Hazards in Realization of Railway Investments Carried Out in Poland Based on Red Book FIDIC Contractual Conditions

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Abstract. The article contains information on identified hazards during the implementation of railway investments in Poland. The study covered investments that were carried out on the basis of the FIDIC Contractual Conditions – Red Book. In recent years, railway investments in Poland have been largely implemented in the Design and Build formula. Unfortunately, this formula is fraught with many hazards, both for the contractor and the contracting entity. The aim of leveling the difficult-to-predict hazards (especially those occurring at the stage of investment implementation), whose effects negatively affect the implementation of investments, contracting entities more and more often decide to implement investments according to the FIDIC Red book. This procedure transfers most of the risk to the contractor, but according to the authors, it is also burdened with numerous hazards, which is demonstrated in the presented results. The research was carried out with the participation of a large group of selected experts and developed statistically. The paper presents a list of hazards with an indication of the frequency of their possible occurrence on future railway investments. The analyses were limited to risk factors resulting exclusively from the specificity of railway investments, omitting classical hazards associated with traditional construction. Statistical analyses were performed using the IBM SPSS Statistics 23 package. It was used to test \(\chi^2\) and a one-way analysis of variance in the intergroup scheme.

1. Introduction

Efficient management of construction contracts requires the use of effective, practical methods and procedures for their implementation. One of them is the implementation of investments based on the FIDIC Contractual Conditions (CC FIDIC) [1,2]. The idea of using CC FIDIC is to facilitate the implementation of the construction investment for all its participants. Currently, the mode of application of CC FIDIC is widely sanctioned not only in Europe but throughout the world. CC FIDIC is a model of international contractual conditions functioning in the construction process [3], which, despite clear regulations regarding the implementation of investments, may also be a source of conflicts.

Procedures of FIDIC contractual conditions have been developed based on many years of experience of engineers and professionals operating in market economy conditions in the scope of conducting various investments, including construction projects. The structure of patterns is divided into three parts: part I - General conditions, part II - Guidelines for preparing special conditions, part III - Forms [4].

Due to the assigned colour of covers for individual patterns, the following words exist in colloquial language:

- Red FIDIC, when works are carried out on the basis of documentation provided by the Contracting Entity,
Orange / silver [4] on the basis of which the contractor carries out not only works, but also the necessary design for them, along with securing a complete supply of equipment. The contractor is also responsible for the start-up and training of the staff supporting the investment,

- Yellow FIDIC on the basis of which the contractor in the first step develops technical documentation and on the basis of it realizes works,
- White FIDIC book regarding supervision over a given investment,
- Green FIDIC covering small investments, so-called short form of the contract.

The main factors determining which patterns of FIDIC conditions should be applied in a specific task (investment) are the type of works (construction, mechanical, electrical) and the distribution of responsibility for the preparation of project documentation [4].

In recent years, construction investments in Poland have largely been implemented in the Design and Build formula, i.e. based on the Yellow Book. Unfortunately, this formula is fraught with many hazards, both for the contractor and the contracting entity. This also applies to railway investments with all the specificity of performing these works [5]. In order to limit a number of risks arising directly at the design stage and errors from this stage, which only become apparent at the execution stage, the contracting entities more and more often decide to submit the project documentation themselves and carry out the investment implementation procedure according to the FIDIC Red Book. This method of contract execution also requires appointing by the contracting entity an independent Contract Engineer with extensive professional experience acting as an effective contract administrator. The Engineer has a wide range of powers. His basic task is in the interest of both parties to administer the contract in an impartial manner, so that the works are performed in accordance with the agreed material scope and at the appropriate quality level, and the contractor receives the remuneration due for the work performed. He also has the power to set additional payments, to a level limited by special conditions or agreement with the contracting entity [4].

Due to the fact that many railway projects will be implemented in Poland in the coming years, planning them requires not only the necessary technical and financial resources, but also proper preparation and implementation. Thus, it is necessary to properly cooperate with the investor and contractors, since only such approach ensures effective and timely execution of the implemented and planned investments. Increasing conflicts of parties may lead to the failure to use EU funds and delay the country's economic development. The source of disputes is often inaccurate and incorrect provisions of contractual conditions that may cause claims between parties during the execution of works. Other authors [3] also pay attention to this aspect. The authors of this article indicate that contract documents may contain additional contractual provisions (general and detailed conditions) that transfer the entire risk related to the contract for the contractor. The confirmation of such approach are the responses of the contracting entity mentioned during the tender procedure. As part of these responses, the Employer indicates that "the Contractor is responsible for all delays regardless of the degree of his fault" [3].

