Method of Assessing the Risk of Implementing Railway Investments in Terms of the Cost of Their Implementation

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Abstract: Exceeding the approved budget is often an integral part of the implementation of construction projects, especially those where unforeseen threats may occur. Therefore, each construction investment should contain elements of risk forecasting, mainly in terms of the cost of its implementation. Only a small number of institutions apply effective cost control methods, taking into account the specifics of a given industry. Especially small construction companies that participate in the structure of the implementation of large construction projects as subcontractors. The article presents a method by which it is possible to determine, with certain probability, the final cost of railway construction investments carried out in Poland. The method was based on a reliable database of risk factors published in sources. In this article, the main presumptions of the original method are presented, which take into account the impact of potential, previously recognized, risks specific to railway investments, and enable project managers to relate them to the conditions where the implementation of a specific object is planned. The authors assumed that such a relatively simple method, supported by a suitable computational program, would encourage teams that plan to implement railway projects to use it and increase the credibility of their schedules.

Keywords: threat identification; railway investments; risk; construction works planning; risk matrix

1. Introduction

Sustainable development is considered one of the major global challenges facing the world today and is an important aspect of transport development. As the most environmentally friendly transport, rail transport has an important role in creating sustainable lifestyles and economies. From the point of view of the national economy, the development of the transport sector is a key process in which many other sectors are involved. When properly organized and coordinated, sustainable development of the transport sector leads to synergies with other sectors [1]. Various issues related to the sustainable development of railways have already been the subject of research by scientists.

Zeng et al. noted that using trains to move passengers and goods helps protect the environment by reducing energy consumption and emissions of pollutants such as CO₂ into the atmosphere [2]. Nachtigall et al. emphasized that rail transport is the most environmentally friendly form of land transport, but that, in recent decades, the growth of individual road and air transport can also be observed [3]. Given its lower environmental impact and high traffic volume, rail transport can become an important sustainable system in the future [4]. Thus, the use of rail transport is an important way to reduce energy consumption and emissions of pollutants into the atmosphere.

The experience from previous EU subsidies (2013–2021) showed that, during the implementation of railway investments in Poland, all parties to the investment process encountered a number of random risks not previously taken into account, which affected the extension of the completion date of the investments and increase in the planned cost.
In the future, however, railway investments in Poland will be very limited. This may result from the currently implemented European funds, which in the future will be redirected to other member states. Contracts of this type will be largely financed by the main Polish investor, PKP PLK S.A. That is why Polish companies should create added value today, so that they are ready not only to survive on the domestic railway investment market, but also to actively compete in other parts of Europe or the world. A situation in which international construction companies cease operations in Poland and move to other places and domestic contractors without the appropriate technological, financial, or logistic potential, which will be reduced to the role of their subcontractors or suppliers, without the possibility of applying for them applying for their own large infrastructure contracts, cannot be allowed [5]. Therefore, if you want to build the railway infrastructure to be used in the next several dozen years, you need to be able to foresee the risks that may arise during the implementation of these investments and properly prepare investment plans. For example, in terms of the cost of their implementation.

The literature provides many methods of cost control. The source [6] presents the analysis of costs and emissions of greenhouse gases, while the authors of the paper [7] present optimal Pareto decisions explained in cases connected with construction costs. The source [8] also presents original Model for Estimating the Whole Life Costs of Buildings, and support of the implementation of construction projects. The PMI [9] and Prince 2 methodology [10] are the examples. These methods are often universal and can be adapted to any type of facility. One of them is the earned value method (EVM or EV) and its extensions [11–13]. Additionally, the source [14] presents the estimation of the range of construction costs after completion of the construction works. The method is well known and is applied to control objects in terms of cost and time. Reports, available in international publications, indicate great popularity of the method and the positive effects of its use. Most of the research concerned interdisciplinary fields [15,16]. A relatively small part of the studies concerned construction projects and the possibility of adapting the method to the conditions prevailing during their implementation. In the literature, the method has not been applied in the field of complex investments, such as railway investments. In the current literature review in the field of railway investments, the planning process showed, for example, information on: identifying the critical risks in railway projects implemented under belt and road initiative (BRI) [17], risk analysis of the railway transportation [18], an assessment approach for environmental risk [19], a method for the control-command and signaling functions [20], the modelling of risk using fuzzy logic [21], or information about a social network analysis on a construction project [22,23].

