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Risk Assessment in Sustainable Infrastructure Development Projects: A Tool for Mitigating Cost Overruns

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Abstract: The persistent decline in infrastructure spending, notably within the transportation sector, raises concerns about governments' capacity to meet the demands of a sustainable growing economy. The incorporation of risk assessment in the analysis and computation of potential cost overruns emerges as an effective and efficient tool, underpinning the economic and financial sustainability of infrastructure expansions. Focusing on the "State Road No. 51 of Alemagna Vittorio Veneto" (SSv-51) variant, this study analyzes and proposes a model to forecast the possible cost overruns of an infrastructure project. The application of the risk assessment tool proposed by the National Anti-Corruption Authority (ANAC) offers valuable insights into potential risks associated with project costs and their valuation. The matrix developed in the current study draws from the ANAC Matrix, which comprises four categories of risk divided into 21 risk types. The selection is based on the project's characteristics, and a matrix is compiled that forecasts the combination of the probability of risk occurrence and the cost impacts on the project. The proposed risk matrix serves as a practical tool for managing uncertainties and estimating potential cost overruns, estimating ex ante a possible cost increase of 7.53%. This projected increase differs only by 1.34% from the final execution costs, mitigating the unforeseen cost overruns not estimated by the initial project. The proposed risk assessment tool emphasizes the importance of integrating risk management into project planning and execution. The research investigated an applied case utilizing an easily adaptable tool, suitable for potential future implementation, further advancement, and broader testing across various project samples in the future. The study provides a framework to assess and mitigate risks linked to cost overruns. As nations navigate infrastructure development complexities, proactive risk management practices are indispensable for efficient resource management, ensuring the economic and financial sustainability of these complex projects.

Keywords: sustainable projects; risk assessment; probability; impact; matrix index; cost overrun; infrastructure project

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1. Introduction

An adequate and advanced infrastructure system plays a pivotal role in a country's development, serving as an essential prerequisite for realizing its economic and environmental potential. In general, an adequate infrastructure and transportation services system is a key element for fostering smart, sustainable, and inclusive economic growth. Furthermore, the transportation sector significantly influences economic development and societal well-being. Infrastructure development generates value and contributes to the economic growth of countries, resulting in direct and indirect outcomes such as GDP growth, job creation, increased productivity, and the promotion of competitive cooperation.

Currently in Italy, there has been a consistent decline in investment spending on infrastructure over the years. Despite road and highway infrastructure handling over 90% of passenger transportation and 55% of freight transportation in 2019, the transportation sector's share in total expenditure across all sectors has steadily decreased from 2007 to the present day. The peak of 4.5% in 2007 has declined to an average just above 3% between 2011 and 2020 (the latest available data), marking an average annual contraction of nearly 2.8%. This rate is five times higher than the rate at which the GDP decreased during the same period [1]. This negative trend has been prevalent, albeit to a lesser degree, within the Eurozone as well, with Spain and Greece experiencing the most significant contractions. Furthermore, according to the last report released by the European Union in 2019, Italy's performance falls below the EU average in all the key infrastructure quality indicators [2]. In 2021, Italy's average infrastructure spending, as a percentage of the country's GDP, stood at 0.9%, approximately five times lower than China's (4.8%). Italy's performance was similar to that of France, the United Kingdom, and Russia, but over 50% higher than that of the United States, at 0.5%. (0.5%). The data just reported highlight a national scenario that, for almost a decade, has seen a decrease in allocated resources for infrastructure projects, despite the high demand for interventions in this sector. This reduction in funds necessitates a more meticulous analysis of both their allocation and subsequent monitoring. Considering the above-mentioned limited financial resources, prudent and effective spending and management become of paramount importance. It is well known that in infrastructure projects, significant issues like cost and time overruns can occasionally result in project failure or suspension. The current study is centered on the ex ante assessment of potential cost overruns within a transportation infrastructure project. The primary objective of this paper is to determine whether utilizing a user-friendly risk assessment tool, designed for smaller public administrations, allows for the ex ante estimation of potential project cost increases (cost overruns). The selected risk tool, developed in this research, originates from the risk matrix proposed by the National Anti-Corruption Authority (ANAC). This matrix considers the probability of occurrence and the impact scale of various cost categories of public works. We applied this risk management tool to a specific case study, namely, the variant of the "State Road No. 51 of Alemagna Vittorio Veneto" (SSv-51). After identifying risk elimination or mitigation strategies, a risk matrix was constructed to catalog and assess each risk based on its probability of occurrence and expected impact on the project. Given the stochastic nature of unexpected events, risk evaluation was carried out on a probabilistic basis, estimating the likelihood of adverse situations challenging predictive success. The exante project's risk assessment was supported by drafting an impact/probability matrix. Risks with higher potential impact and a greater probability of occurrence are pinpointed. Subsequently, these risks are quantified by converting them into a percentage impact on the initial cost, relative to their probability of occurring. Finally, the estimated risk value will be compared (i) with the ex ante cost estimation, specifically with the "Contingencies" category included in the project developer's schedule, and (ii) with the costs recorded post-project completion. This application allows for the ex ante estimation of possible cost overruns, which are not assessed in the initial project but actually occur during the construction of the work.

