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Research paper

Development of emergency schedules in renovations of building structures

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Abstract: Construction projects are characterized by high complexity of the tasks performed. They are planned over a long period of time and are often very technologically complex. All these factors cause various types of disruptions to the construction process very often occur during the construction of buildings. In the theory and practice of construction management, the possibility of such disruptions is called risk factors. Due to the fact that they have a significant impact on the preservation of two basic characteristics of construction, i.e. the time and cost of building the facility, they are subject to intensive research. In other words, the challenge for every construction project is to predict risk factors that may disrupt the construction process. Moreover, their specification and quantification, which allows us to estimate the possible impact of disruptions to the construction process on its time and cost. Various risk analysis methods are used for this purpose. The authors of the article propose the use of emergency schedules. Schedules of this type have great utilitarian advantages. That is, they enable illustrating the quantified impact of risk factors on individual tasks and the entire construction project. The material describes the idea of this type of schedules. An example of developing this type of schedule is also given, based on the example of the renovation of a building structures.

Keywords: construction, risk analysis, emergency schedules

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1. Introduction

Material and financial schedules are one of the basic documents necessary to apply for a construction investment. If the construction company wins the tender, such a schedule contains binding arrangements between the investor and the contractor. Therefore, a very reliable approach seems necessary when preparing data for the material and financial schedule [1–5]. Legal and administrative requirements force the contractor to develop a deterministic schedule, i.e. one in which the times and costs of implementing individual tasks are precisely defined. As is commonly known, the future is always probabilistic, so planning is always subject to error. The size of this error depends on the planner's experience and ability to identify potential risk factors that may cause disruptions to the construction process. The disadvantage of probabilistic areas is the probable values. They reflect reality well, but do not meet formal and legal requirements. A possible solution to this problem are contingency schedules, which to some extent enable the transition from probabilistic analyzes to deterministic values. This type of schedules can be used to vary the planning of construction processes due to the possibility of various types of risk factors. Their main advantage is the simple transfer of the effects of disruptions in the implementation of a construction project to the time and cost of individual tasks. Analysis and examples the use of this type of schedules is the main content of the article

2. The idea of developing emergency schedules

Emergency schedules can be a very good tool for managing the risk of a construction project. It is assumed that anticipation of what may happen, combined with prior allocation of resources, personnel, equipment, and tasks, maximizes the chances of an effective response in the event of disruptions [6–11]. However, even the best contingency planning does not fully protect a construction investment against risk factors. However, it offers a chance to significantly reduce the effects of disruptions. So what is needed to develop reliable contingency schedules? Certainly selected, trained staff aware of the impact of negative events on the construction of the building. Designated staff should be equipped with appropriate IT tools to perform this type of analysis. The spectrum of methods and tools is very wide and ranges from very simple to more complex and professional. However, the success of the analyzes and the accuracy of the resulting forecasts depend primarily on the analysts' experience and skillful creation of the database. The database should contain information on completed construction projects. This information should concern the conditions for the implementation of construction works, their technologies, as well as the specification of risk factors. The risk factor should be identified and quantified. The accuracy of future forecasts will depend on the reliability of their description [12–21]. For utilitarian reasons, the forecasts developed may be presented in the form of emergency schedules.

3. An example of the use of emergency schedule in renovations of building

This issue focuses on presenting an example of the use of an emergency schedule in construction practice. The emergency schedule was developed based on the renovation of the tenement house. A detailed description of the construction project being implemented is provided in the next subchapter.

3.1. Description of the construction investmen

The investment project involves the renovation and reconstruction of a building based on the standard of a 4-stars hotel category, along with accompanying infrastructure, located in the city center. The building has five above-ground floors plus an attic. The building has a full basement. The building is made in traditional masonry technology, with a load-bearing wall system and stabilizing transverse walls.

