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RISK ANALYSIS OF THE CONSTRUCTION VENTURE IN THE ECONOMIC ASPECT

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Purpose: The purpose of the work was to analyze the construction project from the investor's position, with particular emphasis on the implementation phase. Factors influencing individual stages of the investment process may contribute to a change in the investor's risk level, which can be minimized at the right moment. The article attempts to qualitatively analyze selected risk factors, define them and possible reduction.
Design/methodology/approach: The topic of the article is the risk analysis of the process of organizing the construction of an estate of five single-family houses in terms of time and cost of implementation. The analysis was carried out with the use of modern tools to support the work of an engineer, with particular use of computer methods, with the help of the Risky Project 5.0 program.
Findings: The result of the analysis was the identification of risks for which preventive measures should be introduced. The main risks threatening the construction process and delaying the project implementation date turned out to be: the risk of equipment failure, the risk of absenteeism, and the risk of insufficient qualifications of employees. The key process of building an estate of five single-family houses turned out to be finishing works due to their diversity, scope of works, cost and labor intensity. The most important parameters of the project are the total cost of the project, as well as the investment completion time.
Originality/value: The publication covers the subject of cost logistics in the process of implementing a construction project, with particular emphasis on the implementation phase, as well as an analysis of selected risk factors, their definitions and possible reduction possibilities. Based on the project a qualitative risk analysis was performed, the result of this analysis was the identification of risks for which preventive measures should be introduced. After identifying the risk, it is recommended to be thorough estimation of risk factors and their evaluation, as well as planning the response to risk based on the selected model.

Keywords: construction economics, cost logistics, risk management.

Category of the paper: Case study.

1. Introduction

Risk as a possible state is present in all areas of human activity. The article will refer to the sphere of a construction project in the aspect of time and the cost of implementation. Construction projects are one of the most complex in terms of the implementation process, the implementation of a construction investment involves various groups of groups, i.e. designers, material producers, suppliers, contractors, and subcontractors. Each from individual participants in the process may have a different level of responsibility, other possibilities of internal or external influence on the project, which leads to disruptions in the overall implementation process. Therefore, a very important element of each project is the precise definition of the possibility of risk occurrence and the appropriate analysis of all possible events and the consequences of deviations from the assumed process (Miłosz, Szyjewski, 2001).

If want to limit the negative effects of random events that disrupt the implementation of the adopted plan, should be able to manage the risk. Risk is always related to the probability that a given event will not occur (Berliński, Gralak, Sitkiewicz, 2004). Risk management is a process aimed at developing and introducing a risk control strategy to a planned project. It makes it possible to forecast the occurrence of an undesirable event through the use of appropriate methods and processes, and the development of scenarios to prevent them. the risk management procedure should be an integral part of the documentation of complex, complicated and large investment or construction projects, etc., and should constitute the project management subsystem (Kaczmarek, 2005).

The basic phases of risk management are: risk analysis, assessment and communication. Risk analysis in its technical aspect, as defined in the standard (N-IEC 60300-3-9 Risk analysis in technical systems, 1999), is a process during which the probability of an undesirable event and its consequences are identified. They can be caused by activities, devices or systems used. The risk analysis includes the following elements that should be specified here: scope of the analysis, identification and analysis of threats and risk assessment (Skorupka, 2006). In order to properly manage risk, it must first be discovered, that is, identified (Royer, 2002). The existing methods for identifying risk include: SWOT analysis (strengths, weaknesses, opportunities, threats), brainstorming with its many variations and the Ishikawa diagram, as well as checklists (Jaworski, 2009). All of them are aimed at analysing, searching for or organizing activities at risk in order to reduce its effects as much as possible in the future.

Risk assessment is a process that consists of an organized, logical series of actions taken, often illustrated in the form of the so-called event trees or hazard trees that lead to the study of hazards related to the project under consideration (PN-EN 1050 Principles of risk assessment, 1996). At the same time, a specific ranking of adverse events is created, assessing both the frequency and the size of the losses caused. Then, the acceptable level of risk is determined and the analysis of various variants of the possibility of undesirable variants for the same event is carried out. All this leads to the collection of as much information as possible about the possible future course of events and, consequently, to enable risk control by making appropriate decisions during the planned activities. The concept of risk communication should be understood as both the process of mutual exchange of information between individual participants of the investment process (at the investment planning stage regarding the elements of risk related to the implementation of the project), as well as control and monitoring during the implementation of the investment and the final assessment of actions taken after completion of the planned project. It is an important component of risk management – at this stage it possible to eliminate previously unnoticed errors and spot new ones and remedy them early enough. Risk communication also allows to draw the right conclusions so as to avoid similar risky events in the future (Jamróż, 2006).

