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# Analysis of additional works in completed railway construction projects

**Key words:** additional works, railway construction projects

## Introduction

The implementation of railway construction projects in Poland is closely related to the execution of strategic government investment programmes. The most important of these include the National Railway Programme to be implemented by 2023, with a budget of approximately PLN 67 billion, according to the Resolution No 186/2017 of the Council of Ministers. The execution of such a huge strategy is connected with proper planning of the construction investment process by the manager of the Polish railway network. The implementation of the key stages of the investment does not differ significantly from other construction sectors, and the most important stages include: pre-design works, feasibility study, design and construction. However, unlike other industries, railway construction investments are characterized by a significant extension of individual phases and an increased number of entities participating in the construction investment process (Civil Code of 1964; Act amending the Public Procurement Law and some other acts of 2016.

The most common methods of planning construction investments include various techniques aimed at minimizing the negative effects that may occur during the design stage or during the construction and assembly works. In some countries an extensive researches on problems with an appropriate preparation of design documentation were carried out (Juszczyk, Kozik, Leśniak, Plebankiewicz & Zima, 2014; Hoła, 2015; Kozlovska, Mackova & Spisakova, 2016). The most frequent and serious consequences of errors in project documentation at the stage of investment implementation include among others increase in the value of the contract due to additional works or suspension of works. Different approaches are proposed in relation to the risk analysis in construction (Gładysz, Kuchta, Skorupka & Duchaczek, 2015;

Kaczorek, Krzemiński & Ibadov, 2017; Kembłowski, Grzyl, Kristowski & Siemaszko, 2017; Hanak & Korytarova, 2018; Wieczorek, Plebankiewicz & Zima, 2019), calculation of costs of construction works (Leśniak & Juszczyk, 2018; Leśniak & Zima, 2018) and identification of problems at the stage of planning, execution and operation of buildings (Lendo-Siwicka, Połoński & Pawluk, 2016; Nowogońska & Cibis, 2017). The specificity and high costs of railway projects generate the high risk in the entire investment and construction process. The indicated articles present risk management methodologies developed for years by various scientists. The construction process is dynamic and despite the use of many modern methods and techniques (Kapliński, 2018) unforeseen phenomena and events which may occur during the execution of the investment cannot be excluded, especially those which are as complex as railway construction projects. All unexpected situations (those occurring before the commencement of construction works, as well as those revealed during works) usually initiate consequences in the form of additional workload and costs not included by the contractor and longer duration of works. This fact is commonly referred to as the occurrence of the so-called "additional works" (Czemplik, 2012). Additional works in the construction industry are a frequent phenomenon, having a significant impact on the implementation of construction and assembly works (Czemplik, 2012; Juszczyk, Zima & Leśniak, 2013).

The paper presents the results of research concerning additional works during the implementation of railway construction projects performed in southern Poland. The aim of the research was to analyze the reasons for the occurrence of additional works and to indicate the types of industry works included in their scope, together with an estimation of their frequency.

## Selection of completed railway construction projects

The database of additional works occurring in the completed railway infrastructure projects was created on the information obtained from the public investor. The analysis involved a construction project including the construction, reconstruction, modernization or revitalization of any long section of the railway track. Subsequently, investments were limited to those whose contract value amounted to a minimum of PLN 4 million. Finally, only completed projects form 1 January 2012 to 31 December 2018 were selected for further analysis.

Seventeen investments were selected based on the assumed criteria. Investments have been assigned the ordinal number and then they were described with the following parameters: type of implementation, duration (contractual), value of the contract (contractual) and the number of documents on the basis of which additional works were procured. The projects selected for the further analysis are presented in Table 1.

