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An Integrated Quality Index of High-Rise Residential Buildings for All Lifecycle Stages of a Construction Facility

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Abstract: The study focuses on developing a methodology for calculating an integrated quality index of administrative and engineering solutions that affect the safety of multi-storey residential buildings at each stage of their lifecycle. This method can be used to design a tool for assessing the integrated quality of multi-storey residential buildings at each stage of production. Advanced quality assessment methods were analyzed within the framework of this study. The analysis led to the conclusion that the most relevant problem is the lack of an integrated approach to the quality assessment of multi-storey residential buildings. Having studied an extensive number of research works, the authors identified the main parameters that affect the quality of a construction facility. The aims of the study were to (1) develop an integrated quality index for multi-storey residential buildings (this index is to be applicable as early as at the stage of pre-construction arrangements); (2) develop methods for calculating and evaluating the integrated quality index for high-rise residential buildings at the stage of construction arrangements; (3) improve the efficiency of administrative and engineering solutions; and (4) devise a mathematical model that will identify the numerical value of the proposed multi-factor criteria. The research results show the feasibility and expediency of introducing this methodology in residential construction as it allows for a comprehensive measurement and quality assessment of high-rise residential buildings.

Keywords: integrated quality index; multi-storey residential buildings; lifecycle; mathematical model

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1. Introduction

At present, one of the priority directions in the economic development of any country is providing its citizens with affordable, comfortable, and high-quality housing. Improving the quality of construction products is one of the main challenges in the construction industry [1]. Although a large number of published papers have addressed this problem, it has not been solved in its entirety.

Denis Leonard emphasizes that the application of advanced structured approaches to the issue of quality is very limited; quality is viewed as a minor issue; industry leaders need to strive for quality and apply consistent and systematic company-wide approaches [2].

Construction quality is a complex task, which can be successfully solved if each construction participant complies with codes, regulations, and standards set by the government.

To date, housing construction is the most important sector of the real estate market. The volume of residential construction should be increased to solve social problems and facilitate economic development.

Multi-storey residential buildings make up a large share of the global housing construction market; their mission is to save urban areas and, accordingly, ensure a significant increase in settlement density.

The term "quality" has a number of definitions which can be characterized on behalf of either consumers or manufacturers of construction products. After analyzing various interpretations of the concept of "quality", the authors concluded that most researchers

believed that quality was understood as the characteristics and properties of products in the aggregate, which would satisfy consumer needs [3–6].

Information technologies are used to study supervision over the quality of construction projects and their implementation [7].

Particular attention is drawn to the successful implementation of universal or total quality management methods. For example, Japan's national markets inhibit the introduction of a unified management system due to the lack of a universal production culture shared by construction participants [8]. The studies, conducted in Palestine, have identified a total of 8 principal factors and 81 sub-factors. Seven critical factors and 38 important sub-factors of success were identified as boosters of successful assimilation of a comprehensive quality management system by construction companies located in the Gaza Strip [9]. In Nigeria, quality management protocols were implemented to improve the efficiency of national projects. Twenty-five factors affecting the satisfaction of construction project participants, were identified [10]. The studies, conducted in Jordan, identified 20 factors; the principal ones are human resources management, applied technologies, logistics management, and customer satisfaction [11]. In Taiwan, construction companies study relationships between corporate culture, overall management, and project efficiency [12].

Individual production processes have been examined to improve the performance of construction projects: the construction efficiency of reinforced concrete residential buildings could be improved by a higher quality non-destructive control system designed for monolithic structures [13,14]. The programme for the non-destructive testing of monolithic residential structures enhances the quality of end products [15].

An attempt was made to enhance low-cost housing design by introducing a quality function [16].

The management decision-making system has improved [17]. For example, the implementation of a fair contract method, based on the analysis of all possible scenarios affecting the profit/loss ratio, was the focus of another research project [18].

Interesting works address the impact of public investment on financial standing and demand in the construction industry. The Monte Carlo method was employed to analyze factors and parameters positively influencing cost adjustments during the implementation of a construction project [19].

A management decision-making methodology, based on the Gaussian mixture model, was developed to ensure the optimal distribution of state support between construction companies during the COVID-19 pandemic [20].

Recent construction research projects focus on new areas, where construction process efficiency, viewed from the standpoint of administrative and engineering actions, is described by a single "integrated quality index" [21–26].

The term "integrated quality index" (IQI)is defined in the research works as a quality index that consolidates several properties. This index may characterize any object as a whole or single out a group of its properties.

Each participant in a construction project, performing its functions, should strive to finance the project as efficiently as possible to reduce the construction term and produce the best quality structures [27,28]. The optimal combination of these requirements is the most difficult task, and the correct solution will determine successful project implementation.

Currently, such an evaluation method should be universal to clearly demonstrate the effectiveness of control arrangements and solutions.

This study is aimed at developing a method for calculating the IQI for the housing construction industry. The authors analyzed the possibility and feasibility of implementing this method and in so doing, considered the IQI in terms of systems engineering as a set of individual factors affecting the quality of a multi-storey residential building.

The scientific novelty of the research consists in the development of an IQI calculation method focused on administrative and engineering solutions which influence the safety of multi-storey residential buildings at all stages of their lifecycle. This method will allow

participants in a construction project to determine its level of quality and adjust project control where destructive factors arise in the course of a project's implementation.

The research hypothesis is that this method will improve the quality of multi-storey residential buildings by applying an IQI.

2. Methods

2.1. Collecting Data for the Study

The following optimal theoretical research methods were selected to solve the tasks of the research project: expert survey, system analysis, qualimetry, statistical analysis, systems engineering in the construction industry, experimental design theory, and robust methods in statistics.

System analysis was employed in the process of justifying the need to solve the research tasks. This is how the authors developed unified approaches, outlined stages of research, and described the process of planning and implementing an experiment. The main principles and approaches of systems engineering in the construction industry were formulated to develop an IQI for multi-storey residential buildings.

Qualimetry analysis has several stages:

- Calculation of the required number of experts;
- Group selection;
- Identification of the construction facility properties that affect quality, and their further structuring as a hierarchical tree, taking into account the importance characteristics of each property;
- Using methods of mathematical statistics to process the results.

In the course of planning an experiment that involves a construction facility, any information about it must be carefully studied so that reliable information can be obtained. Regardless of what these factors are, they should have a whole set of features required for the best possible experiment. The availability of a number of factors, varying at several levels, can ensure the following factor-based experiment:

$$N = M^k \quad (1)$$

where M is the number of levels of variation, and k is the number of factors.

Hence, the emerging complexities and the scale of production processes underway in the construction industry make this schedule quite problematic to implement. Therefore, to solve this problem during the construction of the matrix, we reduced the number of factors, using factor analysis, as well as D-optimal schedules whose characteristics are similar. Materials for the factor analysis are correlation relationships, Pearson correlation criteria, which can be calculated using variable factors.

