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BRIDGES AND TUNNELS: THEORY, RESEARCH, PRACTICE

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SYSTEM-INTEGRATED APPROACH TO ORGANIZATIONAL AND TECHNOLOGICAL SOLUTIONS FOR ENERGY EFFICIENCY IN CONSTRUCTION

Purpose of the research is to develop and substantiate the theoretical and methodological foundations of a system-integrated approach to the formation of organizational and technological solutions for ensuring energy efficiency in construction. Special attention is paid to taking into account the interconnections between technological processes, organizational management mechanisms, economic factors, and modern energy conservation requirements. Achieving the stated purpose involves identifying the key principles for integrating energy-efficient solutions into all stages of the life cycle of a construction object, from design to operation. **Methodology** is based on the application of systemic and comprehensive approaches, which make it possible to consider the construction process as an integral multi-criteria system. The methods of system analysis, comparative evaluation, structural and functional modeling, generalization of scientific research, as well as elements of economic and mathematical analysis were used. The methodological basis consists of the principles of energy-efficient, resource-saving, and environmentally oriented construction, which ensure the possibility of evaluating the effectiveness of implementing innovative technologies and organizational solutions. **Findings** consist in identifying a system of factors that influence the effectiveness of organizational and technological solutions in the field of energy conservation, in particular technical, managerial, economic, and environmental factors. An integrated model for the formation of such solutions has been substantiated, which takes into account the interdependence of planning, organization, and control processes of energy consumption. Recommendations have been developed for optimizing the use of energy resources, improving the management of construction processes, and increasing the efficiency of applying modern technologies. **Originality** lies in the formation of a system-integrated approach to combining organizational, technological, and energy parameters within a single model of managerial decision-making. The proposed approach makes it possible to take into account the mutual influence of various factors on the energy efficiency of construction and ensures a more substantiated selection of technologies and methods of work organization. **Practical value** of the obtained results lies in the possibility of their use during the design, planning, and management of construction processes. The proposed provisions contribute to reducing energy consumption, optimizing resource provision, decreasing operational costs, and increasing the overall economic and environmental efficiency of construction activities.

Keywords: system-integrated approach; energy efficiency; construction; organizational and technological solutions; energy conservation; resource efficiency; management of construction processes; building life cycle, innovative construction technologies

Introduction

The construction sector is one of the largest global consumers of energy and sources of carbon dioxide emissions. In 2020, buildings and construction accounted for approximately thirty-six percent of total final energy consumption and thirty-seven percent of energy-related carbon dioxide emissions (Dasović, & Klanšek, 2022; Zajemska, Wojtyto, Michalik, & Berski, 2025). This underscores the critical importance of energy-efficient solutions in construction within the context of the global fight against climate change. Contemporary trends in sustainable construction are focused on the implementation of “green” technologies that reduce energy consumption and greenhouse gas emissions (Fuchs, Therkelsen, Miller, Siciliano, & Sheaffer, 2023; Zhang, Yang, Wu, et al., 2025; Das, 2025). In particular, the use of renewable energy sources, “smart” building management systems, energy-efficient materials, and passive solutions (such as improved insulation, sun protection, and so on) is becoming increasingly widespread – all of which ensure the reduction of fossil fuel consumption and economic returns.

However, achieving the goals of the Paris

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Agreement and the European Green Deal requires system-integrated approaches that cover the entire life cycle of buildings, combining organizational strategies and modern technologies. Currently, the industry is undergoing a digital transformation of a revolutionary nature – technological innovations enhance the quality and speed of construction while simultaneously ensuring energy efficiency, safety, and comfort (Cao, Kamaruzzaman, & Aziz, 2022).

Below is an overview of the latest research from 2020 to 2025 on the implementation of a system-integrated organizational and technological model of energy-efficient construction, with a focus on digitalization, information modeling, energy management, resource optimization, and artificial intelligence in construction technologies (Yang, Chen, Liu, & Zhang, 2025).

Purpose

The purpose of the research is the development, theoretical substantiation, and practical formation of a system-integrated approach to the creation and selection of organizational and technological solutions for ensuring energy efficiency in construction. This approach is aimed at the comprehensive coordination of technical, organizational, economic, managerial, and resource factors at all stages of the life cycle of construction objects – from design to operation – with the goal of minimizing energy consumption, optimizing costs, improving the quality of construction production, and promoting the sustainable development of the industry.

