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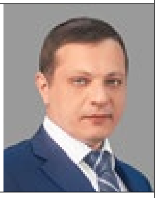
Methodological approach to calculating the integral indicator of organizational and technological reliability of repair and restoration processes of apartment buildings

The housing stock is subject to moral and physical deterioration, which requires timely repair and restoration work. The efficiency of such work directly affects the durability of structural elements, the performance characteristics of buildings and the cost of their maintenance. In the context of limited resources and increasing demands on the quality of repairs, there is a need to develop methods to objectively assess the reliability of repair processes. One of the key approaches to such an assessment is the use of an integral organizational and technological indicator of reliability, which takes into account a set of factors affecting the efficiency of the repair work performed. This indicator allows you to quantitatively assess the impact of organizational, technological and economic factors on the reliability of the process, identify problem areas in the repair management system and predict the time between repairs. This article presents a methodology for calculating the integral indicator of the organizational and technological indicator of the reliability of repair processes, based on a comprehensive consideration of many factors and their significance. The development of this methodology will improve the objectivity of assessing the reliability of repair processes, optimize the distribution of resources, and increase the service life of buildings through rational planning of repair activities. The proposed approach can be used both in the design of repair work and in their analysis and improvement during the operation of buildings.
The developed neural network model uses a multi-layer approach with an activation function in hidden layers and a sigmoid in the output layer. Input data are normalized and processed using the backpropagation method, which allows for more accurate forecasting of inter-repair periods and assessment of the operational reliability of a building.
Keywords: *reliability of buildings, inter-repair period, indicator of organizational and technological reliability, neural network model, repair and restoration process*



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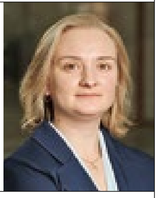

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The reliability of repair and restoration processes is determined by their ability to ensure the required level of operational characteristics of the building during the period between repairs [1]. Reliability is influenced by organizational, technological and economic factors that determine the quality of work, the durability of structural elements and the efficiency of repair management [2].

For a comprehensive assessment of reliability, an integral indicator is introduced that combines various aspects of repair work [3, 4] and allows taking into account their significance. Such an indicator is formed on the basis of standardized values of factors reflecting the key characteristics of the repair and restoration process.

Traditional methods of calculating reliability are based on statistical data, expert assessments and standard indicators [5]. However, these methods often do not take into account complex nonlinear dependencies between parameters, which complicates accurate forecasting between repairs [6]. In this regard, a promising direction is the use of artificial neural networks, which allow analyzing multidimensional dependencies and identifying hidden patterns [7].

To build a neural network model for calculating the integral organizational and technological indicator of the reliability of repair and restoration processes, a multi-layer neural network (MLP — Multi-Layer Perceptron) is used [8]. Such a network allows analyzing the relationships between factors, taking into account their significance and predicting the overall reliability indicator (Fig. 1) [9].