Robust procedures should be employed to process the expert data. Here, the following approach was used: in the first stage, "atypical" observations were identified and excluded; in the second stage, the least square method was applied to remaining observations. The "trimmed mean of the pre-set level" was used as a robust procedure. The level of 5% was taken. This means that sufficiently effective and reliable estimates are ensured, if about 5% of "atypical observations" are present in the sampling.

The above methods and principles serve as the basis for this experiment and the mathematical model developed using the most significant factors.

2.2. Launching an Expert Survey

Analysis of the sources, written by foreign and Russian experts, helped to identify the main parameters influencing the quality of a construction product at different stages of its lifecycle:

- Initial permits (IP).
- Engineering surveys.
- Project documentation (PD).

- Corporate structure.
- Equipment and materials used.
- Construction and installation works.
- Executive and other documents that need to be issued in order to put the facility into operation, to undergo an examination for compliance with approved standards [29–31].

The research work was divided into two phases: the first identified groups of factors that could have a great impact on the quality of high-rise residential buildings, while the second evaluated the impact of each factor considered separately; how they interact with and influence each other.

The use of the expert survey method allowed the authors to obtain initial information for the first phase of the study; hence, only those factors which had a strong impact on the quality of high-rise residential buildings were considered.

The expert survey was launched among construction industry specialists; 113 experts participated in the selection procedure pursuant to the competence requirements applied to each expert [32].

The authors selected professional experts who had the necessary qualifications and experience in this area. They included directors of construction enterprises, professional builders experienced in the construction of various purpose buildings; chief engineers of construction companies, engaged in design and quality control (the register of builders is available on the NOSTROI (National Association of Builders) website, and the register of designers and surveyors is maintained by the National Association of Designers and Surveyors).

Initially, each expert was asked to give a yes/no answer to the question as to whether any of the factors considered by the authors had any impact on the quality of a multi-storey residential building.

After studying and analyzing the research literature, the authors concluded that, of all the factors studied, the quality and safety of the construction of multi-storey residential buildings were most influenced by the following characteristics:

- Engineering specifications for construction facilities (P_1);
- Reliable and sufficient pre-construction surveying reports (reports on engineering-geodesic, engineering-geological, engineering-ecological, engineering-hydrological surveys, etc.) (P_2);
- Compliance of design solutions with the requirements of construction regulations, state standards, and other regulatory documents in effect at the time of the building examination (P_3);
- Full compliance of materials and equipment with regulatory and design documentation requirements (P_4)
- Compliance with administrative and engineering solutions (P_5);
- Compliance with the sequence of works (P_6);
- Geotechnical monitoring (P_7);
- Availability of hoisting machinery (P_8);
- Number of employees, including specialists, with sufficient work experience and appropriate qualifications (P_9);
- Application of industrial formwork systems (P_{10});
- Application of advanced engineering machinery (P_{11}) [33].

The expert survey method enabled the authors to identify indexes of importance of duly selected parameters, and they consequently decided to choose the widely spread method known as ranking (or the questionnaire method) (Table 1). The questionnaire was compiled with due regard for all the features of the construction industry [34–36]. In the process of studying the questions and completing the questionnaire, each of the experts was instructed to assign a score of 1 to 11 to each factor to identify their significance and establish their impact on the quality of work.

Table 1. The questionnaire to be completed by the experts (the template).

№	Factors	Expert's Score
1.	Specifications for construction facilities	
2.	Reliable and sufficient materials, including all sections on engineering surveys (reports on engineering-geodesic, engineering-geological, engineering-ecological, engineering-hydrological surveys)	
3.	Compliance of design solutions with requirements of Construction Regulations, State Standards, and other regulatory and engineering documents in force at the moment of examination	
4.	Full compliance of supplied materials and equipment with the requirements of regulatory and design documentation	
5.	Compliance with administrative and engineering solutions	
6.	Compliance with the sequence of work procedures	
7.	Geotechnical monitoring	
8.	Availability of hoisting machinery	
9.	Number of employees, including specialists with sufficient work experience and appropriate qualifications	
10.	Use of industrial formwork systems	
11.	Use of advanced engineering machinery	

The expert questionnaire enabled the identification of the eight most significant factors. The remaining three were rejected due to the acceptable loss of information (the total influence of which did not exceed 5%).

Consistency of expert opinions was evaluated using the concordance coefficient:

$$W = \frac{12\sum_{i=1}^{n}\left(\sum_{j=1}^{m} a_{ij} - \frac{1}{2}m(n+1)\right)^2}{m^2(n^3-n)} = 0.887, \quad (2)$$

where n is the number of factors (11),

m is the number of experts (113),

a is the matrix of experts' opinions.

Further, according to the findings of the expert questionnaire, the most significant eight parameters, having the greatest influence on the quality of a construction facility, were identified:

- Specifications for construction facilities (P_1);
- Reliable and sufficient materials, including engineering surveys (P_2);
- Compliance with administrative and engineering solutions (P_5);
- Compliance with the sequence of work procedures (P_6);
- Geotechnical monitoring (P_7);
- Availability of hoisting machinery (P_8);
- Use of industrial formwork systems (P_{10});
- Use of advanced engineering machinery (P_{11}).

The presence of eight factors, changing at three levels, entails the following factor-based experiment:

$$N = 3^k = 3^8 = 6561 \quad (3)$$

where 3 is the number of levels of variability,

k is the number of factors.

According to the results of the analysis of the intercorrelation matrix, we can identify four groups of interrelated variables (z_1, z_2, z_3 and z_4):

- First group z_1: facility specifications (P_1) and work sequence compliance (P_6);
- Second group z_2: reliable and sufficient materials, including all sections on engineering surveys (P_2) and geotechnical monitoring (P_7);
- Third group z_3: compliance with the requirements of administrative and engineering solutions (P_5) and availability of hoisting machinery (P_8);
- Fourth group z_4: use of industrial formwork systems (P_{10}) and advanced engineering machinery (P_{11}).

The significance of all groups of factors was determined using the dispersion index of factor loading and factors.

To calculate the value of group z_i, we need to find the total sum of squares of loading of each of x_1 factors in all columns of the factor matrix.

Their importance characteristics indicate how much dispersion the particular group z_i takes up in the intercorrelation matrix. The values of Y(z_i) and z_i are shown in Table 2.

Table 2. Calculated values of Dz_i and Y(z_i).

	Dispersion of the Group	Importance Characteristic of the Group
Group z_1	0.1914	0.0239
Group z_2	0.2421	0.0303
Group z_3	0.2248	0.0281
Group z_4	0.1812	0.0227

The sum of values $D(z_i)$:

$$D(z_i) = 0.19147 + 0.242148 + 0.224855 + 0.1812 = 0.839674 = 84\%. \quad (4)$$

This means that as a result of factorization of the intercorrelation matrix, some of the original information was "sacrificed" due to the construction of the four-factor model. As a result, 16% of the information was lost.

This calculation error is acceptable, because the research findings show that the four-factor model allows the reduction of the number of experiments.

The most significant group is group z_2.

This expert survey determines the importance of each individual factor for the evaluation of the quality of multi-storey residential buildings. Pairwise correlation solves the local problem of research in two stages, which ultimately means a reduction in the number of trials in an experiment needed to obtain the desired model.