Methodology

The essence of integrated approaches to resource optimization in construction lies in the comprehensive consideration of the construction process as a single interconnected system in which technical, organizational, economic, and energy aspects are coordinated (Castrillón-Mendoza, R., Rey-Hernández, Castrillón-Mendoza, L., & Rey-Martínez, 2024). This approach implies not making decisions in isolation, but forming them with consideration of the mutual influence of all elements of construction activity – from design and planning to execution of works and subsequent operation of the facility.

Integration means the coordination of actions of all construction participants, the combination of modern technologies, management methods, digital tools, and engineering solutions. It ensures the alignment of goals regarding quality, timelines, cost, and energy efficiency. In practical terms, this manifests in the application of comprehensive planning, information modeling, resource management systems, and the use of innovative materials and technologies.

Resource optimization in construction is a key element of the integrated approach and involves the rational use of material, energy, labor, and financial resources. Its goal is to minimize costs while simultaneously ensuring high quality and reliability of construction output. This is achieved through the selection of efficient technological processes, reduction of material losses, lowering energy consumption, optimal allocation of labor resources, and implementation of energy-saving solutions (Castrillón-Mendoza, R., Rey-Hernández, Castrillón-Mendoza, L., & Rey-Martínez, 2024; Ogundiran, Asadi, & Gameiro da Silva, 2024; Sghiri, Gallab, Merzouk, & Assoul, 2025).

Integrated approaches are particularly important in the context of modern sustainable development requirements, as they allow for the consideration of environmental constraints, reduction of the negative impact of construction on the environment, and enhancement of the long-term operational efficiency of buildings. Thus, their essence lies in the creation of a holistic system for managing construction processes aimed at achieving maximum resource and energy efficiency.

Modern energy-efficient construction requires the comprehensive combination of organizational project management methods with digital tools and engineering innovations. One such integration is Lean Construction (LC). Research shows that the Lean paradigm, which focuses on waste minimization and continuous process improvement, allows for a sharp increase in productivity and a reduction in resource wastage in construction (Ogundiran, Asadi, & Gameiro da Silva, 2024; Sghiri, Gallab, Merzouk, & Assoul, 2025).

The integrated LC approach encompasses: information integration – unified digital data eliminates information gaps between project stages; supply chain management – transparent planning of materials and logistics based on digitalization reduces excess inventory and downtime. This approach allows for maximizing customer value while minimizing resource costs, eliminating un-

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productive operations and delays. However, there are obstacles: research highlights the fragmented implementation of LC (often limited to either the design stage or the construction site) and the lack of unified data standards, which complicates full integration across all stages (Palomar-Torres, Rey-Hernández, J. M., Rey-Hernández, A., & Rey-Martínez, 2024; Sghiri, Gallab, Merzouk, & Assoul, 2025).

Another important aspect is the optimization of energy efficiency at the stage of construction production. Traditionally, construction planning focused on timelines and budgets, but today researchers add a third goal – energy consumption and emissions during the construction process itself. A 2022 review showed that the application of optimization algorithms (genetic algorithms, particle swarm optimization, and others) in the preparation of construction schedules allows for minimizing the energy consumption of construction equipment and processes without compromising deadlines. In particular, multi-criteria optimization methods make it possible to find a compromise between cost, duration, and energy consumption of a project, which aligns with the concept of the three dimensions of sustainability (economic, environmental, and social) (Fuchs, Therkelsen, Miller, Siciliano, & Sheaffer, 2023; Das, 2025).

These approaches are only beginning to be implemented: the review by Dasović & Klanšek (2022) noted that mathematical methods for optimizing construction schedules with consideration of energy efficiency are still insufficiently developed and represent a promising direction for further research. In practice, heuristic algorithms and simulation modeling are more often used to solve complex construction planning problems in order to reduce energy consumption and emissions on construction sites. Therefore, the integration of optimization tools into construction planning is another element of the system-integrated model that ensures the rational use of resources.

The review also highlights other modern energy-saving technologies that are considered in the formation of a system-integrated model. First, these include highly efficient building envelope structures. New insulation materials are being developed (for example, aerogels, vacuum insulation, phase-change materials), which allow for reducing heat losses in buildings without increasing their mass. By combining these materials with traditional ones, designers achieve nearly zero-energy building standards (nZEB/ZEB), where a building produces as much energy annually as it consumes (Sghiri, Gallab, Merzouk, & Assoul, 2025).