There are five sections in this study. Following the introduction in Section 1, Section 2 details a literature review on cost overruns, and Section 3, after presenting the case study and data, describes the materials and methodology. Section 4 deals with the results obtained and presents a discussion focusing on the estimated risk value and effective cost overrun that occurred during the project's realization. Section 5 discusses the conclusion, limitations, and future research direction.

2. Literature Review

A cost overrun, also known as cost escalation or budget excess, arises when unforeseen expenses exceed the initially estimated amount. This increase often stems from underestimating actual costs during the budgeting phase, resulting in a situation where project objectives exceed the projected budget [3]. Cost overrun can be measured in absolute monetary terms or as a percentage between the excess of actual cost over the budget/estimation or over the contract [4]. The intricate and dynamic nature of construction projects, especially in large and complex projects such as infrastructures ones, has historically presented challenges leading to cost overruns [5]. Managing cost escalations, typically linked to project complexity and risk uncertainty in large projects, involves developing contingency plans to manage risks in such contexts [6].

The literature on cost overruns predominantly branches into two areas: one centered on developing new models and methodologies for ex ante risk assessment, and another focused on ex post assessment, particularly identifying risk cost categories highly impacting construction costs. In the former group of research, numerous studies focus on developing suitable models to assess cost overrun risks, aiming to understand their origins linked to project complexities and uncertainties [7–12]. Several innovative approaches have emerged for managing cost overrun including structural equation modeling, Monte Carlo simulation, decision support system tools, and the use of multi-criteria decision model techniques [13–18]. Recent publications have extensively explored the applications of artificial-intelligence-based models to effectively manage complex, uncertain, and vulnerable cost–risk correlations [19–25]. On this topic, an important and substantial contribution to research was made by Flyvbjerg, who introduced the concept of reference class forecasting (RCF) as an alternative to traditional methods of cost estimation. RCF is grounded in the idea that historical data from similar past projects can provide a more accurate basis for predicting costs in new projects, especially in environments prone to uncertainties [26,27]. The main difference between RCF and traditional estimating lies in its approach to uncertainty. Traditional methods often rely on internal project assessments, using specific project details and assumptions. In contrast, RCF considers external data from a reference class of similar projects, taking into account the actual outcomes and performance of these projects. Overall, Flyvbjerg advocates for RCF as a more robust method for estimating costs by leveraging actual outcomes from similar projects, thereby addressing the inherent uncertainties prevalent in project planning and estimation. However, all these mentioned methods entail a high level of complexity in implementation and management, often beyond the capacity of small local administrations in preparing their project budgets. Such methods typically require development and application by researchers and expert teams. This study aims instead to examine and test the use of a simpler and more accessible tool. This tool is intended to be easily implemented, even by smaller local authorities in peripheral or marginal areas of the country, to estimate possible project cost overruns.

