ЭКОНОМИЧЕСКИЕ НАУКИ

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CLUSTER ANALYSIS OF PROJECT RISKS OF ENTERPRISES IN THE CONSTRUCTION INDUSTRY

Summary. The construction industry is a system-forming element of the Ukrainian economy, the development of which affects other industries, particularly the engineering industry, metallurgy, glass production, the wood industry, energy and others. The consequences of the economic recession and unforeseen events of recent years were caused by the emergence of various types of risks and had a negative impact on the development of construction projects. The study was conducted on the basis of 5 enterprises and 5 projects and covered the period from 2010 to 2018. Identification of the most significant risks was carried out using econometric methods, namely the cluster and correlation analysis. The output of project risks for the correlation analysis was generated in accordance with the list of most significant risks identified by the expert assessment method. The coefficient of determination helps to confirm or to refute hypotheses about the significant impact of risks on the project parameters in the construction industry.

Keywords: project risks, building projects, construction projects, cluster analysis, correlation analysis.

Problem statement. The construction industry is characterized by the complexity of the management system, which is associated with a large number of participants involved in the project, multilateral connection, the impact of the situation on the resource, labor and service markets, which makes it quite risky. In a time of economic instability, the risk level of construction industry projects increases. Accordingly, approaches to risk assessment must be consistent with economic conditions. Therefore, it is important to conduct a cluster analysis of project risks in order to determine the most influential ones, to identify patterns of their influence and to improve the further preventive accounting and risk minimization process.

Analysis of recent research and publications. A wide range of problems in the analysis, assessment and management of project risks was considered in the works of many scientists**.** Among them, it is advisable to distinguish domestic scientists such as A. Algin (1999) K. Baldin (2009), E. Dubinin (2005), E. Kuzmin (2013) [1, 2, 3, 4] and also foreign scientists such as D. Cooper et al. (2005), C. Lee et al. (2012), A. Taroun (2014), C. Fang et al. (2012) [5, 6, 7, 8].

Highlighting previously unresolved parts of a common problem. Most scientists focus on risk management in general, namely on generally accepted methods, which are set forth in the standards of PMBoK, FERMA, COSO and others. In particular, the issues of researching risk assessment and determining the impact on the final indicators of project activities remain relevant due to limited information on project risks and fragmentary analysis of methods.

The aim of the article. The aim of the work is to conduct a cluster risk analysis of the construction project and identify risks that most strongly affect the project parameters.

Statement of basic materials. A list of project risks contains a large number of both qualitative and quantitative indicators, which makes it difficult to identify and evaluate the patterns of their influence on the effectiveness of construction projects. The difficulty is associated with the fact that usually there are several indicators of the of construction projects effectiveness taken into account. Among them are the following:

- net present value (NPV),
- internal rate of return (IRR),
- payback period of the project (PP).

Identification of the most significant risks, which makes it impossible to achieve certain project results for the specified parameters (NPV, IRR, PP), requires the determination of the nature and structure of the relationship between the risk components and the specified project parameters. A study of the identified risks [9, 10] shows that in relation to the resulting project parameters (NPV, IRR, PBP) project risks as predictors will be endowed with multidimensional factors.

A multidimensional factor is understood as p-dimensional vector $x = (x_1, x_2, \ldots, x_p)$ of indicators (signs) $x_1, x_2, \ldots, x_p$ of the identified project risks, which may include:

- quantitative, those that scalar measure on a certain scale the degree of manifestation of the studied properties of the object;
- ordinal, those that allow you to order the objects of analysis according to the degree of manifestation of the investigated properties in them;
- classification (or nominal) - those that allow you to divide the studied set of objects into ordering into homogeneous classes (relative to the studied properties).

$$\{\mathrm{Xi}\}_1^n = \{(x_{1\mathrm{i}}, x_{2\mathrm{i}}, \ldots, x_{\mathrm{pi}})'\}_1^n \quad (1)$$

The results of measuring such indicators on each of the subobjects of the studied population form a sequence of multidimensional observations, or the initial array of multidimensional data for conducting multivariate statistical analysis. A significant part of such statistical analysis involves situations in which the investigated multivariate factor is interpreted as a multidimensional random variable and, accordingly, a sequence of multidimensional observations (1) that is as a sample from the general population. Multidimensional statistical analysis of the geometric structure of the studied set of multidimensional observations combines the concepts and results of such models and schemes as discriminant analysis, cluster analysis, and others [11].