Minimization of the source of disputes requires, among other things, identification of hazards resulting from the specificity of investments undertaken, including railways. This is indicated by research in Poland [5-7] as well as in other countries [8-12]. To this end, the authors attempted to identify and indicate the most likely of them. The described research covered the scope of Contractor's responsibilities related to the implementation of the contract under the Build formula and was aimed at determining those risk factors that may occur during the aforementioned works and have a significant impact on the course and cost of the investment. The results presented in this article are likely to help in the future identify risks in advance, prepare adequate remedies and, as a result, manage risk when planning and implementing Polish railway investments.

2. Methodology of research and development of survey results
Owing to the fact that the implementation of railway investments in Poland is not fully recognized, the first stage of research focused on identifying the most important hazards occurring during their implementation. Data was obtained using a survey, with the participation of carefully selected
respondents (table 1, 2). The selection of appropriate experts participating in the research was a necessary condition for attaining reliable results. They had to be people with extensive administrative, economic and technical experience in performing railway investments, taking into account the occurrence of adverse events and their consequences. The selection of experts concerned people who, on behalf of the Employer, Contractor, Designer or Contract Engineer as part of their professional duties, were responsible for the comprehensive management of railway contracts.

Table 1. Types of functions performed by respondents (party to a contract).

| Percentage of respondents | Respondents’ functions (party to a contract) |
|---------------------------|---------------------------------------------|
| 1                         | 25 % Commissioning Party                     |
| 2                         | 37 % Contractor                              |
| 3                         | 7 % Contract Engineer Office                 |
| 4                         | 31 % Designer                                |

Table 2. The experience of respondents in terms of completed investments (financial scale)

| Percentage of respondents | Internship of respondents [million, PLN] |
|---------------------------|------------------------------------------|
| 1                         | below 10                                 |
| 2                         | 10 to 100                                |
| 3                         | above 100                                |

The final survey was conducted based on a carefully prepared questionnaire, sent to respondents by e-mail. Based on previous studies and literature analysis, the authors proposed a list of factors causing difficulties during the implementation of railway investments in Poland. The questionnaire also took into account the possibility to supplement the proposed list of risk factors and obliged to answer open questions. The study was based on a pre-established four-step process. The individual stages concerned the selection of respondents, conducting a pilot study and two parts of the final study (closed and open questions). The pilot study was conducted with the participation of 4 experts who, during the selection of respondents, received the highest scores in the field of experience. As a result, 85 copies of correctly filled questionnaires were obtained.

3. Results

3.1. The scope of performed analyses

The main purpose of the survey was:

- determining the frequency of occurrence of specific events,
- determining delays due to specific events,
- determining the increase in costs due to specific events,
- determining whether the severity of identified hazards is similar or different.

To accomplish such goals, statistical analyses were performed using the IBM SPSS Statistics 23, where the data were appropriately grouped into numerical sets and developed using appropriate statistical models. They were used to perform χ² tests and one-way analysis of variance in the intergroup scheme, comparing the intergroup variance to the intragroup variance. In a one-factor scheme (one-way analysis of variance), it was checked whether the type of event (independent variable) differentiates the level of weight of a given event (dependent variable). In order to verify which specific events were assessed by the respondents as more or less hazardous to the planned course of work, post-hoc tests were carried out. The necessary condition for making this analysis was to obtain a statistically significant result from the analysis of variance. When interpreting the results of calculations, it should be
remembered that the smaller the level $p$ significance, the smaller the chance that the difference is accidental.

The $\chi^2$ tests were carried out for the tested data on the qualitative scale. They allow to determine if there are stochastic relations between features. With the help of the Cramer $V$ coefficient, the strength of recorded compounds was determined, i.e. if $V = 0 < 0.3$ - weak, $V = (0.3 \div 0.5)$ - moderate, $V = (0.5 \div 0.7)$ - strong, $V = (0.7 \div 0.9)$ - very strong, $V > 0.9$ - almost full relationship. The level of $p < 0.05$ was assumed as the level of statistical significance in the studies.

