

Article

A Method of Optimizing a Set of Programs for Mitigating Threats Related to the Undertaking of a Contract for the Execution of Construction Works

Katarzyna Budek-Wiśniewska *  and Roman Marcinkowski 

Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology,
09-400 Plock, Poland; Roman.Marcinkowski@pw.edu.pl

* Correspondence: kasia.budek@op.pl



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Abstract: This article deals with the problem of limiting the risk of taking up a construction contract for the execution of construction works. The authors have developed an advisory system that will support the analysis of threats on the basis of existing experiences for a specific activity without having to construct an individualized organizational model of an investment. In order to identify a relatively complete set of threats that occur in investment and construction processes in road construction investments, as well as to identify possible programs of their reduction, a model and a method of optimizing programs for reducing risks related to contracts was developed. Threats are considered to be possible events that take place during the preparation, implementation and settlement of any contract. The programs concern specific actions that can be taken in relation to specific threats. Every program contains a set of threats that will be limited as a result of its execution and also has a specific implementation cost. The aim of the proposed optimization is to determine, with regard to costs, a combination of risk reduction programs that is appropriate for the risk states that are accepted by a decision maker. The problem is solved using graph theory and a minimum cover determination algorithm with the use of the minimum alternative formula (*mfa*) of the Boolean function. A method of actively responding to identified threats during the implementation of a construction contract should take the form of an advisory system that will provide an answer as to what risks should be taken into account when undertaking a contract, as well as what actions can be taken to reduce these risks.

Keywords: risk; construction process; construction contracts; optimization; risk reduction

1. Introduction

Any deliberate activity is associated with a risk of its failure, which results from various types of threats that are not fully discovered (identified) in the course of preparing a targeted activity. Risk is considered with regard to the aim of an action, a plan and a decision to act.

During the implementation of construction projects, risk originates from conditions that are not fully discovered for the execution of works, changes in the environment (physical and organizational), the unreliability of contractors, random events and human mistakes, among other factors. It can generally be said that risk is a derivative of threats, which in turn have their own sources [1]. Some equate the concept of risk with the concept of a threat, which is not always the case [2,3]. Risk should be related to a decision or the purpose of an activity and in the construction industry to, for example, a construction contract.

The problems associated with risk in a construction project should be considered from the point of view of the stakeholders with whom the risk of its course is related [4]. An investor, as well as contractors, participates in the implementation of any construction project. Each of them can and should not only analyze the risk of their own actions but

also undertake initiatives in order to reduce this risk [5]. This is performed by transferring the responsibility for disruptions to other entities or by taking additional measures. An investor will most often try to transfer risk to other participants in the investment and construction process. Contractors can either accept this risk, take measures to prevent the occurrence of threats or transfer responsibility for the disruptions to other cooperating entities [6].

A decision of a contractor of construction works regarding participation in the procurement procedure for the performance of a specific scope of works is always associated with many risks [7]. At the time of making a decision, the contractor never has a complete set of information and therefore uses data received from the ordering party or data that is known from a historical analysis when preparing an offer. This results in the need to forecast the effects and future results of current decisions, as well as to identify the threats and methods for counteracting them [8]. Despite the careful preparation of offers, risk cannot be avoided.

The problem discussed in this paper is the method of determining the possibility of limiting the threats for a potential contractor for construction works, which should in turn lead to a reduction in the risk of implementing a construction contract. This risk is mainly related to the costs of completing the contract and, in particular, the risk of completing the contract on a budget. A construction contractor, when considering his decision to submit an offer for the performance of a contract, may take specific actions to reduce this risk by eliminating possible threats [9]. These activities may involve conducting additional monitoring, supervision and control; securing a financial or time reserve for the execution of the contract; and transferring responsibility for disturbances to other contractors (e.g., the insurer), among other activities. These activities are defined in this article as risk mitigation programs when executing a contract. They generate additional costs for the contractor, which the contractor then wants to minimize. Threat mitigation programs (actions) include the ability to eliminate various threats. A given threat can be eliminated in various programs. The problem of selecting a set of risk mitigation programs involves the optimization of decisions. The idea is to establish a set of programs that are sufficient to eliminate threats (sets of significant threats) at the lowest possible cost [10–12].

This study is a dynamic approach to the problem of the risk of undertaking a contract and determines the possibility of influencing contractual conditions in order to reduce the risk to an acceptable level.

