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DEVELOPMENT OF A COMPUTER MODEL FOR EVALUATING THE ALTERNATIVE OPTIONS OF AN INVESTMENT AND CONSTRUCTION PROJECT UNDER CONDITIONS OF UNCERTAINTY AND RISK

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В роботі подається запропонований метод кількісного аналізу ризиків у інвестиційних будівельних проектах, який використовує ймовірнісний підхід. Особливістю підходу є багатоетапний процес оцінювання і комплексне урахування показників для прийняття рішення відносно інвестиційної привабливості об'єктів в умовах невизначеності.

На основі даного підходу розроблена автоматизована комп'ютерна модель оцінювання інвестиційної привабливості об'єктів будівництва. З використанням комп'ютерної моделі досліджено показники інвестиційної ефективності і ризики для різних варіантів реалізації будівельного проекту, здійснено вибір альтернативи розвитку проекту в умовах ризику, визначено найкращий інвестиційний проект.

Достовірність результатів підтверджена дослідженнями стійкості рішень та їх похибками.

Результати отримані з метою підвищення ефективності управлінських рішень в сфері інвестицій в будівельному секторі економіки. Розроблена комп'ютерна модель дозволяє, на підставі статистичних даних попиту на житлову нерухомість, провести кількісний аналіз ризикованості інвестицій в проекти будівництва, зробити вибір проекту будівництва за показниками прибутковості та ризикованості, а також за критеріями прийняття рішень в умовах ризику та невизначеності.

Числові експерименти з комп'ютерною моделлю показали необхідність інвестування у додаткові дослідження з метою уточнення параметрів зовнішнього середовища та інвестування в побудову багатоповерхового будинку.

Отримані результати є актуальними завдяки високому ступеню турбулентності зовнішнього середовища в сфері будівництва, а також у зв'язку з важливістю залучення інвестицій з точки зору конкурентоспроможності. Розроблена в ході досліджень комп'ютерна модель є універсальною стосовно виду об'єкту будівництва житлової нерухомості

Ключові слова: кількісний аналіз ризиків, дерево рішень, інвестиційний проект, прийняття рішень в умовах ризику

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1. Introduction

Today, the issues related to attracting a sufficient volume of capital are relevant, since this is a strategically important direction of further development of any country and one of the elements of the development of its economy. It is through the investment attraction criteria that the process of the economic growth of a country in general is determined [1, 2].

One of the sectors, which has the largest volume of capital investment, is construction. [3] The issue of identifying investment attractiveness for the construction industry, assessing investment risks and controlling them is relevant in terms of specific features of the construction sector [3].

The demand for investment in the construction industry of any region directly influences the development of the region, both on the part of social factors and on the part of economic, institutional and other factors.

The necessity of studies directed towards the development of a computer model of estimation of the investment attractiveness of construction under conditions of uncertainty and risk is caused by a high degree of dynamism and turbulence of the environment of investment and construction projects [4].

Considering these circumstances, the issues of attracting investments, assessing investment attractiveness and risks require universal approaches for their consideration and creation of effective managerial decisions in the field of construction investments. The versatility implies the creation of a model that would represent a sequence in decision making regarding an investment project and reflect multi-step decisions for investing in construction projects. The modeling result is a choice of a construction project according to profitability and risk indicators.

One of the steps of modeling the process of investment in a construction project is conducting marketing research, which will make it possible to identify the input and output data for the estimation of an investment project. Other steps include the issues of identifying numerical valuation of investment attractiveness and investment risks using modern methods of statistical analysis and probabilistic approaches.

Analysis of the stability of obtained decisions and the value of perfect investment information, taking into consideration uncertainty and risk, enable us to determine the best investment strategy, consider alternative construction projects, form a set of alternatives for the investment project participants.

The relevance of research derives from the complexity and multicriterial estimates of investment attractiveness of construction objects. The use of the methods for computer simulation, decision making models under conditions of risk and uncertainty, as well as methods of statistical analysis is a necessary component of enhancing the scientific validity and effectiveness of relevant managerial solutions.

2. Literature review and problem statement

Investment activity is related to uncertainty and, consequently, risk that leads, as a rule, to the occurrence of losses, in particular, this applies to the construction industry.

Investments are always focused on the future and, therefore, relate to significant uncertainty of the economic situation and behavior of people, which characterizes a high level of probability of failure to fulfill investment plans for objective or subjective reasons. The emergence of risk leads to a failure to implement the planned investment targets (profit or social impact) and to suffer monetary losses. In paper [5], it is proposed to consider risk due to occurrence of an adverse event and to assess it through studying only one indicator – probability. Thus, another indicator, such as consequences of occurrence of an unfavorable event, is not considered. To study the probability, it is necessary to use different criteria, using a decision-making theory. The obtained estimate is subjective, for the reliability of results, it is necessary to involve different approaches, make final conclusions concerning the risks of project decisions on their basis.

The issue of risk assessment is quite complicated, which is due to the fact that funding the development of construction industry is associated with a certain term of investment and the risk of untimely return or a failure to return funds. Therefore, there arises the issue of effective analysis and assessment of investment risk, since this will enable potential investors to have a clear picture of actual prospects for returning funds and obtaining profit. Paper [6] provides an analysis of modern methods for assessing project risks, citing their advantages and disadvantages, as well as the scope of application. Among the examined approaches to risk assessment, it is possible to note simulation, that is, a multi-variant computation experiment for developed mathematical models. Thus, the process of determining risky situations is automated, thereby accelerating the evaluation process. However, such issues as reliability and stability of obtained results were not explored.