The small sample chosen for further research is due to the fact that a large part of the construction investments carried out by the Southern Investment Region of PKP PLK (source of the authors knowledge) is currently under construc-

TABLE 1. Characteristics of the selected railway construction projects

| No | Contract type | Contract price [PLN] | Contractual time [days] | Number of contract documents |
|---|---|---|---|---|
| 1 | design and build | 408 199 276.85 | 570 | 4 |
| 2 | design and build | 34 830 500.00 | 211 | 6 |
| 3 | design and build | 18 808 049.99 | 384 | 1 |
| 4 | design and build | 20 424 279.79 | 352 | 1 |
| 5 | design and build | 4 049 998.19 | 211 | 6 |
| 6 | design and build | 34 507 840.36 | 701 | 1 |
| 7 | design and build | 41 953 990.41 | 326 | 30 |
| 8 | design and build | 123 033 760.44 | 211 | 6 |
| 9 | design and build | 50 327 768.20 | 829 | 3 |
| 10 | design and build | 42 499 111.00 | 530 | 0 |
| 11 | design and build | 35 287 450.00 | 700 | 11 |
| 12 | design and build | 26 966 772.70 | 401 | 6 |
| 13 | build | 102 449 500.61 | 211 | 21 |
| 14 | design and build | 10 435 320.00 | 211 | 7 |
| 15 | design and build | 10 653 599.82 | 271 | 6 |
| 16 | design and build | 15 221 295.60 | 275 | 4 |
| 17 | design and build | 17 644 827.00 | 122 | 3 |

tion or settlement phase. This applies to both projects implemented under the current and the previous EU financial perspective. Due to the duration of work on the projects, the authors could not obtain contract documents that formed the basis for further analysis.

## Analysis of additional works in selected projects

The selected construction projects had a set of annexes, protocols of necessity or other contract documents on the basis of which the authors identified the additional works. Additional works have been assigned the ordinal numbers and the following parameters have been defined: impact on the contractual price, impact on the contractual time, types of additional works (characteristic of the railway construction projects) and factors causing additional works. The base of additional works created in this way will be used for further analysis performed in three thematic blocks:

- impact of additional works on the time and cost of the construction project;
- factors causing additional works;
- types of additional works in railway construction projects.

## Impact of additional works on the time and cost of the construction project

The analysis of additional works was started by examining the impact on the time and cost compared to the basic value described in the contract. In order to determine the cost of additional works for each of the discussed projects, the value of all additional works identified at earlier stage was added up. The formula for the cost of additional works can be defined as follows:

$$K = \sum_{i=1}^{n} w_i \quad (1)$$

where:
$K$ – cost of additional works for the analyzed project;
$w_i$ – value of a single "$i$" identified additional work.

Subsequently, the impact of additional works on the duration of the project was determined. The review of the documents received from the public investor revealed that it is impossible to directly designate the value of extension or shorten the duration of a construction project. Some parts of the documentation included specific dates of additional works, while others determined the completion of works before the key stages, or suggested only the duration of additional works. In view of the observed fact, it was suggested that the impact on the duration of the construction project should be determined by the time difference between the end of the additional works at the latest and the basic contractual date. For investments whose determination of the duration of additional works was difficult or impossible, a zero impact on the duration of the construction was assumed. The results are presented in Table 2.

Based on the results developed, it was found that the additional works did not appear only during the realization of one project. It can be assumed that the phenomenon of additional works is common during the conduct of railway construction projects.

In 16 out of 17 cases of the analyzed investments, additional work resulted in effects. A change in the contractual price was observed for this number of projects. The contractual price of 15 investments increased due to additional works, while for the remaining case (one investment) the contractual price was reduced. Among the impact-generating investments, only six were related to the extension of the duration of the project.

Additional works in the three undertakings discussed (investments 6, 11 and 17) resulted in a significant increase in the cost or time. After a detailed analysis of the contract documentation, it was found that this fact is related to the acquisition of an additional contract in the "free-hand" mode for the implementation of additional construction works that complement the basic contract.