The second line of research focuses on identifying the cost factors most susceptible to risk, leading to higher cost overruns in construction projects. Complex projects, whether public or private, particularly in the realm of infrastructure, often encounter amplified possibilities of cost and time overruns. Among these projects, three major factors that impact cost overruns are the following: the project implementation timeline, project scale, and ownership type [28–31]. Other key factors that contribute to cost overruns include inadequate project planning, slow decision-making, construction delays, alterations in project scope, issues in planning and implementation, contractor-related challenges like material and equipment supply, increasing costs of materials and machinery, ineffective contract management, difficulties in land acquisition, inaccurate estimation methods, prolonged periods between design and construction, delays in decision-making by governments, psychological bias, and corruption [4,14,27,32–42]. The literature tends to classify these potential causes into four main groups: technical, economic, psychological, and political [43–45].

The first and last categories are considered to be the most influential and they are often investigated through ex post analyses of the budgets of construction projects that are currently under construction or that have already been completed. These studies rely both on direct interviews with stakeholders involved in the project's development, such as construction companies and project managers, and on indirect analyses based on bills of quantities, which are drafted during the construction phase and upon project completion. Regarding the quantification of the cost overrun phenomenon in infrastructure projects, Flyvbjerg et al. analyze these costs in several projects located in 20 different countries, confirming that escalation appears to be a global phenomenon [46]. They estimated an average cost escalation in rail projects of 45%, in fixed link (tunnels and bridges) projects of

34%, and in roads projects of 20%. The percentage of cost overruns has been shown to be lower in wealthier countries, as evidenced by a study examining infrastructure projects in the Netherlands. In this context, the average cost overrun corresponds to 10.6% for rail, 18.6% for roads, and 21.7% for fixed link projects [47].

However, despite their main categories, most of the analyzed variables appear to have a random nature that cannot be quantified deterministically. Therefore, risk prediction cannot be modeled with Newtonian cause-and-effect criteria, as unexpected events are challenging to foresee. If, in an economic and financial feasibility study, the presence of risks is not considered and consequently not estimated, the ultimate drawback will be an underestimation of the costs incurred for the realization of the construction project. This underestimation of construction costs, resulting from risks not adequately factored in during the design phase, represents one of the major causes of failure in mega-projects, such as infrastructure ones [14,48,49]. As mentioned above, given the stochastic nature of unexpected events, the phenomenon of riskiness must be assessed in probabilistic terms. It is therefore necessary to estimate the percentage probability that an unfavorable situation will occur or, better said, a different situation compared to the baseline considered in the project and in the ex ante budget. To manage the risk allocation between the public and private sectors considering the probability of an event occurring, the Italian National Anti-Corruption Authority (ANAC) developed a risk management and mitigation matrix. ANAC improved a flexible and easily adaptable tool for various types of public works, which we utilized and adapted for our case study. ANAC is the entity responsible for the regulation of public procurement, addressing both contracting authorities and firms. It should be emphasized that this tool was introduced in 2015 through the publication of the ANAC guidelines for the ex ante assessment of the economic sustainability of Public–Private Partnerships (PPPs). This tool was later regulated by the Italian government in 2016 with the update of the Public Works Code, Service Contracts, and Supplies (Legislative Decree no. 50/2016), and subsequently updated by ANAC in implementation of the aforementioned regulation in 2018 and more recently with a draft released in January 2023 [50]. ANAC envisages the use of this tool for the analysis, management, quantification, and allocation of risks in PPPs between the public administration and the private sector. Specifically, the directive mandates the mandatory sharing of risk between the two sectors and places both the construction risk and either or both the operational and market demand risks on the private promoter. In this study, we will use the list of risks proposed by ANAC's guidelines, their allocation, and their comparison matrix as a starting point to be applied to our case study. The first step, as suggested by ANAC, for a proper quantification of risks, is their identification. A thorough planning should carefully outline all the risks that may be embedded in the execution of project activities. After a careful analysis, actions to be taken should be described, considering the impact due to the occurrence of the risk and the cost of the actions to be implemented to mitigate them (Table A1). Our study, using the classification and risk assessment matrices proposed by ANAC, aims to verify the feasibility of using this specific risk-management tool for the ex ante estimation of possible cost overruns in infrastructure projects by local administrations

