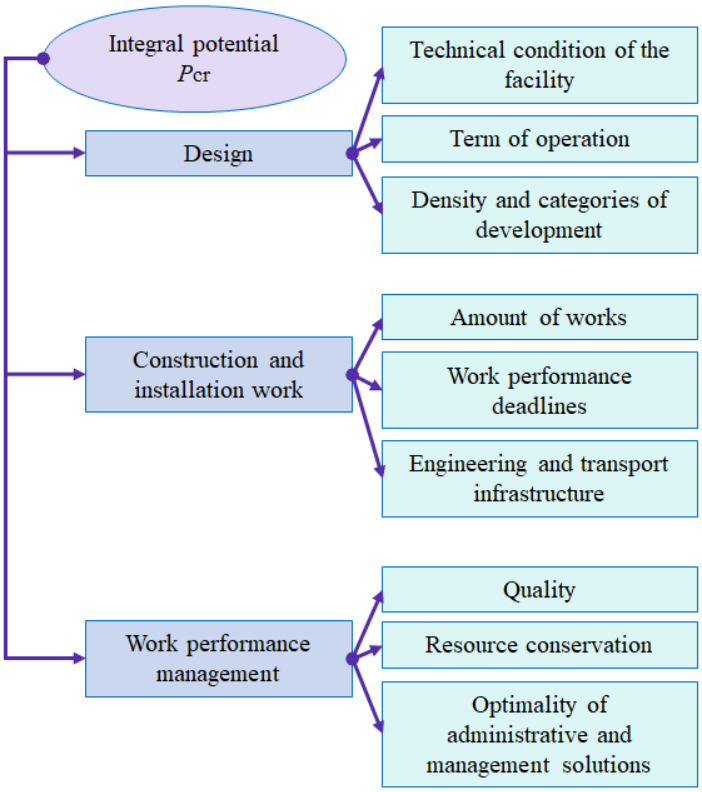


Fig. 3. Structure of the integral potential Pcr.

At the next stage, a mathematical model is developed. It is a second-order regression equation [6]:

$$P_{cr} = k + a * G_1 + b * G_1 * G_2 + c * G_2 + d * G_2 * G_3 + e * G_3 + \\ + f * G_1 * G_3 + g * G_1^2 + h * G_2^2 + j * G_3^2 \quad (1)$$

where G_1, G_2, G_3 are groups of factors; $k, a, b, c, d, e, f, g, h, j$ are experimentally determined coefficients of the regression equation; G_1^2, G_2^2, G_3^2 are squared values of factor groups.

Further, the value of the unit potential is used to assess the influence of each factor on a decision about capital repairs or reconstruction:

$$SP_i = \sum_{j=1}^{N} x_{ij}, \quad (2)$$

where x_{ij} is a set of values of factors x_j, affecting the potential SP_i'. Further we will use the following designations: one-index variable x_j is the j-th factor; two-index variable x_{ij} is the i-th value of the j-th factor; N is the number of factors; M is the number of implementations.

Each factor has its weight v_j, which is determined experimentally. These weight are used to find the value of the unit potential of administrative and management solutions about capital repairs or reconstruction of administrative buildings:

$$SP_i = \sum_{j=1}^{N} x_{ij} * v_j, \tag{3}$$

An expert review is conducted according to the pre-established scheme (Fig. 4) to confirm the significance of a system of factors developed in the course of the research.