The four groups of interrelated variables (z_1; z_2; z_3; z_4) are the result of the process of establishing correlations between the parameters.

2.3. Mathematical Model

It was found that there are four effective factors (z_1, z_2, z_3, z_4) which significantly affect the response function Y.

As a consequence, the experiment was multifactorial. Given that the model is statistical and the processes under study are of probabilistic nature, it is evident that the response function Y obeys the correlation dependence on factors z_i influencing it. This then leads to the identification of a series of different values as the output parameter if the value of the factor is non-variable.

In this regard, the purpose of this multi-factor experiment was to find a mathematical model that is a regression equation that adequately describes the experiment results.

In the present study, in order to perform the experiment, it was necessary to identify the number of trials (as well as the conditions under which they should be performed),

adequate to solve the problems with sufficient accuracy. The theory of scheduling can be used to solve this problem.

In this way, the cost and time of experiments can be minimized and, if necessary, the mathematical model can be upgraded without losing the available information. Experiment scheduling helps to effectively solve a number of vital problems in the course of experiments by:

- Minimizing the total number of experiments;
- Applying appropriate algorithms to simultaneously change variables that determine the process;
- Using a special mathematical apparatus that formalizes the experimenter's actions;
- Choosing the strategy that enables researchers to make sufficiently informed decisions;
- Drafting appropriate experiment schedules to avoid correlation between regression equation coefficients.

The following minor problems must be identified and solved to use the experiment scheduling method:

- Identify a combination of groups of factors and a number of these combinations to determine response functions;
- Determine the response function accuracy;
- Determine coefficients for a regression equation;
- Use the resulting response function to find the most efficient values of the y function.

To build an effective mathematical model, ranges of factor changes must be found, because they determine the area of values of objective function Y.

In this case, the search for a solution was limited to the factor space restricted by the coordinate axes of each factor. Hence, factors should be converted into dimensionless values (which are encoded):

$$\mathrm{zi} = \frac{(\mathrm{zi} - \mathrm{z0})}{\mathrm{dzi}}, \tag{5}$$

where z_i is the encoded value of the factor,

z_i is the value of the factor (*i*) in the natural scale.

$$\mathrm{dzi} = \frac{\mathrm{zimax} - \mathrm{zimin}}{2}, \tag{6}$$

$$\mathrm{z0} = \frac{\mathrm{zimax} + \mathrm{zimin}}{2}. \tag{7}$$

Each of the encoded factors z_i can only take certain values equal to -1; 0 or +1. In other words, the scheduling area is a hypercube (Figure 1) with the following parameters:

$$-1 \leq z_i \leq 1, \tag{8}$$

Here *i* = 1, 2, 3, 4.

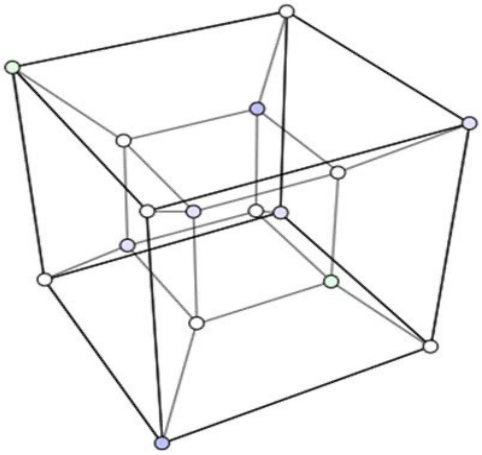


Figure 1. The hypercube factor space formed by four factors.

At the same time, factors must meet certain criteria: they must have a significant impact on the final IQI value, have an unambiguous description, and vary qualitatively at all three levels: the lower level (encoded value = −1), the main level (encoded value = 0), and the upper level (encoded value = +1).

Following experts' consultations with and contributions from construction specialists, eight main factors meeting the above criteria could be identified.

By analyzing the information and systematizing the data, the levels of variation can also be qualitatively interpreted.

Factors that may have different variants, identified through cooperation and questioning of construction specialists, help to recognize the administrative and engineering solutions needed for the successful construction of high-rise residential buildings. It is only necessary to identify the type of functional dependence between them and the process mentioned in the research after the mathematical model is duly made. The coded values of the factors are presented in Table 3.

Table 3. Encoded values of factors.

Factors	Code	−1	0	+1
Specifications for facilities	P_1	Not available	Partially available	Available
Reliable and sufficient materials including all sections on engineering surveys (reports on engineering-geodesic, engineering-geological, engineering-ecological, engineering-hydrological surveys)	P_2	Most sections and reports are unavailable	Some sections and reports are unavailable	All sections and reports are available
Compliance with administrative and engineering solutions	P_5	Not complied with	Partially complied with	Complied with
Compliance with the sequence of works	P_6	The sequence of work is not complied with	The sequence of work is partially complied with	The sequence of work is complied with
Geotechnical monitoring	P_7	Not performed	Partially performed	Performed
Availability of hoisting machinery	P_8	Cranes operate on the construction site, performing all types of lifting	There are cranes and passenger lifts on site	The site has cranes, cargo-passenger lifts, and other mechanisms for lifting concrete and mixtures
Application of industrial formwork systems	P_{10}	Not applied	Partially applied	Applied
Use of modern engineering machinery	P_{11}	Not used	Partially used	Used

The qualitative interpretation of variation levels is presented in Table 4 according to the results of data analysis and systematization.

Table 4. Encoded values of factors.

Description	Code	−1	0	+1
Technical conditions for facilities, compliance with the sequence of work	z_1	Not available; the sequence of work is not complied with	Partially available; the sequence of work is partially complied with	Available; the sequence of work is complied with
Reliable and sufficient amount of materials, including all sections on engineering surveys (reports on engineering-geodesic, engineering-geological, engineering-ecological, engineering-hydrological surveys, etc.), geotechnical monitoring	z_2	Most sections and reports are not available; geotechnical monitoring is not performed	Some sections and reports are not available; geotechnical monitoring is partially performed	All sections and reports are available; geotechnical monitoring is performed
Compliance with the requirements of administrative and engineering solutions; availability of hoisting machinery	z_3	Not complied with; cranes perform all types of operations on the construction site	Partially complied with; there are cranes and passenger lifts on site	Complied with; The site has cranes, cargo-passenger lifts, and other mechanisms for lifting concrete and mixture

A regression analysis was employed to find the mathematical formulas that best describe the experimental data.

The mathematical theory of experiment scheduling should be used to find the coefficients of regression equations. It allows managing the course of an experiment as effectively as possible to obtain the most reliable information using the minimum acceptable amount of experimental data.

Experiment scheduling is a procedure for selecting the number of trials and their conditions that are sufficient to solve the problem with the required accuracy.

A linear model was used as a regression model. Here groups z_1, z_2, z_3, and z_4 were selected as factors. The next model under consideration is a quadratic one. Here groups z_1, z_2, z_3, and z_4, as well as their squares, were used as factors.

To identify the right number of experiments the authors developed a plan in compliance with indexes of optimality of the number of experiments, which was designated as N.