Second, attention is given to the carbon footprint of materials. While operational energy consumption in modern "green" buildings is significantly reduced due to renewable energy sources (for example, up to ninety-five percent of heating energy can come from renewables), the share of emissions embedded in materials becomes dominant. For instance, a study of a LEED-certified nZEB showed that up to sixty-nine percent of total carbon dioxide emissions over the life cycle is attributable to construction materials and structures, and this share may increase in the future. This highlights a research gap: strategies for material reuse, recycling, and the use of low-carbon materials (wood, composites, secondary raw materials) must be more actively implemented to reduce emissions that are independent of operational energy efficiency (Sghiri, Gallab, Merzouk, & Assoul, 2025).

Third, the concept of a building Digital Twin, mentioned above, is being further developed to model complex structures and engineering networks in real time (Palomar-Torres, Rey-Hernández, J. M., Rey-Hernández, A., & Rey-Martínez, 2024).

Modern construction projects are characterized by high organizational complexity, a diversity of technological solutions, multi-factorial material choices, and a large number of parameters affecting cost, energy consumption, and structural reliability. In this context, a model was developed based on system-integrated approaches that combine data, algorithms, engineering calculations, and optimization methods.

The model combines analytical approaches to cost formation, energy balances, reliability assessment methods, and thermal engineering calculations, as well as a module for automated comparison of alternatives. Therefore, its implementation requires a detailed analysis of behavior in a real environment and verification of its ability to adapt to specific conditions.

Special attention is given to the module responsible for the core computational processes of the system-integrated model. This module includes formulas, analytical expressions, and results that ensure transparency of modeling and the possibil-

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ity of verifying each stage. The convenient simultaneous presentation of formulas and their calculated values allows the engineer to monitor the correctness of the model's operation and to detect inaccuracies in the input data.

The practical application of the model on a major renovation project is further highlighted. A complete technical description of the building is provided, including the features of façade systems, roofing structures, the variety of materials, and technological solutions. The facility has a high level of structural complexity and a large number of technological options, making it ideal for testing the system-integrated approach.

A separate section is dedicated to the "New Technology" form, which defines structural layers, materials, and parameters that affect the final technical and economic indicators. This module forms the basis of the system-integrated technological description, which is subsequently used in calculations of cost, energy consumption, reliability, and thermal resistance.

Findings

An important component is the operation of the automatic technology selection module, which uses a multi-criteria evaluation considering the weights of cost, energy consumption, and reliability (Figures 1-2). As a result, a matrix of optimal solutions is generated, and the best and worst alternatives are compared.

The three-dimensional visualization of C, E, R integrates all criteria within a single space and allows for the intuitive identification of the feasible solution region and the position of the optimal configuration. Unlike conventional technology selection methods, where only cost or only duration is considered, here the full life cycle of the technology is taken into account:

- C – costs of materials, resources, and labor;
- E – energy consumption incurred by the technology during execution;
- R – reliability, which affects failure risks and longevity.

The location of the selected solution in the 3D space confirms that optimization is carried out not based on a single indicator, but according to the integral balance of cost, energy consumption, and reliability.

In the context of the completed work, this window serves as the final means of validation and explanation of the results of mathematical modeling: it demonstrates that the developed model indeed generates a set of alternatives, correctly applies the system of constraints (distinguishing feasible from infeasible solutions), and ensures a substantiated choice of the optimal configuration according to the objective function. In fact, these graphs confirm that the conducted optimization is not merely declarative: it is reflected in the real space of trade-offs between cost, energy consumption, and reliability, and the selected solution is mathematically justified and engineering feasible as a result of the performed optimization procedure.

The system achieves high efficiency due to:

1. Comprehensive consideration of three criteria. The simultaneous consideration of all three indicators ensures that the choice is economically, technically, and energetically optimized.

2. Normalization of indicators (bringing to a common scale). Since cost is measured in UAH, energy in kilowatt-hours, and reliability as a probability, they cannot be compared directly. After normalization, all criteria W_C, W_E, W_R are converted to a range of 0 … 1, where 0 represents the best value. This allows for: 1) correct ranking of technologies; 2) avoiding distortions caused by different units of measurement; 3) ensuring mathematical fairness in comparisons.