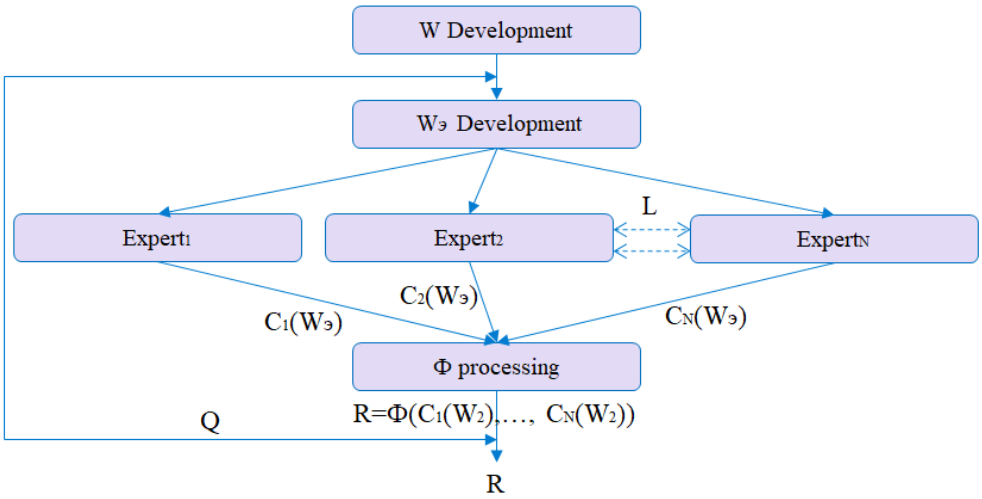


Fig. 4. An expert review conducted to evaluate the significance of factors.

3. RESULTS AND DISCUSSION

Two construction facilities served as the model cases of introduction of research results in the activities of corporate entities planning and implementing capital repairs or reconstruction of administrative buildings.

Construction facilities have the following characteristics:

Facility 1 is a 6-storey administrative building with three underground floors;

Facility 2 is a 4-storey administrative building with a basement.

Factors were identified, and then a description conveying the linguistic variable was made.

Further, the method, including all its steps and stages, was applied.

The expert review of numerical values of input linguistic variables was conducted using the findings of earlier surveys.

MATLAB software applications were employed to model the fuzzy logic system focused on the need to perform repair and reconstruction work.

A decision to perform or not to perform the work is backed by the comparative analysis of output linguistic variables, including capital repairs (CAP), reconstruction (REC) (Fig. 5).

Results of the comparative analysis of output linguistic variables for the two facilities are summarized in Table 2.

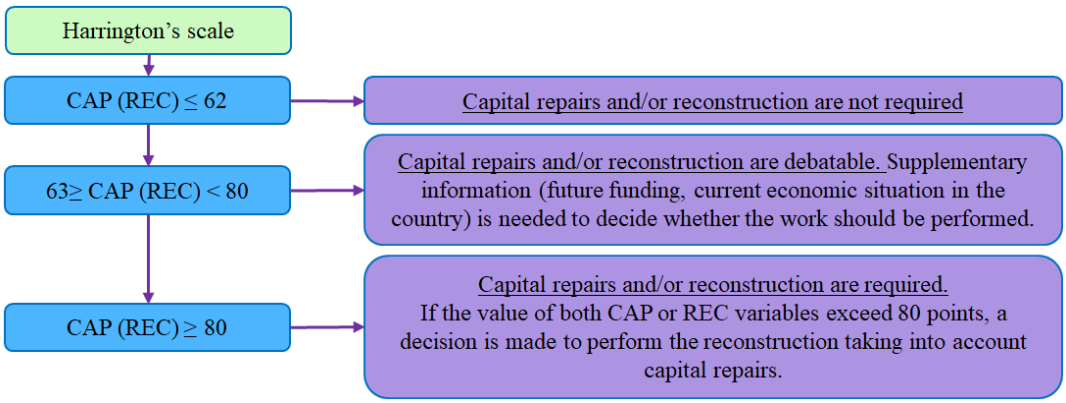


Fig. 5. Decision-making criteria used to identify the need for capital repairs or reconstruction of administrative facilities.

Table 2. Method applied at two construction facilities.

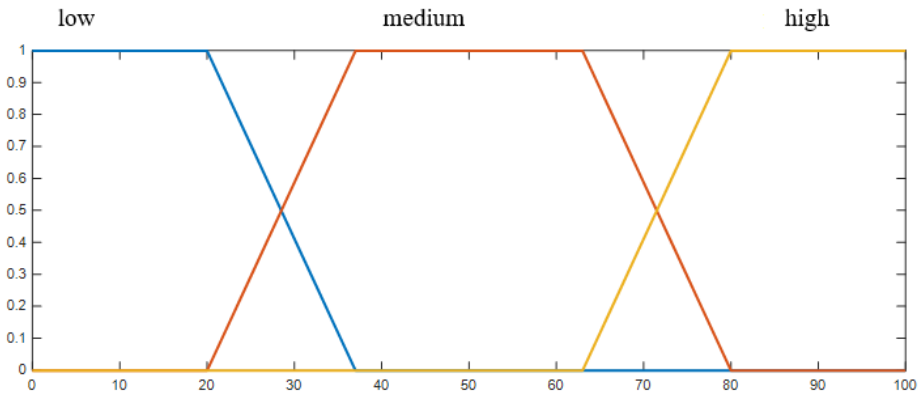
Parameters	Facility 1	Facility 2
CAP	61	82
REC	85.3	50
Solution to perform the work	Facility reconstruction is needed	Capital repairs are needed