1. Input factors (input layer neurons).

1.1. Organizational and technological factors (Q_i).

1.1.1. Q_1 — Quality of repair and construction works.

1.1.2. Q_2 — Equal strength of materials of structural elements and engineering systems.

1.1.3. Q_3 — Level of improvement and landscaping.

1.1.4. Q_4 — Energy efficiency of the building.

1.1.5. Q_5 — Repairability of building elements and systems.

1.1.6. Q_6 — Adaptability to modern design and technological solutions.

1.1.7. Q_7 — Possibility of organizing a flow method for performing repair works.

1.1.8. Q_8 — Selection of rational organizational forms of project management of restoration works.

1.1.9. Q_9 — Level of qualification of workers and engineering and technical personnel.

1.2. Technical factors (T_i).

1.2.1. T_1 — Level of technical equipment of contracting organizations.

1.2.2. T_2 — Durability of structural elements.

1.2.3. T_3 — Reliability of suppliers of materials and equipment.

1.2.4. T_4 — Technical control of the life cycle of repair and restoration works.

1.2.5. T_5 — Level of complexity of repair works.

1.2.6. T_6 — Complexity of repair and restoration works.

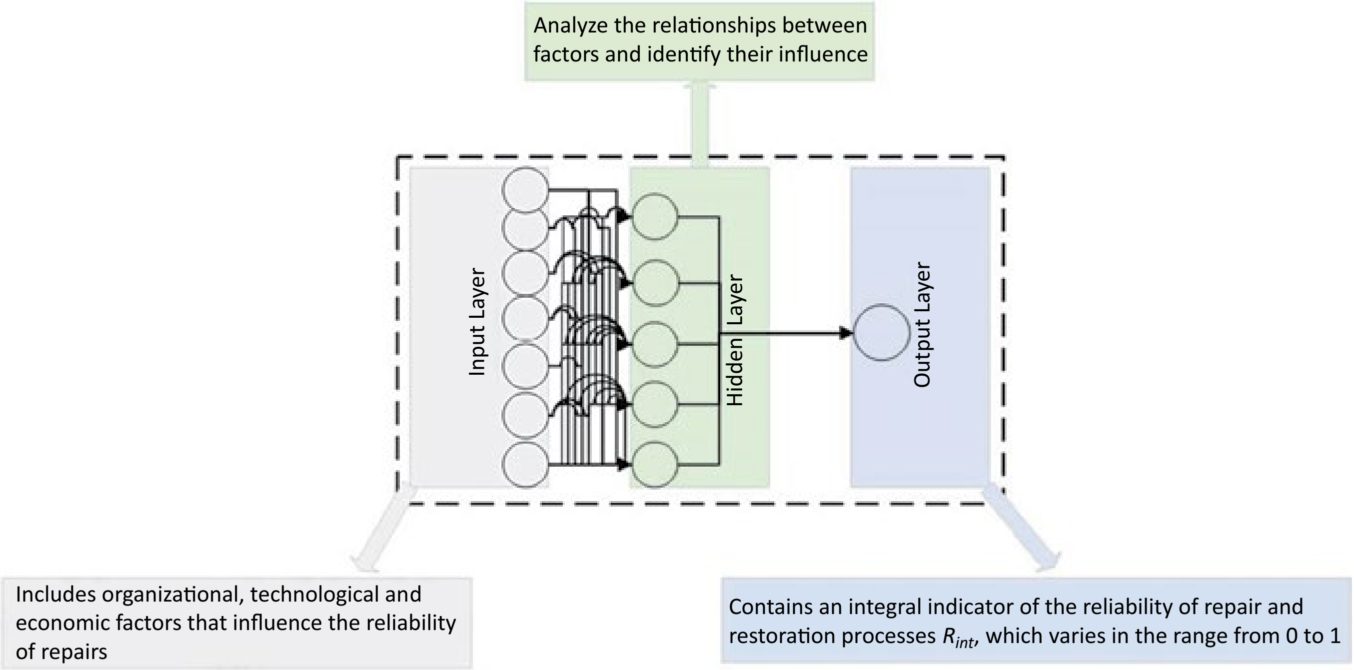

Fig. 1. Neural network model for calculating the integral organizational and technological indicator of reliability

1.2.7. T_7 — Coordination of actions by volume, place and time between successively performed works.

1.2.8. T_8 — Service life of the building and the number of years since the last major repairs.

1.2.9. T_9 — Level of mechanization and robotization of works.

1.2.10. T_{10} — Level of influence of physical wear of elements on the building as a whole.

1.3. Socio-economic factors (E_i).

1.3.1. E_1 — Planned cost of repair and restoration work.

1.3.2. E_2 — Share of physical depreciation in the total replacement cost of the building.

1.3.2. E_3 — Inflation index I_t.

1.3.3. E_4 — Capital-labor ratio.

The input layer consists of 23 neurons (according to the number of factors considered), the first hidden layer includes 10–14 neurons (identification of local dependencies), the second hidden layer of 5–8 neurons (analysis of interactions) and the output final layer consists of 1 neuron (final reliability indicator R_{int}).