3. User-defined weight coefficients**.**

This allows the model to be adjusted according to the objectives of a specific project:

- if saving money is a priority → WeightCost is increased;
- if energy efficiency is important → WeightEnergy is increased;
- if durability is critical → WeightReliability is increased.

In other words, the model adapts to the real context, which is what provides its effectiveness.

4. Elimination of inefficient technologies.

The system automatically excludes technologies that: 1) have excessively low reliability; 2) exceed deadlines; 3) violate global constraints.

This improves the quality and safety of the selected solution.

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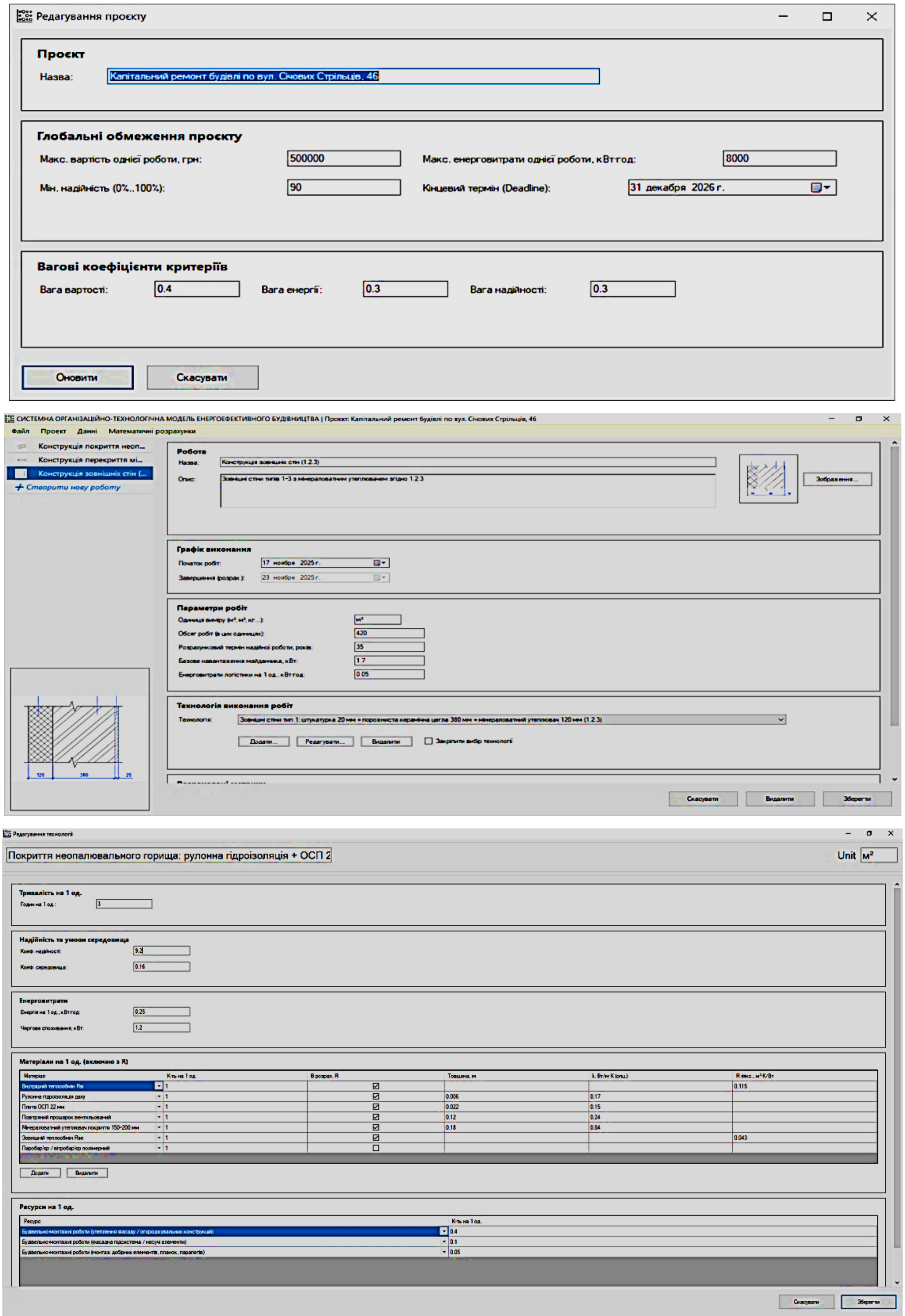

Проєкт

Назва: Капітальний ремонт будівлі по вул. Січових Стрільців, 46

Глобальні обмеження проєкту

Макс. вартість однієї роботи, грн: 500000

Макс. енерговитрати однієї роботи, кВт·год: 8000

Мін. надійність (0%..100%): 90

Кінцевий термін (Deadline): 31 декабря 2026 г.