Modern methods of risk management require an individual approach to risk identification, analysis and treatment. A construction contractor does not have enough information or the time to conduct such studies. Despite the widespread computerization of planning and business activities, risk management in construction activities does not have dedicated computer applications. The reason for this is due to the individual approach to the issue, which requires the definition of an organizational model that is appropriate for the task [13].

The authors have developed an advisory system that supports the analysis of threats on the basis of existing experiences from a specific activity without having to construct an individualized organizational model of an investment. Significant new elements when considering such a problem include the method of analyzing threats, assessing the risk of a contract and determining the possibilities of reducing risk.

2. The Problem of Risk Management

Problems related to risk management in various types of activities are the subject of many publications. There are different definitions, classifications and assessment methods, as well as different ways of dealing with risk. In the classical approach, Marcinek [14] defines risk by its measure. The measure of the risk for all the identified levels of the considered categories is estimated by the probability of their occurrence, which is assessed based on historical data or simulations. The author highlights the fact that in the analysis and assessment of risk in investment projects and other undertakings, the probability is usually not objective.

The process of risk management usually begins with specifying possible risky events and their sources, and this is followed by their classification and ordering with regard to various reasons [15–17]. Risk assessment includes the determination of two factors: the probability of the occurrence of a threat and its impact on the implementation of an investment [18]. Therefore, it focuses on identifying the risk factors that require a response (the elimination of existing threats or the minimization of their effects) in order to limit (directly or indirectly) their impact on an investment [18]. In most cases, risk cannot be completely eliminated, but it can be reduced to an acceptable level. A low level of risk is generally acceptable but requires continuous monitoring. However, other risks should be included in the management plan [19]. The consequence of the risk management process is the constant process of monitoring, prevention and control. It is a planned supervision over the implementation of the entire project and also the monitoring of risk.

This approach is described in the literature using various organizational techniques. However, it is not possible to create an advisory system based on these techniques. Planners have to consider each project individually, create risk matrices, predict ways of proceeding and accept uncertainty in some aspects of operation.

Śladowski [20] proposed a different approach to planning an investment project which takes risk into account. The author presented a systemic and proactive approach for the risk assessment of construction projects. Within this approach, it is proposed to test the resistance of the considered contract to risk factors that are modeled using the meta-network of the project. In this concept, the developed model of the organizational system of the project is exposed to defined risk factors. Simulated random materialization of these factors causes structural changes in the meta-network of the system. The analysis of the susceptibility to risk factors of the modeled project in the method proposed by Śladowski comes down to the assessment of the resulting structural changes in the model and also the efficiency of the meta-network caused by these changes.

In turn, the analysis of the adaptability of a modeled investment is related to the assessment of possible additional costs that must be incurred and also the time that must pass before the model regains its equilibrium. The measure of the system's resistance can be seen to involve deviations from the time and costs of implementing the modeled investment from the values assumed in the baseline plan, which do not take into account the impact of the defined risk factors. The author proposes a simulation (imitation) experiment and an algorithm of assessing the impact of risk on a modeled construction investment [11] for the analysis of susceptibility to risk factors and the adaptability of the investment. He also proposes a proactive approach, which is based on increasing the resistance of a project to risk factors. This leads to the development of the most advantageous planning variant of the considered project, which is characterized by the highest resistance to risk factors.

This approach, preceded by the concepts of Zhu and Mostafavi [21–23], has one quite significant drawback: it requires the construction of an individualized organizational model of an investment. Therefore, each construction project must be modeled with regard to the plan of the main and alternative actions, while at the same time determining the data for simulation and the strategies for increasing the resistance of the planned project [24].

The elimination of threats in order to achieve goals of construction projects is a key problem in risk management [16]. However, it would be worth developing such an advisory system that would support the analysis of threats on the basis of existing experience from a specific activity. It is possible to establish a set of threats which will then be considered as a base of knowledge for planning. When planning, this set can be modified in order to take specific remedial measures. According to the authors' proposals, these measures are threat reduction programs.

3. Risk and Threats

The authors assume that threats constitute the basis for the analysis of reducing the risk of undertaking a construction contract by a potential contractor. Threats in the construction industry are of a technical, organizational, economic and legal nature and can

be analyzed with regard to the macro and micro environment as well as the construction project itself [25]. Therefore, when assessing risk, factors that are specific for a given investment should be taken into account. Even if, statistically speaking, they occur sporadically, they may still be of key importance for a given project [26].