3. Materials and Methods

3.1. The Case Study

The case study is located in the Province of Treviso, in Vittorio Veneto Municipality in the Venetian Prealps and is identified as "State Road No. 51 of Alemagna Vittorio Veneto Variant" (SSv-51). This project was put out to tender for the joint assignment of both design and construction works, better known as an "integrated contract", which is typically used when the project has a high level of technological complexity, leading to economies of scale advantages. The project arises from the need to free the city from automobile traffic, as its historic and residential center is currently entirely crossed by the existing "Alemagna" SSv-51 road, which extends from Cadore to Conegliano (Figure 1).

Figure 1. Study area framework highlighted in yellow.

The project was started in 1987 by the National Autonomous Roads Company (Azienda Nazionale Autonoma delle Strade, ANAS S.p.A.), which is a public national joint-stock company that manages the state infrastructures, roads, and highways.

Over the years, this project has undergone several changes due to some urban planning non-compliances, leading to the preparation of the final project in 2004. This project was divided into two successive road sections (Figure 2). The first section (La Sega–Rindola) involved the Costa di Serravalle slope (St. Augusta Tunnel), and the second section (Rindola-Ospedale) concerned the Fregonia slope (Madonna della Salute Tunnel).

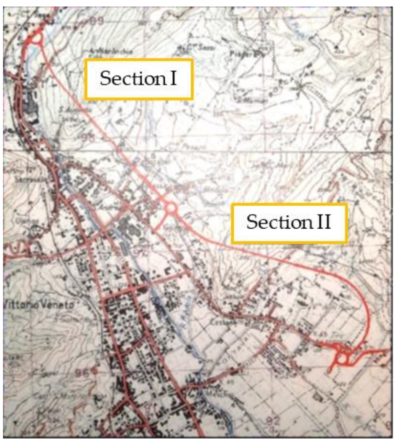

Figure 2. Project plan: Section I and Section II.

In 2009, for landscape reasons, the second section was abolished, and in 2012, the implementation of only the first section was definitively approved. Between March 2017 and March 2019, two additional variants to the project were finally approved following both a regional administrative court ruling, which upheld objections to certain expropriations and some necessary technical changes. These changes included the adaptation of water disposal works, modifications to the tunnel route, the elevation of parapets, adjustments to foundations, and the construction of a new roundabout (Figure 3). These modifications led to a reduction in the involved area and in the associated costs. The final overall estimated costs in the 2017 executive project amounted to EUR 61,024,448.

Figure 3. Project picture after completion in 2021.

Our study involves the comparative analysis of the costs (CC_{2017}) assessed in the quantitative survey approved in 2017 on the executive project with the actual costs incurred for the completion of the works (CC_{2019}). In the next section, we will introduce the model utilized to analyze the risks associated with the construction of the project just described. The proposed risk matrix will be applied to the estimated costs of the project presented and approved in 2017. This risk matrix will then be used to select those potentially most impactful risks quantifying ex ante their associated possible cost overruns.