### 3.2. Analysis of the frequency of occurrence of specific events

In the first phase, the frequency of occurrence of specific events was checked and the analysis was performed using the $\chi^2$ test. A statistically significant result was noted: $\chi^2 (14) = 50.01$, $p < 0.001$, $V = 0.23$ (table 3). This means that individual events occurred with varying frequency during projects. The most frequently occurring events were errors in the preparation of bidding documents and problems with outdated geodetic materials (e.g. underground collisions) that occurred in over 90% of the analysed cases. Incidents that often arose were difficulties in the preparation, in terms of formal, legal and technical areas for investment, errors in project documentation provided by the contracting authority, problems with the supply of materials and other resources, and too many external institutions involved in the investment process. These events occurred in about 80% of cases. On the other hand, the problems with the internal regulations of the main investor (PKP PLK SA) were relatively least frequent, uncoordinated with the provisions of contracts, although it was recorded in more than half of all cases. The strength of the recorded relationship was small, which was confirmed by V Kramer's ratio $= 0.23$.

| Table 3. Prevalence of specific events in questionnaires, where: N - number of questionnaires |
| Description of a studied hazard | Occurrence |
|---------------------------------|------------|
|                                | no  | yes   |
| 1 Errors in the preparation of tender documents (SIWZ, OPZ, PFU). | N 7 | 78 |
|                                 | % 8.20% | 91.80% |
| 2 Improperly estimated time of completion of the investment by | N 18 | 67 |
| the Employer.                   | % 21.20% | 78.80% |
| 3 Too many external institutions involved in the investment process. | N 17 | 68 |
|                                 | % 20.00% | 80.00% |
| 4 Terms of the contract not adapted to the contract specificity (FIDIC Red, FIDIC Yellow, others). | N 23 | 62 |
|                                 | % 27.10% | 72.90% |
| 5 Badly estimated investment costs by the Contractor (financial problems of the Contractor). | N 27 | 58 |
|                                 | % 31.80% | 68.20% |
| 6 Difficulties in the preparation, in terms of formal, legal and technical areas for investment. | N 15 | 70 |
|                                 | % 17.60% | 82.40% |
| 7 Internal regulations of PKP PLK SA not coordinated with the provisions of contracts. | N 36 | 49 |
|                                 | % 42.40% | 57.60% |
| 8 Errors in project documentation. | N 14 | 71 |
|                                 | % 16.50% | 83.50% |
| 9 Problems with the supply of materials and other resources | N 15 | 70 |
|                                 | % 17.60% | 82.40% |
| 10 Awarding shorter track closures to the contractor. | N 18 | 67 |
|                                 | % 21.20% | 78.80% |
| 11 Problems with outdated geodetic materials (numerous collisions with non-inventory of underground infrastructure). | N 7 | 78 |
|                                 | % 8.20% | 91.80% |

### 3.3. Analysis of increased delays due to specific events

After receiving the results from the first analysis, the events that caused delays with similar or different frequency were successively determined. The results of the analysis using the $\chi^2$ test are presented in table 4. The obtained results were determined as statistically significant $\chi^2 (14) = 37.80$, $p < 0.001$, $V =$
0.20. This confirms that individual events with different frequency caused delays. Most often delays were recorded due to errors in the preparation of tender documents. This problem was recorded in as much as 87.1% of cases.

Another problem that strongly affected the deadline was the difficulties with outdated geodetic materials that occurred in 74.10% of the analysed cases. Relatively the least frequent delays occurred due to the internal regulations of PKP PLK SA not coordinated with the provisions of contracts. In addition, it should be noted that all of the hazards analysed caused delays in at least half of the cases.

**Table 4. Frequency of delays resulting from the analysed threats, where: N - number of surveys**

| Description of a studied hazard | Occurrence no | Occurrence yes |
|---------------------------------|---------------|---------------|
| 1 Errors in the preparation of tender documents (SIWZ, OPZ, PFU). | N 11 | 74 |
| 2 Improperly estimated time of completion of the investment by the Employer. | N 23 | 62 |
| 3 Too many external institutions involved in the investment process. | N 33 | 52 |
| 4 Terms of the contract not adapted to the contract specificity (FIDIC Red, FIDIC Yellow, others). | N 26 | 59 |
| 5 Badly estimated investment costs by the Contractor (financial problems of the Contractor). | N 39 | 46 |
| 6 Difficulties in the preparation, in terms of formal, legal and technical areas for investment. | N 24 | 61 |
| 7 Internal regulations of PKP PLK SA not coordinated with the provisions of contracts. | N 40 | 45 |
| 8 Errors in project documentation. | N 23 | 62 |
| 9 Problems with the supply of materials and other resources | N 25 | 60 |
| 10 Awarding shorter track closures to the contractor. | N 23 | 62 |
| 11 Problems with outdated geodetic materials (numerous collisions with non-inventory of underground infrastructure). | N 22 | 63 |