In the construction industry, there are three basic types of risks related to an investment: risk related to costs, which refers to an unexpected increase in the cost of the implementation of an investment; risk related to time, which is associated with an unforeseen extension in the completion time of an investment; and risk related to the quality of execution, which refers to the implementation of an investment that is not in line with the investor's expectations regarding quality [27]. The authors analyze four types of risk: cost, time, quality of workmanship (meeting quality requirements) and the loss of financial liquidity by a potential contractor when making a decision whether to participate in the procurement procedure for a specific scope of works. Each risk is influenced by many threats. The model of the problem proposed by the authors assumes, unlike most of the models from the literature, that at the stage of planning a contract (and also its implementation), potential threats may occur independently (spontaneously) and may also be partially dependent on each other (i.e., one threat may be the source of the occurrence of the subsequent one). This is illustrated well by so-called threat maps (an example of threat map is shown in Figure 1). These maps identify threats, the elimination of which through risk mitigation programs reduces the risk for contractors. The problem of risk map analysis will be solved using a computer application that is equipped with a complete knowledge base about possible threats in specific construction activities.

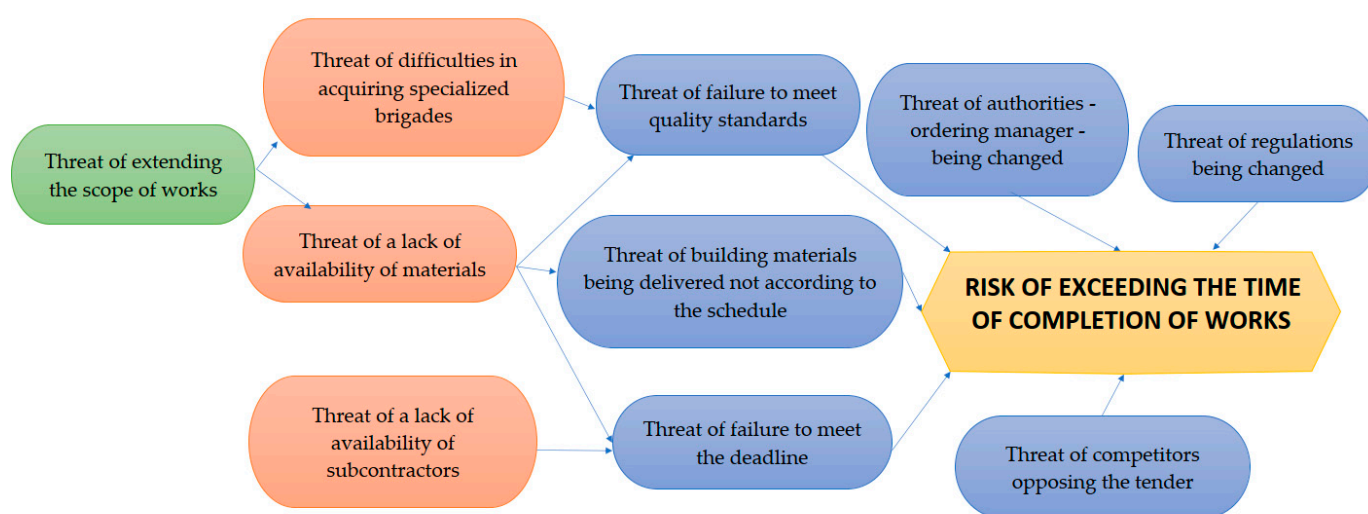


Figure 1. Map of threats that affect the risk of exceeding the time of completing works. Source: own elaboration.

4. Optimizing a Set of Programs for Mitigating Threats

In order to identify the possibility of limiting risk when bidding for a contract for construction works, the methods of limiting threats as well as the types of risk in the process of implementing the construction contract are determined. Threats are identified as possible events in the preparation, implementation and settlement of a contract, in the case of selecting a submitted offer by the contracting authority.