The authors have attempted to examine the relationship between the investment budget and the price of additional work. For this purpose, the projects discussed have been ranked as ascending, starting from investments with the smallest contractual price. Subsequently, the values of additional works (expressed as % of the basic contract price) were assigned to the ranked investments. In order to examine the dependence, the trend line of the value of

TABLE 2. Impact of additional works on the time and cost of the analyzed projects

| No | Impact on the contract price [PLN] | Impact on the contract price [%] | Time extension [days] | Time extension [%] |
|---|---|---|---|---|
| 1 | 3 019 542.56 | 6.26 | 0 | 0 |
| 2 | 174 307.40 | 0.50 | 0 | 0 |
| 3 | 331 419.62 | 1.76 | 0 | 0 |
| 4 | 71 212.60 | 0.35 | 0 | 0 |
| 5 | 36 200.00 | 0.89 | 0 | 0 |
| 6 | 22 200 001.00 | 64.33 | 211 | 30.10 |
| 7 | 1 925 618.89 | 4.59 | 14 | 4.29 |
| 8 | 407 571.48 | 0.33 | 0 | 0 |
| 9 | –17 162.03 | –0.03 | 0 | 0 |
| 10 | 0.00 | 0.00 | 0 | 0 |
| 11 | 9 378 888.66 | 26.58 | 25 | 3.57 |
| 12 | 800 017.98 | 2.97 | 0 | 0 |
| 13 | 6 181 171.76 | 6.03 | 0 | 0 |
| 14 | 496 917.40 | 4.76 | 0 | 0 |
| 15 | 2 337 876.59 | 21.94 | 5 | 1.85 |
| 16 | 179 672.89 | 1.18 | 2 d | 0.73 |
| 17 | 367 655.23 | 2.08 | 56 | 45.90 |

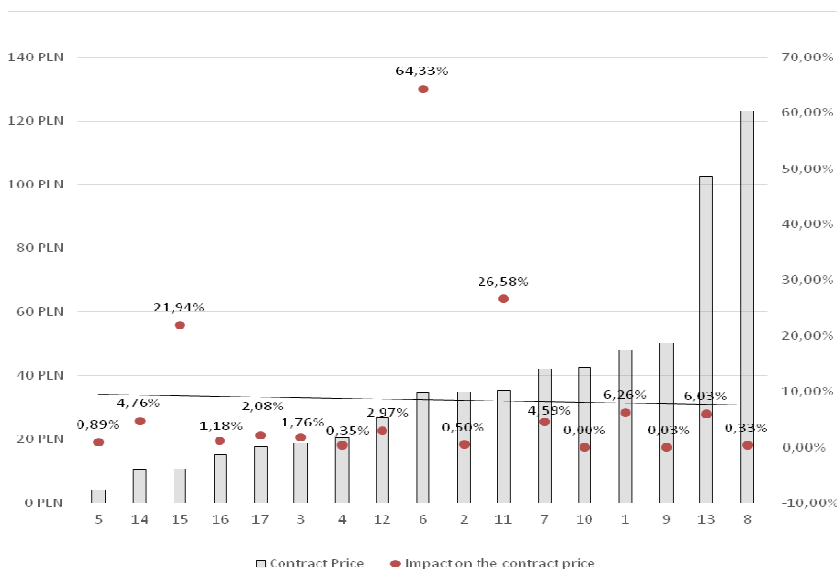


FIGURE 1. Relationship between the investment budget and the price of additional work

additional works was drawn into the chart. Based on the results obtained (presented in Fig. 1), there is no relationship between the growth of the investment budget and the amount of additional work.

## Factors causing additional works

One of the objectives of the research conducted was to identify factors causing additional works and to determine the frequency of their occurrence in the investments discussed. The list of factors was elaborated on the basis of the previous research (Czemplik, 2012), complementing with its own proposals, covering reasons specific to the railway industry. For the purposes of further analysis, a summary including eight factors was created.

The identified additional works are characterized by their uniqueness. Therefore, the authors have developed a way of assigning factors to particular situations that result in additional works. The list of factors causing additional works along with a brief description of the most frequent phenomena, constituting the original methodology, is presented in Table 3.