The building's basic parameters are approximately 23 m high, which classifies it as a medium-rise building (SW). Moreover, the building has external dimensions of approx. 60 m × 20 m, a number of 7 floors (including 6 above ground and 1 underground), which gives a total area of approx. 5,500 m^2. As a result of the reconstruction, the hotel will be equipped with 72 room units (58 double rooms, including 1 room for disabled people and 14 single rooms) capable of accommodating 130 hotel guests. The hotel building that is the subject of the investment was built as a result of adapting and merging four neighboring tenement houses.

The scope of renovation and reconstruction includes all interior spaces of the building's floors, along with the basement and attic, as well as staircases. Additionally, the investment includes the modernization of the adjacent undeveloped land and its lighting. In terms of the facade and architecture of the building, work is planned in the form of a complete replacement and restoration of the window joinery, which has historic features, on the entire building in accordance with conservation recommendations. Wooden windows are planned to be made while preserving the pattern, dimensions, and profiles as in the original, assuming compliance with the applicable thermal parameters. There is also a plan to modernize the facade of the ground floor along with modifying (enlarging) the window openings in the restaurant and conference room. Renovation of entrance canopies along with lighting elements is also to be carried out. It is assumed to maintain the basic functions of the building, especially in the zone of the room units floors. In terms of basements, ground floor, and attic, changes are planned concerning the location and change of the function of the rooms.

As part of the implementation of the construction project, it is planned in particular: the creation of new door openings, widening existing door openings, making individual and collective breakthroughs in load-bearing walls intended for the installation of systems, making individual and collective breakthroughs in existing ceilings for system installation, walling up existing openings, local deepening of basement floors, protecting walls against moisture along with the restoration of waterproof (damp-proof) insulation, strengthening of existing damaged vaults, replacement or strengthening of existing wooden ceilings, and protection of existing cast iron columns.

In the basement level, due to the high groundwater level and neglect in the execution of waterproofing during the previous renovation, the condition of the basements has deteriorated, necessitating the replacement of the floors. As part of the reconstruction and renovation of the building, it is also planned to perform sealed insulation of floors and insulation of external walls. Horizontal damp-proof barriers are planned on all external and internal walls. In part of the building, it will be possible to excavate the walls and perform external insulation (Fig. 1).

Fig. 1. Demolition works related to the chipping off of plasters

The poor condition of the basements obliges the design of a comprehensive waterproofing system. The implementation of this scope of work should ensure the cutting off of groundwater from the interior side of the building as well as thorough drying, desalination, and interior mold removal. Solutions have been planned for the entirety of the basement rooms, including those located outside the outline of the building. After removing all partition walls and linings as well as the current flooring, it is necessary to perform insulation in the form of a horizontal injection barrier for all external and internal foundation walls.

It is assumed that the flooring will be removed across the entire area of the basements and new layers will be made to ensure a sealed insulation of the floor slab (Fig. 2). To achieve the best result of the effectiveness of protecting the building against water, the injection can be carried out from both sides of the external walls.

One of the significant issues of the investment being implemented is the lowering of the floor level. Due to the necessity of adapting the rooms to meet the requirements in line with the architectural design assumptions, local reductions of the floor level have been planned. To keep up with the deadlines set in the investment implementation schedule, it is assumed that the floor slabs in the basement will be constructed using a demolition robot ARE.

Due to the complexity of the construction project, a comprehensive description is not possible. However, to illustrate the scale of challenges when renovating this type of facilities, the following sections of the article present the identification of potential risk factors. The risk

Fig. 2. Construction of a reinforced concrete floor slab and waterproof insulation of walls

factors listed are only part of the identified risk factors. Their broader analysis is presented in the next sub-issue and detailed quantification in subsequent articles. The risk assessment process includes its specification, quantification and analysis of risk reduction possibilities.

3.2. Preliminary identification of risk factors

This part of the article presents selected elements of a detailed analysis of risk factors that were identified during the investment and the risk factors that are expected to occur in the subsequent stages of the investment. The result of the preliminary risk analysis is presented in Table 1. This is a very important stage of the analysis because you cannot afford to omit key risk areas. In other words, if we omit important, potential risk factors at this stage of the analysis, the entire threat assessment may turn out to be imprecise. This, in turn, may result in an increase in the investment time or costs, or even in extreme cases, in its failure. Risk quantification is not effective unless we first identify risk factors.

