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RISK ANALYSIS OF CONSTRUCTION A LOGISTIC CENTRE IN ECONOMIC AND ENVIRONMENTAL ASPECTS

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Purpose: The article attempts a qualitative risk analysis of the feasibility of the construction project of a logistics centre (a warehouse hall with a monolithic reinforced concrete structure), with particular emphasis on the implementation phase. Risk factors may have a negative impact on individual stages of the investment process, and when detected at the right moment, they can be minimized - which will beneficially contribute to changing the investor's risk level.
Design/methodology/approach: The influence of selected risk factors on the scope of works carried out during construction was examined. Particular attention was paid to the time and cost of the investment implementation as well as its impact on the nearest natural environment. The analysis was carried out using modern tools supporting the engineer's work, including computer methods. The Norma PRO 4.75 cost estimating program was used, Microsoft Project supporting project management in terms of resources, time and finances, and Risky Project 7.2 used to manage project risk.
Findings: The components of the construction process that are most exposed to the risk of failure were identified, and preventive measures should be taken against them. The main factors threatening the implementation of the project assumptions, having a significant impact on the extension of time and the increase in the costs of feasibility, include the risk of equipment failure, the risk of employee absenteeism and the risk of negative impact of the works carried out on the immediate natural environment. The key processes in the construction of the logistics centre turned out to be foundation works and assembly of structural elements, due to their complexity, labour-intensity, implementation time and high costs.
Research limitations/implications: Research limitations result from the analysis of a deliberately selected case, which does not allow for formulating general conclusions. Nevertheless, the article refers to engineering practice and describes the challenges faced by the construction sector in the logistics industry.
Practical implications: The information contained in the publication may be of interest to representatives of the business sector, students and doctoral students of technical faculties, analysing the impact of sustainable development on warehouse infrastructure and innovation of project systems in the national and international dimension.
Originality/value: The publication covers the subject of construction logistics in the process of implementation of the project, as well as an analysis of selected risk factors, their definitions, and its 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, infrastructure and environment, logistic centre, risk management.

Category of the paper: Case study.

1. Introduction

Construction is a field of technology in which the implementation of individual technological processes, in comparison to the implementation of analogous processes occurring in other areas of the economy, takes place in specific conditions. In the design, implementation and execution phase of investment projects, one of the basic assumptions is the problem of maximally shortening the construction period and reducing costs, which results primarily from the fact that both the contractor and the investor strive to minimize the planned duration of the project and minimize costs. Very often decision-making is then treated in two-criterion terms as time-cost. The basis for planning construction production is the analysis of material expenditures, which is also the basis for the operation of IT systems. Project managers strive to quickly and reliably determine the use of construction time and costs in order to make appropriate operational decisions (Sypniewski, 2011; Tokarski, 2021).

The problems of determining the appropriate workload are very often underestimated. Contractors most often try to complete tasks quickly, without taking into account the global effects of doing so. However, one should realize that the effectiveness of organizational solutions is measured globally by the cost of lost time (Rytel, 2009; Drzewiecka et al., 2011). The optimal selection of technology for construction processes is an issue that every designer of construction technology and organization encounters very often (Xia et al., 2018).

The idea of engineering construction projects concerns specialized knowledge, skills and competences necessary to develop and make decisions determining the manner, time, costs and place of investment implementation, which is the basis and subject of the study. A construction project can be defined as the construction, extension, modernization or repair of buildings planned and organized at a specific place and time in order to meet the needs of a specific investor. Therefore, it is a complex purposeful process, carried out on and off the construction site, which consists of properly structured construction processes and the necessary processes of information, decision-making, material and technical support coupled with them (Śladowski, 2021).

It can be stated that the development of the construction concept and construction design, due to the required knowledge, skills and competences, is a relatively independent part of the project, which is implemented in accordance with separate rules. However, always taking into account the functional, technical, technological, organizational, economic, system and environmental requirements and conditions that are related to the preparation and implementation of works and the operation of the facility (Obolewicz, 2016; Motowidlak, Tokarski, 2022).