Approaches to attracting investments, their assessment, control and formation of the ways to enhance their effectiveness imply the use of modern methods for the assessment of investment attractiveness. Taking into consideration an adverse event and its impact on risks are examined in article [7], which proposes a generalized comprehensive criterion – the price of risk – using the utility theory. This makes it possible to formalize the approach to risk and decision making. In this case, the assessment depends on individual approaches of an investor, can be subjective in nature and lead to conflict situations. This approach requires consideration of additional factors in the model in order to reach consensus in decision making.

The results from studies of risks related to investment projects are reported in papers [8–18].

The common methods of quantitative analysis of investment risks of enterprises include: the method for adjusting the discount rate (risk award); analysis of sensitivity of performance indicators, that is, reduced net value, the internal return rate, the scenario method, simulation by the Monte Carlo method, etc. [8]. However, these approaches make it possible to determine risky initial factors of a project that contribute to increasing risk, but determining the influence of the factors on the outcome of its implementation causes some difficulty [9].

Simulation of risky situations is given in paper [10], which outlines the characteristic and analysis of the scenario method, but without taking uncertainty into account. In addition, it is necessary to conduct qualitative research into the project model that is, creation of several models according to each scenario, which leads to significant volumes of analytical project-related data processing.

To assess the risk of an investment project, it is proposed to use the utility theory. This enables an investor to make decisions in an attempt to take into consideration the needs of all stakeholders [11], but it may cause a conflict of the parties. This approach requires improvement and generalization.

It is possible to use the notion of "extreme risks" as an alternative way to consider the investment risks, which allows considering a "risk factor" with maximum reliability levels. In practice, calculation of an estimate causes certain difficulty [12].

The risks of investment construction can be determined by applying analytical techniques at all stages of the life cycle of the investment construction project [13]. For specific projects, analytical expressions have a complex appearance and impede their use in the general case [14]. In such cases, it is advisable to simplify the model without losing the project data and to substantiate this simplification.

Forecasting risks and their behavior in dynamics are studied in paper [15]. The new look at risks and the construction of risk-free situations is given in article [16], which emphasizes the possibility of evaluating projects with minimal risk. The presentation of risks as a systemic object will make it possible to explore the behavior of an innovative project taking into consideration the types of risks [17, 18].

However, some problems of assessment of the risks of investment project remain unresolved. The reason for this is objective difficulties related to the term of realization of an investment project, the number of project participants, the project character, etc., which creates additional types of risks under conditions of uncertainty. The lack of a universal model and a software product for identifying risks does not make it possible to substantiate the stability and credibility of obtained solutions for a particular project. In addition, there is insufficient emphasis on the study of investment efficiency based on modeling of the estimation process and investment risk management.

Analysis of methods and approaches regarding the assessment of investment projects in the field of construction revealed that there is no single approach to investment risk assessment, so there are unresolved issues related to creating an approach that would meet the requirements of any construction company.

All this leads to the need to develop a universal approach to assessing the risks of construction projects based on the simulation of these processes in the context of uncertainty and decision-making a construction project.

All this suggests that this direction of analysis of the investment activity requires in-depth research under conditions of limited investment receipts. For the comprehensive assessment of the investment project, it is necessary to assess its attractiveness and solve the risk control issues.

3. The aim and objectives of the study

The aim of this study is to model the investment attractiveness of construction objects under conditions of uncertainty and risk, risk management processes for making the appropriate decision regarding an investment project and automation of determining the investment attractiveness.

To accomplish the aim, the following tasks have been set:

– to develop a simulation model for assessing investment attractiveness of construction projects using statistical methods;

– to conduct marketing research to determine the actual values of the main input data of the investment projects estimation, statistical analysis on the problems of the investment involvement and estimation of investment risks;

– to form the sets of alternatives for investment market participants;

– to analyze the decision stability and to calculate the value of perfect investment information;

– to determine the best investment strategy using the decision tree.

4. Development of a simulation model for evaluation of investment attractiveness of construction objects

The process of deciding on the choice of a construction object is proposed to be solved in two stages: at the first stage, it is necessary to calculate the numerical characteristics of profitability and risk, at the second stage, it is necessary to formulate conclusions by a certain algorithm.

At the first stage, for each of the projects, known cash flows NCF_t for a certain period of time, based on unfavorable, favorable and moderate forecasts, as well as the probability $P(NCF_t)$ of implementation of these forecasts, it is necessary to choose the capital investment option, which will ensure the best combination of expected profit and the degree of investment risk.

At stage 1, it is necessary to determine the following indicators for each option (1) to (7):

– average expected cash flow M;

– variance D;

– standard deviation σ;

– variation coefficient CV;

– semi-variance SD;

– semi-standard deviation $S\sigma$;

– semi-variation coefficient SCV.

Average expected cash flow M is the expected value of result, it is determined from formula:

$$M=\sum_{i=1}^{n} P_i X_i, \quad (1)$$

where X_i is the random magnitude, P_i is the probability at which the random magnitude will acquire value X_i, n is the number of periods of time.

The cash flow for a certain project will be accepted as a random magnitude.

