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Determining the significant input parameters of a forecasting model for material resources of residential construction projects at the investment feasibility assessment stage

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Abstract. Any investor/developer spends considerable time to make a construction decision in analyzing various parameters, such as the building site area, height restrictions, total area, quantity of necessary materials, etc. First of all, this is due to a high level of uncertainty and the complexity of estimating costs for the initial stages of project implementation. The unavailability of detailed design data at the investment justification stage makes it impossible to conduct a sufficiently accurate assessment of the value and period of construction to make highly accurate managerial decisions. However, one of the key issues, namely determining the significant parameters that have the greatest impact on future project-related decisions, has not been studied sufficiently.

This article identifies the most significant parameters that impact the future characteristics of residential buildings based on an expert assessment using the a priori ranking method. The reliability of the assessment is confirmed using the coefficient of concordance. A conclusion is provided about their applicability as the input values of a forecasting model that uses machine learning and artificial intelligence to determine various technical and economic characteristics of residential buildings.

1 Introduction

First of all, it should be noted that many companies currently use traditional methods at such an important stage as investment justification, also known as front-end engineering design (FEED) [1]. Specifically, investment cash flows include an outflow primarily in the form of the costs of creating and putting into operation new fixed assets and removing and replacing retired existing fixed assets, distributed over intervals in the period under review. This also includes noncapitalized costs (for example, land tax on the construction site, construction costs related to external infrastructure facilities, etc.). In addition, investment cash flows include changes in working capital (an increase or a decrease is considered to be a cash outflow or inflow respectively) [1].

Apparently, this structure does not factor in various technical and functional particularities of a future construction project.

It is specifically worth noting that it is not always possible to conduct a sufficiently accurate assessment at the FEED stage because design documents are prepared at the next

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stage, which is why insufficient information concerning different projects makes the selection of various technical solutions insufficiently effective. A practical problem is the significant uncertainty of investment costs [2].

Unlike subsequent stages, FEED involves multivariate design [3]. Whether the employer can objectively assess the prospects of implementing any planned solutions depends on the quality of pre-project planning. It is already possible at this stage to estimate the value and period of basic construction and installation work as an initial approximation, identify potential problems that may affect the process of future design and construction, and select the necessary measures to prevent and resolve these issues. Developers often outsource FEED services, which substantially increases the decision-making period at the pre-investment stage [3].

Generally, costs are estimated using the consolidated price of previously completed projects without factoring in current prices and scopes of work and without giving consideration to various technical and functional particularities of a future project.

This approach involves substantial ranges of error in estimating costs and the impossibility of making detailed multivariate managerial decisions based on a comparison of specific technical and functional parameters of a project, thus preventing a reasonable conclusion about the optimal set of these parameters for each building. Currently, research is underway on this problem; for instance [2] shows the prospects of modeling the economic efficiency of residential construction projects based on the methodology developed to factor in uncertainty and using improved units of the economic model. In the proposed methodology, the proposed financial and economic model with modified units of investing, operating, and financing activities makes it possible to qualitatively improve the processes of planning and carrying out investment and construction projects.

The key aspect of the study described in [4] is an assessment of the economic efficiency of investment projects based on an investment analysis methodology for development or construction investment projects. In general, the “cost flow calculation” includes specifying expenses related to a project’s main goods, taking account of refined indicators of the concept; additionally, expenses are forecasted for each project stage without taking account of the macroeconomic situation. The next step is “analyzing the macroeconomic situation and forecasting investment conditions,” and initial indicators are prepared for cost modeling of several concepts.

[5] contains methodologies used at different stages of an integrated investment analysis algorithm, including a methodology for determining total average-market investment costs in a given market section and the average-market ROI for a construction investment project according to its function and quality class.

[6] describes methods for analyzing the real property market as a tool to obtain accurate initial data, along with methods for assessing investment project efficiency for the processing of such data.

It is quite common to study the issue of the general generation of ROI. For instance, [7] shows methods for calculating ROI indicators in various real property market segments for a comparative assessment of projects at the pre-investment stage.

[8, 9, and 10] contain detailed studies on the use of econometric models to forecast real property market indicators. [11] describes approaches to the financial mathematics of property investment and property appraisal: cost, comparative, and income approaches.

However, the works specified above do not deal with the issue related to the significant impact of a project’s planned technical and functional particularities on the value and period of construction.

Therefore, it is relevant to build a model for assessing material resources at the investment justification stage in order to be able to achieve the following goals:

1) assess of the scope and value of construction with high accuracy at early project stages;

2) assess the value of construction at the zero stage (prior to an investment decision);

3) compare and select the optimal technical and functional solutions for a future building without additional time and money for design.

The purpose of this article is to generate input data determining the fundamental particularities of a future construction project in making initial technical decisions at the investment feasibility assessment stage.