Вагові коефіцієнти критеріїв

Вага вартості: 0.4

Вага енергії: 0.3

Вага надійності: 0.3

СИСТЕМНА ОРГАНІЗАЦІЙНО-ТЕХНОЛОГІЧНА МОДЕЛЬ ЕНЕРГОЕФЕКТИВНОГО БУДІВНИЦТВА | Проект: Капітальний ремонт будівлі по вул. Січових Стрільців, 46

Робота

Назва: Конструкція зовнішніх стін (1.2.3)

Опис: Зовнішні стіни типів 1–3 з мінераловатним утеплювачем згідно 1.2.3

Графік виконання

Початок робіт: 17 ноября 2025 г.

Завершення (розрах.): 23 ноября 2025 г.

Параметри робіт

Одиниця виміру (м², м³, кг...): м²

Обсяг робіт (в цих одиницях): 420

Розрахунковий термін надійної роботи, років: 35

Базове навантаження майданчика, кВт: 1.7

Енерговитрати логістики на 1 од., кВт·год: 0.05

Технологія виконання робіт

Технологія: Зовнішні стіни тип 1: штукатурка 20 мм + порожниста керамічна цегла 380 мм + мінераловатний утеплювач 120 мм (1.2.3)

☐ Закріпити вибір технології

Покриття неопалювального горища: рулонна гідроізоляція + ОСП 2

Unit м²

Тривалість на 1 од.

Годин на 1 од.: 3

Надійність та умови середовища

Коеф. надійності: 9.2

Коеф. середовища: 0.16

Енерговитрати

Енергія на 1 од., кВт·год: 0.25

Чергове споживання, кВт: 1.2

Матеріали на 1 од. (включно з R)

Матеріал	К-ть на 1 од.	В розрах. R	Товщина, м	λ, Вт/м·К (опц.)	R фікс., м²·К/Вт
Внутрішній теплообмін Rsi	1	☑			0.115
Рулонна гідроізоляція даху	1	☑	0.006	0.17	
Плита ОСП 22 мм	1	☑	0.022	0.15	
Повітряний прошарок вентильований	1	☑	0.12	0.24	
Мінераловатний утеплювач покриття 150–200 мм	1	☑	0.18	0.04	
Зовнішній теплообмін Rse	1	☑			0.043
Паробар'єр / вітробар'єр полімерний	1	☐			

Ресурси на 1 од.

Ресурс	К-ть на 1 од.
Будівельно-монтажні роботи (утеплення фасаду / огороджувальних конструкцій)	0.4
Будівельно-монтажні роботи (фасадна підсистема / несучі елементи)	0.1
Будівельно-монтажні роботи (монтаж добірних елементів, планок, парапетів)	0.05