3.2. The Method: Measuring Risks

The aim of the risk management of a construction project is to continuously identify, analyze, and control all uncertainty factors related to the project, in order to minimize the probability of occurrence and the impact of those risks, thereby maximizing the project's chances of completion and success. The Risk Analysis is performed to select sensitive risks associated with potential unexpected events. The aim of this preliminary analysis is to identify and implement actions to mitigate their effects, considering that it is not possible to reduce them to zero. Five phases have been performed to implement the Risk Analysis, as outlined in Figure 4 [51]:

- Phase I: identify a list of items/events that can generate unexpected events during construction;
- Phase II: develop a description to illustrate each risk;

- Phase III: establish a risk matrix by associating both a qualitative probability of occurrence of each event (quite impossible, unlikely, likely, very likely, almost certain) and the estimation of cost overruns in case of occurrence. The assessment of cost overruns is calculated as percentage increases on the base cost for each event and classified as light, mediocre, severe, and critical;
- Phase IV: describe the identified mitigation measures and the assessment of residual risks after prevention;
- Phase V: perform a risk value assessment applying the cost levels of increase.

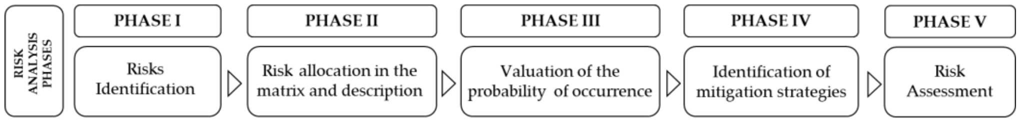

Figure 4. Risk analysis phases.

As anticipated in the Introduction, we apply the approach proposed by ANAC for the analysis and monetization of risks, to assess any monetary discrepancies that could have been estimated ex ante during the project configuration and design. ANAC has developed a "risk matrix" model, which we have adopted in the present study. These risks have been categorized by ANAC into four main designations: Construction Risks (RC), Performance Risks (RP), Demand Risks (RD), and Other Risks (OR).

The Construction Risk (RC) group is associated with delays, non-compliance with project standards, cost increases, technical issues, and the failure to complete the project. This category includes the following specific risks:

(RC1) Planning/Design Risk, which is associated with the possibility of alteration and adjustments to the executive project caused by errors or omissions, which significantly impact the timeline and construction costs.

(RC2) Discrepancy Risk, which is associated with the possibility of construction works being executed differently from the original project due to a failure to comply with project standards.

(RC3) Risk of increase in production costs, which is associated with the probability of an increase in the cost of production factors or the inadequacy or unavailability of those envisaged in the project. This risk is also sensitive to the lengthening of the project implementation timeline.

(RC4) Risk of inaccurate assessment of construction costs and project timelines, which is associated with the probability of an incorrect ex ante evaluation and of delays in the deadlines set by the project schedule.

(RC5) The risk of suppliers and subcontractors failing to meet their contractual obligations, which is also associated with the probability that the replacement of non-compliant suppliers or subcontractors results in increases in costs and project implementation times.

(RC6) Risk of unreliability and inadequacy of the used technology, which requires ongoing replacements and changes in the design of the project.

(RC7) Commissioning risk, which is associated with the probability that the project does not receive approval from the involved public stakeholders, causing subsequent delays and the emergence of disputes and litigations.

(RC8) Administrative risk, which is associated with the probability that authorizations, permits, and licenses are not issued by the public administrations within the expected timeframe, causing delays.

(RC9) Eminent domain risk, which is associated with the probability of incurring delays caused by condemnation procedures and of an increase in their compensation due to incorrect design and/or estimation.

(RC10) Environmental and/or archeological risk, which is associated with the probability of an incorrect assessment of ground conditions, soil contamination, and archeological findings, resulting in delays and increased costs for environmental remediation or archeological protection.

(RC11) Risk of interference, which is associated with the probability of the presence/absence of above and below services (e.g., water, gas, electricity, cables, fiber optics, etc.).

This risk category is closely intertwined with project implementation and the repercussions of overlooking or underestimating these risks. This oversight can significantly extend project timelines and construction expenses.