To reduce the number of experiments the authors used a D-optimal composite three-level plan. This plan includes trials made within the framework of a full parametric experiment, and it also includes other trials in the centre of the plan and in the "star points", located directly on the axes of the fallacious space. A questionnaire was compiled to collect the necessary information. In this questionnaire, a group of experts made an assessment using a scoring system in the range of 0 to 100 with an interval of 5 points. They checked the quality of multi-storey residential buildings, or a combination of constituent parameters. As a result, average values of the experts' assessments were subjected to stratification using a composite plan for each point.

A sample questionnaire was developed by the authors. Ten groups of experts were to rate the value of IQI of multi-storey residential buildings in conditional points from 0 to 100 with the interval of "5" in compliance with each of the 25 possible variants of the plan. Columns Y1,..., Y10 are assessments of 25 plan components made by the members of these groups. The results of the expert survey are presented in Table 5.

Table 5. Results of the expert survey.

№	Z_1	Z_2	Z_3	Z_4	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
1.	1	1	1	1	90	95	95	90	90	90	90	90	95	90
2.	1	1	1	−1	85	75	75	80	75	70	80	80	75	75
3.	1	1	−1	1	80	80	60	65	70	75	75	75	75	80
4.	1	1	−1	−1	75	70	75	70	70	60	65	70	70	60
5.	1	−1	1	1	75	80	70	65	65	75	80	75	70	70
6.	1	−1	1	−1	70	50	65	60	55	50	50	50	55	50
7.	1	−1	−1	1	75	65	70	65	70	75	75	75	70	65
8.	1	−1	−1	−1	55	55	50	50	50	55	60	55	50	50
9.	−1	1	1	1	85	80	85	80	80	85	80	80	85	80
10.	−1	1	1	−1	75	70	80	75	75	80	85	80	80	70
11.	−1	1	−1	1	70	65	70	60	65	70	70	65	60	65
12.	−1	1	−1	−1	45	50	45	50	55	50	45	45	50	50
13.	−1	−1	1	1	50	60	65	60	55	60	65	55	55	65
14.	−1	−1	1	−1	45	45	40	55	40	50	40	55	50	50
15	−1	−1	−1	1	45	40	45	45	50	55	50	45	40	40
16	−1	−1	−1	−1	30	25	30	25	25	30	25	30	25	30
17.	1	0	0	0	55	45	40	60	65	60	50	55	50	55
18.	−1	0	0	0	55	45	50	45	45	50	40	40	45	45
19.	0	1	0	0	65	65	70	70	70	65	65	70	65	70
20.	0	−1	0	0	55	55	50	60	65	60	55	60	55	50
21.	0	0	1	0	60	65	60	65	55	55	55	60	65	65
22.	0	0	−1	0	55	55	50	45	45	50	50	45	45	55
23.	0	0	0	1	65	55	55	60	60	60	60	65	65	65
24.	0	0	0	−1	50	60	45	55	45	50	50	60	65	60
25.	0	0	0	0	55	65	60	65	55	60	55	45	60	55

A robust approach was used to process the expert survey findings. Robust procedures are often used to process these data. The following approach was used in this work: at the first stage, "atypical" observations were identified and excluded; at the second stage, the least squares method was applied to the remaining observations. The procedure of the "trimmed mean of the pre-set level" was used as the robust one. A 5% level was employed as it provides sufficiently effective and reliable assessments if about 5% of "atypical observations" are available in the sampling.

The following table (Table 6) was obtained to calculate parameters of regression models.

Table 6. Processing of expert survey findings.

No. of Experiment	Z_1	Z_2	Z_3	Z_4	Y
1.	1	1	1	1	91.25
2.	1	1	1	−1	76.87
3.	1	1	−1	1	63.75
4.	1	1	−1	−1	68.75
5.	1	−1	1	1	72.5

Table 6. *Cont.*

No. of Experiment	Z_1	Z_2	Z_3	Z_4	Y
6.	1	−1	1	−1	54.37
7.	1	−1	−1	1	70.62
8.	1	−1	−1	−1	52.5
9.	−1	1	1	1	81.88
10.	−1	1	1	−1	76.88
11.	−1	1	−1	1	66.25
12.	−1	1	−1	−1	48.12
13.	−1	−1	1	1	59.37
14.	−1	−1	1	−1	46.87
15	−1	−1	−1	1	45
16	−1	−1	−1	−1	27.5
17.	1	0	0	0	53.75
18.	−1	0	0	0	45.62
19.	0	1	0	0	67.5
20.	0	−1	0	0	56.25
21.	0	0	1	0	60.62
22.	0	0	−1	0	49.87
23.	0	0	0	1	61.25
24.	0	0	0	−1	53.75
25.	0	0	0	0	58.12

The following models were obtained:

Y. Linear model. General view of the formula for evaluating the coefficients of the regression model:

$$Y = z^*a + e, \quad (9)$$

where a is the matrix of expert assessments,

y is the vector of errors.

Y is the size vector of expert assessments obtained using the robust method.

Regression statistics using a linear model are presented in Table 7.

Table 7. Regression statistics obtained using the linear model.

Regression statistics				
Multiple R	0.879488			
R-Square	0.773499			
Normalized R-Square	0.728199			
Standard error	7.191446			
Observations	25			
Analysis of variance				
	df	*MS*	*F*	Significance of F
Regression	4	883.0661097	17.07500251	3.10424×10^6
Remainder	20	51.71689486		
Total	24			
	Coefficients	*t*-statistics	*p*-value	
Y-intersection	60.3684	41.97236579	5.6264×10^{21}	
Variable X 1	5.937222	3.502703176	0.002241053	
Variable X 2	8.681667	5.121806169	5.19784×10^5	
Variable X 3	7.125	4.203440463	0.000437187	
Variable X 4	5.903333	3.482710204	0.002347197	

The following dependence was obtained:

$$Y = 60.37 + 5.94\ z_1 + 8.69\ z_2 + 7.13\ z_3 + 5.9\ z_4 \quad (10)$$

With a confidence probability of 0.95 (p-value is less than 0.05) all coefficients are significant (according to Student's test).

The coefficient of determination of the model is 0.879, which confirms its high adequacy.

It should be noted that the closer the coefficient of determination to 1, the better the model approximates the data.

1. Quadratic model

Regression statistics using the quadratic model are presented in Table 8.

Table 8. Using a quadratic model to obtain regression statistics.