Figure 1. Software Tool for Calculating the System-Integrated Model

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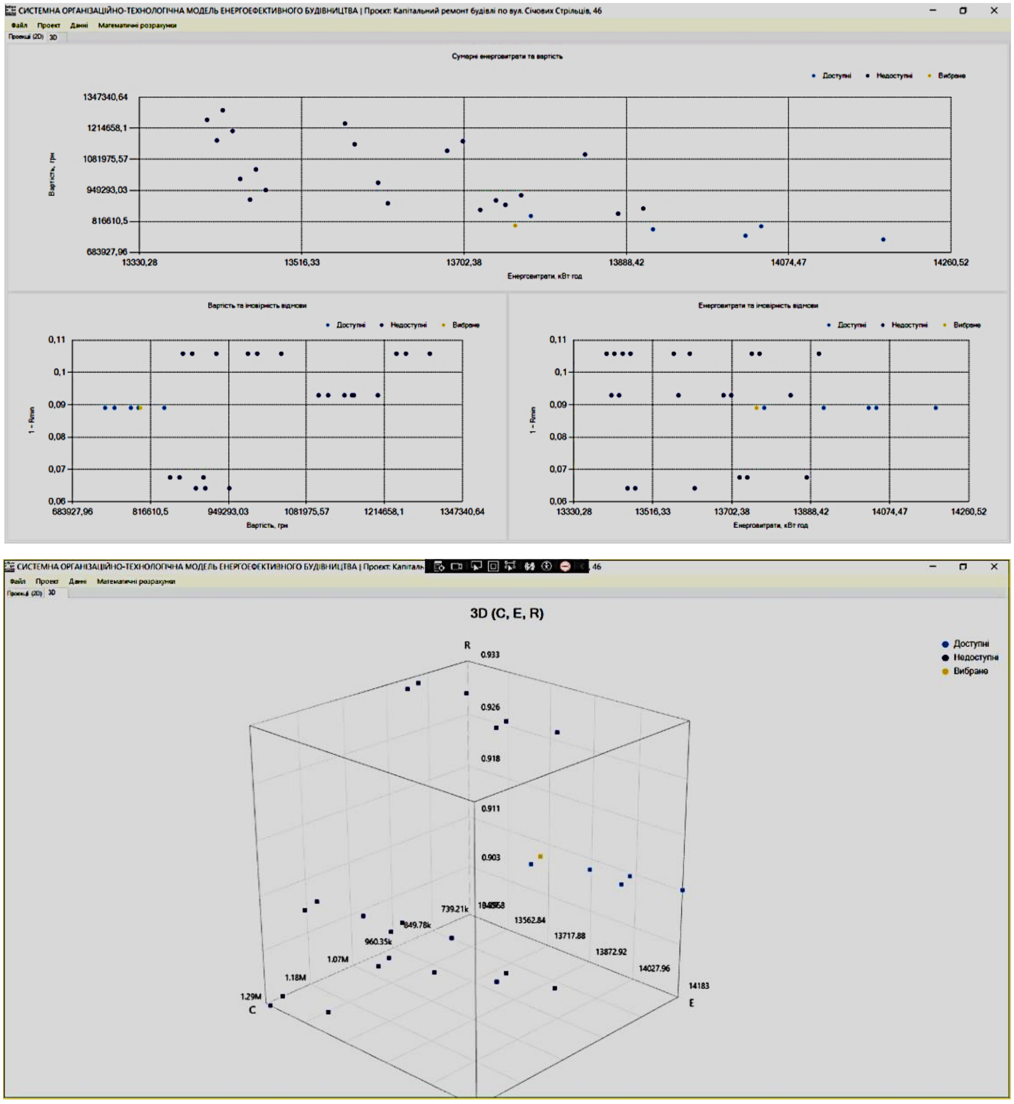

Figure 2. The visualization of the results of mathematical calculations is designed for the graphical comparison of different project alternatives according to key criteria

5. Comparison not only with the best but also with the worst technology. This allows:

- engineers to see the amount of savings achieved;
- visually demonstrate the benefits of optimization;
- understand how risky or costly an alternative choice would have been.

The model uses a multi-criteria objective function:

$$\min(Score) = w_E \frac{E_{tot} - E^{min}}{E^{max} - E^{min}} + w_C \frac{C_{tot} - C^{min}}{C^{max} - C^{min}} - w_R \frac{\ln R_{obj} - \ln R^{min}}{\ln R^{max} - \ln R^{min}}$$

where $Score$ is the integral assessment is defined as the weighted sum of normalized indicators, taking into account the weighting coefficients w_C, w_E, and w_R set by the user. It is considered for each technology; the lower the S_{core}, the better the technology; w_C, w_E, w_R– weight coefficients (0 … 1); E_{norm} – normalized value for the energy Consumption of the technology; R_{norm} – normalized value for the reliability of the technology.

The values are normalized within a single study among all other technologies as follows:

$$C_{norm} = (C - C_{min})(C_{max} - C_{min}),$$

where C_{norm} – normalized value for the Cost of the technology; C – total cost of the given technology; C_{max} – maximum cost among all technolo-

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gies; $C_{\min}$ – minimum cost among all technologies.

Similarly, values for Energy Consumption and Reliability parameters are normalized.

Essence: This is a formula that transforms three different criteria into a single integrated indicator – S_{core}, so that the system can automatically compare technologies with each other.

How the objective function works:

- Minimization of C_{norm} → reduces costs;
- Minimization of E_{norm} → reduces energy consumption;
- Maximization of R_{norm} (through the "–" sign) → increases reliability.

The smallest S_{core} = the best technology.

