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Construction delays in clients opinion – multivariate statistical analysis

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Abstract

Timely implementation of construction works (at the scheduled time) is vital for both the investor and the contractor. Yet construction projects, even those perfectly planned and organized, run the risk of delays. Despite many tools supporting construction management, delays keep occurring in construction projects. The present paper presents the findings of a survey aimed at identifying the most important causes of delays in construction works from the client's perspective. A factor analysis that was performed allow to interpret the dependencies between them. The knowledge can be helpful for minimizing the risk of delays.

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Keywords: delays in works; statistical analysis; questionnaire survey

1. Introduction

The course of the construction process within a given time is shaped by numerous factors which are frequently predicted already at the planning stage. However, there exists a group of factors that are rather hard to foresee, such as weather conditions, breakdowns or suppliers' incompetence. The risk that unexpected events and problems will occur, which will potentially lead to delayed works completion or even discontinuation of the investment, concerns also these projects that are carefully prepared and organized. Identification of construction risk factors, based on both subjective and objective measures, can be used to optimize agreements between investor and contractors [23].

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At a micro-level construction industry in most countries in the world is based on relations between investors, project managers, contractors and other parties, and many factors that affect its dynamics are common [19].

Some of the first studies into the causes of delays in construction works were performed in the 1970s in the United States [4]. Seventeen factors causing delays were specified. They included: weather conditions, availability of labour, participation of subcontractors, design changes, quality of design documentation, foundation conditions, availability of materials, equipment failures, execution errors, construction inspections, financial issues, obtaining relevant permits and others. Further research locations included Turkey [3], the UK [16], Nigeria [1] Thailand [22]. As a result of more frequent and more extensive studies, new delay factors were identified. Ultimately, more than a hundred of them were listed and classified. The simplest breakdown into three groups of factors was proposed in [21] naming the following:

1. a group of input factors – defined as resources required for project execution: labour, material, equipment,
2. a group referred to internal environment – including participants in the project, such as: investors, consultants, contractors,
3. a group of unpredictable factors - defined as weather conditions, legal regulations, and other random events.

A much broader breakdown was proposed in study [7], in which eight groups were identified, such as:

1. contractor – availability of resources, supervision and his experience,
2. designer and consultants – efficiency of the design and consultation team
3. investor – feasibility of the plan, time for decision-making,
4. finance – timeliness of settlements between participants,
5. schedule of works – erroneous estimate of execution time of individual works,
6. relationships between participants - no partnership, conflicts, protracted negotiations,
7. regulations - unexpected changes in the law,
8. unpredictable conditions - random events outside the influence of the participants.

The most detailed breakdown suggested so far was presented in study [22]. The authors singled out as many as ten categories of factors, including: investor, designer, consultant/project manager, contractors, manual labourers, finance, contract, communication, environment and context as well as other factors.

The present article describes the results of research performed among Polish public investors. One of its aims was identification and prioritizing factors that investors believed to cause delays in works implementation. A factor analysis allowed to present an output set of observed variables in terms of a smaller number of latent variables, and enabled an interpretation of the dependencies between them.

2. Delays in construction works

In the construction industry, a delay can be defined as exceeding the date of works execution which was defined in the contract. For the investor, a delay may mean an inability to obtain the benefits of the investments at the scheduled time. In special situations, it may even turn a profitable venture into an unviable project. For the contractor, on the other hand, delays may cause the costs of works to become higher than planned. In extreme cases this can lead to a situation in which, instead of a planned profit, the contractor incurs losses. In addition, untimely completion of the project exerts an impact on the contractor's image on the construction market, namely the perception of their credibility and reliability. In terms of the cause, delays can be divided into two groups: justified or unjustified; moreover, partly responsible (suffering the consequences) can be either the investor or the contractor.

Justified delays are usually through the fault of the investor and may be subject to compensation. During the execution of works, interference with and modification of the design documentation often occurs. This is a result of changes made during the execution of works or errors made at the design stage [10]. Extending the time needed to prepare the author's supervision may cause delays in the execution of works. The investor's interference in the competences of the contractor, modifications of earlier findings and a long decision-making process are further reasons leading to possible delays.