Regression statistics				
Multiple *R*	0.925099193			
R-square	0.855808516			
Normalized *R*-Square	0.783712774			
Standard error	6.415144034			
Observations	25			
Analysis of variance				
	df	MS	F	Significance of F
Regression	8	488.517146	11.87044467	2.0448×10^5
Remainder	16	41.15407298		
Total	24			
	Coefficients	*t*-statistics	*p*-value	
Y-intersection	54.67322034	19.73776195	1.17275×10^{12}	
Variable X 1	5.937222222	3.926568201	0.001204454	
Variable X 2	8.681666667	5.741600194	3.03206×10^5	
Variable X 3	7.125	4.71210229	0.000234952	
Variable X 4	5.903333333	3.904155863	0.00126267	
Variable X 5	−4.413757062	−1.097984589	0.288460441	
Variable X 6	7.776242938	1.93445058	0.070942481	
Variable X 7	1.146242938	0.285144167	0.779191732	
Variable X 8	3.401242938	0.846107359	0.409969175	

The following dependence was obtained:

$$Y = 54.67 + 5.94\ z_1 + 8.68\ z_2 + 7.125\ z_3 + 5.90\ z_4 - 4.41\ {z_1}^2 + 7.78\ {z_2}^2 + +1.15\ {z_3}^2 + 3.40\ {z_4}^2. \quad (11)$$

Only coefficients of linear terms are significant (according to the Student's test, coefficients at the squares have a level of confidence less than the generally accepted value of 0.95).

The coefficient of determination of the model is 0.925, which confirms its high adequacy (according to the Fisher's test, significance is 2.0448×10^5).

2. General quadratic model

Regression statistics using the general quadratic model are presented in Table 9.

Table 9. Regression statistics using a general quadratic model.

Regression statistics				
Multiple paired	0.96528285			
R-Square	0.93177098			
Normalized *R*-Square	0.836250352			
Standard error	6.101291117			
Observations	25			
Analysis of variance				
	df	*MS*	*F*	Significance of F
Regression	14	363.1244619	9.754657187	0.000481547
Remainder	10	37.2257533		
Total	24			
	Coefficients	*t*-statistics	*p*-value	
Y-intersection	54.83050847	20.81278458	1.45333×10^9	
Variable X 1	8.888888889	6.1810461	0.000104001	
Variable X 2	9.444444444	6.567361481	6.33279×10^5	
Variable X 3	5.833333333	4.056311503	0.002300141	
Variable X 4	5.833333333	4.056311503	0.002300141	
Variable X 5	0.197740113	0.051721041	0.959769548	
Variable X 6	5.197740113	1.359524519	0.203845229	
Variable X 7	2.697740113	0.70562278	0.496531057	
Variable X 8	2.697740113	0.70562278	0.496531057	
Variable X 9	−2.5	−1.638997355	0.13225181	
Variable X 10	-5.84416×10^{16}	-3.83142×10^{16}	1	
Variable X 11	−1.25	−0.819498677	0.431599903	
Variable X 12	1.875	1.229248016	0.247117996	
Variable X 13	−1.875	−1.229248016	0.247117996	
Variable X 14	−3.125	−2.048746693	0.06765007	

The following dependence was obtained:

$$Y = 54.83 + 8.89\ z_1 + 9.45\ z_2 + 5.83\ z_3 + 5.83\ z_4 + 0.2\ z_1^2 + 5.2\ z_2^2 + \\ + 2.7\ z_3^2 + 2.7\ z_4^2 - 2.5 z_1 z_2 - 1.25\ z_1 z_4 + 1.86\ z_2 z_3 - 1.86\ z_2 z_4\ - 3.12\ z_3 z_4. \quad (12)$$

Only coefficients of linear terms were significant (according to the Student's test, coefficients at squares and products of factors have a level of confidence less than the generally accepted value of 0.95).

The coefficient of determination of the model is 0.965, which confirms its high adequacy (the significance is 0.000481547according to the Fisher's test).

The authors believe that the general quadratic model (the coefficient of determination is 0.965) is the most adequate.

The mathematical model allows adjustments to achieve the desired levels of reliability, quality, and durability at any stage of any construction project.

The use of the mathematical model, which conveys the essence of the phenomenon considered here, is the optimal solution; it successfully predicts and evaluates the impact of individual factors on the IQI [37–42].

In our further calculations, the IQI, determined by its parameters, rather than groups of factors, will be referred to as IQI.

To obtain a detailed mathematical model based on a particular functional relationship, allowing to calculate IQI values, the factor systems modelling technique was used:

$$\mathrm{CQI} = \sum_{i=1}^{n} \mathrm{W_i pi}, \tag{13}$$

where *Wi* is the coefficient of importance (weight) of the *i*-th parameter.

The resulting model not only fully characterizes the process of studying the IQI, but can be modernized to complicate or simplify the process.

The analysis of dependence between the IQI and the studied group of factors can be presented in a graphical form. To this end, a three-dimensional graph of the surface of the obtained regression equation must be created, depending on different groups of factors. Considering that there are four factors, it was convenient to study the obtained surfaces by alternating a combination of two active factors when the other two are in a fixed position. In this case, it became a series of six dependencies in a graph which describes the alternating influence of two groups of factors on changes in IQI The nature of the change in CPR from the influence of two groups of factors z1, z2 is reflected in Figure 2, the nature of the change in CPR from the influence of two groups of factors z1, z3 is reflected in Figure 3. For example:

$$\mathrm{IQI} = \mathrm{f}\,(z_1,\ z_2) = 54.83 + 8.89\ z_1 + 9.45\ z_2 + 0.2\ z_1^2 + 5.2\ z_2^2 - 2.5 z_1 z_2. \tag{14}$$

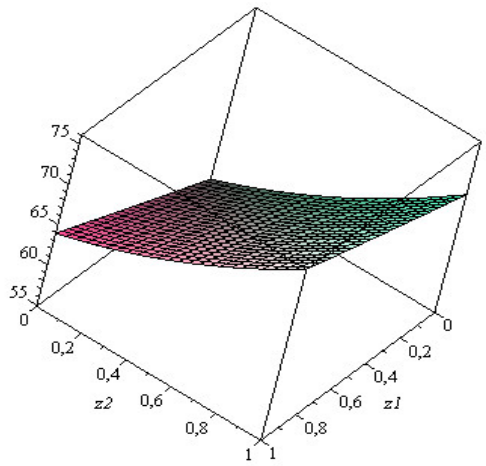


Figure 2. The nature of changes in IQI caused by the influence of two groups of factors z_1, z_2.

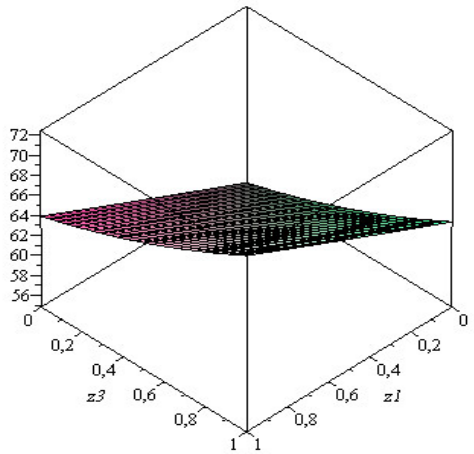


Figure 3. The nature of changes in IQI caused by the influence of two groups of factors z_1, z_3.

The combined effect of factors z_1 and z_2 has a moderate effect on the value of IQI, and ensures the linear nature of processes that are underway.

$$IQI = f(z_1, z_3) = 54.83 + 8.89\, z_1 + 5.83\, z_3 + 0.2\, z_1^2 + 2.7\, z_3^2. \quad (15)$$

When studying the joint influence of factors z_1 and z_3 on the value of integrated index IQI = f (z_1, z_3), linear dependence on z_1 and z_3 prevails, although a more pronounced quadratic dependence on factor z_3 was observed.