Divergence in possible results, that is, the degree of deviation of possible results from their expected value, is characterized by variance D and standard deviation σ (2), (3).

$$D=\sum_{t=1}^{n}\left(CF_t-M\right)^2 P_t, \quad (2)$$

$$\sigma=\sqrt{D}. \quad (3)$$

If there is a situation where it is necessary to verify whether the increased risk is compensated by increased income, such criterion as relative risk is introduced for consideration. In statistics, a variation coefficient corresponds to this criterion:

$$CV=\frac{\sigma}{M}100\,\%. \quad (4)$$

Semi-variance SD, semi-standard deviation $S\sigma$ and semi-variation coefficient SCV are the semi-characteristics of a random magnitude, in calculation of which one takes into account the deviation of possible results from the expected result value only towards decreasing (5) to (7).

$$SD=\frac{1}{n-1}\sum_{t=1}^{n}\left(CF_t-M\right)^2, \quad (5)$$

where n is the number of periods, in which the profit norm is smaller than its expected value E

$$S\sigma=\sqrt{SD}, \quad (6)$$

$$SCV=\frac{S\sigma}{M}100\,\%. \quad (7)$$

According to the calculated indicators (1) to (7), performance indicators CF_t (Cash Flow) for a certain period of time, are determined (8). It is assumed that the payment flow generated by a project enters in equal parts within a certain period of time. Then the magnitude of cash flow for a certain period t can be determined from ratio:

$$CF_t=[S^r{\cdot}P-S^g{\cdot}V-S^g{\cdot}F-S^g{\cdot}A](1-T)+S^g{\cdot}A$$

or

$$CF_t = [S^r \cdot P - S^g \cdot (V + F + A)] \cdot (1 - T) + S^g \cdot A, \qquad (8)$$

where S^r is the area implemented within given period of time, S^g is the total area of a construction object, P is the mean value of the cost of 1 sq. m. at implementation; V is the cost of one square meter, F is the constant costs for 1 square meter, A – depreciation expense per 1 square meter, T is the income tax.

The value of the total area of the construction object constant expenditures depreciation and income tax are considered permanent values – these are model parameters. The value of the price of implementation, cost of one square meter and sold area depend on the market conditions of building sites, which are considered as investment projects, they are random quantities.

The area that was realized for a certain period of time also depends on the useful area of the house (S^h) and can be calculated from formula (9):

$$S^r = z \cdot S^h = z \cdot (1 - q) \cdot S^g, \qquad (9)$$

where z is the percentage of the realized area at a certain forecast of market conditions, q is the coefficient of losses of useful area, which is calculated as the ratio of useful area to the total area ($q = S^h / S^g$).

Stage 2 is the formation of conclusions by the algorithm of qualitative analysis of risk using the probabilistic approach (Fig. 1).

The presented algorithm makes it possible to select the best project based on the numerical characteristics of a random magnitude the cash flow for a project.

