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Risk analysis in surveying works related to roads construction

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Introduction

A road construction project is a complex process consisting of a variety of activities having a significant impact on the occurrence of various risk factors causing delays or cost overruns (Kasprowicz, 2002). The willingness to identify elements threatening the proper implementation of these projects is the main subject of scientific work with varying degrees of advancement in the risk analysis process (Sobotka, Pawluś, Wałach, & Czarnigowska, 2012; Głuszak & Leśniak, 2015; Leśniak, Piskorz, Spišáková, & Mačková, 2018). The observation of the market confirms that during such operations disturbances related to surveying works may occur (Rybka & Bondar-Nowakowska, 2013). They are rarely analyzed and presented in scientific studies. Surveying works during the road construction project are an indispensable element from the very beginning to the very end. During the project execution, the presence of a surveyor is connected to preliminary and control measurements, measuring current elements as well as those to be demolished, and others.

Based on the above observations and expert interviews, experience, literature analysis, verification of documentation provided by companies dealing with such projects and a case study, the subject matter has been explored, and the issue has been taken up in research. This article focuses on the first stage of the method of risk analysis for geodesy – MORAG, namely the identification of risk factors.

Assumptions of the proposed risk assessment method

The research took four and a half years and was carried out in different directions to finally select the path presented in the further part of the work.

At the beginning of the research, the problem of the lack of a proper risk analysis method for surveying works in road construction projects was diagnosed. One can find various ways of risk analysis in the literature (Czarnigowska & Sobotka, 2013; Gładysz, Kuchta, Skorupka, & Duchaczek, 2015), which was presented in Kowacka (2019), but there was a need to introduce a dedicated approach. A specialist literature and trade journals review and market observation were subsequently carried out. The necessity to continue the research was confirmed based on the above.

The analyses started with defining the concept of risk. Among many definitions of risk, the one that results from the norm was adopted. It has been assumed that the risk is often expressed as a combination of the consequences of the event and the related probability and its occurrence (PN-ISO 31000:2012).

The existing methods of the risk analysis were verified, and then the risk factors of geodetic operations were identified from the study of the acquired documentation, i.e. project schedules and documentation, and successively the knowledge and experience of the experts, who determined the values of probability and consequences of risk factors and pointed to problematic elements. Then, the collected material on this subject and a review of several case studies contained in the documentation obtained from construction companies as well as the knowledge they provided during the interviews. Selected risk factors are an essential element in the presented risk analysis method and constitute its first, yet crucial, stage on which further analysis depends. This method creates a new perspective on risk analysis in road construction works, including surveying ones.

The paper presents the method of risk analysis for geodesy – MORAG (Kowacka, 2019) by explaining its stages and pointing to individual elements of the procedure, thereby leading in consequence to the allocation of risk in surveying works.

Figure 1 displays the ideographic model and operating procedure of the discussed method, hereinafter referred to as MORAG, for geodetic risk analysis in road construction projects. The method in question includes both original solutions and those implemented from other methods used in risk analysis, which together fit into the system of its operation.

The first stage of the method, i.e. identification of risk factors, which is an essential element of this work, is presented in detail later in the article. The second stage, i.e. risk analysis, is carried out in two ways using the analytical method and fuzzy logic. These methods complement each other, thus giving an overall picture of the risk analysis, which was the aim of the study. The next step is to analyze the results obtained, compare them, and compile observations. Then, the risk analysis method in the schedules is evaluated. The following two points, i.e. the evaluation of the risk analysis method and risk management, are the final stages of the risk assessment.