To make a formal presentation of expert data on the evaluation of capital repairs or reconstruction of administrative buildings, the researchers used fuzzy sets, which allowed developing an algorithm for computing the potential using the fuzzy inference rule base.

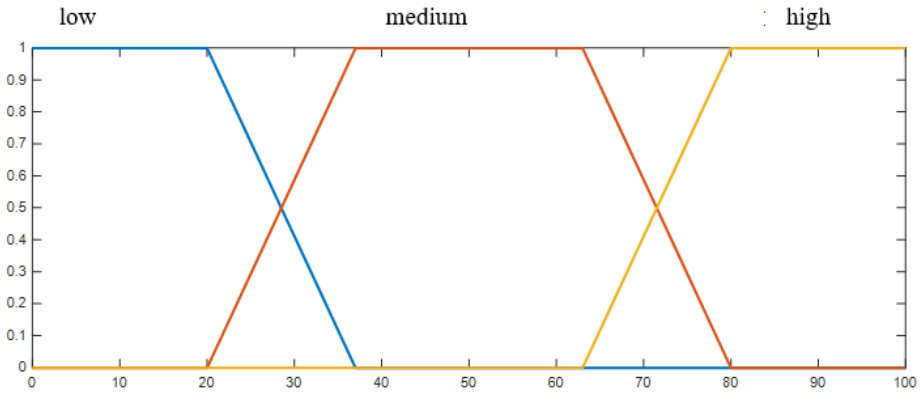
Two values were used as output variables of the inference system:

1. The need for capital repairs (CAPITAL REPAIRS)
2. The need for reconstruction (RECONSTRUCTION).

Membership functions, known as Capital repairs and Reconstruction, are presented in Fig. 6.



(a) Capital repairs membership functions



b) Reconstruction membership functions

Fig. 6. Capital repairs and Reconstruction membership functions.

The threshold value backing the unambiguous solution to conduct capital repairs or reconstruction, is 80 points ("very bad"). If values of variables are within the range of 63 to 80, it is necessary to provide more information (for example, the amount of funding) to make a decision to conduct or not to conduct capital repairs or reconstruction. If values of variables are below 63, then repair and restoration work is not required.

The method proposed to identify the need for capital repairs or reconstruction of administrative buildings includes the consequent implementation of the above stages (Fig. 7).