Only full and dynamic cooperation between the above elements of risk management can guarantee the achievement of total success. When designing a construction project, risk management usually concerns the deadline and the closely related cost (time-cost risk). However, in the process of implementing this facility, it is divided into the management of many components at risk, such as, for example, unforeseen soil and water conditions, weather conditions, availability of human resources, materials and equipment (Tokarski, 2017).

2. Motivation and purpose of the analysis

Risk at the level of implementation of a construction project is the probability of the occurrence of undesirable events and their consequences in the scope of conducted activity, having a direct or indirect impact on the development of a given construction process or its part. Taking into account the specificity of construction investments, risk management issues are of great importance and affect the results of individual logistics (construction) processes, and consequently, the implementation of the entire investment process. The risk in construction projects is significant due to the very large number of threats resulting mainly from the specificity of the work execution process, as well as the special impact of environmental hazards, failure of construction machines or employee absenteeism. Unfortunately, there are no analyses, models and tools that would support the risk management process of construction projects. Therefore, creating a risk management system model will allow in the future to support control and prevent the effects of threats in this type of projects. Taking this into account, it can be concluded that the risk related to planning, implementation and operation of a construction project is a complex issue that is difficult to clearly define, let alone manage it effectively. This certainly requires, apart from theoretical knowledge, some practical experience related to it. The article presents the results of the analysis of the conceptual approach to this issue. The authors of the article introduces the term "cost logistics", which he defines as optimization of planning, organizing and proper spending of funds.

3. Methodology

The subject of the study is the analysis of the technology design and organization of the construction of a single-family housing estate. The estate consists of five identical buildings located on adjacent plots of the same area and shape. The construction design together with the description of the building structure is part of a separate study. The implementation process of the construction project in question assumes: organizational works, earthworks, foundations, construction of the walls of the ground floor, construction of the floor on the ground, construction of the ceiling above the ground floor, construction of stairs, construction of the walls of the first floor, construction of the roof truss, construction of door and window joinery, installation, finishing works, elevations, paving works, as well as fencing the plot.

The expenditure has been calculated and determined for works performed in average local conditions, in areas enabling the delivery and storage of materials in the zone next to the facility, without taking into account special difficulties caused, among others, by in the immediate vicinity of active railway and tram tracks or other similar circumstances. The expenditures included in the KNR Catalog 2-02 take into account all technological processes, assuming the proper organization and technology of works, and taking into account all activities and expenditures necessary to perform elements or works. The catalog provides expenditure on the execution of structural elements or works for the adopted measurement units. The costs of labour and equipment work specified in the catalog apply regardless of the height or depth of execution, subject to vertical transport by a shaft or goods-passenger hoist to a height of more than 18 m. works and auxiliary activities:

- preparation of the workstation,
- internal horizontal and vertical transport of materials and accessories to the average distances and heights on the construction site, taken into account when determining the expenditure for costing purposes,
- positioning, relocating, carrying and removing temporary supports and portable scaffoldings, enabling the performance of works at a height of up to 4 m,
- stacking, sorting and sorting product materials on the construction site or in the warehouse at the facility,
- operating equipment that does not have a full-time service,
- checking the correctness of the works,
- removal of defects and faults as well as repairing damage caused during the execution of works,
- keeping the workstation clean and tidy,
- carrying out activities related to the liquidation of the workstation.