3.4. **Analysis of increased costs due to specific events**

Analysing the impact of individual events on the increase in costs, the tests were again performed using the χ² test and a statistically significant result was recorded: χ² (14) = 82.36, p <0.001, V = 0.30, (table 5). It means that individual events with varying frequency resulted in increased costs of works. The strength of the recorded effect was moderately high. It was found that, as in the case of delays, the increase in costs most often generated errors in the preparation of bidding documents and problems with outdated geodetic materials. This happened in over 80% of cases. On the other hand, the increase of costs was least frequent due to problems with internal regulations of PKP PLK SA, uncoordinated with the provisions of contracts, which resulted in an increase in costs in slightly over 33% of the analysed cases. In less than half of the cases, there was an increase in costs due to the excessive number of external institutions involved in the investment process.
### Table 5. Frequency of increased costs resulting from the analysed threats, where: N - number of surveys

| Description of a studied hazard                                                                 | Occurrence |   |
|-------------------------------------------------------------------------------------------------|------------|---|
| 1 Errors in the preparation of tender documents (SIWZ, OPZ, PFU).                             | N 13       | 72 |
|                                                                                                 | % 15.30%   | 84.70% |
| 2 Improperly estimated time of completion of the investment by the Employer.                   | N 26       | 59 |
|                                                                                                 | % 30.60%   | 69.40% |
| 3 Too many external institutions involved in the investment process.                           | N 45       | 40 |
|                                                                                                 | % 52.90%   | 47.10% |
| 4 Terms of the contract not adapted to the contract specificity (FIDIC Red, FIDIC Yellow, others). | N 31       | 54 |
|                                                                                                 | % 36.50%   | 63.50% |
| 5 Badly estimated investment costs by the Contractor (financial problems of the Contractor).   | N 41       | 44 |
|                                                                                                 | % 48.20%   | 51.80% |
| 6 Difficulties in the preparation, in terms of formal, legal and technical areas for investment. | N 35       | 50 |
|                                                                                                 | % 41.20%   | 58.80% |
| 7 Internal regulations of PKP PLK SA not coordinated with the provisions of contracts.          | N 54       | 31 |
|                                                                                                 | % 63.50%   | 36.50% |
| 8 Errors in project documentation.                                                             | N 26       | 59 |
|                                                                                                 | % 30.60%   | 69.40% |
| 9 Problems with the supply of materials and other resources                                   | N 20       | 65 |
|                                                                                                 | % 23.50%   | 76.50% |
| 10 Awarding shorter track closures to the contractor.                                         | N 24       | 61 |
|                                                                                                 | % 28.20%   | 71.80% |
| 11 Problems with outdated geodetic materials (numerous collisions with non-inventory of underground infrastructure) | N 16       | 69 |
|                                                                                                 | % 18.80%   | 81.20% |

#### 3.5. Weight analysis of specific problems

During the last analysis, a one-way analysis of variance in the intergroup scheme was performed. This study was carried out to determine whether the weight of specific problems is similar or different. Because there were statistically significant results $F(10, 924) = 8.27, p < 0.001, \eta^2 = 0.08$ (table 6) post-hoc analysis of the Sidak test was possible. In this analysis, comparisons were made of each event and the most statistically significant differences are indicated below:

- errors in the preparation of tender documents was assessed as being more threatening than internal regulations of PKP PLK SA uncoordinated with the provisions of contracts ($p < 0.001$);
- improper estimation of the deadline for preparing project documentation by the Employer was significantly less important than problems with outdated geodetic documents ($p = 0.026$); on the other hand, more important than the internal provisions of PKP PLK SA, uncoordinated with the provisions of contracts ($p = 0.006$);
- too many external institutions involved in the investment process were less important than errors in the project documentation ($p = 0.007$), problems with the supply of materials and other resources ($p = 0.001$), granting shorter track closures ($p = 0.008$) and problems with obsolete geodetic materials ($p < 0.001$);
- contract terms not adjusted to the contract specificity were more significant than the internal provisions of PKP PLK SA uncoordinated with contract entries ($p < 0.001$);
- misestimate investment costs by the Contractor were more significant than the internal provisions of PKP PLK SA uncoordinated with the provisions of contracts ($p < 0.001$);
- difficulties in preparing, in terms of formal, legal and technical areas for investment, were more important than the internal provisions of PKP PLK SA uncoordinated with the provisions of contracts ($p < 0.001$);
internal provisions of PKP PLK SA uncoordinated with the provisions of contracts were considered to be less significant than errors in the project documentation (p <0.001), problems with the delivery of materials and other resources (p <0.001), granting shorter track closures (p <0.008) and problems with outdated geodetic materials (p <0.001).

Table 6. Importance of defined events where: M – importance of a problem, SD – standard deviation

| Description of a studied hazard                                                                 | M   | SD  |
|-------------------------------------------------------------------------------------------------|-----|-----|
| 1 Errors in the preparation of tender documents (SIWZ, OPZ, PFU).                              | 5.40| 3.40|
| 2 Improperly estimated time of completion of the investment by the Employer.                    | 4.91| 3.46|
| 3 Too many external institutions involved in the investment process.                            | 3.80| 3.15|
| 4 Terms of the contract not adapted to the contract specificity (FIDIC Red, FIDIC Yellow, others).| 5.36| 3.31|
| 5 Badly estimated investment costs by the Contractor (financial problems of the Contractor).    | 5.28| 3.20|
| 6 Difficulties in the preparation, in terms of formal, legal and technical areas for investment. | 5.36| 3.07|
| 7 Internal regulations of PKP PLK SA not coordinated with the provisions of contracts.          | 2.93| 3.21|
| 8 Errors in project documentation                                                             | 5.76| 3.54|
| 9 Badly estimated investment costs by the Contractor (financial problems of the Contractor).   | 6.00| 3.57|
| 10 Awarding shorter track closures to the contractor.                                           | 5.74| 3.69|
| 11 Problems with outdated geodetic materials (numerous collisions with non-inventory of underground infrastructure). | 6.69| 2.94|

4. Results and discussions
The article presents the results of extensive research in the field of hazards that occurred during the implementation of railway investments in Poland and had an impact on the extension of the planned date of their completion and increase in costs. The research concerned railway facilities implemented in the Build formula. In the presented part of the research, only those hazards that may occur at the stage of the works' implementation are taken into account and result from the specifics of this type of investment.

The analysis presented in the article clearly indicates that the assessed hazards are statistically significant and can have a significant impact on the course of railway investments. The most important hazards, which in the authors' opinion may significantly affect future railway investments and were indicated by respondents as hazards of the highest importance are: problems with the supply of materials and other resources, problems with outdated geodetic documents (numerous collisions with non-inventory of underground infrastructure), errors in project documentation and awarding the contractor shorter track closures than planned. As the rarest hazards, the following were indicated: internal regulations of the main railway investor in Poland (PKP PLK SA) uncoordinated with the provisions of contracts, too many external institutions involved in the investment process and improperly estimated time of completion of the investment by the Employer.

The indicated hazards result strictly from the specificity of railway investments. Some of them, both contractors and investors, may have a direct impact on the planning and execution stage (e.g. track closures). There are also those on which neither party has a big influence (e.g. availability of subcontractors). It should also be noted that in the current period, when a very large number of infrastructure investments is planned and implemented in Poland, the supply of some building materials (e.g. aggregates) may become one of the greatest hazards to meeting the planned dates and costs of these investments.
5. Conclusions
Due to the high assessment of the weights of the analysed hazards, during the planning of future railway investments, particular attention should be paid to the hazards that during the study were determined with the average importance of the problem M above 5.28 (table 6, figure 1). These hazards, when planning and developing schedules of future railway investments, should be secured with appropriate time-cost buffers [13,14], the use of which should be constantly monitored during the execution of construction works.

In order to better identify problems related to the risk of railway investments in Poland, the authors expect further research in this area.

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