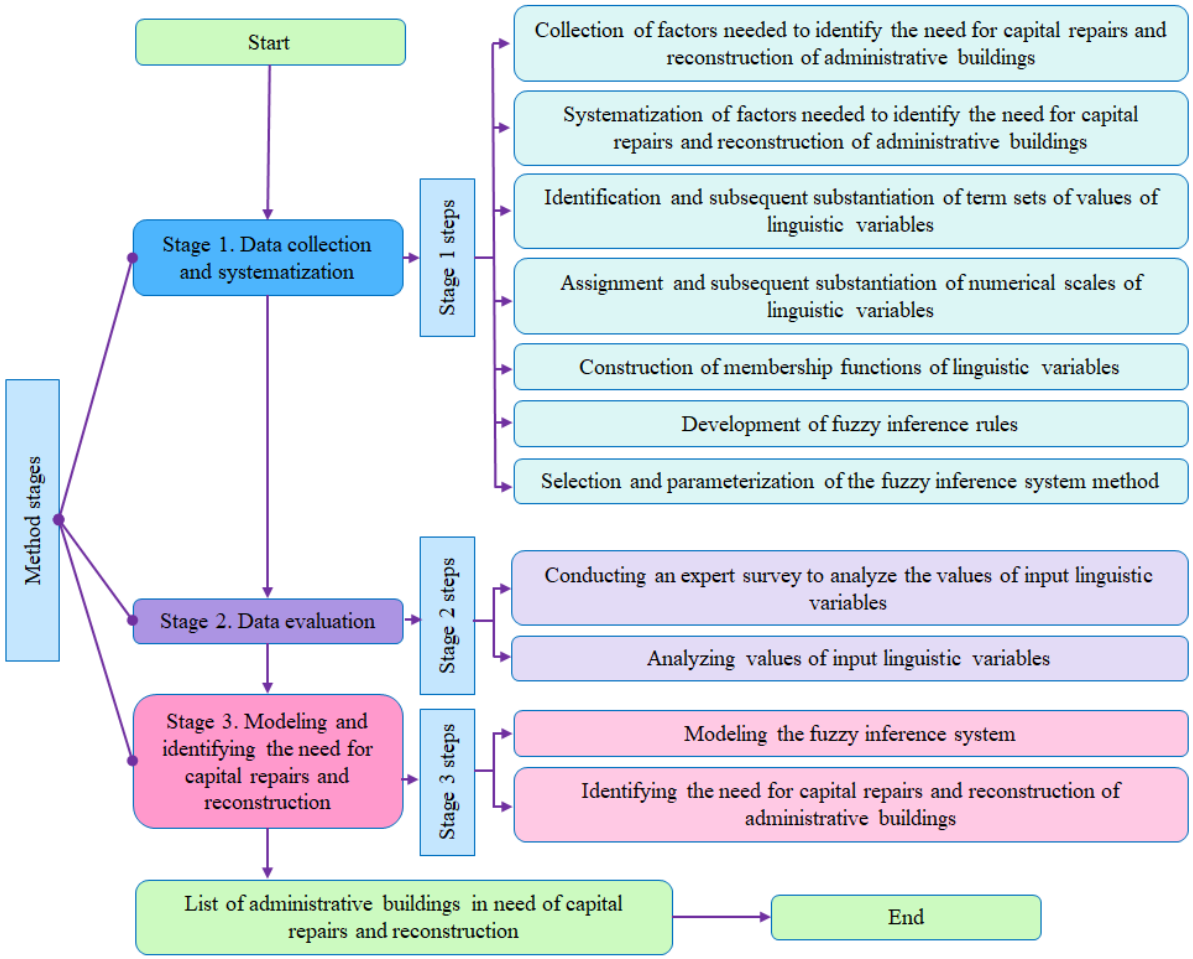


Fig. 7. The method for identification of the need for capital repairs or reconstruction of administrative buildings.

4. CONCLUSIONS

Deteriorated and obsolete administrative buildings is a cumulative problem due to the growing demand for high standards of living among the population of mature economies. A great number of administrative and office buildings, located in the historical centers of cities, fail to meet the requirements of the working population in terms of accessibility, comfort, safety and environmental friendliness. However, accessibility of a place of employment is still a significant factor for the population alongside the level of wages and comfortable working conditions. A growing demand for offices in urban centers is explained by their well-developed infrastructure, transport accessibility, rational.ly scheduled business meetings, and the prestige of the area. Timely capital repairs or reconstruction of administrative buildings will increase the investment attractiveness of the areas and ensure more comfortable workplace conditions. The study revealed the problem of designing administrative and engineering solutions in the context of identifying the need for production resources during repair, restoration and reconstruction. The problem lies in limited production and non-production resources, as well as the unpredictability of external risks, consisting in the uncertainty of initial information about construction facilities.

The novel methodology will also allow for the rational allocation of resources and reasonable planning of capital repairs or reconstruction of administrative buildings.

Tasks were formulated and solved within the framework of the problem. As a result, a new method was developed and tested. Its objective was to identify the need for construction and installation work as part of capital repairs or reconstruction.

The following conclusions can be drawn by summarizing the research work:

1. The study encompasses a scientometric analysis of existing methods and approaches to identifying the need to include administrative facilities in the schedule of repair, restoration and reconstruction work.

2. Factors were identified and systematized at the stages of (1) facility inspection and (2) scheduling of repair, restoration and reconstruction work.