Table 1. Identification of risk in renovations of building structures

Task number	Task name	Type of risk	Reason for possible delay
1	Demolition works	Technical and organizational	During the renovation of a historic hotel, the dismantling of certain elements such as plasterboard walls and floors reveals a series of improperly executed works from the past, necessitating a technical assessment of each incorrectly executed or degraded element and the execution of additional works, for instance, improperly set lintels, improperly constructed walls, cracks, lack of waterproof and fireproof protections, etc.

Continued on next page

Table 1 – *Continued from previous page*

Task number	Task name	Type of risk	Reason for possible delay
2	Waterproof insulation of basements	Technical and administrative	When excavating to lay insulation, there is a necessity for additional work, such as leveling the plane of the foundation walls, restoring parts of the foundation walls, and preparing them for laying waterproof insulation. Before starting the excavation in the pavements for waterproof insulation, it is necessary to obtain permission to occupy the strip. A traffic organization project must be prepared and approved if the occupation of the roadway affects traffic flow or reduces visibility on the road, or causes changes in the existing organization of vehicle or pedestrian traffic or information on how to secure the works.
3	Masonry works	Quality	Low quality of performed works, necessity for corrections. The most common errors causing delays are: discrepancies with the project documentation (dimensions), lack of proper bonding of masonry elements, improper connections with other structural elements, careless laying of masonry elements and mortar, lack of joint filling, deviations from verticality, use of damaged masonry elements.
8	Reinforcing structure around installation openings	Design	After dismantling part of the flooring layers, there is a need to perform additional reinforcement work not anticipated in the project documentation. Additional structural calculations and elements need to be made.
9	Canopy over the entrance – entry box	Contractual	Difficulty in contracting a professional contractor capable of dismantling the historic canopy, restoring it, and remounting it. Experience shows that such work always takes longer than planned.
12	Floorings	Organizational	Performing flooring generates the need to halt other works in the room for several days, hence the schedule of all works must be precise and should be carried out without delays.
13	Ceilings	Design	In a historic building, the necessity to "fit" all elements of electrical, ventilation, water, and fire installations generates the need to redesign and find alternative design solutions due to numerous changes in heights and the need to adapt the building to current technical and building regulations.

Continued on next page

Table 1 – *Continued from previous page*

Task number	Task name	Type of risk	Reason for possible delay
14	Plastering, cladding, wall painting	Design, technical	The necessity to perform additional work, for example, applying a leveling plaster under mineral insulating boards. In a historic building where thermal insulation is provided by mineral insulating boards made from a very light variety of cellular concrete.
15	Joinery and metalwork for openings	Administrative	In a historic building, the necessity to have the color scheme of joinery approved by a conservation inspector, which is preceded by the need to produce samples. This is often a time-consuming process.
16	Facade	Technical, design	A series of problems not considered at the project stage, e.g., the necessity to dismantle skirting boards to perform proper waterproof insulation.
17	Elevator	Contractual	Contractual difficulties in adjusting the dimensions of elevators to the dimensions of the elevator shaft.
18	Visual signage and barriers	Organizational	In the production of individual elements, the process is often extended due to technical problems of the contractor.
19	Hard surface and terrace	Organizational	The necessity to organize the construction site in such a way that it is possible to perform staging works related to land development.

Table 1 lists the tasks that may be interfered with. Disruptions may be caused by risk factors. Potential risk factors were described in detail and matched to individual tasks in the schedule. This analysis allowed for the quantification of risk factors. The quantification of risk factors was presented in the form of emergency schedules. An example of developing such schedules is presented in the next issue.