Identification of risk factors

According to standard PN-ISO 31000:2012, this is a stage that aims to draw up a list of risk factors “based on

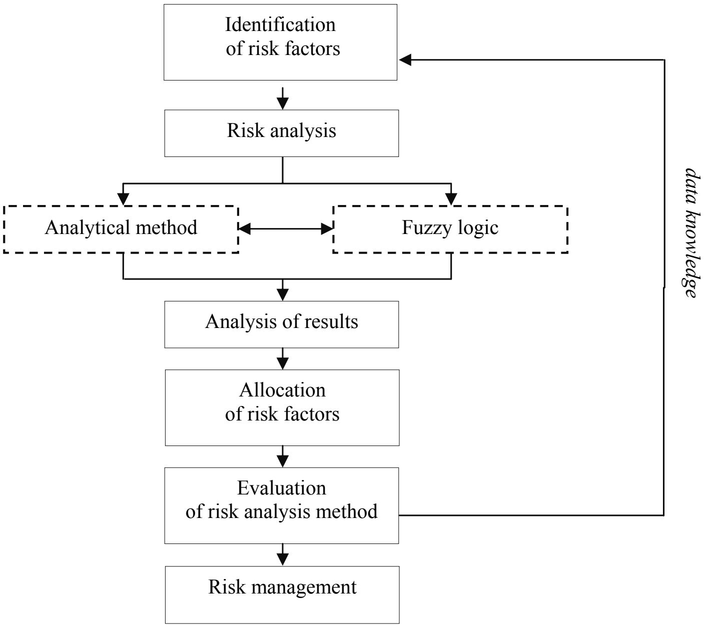

FIGURE 1. Ideographic model of MORAG (own studies)

those events that can create, stimulate, prevent, hinder, accelerate or delay the achievement of objectives. It is important to identify risks associated with missed opportunities".

The identification of risk factors in the presented method (Fig. 2) is based on the analysis of knowledge of six experts who have at least several years of experience in the surveyed road construction projects and were contractors of surveying works on the road facilities under analysis. Their knowledge and experience are supported by the analysis of construction schedules and case studies. The review of the literature and the authors' expertise are also helpful when risk factors are being identified.

The analysis of documentation and observations was possible thanks to the acquisition of various data from the implemented road construction projects. The added value in analyzing the schedules and pointing out their differences between the planned and completed work plans were: gained expert knowledge, case studies, and observations of works on construction sites to authenticate and select possible risk factors in surveying works. Risk factors in surveying works during road construction are presented below. They include:

- R1 – the incorrectly adopted horizontal layout;
- R2 – the incorrectly adopted altitude system for the development of data and the terrain elevation;
- R3 – a failure to develop a master plan and then update it;
- R4 – no Geodetic Register of Land Utilities Network (Polish acronym GESUT) information obtained from the District Center for Geodetic and

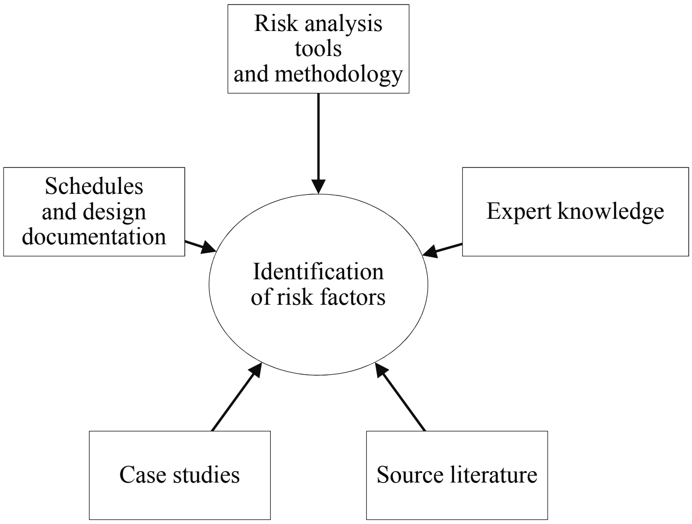

FIGURE 2. Identification of risk factors in MORAG (own studies)

Cartographic Documentation (Polish acronym PODGiK) resources;