There can also be delays which are justified but are not subject to compensation, since none of the parties are responsible for their occurrence. Such delays include weather conditions, changes in legislation and other random events. Random cases include theft, failures and technical problems in the construction equipment used, occurrence of archaeological excavations, explosives found etc. Some of them are related to the need to perform time-consuming procedures and processes.

An entirely different group includes unjustified delays, the responsibility for which usually rests with the contractor. In this case, however, the contractor is not authorized either to extend the deadline for the project or to receive a salary. Contractor-dependent factors are associated primarily with the availability of resources, proper organization, supervision and experience. What is essential for the smooth operation of the construction process is the efficiency of the administration of the management team, including the proper control and supervision over the execution of works and experience of the contractors in the implementation of the particular types of projects. This group also includes subcontractor actions. Yet responsibility for any delays caused by subcontractors always belongs to the general contractor. It is worth mentioning that for a smooth construction process, the relations between the various participants in the project are vital [14]. Limited or inadequate flow of information between the investor, contractor and designer, frequently occurring conflicts or difficult and lengthy negotiations can also cause delays.

3. Causes of construction delays in Poland - a survey

The research received the form of an online survey. An online questionnaire, as the research tool, was used and the respondents from all offices in all communities received a link to it by email. As many as 967 completed questionnaires (40% of returns) were received, among which some had to be rejected due to their incompleteness. Eventually, the survey included 927 relevant questionnaires.

The survey consisted of two parts. The first one contained seven closed-ended questions for the initial diagnosis of the problem. One of the first questions concerned the most common causes of delays in construction works. The second part of the survey offered a list of 18 factors that caused delays in construction works. The respondents evaluated, among others, the different levels of priority of the factors proposed. Their opinions were expressed numerically using a five-point scale where:

1 – meant invalid,
2 – less important,
3 – of average importance,
4 – important,
5 – very important.

Then, for each of the factors, average results were calculated (1) thus giving the response a particular rank, which allowed to create a ranking of the proposed factors.

$$S_i = \frac{\sum_{j=1}^{N_i} a_{ij}}{N_i} \qquad \text{for} \qquad i = 1,2...5 \tag{1}$$

where:
S_i – average for the i-th factor

N_i – total number of responses for the i-th factor;
a_{ij}– assessment degree assigned to the i-th factor in the j-th response.

Figure 1 illustrates the results of studies by presenting the sequence based on importance and rank. For the sake of clarity, only the first ten of the eighteen factors proposed were included.