The activation function for hidden layers is calculated using formula 1 and allows for nonlinear dependencies to be taken into account:

$$ReLU\ f(x) = \max(0, x). \tag{1}$$

The activation function for the output layer is calculated using the sigmoid function according to formula 2 (R_{int} must be in the range [0.1]):

$$f(x) = \frac{1}{1 + e^{-x}}. \tag{2}$$

Each neuron in the hidden layers calculates an output value using formula 3:

$$H_i = f\left(\sum_{j=1}^{n} W_{ij} \cdot X_j + b_i\right), \tag{3}$$

where $f(x)$ — activation function;

W_{ij} — weight coefficient of connection;

X_j — input values of factors;

b_i — bias.

The final formula for calculating the integral indicator of the organizational and technological indicator within the framework of the analysis under consideration is calculated using formula 4:

$$R_{int} = f\left(\sum_{i=1}^{n} W_i \cdot R_i + b\right), \tag{4}$$

where W_i — weight coefficients of factors;

R_i — normalized input values of factors;

b — bias.

Fig. 2 shows a graphical model of a neural network for calculating the reliability of repair processes.

The developed neural network model for calculating the integral organizational and technological indicator of the reliability of repair and restoration processes allows for the effective analysis of complex relationships between organizational, technical and economic factors affecting the durability and efficiency of building operation [10, 11].

The use of a multilayer neural network (MLP) makes it possible to take into account various parameters, including the quality of construction work, the technical condition of structural elements, economic costs and the predicted reliability of repair processes. The inclusion of hidden layers in the network architecture made it possible to identify nonlinear dependencies that are difficult to use traditional analysis methods [12].

The advantages of using this calculation method include increased accuracy of forecasting the time between repairs, optimization of repair and maintenance costs by identifying critical factors, and the flexibility of the model allows for adapting various situations to specific operating conditions and changing parameters [13, 14].

The developed approach can be used to make informed decisions on planning and implementing repair activities [15]. Further