Risk reduction programs should be defined on a set of threat elements (set T). Let us assume that they form a set $R = \{r_j : j = 1, 2, \dots, m\}$ (reduction). The programs relate to specific actions that can be undertaken in order to eliminate identified threats. Each program establishes a set of threats that will be limited as a result of its execution and has a specific implementation cost $C = \{c_j : j = 1, 2, \dots, m\}$ (cost). The essence of the problem is to determine the optimal sets of programs for mitigating threats in the defined cross-sections of the T set.

The model of the problem is as follows. For each set $T_0 \subset T$, which constitutes a cross-section of set T , sets of programs $R_w \subset R$ that are sufficient to cover set T_0 with their impact should be determined. A set of programs that meets the criterion of minimizing the sum of the costs of the R_w programs should also be specified. The criterion is defined as follows:

$$R_{opt} = R^* : C(R^*) = \min_{R_w \subset \varphi} C(R_w),$$

$$\varphi = \{R_w : R_w \subset R, w = 1, 2, \dots, z\} \quad z = \sum_{k=1}^r \frac{r!}{(r-k)!}; \quad r = |R|, \quad (1)$$

where R_w is a set of combinations of programs that are sufficient to cover set T_0 with their impact and $C(R_w)$ is the cost of the R_w programs.

The algorithm for determining the minimum coverages in the directed graph, which is formed from threats and their mitigation programs, is used to solve the problem. The algorithm is as follows.

The presentation of the structure of the system with the use of a directed graph is expressed as

$$G = \langle X, \Gamma \rangle \quad (2)$$

where $X = T_0 \cup R$ is a set of vertices, namely the elements of the system $T_0 = \{t_1, t_2, \dots, t_n\}$ and verification programs $R = \{r_j : j = 1, 2, \dots, m\}$ and Γ is a set of relations (arcs), a function defined on the set of vertices X , the values of which are the appropriate subsets of $x(r_j)$ of the successors of vertex r_j .

The expression of the graph in the form of a vertex adjacency matrix is

$$\text{matrix } B = B = [b_{i,j}]_{n \times m} \quad b_{i,j} = \begin{cases} 1 & \text{— when } t_i \in \Gamma[x(r_j)] \\ 0 & \text{— otherwise} \end{cases} \quad (3)$$

These elements are treated as Boolean constants of the two-element Boolean algebra:

Using the algorithm for determining the minimum coverages, which are known from the theory of graphs and networks:

- a. Assign Boolean variable w_j to each subset $x(r_j)$;
- b. Create an alternative conjunctive expression:

$$\prod_{i=1}^n \sum_{j=1}^r b_{i,j} \cdot r_j \quad (4)$$

- c. Convert this expression to the form of an irreducible Boolean sum (*mfa*):

$$\sum_{s=1}^S r_{j(1),s} \wedge r_{j(2),s} \wedge \dots \wedge r_{j(L),s} \quad (5)$$

The components of the irreducible Boolean sum determine the combinations of threat mitigation programs R_w , which cover all the elements of the tested system. The assessment of the costs of these combinations of programs enables the optimal set R_{opt} to be determined.

Using the presented algorithm, combinations of programs for mitigating risk which are sufficient to eliminate the T_0 set are determined. The algorithm for determining the minimum coverages in the graph requires the use of Boolean algebra which, without appropriate software, is quite burdensome. A computer program developed by the authors which transforms the alternative conjunction expression to the form of an irreducible Boolean sum (*mfa*) significantly improves this type of analysis. The authors are able to provide a detailed algorithm to transform an alternative conjunction expression into the form of an irreducible logical sum (*mfa*); that is, an algorithm of the program that determines the minimum combinations of risk mitigation programs that cover defined sets of threats is created.

5. Example

5.1. Data for Analysis

In order to illustrate the presented approach, a simple example of the practical use of the method of optimizing threat mitigation programs is provided below.

The characteristics of the considered public procurement notice for the performance of construction works are as follows.

The construction investment was the extension of a bridge with access roads, with the construction located in a commune town.

The completion date was after 20 weeks in July–November during the summer and autumn period.

The scope of the works was the execution, approval and implementation of the project of organizing traffic during the construction and demolition of the existing bridge and the construction of a new one with a steel structure made of plate girders; the construction of a rainwater drainage system with a length of 1200 m; and the construction of a bypass in order to avoid a collision with the teletechnical network. The scope of the road works included the rebuilding of the road section with a length of 1 km; the demolition of the existing road surface and pavement; the construction of a new road surface (9000 m²), which involved the construction of a bed, an anti-frost layer and a mechanically stabilized crushed aggregate foundation, as well as the laying of a bituminous surface (the binding and wearing layer); the construction of pavement (4500 m²); the construction of a parking area (600 m²) from stone cubes; and the execution of vertical and horizontal markings.