In order to limit the negative effects of random events disrupting the implementation of the adopted plan, the risk of investment implementation should be taken into account. This risk is always associated with the probability of a given event not occurring (Siemaszko, Jakubczyk-Gałczyńska, 2014). Risk management is a process aimed at developing and introducing a risk control strategy to the planned project. It makes it possible to forecast the occurrence of an undesirable event by applying appropriate methods and processes and developing scenarios to prevent it (Aven, 2016; Banera, 2021). The risk management procedure is an integral part of the documentation of complex investment or construction projects, etc. and should be a project management subsystem. When designing a construction project, risk management is usually concerned with the deadline and the closely related cost (time-cost risk). However, in the investment implementation process, it is broken down into the management of many risk-bearing components, such as, for example, unforeseen ground and water conditions, weather conditions, availability of human resources, materials or equipment (Tokarski, Sawicki, 2021).

2. Motivation and purpose

Defining the concept of risk is not easy, especially due to its ambiguity. It is mainly an indicator of a condition or event that may lead to some loss. In colloquial speech, it usually defines some measure or assessment of a threat or danger resulting either from probable events beyond our control or from the possible consequences of decisions made. Each investment carries a risk, this also applies to construction companies. There is no such investment that is risk-free, and construction is sometimes referred to as a high-risk industry. The issue of risk in construction projects is noticeable not only at the planning stage, but also during the implementation period (e.g. by monitoring the actual time and costs of the investment). Identification of random factors, determining the probability of their occurrence and their impact on the course of the construction project are the main elements of the project risk management process. As a result, this is reflected in the deviation of the actual time as well as the cost of the works from the originally planned (Teixeira et al., 2011).

Among the issues discussed in the construction industry, there was the issue of creating risk assessment procedures, schematic diagrams using a systemic approach, as well as algorithms of conduct. In order to simplify the procedure of risk management, its three basic links can be distinguished: identification, quantification and response (PN-ISO 31000:2018). Of course, this procedure is definitely a more extensive process depending on the expectations of the decision maker, the ability to control and analyse the effects. The identification stage includes specifying the hazardous factors that may occur during the execution of a given project.

This method of risk assessment is characterized by ease of calculation and readability of its results. The purpose of risk management is to analyse the initially selected and unwanted random factors, as well as to determine their impact on the price and duration of the construction project, as well as to prepare an alternative solution (Kos, 2019). The methods of identifying risk factors and areas include, among others, assessments by experts and consultants, brainstorming, ready-made "checklists" and internal control in the enterprise. This method of risk analysis includes: local and global risks, external and internal risks, macro and micro level risks, as well as risks closely related to the project. There is also a proposal to classify the risk taking into account the relationship between the amount of damage and the probability of its occurrence (ISO/IEC 31010:2009).

An even more detailed breakdown of existing threats is possible, so professional computer software can help. It is very important to carefully determine the risk factors taking into account the characteristics and size of the project. The purpose of the quantification stage, i.e. the assessment of risk factors, is their analysis and quantitative description. Appropriate tools should be used to assign appropriate measurable values to risk factors, only then it is possible to analyse a construction project according to the forecasted completion time and costs. The risk assessment primarily involves quantifying two factors (probability of occurrence, impact on the project if materialized) to decide what action should be taken on each of them. The final stage is the adoption of one of the proposed risk reduction strategies (Miszewska, Niedostatkiewicz, 2020), namely:

a) transfer of risk - transfer of possible costs related to the possibility of a loss of a participant in the investment process,
b) risk reduction - possible elimination of the risk problem by introducing changes to the design, organization of construction works, etc.,
c) risk avoidance - targeting avoiding solutions for which losses can be expected,
d) risk absorption – taking the possible consequences of adverse events on oneself in their entirety.