By filling the gap in forecasting the costs of implementing construction projects, especially in the field of railway investments, the article presents an original method for planning railway investments, taking into account the conditions for their implementation in Poland. The method was called the Railway Matrix of Risk Factors (RMRF) [24]. Forecasting the real costs of completing railway investments is based on a reliable database with regard to specific risk factors. These factors have been identified nationwide. This was done on the basis of extensive research on domestic and foreign literature [5,25], an analysis of contract documents of one of the biggest railway investments in Poland, and a nationwide survey [24]. The study was conducted among carefully selected engineers participating in the construction processes of railway facilities, representing all sides of the investment process. The obtained data were grouped into sets and, afterwards, were developed through the use of proper statistical models that are available in the IBM SPSS Statistics 23 package [25]. The results of these analyses are lists of risk factors which most often have a massive impact on the course of works on railway contracts in Poland, according to the research. The lists, along with identified risk factors, have been published, inter alia, in the source [26].

The risk assessment relates to the “Design and Build” and “Build” contract performance formulas. The general assumption of the method is the correlation of the identified risk factors with the conditions and specificity of the implementation of planned invest-
ments. A detailed description of this method is presented in the source [24]. The schematic diagram (Figure 1) shows the consecutive calculation steps assigned to the two main blocks. The first is a fixed block (quantitative analysis), not subject to changes during its implementation. It contains the most important identified risk factors and their initial quantitative assessment. The final result is the determination of a risk index, which is allocated successively in the material and financial schedule (HRF) of a given investment.

Figure 1. Conceptual model of the proposed method for risk assessment. Source [24].

The second is a variable (qualitative analysis) block and the risk assessments adopted there is dependent on the manager who creates the schedule and his decisions.

In order to increase the utilitarian value of the method, it was designed so that the impact of the identified risk factors on the implementation of a railway undertaking could be assessed from both the point of view of investors and contractors.

2. Materials and Methods

The next step of the proposed method aimed to determine the quantitative assessment of the individual risk factors. This was carried out on the basis of the statistical analysis of obtained results of the research and the adopted assumptions. Below, the most important calculation formulas applied are presented. First, the data were normalized. Then, individual normalized values were aggregated successively.
The value-standardized impact of each risk factor $QD_i$ was calculated according to the following formula:

Design stage

$$QC_i^D = \frac{QnC_i^D}{I^D}$$  \hspace{1cm} (1)

Build stage

$$QC_i^B = \frac{QnC_i^B}{I^B}$$  \hspace{1cm} (2)

where:

$QC_i^D, QC_i^B$—standardized impact of the $i$-th risk factor at the Design ($QC_i^D$) or Build stage ($QC_i^B$) that affects the investment cost;

$QnC_i^D, QnC_i^B$—non-standardized impact of the $i$-th risk factor at the Design ($QnC_i^D$) or Build stage ($QnC_i^B$) that affects the investment cost;

$I^D, I^B$—the number of surveys for the assessment of risk factors at the Design ($I^D$) or Build stage ($I^B$).

The coefficient of variation of each risk factor was calculated:

Design stage

$$V_i^D = \frac{SD_i^D}{M_i^D}$$  \hspace{1cm} (3)

Build stage

$$V_i^B = \frac{SD_i^B}{M_i^B}$$  \hspace{1cm} (4)

where:

$V_i^D, V_i^B$—coefficient of variation of the $i$-th rating of the risk factor at the Design or Build stage;

$SD_i^D, SD_i^B$—standard deviation of the assessment of the $i$-th risk factor at the Design or Build stage;

$M_i^D, M_i^B$—average point estimate of the $i$-th risk factor at the Design or Build stage on a 0–10 scale.