In the presented (analyzed) situation, a relatively complete set of threats and risks was identified. This set was determined on the basis of observations, the analysis of procedures, documentation of the descriptions of the subject of the contract, documentation of already completed contracts, the professional experience of the authors and conversations with experienced people performing technical functions during the implementation of contracts in the road industry. Knowledge was also obtained from experts by conducting a survey. The mitigation programs for this construction work are specified in Tables 1 and 2.

Table 1. Threats identified in the examined contract. Source: own elaboration.

Threat Symbol	Description of Threats
t ₁	Threat of failure to meet quality standards: due to the fact that the deadline is short with regard to the scope of work to be done, the implementation will be rushed.
t ₂	Threat of extending the scope of the work: the geological documentation shows that due to the fact that there may be organic soils in the substrate, it may be necessary to replace the soil.
t ₃	Threat of reducing the scope of the work: a “quantity survey contract” where, on the basis of the design documentation, it turns out that the bill of quantities is overestimated.
t ₄	Threat of a lack of availability of subcontractors: a large range of industry and specialist works, a short deadline of work and the tender announced in the middle of the year when some companies already have a full portfolio of orders.
t ₅	Threat of failure to meet the contractual deadline: a large scope of work.
t ₆	Threat of difficulties in acquiring specialized workers: a large scope of industry and specialist works, a short deadline of works and the tender announced in the middle of the year when some companies already have a full portfolio of orders.
t ₇	Threat of inexperienced and unreliable subcontractors.
t ₈	Threat of exceeding the planned costs due to deadlines: due to the short implementation time, it will be necessary to hire additional contractors.
t ₉	Threat of exceeding the planned costs due to weather conditions: the task is carried out in unsuitable weather conditions, and there are additional costs in order to maintain quality.

Table 1. Cont.

Threat Symbol	Description of Threats
t_{10}	Threat of availability of materials at a given time: short completion time (e.g., a bridge is meant to be built, and the waiting time for the designed load-bearing structure is longer than the time for the completion of the contract).
t_{11}	Threat of investor's preferences being unfavorable for the project: (e.g., when calculating an order, an alternative solution is assumed) replacement of the bridge structure with one that is available faster.
t_{12}	Threat related to the investor's decision making: (e.g., the structure of the bridge is planned to be changed) there is a risk of delays in making decisions by the investor.
t_{13}	Threat of incurring costs too high for the purchase of materials and structures (e.g., the bridge structure is planned to be exchanged from plate girder beams to rolled beams, which are 40% cheaper and available faster).
t_{14}	Threat to the timely delivery of building materials: we need a bridge structure, and the schedule does not have enough time for possible delays.

Table 2. Risk mitigation programs and their costs for the examined contract. Source: own elaboration.

Risk Mitigation Programs		
Symbol	Description	Cost
r_1	Increasing the employment of "own employees" and conducting appropriate training.	$c_1 = 200,000$
r_2	Conducting on-site supervision.	$c_2 = 2500$
r_3	Carrying out geological surveys.	$c_3 = 5000$
r_4	Finding subcontractors and suppliers at the tender stage.	$c_4 = 10,000$
r_5	Detailed analysis of the project and the verification of the bill of quantities.	$c_5 = 4000$
r_6	Applying (at the tender stage) for making an appropriate provision in the contract in order to regulate the possibility of extending the time needed to perform the task without charging the contractor financial penalties.	$c_6 = 0$
r_7	Adding contractual penalties to the offer price for failure to meet the completion deadline.	$c_7 = 170,000$
r_8	Obtaining a structure supplier and guaranteeing delivery on time at the tender stage.	$c_8 = 25,000$
r_9	Acceptance of calculation provisions for performance difficulties (e.g., in the event of disagreement with the change in construction).	$c_9 = 110,000$
r_{10}	Replacement designs (e.g., a question to the investor regarding whether he will allow a change in the structure).	$c_{10} = 20,000$
r_{11}	Acceptance of calculation provisions for the increase in material purchase costs.	$c_{11} = 30,000$