This function ensures:

- balanced decisions (no criterion dominates without the specified weights);
- universality for any type of work;
- mathematical stability even with highly varying criterion values;
- the ability to automatically select technologies without engineer intervention;
- a consistent approach for different tasks within the project.

The objective function is the heart of the system – it ensures optimization across the entire project, not just in individual parts (Table 1).

Table 1

Values for all tasks

Number task	Number technology	C, UAH	E, kWh	Coefficient reliability, R
1	1	262864,0	1030,4	0,9390
	2	351328,0	894,4	0,8956
	3	218908,0	1342,4	0,9302
2	1	92759,00	676,0	0,9716
	2	133518,0	694	0,9547
	3	76689,00	1013,2	0,9698
3	1	554277,0	2154,6	0,9332
	2	807210,25	1979,8	0,9073
	3	443614,85	1774,6	0,9108

After this, the algorithm ranks the technologies for each task according to the **Score**, and calculates the total project cost, the total cost per kilowatt, and takes the minimum reliability coefficient from all tasks to form the project values.

For all possible combinations – for example, (Task 1 Tech 1, Task 2 Tech 1, Task 3 Tech 1) or (Task 1 Tech 2, Task 2 Tech 1, Task 3 Tech 1), and so on – we generate graphs.

Global constraints are applied to each individual task: maximum cost, maximum energy consumption, and maximum reliability. On the graph, these indicate whether a particular combination of tasks with technologies is feasible or not.

The reliability values vary because the minimum reliability across all tasks is taken and used to measure the overall value.

The effectiveness of the analytical model is achieved through multi-criteria analysis of each technology, normalization of indicators, automatic consideration of weight coefficients, and the elimination of infeasible solutions. The S_{core} objective function integrates three criteria – cost, energy, and reliability – and allows the selection of the optimal technology, minimizing expenses and energy consumption while simultaneously maximizing reliability.

The conducted analysis demonstrated that the model not only calculates the indicators but also generates full project analytics, including:

- total cost of technologies (materials, resources, overhead, waste);
- energy consumption (process energy, standby energy, energy of mechanisms);
- reliability of structures considering the failure rates of materials;
- thermal resistance of enclosing structures;
- normalized criterion values for comparison;
- the integral **Score** indicator for each technology;
- cumulative indicators for the entire project.

In addition to computational functions, an important component is the visualization of results, which allows project alternatives to be presented in the coordinates "cost–energy–reliability". The user can see the entire set of possible solutions, including infeasible options, enabling quick elimination of non-viable approaches and focus on those that meet the requirements.

As a result of the analysis, the following key advantages of the model can be highlighted:

1. Comprehensiveness and system integration –

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the model combines technical, economic, energy, thermal, and reliability characteristics within a single structure. This allows for a comprehensive analysis of technologies and construction solutions.

2. Modularity and flexibility – the user can create an unlimited number of tasks, technologies, materials, resources, and scenarios. The model adapts to any project – from small-scale repairs to large construction projects.

3. Support for multi-criteria optimization – the ability to set weight coefficients allows changing project priorities and adapting technology selection to the client's needs.

4. High calculation accuracy – due to detailed parameters of materials and technologies, the model ensures precision in the calculation of cost, energy, reliability, and thermal performance indicators.

5. Transparency of algorithms – displaying formulas and their results in real time allows verification of the correctness of each calculation.

6. Speed of decision-making – automatic selection of the optimal technology reduces the engineer's workload and improves the quality of management decisions.

7. Elimination of the human factor – the model is based on algorithms that remove subjectivity from technology selection by the engineer.

8. Clear graphical analytics – graphs allow evaluation of the entire set of alternatives and quickly identify the most efficient options.

9. Adaptability to changes – in case of changes in material costs, resource availability, or deadlines, the system instantly updates all calculations.

10. Applicability to real projects – testing on an actual site confirmed the model's operability and practical effectiveness.

In summary, the developed system-integrated organizational and technological model is a modern, effective, and practically significant tool capable of significantly improving the management of construction projects. It provides comprehensive analysis of solutions, accelerates the adoption of optimal technological strategies, and enhances the accuracy of forecasting and structural reliability.

Originality and practical value

Originality lies in the formation of a system-integrated approach to combining organizational, technological, and energy parameters within a single model of managerial decision-making. The proposed approach makes it possible to take into account the mutual influence of various factors on the energy efficiency of construction and ensures a more substantiated selection of technologies and methods of work organization.