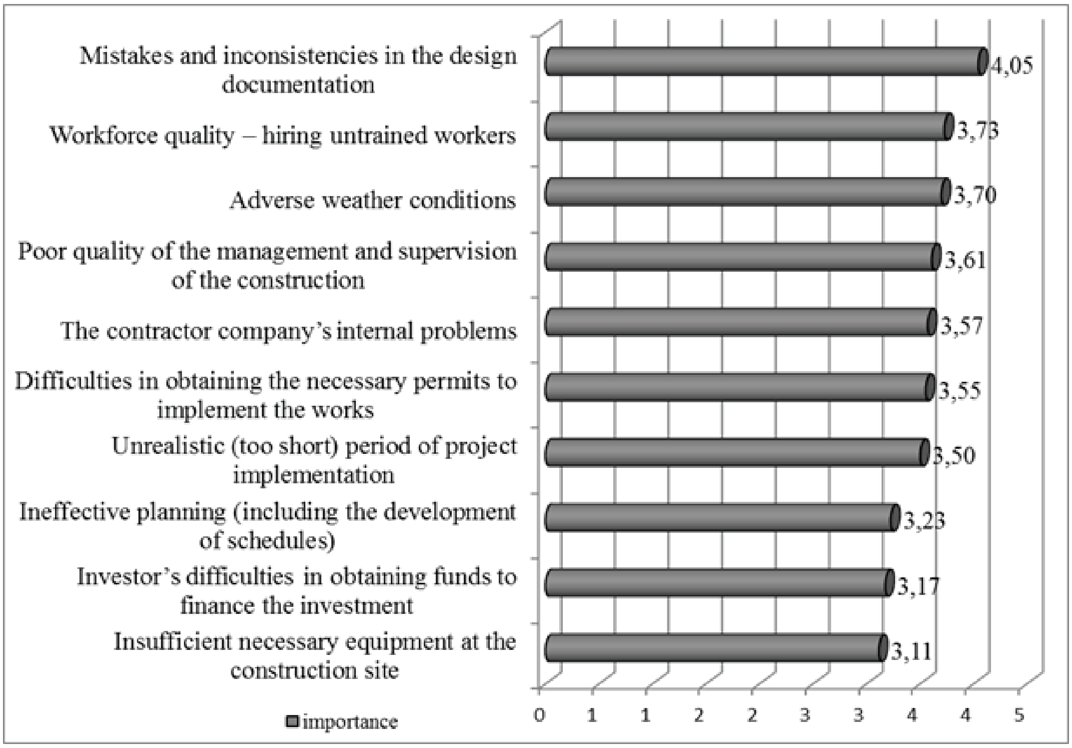

Fig.1 The main causes of delays – order of the importance

Figure 1 reveals that, according to the clients, the most significant factors causing delays in construction works are mistakes in design documentation (average evaluation: 4,05). Non-uniform studies, lack of annotation or details in the drawings were mentioned as the most frequent problems that contractors have to face. They are, therefore, constantly forced to consult the designer thus prolonging the construction execution time. Another factor concerned the quality of workforce (average evaluation: 3,73) and poor weather conditions (3,70). Factors that were considered less vital included contractor's lack of access to modern technologies (2,63) and investor's delays in payments to the contractor (2,66).

4. Factor analysis of the expert opinions obtained

The literature provides various classification of delays in construction works [2, 7, 21, 22] some of which is not based on empirical studies. This article employs factor analysis which belongs to classic methods of multi-dimensional data analysis [17]. Its aim is to depict an output set of observed variables in terms of a smaller set of latent variables which cannot be directly observed.

In this approach the observed variables Ki can be represented by linear functions of latent common factors Fk and a set of unique factors Ui, which characterise each particular variable [16]. Factor analysis model can be presented as a set of equations:

$$k_1=\lambda_{11} f_1+\lambda_{12} f_2+\cdots+\lambda_{1k} f_k+u_1$$
$$k_2=\lambda_{21} f_1+\lambda_{22} f_2+\cdots+\lambda_{2k} f_k+u_2$$
$$\ldots$$
$$k_i=\lambda_{i1} f_1+\lambda_{i2} f_2+\cdots+\lambda_{ik} f_k+u_i \quad (2)$$

where:
k_i – are observed variables (manifested by responses from the survey)
f_k – are common factors (latent, unobserved)
u_i – are specific factors (unique to each observed variable)
λ_{ik} – are factor loadings.

As noted by Rummel [20] factor analysis is general data analysis tool that can be applied to information from different scientific disciplines, as long as they can be organized in matrix. There are two types of factor analysis: (i) exploratory factor analysis, (ii) confirmatory facor analysis. Exploratory factor analysis is used to reduce complexity found in original dataset in order to find meaningful interpretation of the hidden structure and latent dimensions [20]. Confirmatory factor analysis is used to investigate if the data fit a theoretical model, theory or previous research [8]. In the article we use exploratory factor analysis in order to understand experts' perceptions of causes of delay in construction works. Observed variables (ki) were manifested by subjective assessments of relative importance of causes of construction delay made by respondents in the survey. Intuitively, some reasons of construction works delay are related (correlated), and may be caused by some latent factors. The aim of the factor analysis is to reduce complexity of experts' opinions and to find latent (unobserved) major determinants (factors) of construction works delay.