Due to the nature and specificity of the construction industry, the analysis of the impact of risk factors on the investment project is undertaken more and more often, despite the considerable difficulty of their quantification. The issue of risk management is not so much up-to-date as important for the efficient planning and implementation of a construction project. When choosing the method of analysis and final risk assessment, one should be guided by its usefulness as well as readability and ease of interpretation of the results obtained. Unfortunately, there is a lack of analyses, models and tools that would support the process of managing the risk of construction projects. Therefore, the creation of a risk management system model will allow in the future to support control and prevent the effects of threats in this activity. Taking this into account, it can be concluded that the risk associated with the planning, implementation and operation of a construction project is a complex issue that is difficult to clearly define, and even more so to manage effectively. Apart from theoretical knowledge, it certainly also requires some practical experience (Szafranko, 2014).

3. Methodology

The subject of the study is the analysis of the project of technology and organization of the construction of a logistics centre, which consists of a hall with a monolithic structure intended for a warehouse, designed in accordance with the currently applicable standards (PN-EN 1992-1-1:2008). The implementation process of the discussed construction project includes: organizational works, earthworks, foundations (including the construction of reinforced concrete columns), assembly of structural elements (i.e. frames and frame systems, wall and roof panels, corner elements, gate sets), installation (e.g. water, sanitary and rainwater drainage, gas, heating, internal mechanical ventilation and electrical installations on the premises), finishing works, paving works and fencing of the plot. The construction design, description of the hall structure, cost estimate and schedule are part of a separate study.

The outlays have been determined for works carried out in average local conditions, in areas enabling the delivery and storage of materials in the zone near the facility, without taking into account any special difficulties. The outlays include all technological processes, assuming proper organization and technology of works and taking into account all activities and expenditures necessary to perform elements or works. The catalog lists expenditures for the execution of structural elements or works for the adopted measurement units. Labour and equipment expenditures specified in the catalog apply regardless of the height or depth of execution, with the reservation of vertical transport by a shaft or goods and passenger hoist to a height above 18 m. Labour expenditures include basic works specified in the specification of works on boards, as well as the following works and activities auxiliary (KNR 2-02):

- internal horizontal and vertical transport of materials and accessories to the average distances and heights occurring on the construction site, taken into account when determining expenditures for cost estimation purposes,
- setting, moving, moving and removing temporary supports and portable scaffolding, enabling the performance of works at a height of up to 4 m,
- stacking, segregating and sorting product materials at the construction site or in the warehouse at the facility,
- operation of equipment that does not have full-time staff,
- checking the correctness of the execution of works,
- removal of defects and faults and repairing damage caused during the execution of works,
- keeping the workplace clean and tidy,
- performing activities related to the liquidation of the workstation.

The schedule was created to estimate and optimize the duration of the investment. The preparation of the schedule began with determining the duration 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 performing individual construction works was determined and a list of equipment planned to be used was prepared. The next stage was to determine the time of completion 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 work of the teams and at the same time not significantly extend the course of the investment implementation. Simultaneous performance of several non-colliding works within the plot in order to shorten the duration of the project was not ruled out. Commencement of the investment is scheduled for May 9, 2021, while the complete completion of the construction of the facility suitable for commissioning according to the schedule is set for March 13, 2022. A one-shift, 8-hour working time from 6:00 a.m. to 3:00 p.m. with two breaks not included in the working time (the first one, in the morning, 20 minutes long, and the lunch break, lasting 40 minutes), 5 working days a week, from Monday to Friday). The course of work is carried out by 14 construction brigades, and their composition is permanent (Banach, Marcinkowski, 2016). The list of the number of construction brigades involved in the implementation of the logistics warehouse construction process is presented in Table 1.

Table 1.
List of the number of construction brigades in the process of building a logistics centre

No.	Brigade	No. of employees
1	General construction workers A	5
2	General construction workers B	5
3	Bulldozer operator	1
4	Crawler excavator operator	1
5	Truck driver	1
6	Surveyor	1
7	Electricians	3
8	Contractors of water and sewage installations	3
9	Steel construction fitters	5
10	Armorers	3
11	Concrete mixers	5
12	Bricklayers	5
13	Roofers	5
14	Pavers	6

Source: own study based on research results.