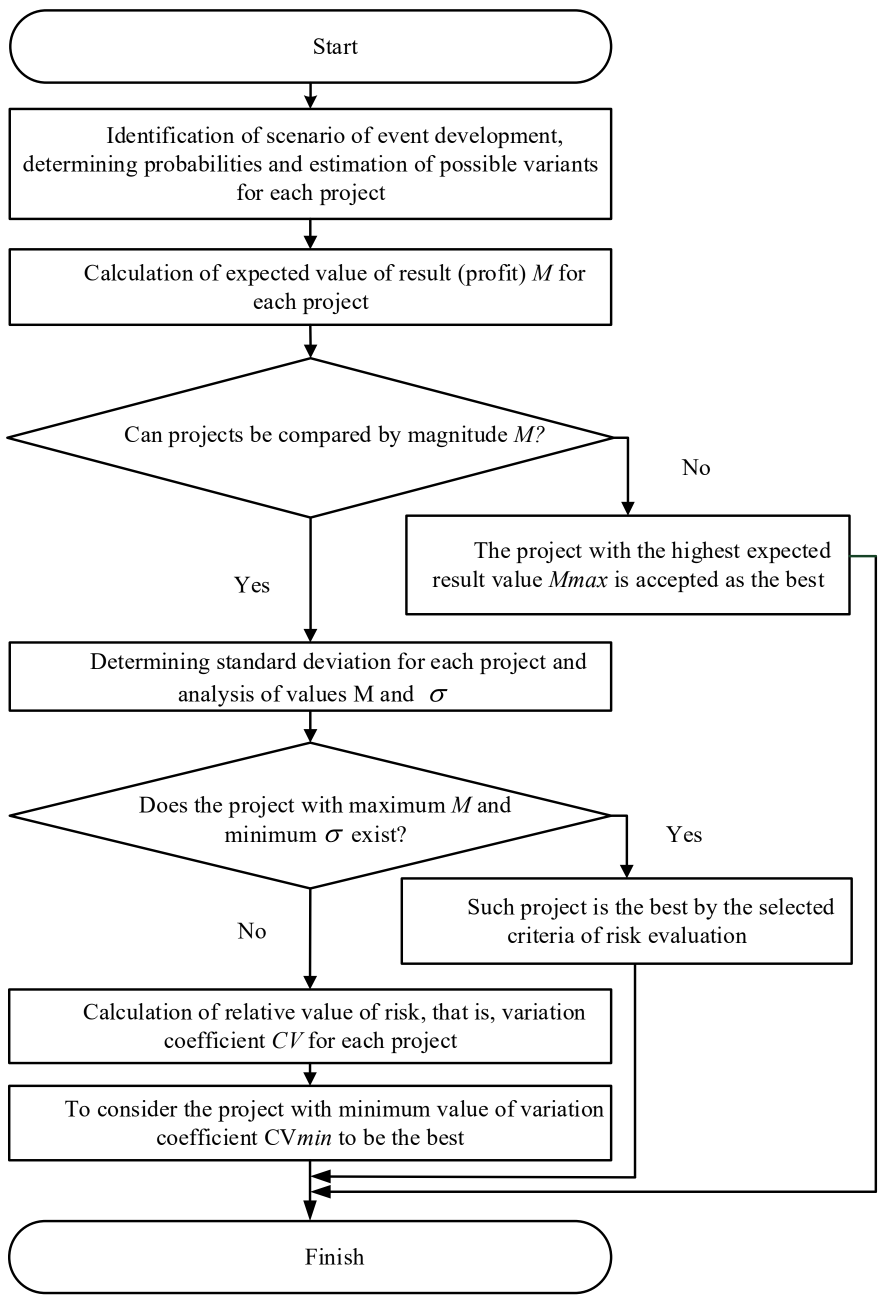

Fig. 1. The algorithm for quantitative analysis of construction risks

5. Marketing research to determine the actual values of the main input data of assessment of investment projects

During conducting marketing research, the comparative analysis and studying of the following indicators were carried out separately:

– demand for and supply of using the physical space of real estate sites for each class of real in the segment of primary housing;

– demand and supply of the investment and construction resources in the segment of primary housing;

– average statistical price indices and indices of market profitability;

– preliminary assessment of total financial profitability of typical projects in the segment of primary housing.

As a result of market research into real estate market, it was determined that in making investment decisions about the construction of residential facilities, it is necessary to consider the following factors:

– economic: availability of loan resources, living standards of population (level and dynamics of income, population differentiation by income level, inflation rate, unemployment), construction cost, investment risks, state of the currency market;

– social: demographic situation and migration flows, provision of population with housing.

An integrated market parameter that reflects the comprehensive effect of the above factors is the market value per square meter in new buildings.

The main price-forming factors in the market of primary residential real estate are:

– the class of a site (location factor is included in the class of a site);

– the stage of readiness of a site;

– proximity to underground and public transport stops;

– development of the social infrastructure in the area of the site's (residential building) location;

– image of the company-developer.

Here are the results of the study of risks for the following problem: to find a solution for building up an area of land with residential real estate by three alternative projects, that is, to choose the variant of capital investment that will provide the best combination of the expected profit and the degree of investment risk.

The first project involves the construction of a nine-storey building, the second – of the twelve-storey building, the third – of the sixteen storey building. All the sites are objects of economy class.

For each of the projects, we know cash flows NCF_t for a certain period of time based on unfavorable, favorable and moderate forecasts, as well as probability $P(NCF_t)$ of implementation of these forecasts.

The cost indicators, such as the mean value of the cost of 1 sq. m. for sale, the cost of 1 sq. m., specific indicators of permanent expenditures given in the national currency of Ukraine – hryvnia, which is due to the peculiarity of pricing in the primary housing market. As of 30 August 2019, the hryvnia rate to the US dollar was USD 1= =UAH 25.23.

Consider stage 1 of the choice of the built-up option for several variants. To do this, the investment assessment for several projects for residential real estate was conducted (Tables 1, 2, Fig. 2).

Table 1

Initial investment related to construction of multi-storey buildings

Project parameters	Number of storeys		
	9	12	16
Area of the land, ha	1.2	1.2	1.2
Total area of a building, sq. m.	4,500	6,000	8,000
Useful area of a building, sq. m.	3,600	4,500	5,600
Term of construction, years	1	1,5	2
Permanent costs (calculated for 1 sq. m of total area of a house), UAH	250	200	150
Depreciation (calculated for 1 sq. m of total area of a house), UAH	350	320	300
Income tax	25 %	25 %	25 %
Discount rate	20 %	30 %	35 %
Project term, years	1	1.5	2
Initial investments (calculated for 1 sq. m of total area of a house), UAH	80	60	45

The probability of acquisition of a certain value from the set of possible values by random magnitudes, which are the characteristics of an investment project, depends on the probability of a favorable, unfavorable or moderate forecast concerning the market situation (Table 2).

In Tables 2, 3, the following designations were introduced: UF – unfavorable forecast, FF – favorable forecast, MF – moderate forecast. The shown quantitative indicators at this stage of research were determined by the expert method.

Automation of modeling of the estimates of investment attractiveness of construction projects based on the proposed approaches was implemented in electronic tables [19, 20] (Table 3).

Table 2

Forecasted values for the implementation of investment projects

Project parameters	Number of storeys								
	9			12			16		
	Implemented forecast								
	UF	FF	MF	UF	FF	MF	UF	FF	MF
Percentage of sold area	60 %	100 %	80 %	60 %	100 %	80 %	60 %	100 %	80 %
Sold area, sq. m	2,160	3,600	2,880	2,700	4,500	3,600	3,360	5,600	4,480
Mean value of the cost of 1 sq. m for sale, UAH	12,000	10,200	11,000	12,500	11,000	11,500	13,000	11,700	12,200
Cost of 1 sq. m, UAH	5,500	5,000	5,200	6,000	5,200	5,500	6,000	5,500	5,800

Analyzing the results of calculations by the algorithm, shown in Fig. 1, it should be noted that according to mathematical expectations, the efficiency indicator $M(CF_t)$, the projects may be compared. The value of this quantifiable characteristic of the performance indicator is insignificantly different from one another (in absolute ratio 5,767.5–5,584.5=183; 5,767.5–5,995.2=227.7; which in relative ratio is +/–3 %).