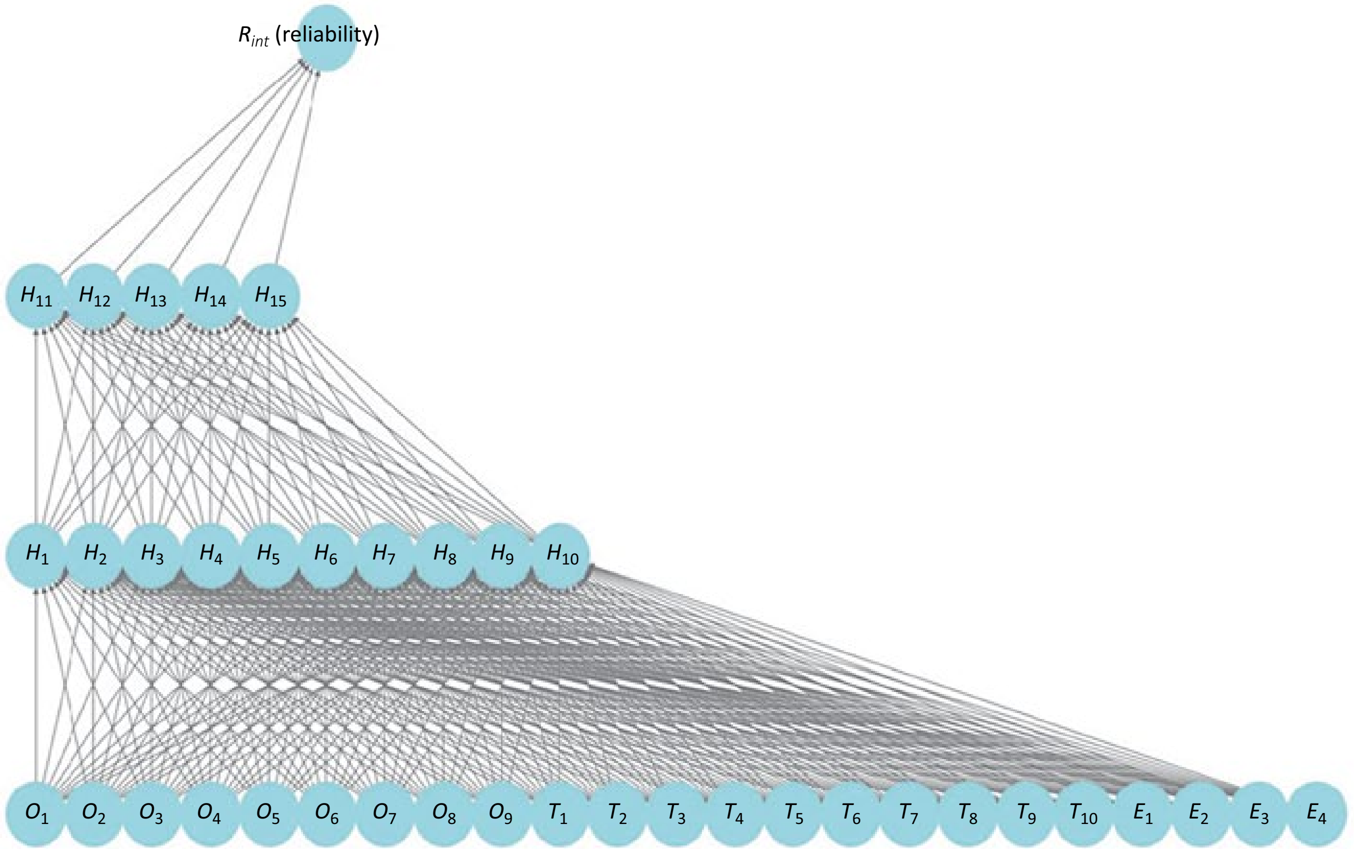

Fig. 2. Graphic model of a neural network for calculating the reliability of repair processes

development of the model is possible by including additional factors, expanding the data set, and using deep learning to more accurately forecast the reliability of buildings [16, 17].

Thus, the neural network method for calculating the integral reliability indicator is an effective tool for analysis and decision-making, contributing to an increase in the service life of buildings, a reduction in operating costs and an increase in functional reliability.

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Методический подход к расчету интегрального показателя организационно-технологической надежности ремонтно-восстановительных процессов многоквартирных домов

Жилой фонд подвержен моральному и физическому износу, что требует проведения своевременных ремонтно-восстановительных работ. Эффективность проведения таких работ напрямую влияет на долговечность конструктивных элементов, эксплуатационные характеристики зданий и затраты на их содержание. В условиях ограниченности ресурсов и роста требований к качеству ремонта возникает необходимость в разработке методов, позволяющих объективно оценить надежность ремонтно-восстановительных процессов.

Одним из ключевых подходов к такой оценке является использование интегрального организационно-технологического показателя надежности, который учитывает совокупность факторов, влияющих на эффективность проведенных ремонтных работ. Данный показатель позволяет количественно оценить влияние организационных, технологических и экономических факторов на надежность процесса, выявить проблемные места в системе управления ремонтом и прогнозировать межремонтные сроки.

В данной статье представлена методика расчета интегрального показателя организационно-технологического показателя надежности ремонтно-восстановительных процессов, основанная на комплексном учете множества факторов и их весомости. Разработка данной методики позволит повысить объективность оценки надежности ремонтных процессов, оптимизировать распределение ресурсов, увеличить срок службы зданий за счет рационального планирования ремонтных мероприятий. Предложенный подход может быть использован как при проектировании ремонтных работ, так и при их анализе и совершенствовании в ходе эксплуатации зданий.

Разработанная нейросетевая модель использует многослойный подход с функцией активации в скрытых слоях и сигмоиду в выходном слое. Входные данные нормализуются и обрабатываются с помощью метода обратного распространения ошибки, что позволяет повысить точность прогнозирования межремонтных сроков и оценки эксплуатационной надежности здания.

Ключевые слова: *надежность зданий, межремонтный срок, показатель организационно-технологической надежности, нейросетевая модель, ремонтно-восстановительный процесс*

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