The algorithm of factor analysis consists of a number of stages:

1. Determining whether the variables satisfy the assumptions of factor analysis. In order to assess whether data can be analyzed using factor analysis Bartlett's test of sphericity [5] is used. It allows to test the hypothesis that all of the variables are unrelated (technically correlation matrix being an identify matrix). Another method involves the computation of the Kaiser-Mayer-Olkin measure specifying the closeness of the relationships between observable variables (on a scale from 0 to 1). In practice it is assumed that the factor model can be used when the KMO value is greater than 0,5 [18].
2. Selecting a factor model (method) and evaluating factor loadings. The factor analysis was performed by means of the maximum likelihood method [9] in which factor loadings are specified in such a way that the probability of the model's interpretation of the correlation coefficients of observed variables was the greatest.
3. Determining the number of factors. Establishing the number of factors seems rather subjective, although many studies provide a few criteria and techniques facilitating the researcher's decision. One of them is the criterion of the minimum eigenvalue proposed by Kaiser [12] which assumes that the analysis should include only these factors whose eigenvalue is greater than 1. Another common criterion is Cattell's scree test [6]. This method is based on the interpretation of a scree plot with eigenvalues as the Y-axis and the corresponding components as the X axis joined with a line. The task is to find a break point marking the boundary between the hypothetical steep slope and a levelling off.
4. Rotation of factors. The subsequent step in the research is usually factor rotation which aims at facilitating the interpretation of the results obtained. There exists a considerable number of rotation [13]. Regardless of the rotation method chosen, the share of the factors in the explanation of the common variance of the variables in the model is unchanged [18]. The study used Varimax rotation, which minimizes the number of variables having high factor loadings. This facilitates the interpretation of particular latent factors [11].

4.1. Factor analysis for the importance of reasons for construction works delays

The Bartlett's test of sphericity disproved the zero hypothesis stating that the correlation matrix was an identity matrix. Thus it was assumed that the statistical correlations between the variables could undergo the next analysis. An additional proof was provided by the Kaiser-Mayer-Olkin criterion whose value equal to 0,934 suggested that the empirical data are well suited to the factor analysis. Another step involved the determination of the number of factors by means of the scree test (Fig. 2) and Kaiser’s criterion. With these criteria under consideration, a solution with three factors (F1, F2 and F3), each with the value greater than 1, was adopted.

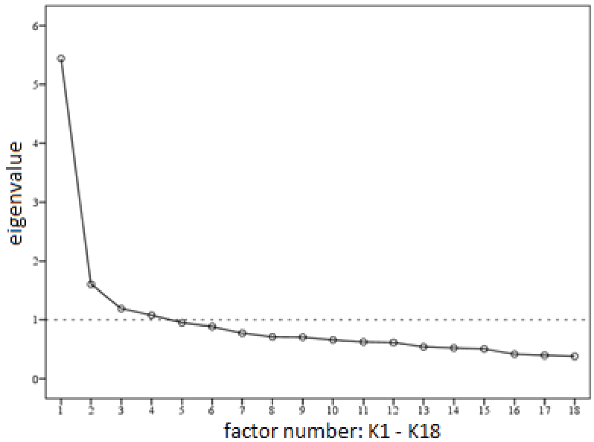

Fig.2 The scree plot

Such solution allows to explain about 52,9% of the variance of the variables in the factor model. The contribution of the other factors is rather insignificant. To facilitate the interpretation of the results, the factors underwent orthogonal rotation in terms of the Varimax method with Kaiser normalisation. Table 1 presents the correlations of individual factors with the original variables representing expert evaluations of the importance of particular criteria for the potential delays in construction works.