3.3. Principle of risk identification, quantification and allocation

The proprietary Method of Construction Risk Assessment (MOCRA) was used to quantify the risk. The method has been widely described in publications [22]. The idea of the method is presented in Fig. 3. The use of the MOCRA method enables detailed risk analysis, including risk identification and quantification, risk verification and risk allocation in the material and financial schedule. Detailed calculations are very extensive (they take up over 70 A4 pages), so they will be presented in subsequent publications. The partial presentation of the calculations does not make it possible to learn the algorithm of the MOCRA method. The authors refer interested readers to the above-mentioned literature, especially to the position [23] where you can read the details of the calculation process.

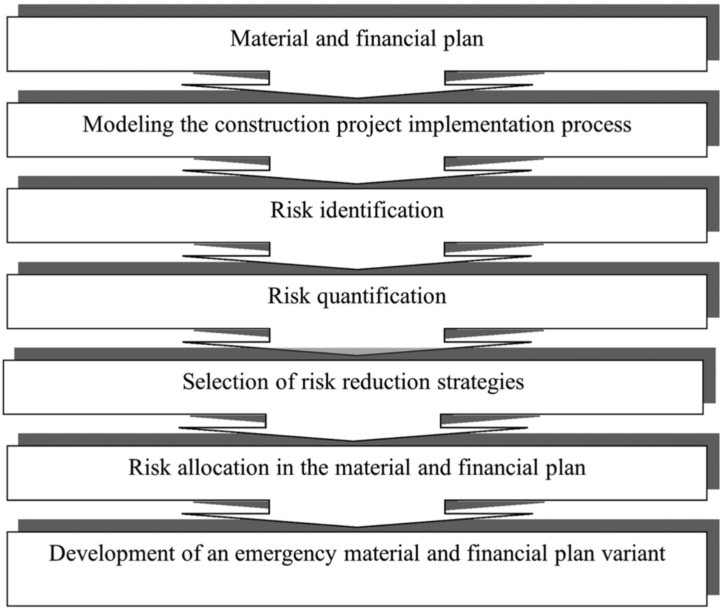

Fig. 3. Ideographic model of risk allocation – MOCRA

In the method proposed by the author, the utilitarian aspect plays an important role. The conducted research showed that the implementers of construction projects are little interested only in the percentage assessment of the risk of the project to be implemented. Construction engineers care more about the relationship of risk to the budget plan and schedule than the percentage rating. Therefore, it was decided to conduct research on the use of possible methods (or finding your own) to reliably transfer the estimated risk to the material and financial schedules of construction projects. The main purpose of such risk allocation is to enable the construction of emergency budget plans and contingency schedules (contingency plan, contingency budget). Two methods were used for the analysis: the "β Function Analysis Method" and the "Monte Carlo Method", which are effective and often used for risk analysis issues. At this stage of risk analysis, after identifying and quantifying its factors, correlations are made. Correlation involves finding interdependencies between quantified risk factors and specific operations in the construction project implementation process. There is a division into the time criterion and the cost criterion. Fig. 3 presents an ideographic model of risk allocation in construction material and financial schedules. The result of the analysis is an emergency plan that assumes time and cost contingency for the construction project being implemented. In practice, it is possible to develop several variants of emergency plans. It depends directly on the needs, experience and knowledge of the contractor.

The presented method of building emergency schedules, and currently only its results, presents a different approach to risk analysis than Rogalska, Hejducki, Radziszewska Zielina or Kostrzewa-Demczuk [24–26]. The authors, recognizing the logic and accuracy of the assessments of the mentioned publications, propose their own basis on the modified MOCRA method.

3.4. Application of emergency schedules

Identification of risk factors enables their quantification in relation to individual tasks of the construction schedule. This approach has two main advantages. Firstly, it enables forecasting disruptions and estimating their impact on the cost and time of individual tasks in the construction schedule. Secondly, the use of emergency schedules, as emphasized earlier, has a very high utilitarian value. Risk quantification illustrated in this way has a much better impact on investors' imagination than the ocean of risk presented in the form of probability. A fragment of the tenement house renovation schedule was used as an example of building an emergency schedule (Fig. 4). The above-mentioned drawing, illustrating a fragment of the schedule of the previously mentioned construction project, summarizes the construction tasks and their implementation time. It is not possible to include the entire schedule due to its complexity and span. The schedule presents, in accordance with the actual material and financial plan, only the predecessors. However, the main goal of the authors was to present the possibility of graphical analysis of risk factors through changes in the Gantt chart. In the presented fragment of the schedule for the described construction project, disruptions were allocated.