The final weight of each risk factor that was calculated as:

Design stage

$$WC_i^D = QC_i^D$$  \hspace{1cm} (5)

Build stage

$$WC_i^B = QC_i^B \cdot \left[ M_i^B - \left( M_i^B \cdot V_i^B \right) \right]$$  \hspace{1cm} (6)

where:

$WC_i^D, WC_i^B$—weight value of the $i$-th risk factor for the Design or Build stage phase affecting the investment cost.

The final, normalized weight value of individual threats was computed as:

Design stage

$$WCh_i^D = \frac{WC_i^D}{\sum_{i=1}^{N^D} WC_i^D}$$  \hspace{1cm} (7)

$$\sum_{i=1}^{N^D} WCh_i^D = 1$$  \hspace{1cm} (8)

Build stage

$$WCh_i^B = \frac{WC_i^B}{\sum_{i=1}^{N^B} WC_i^B}$$  \hspace{1cm} (9)

$$\sum_{i=1}^{N^B} WCh_i^B = 1$$  \hspace{1cm} (10)
where:

\( WCn^D_i, WCn^B_i \) — normalized weight of \( i \)-th risk factor that affects investment duration (\( WD \)) or cost (\( WC \)) for Design (\( n^D \)) or Build (\( n^B \)) stage;

1—1 \( \ldots \) \( N^D \), 1 \( \ldots \) \( N^B \) where \( N \) stands for a number of identified risk factors in Design or Build stage.

Risk assessment for certain risks:

**Design stage**

\[ R^C_{iD} = P^D(a_i) \cdot C^C_{iD}(a_i) \]  
(11)

**Build stage**

\[ R^C_{iB} = P^B(a_i) \cdot C^C_{iB}(a_i) \]  
(12)

where:

\( R^C_{iD}, R^C_{iB} \) — risk of \( i \)-th factor for Design or Build stage that affects investment cost [%];

\( P^D(a_i), P^B(a_i) \) — the probability of occurrence of \( i \)-th risk factor (designated based on a nationwide survey) in the stage of Design or Build;

\( C^C_{iD}(a_i), C^C_{iB}(a_i) \) — a consequence of influence of \( i \)-th risk factor on implementation of the undertaking made by team implementing a given project, for Design \( C^C_{iD}(a_i) \) or Build \( C^C_{iB}(a_i) \) stage, that affects investment cost [%].

Weight assessment of the risk factor:

**Design stage**

\[ W^C_{iD} = R^C_{iD} \cdot WCn^D_i \]  
(13)

**Build stage**

\[ W^C_{iB} = R^C_{iB} \cdot WCn^B_i \]  
(14)

where:

\( W^C_{iD}, W^C_{iB} \) — index of weight-based risk assessment for \( i \)-th factor at the Design or Build stage; that affects the cost investment [%].

Total weighted risk:

**Design stage**

\[ S^C_{iD} = \sum_{i=1}^{N^D} R^C_{iD} \cdot WCn^D_i \]  
(15)

**Build stage**

\[ S^C_{iB} = \sum_{i=1}^{N^B} R^C_{iB} \cdot WCn^B_i \]  
(16)

where:

\( S^C_{iD}, S^C_{iB} \) — total weighted risk of a construction project at the Design or Build stage that affects the cost investment [%].

After quantifying the risk factors, they are linked with specific tasks in material and financial schedule (HRF). This is a step to be taken by the manager who plans the project. Therefore, it is crucial to find answers to which risk factors affect the individual real tasks in the HRF (Tables 1 and 2).

**Table 1.** Sample correlation of real tasks of the summary task X with risk factors. Own study based on the source [27].

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Correlation of Risk Factors with the Schedule (with Real Tasks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>( a, c )</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( c )</td>
</tr>
<tr>
<td>( a_3 )</td>
<td>( b, c, d )</td>
</tr>
<tr>
<td>( a_4 )</td>
<td>( a, c )</td>
</tr>
<tr>
<td>( a_5 )</td>
<td>( c, d )</td>
</tr>
<tr>
<td>( a_6 )</td>
<td>( d )</td>
</tr>
<tr>
<td>( a_7 )</td>
<td>( c, d )</td>
</tr>
</tbody>
</table>
Table 2. Sample allocation of risk factors in the HRF structure.