We analyzed the set of parameters $\{X_i\}_1^n = \{$NPV, IRR, PP$\}$ and the corresponding list of risks from the set $\{(x_{1i}, x_{2i}, \dots, x_{pi})'\}_1^n$, which corresponded to the signs of multidimensional observations (1), and cluster analysis was one of the research methods.

The necessity to use the cluster analysis method in this work was dictated by the fact that it allowed us to identify internal relationships between units of the totality of the project risk set observed in accordance with the totality of the project implementation parameters. The construction of classifications is especially relevant for such poorly studied phenomena as project risks and their impact on the parameters of project performance (or project implementation), when it is necessary to establish the presence of relationships within the aggregates and highlight its structure.

Isolation of the indicated structure as part of the task is advisable according to the criterion of the proved variance share of the dependent variables' deviations from their average values, i.e the determination coefficient, which reflects the correlation between the effective parameters of project implementation and project risks. The rationale for using the coefficient of determination as a criterion for clustering is also supported by the fact that there is the possibility of a reasonable allocation. So, according to the qualitative interpretation of the coefficient of determination (R^2) on the Cheddock scale [12, 13] if R^2 takes the value from 0 to 0.5, the relationship between the parameters is missing or weak. If the value ranges from 0.5 to 0.7, the connection is already noticeable. If the value variates from 0.7 to 0.9, the relationship between the parameters is high. Lastly, if the R^2 value ranges from 0.9 to 0.99, the connection is considered significant.

Therefore, the cluster centroid in this work was adopted at a size of 0.5, which allowed to divide the project risks into significant and weak ones.

The initial data of the correlation analysis made it possible to determine that the values of the productive parameters of the five studied enterprises' projects had different development tendencies. It is natural because, despite their belonging to a single holding, all enterprises have different potentials and internal functioning environment. Thus, the total net present value (NPV) of construction projects carried out by these enterprises over the period under review fluctuated, and their total value increased nominally by 3.98% from 2010 to 2018. However, the average return rate (IRR) decreased by 43.2% over the same period with the payback period of 2.3 years.

The output of project risks for the correlation analysis was generated in accordance with the list of most significant risks identified by the expert assessment method. Due to the analysis of the data obtained as a result of the expert commission survey and the generated matrices and maps of project risks, the experts identified the significant project risks, which were financial, economic, technological, personnel, construction and installation risks.

At the same time, with regard to these results, the top management of the enterprises noted that these risks were completely manageable, as the enterprises took all necessary measures to minimize them. Specialists who were directly related to project activities and technological processes confirmed the level of exposure to risk and noted that various complex problems and threats often arise in the process of complex labor-intensive projects implementation. There were also disagreements in the expert groups regarding the impact of human, political and economic risks, however, as the data showed, these differences were not significant.

Regarding the influence of internal factors, it was not difficult for experts to evaluate the impact through the reliability of effective indicators. Assessment of the influence of external factors, such as amendments to legislation and regulations of enterprises in the construction industry, low investment activity, delays in delivery or lack of necessary building materials, etc., turned out to be the most difficult process due to the uncertainties in the external environment.

A number of specialists in the construction industry note that technological risks bear a severe impact on the dangers of further operations in construction [14]. They can also impact the profitability of the object, therefore when building the facility, they must be taken into account in the first place. Statistics show an increase in the number of collapses of building structures. Such accidents tend to be caused by errors made both in the design and in the construction and operation of structures. These seemingly small errors can snowball into a wide range of other problems, i.e lack of a person bearing an official responsibility for the building, breach of requirements of the expert commission and failure to comply with the terms for the restoration works.

Technological risks arise as a result of human error, which implies a personnel risk considering unskilled labor, the turnover of the best specialists abroad. Associated General Contractors of America (AGC) found that 78% of companies had problems finding skilled workers [15].

Due to personnel risks, economic, financial, social risks arise, etc. It is not possible to claim that there is only one type of risk, any irregularities have a chain reaction, so the risk analysis and assessment should be systematic and consistent.

Thus, econometric methods made it possible to confirm or refute the hypotheses about the significant impact of the risks identified by experts on the parameters of the project for construction enterprises.

As shown by the correlation analysis of the impact of project risks from Demand and Sales Market category on the parameters for the implementation of construction projects (Table 1), two indicators demonstrate a significant impact on NPVs: the purchasing power index of the population (linear correlation coefficient 0.73) and the price index for residential construction works (linear correlation coefficient 0.69).