3. The expert review method was selected to determine the most significant factors required to evaluate the extent of risk influence.

4. Methods of hierarchies, Delphi and the Harrington's scale were employed to conduct theoretical studies of membership functions of terms of linguistic variables in a fuzzy inference system. As a result, a trapezoidal membership function was identified.

5. A system of input and output linguistic variables indicating their term sets was developed, describing the risks (factors) and values required to describe repair, restoration and reconstruction work as part of capital repairs and reconstruction of administrative facilities.

6. A method of identifying the need for construction and installation to be performed as part of capital repairs or reconstruction work is developed. It has 3 stages and 11 steps. The method can help in the numerical evaluation of the need for repair, restoration and reconstruction work, which is the basis for making a decision about the need or lack of need for capital repairs or reconstruction of administrative facilities. An alternative research option consists in conducting further studies, in which a detailed version of the proposed method of constructing membership functions will be used. Probabilistic approaches can be used for this purpose.

5. ACKOWLEDGEMENTS

The research was funded by the National Research Moscow State University of Civil Engineering (grant for fundamental and applied scientific research, project No. 11-392/130).

REFERENCES

[1] Ershov R.M., Topchiy D.V. Problems of legal regulation of capital repairs of public buildings. Construction Production. 2020. 4. P. 63 – 67. DOI: https://doi.org/10.54950/26585340_2020_4_63

[2] Shesterikova Y., Bidov T. Assessing the impact of a comprehensive engineering survey on the efficiency of a construction project. AIP Conference Proceedings. 2023. 2936 (1). 020008. DOI.org/10.1063/5.0178526

[3] Shesterikova Y., Bidov T., Fatullaev R., Elnikova D. Evaluating the impact of a comprehensive technical building survey using a cultural heritage site as an example. International Journal of Engineering Trends and Technology. 2023. 71 (6). P. 1 – 7. Crossref, https://doi.org/10.14445/22315381/IJETT-V71I6P201

[4] Miklashevsky A.A. Proper technical condition and requirements for major and current repairs. International Journal of Applied Sciences and Technologies Integral. 2020. 3. P. 17.

[5] Semenov A.S. Organization of capital repairs of buildings based on a systematic approach. Bulletin of Belgorod State Technological University named after. V.G. Shukhov. 2016. P. 64 – 66.

[6] Oleinik P.P. Arrangement of construction work. Saratov, 2019. 599 p.

[7] Aleksanin A.V. Promising directions of development of construction process. Scientific Review. 2015. 10. P. 378 – 381.

[8] Lapidus A.A. Potential for the effectiveness of administrative and engineering solutions of a construction project. 2014. P. 175 – 180.

[9] Lapidus A.A., Govorukha P.A. Administrative and engineering potential of enclosing structures of multi-storey residential buildings. Economics, Management and Organization of Construction. 2015. 4. P. 143 – 149.

[10] Volkova L.V. The influence of probabilistic conditions on administrative and engineering solutions in the construction of residential buildings. Bulletin of Civil Engineers. 2015. 4 (51). P. 87 – 95.