Table 3

Estimation of investment attractiveness of construction projects

Project parameters	Number of storeys								
	9			12			16		
	Implemented forecast								
	UF	FF	MF	UF	FF	MF	UF	FF	MF
CFt, UAH	427.5	10,215	5,760	–2,107,5	13,305	5,880	–3,540	15,840	5,892
P(*CFt*)	0.2	0.2	0.6	0,2	0,2	0,6	0,2	0,2	0,6
M(*CFt*)	5,584.5			5,767.5			5,995.2		
D(*CFt*)	9,625,716			14,049,495			20,596,008.96		
Standard σ	3,102.53			3,748.27			4,538.28		
Variation coefficient *CV*	56 %			65 %			76 %		
Semi-standard deviation *S*σ	2,306.28			3,521.81			4,265.02		
Semi-variation coefficient *SC*V	41 %			61 %			71 %		

Comparing the values of mathematical expectation of the efficiency indicator $M(CF_t)$ and standard deviation σ, it is possible to determine that the construction of a 16-storey building is a variant of capital investment that will ensure the best value of expected income.

At the same time, this project has high investment risks. This conclusion clearly proves the comparison of the values of variation coefficients δ and semi-variation coefficient *S*δ.

The project of construction of a sixteen-storey building has the maximum value for these indicators: δ=76 %; *S*δ=71 %.

In this situation, making an investment decision on choosing an alternative requires the next phase of research.

The second stage of the research by the algorithm (Fig. 1) includes the process of detection of probability development and evaluation of possible results for investment project implementation for each project of the events development scenario.

With the use of the probability theory and mathematical statistics, a priori probabilities of occurrence of certain states of environment were determined.

As a result of analysis of the subject area of the study based on static information for the previous stages of enterprise functioning, the set of environment states, which consists of three elements: "Low sales", "Medium sales", "Big sales", was developed.

Probabilities of each of the environment states can be calculated from formula (10):

$$P_{LS}=K_{LS}/N,\ P_{BS}=K_{BS}/N,\ P_{MS}=K_{MS}/N, \quad (10)$$

where K_{LS} is the number of sales, which is lower than Mean value–Mean value/2, K_{BS} is the number of sales, which are higher at Mean value+Mean value /2, K_{MS} is number of sales that are in the interval from Mean. value–Mean value/2 to Mean value+Mean value/2, Mean values are arithmetic mean of the sales level, *N* is the number of periods of time of observation of the number of sales.

Probabilities of environmental states were determined based on processing the data on monitoring supply, demand and prices in the primary market of residential real estate in Kharkiv during 2014–2018 [21].

The results of the procedure of automation of determining the probabilities of occurrence of environment states are given in Table 4.

Table 4

Values of probabilities of possible environment states

Mean value	27.59	A priori probabilities of states	
Number of months with low sales	5	0,14	
Number of months with medium sales	26	0,72	
Number of months with high sales	5	0,14	
Size of samples (Total number of months)	36	Sum of probabilities	1

Here the Mean value corresponds to the arithmetic mean of the magnitudes of sales in the entire statistical sample. Then, the months with high sales are considered those, the values of sales in which are higher than Mean value+Mean value/2. Accordingly, months with low sales are those, the values of which are lower than Mean value – Mean value/2. Months with medium sales are considered those, the value of sales in which belongs to the interval [Mean value – Mean value/2; Mean value+Mean value./2].

According to the main provisions of the game theory [22–25], the sum of probabilities of all environment states should be equal to unity, as these states must be mutually exclusive and collectively exhaustive.

For clarity of changes in sales level, the diagram of volumes of demand and supply were constructed based on static information (Fig. 2).

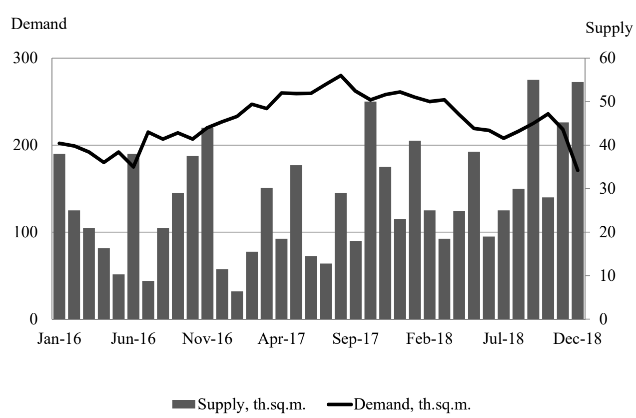

Fig. 2. Diagrams of volumes of demand and supply in real estate market in Kharkiv, 2016—2018

The diagram (Fig. 2) shows that the level of supply satisfies the demand throughout the studied period, so the level of sales can be analyzed by the values of demand.

6. Formation of the sets of alternatives for participants of investment market

The next step is to form the set of alternatives of the participant of the investment process, that is, a decision-maker (DM), and to determine the estimate of perfect information. Within the theory of games with nature, in this case it is possible to form a set of alternative DM, consisting of three elements: "Construction of a 9-storey building", "Construction of a 12-storey building" and "Construction of a 16-storey building".