Table 2 contains a list of equipment planned to be used during the implementation of the assumptions of the discussed investment project.

Table 2.
List of equipment in the process of building a logistics centre

No.	Equipment	No. of sets
1	Crawler bulldozer	1
2	Backhoe crawler excavator	1
3	Wheel loader 3.5 m^3	1
4	Self-dumping truck 20-25 T	2
5	Compactor 100 kg	4
6	Diesel rammer 200 kg	8
7	Concrete pump on the car	4
8	Electric slow fall concrete mixer	4
9	Electric lift	4
10	Reinforcement equipment	4
11	Scaffolding	4

Source: own study based on research results.

The risk analysis was performed using Risky Project 7.2, a software for planning, scheduling, quantitative and qualitative risk analysis and measuring the progress of projects with multiple risks and uncertainties developed by the Intaver Institute (Risky Project Version 7.2, 2022). The risks whose impact on the course of the construction process was examined included:

- risk of employee absenteeism,
- risk of equipment failure,
- risk of negative impact on the natural environment,
- risk of adverse weather conditions,
- risk of not maintaining standards,
- risk of insufficient qualifications of employees (employee efficiency),
- risk of poor management of material resources.

Table 3 summarizes the activities carried out in the course of the implementation of the project assumptions, along with specific risk values broken down into individual activities and their percentage probability of occurrence during the construction process.

Table 3.
List of risk values in individual activities of building a logistics centre

No.	Activity	Risk	Chance of occurrence [%]
1	Organizational works	Risk of employee absenteeism	10.0
		Risk of equipment failure	5.0
		Risk of negative impact on the natural environment	2.0
		Risk of adverse weather conditions	2.0
		Risk of not maintaining standards	1.0
2	Earthworks	Risk of employee absenteeism	5.0
		Risk of equipment failure	10.0
		Risk of negative impact on the natural environment	10.0
		Risk of adverse weather conditions	4.0
		Risk of not maintaining standards	2.0

Cont. Table 3.

3	Foundations	Risk of employee absenteeism	10.0
		Risk of equipment failure	15.0
		Risk of negative impact on the natural environment	5.0
		Risk of adverse weather conditions	4.0
		Risk of not maintaining standards	4.0
		Risk of insufficient qualifications of employees	5.0
4	Assembly of structural elements	Risk of employee absenteeism	10.0
		Risk of equipment failure	15.0
		Risk of negative impact on the natural environment	5.0
		Risk of adverse weather conditions	4.0
		Risk of not maintaining standards	4.0
		Risk of insufficient qualifications of employees	5.0
		Risk of poor management of material resources	3.0
5	Installation execution	Risk of employee absenteeism	10.0
		Risk of equipment failure	10.0
		Risk of negative impact on the natural environment	5.0
		Risk of adverse weather conditions	5.0
		Risk of not maintaining standards	5.0
		Risk of insufficient qualifications of employees	4.0
		Risk of poor management of material resources	3.0
6	Finishing works	Risk of employee absenteeism	10.0
		Risk of equipment failure	10.0
		Risk of adverse weather conditions	5.0
		Risk of not maintaining standards	5.0
		Risk of insufficient qualifications of employees	5.0
		Risk of poor management of material resources	2.0
7	Paving works	Risk of employee absenteeism	10.0
		Risk of negative impact on the natural environment	5.0
		Risk of adverse weather conditions	2.0
		Risk of not maintaining standards	2.0
		Risk of poor management of material resources	2.0
8	Plot fence	Risk of employee absenteeism	5.0
		Risk of negative impact on the natural environment	2.0
		Risk of adverse weather conditions	1.0
		Risk of not maintaining standards	1.0

Source: own study based on research results.