Practical value of the obtained results lies in the possibility of their use during the design, planning, and management of construction processes. The proposed provisions contribute to reducing energy consumption, optimizing resource provision, decreasing operational costs, and increasing the overall economic and environmental efficiency of construction activities.

Conclusions

The conducted literature analysis demonstrates that ensuring energy efficiency in construction is no longer limited to individual technical solutions – it is a multifaceted task requiring a system-integrated approach. Such an approach combines organizational innovations with advanced technologies while taking into account modern energy-saving materials and equipment.

A review of current research from 2020–2025 showed that:

1. The construction sector is under pressure from decarbonization goals, which stimulates the development of new energy management methods at both project and organizational levels;

2. Digital tools have significantly expanded the possibilities for optimizing energy consumption during both building design and construction and operation;

3. Integrating these tools into unified models represents the next step in the industry's evolution, already demonstrating promising results in terms of increased productivity, cost reduction, and decreased environmental impact.

At the same time, knowledge gaps and directions for further research have been identified: standardized approaches for data and model compatibility are needed, more empirical evidence of the effectiveness of integrated systems in real projects is required, cybersecurity issues must be addressed, and methodologies for assessing the economic feasibility of digital innovations need to be developed.

The novelty of recent research lies in forming a holistic vision of energy-efficient construction as a socio-technical-economic system, where management decisions are supported by accurate data and

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analytics, technologies are interconnected and mutually reinforcing, and the ultimate goal – sustainable development – is achieved through a balance of energy, environmental, and economic efficiency.

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СИСТЕМНО-ІНТЕГРОВАНИЙ ПІДХІД ДО ОРГАНІЗАЦІЙНО-ТЕХНОЛОГІЧНИХ РІШЕНЬ ЕНЕРГОЕФЕКТИВНОСТІ В БУДІВНИЦТВІ

Мета дослідження полягає у розробленні та обґрунтуванні теоретико-методичних засад системно-інтегрованого підходу до формування організаційно-технологічних рішень забезпечення енергоефективності в будівництві. Особлива увага приділяється врахуванню взаємозв’язків між технологічними процесами, організаційними механізмами управління, економічними чинниками та сучасними вимогами енергозбереження. Досягнення поставленої мети передбачає визначення ключових принципів інтеграції енергоефективних рішень у всі етапи життєвого циклу будівельного об’єкта – від проєктування до експлуатації. **Методика** дослідження базується на застосуванні системного та комплексного підходів, що дозволяють розглядати будівельний процес як цілісну багатокритеріальну систему. Використано методи системного аналізу, порівняльної оцінки, структурно-функціонального моделювання, узагальнення наукових досліджень, а також елементи економіко-математичного аналізу. Методичну основу становлять принципи енергоефективного, ресурсозберігаючого та екологічно орієнтованого будівництва, що забезпечують можливість оцінювання ефективності впровадження інноваційних технологій та організаційних рішень. **Результати** дослідження

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полягають у визначенні системи чинників, що впливають на ефективність організаційно-технологічних рішень у сфері енергозбереження, зокрема технічних, управлінських, економічних та екологічних. Обґрунтовано інтегровану модель формування таких рішень, яка враховує взаємозалежність процесів планування, організації та контролю енергоспоживання. Розроблено рекомендації щодо оптимізації використання енергоресурсів, удосконалення управління будівельними процесами та підвищення ефективності застосування сучасних технологій. **Наукова новизна** полягає у формуванні системно-інтегрованого підходу до поєднання організаційних, технологічних та енергетичних параметрів у єдиній моделі прийняття управлінських рішень. Запропонований підхід дозволяє враховувати взаємний вплив різних факторів на енергоефективність будівництва та забезпечує більш обґрунтований вибір технологій і методів організації робіт. **Практичне значення** отриманих результатів полягає у можливості їх використання під час проєктування, планування та управління будівельними процесами. Запропоновані положення сприяють зниженню енерговитрат, оптимізації ресурсного забезпечення, скороченню експлуатаційних витрат та підвищенню загальної економічної й екологічної ефективності будівельної діяльності.

Ключові слова: системно-інтегрований підхід; енергоефективність; будівництво; організаційно-технологічні рішення; енергозбереження; ресурсоефективність; управління будівельними процесами; життєвий цикл будівлі; інноваційні будівельні технології

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