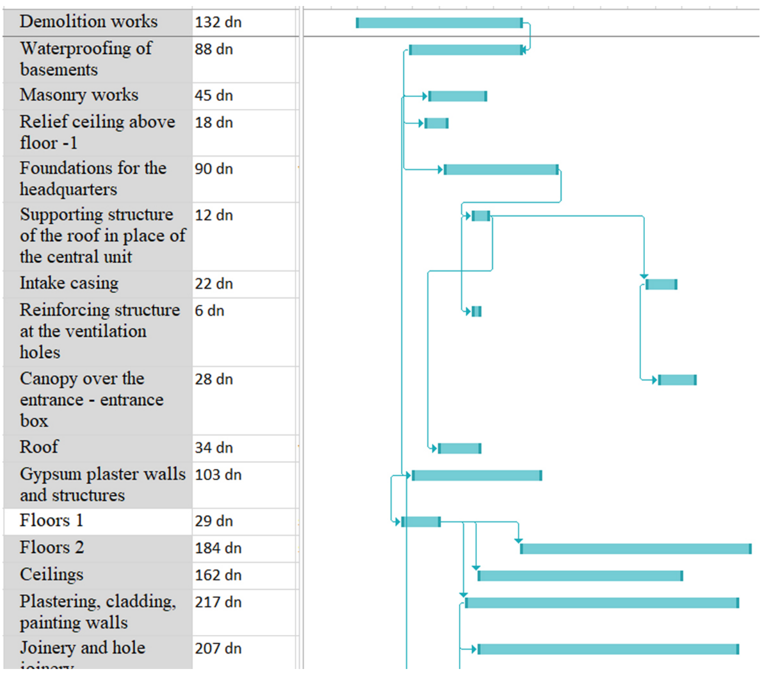

Fig. 4. Schedule for the renovation of a building (scrap)

The disruptions were determined on the basis of a detailed analysis, which resulted in the risk quantification presented in Table 2. The percentage description of the effects of risk factors was deliberately omitted, because the use of the Gantt chart in MS Project did not require such an operation.

Table 2. Identification potential risk factors

Tasks from the schedule Number	**Type of risk**	**Risk quantification (delay in days)**
1	Technical and organizational	60
2	Technical and administrative	30
3	Qualitative	20
12	Organizational	5
13	Design	30
14	Design and technical	40
17	Contractual	30

In the Tab. 2, we see the numbers of individual tasks in the tenement house renovation schedule. Specific implementation delays caused by expected disruptions were assigned to each task. Delays are counted in days.

Based on the data from the above-mentioned table, a graphical allocation of expected delays was made. A graphical interpretation of risk allocation is presented in Fig. 5. This approach enables the visualization of threats, which in turn works very well on investors' imagination. The construction of such emergency schedules also helps the contractor in effective planning and implementation of the construction project.

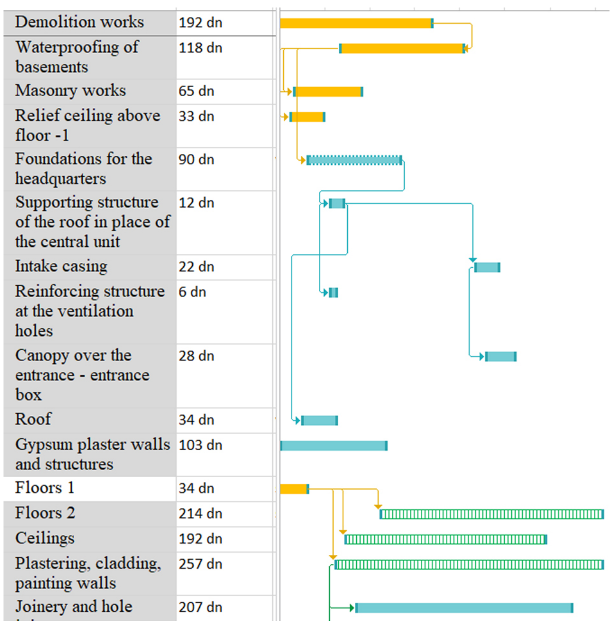

Fig. 5. Emergency schedule for the renovation of a building (scrap)