Table 1. A matrix for the rotated factors (importance of the reasons of delays)*. Source: research-based own study

Factors influencing delays	F1	F2	F3
K1 – Mistakes and inconsistencies in the design documentation	,273	,349	,006
K2 – Changes in the project under implementation requested by the investor	,056	**,453**	,087
K3 – Investor’s delay in payments to the contractor	,141	**,482**	,312
K4 – Investor’s difficulties in obtaining funds to finance the investment	,064	**,486**	,303
K5 – Workforce quality – hiring untrained workers	**,544**	,170	,313
K6 – Adverse weather conditions	,204	,297	,167
K7 – Delays in the supply of materials	,313	,352	**,484**
K8 – Poor quality of the management and supervision of the construction	**,631**	,202	,330
K9 – Ineffective planning (including the development of schedules)	**,501**	,267	,400
K10 – Unforeseen changes in the existing law	,234	,439	**,451**
K11 – Contractor’s lack of access to modern technologies	,253	,250	**,675**
K12 – Insufficient necessary equipment at the construction site	**,497**	,197	**,559**
K13 – Poor relations between the investor and the contractor	**,438**	**,504**	,296

K14 – Investor's slow decision-making	,346	**,604**	,316
K15 – Personnel changes of contractor's key staff	**,518**	,331	,340
K16 – Difficulties in obtaining the necessary permits to implement the works	,260	**,522**	,239
K17 – Unrealistic (too short) period of project implementation	**,407**	**,556**	,145
K18 – The contractor company's internal problems	**,680**	,172	,098

*Method of establishing factors – the maximum likelihood. Rotation method – Varimax with Kaiser normalisation (rotation reached convergence in 10 iterations). The correlation coefficients greater than 0,4 are in bold.

The F1 factor is positively correlated with expert evaluations of the importance of such reasons for delays as: low quality of the workforce, low quality of management and supervision on the construction site, ineffective planning, internal problems of the contractor company, changes of the key personnel, poor relations between the investor and the contractor or the insufficient amount of the necessary equipment on the construction site. It can be said that these reasons of delays are wholly (or at least partially) related to the contractor's activities or neglect.

The F2 factor is positively correlated with expert evaluations of the importance of such reasons for delays as: investor's slow decision-making, unrealistic time of the project implementation, difficulties in obtaining the necessary permits, poor relations between the investor and the contractor, changes to the project under implementation that the investor introduced, delays in payments to the contractor or investor's financial problems. Here it is evident that the reasons for delays are related to the activities, or their lack, on the part of the investor. In the case of one variable, the poor relations between the contractor and the investor, significant correlations with both factor F1 and F2 were observed, though the latter was higher (0,44 and 0,5 respectively). This seems logical, as the relations between the contractor and the investor naturally require the commitment of both parties.

The F3 factor is positively correlated with expert evaluations of the importance of such reasons for delays as: delays in the supply of building materials, unforeseen changes in the existing law, the contractor's lack of access to modern technologies and insufficient amount of necessary equipment and tools on the construction site. This group includes the reasons which wholly, or at least partially, remain beyond the contractor's or investor's influence. The existence of these external reasons for delays may be random, not caused by errors or neglect of the parties engaged in the construction project.

The summary of the factor analysis results based on the experts' evaluation of the importance of the individual reasons reveals three basic categories of delay in construction works: (1) caused by the contractor, (2) caused by the investor and (3) external.

5. Summary

Twelve factors out of eighteen presented in this article were evaluated as important – the average evaluation ranged from 3,5 to 4,5 points. The study included only one group of participants in the investment process, namely the investors. Therefor it was expected that the evaluation of the proposed reasons for delays of construction works would be subjective at times. Such a situation could occur in the case of the assessment of the investor's delay in payment to the contractor. This factor was indeed considered as one of the least important and the least frequent, while the studies involving contractors [15] it took the third place. The investors believed that the most significant factor influencing delays in construction works was the one concerning errors in design documentation (average evaluation: 4,05). The research among contractors [15] indicated exactly the same factor as the most vital. It may be concluded that the investor, being the one responsible for providing the project design, should pay extra attention to its accuracy and quality of development before the construction begins.

The statistical methods of analysis and evaluation of data proved a sufficient compliance of experts' opinions, despite a large research group (927 investors). Factor analysis helped to distinguish three main latent factors of delays in construction works: (1) a factor involving activities and neglect, (2) a factor associated with investor problems and (3) a factor connected with external circumstances on which the parties of the contract have a limited or no influence. The factors specified by the exploratory analysis of empirical data partially overlaps with a priori classifications which can be found in literature.

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