Table 1

CORRELATION ANALYSIS RESULTS OF THE PROJECT RISKS IMPACT FROM DEMAND AND MARKET CATEGORY ON THE PARAMETERS * IMPLEMENTATION OF CONSTRUCTION PROJECTS OF FIVE HOLDING COMPANIES

Risk subcategory	Impact on y1 *		Impact on y2*		Impact on y3*	
	Pearson's coefficient	R2	Pearson's coefficient	R2	Pearson's coefficient	R2
Purchasing Power Index of the Population **	0,73	0,53	0,44	0,19	-0,32	0,10
GDP per capita, thousand UAH	-0,21	0,05	-0,76	0,59	-0,36	0,13
Demand for real estate, thousands of families ***	0,29	0,08	0,81	0,66	0,44	0,19
Price indices for residential construction works, % to previous year	0,42	0,17	-0,47	0,22	0,49	0,24
Household cash costs for real estate, UAH in avg. per month	-0,33	0,11	-0,10	0,01	-0,27	0,07

* y_1 - total NPV value of enterprises, y_2 - average IRR for enterprises, y_3 - average PP value for enterprises that investigated.

** - real average wage / actual living wage;

*** - number of families and singles registered for housing during the year - number of families and singles receiving housing during the year, thousand.

Risks that significantly affect the IRR parameter from Demand and Sales Market category include GDP per capita (Pearson coefficient 0.76) and real estate demand index (linear correlation coefficient 0.81). Risk indicators that significantly affect the payback period of construction projects in this category were not found, since all linear correlation coefficients for this parameter were less than 0.5.

The calculated coefficients of determination (R2) indicate that the change in the NPV parameters depends on the change in the purchasing power index of the population by 53%, and on the index of the price index for residential construction and installation works by 48%. Changes in IRR parameters depend on changes in GDP per capita by 59%, and on real estate demand by 66%.

As seen on Table 2, the Pearson and the determination coefficients for all parameters show a negligible effect of the operational risk indicators.

Table 2

CORRELATION ANALYSIS RESULTS OF THE PROJECT RISKS IMPACT FROM OPERATIONAL RISK CATEGORY ON THE PARAMETERS * OF CONSTRUCTION PROJECTS OF FIVE HOLDING COMPANIES

Risk subcategory	Impact on y1 *		Impact on y2*		Impact on y3*	
	Pearson's coefficient	R2	Pearson's coefficient	R2	Pearson's coefficient	R2
Solvency of (partners) suppliers of building materials	-0,53	0,28	0,27	0,08	-0,17	0,03

* y_1 - total NPV value of enterprises, y_2 - average IRR for enterprises, y_3 - average PP value for enterprises that investigated.

Correlation analysis of the impact of project risks from Macroeconomic Risks category on the parameters of the implementation of construction projects (Table 3) allows to determine the interest rates NPV (linear correlation coefficient is 0.78) and the hryvnia to the US dollar exchange rate (linear correlation coefficient is 0.89).

Table 3

CORRELATION ANALYSIS RESULTS OF THE PROJECT RISKS IMPACT FROM MACROECONOMIC RISKS CATEGORY ON THE PARAMETERS * OF CONSTRUCTION PROJECTS OF FIVE HOLDING COMPANIES

Risk subcategory	Impact on y1 *		Impact on y2*		Impact on y3*	
	Pearson's coefficient	R2	Pearson's coefficient	R2	Pearson's coefficient	R2
Interest / credit rate, %	-0,78	0,62	-0,91	0,83	0,05	0,00
Inflation, %	-0,59	0,35	-0,65	0,42	0,15	0,02
hryvnia exchange rate to USD	-0,89	0,78	-0,94	0,88	-0,31	0,10
Quantity / volume of construction work in progress, units	0,41	0,17	0,49	0,24	-0,20	0,04
Index of volume of construction work, % to previous year	-0,16	0,03	-0,31	0,09	-0,53	0,28

* y_1 - total NPV value of enterprises, y_2 - average IRR for enterprises, y_3 - average PP value for enterprises that investigated.

Correlation analysis of the impact of project risks from Macroeconomic Risks category on the IRR (Table 3) showed a significant impact of such indicators as interest rate (linear correlation coefficient is 0.91), inflation (-0.65) and also the hryvnia to US dollar exchange rate (linear correlation coefficient is 0.94). There was no significant effect of project risk indicators from Macroeconomic Risks category on the PP parameter (Table 3).

The calculated coefficients of determination (R2) indicate that a 78% change in NPV parameters depends on a change in the interest rate and 89% change of the hryvnia to US dollars exchange rates; 91% change in IRR parameters depends on changes in the interest rate indicator, 65% on the inflation rate and 94% on changes in the hryvnia to US dollars exchange rate.