While the risk factors appearing in the process of building a warehouse that is part of a logistics centre related to the area of human, material and technical resources are sufficiently specified, the significance of the impact of the risk of negative impact on the natural environment requires explanation. Most often, environmental risk is understood as a specific type of risk, which is primarily associated with a negative impact on the environment and excessive exploitation of raw materials (Tokarski, 2022). Therefore, environmental risk can be defined as a combination of the likelihood of an environmental event and its consequences. The aforementioned effects of the environmental event should be considered on the basis of the assessment of the threat to: natural elements (ecological risk), property assets (property risk), human health and life (health risk). When characterizing environmental risk, one cannot forget about its dynamics. This is because it indicates the development over time of a potential threat resulting from human activity. At the same time, it becomes important to take into account the changes taking place in the society in which a given enterprise operates (PN-ISO 31000: 2018-08).

4. Results

The risk analysis of the construction project was carried out using the capabilities of the Risky Project 7.2 program. Components used: risk matrix, cost analysis, cash flow, risk chart (task duration, total task cost), success ranking, critical tasks, project summary (for three variants, i.e. 100, 95 and 80% probability of occurrence), project report .

The risk matrix shows the impact of a given risk based on the calculated probability of occurrence, which is very low in the case of the risk of poor management of material resources (12%) and the risk of insufficient qualifications of employees (23%). The risk associated with failure to maintain standards at the construction site also has a low probability of occurrence (30%). The risk of adverse weather conditions (33%) and the risk of negative impact on the natural environment (43%) are low, but with an increasing tendency. The risk related to equipment failure (82%) and employee absenteeism (88%) should be included among the risks with the highest degree of probability of occurrence, due to the complexity of processes at subsequent stages of construction and the high failure rate of machines during the construction process.

The Cost Analysis module shows the costs in a graph. The actual cost means the actual costs incurred so far, the current schedule indicates the assumed budget. Subsequently, the costs were analysed, which show the total cost of the works before and after taking into account the risks. By moving the slider located under the graph, you can track the cost in subsequent phases of the project. The largest expenses are related to foundation works processes (USD 54,225.04) and assembly of structural elements (USD 52,806.76). The costs of the current schedule amounted to USD 374,877.00, while after the simulation involving risks, the costs increased by USD 12,587.00 and amounted to USD 387,464.00.