- R5 – the incorrectly developed digital elevation model;
- R6 – improper transport of geodetic instruments, e.g. jumping over obstacles with a tripod on the shoulder;
- R7 – no current equipment inspection – this applies in particular to equipment used for geometric leveling;
- R8 – no appropriate equipment selection, e.g. the precise stake-out made with a GPS receiver does not meet the accuracy requirements;
- R9 – erroneous height coordination, e.g. the acceptance of only one benchmark to perform measurements, which results in the inability to control the equipment and the condition of the surveying point;
- R10 – erroneous situational coordination – the acceptance of only one warp point, which results in the inability to control the equipment and the condition of the surveying point;
- R11 – no control of the stake-out performed – a lack of control measures (headlamps), both between the designated and existing surveying points;
- R12 – incorrect stake-out made through the description on a stake of the elevation to the design level, where the appropriate method is situational coordination, altitude indication, and installation of benchmarks;
- R13 – the improper selection of the marking method for the points being staked, e.g. it is erroneous to mark surveying points with spray paint;
- R14 – no staking of cubature objects on the banks – staking is incorrectly performed and resumed after each stage (earthworks, continuous footings, foundations, walls);
- R15 – no inventory of existing elements intended for demolition – this results in stopping demolition works;
- R16 – the incorrect location of control points of geodetic matrix – wrong

choice of ground medium causing vertical displacements of points;
- R17 – the incorrect location of implementation matrix points that cause collisions with design elements and should be partially eliminated at the stage of the master plan; however, the stabilization of the matrix points is one of the first activities on the construction site, often before a complete plan has been created;
- R18 – no control of data from the resources of the PODGiK – the data concerning, e.g. matrix points are often accepted by the contractor as faultless, although later they turn out to be inaccurate;
- R19 – a lack of communication with contractors of particular assortments – imprecise ordering of works, incomprehension of the applicable nomenclature, mechanical entry of orders,e.g. into the application log without a conversation about what is expected, often results in delineation of the element in a way far from expected;
- R20 – often an element that can be measured with 10 pickets is measured by a surveyor using e.g. 80 pickets – it leads to disturbances in desk studies, and often also causes a repetition of measurement.

As a result of the conducted research, 20 risk factors were identified, each of which as one possible to occur in a specific geodetic activity. However, this does not mean that it was eliminated during the surveying works while a given project was being implemented.

During the selection of the factors mentioned above, it was essential to determine their location in the road construction process for further analysis. Each of the above-selected risk factors is of vital importance for the proper performance of surveying works. Their occurrence may cause serious consequences disrupting the successful completion of a road construction project.

Conclusions

Starting with the analysis of risk factors, the main conclusion to be drawn is that the human element plays a crucial role in them, regardless of which risk factor occurs in connection with surveying works.

Twenty risk factors (R1–R20) were selected for the analysis described in the paper. However, the analysis method allows the expansion of the risk factors database with new ones, using data knowledge. Moreover, it enables the improvement of adopted weights used at a later stage. These weights make it possible to indicate the hierarchy of values obtained, which is necessary during further work.

The risk factors identified form the basis for the presentation of the MORAG, while the next steps and results of its operation will be discussed in subsequent works.

The MORAG is the first method dedicated to surveying operations that focuses on specific risk factors such as geodetic ones. The duration of surveying activities in relation to the whole construction project is significantly shorter, but due to the necessity of their execution, their specificity and enormous value in the correctness of their implementation for the entire project are even key to the success of the investment.

Refraining from geodetic activities or their incorrect execution may lead to substantial financial losses, the extension of the project implementation time to an unacceptable level, or a lack of maintenance of quality standards. As it is easy to notice, the necessity to carry out such analyses, broaden knowledge, even in elements which at first glance are not of great importance, as well as pay attention to simple activities, is also necessary to reduce the risk and failures.

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Summary

Risk analysis in surveying works related to roads construction. This study aimed to indicate the identified risk factors, which is the first stage in the presented method for risk analysis in geodetic works. The experts' opinion, analysis of available documentation, experience, subject literature review, and observation allowed for obtaining information due to which 20 risk factors were selected. The presented method for risk analysis was developed as a result of investigations and verification of existing risk analysis methods, as well as the market needs. The results of the study on the identification of risk factors and the presented risk analysis method are the first stage of the research on the given subject, the continuation of which will be presented in subsequent works.

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