Similar graphs were obtained for other variables.

The final stage of data collection and structuring was the measurement of values of potential states of parameters, determined using parameter weights. The method of variation series was applied to find the weights of parameters. The process of determining the values of potential states of parameters followed the process of determining the value of parameter weights. Groups of experts using the analysis of hierarchies method created a table of parameters which allows evaluating the current state and effectiveness of administrative and engineering solutions. After obtaining a dimensionless discrete value for its qualitative interpretation in the course of constructing a multi-storey residential building, the "use of quantitative ranges of values of the generalized Harrington's desirability function" must be adapted. Since the quantitative range of values, having such qualitative interpretations as "good" and "very good", "bad" and "very bad", has the same meaning for construction, they should be combined. The final table of the qualitative interpretation of the discrete evaluation of the quality of multi-storey residential buildings is presented as Table 10.

Table 10. Conversion of quantitative evaluation into a qualitative evaluation.

№	Value Gradation	Desirability Scale Gradation	Psychophysical Evaluation
1	Over 63.10	0.64–1.00	Good
2	58.12–63.00	0.37–0.63	Satisfactory
3	Less than 58.11	0.00–0.36	Poor

Description of a method of integrated assessment of the quality of multi-storey residential buildings followed the development of integrated quality assessment and IQI calculation algorithms:

1. Monitoring of administrative and engineering solutions, involved in the process of construction of multi-storey residential buildings, factoring in their compliance with the current standards;
2. Correlation between administrative and engineering solutions, considering parameters, provided in the tabular form;
3. Determination of the IQI for a multi-storey residential building;
4. The obtained value duly correlates with the tabulated data on the qualitative interpretation of discrete evaluation as well as with the qualitative evaluation of administrative and engineering solutions.

If the quality evaluation is unsatisfactory, the following method can be employed:

1. Implement actions to raise the quality index and minimize financial costs and potential adverse effects on the customer itself;
2. Calculate new values of adjusted indexes;
3. Redefine the index;
4. Repetitive correlation of the criterion with the tabulated data on the qualitative interpretation to determine the qualitative evaluation of approved administrative and engineering solutions [43].

The algorithm for calculating and improving the IQI is shown in Figure 4.

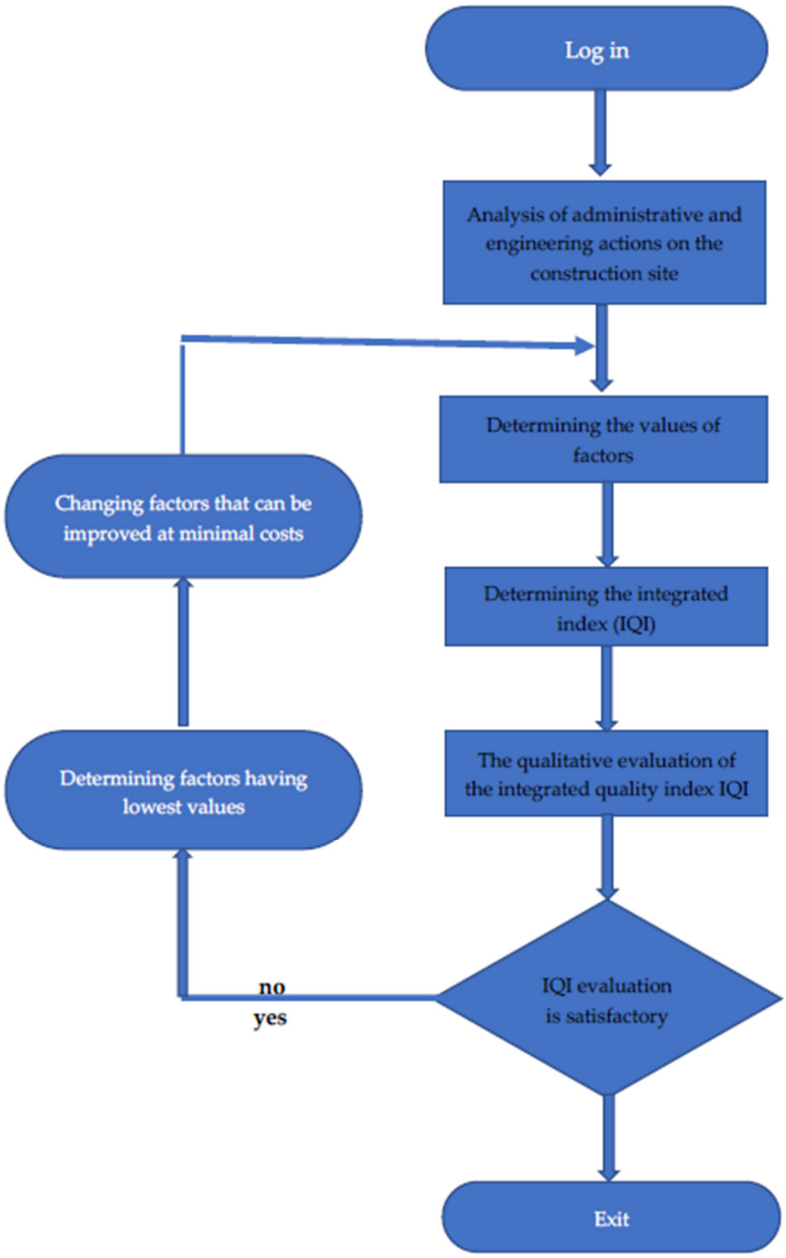


Figure 4. Algorithm for calculating and improving the IQI.

3. Discussion

Following a thorough analysis of the research literature, the main factors influencing the quality of construction of multi-storey residential buildings at various stages of their lifecycles were identified and defined.

The authors conducted an expert survey among 113 specialists of the construction industry, whose work experience exceeded 10 years; this facilitated identifying the most important 8 factors affecting the quality of multi-storey residential buildings; questionnaires were drafted using specialized literature.

The authors' method of calculation of an IQI of acceptability of administrative and engineering solutions, influencing the safety of multi-storey residential buildings at all stages of their lifecycle allows a tool for the evaluation of the IQI of multi-storey residential buildings to be devised. To this end, the authors introduced a previously unused concept (or an IQI) of multi-storey residential buildings. By applying this coefficient, a contractor

can compare possible variants aimed at improving the quality and correcting administrative and engineering solutions to raise the efficiency of construction.

The research findings (calculation of an IQI) were applied in the process of construction of multi-storey residential buildings in the Moscow region.

The first stage of the research included initial data collection and analysis. Subsequently, comments were invited and recommendations developed to increase the value of the IQI of a multi-storey residential building. At the second stage, a change in the adjusted value of an integrated performance index was identified with the recommendations being taken into account.