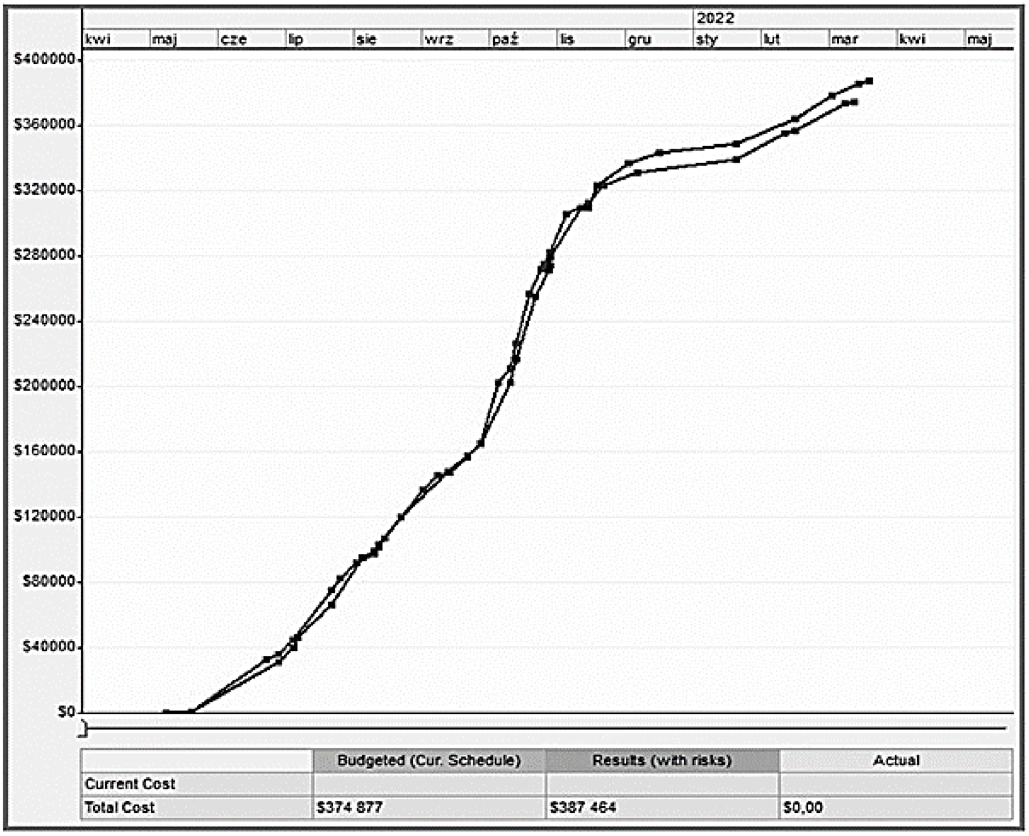

Figure 1. Cost Analysis**.**

Source: own study based on research results.

The Cash Flow module contains information about the cash flow in the selected period. Expenses related to the process of building a warehouse are systematized. The increase recorded at the turn of October and November is the reason for the increase in expenses related to the start of the "assembly of structural elements" process. Expenditures gradually decreased as construction works approached completion. The costs with the calculated risks are comparable to the basic ones, which does not pose a threat to the profitability of the entire project.

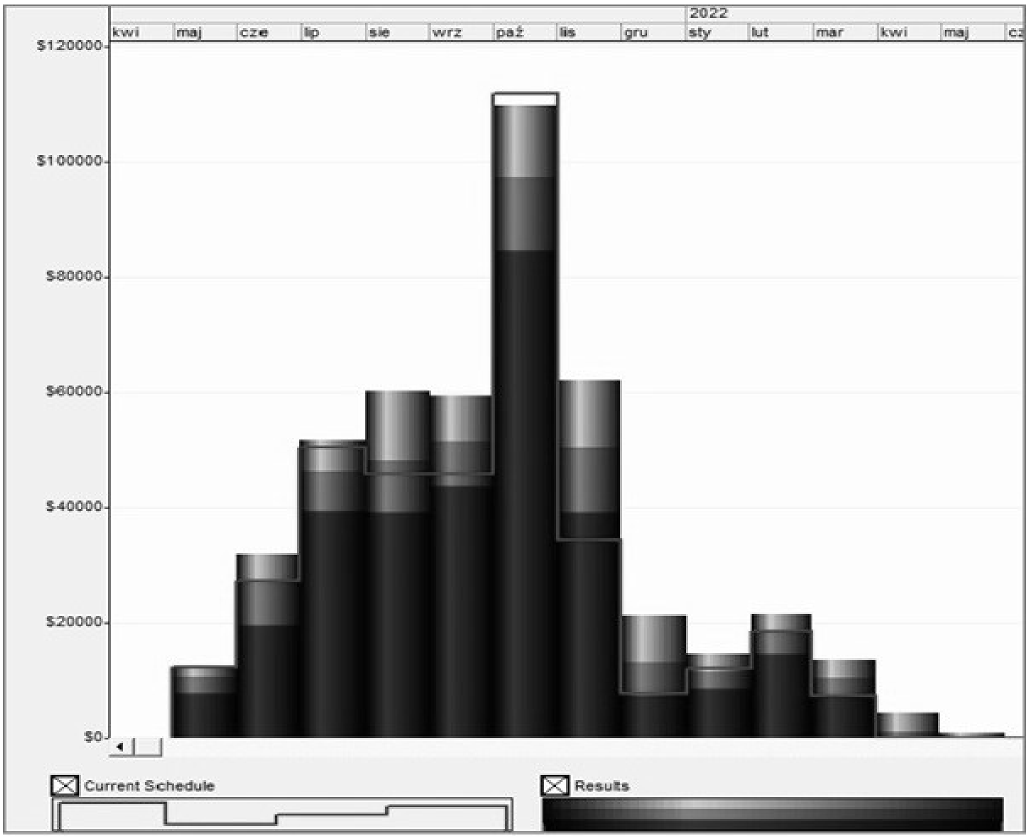

Figure 2. Cash Flow.