The schedule was created in order to estimate and optimize the construction time of the estate of five single-family houses. The preparation of the schedule began with determining the length of individual works. For this purpose, a bill of quantities was made and a detailed cost estimate was prepared on its basis. Then the number of brigades carrying out individual construction works was determined. The next stage was to determine the time of execution of these works (number of working days) and to determine the appropriate sequence of construction processes resulting from the technology. The sequence of individual works was optimized in such a way as to maintain the continuity of the work of the brigades and at the same time not to significantly extend the course of the investment. The simultaneous performance of several non-conflicting works within one plot in order to shorten the duration of the project (Radkowski, 2003). The commencement of construction works was set no earlier than March 16, and the final deadline for the completion of the shell and facade was set on November 18, 2019. A one-shift, 10-hour working time was assumed, lasting from 7:00 a.m. to 6:00 p.m. with a 1-hour break. The working week is 6 days, from Monday to Saturday. The course of works is carried out by 24 construction brigades, and their composition is constant for the entire course of the investment. The number of individual construction brigades is presented in Table 1.

Table 1.
The number of individual construction brigades

No.	Brigade	Number of employees
1	general construction workers I	5
2	general construction workers II	5
3	bulldozer	1
4	excavator	1
5	dump truck	1
6	surveyor	1
7	electricians	3
8	plumbers	3
9	carpenters	5
10	fixers	3
11	concrete workers	5
12	bricklayers	5
13	roofers	5
14	woodwork fitters	4
15	plasterers	6
16	floor builders	5
17	plaster brigade	4
18	tilers	4
19	painters	4
20	parquet flooring	4
21	the facade team	6
22	pavers	6
23	fireplace fitters	2
24	kitchen fitters	2

Source: own study based on research results.

One storey of the building constitutes the working plot. The exceptions are works carried out outdoors, in which the working plot is the entire building. Preparatory works, i.e. temporary fencing of the construction site and construction of social and sanitary buildings along with their demolition, are carried out for the entire investment. Continuity of work of heavy equipment: excavators and bulldozers, and possibly continuous work of other construction brigades were assumed. The cost estimate with the schedule is part of a separate study.

The risk analysis of the construction project was carried out using the Risky Project 5.0 Professional program. Risky Project is software for planning, scheduling, quantitative and qualitative risk analysis and measuring the progress of projects with many risks and uncertainties. Developed by Intaver Institute and introduced in Poland by EnergSys (Risky Project: Risk analysis software...).

The risks which the impact of the research on the course of the construction process have been examined include:

- risk of unfavourable weather conditions,
- risk of absenteeism of employees,
- risk of equipment failure,
- risk of insufficient qualifications of employees (employee productivity),
- risk of poor management of material resources,
- risk of non-compliance with standards.

Table 2 presents the values of risks in individual activities and their percentage probability of occurrence during the construction process.

Table 2.
Risk values in individual activities of the construction process of an estate of five single-family houses

No.	Name of activity	Risk	Chance of occurrence [%]
1	Organizational works	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	2.0
		Risk of hardware failure	11.0
2	Earthworks	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	2.0
		Risk of hardware failure	20.0
3	Foundations	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	4.0
		Risk of hardware failure	15.0
		Risk of insufficient qualifications of employees (employee productivity)	5.0
4	The walls of the ground floor	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	3.0
		Risk of hardware failure	15.0
5	The floor is on the ground	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	2.0
		Risk of hardware failure	10.0

Cont. table 2.

6	Ceiling above the ground floor	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	3.0
		Risk of hardware failure	20.0
		Risk of insufficient qualifications of employees (employee productivity)	5.0
7	Stairs	Risk of absenteeism of employees	5.0
		Risk of hardware failure	15.0
		Risk of insufficient qualifications of employees (employee productivity)	5.0
		Risk of non-compliance with standards	5.0
8	The walls of the first floor	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	3.0
		Risk of hardware failure	20.0
9	The structure of the roof truss	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	5.0
		Risk of hardware failure	20.0
		Risk of insufficient qualifications of employees (employee productivity)	15.0
		Risk of non-compliance with standards	7.0
10	Door joinery and window	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	2.0
		Risk of hardware failure	10.0
		Risk of poor material resource management	5.0
11	Installations	Risk of absenteeism of employees	5.0
		Risk of insufficient qualifications of employees (employee productivity)	5.0
		Risk of non-compliance with standards	5.0
12	Finishing works	Risk of unfavourable weather conditions	3.0
		Risk of absenteeism of employees	8.0
		Risk of hardware failure	25.0
		Risk of insufficient qualifications of employees (employee productivity)	5.0
		Risk of poor material resource management	5.0
		Risk of non-compliance with standards	5.0
13	Elevations	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	3.0
		Risk of hardware failure	15.0
		Risk of non-compliance with standards	5.0
14	Paving works	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	1.0
		Risk of hardware failure	5.0
		Risk of poor material resource management	1.0
		Risk of non-compliance with standards	1.0
15	The fence of the plot	Risk of unfavourable weather conditions	1.0
		Risk of absenteeism of employees	2.0
		Risk of hardware failure	10.0