If there is one set of X alternatives for the first player and known values of a priori probabilities p_j, the occurrence of certain states of environment, the choice of the best solution x_{k0} can be made by the Bayesian criterion [22–25]. If the estimation function has a positive ingredient $\Phi=\Phi^+$, optimal solution x_{k0} is found based on condition:

$$x_{k0}: B^+(x_{k0},P)=\max_{x_k\in X}\sum_{j=1}^{n} p_j\varphi_{kj}^+ = M(\Phi_k^+), \quad (11)$$

if $\Phi=\Phi^-$, the optimal solution is determined based on condition:

$$x_{k0}: B^-(x_{k0},P)=\min_{x_k\in X}\sum_{j=1}^{n} p_j\varphi_{kj}^- = M(\Phi_k^-). \quad (12)$$

The result of using a Bayesian criterion is *EMV* – expected monetary valuation or expected monetary value. Based on this valuation, it is possible to make a decision on additional market research at the first stage (in the first year of the project implementation at the smaller profit and a higher risk level). The expected monetary valuation is calculated for each alternative as the sum of products of gains for different scenarios for future $\varphi(x,\theta)=O_{ij}$ on the probability of these scenarios of p_j:

$$EMV_i=\sum_{j=1}^{N} O_{ij}p_j\ . \quad (13)$$

After this, it is necessary to choose the alternative, for which *EMV* will be maximal.

The choice of an alternative with the maximum expected value does not always guarantee the gain, so it is necessary to address the criterion of minimum of Expected Opportunity Loss – *EOL* [22, 25]. Expected opportunity loss for these alternatives is computed as the average weighted from lost opportunities r_{ij} for each of the examined scenarios of the future with weights, equal to probabilities of these scenarios p_j:

$$EOL_i=\sum_{j=1}^{N} r_{ij}p_j\ . \quad (14)$$

Results of research by the following game-theoretic model are given in Table 5.

Table 5

Determining the best project by risk and uncertainty criteria

	Project choice under conditions of uncertainty (without additional studies of environment)						Project choice under conditions of risk (with additional studies of environment)			
Decision making criterion	Maximax	Wald	Savage	Gurwiz, by gain matrix	Gurwiz, by risk matrix	Laplace	Bayesian, by gain matrix	Bayesian, by risk matrix	Hodges-Lehman	Hermeyer
Number of storeys of the best construction object according to the criterion	16	9	12	9	12	16	16	16	16	16

The above results were obtained according to the following parameters: the value of factor pessimism of a decision-maker 0.7; the value of the parameter that characterizes the trust of a decision-maker to a priori probabilities 0.8. Conclusion of the above results is that the project of construction of a 16-storey building is the best by most criteria.

7. Analysis of decision stability and calculation of value of perfect investment information

Statistical information regarding demand in the real estate market may not always be available, then, in order to clarify a priori probabilities of environment states, it is possible to conduct market research. The value of perfect information *EVPI* will enable making a decision on conducting additional marketing research.

We will give the results of the program implementation of the Bayesian criterion and the model for determining the value of perfect information regarding the probabilities of environment states (Tables 6, 7).

Table 6

Bayesian criterion and model for determining the value of perfect information by the gain matrix

Alternative investment projects	Possible environment states			Expected monetary value (*EMV*)
	Low sales	Medium sales	High sales	
9-storey building	427.5	10,215	5,760	5,638.13
12-storey building	–2,107.5	13,305	5,880	5,801.88
16-storey building	–3,540	15,840	5,892	5,963.67
Maximum gain	427.5	15,840	5,892	6,514.71
Probability of environment state	0.14	0.14	0.72	–
Expected value of perfect information (*EVP*)				551.04
Number of storeys of the best construction object by the criterion				16

Thus, based on a Bayesian criterion, the best alternative is the "Construction of a 16-storey building".

By making a responsible managerial decision, it is necessary to check how sensitive the made choice is to a change in predicted parameters and probability valuations, using which the *EMVT* were calculated for each alternative, that is, to conduct analysis of solutions stability.

Table 7

Bayesian criterion and model for determining the value of perfect information by the risk matrix or lost opportunity matrix

Alternative investment projects	Possible environment states			Expected opportunity loss (*EOL*)
	Low sales	Medium sales	High sales	
9-storey building	0	5,625	132	876.58
12-storey building	2,535	2,535	12	712.83
16-storey building	3,967.5	0	0	551.04
Expected value of perfect information				551.04
Number of storeys of the best construction object by the criterion				16

Conducting the analysis of solutions stability involves the calculation of relative errors in determining probabilities of the environment states. The result of stability analysis is given in Tables 8, 9.

For a case of the environment state "Low sales", the probability value varies from 0.14 to 0.16. Accordingly, the values of a priori probabilities of other environment states change. From the conducted stability analysis, it can be concluded: the value of perfect information did not change, as well as the choice of the best alternative to the solution that did not change and corresponds to construction of a 16-storey building.