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Risk Factors Affecting Individual Tasks</th>
<th>$\sum_{j=1}^{Z} W_{Ri}^{p} \cdot K_{1}$</th>
<th>$K_{1}$</th>
<th>$K_{2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary task X (Id = 1.1)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Id = 2.1.1 a</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Id = 2.1.2 b</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
<td>WR_{j}^{p}</td>
<td>WR_{i}^{p}</td>
</tr>
<tr>
<td>Id = 2.1.3 c</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
</tr>
<tr>
<td>Id = 2.1.4 d</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
<td>WR_{i}^{p}</td>
</tr>
</tbody>
</table>

Then, we allocate the Risk Index in the material and financial schedule. In the next step, we calculated the most likely cost of completing the task for each actual activity, taking the risk factors into account. We made the calculations according to the following formulas:

**Design stage**

$$K_{2,j}^{D} = K_{1,j}^{D} + \left( \sum_{i=1}^{Z} W_{Ri}^{p} \cdot K_{1,i}^{p} \right)$$

**Build stage**

$$K_{2,j}^{B} = K_{1,j}^{B} + \left( \sum_{i=1}^{Z} W_{Ri}^{p} \cdot K_{1,i}^{p} \right)$$

where:

- $K_{1,j}^{D}, K_{1,j}^{B}$—the original cost of the $j$-th task;
- $K_{2,j}^{D}, K_{2,j}^{B}$—the most probable cost of $j$-th task including risk factors;
- $W_{Ri}^{p}$—index of weight-based risk assessment for $i$-th factor, affecting cost investment [%],
- $Z$—number of risk factors.

To facilitate the application of the computations, we developed a special calculation sheet in Excel, in which user-defined data calculates the percentage index of weighting for individual risk factors and the costs of individual stages of work. The results we obtained are strictly dependent on defined threats and the assessment of their occurrence and the effects on the analyzed project. A comprehensive description of the tool will be presented in subsequent publications.

When implementing the method, the user is only required to specify the consequence of the impact of a given risk factor ($C$), which should be entered in a specially defined field (Figure 2, column 9). The remaining elements were determined on the basis of the proposed Equations (1)–(18).

It should be emphasized that the necessary step to use the recommended sheet must be a thorough identification of the conditions of the implementation of the investment planned. It should cover all aspects that may affect the course of the implementation of the future investment, that is: technical, financial, legal, organizational, and technological ones. Correct identification of these conditions will be facilitated by a query of all available documentation, and its results will allow the analysis team to determine the consequences of the impact of a given risk factor on the planned investment. It is important that these activities are performed as a team. This helps to minimize the impact of the subjective assessments of individual experts, which is a disadvantage of risk scoring.
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Only a combination of these two elements: a general assessment of individual threats contained in the matrix and a subjective assessment, considering the conditions for the implementation of the investment planned, should, in the mind of the authors, allow to precisely define the elements of risk of the analyzed investment and undertake adequate preventive measures in a form of reserve funds.

3. Results

The method of calculating the probable costs of the investment implementation on the basis of the proposed method will be presented on the example of the material and financial schedule for the construction of the E20 railway line—OPI & E project 7.1–9.1. The contract was performed according to the FIDIC yellow book of procedures, which is in the “Design and Build” system.

As the entire detailed schedule included many tasks, the article presents an exemplary analysis of its fragment concerning the track industry “Railway pavement and roadbed—railway station No. 1”.

In accordance with the assumptions of the method, in the first step, the risk matrices were completed in terms of the consequences of the impact of individual risk factors on the tested object (Figure 2, column 9).

Successively, after the identification and quantification of risk factors, correlation was made with specific operations in the construction project implementation process (Table 3). Then, the previously designed calculation sheet (Table 3, column 17) determined the most probable cost of completing individual tasks.

![Figure 2. Risk matrix. “Build” stage. Own study.](image-url)
Table 3. Risk matrix. “Build” stage. Own study.