The goals of this study include:

- Considering the quantitative and qualitative input parameters that affect the characteristics of a planned project.
- Conducting an expert survey to determine significant input parameters; processing the expert survey results and calculating the coefficient of concordance; drawing a conclusion about whether there is concordance among the expert survey results.
- Using Pearson's chi-squared test to confirm the hypothesis for nonrandom agreement among the experts.
- Analyzing the results for the applicability of input parameters in building a forecasting model for the output parameters of a construction project in order to select the optimal technical solutions meeting the goals of construction project management for the investment justification stage of an apartment building project.

2 Study methodology

In order to confirm the hypothesis, the quantitative and qualitative input parameters affecting the characteristics of a planned project were selected (technical and economic indicators and specific architectural, space-planning, and technical solutions contained in Table 1). Design and construction experts with at least 10 years of experience ("experts") selected from 48 different parameters.

In order to solve the problem of ranking the input parameters according to their significance and impact on the output parameters of a construction project, namely the quantity of material resources necessary for construction (QMR), the a priori ranking method was used.

As shown in [12], at least five experts should be involved to ensure the statistical significance of an a priori ranking.

It is worth noting that the goal of the study in [12] is to determine the minimum number of experts to rank the factors that impact the composition of work on scientific and technical support for design; however, the results of the study are generally applicable to other similar goals.

Seven design and construction experts from three different business companies were involved in the work. The selected experts met the following requirements: higher education in design or construction; at least 10 years of professional experience in design and construction; requisite registration on the national register of experts in engineering surveys and architectural and construction design or on the national register of experts in construction in accordance with [13].

The expert survey was conducted in two stages.

The first stage included putting the input parameters into three groups according to their significance: high, medium, and low. Next, within these groups, the parameters were ranked according to their significance from high to low, starting from 1. This approach made it possible for each expert to resolve the issue related to a primary reasonable assessment of a large array of heterogeneous information at the preliminary stage.

At the second stage, the experts combined the three resulting groups into one, with continuous numbering applied to all 48 parameters of the three groups according to their

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significance from high to medium to low. This enabled the input parameters to be assigned their ranked sequence numbers from 1 to 48, with the significance of the parameters decreasing from 1 (the highest) to 48 (the lowest).

The expert survey resulted in obtaining the values of the ranked sequence numbers for each input parameter as determined by the experts. Based on the sum of ranks assigned by all experts for each factor, the factors were ranked. Then, for the purposes of this study, calculations were made in order to determine the intermediate values (deviation of the sum of ranks for each factor from the average sum of ranks; square of deviations of the sum of ranks for each factor from the average sum of ranks; weight of factors (subsystems) according to their impact on the target indicator) necessary to apply the a priori ranking method. The results are shown in the table below:

Table 1 The results of expert survey

No.	Project indicators (input parameters)	Values of the ranked sequence numbers for each indicator as determined by the experts							Sum of ranks assigned by all experts for each factor	Deviation of the sum of ranks for each factor from the average sum of ranks	Square of deviations of the sum of ranks for each factor from the average sum of ranks	Factor ranking	Weight of factors (subsystems) according to their impact on the target indicator
		1	2	3	4	5	6	7					
	k factor	Assessment ranks a_{km}							Δk	Δ'k	$\Delta'k^2$	M	qk
1	Building area	25	48	30	24	34	44	16	221.00	49.50	2,450.25	31	0.02
2	Total site area	1	2	2	4	1	2	1	13.00	-158.50	25,122.25	1	0.04
3	Total structural volume	2	1	1	1	3	3	2	13.00	-158.50	25,122.25	2	0.04
4	Structural volume of the substructure	4	5	5	2	6	1	6	29.00	-142.50	20,306.25	3	0.04
5	Structural volume of the superstructure	3	3	4	3	5	4	7	29.00	-142.50	20,306.25	4	0.04
6	Total area of apartments (including	5	4	3	5	4	7	5	33.00	-138.50	19,182.25	5	0.04