Table 8

Result of analysis of stability of investment projects by the gain matrix

Alternative investment projects	Possible environment states			Expected monetary valuation (*EMV*)	Initial expected monetary value (*EMV*)
	Low sales	Medium sales	High sales		
9-storey building	427.5	10,215	5,760	5,514.69	5,638.13
12-storey building	–2,107.5	13,305	5,880	5,616.98	5,801.88
16-storey building	–3,540	15,840	5,892	5,745.33	5,963.67
Maximum gain	427.5	15,840	5,892	6,388.22	–
Probability of environment state	0.16	0.14	0.70	1	–
Initial probability	0.14	0.14	0.72	1	–
Expected values of perfect information (*EVP*)					642.88
Number of storeys of the best construction object by the criterion					16

High stability of decision is predetermined by a rather large dimensionality of the sample [26]. However, in the absence of statistical data, the deviation of probabilities of environment states by the magnitude equal to the statistical error, can lead to a significant decrease in expected monetary valuation of strategies [26]. The magnitude of statistical error is determined as unity divided by square root of a sample size and in this case is 14 %. That is why the possibility of additional marketing research to clarify the probabilities of environment states should be taken into consideration. According to the analysis, we get the second set of strategies of the first actor, consisting of alternatives: "To conduct additional studies", "Not to conduct additional studies".

Table 9

Result of analysis of stability of investment projects by risk matrix or lost opportunity matrix

Alternative investment projects	Possible environment states			Expected opportunity loss (*EOL*)	Initial expected opportunity loss (*EOL*)
	Low sales	Medium sales	High sales		
9-storey building	0	5,625	132	873.53	876.58
12-storey building	2,535	2,535	12	771.24	712.83
16-storey building	3,967.5	0	0	642.88	551.04
Probability of environment state	0.16	0.14	0.70	–	–
Number of storeys of the best construction object by the criterion					16

Thus, we will obtain two sets of alternatives for the first actor constituting a chain of interrelated decision, for the selection of which it is appropriate to use the decision tree [27].

8. Determining the best investment strategy with the help of a decision tree

The choice of the best alternative is determined by the maximum value of the net present value *NPV,* which is the sum of discounted values of payment flows indicated to today that is calculated from formula:

$$NPV = \frac{EMV1}{k} + M, \tag{15}$$

where *NPV* is the sum of discounted values of payment flows, *EMV1* is the expected monetary valuation (decision valuation at the first stage), k is the discount coefficient, M is the payment flow up to now.

In turn, *EMV*1 is calculated from formula:

$$EMV1 = \sum_{j=1}^{N} DCF \cdot p_j, \tag{16}$$

where *DCF* is the discounted cash flow, p_j is the probability of occurrence of a certain environment state (sales level).

Magnitude of *DCF* is calculated from formula:

$$DCF = EMV2/k + CF1, \tag{17}$$

where *EMV*2 is the expected monetary valuation (decision valuation at stage 2).

*CF*1 is the monetary flow at stage 1, calculated from formula (8) for each of the projects at certain forecast of the market situation.

Based on the theory of temporal monetary value [28–31], in order to obtain the sum of payment flow, normalized to the present moment, one uses the discounting method, which is realized in this research by formulas (15) to (17).

The initial part of a tree of alternatives contains the elements of the first set of decision of the first actor whether to conduct or not to conduct additional research. That is why the source data of the model is a decision chain, which for numerical example looks like: "Conduct additional studies"→"Construction of a nine-storied building".

Further branching of the decision tree will be designated in capital letters:

– tree *A* corresponds to the alternative "Not to conduct additional research", according to which subsequent decision regarding selection of the construction investment project is made without specifying a priori probabilities of environment state;

– tree *B* corresponds to low sales at stage 2 of decision implementation, which will lead to a decrease in monetary flow;

– tree *C* corresponds to medium sales at stage 2 of decision implementation, which will lead to an insignificant decrease in monetary flow;

– tree *D* corresponds to high sales at stage 2 of decision implementation, the assumption about an increase in monetary flow is logical.

The initial part of the tree alternatives, which corresponds to the first set of decisions of the first actor – whether to conduct or not to conduct additional research – is shown in Fig. 3.

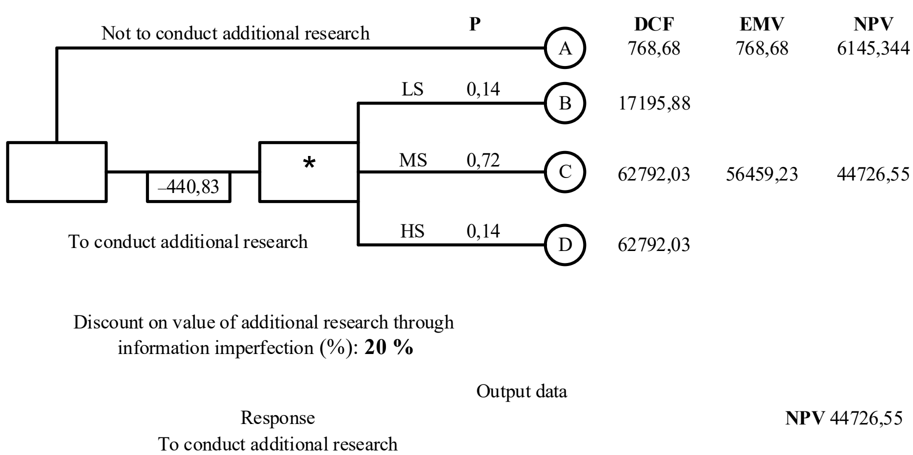

Fig. 3. Appropriateness to conduct additional research

It should be noted that in the change of these indicators and model parameters, other decision chains can be formed. In addition, with the help of this model, it is possible to conduct an analysis of decision stability depending on a change of input parameters.

The result of calculation of tree *A* – "Not to carry out additional studies', the maximum value of net present value *NPV*=UAH 7,681.68. According to the found value, "Construction of a 9-storey building" was determined as the best alternative.