<table>
<thead>
<tr>
<th>No</th>
<th>Levels and Numbering According to HRF</th>
<th>Risk Index [%]</th>
<th>Total%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WR 1BD</td>
<td>WR 2BD</td>
</tr>
<tr>
<td>1</td>
<td>Build stage</td>
<td>6.10</td>
<td>1.03</td>
</tr>
<tr>
<td>2</td>
<td>RAILWAY SURFACES AND TRACKS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1-Railway station nr 1</td>
<td>6.10</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>PHASE I: Main main tracks.</td>
<td>6.10</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>PHASE II: Main main tracks.</td>
<td>6.10</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>PHASE I: Main additional and station tracks.</td>
<td>6.10</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>PHASE II: Main additional and station tracks.</td>
<td>6.10</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>PHASE I: Demolition of turnouts; disassembly, removal, and utilization of unnecessary materials.</td>
<td>6.10</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PHASE II: Demolition of turnouts; disassembly, removal, and utilization of unnecessary materials.</td>
<td>6.10</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>54.5%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

1 RAILWAY SURFACES AND TRACKS
2 1-Railway station nr 1
3 PHASE I: Main main tracks. 6.10 - - 3.11 - 1.46 2.01 - 2.50 - 17.39 32.57 1,332,661 4,091,413 5,424,075
4 PHASE II: Main main tracks. 6.10 - - 3.11 - 1.46 2.01 - 2.50 - 17.39 32.57 1,332,661 4,091,413 5,424,075
5 PHASE I: Main additional and station tracks. 6.10 - - 3.11 - 1.46 2.01 - 2.50 - 17.39 32.57 2,581,508 7,925,505 10,507,014
6 PHASE II: Main additional and station tracks. 6.10 - - 3.11 - 1.46 2.01 - 2.50 - 17.39 32.57 2,581,508 7,925,506 10,507,014
7 PHASE I: Demolition of turnouts; disassembly, removal, and utilization of unnecessary materials. 6.10 - - 3.11 - 1.46 2.01 - 2.50 - 17.39 32.57 2,881,061 8,845,165 11,726,226
8 PHASE II: Demolition of turnouts; disassembly, removal, and utilization of unnecessary materials. 6.10 - - 3.11 - 1.46 2.01 - 2.50 - 17.39 32.57 2,881,061 8,845,165 11,726,226
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<th>No</th>
<th>Risk Index [%]</th>
<th>Total%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.10</td>
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<td>1.46</td>
</tr>
<tr>
<td>3</td>
<td>2.01</td>
<td>2.50</td>
</tr>
<tr>
<td>4</td>
<td>7.17</td>
<td>2.50</td>
</tr>
<tr>
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<tr>
<td>8</td>
<td>13,590,461</td>
<td>41,724,169</td>
</tr>
<tr>
<td>9</td>
<td>55,314,631</td>
<td>55,314,631</td>
</tr>
</tbody>
</table>

[1] - [17]
As a consequence of the above actions, project teams receive the probable costs of all real tasks, which, when put on the baseline, create an updated version of the HRF. From a schedule prepared in this way, it is very easy to read the calculated values of deviations from the base, original implementation costs.

4. Discussion

The use of the Railway Matrix of Risk Factors method, or any other method, does not result in 100% certainty of the forecast made in terms of risk analysis, and certainly its complete elimination. In American publications, you can find the sentence: “Unfortunately, many people have mistakenly assumed that Risk Analysis techniques are magic—black boxes” [28]. This means that the risk analysis is not a magic box that provides comprehensive, unambiguous answers and directions on how to respond to given threats. Therefore, one should carefully follow the progress of works, e.g., by analyzing the material and financial schedule.

The material and financial schedule should reflect the planned structure of the project, their times and deadlines, as well as the planned costs. The material and financial schedule presents a project divided into activities with a possible division into subtasks, so that it shows the full dimensioned scope of activities and all costs necessary for their implementation. Schedules that can be used to predict deviations from the baseline plan with a certain degree of probability should be of particular importance. Undoubtedly, reliable databases on potential risk factors are of great help in this regard. It should be remembered that each implementation of a construction project is different from the previous one, and that the risk factors are difficult to identify. Therefore, new, easy-to-use methods are constantly searched for, where data transformation is based on a reliable database.