Another element of the analysis was an attempt to estimate the number of in-

TABLE 3. List of factors causing additional works along with characteristics of phenomena

| Name of factors | Situations causing additional works – examples |
|---|---|
| Delay of deliveries of materials and construction products to the construction site by suppliers | • no specified materials on the market<br>• late delivery of materials due to the fault of the suppliers<br>• changes in the cost of materials during the work |
| Bad organization of works | • incorrect application of the works technology<br>• failing to effectively carry out work |
| Not disclosed – in available maps of the construction site – elements of underground infrastructure | • unidentified underground infrastructure and erroneously marked collisions<br>• unidentified elements of structures or buildings (archaeological objects) |
| Incomplete geological and engineering recognition of the construction | • incorrectly accepted ground and geological conditions<br>• incorrectly assumed mechanical parameters of soils |
| Changes in design solutions introduced by the Investor during the implementation of the investment | • change in the scope of works resulting from the current financial situation of the employer<br>• clarification of the scope of works due to imprecise entries in the tender documentation<br>• degradation of railway infrastructure since the tender procedure |
| Substantive errors and incompleteness of project documentation | • errors in the tender documentation<br>• errors in construction and executive projects<br>• discrepancies in the planned construction solutions and technological projects |
| No closure of track, despite the fulfillment of contractual conditions | • decisions of the investor not in compliance with applicable regulations<br>• delays of scheduled trains preventing the closing of track closures |
| Implementation problems on neighboring projects (on “contract contacts”) | • no possibility of delivery of key materials by means of railway machines<br>• delays of works on neighboring sections by different contractors |

dividual factors causing additional work in the identified cases of additional work. When assigning individual factors to additional works, it was assumed that one additional work may result from the occurrence of more than one factor. This is due to the characteristics of individual situations that may occur during the implementation of the investment.

The calculations led to the estimation of the number of existing factors, which amounted to 120. The most common factor was "substantive errors and incompleteness of project documentation", while the least frequent (not appearing at all) was "implementation problems on neighboring projects". The percentage share of individual factors is shown in Figure 2.

For the purposes of further research work, the authors specified the frequency of individual factors causing additional work. In order to determine the frequency of occurrence, the number of investments in which a given factor causing additional works was specified and related to the number of projects under consideration was established. The result obtained was presented as the probability of occurrence of factors causing additional works. Based on calculations, it was determined that the factor "substantive errors and incompleteness of project documentation" has the highest probability of occurrence, while "implementation problems on neighboring projects" the smallest (Fig. 3).

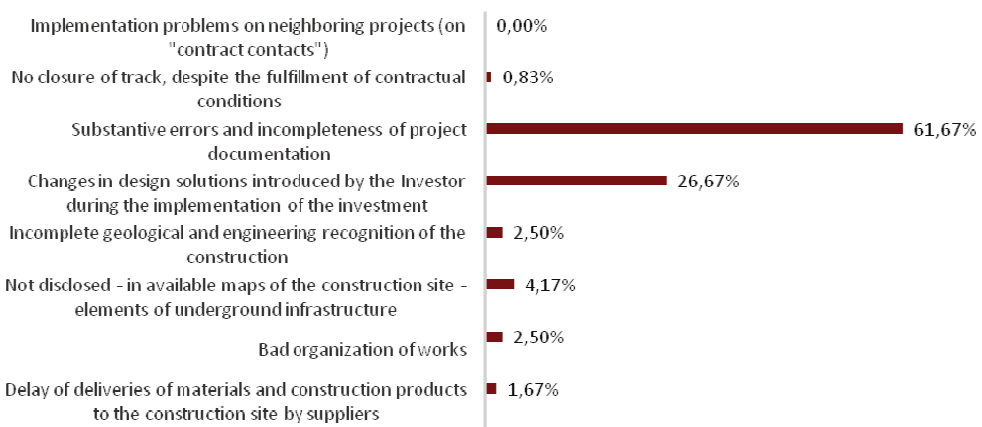


FIGURE 2. Share of the factors causing additional works

## Types of additional works in construction projects of railway infrastructure

The last element of the analysis was to identify the types of industrial works entering in the scope of additional works and estimation of their occurrence frequency. Nine types of industry works were adopted for the needs of the research, consistent with the specificity of railway construction projects:

– track and drainage works;
– network works (electrotraction);

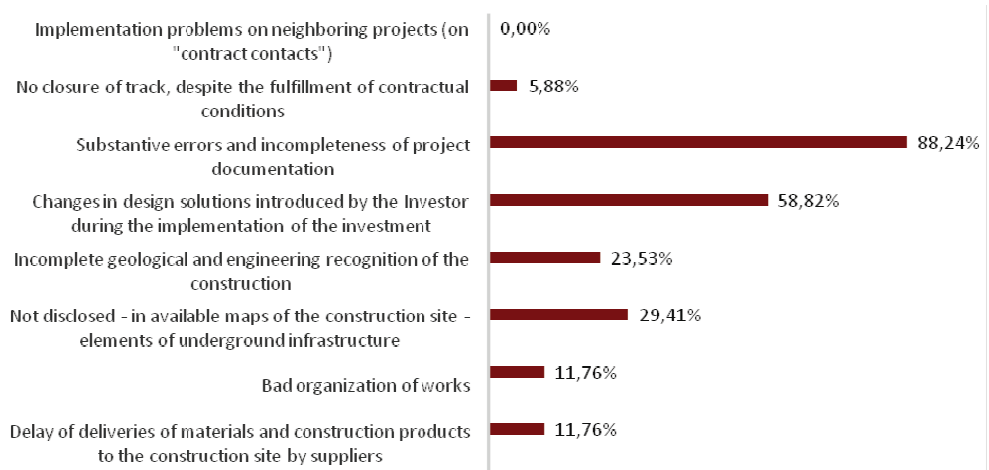


FIGURE 3. Probability of factors causing additional works

- works related to engineering objects;
- road works and railroad crossings;
- works related to the reconstruction of railway connection devices;
- platforms and building works;
- works related to the reconstruction of water-sewage, gas, energy and installation networks;
- preparation of project documentation;
- other works.

In the further part of the research, the same methodology was used as in the case of factors causing additional works, i.e. the estimation of the share of the occurrence of additional works types and the calculation of the probability of their occurrence. It was assumed that one additional job may consist of several types of industry works.

The total number of industrial works occurring in the discussed construction projects included 144 cases. The most frequently appearing type of additional works are "robots related to the reconstruction of railway connection devices", while the least frequent ones are "other works" and "preparation of project documentation". The share of particular types in additional works is presented in Figure 4.

The determination of the frequency of occurrence of particular types of works was related to the determination of the probability of their appearance. It required estimating the number of investments in which a given type of works occurred and the number of all analyzed projects. After performing the calculations, it was found that the most frequently appearing type of industry works are "track and drainage works" and "works related to engineering objects", while the rare are "other works" and "platform and building works". The probability of the occurrence of industrial works in additional works is presented in Figure 5.