Source: own study based on research results.

4. Results

The risk analysis of the construction project was carried out using the capabilities of the Risky Project 5.0 Professional program. The Risk Matrix shows the impact of a given risk on the basis of the calculated probability of occurrence, which in the case of the risk of adverse weather conditions (13.2%) and the risk of poor material resource management (9.6%) is very low. Low probability of occurrence, because 21.3%, also has the risk of not maintaining standards at the construction site. Low probability, but with an increasing tendency as a result of the complexity of the processes at subsequent stages of construction, has a risk related to insufficient qualifications of employees – 34.4%. The course of works is carried out by 24 construction brigades, and their composition is constant for the entire course of the investment, therefore the probability of risk related to employee absenteeism was 37%. The risk related to equipment failure is classified as the one with the highest probability of occurrence – 88.9% - due to the high failure rate of machines during the construction process.

The Cost Analysis view shows the costs in a chart. Actual cost means actual costs so far, the current schedule shows the assumed budget, and the results are simulated data. By moving the slider under the graph, can track the cost in the subsequent phases of the project. The largest expenses are related to the construction of the roof truss structure (93,824.23 USD) and finishing works (145,437.00 USD). The cost of the current schedule was 556,993.00 USD, and after the risk-based simulation, the cost increased by 333.00 USD to 587,326.00 USD.

The Cash Flow view shows information about the cash flow for the selected time period. The expenses related to the process of building an estate of five single-family houses are systematized. The increase recorded at the turn of July and August is the reason for the increase in expenses related to the commencement of the "Finishing works" process, which is one of the most resource-intensive, both cost-effective and resource-intensive. The NPV (Net Present Value) of the current schedule was 558,610.00 USD, and after simulation, it was down 70,189.00 USD to 488,421.00 USD. As construction works approached the end, the expenses were gradually decreasing.

The Risk Graph view determines the cost or duration versus risk. In the case of the Task duration (Current Schedule) chart, the risk, due to the duration, is most likely to occur in the "Finishing work" process - 182/281 days. The smallest, however, during Paving works – 5/281 days. Total Task Cost (Current Schedule) illustrates the risk due to the total cost of the task, which turned out to be the highest during the finishing works (145,437.00 USD) and the construction of the roof truss structure (93,824.23 USD). The lowest cost is the construction of stairs (1,879.16 USD) and paving (8,519.83 USD). Increased costs of construction works may come from increased (compared to standard) outlays for their performance, exceeding contractual deadlines or the need to employ overtime workers and machines.

Using the Success Rate, the probability of success or completion was calculated for individual tasks. The results are marked in different colors on the Gantt chart. Tasks with a high success rate are shown in green, with medium in yellow, and with low in red. In the case of the construction process of an estate of five single-family houses, all planned tasks have a high success rate – 100.00%.

The Crucial Tasks view shows the correlation between risks and the likelihood of completing tasks. The higher the correlation, the more risk influences the performance of the task. The uncertain ones whose variable duration has the greatest impact on the project are shown in red. In the case of the construction of an estate of five single-family houses, the least certain activity is "Finishing works". The only critical activity of finishing works includes all types of risks included in the project.