The presented emergency schedule illustrates the impact of various types of disruptions on the construction project. Orange shows tasks that have already been affected by risk factors. As a result, there was a delay, which was graphically presented in the schedule. Green shows tasks that may be interrupted during construction. This means that green indicates predictive events and orange indicates historical events. Tasks described graphically in the same color as in Fig. 4 were not interfered with or are not expected to be interfered with.

4. Conclusions

ents an analysis of the possibility of using emergency schedules. The undoubted advantage of emergency schedules, which the authors tried to present in the article, is the ability to visualize the risks of the construction process. The illustration is only as good as the risk analysis. Risk analysis should be based on appropriate specification of potential threats. Big challenges for teams of analysts developing emergency schedules are the identification and quantification of risk factors that may be a source of potential disruptions to the construction process. Certainly, a great advantage of the proposed method is its utilitarian nature. Most contractors, as well as investors, have an aversion to probabilistic examples. The use of emergency schedules enables the transition from probabilistic to deterministic areas. At the same time, it can be very graphically presented how the occurrence of probable risk factors will affect the cost and time of the construction project. In the construction industry, the use of emergency schedules is gaining more and more supporters. The analyzes presented in the article are part of research conducted by the authors of the publication.

Detailed quantification of risk factors was based on the MOCRA method. The calculations are so complex and extensive that they will be presented in subsequent articles. The idea and algorithm of the method are described in detail in the publications mentioned earlier in the material. The authors' research is currently focused on finding precise methods of risk quantification. Risk quantification is the foundation of every assessment. Graphical interpretation of the results of such analyzes is only as useful as the risk assessment is precise. The goal set by the authors is to be achieved by building large databases of risk factors. It is also assumed that construction projects will be grouped together. This approach should allow for the development of a specification of unified risk factors and the identification of dedicated risk factors.

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Zastosowanie harmonogramów awaryjnych przy remontach obiektów budowlanych

Słowa kluczowe: harmonogramy awaryjne, analiza ryzyka w budownictwie

Streszczenie:

Projekty budowlane charakteryzują się dużą złożonością realizowanych zadań. Są one zaplanowane na długi okres czasu i często są bardzo skomplikowane technologicznie. Wszystkie te czynniki powodują, że różnego rodzaju zakłócenia procesu budowlanego bardzo często występują podczas wznoszenia budynków. W teorii i praktyce zarządzania budową możliwość wystąpienia takich zakłóceń nazywana jest czynnikami ryzyka. Ze względu na to, że mają one istotny wpływ na zachowanie dwóch podstawowych cech konstrukcji, czyli czasu i kosztu budowy obiektu, podlegają intensywnym badaniom. Innymi słowy, wyzwaniem dla każdego projektu budowlanego jest przewidzenie czynników ryzyka, które mogą zakłócić proces budowy. Ponadto ich specyfikacja i kwantyfikacja, co pozwala oszacować możliwy wpływ zakłóceń procesu budowlanego na jego czas i koszt. W tym celu wykorzystywane są różne metody analizy ryzyka. Autorzy artykułu proponują wykorzystanie harmonogramów awaryjnych. Zestawienia tego typu mają ogromne zalety użytkowe. Oznacza to, że umożliwiają zilustrowanie ilościowego wpływu czynników ryzyka na poszczególne zadania i cały projekt budowlany. W materiale opisano ideę tego typu harmonogramów. Podano także przykład opracowania tego typu harmonogramu na przykładzie renowacji obiektu budowlanego.

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