When considering the option "To conduct additional studies" of tree *B*, the maximum value of net present cost is UAH 17,195.

Tree *B* corresponds to low sales at stage 2 of decision implementation, which will result in a decrease in cash flow and the answer in this case will be "Construction of a 16-storey building".

Likewise, we simulate the situations that correspond to medium sales at stage 2 of decision implementation, as well as to high sales at stage 2 of decision implementation and an increase in cash flow.

9. Discussion of results from studying valuations of investment attractiveness of construction objects

Based on the results of research into investment attractiveness of construction objects, the model of making multi-stage decisions in the field of investment in construction objects, taking into consideration losses that may arise during the implementation of adverse events was created. Results of marketing research shown in Fig. 2 revealed that according to mathematical expectation of the magnitude of cash flows for project (1), (8) the best alternative is investment in the construction of a 16-storey building ($M(CFt)16=\max\{M(CFt)\}=5{,}995.2$). However, this project is also the riskiest, it has the maximum value of variation factor ($\delta=76$ %) and semi-variation ($S\delta=71$ %) (4), (7). Such results are explained by a significant size of investment in the project at the initial stage, a longer term of project implementation and a higher probability to realize adverse events during this period.

Such results predetermined the need to continue research, specifically, conducting the analysis of decision stability and calculation of the value of perfect investment information, are given in Tables 7, 8. High decision stability was predetermined by a large dimensionality of the sample. The value of perfect information (*EVP*=UAH 642.88) equals to the expected lost opportunities.

The lack of statistical data can lead to a significant decrease in expected monetary valuation of strategies and a change is decision. That is why the best investment strategy was determined with the help of the decision tree, provided that the information about investment parameters was clarified. The result of this part of the research was that the construction of a 16-storey building was determined as the best investment project by most decision-making criteria under conditions of risk and uncertainty. The decision chain was formed with the use of multi-stage methods for the improvement of the effectiveness of investment risk management: TO CONDUCT ADDITIONAL RESEARCH→ →TO CONSTRUCT A 16-STOREY BUILDING (Fig. 3). Such a chain is predetermined by the preliminary research results, specifically, the values of perfect investment information value and decision making criteria under conditions of risk and uncertainty.

The specific feature of the developed model is comprehensive taking into account of many indicators of investment attractiveness of sites (input variables of the model):

– cash flow in the first year of decision implementation;

– cash flow in subsequent years of decision implementation;

– prices for real estate;

– size of initial investment;
– sold areas;
– values of additional research.

Another feature is the clarity of decision dependence on the above indicators due to the graphic interpretation of the decision-making process by means of the decision tree.

The limitation of this study is that some parameters are considered constant magnitudes within one experiment (model parameters). These parameters include: percentage of variables and permanent costs; percentage of taxes; discount rate; percentage of a change in cash flow in case of realization of one or another forecast of market conditions.

The model for evaluation of investment attractiveness of construction objects is universal in relation to the type of sites of residential real estate. However, at the change in the set of alternatives or environment states, there occurs the need to edit the graphic part of the model. This drawback is caused by the program implementation environment and can be eliminated in the application of other software.

The development of these studies involves an increase in the number of indicators of investment attractiveness, based on which the decision on the choice of the investment object is made. It is also necessary to take into consideration social and macroeconomic indicators, which can influence the decision formation.

10. Conclusions

1. The simulation model for evaluation of investment attractiveness of construction objects was created. The specific feature of this model is obtaining the numerical characteristics of profitability and risk based on statistical methods. The best from the profitability position alternative of the investment in the construction of a 16-storey building was identified (*M*(*CFt*)=5,995.2 – the maximum value among alternatives). It was shown that this choice at the same time is risky because it has the maximum values of coefficients of variation (*CV*=76 %) and semi-variation (*SCV*=71 %). This is explained by the large amount of capital investment in the project at an early stage, a longer term of project implementation and higher probability of implementation of adverse events during this period. This makes it possible to consider that additional research is necessary.

2. The specific feature of marketing research is the possibility of determining and taking into account economic and social factors and their comprehensive consideration when making investment decisions concerning housing sites. The consideration of these factors in the case of three specific alternative projects for the choice of an investment option made it possible to consider the alternative with a maximum income and an appropriate degree of investment risk to be the best option. Based on these factors, the option of the construction of a 16-storey building with the best expected profit was selected (*EMV*=UAH 5,745.33) and degree of investment risk (*EOL*=642.88) based on unfavorable, favorable, and moderate forecasts, as well as on probability of implementation of these forecasts.

3. An analysis of the best project by the risk and uncertainty criteria without additional research into environment and their consideration was carried out. This has made it possible to develop the program implementation of the Bayesian criterion, the decision-making criterion under uncertainty conditions and the model for determining the value of perfect information on the probability of environment state and to form the set of alternatives for participants of the investment process, using the game theory.

4. The stability of the obtained decisions regarding a change of the predicted parameters of a project using statistical data was analyzed, due to which the relative error was calculated in determining the probabilities of the environment states, which made up 14 %. The conducted stability analysis has made it possible to consider the value of perfect information based on the gain matrix and by the risk or lost opportunities matrix to be sufficient.

5. The best investment strategy was determined with the help of the decision tree, provided that the information on the investment parameters is clarified. This made it possible to draw conclusions about the dependence of decision stability on a change in the input parameters, to simulate the situations that correspond to changes in cash flow.

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