In the advisory system being developed, the sets of threats and their mitigation programs constitute knowledge bases. These databases are created on the basis of the analysis of several dozen projects implemented by companies in a given industry. The authors are working on the development of relatively complete knowledge bases with regard to road construction. It is expected that the decision maker assisting with the computer application in question will only indicate the threats and risk mitigation programs that may occur in a given decision-making situation. Additionally, the decision maker should identify the costs of implementing risk mitigation programs. It is not expected that the application will assist the decision maker in determining these costs. The costs of a given risk mitigation program may be different in each construction contract situation. It depends on the type and scope of the project, the company's capabilities and the conditions in which the contract will be carried out. The decision maker, by defining the programs and their costs, will be able to ensure that the risk mitigation analysis is tailored to their own needs and capabilities.

5.2. Application of the Algorithm

The considered issue can be presented in the form of the following task.

DATA: For a specific set of threats $T_0 = \{t_1, t_2, t_3, \dots, t_8\}$ (Table 1), seven programs of their limitations were defined as $R_w = \{r_1, r_2, r_3, \dots, r_7\}$ (Table 2). The cost was specified for each program as $c = \{c_1, c_2, c_3, \dots, c_7\}$ (Table 2). The matrix that identifies the risk mitigation possibilities in individual programs is presented in Table 3.

Table 3. Model of threat mitigation programs in the examined contract. Source: own elaboration.

Threat Mitigation Programs and Their Costs		Threats and the Binary Matrix B of the Impact of the Programs on These Threats													
R	C	t ₁	t ₂	t ₃	t ₄	t ₅	t ₆	t ₇	t ₈	t ₉	t ₁₀	t ₁₁	t ₁₂	t ₁₃	t ₁₄
r ₁	c ₁	1	0	0	1	1	1	1	0	0	0	0	0	0	0
r ₂	c ₂	0	1	1	0	0	0	0	0	0	0	0	0	0	0
r ₃	c ₃	0	1	0	0	0	0	0	0	0	0	0	0	0	0
r ₄	c ₄	1	0	0	1	0	1	1	1	0	1	0	0	0	1
r ₅	c ₅	0	1	1	0	0	0	0	0	0	0	0	0	0	0
r ₆	c ₆	1	0	0	0	1	0	0	1	0	0	0	0	0	0
r ₇	c ₇	0	0	0	0	1	0	0	0	0	0	0	1	0	1
r ₈	c ₈	0	0	0	0	0	0	0	0	0	1	0	0	0	1
r ₉	c ₉	0	0	0	0	0	0	0	0	0	0	0	0	1	0
r ₁₀	c ₁₀	0	0	0	0	0	0	0	0	0	1	1	1	1	0
r ₁₁	c ₁₁	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Using the presented algorithm for determining the minimum coverages in the graph (used in a computer application), the least numerous combinations of the risk mitigation programs, which were sufficient to limit all the threats (elements of the tested T_0 set), were determined. These were the following combinations: r_1, r_2, r_4, r_{10} and r_{11} ; r_2, r_4, r_6, r_{10} and r_{11} ; or r_4, r_5, r_7, r_{10} and r_{11} . The final selection of the programs that could be used in a given contract took place after analyzing the costs of the combinations of the programs, which are identified in Table 4.

Table 4. Assessment of the costs of the combinations of the risk mitigation programs in the evaluated contract. Source: own elaboration.

R_w	Threat Mitigation Programs	Cost c_w	Total Cost
r ₁	Increasing the employment of “own employees” and conducting appropriate training.	$c_1 = 200,000$	$c_1 + c_2 + c_4 + c_{10} + c_{11} = 262,500$
r ₂	Conducting on-site supervision.	$c_2 = 2500$	
r ₄	Finding subcontractors and suppliers at the tender stage.	$c_4 = 10,000$	
r ₁₀	Replacement designs (e.g., a question to the investor regarding whether he or she will allow a change in the structure).	$c_{10} = 20,000$	
r ₁₁	Acceptance of calculation provisions for the increase in material purchase costs.	$c_{11} = 30,000$	

Table 4. Cont.