	summer premises)												
…	…	…	…	…	…	…	…	…	…	…	…	…	…
22	Availability of attics or utility premises	14	25	24	25	44	39	35	206.00	34.50	1,190.25	27	0.02
23	Availability of trafficable roofs	30	20	44	15	36	23	46	214.00	42.50	1,806.25	30	0.02
24	Number of underground floors	9	10	11	6	12	9	15	72.00	-99.50	9,900.25	10	0.03
25	Average underground floor area	10	12	13	11	8	10	12	76.00	-95.50	9,120.25	11	0.03
…	…	…	…	…	…	…	…	…	…	…	…	…	…
32	Number of dwellers	6	7	8	9	2	6	4	42.00	-129.50	16,770.25	6	0.04
33	Availability of garbage chutes	29	43	47	29	46	29	29	252.00	80.50	6,480.25	42	0.01
34	Characteristics of integral premises (number, total area, location floors)	8	6	9	8	11	12	13	67.00	-104.50	10,920.25	9	0.03
35	Availability of integral underground parking structures	27	24	14	38	15	21	24	163.00	-8.50	72.25	16	0.03
36	Total number of underground parking spaces	7	11	6	7	10	5	8	54.00	-117.50	13,806.25	7	0.04
37	Total parking area of all floors	11	8	7	12	7	8	3	56.00	-115.50	13,340.25	8	0.03
…	…	…	…	…	…	…	…	…	…	…	…	…	
47	Radial collection systems for common areas	40	33	25	28	47	34	38	245.00	73.50	5,402.25	39	0.01
48	Type of supply ventilation for residential premises (mechanical ventilation,	38	37	40	14	39	25	19	212.00	40.50	1,640.25	29	0.02

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	natural ventilation)												

Kendall's coefficient of concordance is in the range of 0 to 1. As specified in [14], it should be calculated in accordance with the following formula:

$$W = \frac{12S}{m^2(k^3 - k)}, \text{ where} \quad (1)$$

k is the number of factors, $k = 48$;
m is the number of experts, $m = 7$;
S is the sum of squares of deviations of the sum of ranks for each factor from the average sum of ranks, calculated in accordance with the following formula:

$$S = \sum_{k=1}^{k} (\Delta_k^1)^2, \text{ hence} \quad (2)$$

Kendall's coefficient of concordance is $W = 0.67$.

As shown above, the coefficient is substantially different from zero and greater than 0.5. Therefore, it can be assumed that there is concordance among the factor ranks assigned by the experts.

In order to confirm the hypothesis for nonrandom agreement among the experts, the following inequation is solved [14]:

$$\chi_p^2 > \chi_t^2, \text{ where} \quad (3)$$

χ_p^2 is the calculated value of Pearson's chi-squared test;
χ_t^2 is the tabular value of Pearson's chi-squared test,
while:

$$\chi_p^2 = W * m * (k - 1), \quad (4)$$

resulting in:
$\chi_p^2 = 221.01.$

3 Results

Based on the number of ranked projects and the accepted level of statistical significance, χ_t^2 is α. In order to reduce the risk of erroneously rejecting the hypothesis, the tabular value of Pearson's chi-squared test is taken for the minimum value of α equal to 5%. In accordance with [15], the value is taken as 65.17 for $k = 48$.

The final result is 221.01>65.17.

With the inequation solved, the hypothesis for nonrandom agreement among the experts is confirmed, which proves the validity of solving the problem of statistical significance for the a priori ranking and demonstrates the reliability of the input ranking parameters selected for the study.

Therefore, it is possible to generalize the expert survey results and sort out the following input parameters that have a significant impact on QMR in particular and on the characteristics of a planned project in general for further consideration:

Table 2 Project indicators ranks

No. in Table 1	**Project indicators (input parameters)**	**Rank based on the expert survey results**

2	Total site area	1
3	Total structural volume	2
4	Structural volume of the substructure	3
5	Structural volume of the superstructure	4
6	Total area of apartments (including summer premises)	5
32	Number of dwellers	6
36	Total number of underground parking spaces	7
37	Total parking area of all floors	8
34	Characteristics of integral premises (number, total area, location floors)	9
24	Number of underground floors	10
25	Average underground floor area	11

4 Discussion

The problem of statistical significance of the a priori ranking was solved, and the reliability of the input ranking parameters selected for the study was confirmed. The study identified the most significant input parameters having an impact on the characteristics of a planned project. Continuing the study will make it possible to determine the strength and quality of this impact and evaluate the possibility of using the obtained significant input parameters to build a forecasting model for the output parameters of a construction project in order to select the optimal technical solutions meeting the goals of construction project management for the early pre-investment and investment stages of an apartment building project.

5 Conclusion

Based on the results of the study described in this article, the authors examined the quantitative and qualitative input parameters having an impact on the characteristics of a planned project.

An expert survey was conducted to identify significant input parameters. The results of analyzing the ranks assigned by the experts were used to calculate Kendall’s coefficient of concordance, which shows that there is concordance among the expert survey results. Based on Pearson’s chi-squared test, it was concluded that agreement among the experts was not random.

The problem of statistical significance of the a priori ranking was solved, and the reliability of the input ranking parameters selected for the study was confirmed. The a priori ranking method was used to sort out the most significant input parameters (characteristics) of a construction project for further research.

The authors believe that the identified input parameters can serve as the basis for a forecasting model for output parameters. It appears that there are good prospects for further research into a correlation between the input and output parameters of a construction project, such as the material resources necessary for construction, the parameters of utility connections for a project, the results of cost estimation for sections of design documents, and other parameters that have unambiguous quantitative values.

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