After completing the analysis of the facility titled "Building 9 of Residential 25-storey Complex Salarevo Park" (built by PIK Group), the following result was obtained:

$$\text{IQI} = \sum_{i=1}^{n} W_i pi = 46.17 \tag{16}$$

The obtained value was in the range of values of a "bad" psychophysical assessment.

Having analyzed the data, we concluded that an increase in the values of four parameters ($P_{6,8,10,11}$) would be necessary to achieve the psychophysical assessment known as "good". This can be achieved by applying administrative and engineering solutions, directly or indirectly related to the parameters in question. As a result, the following value was obtained:

$$\text{IQI} = \sum_{i=1}^{n} W_i pi = 63,39 \tag{17}$$

This value corresponded to a "good" psychophysical assessment. The data is presented in Table 11.

Table 11. Levels of variation of factors and their values.

№	Factor	Symbol	Levels of Variation	Value/ Value Code before Methodology Implementation	Value/ Value Code after Methodology Implementation
1.	Technical specifications for facilities	P_1	Partially present	58.12/2	58.12/2
2.	Reliable and sufficient materials, including all sections on engineering surveys	P_2	No individual sections and reports	58.12/2	58.12/2
3.	Compliance with the requirements of administrative and engineering solutions	P_5	Partially complied with	58.12/2	58.12/2
4.	Compliance with the sequence of work procedure	P_6	Not complied with	27.5/1	91.25/3
5.	Geotechnical monitoring	P_7	Not performed	27.5/1	27.5/1

Table 11. *Cont.*

№	Factor	Symbol	Levels of Variation	Value/ Value Code before Methodology Implementation	Value/ Value Code after Methodology Implementation
6.	Availability of hoisting machinery	P_8	Cranes and man lifts on the site	58.12/2	91.25/3
7.	Application of industrial formwork systems	P_{10}	Not applied	27.5/1	58.12/2
8.	Use of modern engineering machinery	P_{11}	Not used	27.5/1	58.12/2

The value, obtained as a result of analysis of the facility "Building 18.2 of Residential 25-storey Complex Salarevo Park" (built by PIK Group), was in the range of a "satisfactory" psychophysical assessment. The algorithm was then applied to raise the integrated performance index value. The obtained value corresponded to a "good" psychophysical assessment.

The value of the method developed by the authors was proven in the course of its application on real construction sites.

This method is a full-fledged tool designed for construction participants which allows (1) determining the quality level at various stages of a construction project by using "an IQI of multi-storey residential buildings" and (2) adjusting administrative and engineering solutions, if necessary.

Within the framework of the research, we used the case of the construction facility "Building 9 of Residential 25-storey Complex Salarevo Park" to consider the economic efficiency of this method.

It has been proved that to achieve a "good" psychophysical assessment one should increase the values of such four factors as:

- Compliance with the sequence of work (P6);
- Availability of hoisting machinery (P8);
- Use of industrial formwork systems (P10);
- Use of modern engineering machinery (P11).

The analysis of the real construction facility leads to the conclusion that raising the values of factors to a higher level will lead to a reduction in the duration of construction by 19 days and, accordingly, a cost reduction of about 15,805,340 rubles, thereby increasing the economic benefits.

4. Conclusions

The following conclusions can be made on the basis of the research conducted by the authors:

1. Modern methods of evaluating the quality of multi-storey residential buildings have been analyzed; the main stages of the lifecycle of an investment and construction project have been identified; the validity of the hypothesis put forward in the work about the practical use of the concept "the IQI of multi-storey residential buildings" has been proved.
2. The selection, structuring, and ranking of the main factors which influence the quality of multi-storey residential buildings at various stages of their lifecycles, was undertaken.
3. The mathematical apparatus for determining the numerical value of the proposed multi-factor criteria was developed and the technique for calculating the IQI of multi-storey residential buildings in the process of making pre-construction arrangements

was composed. This method can be used to determine quality at various stages of an investment and construction project using the "IQI of multi-storey residential buildings" and to adjust administrative and engineering solutions, if necessary.

4. The behaviour of the IQI of multi-storey residential buildings was studied amid changes in the values of indexes of various groups of factors. A three-dimensional graph of the surface of the regression equation, based on various groups of factors, was created. Resulting surfaces were studied by alternating the combination of the two factors in effect, while the other two remained in a fixed position.
5. The feasibility and expediency of introducing the above method into housing construction has been proven. This technique allows for the comprehensive evaluation and quality measurement of multi-storey residential buildings. It was proved that an increase in the values of factors reduces construction time and, accordingly, costs of construction at various stages of the lifecycle of a project at the stage of making pre-construction arrangements.
6. Any future research in this area should focus on database expansion, which would allow (1) determination also of the value of the IQI of multi-storey residential buildings and (2) the development of software to computerize the data collection process and visualize the results of the method of improving the quality of multi-storey residential buildings.

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References

1. Aberdeen Group. *The Role of Quality in Global Manufacturing*; The Product Quality Benchmark Report; Aberdeen Group: Boston, MA, USA, 2005.
2. Leonard, D. Quality management practices in the US home building industry. *TQM J.* **2010**, *22*, 101–110. [CrossRef]
3. Barrett, P. Systems and relationships for construction quality. *Int. J. Qual. Reliab. Manag.* **2000**, *17*, 377–392. [CrossRef]
4. Pheng, L.S.; Hong, S.H. Strategic quality management for the construction industry. *TQM Mag.* **2005**, *17*, 35–53. [CrossRef]
5. Kluchnikova, O.; Pobegaylov, O. Application of strategic management principles as a tool to improve the quality of construction process. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *262*, 012075. [CrossRef]
6. Dahlgaard, J.; Kristensen, K.; Gopal, K. *Fundamentals of Total Quality Management*; Chapman & Hall: London, UK, 1998.
7. Tokarsky, A.; Topchiy, D. The concept of quality control of the organization of construction processes during construction supervision through the use of information technology. *E3S Web Conf.* **2021**, *258*, 09028. [CrossRef]
8. Abdul-Aziz, A.-R. The realities of applying total quality management in the construction industry. *Struct. Surv.* **2002**, *20*, 88–96. [CrossRef]
9. Altayeb, M.M.; Alhasanat, M.B. Implementing total quality management (TQM) in the Palestinian construction industry. *Int. J. Qual. Reliab. Manag.* **2014**, *31*, 878–887. [CrossRef]
10. Obunwo, C.; Chinyio, E.; Suresh, S. Quality Management as a Key Requirement for Stakeholders' Satisfaction in Nigerian Construction Projects. In Proceedings of the 11th International Post Graduate Research Conference, University of Salford, Manchester, UK, 8–10 April 2013. 14p.
11. Sweis, R.J.; Shanak, R.O.; Abu El Samen, A.; Suifan, T. Factors affecting quality in the Jordanian housing sector. *Int. J. Hous. Mark. Anal.* **2014**, *7*, 175–188. [CrossRef]
12. Kuo, T.-H.; Kuo, Y.-L. The effect of corporate culture and total quality management on construction project performance in Taiwan. *Total Qual. Manag. Bus. Excell.* **2010**, *21*, 617–632. [CrossRef]
13. Lapidus, A.; Bidov, T.; Khubaev, A. The study of the calibration dependences used when testing the concrete strength by nondestructive methods. *MATEC Web Conf.* **2017**, *117*, 00094. [CrossRef]
14. Lapidus, A.; Khubaev, A.; Bidov, T. Administrative and engineering solutions justifying the use of non-destructive methods of control when building monolithic constructions of civil buildings and structures. *MATEC Web Conf.* **2018**, *251*, 05014. [CrossRef]