The aim of the authors was to present a method that will enable its future users to reliably estimate the cost of a given investment project even before its commencement. An important element increasing the utilitarian nature of the method was its ease of use. It was assumed that the easy-to-apply method would be more willingly implemented by teams planning Polish railway undertakings. The great advantage of the proposed method is that it can be used by all parties for a given investment process.

When performing analyzes using the RMRF method, it should be remembered that the end result is strictly dependent on the reliability of the data that is adopted by the users of the method. It is the users who decide on the correlation of risk factors with given items in the material and financial schedule and on assigning the expected consequences of their impact on the costs of individual tasks.

It is worth noting that research on the identification of risk factors was carried out in other countries. For example, in Afghanistan [29], researchers compiled a list of 81 causes of delays. Scientists in India [30] have developed 45 various possible causes. Researchers from Jordan [31] received 12 potential risk factors as a result of specific research. Threat recognition studies were also conducted in Turkey [32], Malaysia [33], Ghana [34], Nigeria [35], and even Thailand [36] and Zambia [37]. All the exemplary studies, however, concerned general investment problems and were not correlated with a specific method of planning construction projects. Thus, the conducted literature review proved that, despite the fact that, so far, many studies in the field of research on risk factors have been published, there is still no list of threats to specific railway investments.

5. Conclusions

Despite the very dynamic development of science in the field of risk management, there is still a lack of methods based on the currently recognized diseases on the market. The available methods do not have adequate so-called advisory databases (i.e., databases of identified, current threats for a given segment of the construction market). The authors believe that the reason for this situation are the difficulties in obtaining reliable databases, which should be adapted to a given type of construction project (hydrotechnical, teletechnical, demolition).
The method proposed in this article solved the above problem in the field of Polish railway investments. As mentioned, the starting material for the design of the mateda are the currently identified risk factors (Figure 2, column 2). A very big advantage of the RMRF method is that the factors were obtained nationwide (Poland) with the participation of practitioners with many years of professional experience. Representatives of the largest public investor Polish State Railways (PKP S.A.) also participated in the survey. The article presents only the main assumptions of the method, which are the result of extensive research exhaustively described in the source [24].

According to the sensitivity analysis, within the scope of the example described in this article, the most critical risk factors contribute to the highest cost increase of the exemplary investment (risk factors with the highest WRICB). The three risk factors with the higher risk index are: Problems with outdated geodetic materials (numerous collisions with non-inventory of underground infrastructure (where WRICB = 17.39%); Awarding shorter track closures to the contractor (where WRICB = 7.21%); Errors in project documentation (where WRICB = 7.17%). The risk factor with the lowest risk index value is improperly estimated time of completion of the investment by the Employer (where WRICB = 1.03%).

Based on the calculations made, a significant increase in costs, compared to the baseline can be noticed. Originally, the sum of the costs of the analyzed tasks amounted to PLN 41.7 mln, while after the analysis it was PLN 55.3 mln. The analyzed amounts are net amounts. The increase in costs is at a level of approx. 32.5%. Therefore, in order to secure the implementation of the analyzed investment with reserve costs, it is necessary to increase the costs by approx. PLN 13.6 mln.

The broader studies performed by the authors give grounds to believe that the risk factors identified by them and the method of determining probable investment costs proposed in the article may significantly increase the credibility of planned railway investment costs in Poland and significantly affect the implementation of construction investments.

The calculation example proposed in the article did not include the issue of combining the value of cost contingency with the duration of works and time contingency.

However, the presented RMRF method has some limitations. The authors are aware that the current list of risk factors becomes obsolete after some time. Therefore, in the future, the design of a program for the automation of risk factors is planned.

Additionally, research is being conducted on the application of the method to the risk analysis of engineering projects implemented with the participation of subcontractors.

Author Contributions: J.K. designed the method, M.P.—conducted a numerical analysis, M.L.-S.—collected the material, R.T.—gave valuable tips during the research, G.W.—conducted a literature analysis. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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