R_w	Threat Mitigation Programs	Cost c_w	Total Cost
r_2	Conducting on-site supervision.	$c_2 = 2500$	$c_2 + c_4 + c_6 + c_{10} + c_{11} = 62,500$
r_4	Finding subcontractors and suppliers at the tender stage.	$c_4 = 10,000$	
r_6	Applying (at the tender stage) for making an appropriate provision in the contract in order to regulate the possibility of extending the time needed to perform the task without charging the contractor financial penalties.	$c_6 = 0$	
r_{10}	Replacement designs (e.g., a question to the investor regarding whether he will allow a change in the structure).	$c_{10} = 20,000$	$c_4 + c_5 + c_7 + c_{10} + c_{11} = 214,000$
r_{11}	Acceptance of calculation provisions for the increase in material purchase costs.	$c_{11} = 30,000$	
r_4	Finding subcontractors and suppliers at the tender stage.	$c_4 = 10,000$	
r_5	Detailed analysis of the project and the verification of the bill of quantities.	$c_5 = 4000$	
r_7	Adding contractual penalties to the offer price for failure to meet the completion deadline.	$c_7 = 170,000$	
r_{10}	Replacement designs (e.g., a question to the investor regarding whether he or she will allow a change in the structure).	$c_{10} = 20,000$	$c_4 + c_5 + c_7 + c_{10} + c_{11} = 214,000$
r_{11}	Acceptance of calculation provisions for the increase in material purchase costs.	$c_{11} = 30,000$	

5.3. Conclusions

A contractor should know all the possibilities of mitigating the contract's risk and not only the optimal set. The costs of the combinations of threat mitigation programs may not always be a determinant for proceedings when concluding a contract for construction works. A computer program that converts an alternative conjunction expression into an irreducible Boolean sum allows for the least amount of combinations of the risk mitigation programs that will reduce all threats to be determined. When the threats, as well as the combinations of their reduction programs and their costs, have been identified, we can decide whether it is worth undertaking the contract.

6. Summary

Building is a particularly complex and many-sided production activity. In addition to the technical dimensions (construction and technology), there are many issues related to the organization and management of a construction site and these are of an individual nature. In construction management, we deal with varied terrain conditions, the impact of weather, changing market conditions, new design solutions and a multitude of cooperating partners, among other factors. Therefore, despite the very dynamic development of knowledge and digitization, there is still a shortage of computer-aided management processes regarding this type of production activity. We believe that the reason for this is that some tools are not adapted to the needs of construction managers. This is also the case with risk management in construction activities.

The failure mode and effect analysis (FMEA) method is commonly used to manage risk in construction [28]. In 2010, this method was identified as a promising risk assessment tool in civil engineering [29]. The method undoubtedly has many advantages (e.g., simplicity, pragmatism, synopticism, openness and flexibility) which enable many investment projects to be successfully carried out. However, this method is for the investor, who has the time and possibility to identify threats regarding the implementation of an investment. He or she can also take appropriate remedial measures to ensure the achievement of the assumed effects. The method has no advisory base (i.e., threats are not identified in advance, and

there are no programs to mitigate them), and it is therefore a specific methodology for risk management. There is also no assigned reference for the type of activity.

The model and method of analysis presented in the article are part of the research and creative work regarding a computer advisory system for entrepreneurs who need to make decisions about the performance of contracts for construction works. Entrepreneurs have to assess the risk of taking an order in a very limited time (i.e., they need to identify risks and the possibilities to reduce them). This task can only be met with the use of computer analytical tools equipped with knowledge bases from a given construction industry. Such tools should generate (i.e., suggest) possible solutions in a situation defined by the decision maker, which here is the possible impact on identified threats. The authors are currently creating such a system for road construction companies. The structure of such a system is schematically presented in Figure 2.