Source: own study based on research results.

The Risk Graph module calculates the cost or duration against the risk. In the case of the Task duration (Current Schedule) chart - the risk due to duration has the highest probability of occurring in the assembly process of structural elements, as well as during foundation works. The smallest, however, during the installation of the plot fencing. Total Task Cost (Current Schedule) presents a risk due to the total cost of the task, which turned out to be the highest during foundation works (USD 54,225.04) and assembly of structural elements (USD 52,806.76). The lowest costs are tasks related to fencing the plot (USD 5,322.22). Increased costs of construction works may come from increased (compared to standard) outlays for their execution, exceeding contractual deadlines or the need to employ workers and machines overtime.

Thanks to the Success Rate module, the probability of success or completion for individual tasks was calculated. The results are marked in different colours on the Gantt chart. Tasks with a high success rate are shown in green, medium in yellow, and low in red. In the case of the logistics warehouse construction process, all scheduled tasks have a high success rate of 100%.

The Crucial Tasks module indicates the correlation between risks and the probability of completing tasks. The higher the correlation, the more the risk affects the performance of the task. Uncertain ones whose variable duration has the greatest impact on the project are shown in red. In the case of the construction of a logistic warehouse, the least certain action is "assembly of structural elements". In the critical operation of finishing works, all types of risks included in the project are present as the only one.

In the Project Summary module, the budget range, duration and end date of the project are given. Using the program, three variants of the effectiveness of activities related to the implementation of the construction process were analysed.

And so for variant I - the most probable,

- the budget range was USD 387,377.75 with 50% probability,
- the duration of the construction process with 66% probability was estimated at 234 days,
- the date of completion of the construction process with 65% probability is scheduled for no earlier than March 30, 2022.

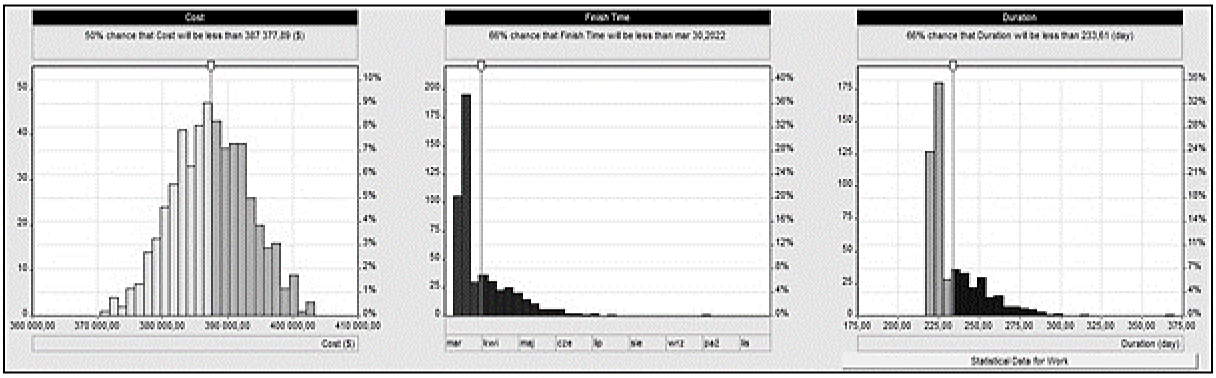

Figure 3. Project Summary – Variant I (the most probable).

Source: own study based on research results.

Variant II - 80% probability,

- the budget range was USD 392,390.75,
- the duration of the construction process was estimated at 246 days,
- the date of completion of the construction process is scheduled for no earlier than April 17, 2022.