15. Lapidus, A.; Khubaev, A.; Bidov, T. Development software for the non-destructive control of monolithic structures in housing construction. *E3S Web Conf.* **2021**, *258*, 09003. [CrossRef]
16. Abdul-Rahman, H.; Kwan, C.L.; Woods, P.C. Quality function deployment in construction design: Application in low cost housing design. *Int. J. Qual. Reliab. Manag.* **1999**, *16*, 591–605. [CrossRef]
17. Shehadeh, A.; Alshboul, O.; Hamedat, O. Risk Assessment Model for Optimal Gain–Pain Share Ratio in Target Cost Contract for Construction Projects. *J. Constr. Eng. Manag.* **2022**, *148*, 04021197. [CrossRef]
18. Alshboul, O.; Shehadeh, A.; Hamedat, O. Governmental Investment Impacts on the Construction Sector Considering the Liquidity Trap. *J. Manag. Eng.* **2022**, *38*, 04021099. [CrossRef]
19. Shehadeh, A.; Alshboul, O.; Hamedat, O. A Gaussian mixture model evaluation of construction companies' business acceptance capabilities in performing construction and maintenance activities during COVID-19 pandemic. *Int. J. Manag. Sci. Eng. Manag.* **2022**, *18*, 112–122. [CrossRef]
20. Alshboul, O.; Shehadeh, A.; Mamlook, R.E.A.; Almasabha, G.; Almuflih, A.S.; Alghamdi, S.Y. Prediction Liquidated Damages via Ensemble Machine Learning Model: Towards Sustainable Highway Construction Projects. *Sustainability* **2022**, *14*, 9303. [CrossRef]
21. Lapidus, A.A.; Shesterikova, Y.V. The study of the integrated index of the quality of work during the construction of a building facility. *Mod. Sci. Innov.* **2017**, *3*, 128–132.
22. Lapidus, A.A.; Shesterikova, Y.V. The formation of a tool for assessing the integrated quality index in construction. *Syst. Methods Technol.* **2018**, *37*, 90–93. [CrossRef]
23. Lapidus, A.A.; Shesterikova, Y.V. The formation of the potential of a comprehensive index of quality in construction. *Bull. Civ. Eng.* **2019**, *72*, 90–93.
24. Bayburin, A.H. Complex Assessment of the Quality of Construction of Civil Buildings, Taking into Account the Factors Affecting Their Safety. Ph.D. Thesis, Saint Petersburg State University, Saint Petersburg, Russia, 2012.
25. Topchiy, D.; Chernigov, V.; Grunina, I.; Kochurina, E. Administrative and engineering solutions to optimize the quality control of building materials. In Proceedings of the E3S Web of Conferences, Series "Ural Environmental Science Forum "Sustainable Development of Industrial Region", UESF 2021, Chelyabinsk, Russia, 17–19 February 2021.
26. Bidov, T.; Khubaev, A.; Nesterova, V.; Bzhenikov, A. Modern Russian high-tech construction materials and their application in domestic construction industry. *IOP Conf. Ser. Mater. Sci. Eng.* **2018**, *365*, 032005. [CrossRef]
27. Hussey, D.E. *Strategic Management: From Theory to Implementation*; Linacre House, Jordan Hill: Oxford, UK, 1998; p. 700.
28. Karpov, A.A. *Strategic Management and Effective Business Development*; Moscow, Russia, 2015; p. 528.
29. Lapidus, A.; Sinenko, S.; Shesterikova, Y. Qualitative analysis of safety factors of administrative and engineering solutions made at the stage of development of project documentation. *E3S Web Conf.* **2020**, *164*, 08005. [CrossRef]
30. Hromada, E.; Vitasek, S.; Holcman, J.; Heralova, R.S.; Krulicky, T. Residential Construction with a Focus on Evaluation of the Life Cycle of Buildings. *Buildings* **2021**, *11*, 524. [CrossRef]
31. Shesterikova, Y.V. Formation of an Integrated Index of Quality of Multi-Storey Residential Buildings in the Process of Making Construction Arrangements. Ph.D. Thesis, Ivanovo State University, Ivanovo, Russia, 2021; 160p.
32. Ruposov, V.L. Metody opredeleniya kolichestva ekspertov [Methods of determining the number of experts]. Sotsial'no-ekonomicheskie I obshchestvennye nauki [Vestnik National Research Irkutsk State Technical University. Socio-economic and social Sciences]. *Vestn. IrGTU* **2015**, *3*, 286–292.
33. Xiao, H.; Proverbs, D. Factors influencing contractor performance: An international investigation. *Eng. Constr. Archit. Manag.* **2003**, *10*, 322–332. [CrossRef]
34. Efimenko, A.; Zlobin, I.; Avilov, A.; Markov, A. Application of expert survey method for realization of tasks in construction industry. *E3S Web Conf.* **2019**, *91*, 08034. [CrossRef]
35. Fisher, R.A. *The Design of Experiments*; Oliver and Boyd Press: Edinburgh, UK, 1935.
36. Ruposov, V.L.; Chernykh, A.A. Processing formalized SWOT-analysis expert evaluation data. *Proc. Irkutsk. State Tech. Univ.* **2017**, *21*, 81–89. [CrossRef]
37. Lapidus, A.A.; Shesterikova, Y.V. Development of a mathematical model for evaluating the integrated quality index during the construction of multi-storey residential buildings. *Sci. Bus. Ways Dev.* **2019**, *91*, 44–48.
38. Lapidus, A.A.; Shesterikova, Y.V. Analysis of the mathematical model for evaluating the integrated index of quality. *Sci. Bus. Ways Dev.* **2019**, *94*, 91–94.
39. Basiri, M.E.; Naghsh-Nilchi, A.R.; Ghasem-Aghaee, N. Sentiment prediction based on Dempster–Shafer theory of evidence. *Math. Probl. Eng.* **2014**, *2014*, 361201. [CrossRef]
40. Shafer, G. *A Mathematical Theory of Evidence*; Princeton University Press: Princeton, NJ, USA, 1977; Volume 83, pp. 667–672.
41. Lapidus, A.A.; Shesterikova, I.V. Mathematical model for assessment the potential of the high-rise apartment buildings integrated quality index. *E3S Web Conf.* **2019**, *91*, 02025. [CrossRef]

42. Lapidus, A.A.; Shesterikova, I.V. Development of mathematical model of high rise apartment buildings construction integrated quality index evaluation. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *753*, 032033. [CrossRef]
43. Shesterikova, Y.V. Practical application of the integrated index of quality of multi-storey residential buildings. *Constr. Proced.* **2020**, *1*, 17–21.

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