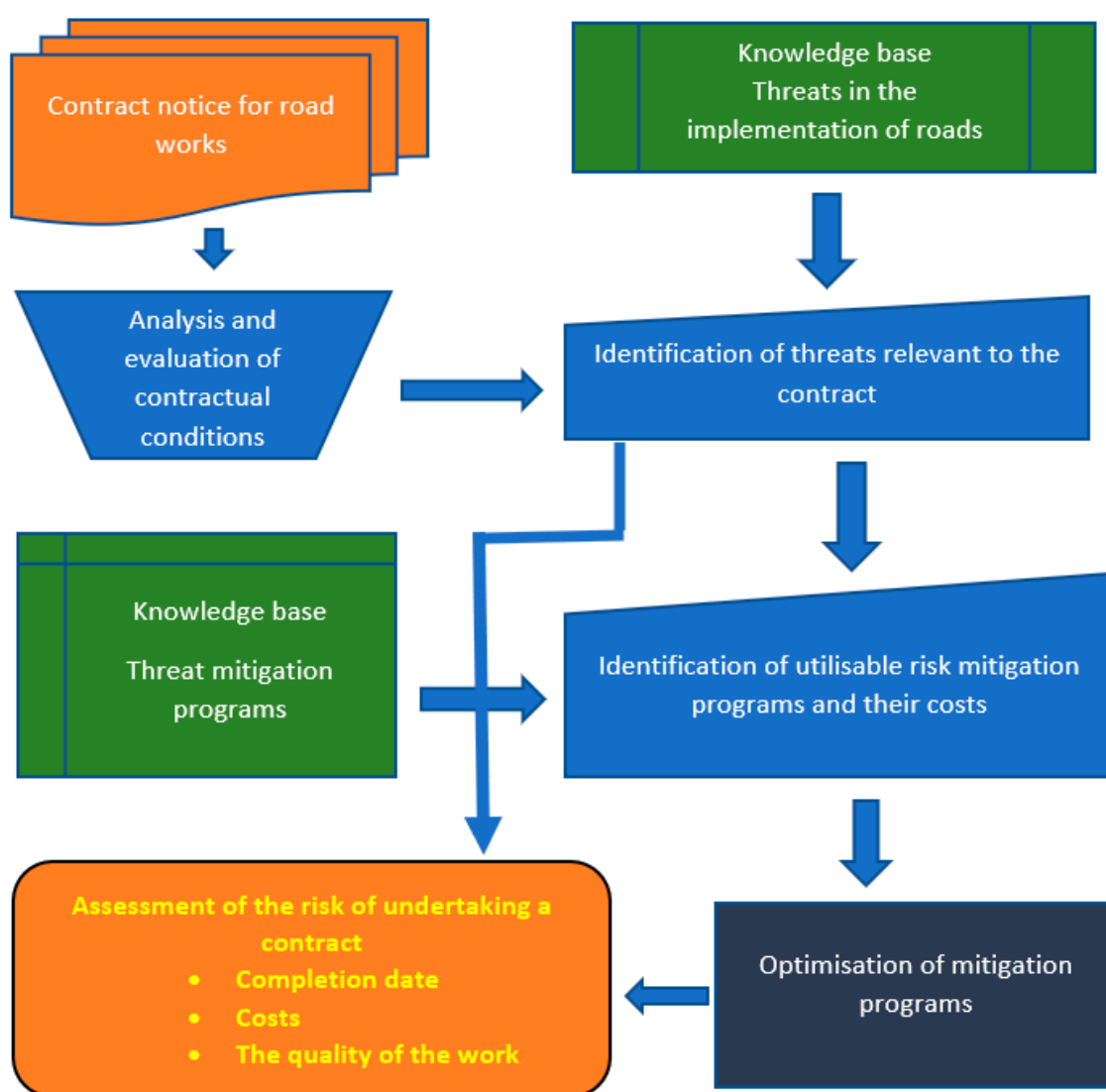


Figure 2. Schematic diagram of the structure of the advisory system for assessing risk related to the implementation of a construction contract. Source: own elaboration.

The authors aim to develop a computer program that will be useful in various road construction projects (with a different scope of works and different terms for executing the contract). Contractors need analytical tools that allow them to assess the risk of taking an order and to make an offer for the performance of the work. The development of such a tool requires extensive research and analysis, as well as the development of reasonable

decision-making procedures with elements of decision optimization, which the authors are currently working on. That is why this research aimed to identify the causes of losses incurred by contractors in particular types of activity. The analyses will be used to prioritize and evaluate various types of threats and risks when making decisions to undertake a contract. Decision-making procedures should focus on indicating possible and necessary influences on the contract and implementation process in order to ensure the performance of the contract with the assumed profit. The main point of this is for the construction contractor to be able to assess the risk of taking a contract and also be able to define a set of necessary procedures (e.g., operational, financial and contractual) in order to reduce this risk to an acceptable level. A construction contractor should be able to assess the risk of taking a contract and then define a set of necessary procedures (e.g., operational, financial and contractual) to reduce this risk to an acceptable level.

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