Based on Table 4, we can summarize the significant impact of such project risks as foreign direct investment in construction, capital investment in construction, accounts payable, average monthly salary, the degree of depreciation of fixed assets in the Finance category, Social and Political Risks category, Technology category.

Table 4

CORRELATION ANALYSIS RESULTS OF THE PROJECT RISKS IMPACT FROM THE FINANCE CATEGORY, SOCIAL AND POLITICAL RISKS CATEGORY AND TECHNOLOGY CATEGORY ON THE RESULTING PARAMETERS * OF CONSTRUCTION PROJECTS

Risk subcategory	Impact on y1 *		Impact on y2*		Impact on y3*	
	Pearson's coefficient	R2	Pearson's coefficient		Pearson's coefficient	R2
Financial risks:						
Availability of financing (FDI for construction), UAH billion	0,79	0,62	0,23	0,05	-0,28	0,08
Capital investment in construction, UAH billion	-0,15	0,02	-0,63	0,75	0,30	0,09
Capital investment indices for construction, %	0,09	0,01	0,23	0,05	0,35	0,13
Mortgage loan rate	-0,18	0,03	-0,39	0,16	0,36	0,13
Retail mortgage lending, UAH billion	0,43	0,18	0,52	0,27	0,14	0,02
Current arrears on long-term liabilities in the construction industry, UAH billion	-0,25	0,06	-0,45	0,21	-0,45	0,20
Accounts payable, UAH billion	0,41	0,16	0,59	0,35	0,43	0,19
Private partner financial capacity (business solvency)	-0,15	0,02	0,19	0,04	-0,38	0,14
Social and political risks						
The turnover of personnel in the construction industry, %	-0,04	0,01	-0,33	0,11	0,44	0,19
Labor productivity, at actual prices, UAH	0,38	0,14	0,08	0,01	0,37	0,14

Average monthly salary, UAH.	-0,31	0,09	-0,68	0,47	0,44	0,19
Technological risks:						
The degree of depreciation of fixed assets, %	-0,38	0,15	-0,80	0,65	-0,43	0,18

* y_1 - total NPV value of enterprises, y_2 - average IRR for enterprises, y_3 - average PP value for enterprises that investigated.

The Pearson coefficients of the above subcategories of the most significant design risks exceed 0.5. According to the calculated values of the coefficients of determination, a change in the NPV value of 62% was caused by a change in the foreign direct investment in construction. A 75% change in the IRR can be explained by fluctuations in the amount of capital investment in construction, a 47% change in the average monthly wage and a 65% deterioration in fixed assets.

In this regard, the correlation analysis made it possible to obtain the values of determination coefficients, which reflected the degree of dependence of the parameters of construction projects (NPV, IRR, PP) on design risks in the categories identified by experts as significant. As noted earlier, this allows to identify unrelated compact risk groups and divide them in the accumulation area by the criterion according to the value of the coefficients on the Cheddock scale.

The algorithm of this classification is performed using clustering with tools of the Excel table processor, the results of which are presented in Figure 1.

The clustering results in Figure 1 made it possible to draw conclusions about the quality of the resulting structure of project risks in terms of their impact on project parameters in accordance with the task set at the beginning of this article. Based on the results of the cluster analysis according to the degree of locality and separability of the distribution of quantities, four significantly different segments were obtained.