Figure 4. Project Summary – Variant II (80% probability).

Source: own study based on research results.

Variant III - 95% probability,

- the budget range was: USD 397,403.60,
- the duration of the construction process was estimated at 268 days,
- the date of completion of the construction process is scheduled for no earlier than May 18, 2022.

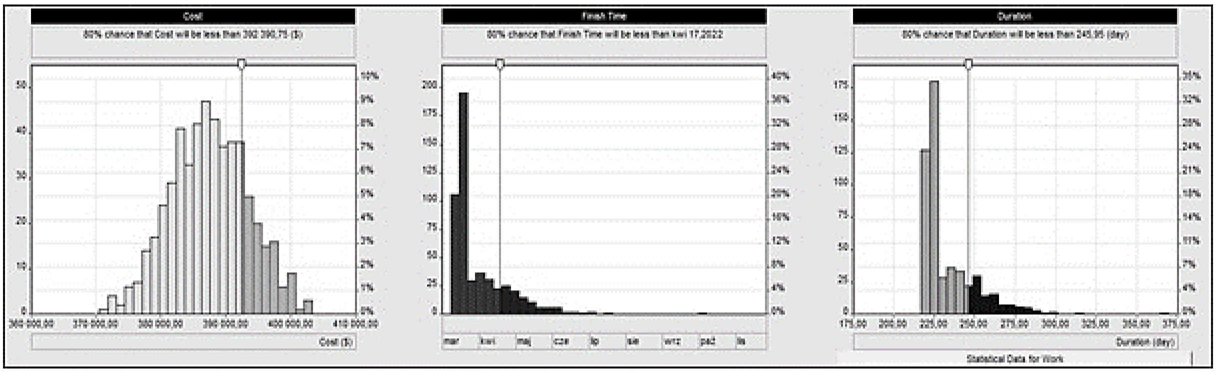

Figure 5. Project Summary – Variant III (95% probability).

Source: own study based on research results.

The most advantageous solution is the most probable variant due to the lowest costs, completion date and duration of the construction process. The project report contains information about the three most important parameters of the project, the three most crucial tasks and the three most critical risks.

5. Conclusions

The conducted analysis showed that the most important parameters of the project implementation are the total investment costs, which amounted to USD 374,877.00 without including the risks, and increased by USD 12,587.00 and amounted to USD 387,464.00 with the risks taken into account. Another important parameter is the time of completion of the investment, which in the case of not including the risks provides for the completion of works on March 13, 2022, while with the risks taken into account, the process was extended by 13 days and its completion date is scheduled for March 26, 2022.

The most common risk factors threatening and delaying the date of implementation of the investment project turned out to be:

- the risk of equipment failure, the probability of which was 82% and occurred in 6 activities out of 8,
- the risk of employee absenteeism, the probability of which was 88% and occurred in all 8 activities,

- risk of negative impact on the natural environment, the probability of which was 43% and occurred in 7 out of 8 activities,
- the risk of adverse weather conditions, the probability of which was 33% and occurred in all 8 activities,
- the risk of not maintaining standards, the probability of which was 30% and occurred in all 8 activities,
- the risk of insufficient qualifications of employees, the probability of which was 23% and occurred in 4 out of 8 activities,
- the risk of poor management of material resources, the probability of which was 12% and occurred in 4 out of 8 activities.

The key process of building the logistics centre turned out to be the foundation works and assembly of structural elements, due to their complexity, demanding scope of work (labour-intensive), high costs and time-consuming.

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 (Carr, Tah, 2001), ICRAM: Model for International Construction Risk Assessment (Hastak, Wstrząśnięty, 2000), MOCRA: Method of Construction Risk Assessment (Połoński, 2013) and tools: Pertmaster (Połoński, Bogusz, 2005), Microsoft Project (Marmel, 2011), Primavera Project Planner (Zima, 2003), Statistica Neural Network (Hilbe, 2007). The possibilities of using the above-mentioned methods and tools will be presented in the following articles by the authors.

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