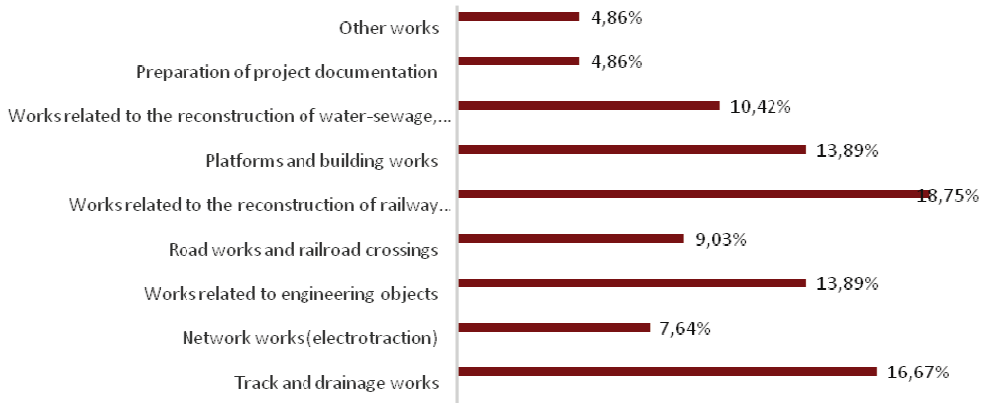


FIGURE 4. Share of the occurrence of types of industry works in additional works

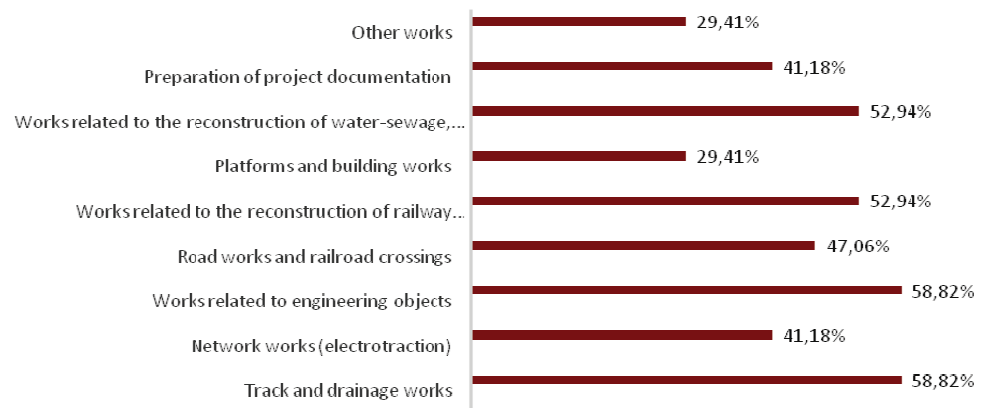


FIGURE 5. Probability of the occurrence of industrial works in additional works

## Recapitulation

The analysis of the selected railway construction projects indicates that additional works are a frequent occurrence during the duration of the investment. It can be concluded that they cause effects not anticipated at the stage of investment preparation (the change of the duration of works and the increase of costs). Some of them significantly deviate from the plans, and therefore may be a problem for the Investor, both in terms of the need for additional financing or the allowed extension of the construction and assembly works.

The most frequently occurring problems include changes made by the investor and errors in the documentation prepared. Both issues depend on the investor, therefore the Investor should exercise due diligence to minimize the risk of these factors.

Effective implementation of strategic investment plans should be preceded by a proper preparation of a construc-

tion project. The authors showed that the inclusion of additional works and their effects is an important factor that the Investor should take into account when estimating the budget and duration of the investment. Despite the completion of all formal requirements and the proper preparation of the project, the risk of additional works is still highly probable with which the Investor should also have the ability to cope.

The presented effects and factors of the occurrence of additional works constitute an important part of the additional risk management strategy developed by the authors in railway construction projects. The construction of the model will require a lot of data, including historical data, presented in the work. Further research by the authors is related to the implementation of qualitative and quantitative features of additional works to the original model of risk estimation.

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## Summary

**Analysis of additional works in completed railway construction projects.** The railway construction investments are characterized by a significant extension of individual phases and an increased number of entities participating in the construction investment process. Despite the use of many modern methods and techniques unforeseen phenomena and events which may occur during the execution of the investment cannot be excluded. All unexpected situations usually initiate consequences in the form of additional workload and costs not included by the contractor and longer duration of works. This fact is commonly referred to as the occurrence of the so-called additional works. The paper presents the results of research concerning additional works occurring during the realization of railway construction projects performed in southern Poland. The analysis was based on data which concerned projects completed in the period from 1 January 2012 to 31 December 2018.

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