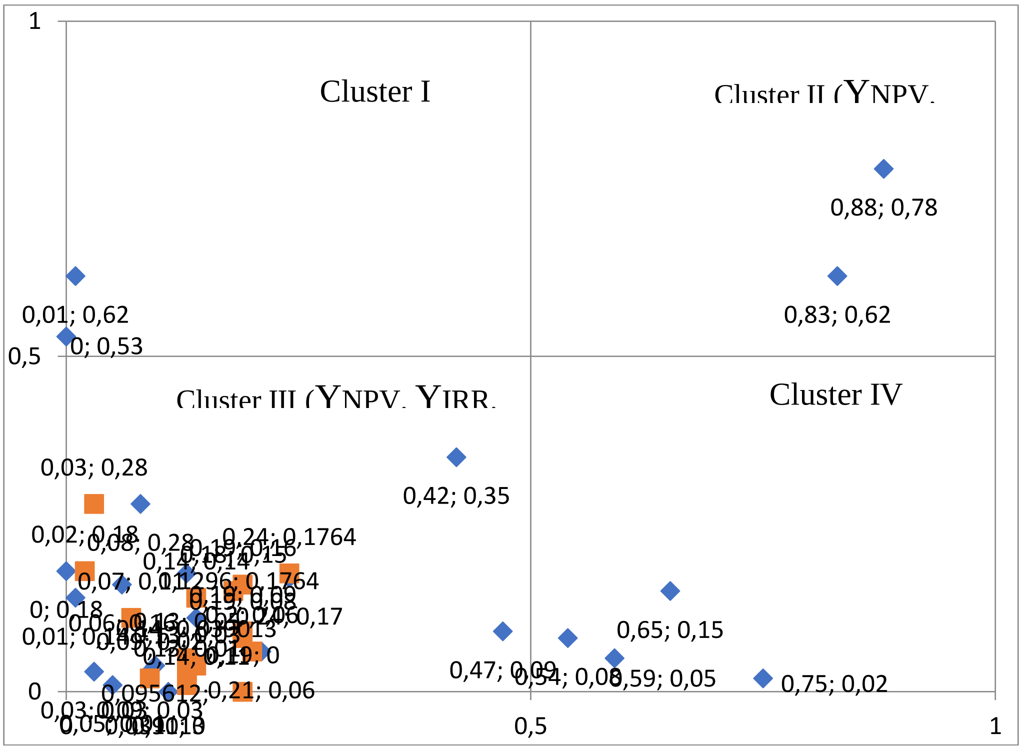

Figure 1. Cluster analysis results of project risks affecting the implementation parameters of construction projects enterprises of the Kyiv region on the coefficient determination criterion

Figure 1 shows that the third cluster is the densest because most of the determination coefficients (the distribution density of the observations inside the cluster is 88.4% of the sample) are located in this cluster. The values are represented by the degrees of project risks influence on all three parameters, namely: y1 = total NPV of enterprises, y2 = average IRR for enterprises, y3 = average PP for studied enterprises. All values of this coefficient are insignificant, so their respective risk groups cannot be included in the further modeling process to identify patterns of their influence on the resulting parameters of construction projects. It is also important to note that the resulting project parameter by the name of Average PP Value for Enterprises only entered the III cluster, which contained only those risk predictors that had the least correlation with the performance parameters of construction projects.

Cluster I (distribution density of observations within the cluster is 2.9% of the sample) contains project risks from the Demand and Sales Market category and Financial Risks category, which most significantly affect the total NPV of enterprises, such as the population purchasing power index, which influences this parameter by 53% and the availability of financing (direct investment in construction), which affects the total value of the NPV of the surveyed enterprises by 62%.

Cluster II is the least dense among all (the cluster distribution of observations within the cluster is 2.9% of the sample), but contains the values simultaneously influential for two parameters: y1 = total NPV of enterprises, y2 = average IRR for enterprises, namely the interest rate, which has 62% impact on NPV and 83% on IRR and the UAH to USD exchange rate, which has 78% influence on NPV and 88% on IRR.

The last cluster IV, which was the second largest cluster among all (observational density within the cluster was 5.8% of the sample), included the most significant project risks solely for the parameter IRR for enterprises in Demand and Market group, Finance group and Technology group. The risks were:

- GDP per capita is an indicator that affects the average value of the IRR parameter by 59%;
- real estate demand - 54% of the impact;
- capital investment in construction - 75% of the impact on the resulting parameter;
- the degree of depreciation of fixed assets - 65% of the impact.

Consequently, with the help of economic statistical analysis, some hypotheses about the existence of a correlation between project risks were confirmed and some were debunked. Risks were allocated in accordance with expert assessments and performance parameters of construction projects, which are regulated by the Resolution of the Cabinet of Ministers and by the Law on state-private partnership [16, 17]. In addition, the cluster analysis allowed us to group the confirmed correlations of the most significant risks according to the identified production parameters (Clusters I, II, IV). Therefore, identifying the patterns of their impact was found to be useful for developing the necessary measures to prevent and minimize their impact.

Conclusions and suggestions. A cluster analysis of project risks allowed to draw conclusions about the quality of the obtained structure of project risks according to their influence on the project parameters. Having used econometric methods, we either confirmed or debunked hypotheses about the existence of a correlation between project risks. This allowed us to group confirmed correlations of the most significant risks in accordance with the effective project parameters (NPV, IRR, PP). The most influential risks fell into clusters I, II and IV. Therefore, further research objectives are to identify patterns of influence of risks on project parameters and develop appropriate measures for their preventive accounting or minimization.

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