[11] Abramyan S.G., Klyuev S.V., Emelyanova O.E., Oganesyan O.V., Chereshnev L.I., Akopyan G.O., Petrosian R.O. Improving reinforced concrete column strengthening techniques for reconstruction projects using composite jacketing formworks. Construction Materials and Products. 2023. 6 (5). 1. https://doi.org/10.58224/2618-7183-2023-6-5-1
[12] Gansen E.V., Lapidus A.A. A fuzzy inference system for assessing the need for major repairs and reconstruction based on the potential of administrative engineering solutions. Components of Scientific and Technological Progress. 2021. 11 (65). P. 16 – 22.
[13] Lapidus A., Khubaev A., Bidov T. Regression analysis of the calculation of the organizational and technological potential for the production of cold weather concreting. IOP Conference Series: Materials Science and Engineering. 5 Giai Phong Road, Hanoi, 2020. P. 072033. DOI 10.1088/1757-899X/869/7/072033
[14] Vaisman S.M., Bayburin A.Kh. Development of administrative and engineering solutions in construction using information modeling technologies (TIM). Bulletin of SUSU. Construction and Architecture Series. 2016. 16 (4). P. 21 – 28. DOI: 10.14529/build160404
[15] Lapidus A.A., Makarov A.N. Formation of administrative and engineering potential for the production of roofing structures for residential multi-storey buildings. Vestnik MGSU. 2015. 8. P. 150 – 160.
[16] Shesterikova Y., Koroteeva M., Bidov T., Fatullaev R.. Influence of the results of verification calculations of the building on the comprehensive examination and determination of the technical condition of the bearing structures of the building. International Journal of Engineering Trends and Technology. 2023. 71 (6). P. 134 – 140. Crossref, DOI: https://doi.org/10.14445/22315381/IJETT-V71I6P216
[17] Ganzen E.V. Research of the response surface of the integral potential of capital repairs and reconstruction of public buildings in the fuzzy inference system. Construction Materials and Products. 2022. 5 (2). P. 35 – 42. https://doi.org/10.58224/2618-7183-2022-5-2-35-42
[18] Sarvut T.O. Circumpolar aspect in the development of urban environment organization in Russian cities. Construction Materials and Products. 2023. 6 (5). 8. DOI: 10.58224/2618-7183-2023-6-5-8
[19] Cordon O., Herrera F.A. General study on genetic fuzzy systems. Genetic algorithms in engineering and computer science. 1995. P. 33 – 57.
[20] Froese T.M. The impact of emerging information technology on project management for construction. Automation in Construction. Aug. 2010. 19(5). P. 531 –538.
[21] Jones K., Sharp M. A new performance-based process model for built asset maintenance. Facilities, 2007. 25 (13/14). P. 525 – 535.
[22] Mitropoulos P., Howell G. A. Renovation Projects: Design process problems and improvement mechanisms. ASCE Journal of Management in Engineering. 2002. 18 (4). P. 179 – 185.
[23] Mubarak S. Construction project scheduling and control. New Jersey. Hoboken, John Wiley & Sons, Ins. 2010. 478 p.
[24] Topchiy D.V., Shatrova A.I. Formation of a basic management strategy for a construction organization in the implementation of projects of redevelopment of major urban areas. International Journal of Mechanical Engineering and Technology. 2018. 9(4). P. 539 – 547.
[25] Waheed Z., Fernie S. Knowledge based facilities management. Facilities. 2009. 27 (7/8). P. 258 – 266.

INFORMATION ABOUT THE AUTHORS

Lapidus A.A., e-mail: LapidusAA@gic.mgsu.ru, ORCID ID: https://orcid.org/0000-0001-7846-5770, SCOPUS: https://www.scopus.com/authid/detail.uri?authorId=57192378750, Moscow State University of Civil Engineering (National Research University), Department of Construction Technologies and Construction Process Management, Doctor of Engineering Sciences, Professor

Topchiy D.V., e-mail: TopchiyDV@gic.mgsu.ru, ORCID ID: https://orcid.org/0000-0002-3697-9201, SCOPUS: https://www.scopus.com/authid/detail.uri?authorId=57201154714, Moscow State University of Civil Engineering (National Research University), Department of Testing of Structures, Doctor of Engineering Sciences, Professor

Kuzmina T.K., e-mail: KuzminaTK@gic.mgsu.ru, ORCID ID: https://orcid.org/0000-0002-8454-1765, SCOPUS: https://www.scopus.com/authid/detail.uri?authorId=57192382306, Moscow State University of Civil Engineering (National Research University), Department of Construction Technologies and Construction Process Management, Candidate of Engineering Sciences (Ph.D.), Associate Professor

Bolshakova P.V., e-mail: BolshakovaPV@gic.mgsu.ru, ORCID ID: https://orcid.org/0000-0002-5386-5388, SCOPUS: https://www.scopus.com/authid/detail.uri?authorId=57224225877, Moscow State University of Civil Engineering (National Research University), Department of Construction Technologies and Construction Process Management, Candidate of Engineering Sciences (Ph.D.), Associate Professor

Ganzen E.V., e-mail: hansen@yandex.ru, ORCID ID: https://orcid.org/0000-0002-9298-0151, Moscow State University of Civil Engineering (National Research University), Department of Construction Technologies and Construction Process Management, Candidate of Engineering Sciences (Ph.D.)