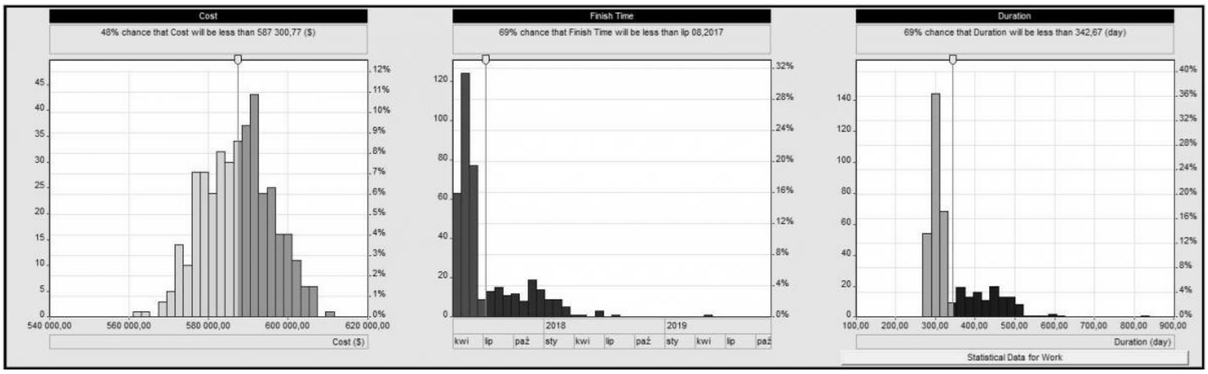

Figure 1. Project Summary, Option I.

The Project Summary lists the budget, duration, and end dates for the project. With the help of the program, three variants of the effectiveness of the implementation of activities related to the construction process were analysed. And so for option I – the most likely one,

- the scope of the budget was 587,300.77 USD with a 48% probability,
- the duration of the construction process with a 69% probability was estimated at 343 days,
- the completion date of the construction process with a 69% probability is scheduled for no earlier than 07/07/2019.

Option II – 80% probability,

- the scope of the budget was 594,910.03 USD,
- the duration of the construction process was estimated at 405 days,
- the completion date of the construction process is scheduled for no earlier than 02/10/2019.

Option III – 95% probability,

- the scope of the budget was: 601,696.66 USD,
- the duration of the construction process was estimated at 493 days,
- the completion date of the construction process is scheduled for no earlier than 29/01/2020.

The most favourable option is the most likely one due to the lowest costs, completion date and duration of the construction process. The Project Report provides information on the three most important parameters of the project, the three most critical tasks and the three most critical risks.

5. Conclusions

The publication covers the subject of cost logistics in the process of implementing a construction project, with particular emphasis on the implementation phase, as well as an analysis of selected risk factors, their definitions and possible reduction possibilities. Based on the architectural design of a housing estate of five single-family houses and the design of technology and construction organization, a qualitative risk analysis was performed, the result of this analysis was the identification of risks for which preventive measures should be introduced. The analysis showed that the most important parameters of the project are the total costs of the project, which in the case of excluding risks amounted to 586,993.00 USD, and with included risks increased by 333.00 USD and amounted to 587,326.00 USD. Another important parameter is the time of completion of the investment, which, in the case of no risks included, provides for the completion of works on 11/04/2019, while with the risks taken into account, the process was extended by 87 days and its completion date is scheduled for 07/07/2019. Project duration in the case of no risks included the risks taken into account was 281 days, while after taking into account the risks, the process was extended by 63 days and amounted to 344 days. The main risks threatening the construction process and delaying the project implementation date turned out to be: risk of equipment failure, the probability of an incident was 88.9% and occurred in 14 out of 16 activities; the risk of employee absenteeism, the probability of which was 37%, and occurred in 15 activities; the risk of insufficient qualifications of employees (employee productivity), the probability of which was 43.4% and occurred in 6 activities. The key process of building an estate of five single-family houses turned out to be finishing works due to their diversity, scope of works, cost and labour intensity.

The conducted research does not exhaust the issues of identification and hierarchy risk factors in construction projects. However, they draw a picture the problem of risk analysis and assessment. The method of risk analysis presented by the authors can be used for its initial estimation. Detailed analysis requires more application sophisticated methods, e.g. RAMP (Risk Analysis and Management for Project), ICRAM (Model for International Construction Risk Assessment), MOCRA (Method of Construction Risk Assessment) and tools (e.g. Pertmaster, Risk 4.1 for Project, Primavera Project Planer, Statistica Neural Network). The possibilities of using the above-mentioned methods and tools will be presented in the following articles by the authors.

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