The Performance Risks (RP) category is associated with the concessionaire's capacity to meet the contractual performance standards agreed upon during both the construction and management phases, encompassing dimensions and specifying quality benchmarks. For a project's design to be considered comprehensive, it must include a maintenance plan, as required by Article 33 of Legislative Decree 207/2010. This document outlines schedules and activities, considering the executive plans, to maintain the project's functionality, quality, efficiency, and economic value over time. An incorrect design might necessitate extensive maintenance or early refurbishment, resulting in an increase in maintenance costs. This category encompasses the following specific risks:

(RP1) Risk of extraordinary maintenance, which is linked to the likelihood of facing unexpected extraordinary maintenance expenses due to design or construction defects or inadequacies, potentially resulting in the unavailability of the infrastructure.

(RP2) Performance risk, which is associated with the probability that the project and/or the services provided do not conform to the pre-established functionalities, resulting in the lower availability of estimated incomes and revenues.

(RP3) Risk of unavailability, which is associated with the probability of the total or partial incapacity of the project to provide the expected services.

(RP4) Risk of technical obsolescence, which is associated with the rapid technical obsolescence of the structures, consequently increasing both repair and maintenance expenses, and capex.

The Demand Risks (RD) category is linked to the varying volumes of service demand that the concessionaire must meet, i.e., the risk associated with the lack of users and, consequently, future cash flows. This category includes the following specific risks:

(RD1) Risk of contraction in market demand, which is associated with the probability of a reduction in the overall market demand for that specific service, affecting the operator's income.

(RD2) Risk of contraction in specific demand, which is associated with the probability of a decrease in the attractiveness of that specific project.

Finally, the Other Risk (RO) category includes the following specific risks:

(RO1) Planning-regulatory risk, which is associated with the probability of changes in the regulatory framework and unforeseeable policy decisions, leading to an increase in costs for compliance. This risk can result in the failure of the assignment procedure.

(RO2) Financial risk, which is associated with the probability of an increase in interest rates and consequent difficulty in reimbursing the loan by the developer, resulting in the inability to complete the construction.

(RO3) Risk of insolvency by the concessionaire and indebted parties.

(RO4) Residual value risk, which is associated with the probability of returning, at the end of the contractual relationship, an asset with a value lower than the initial estimated assumptions.

Table 1 summarizes the risk categories and types defined by ANAC and described above.

Given the stochastic nature of unexpected events, we proceed to evaluate the phenomenon of risk in probabilistic terms. We considered the possibility of an unfavorable situation occurring compared to the initial forecasts, filling out the matrix with five classes of probability of occurrence and four categories of impact on costs.

Table 1. Risk categories and risk type classifications.

Risk Category	Risk Type	Risk Code
Construction Risks (RC)	Planning/Design Risk	RC1
	Discrepancy Risk	RC2
	Risk of increase in production costs	RC3
	Risk of inaccurate assessment of construction costs and project timelines	RC4
	The risk of suppliers and subcontractors failing to meet their contractual obligations	RC5
	Risk of unreliability and inadequacy of the used technology	RC6
	Commissioning risk	RC7
	Administrative risk	RC8
	Eminent domain risk	RC9
	Environmental and/or archaeological risk	RC10
	Risk of interference	RC11
Performance Risks (RP)	Risk of extraordinary maintenance	RP1
	Performance risk	RP2
	Risk of unavailability	RP3
	Risk of technical obsolescence	RP4
Demand Risks (RD)	Risk of contraction in market demand	RD1
	Risk of contraction in specific demand	RD2
Other Risks (RO)	Planning-regulatory risk	RO1
	Financial risk	RO2
	Risk of insolvency	RO3
	Residual value risk	RO4

The Probability of occurrence of a specific risk is implemented as follows:

- Quite impossible (A): [0%,1%]
- Unlikely (B): [1%,25%]
- Likely (C): [25%,50%]
- Very likely (D): [50%,75%]
- Almost certain (E): [75%,100%]

The considered impact categories, which imply a percentage increase in costs, are classified as follows:

- Light (1), which implies an increase in costs of [0%,5%]
- Mediocre (2), which implies an increase in costs of [5%,10%]
- Severe (3), which implies an increase in costs of [10%,20%]
- Critical (4), which implies an increase in costs of [20%,∞]

These ranges of increases have been precisely delineated concerning the specific project and necessitate adaptation on an individualized basis, contingent upon the micro- and macroeconomic as well as financial contextual factors. Having evaluated the probability of an unexpected event occurring and the potential impact it could generate on costs for each type of risk, we implemented the risk assessment matrix, as presented in Table 2. It is crucial to emphasize that the utilization of the identical risk matrix (Table 2) can extend beyond assessing prospective cost overruns to anticipate potential time overruns. This implementation could be achieved by substituting the "Impact on Costs" assessment with "Impact on Times" considering the potential effects on the project's execution timeline for each Risk Category. The evolution of this model adaptation could be explored as a future phase in the research.

The colors, which are represented in the matrix, correspond to different possible outcomes following the combined risk assessment, compiled through the matrix, which integrates the probability of occurrence with the financial impact on costs. Green identifies risks that require minimal mitigation action (minimum), yellow indicates risks that require planning corrective actions in the medium to short term (low), orange represents risks that require urgently scheduling corrective action plans (medium), and finally, red demands the immediate implementation of corrective actions (high).

Table 2. Risk matrix implemented by the authors.

				Impact on Costs			
				Light	Mediocre	Severe	Critical
				1	2	3	4
				[0%,5%]	[5%,10%]	[10%,20%]	[20%,∞]
Probability	Quite impossible	(A)	[0%,1%]				
	Unlikely	(B)	[1%,25%]				
	Likely	(C)	[25%,50%]				
	Very likely	(D)	[50%,75%]				
	Almost certain	(E)	[75%,100%]				
	Risk			*Action*			
	MINIMUM		→	EVALUATE IMPROVEMENT ACTIONS			
	LOW		→	PLAN CORRECTIVE ACTIONS IN THE MEDIUM-SHORT TERM			
	MEDIUM		→	URGENTLY SCHEDULE CORRECTIVE ACTIONS			
	HIGH		→	IMPLEMENT IMMEDIATE CORRECTIVE ACTIONS			

The risk analysis matrix, proposed by ANAC, has been completed for the SS-v51 project, considering only the risks directly attributable to this specific project, as developed in 2017, and strictly related to the construction phase (Appendix A, Table A2). This risk matrix (Table A2) was filled out by local stakeholders with extensive knowledge of the area where the project was carried out, coupled with technical expertise in engineering within the realm of infrastructure projects.

This matrix comprises eight columns:

- Risk Category;
- Risk Type;
- Risk Code;
- Risk Description, which includes the description of the risk associated with the examined SSv-51 project. This column also describes the reasons that led to the estimations in columns 5 and 6;
- Probability of risk occurrence, which defines the selected probability of occurrence as defined above (quite impossible, unlikely, likely, very likely, and almost certain),
- Impacts on Costs, which defines the expected quantification of costs to be accounted for if that risk will occur, as defined above (light, mediocre, severe, and critical);
- Matrix combination is derived from the compilation of the matrix presented in Table 2 as a combination of columns 5 and 6;
- Risk mitigation tools, which indicate the risk mitigation measures proposed for the analyzed infrastructure project.

In the following section, we will present the results of the risk analysis as presented above for the infrastructure project SSv-51.

4. Results and Discussion

Table 3 represents the summary table, where we identified the selected risks and defined their matrix combination, considering both their probability of occurrence and their associated impact. Given the tool's primary objective of the ex ante estimation of potential cost overruns not accounted for in the initial project estimates, the Matrix Combination has identified risks within the "Construction Risk" category as having higher priority.

Table 3. Project risk matrix.

Risk Category	Risck Code	Probability of Risk Occurrence (Quite Impossible-A, Unlikely-B, Likely-C, Very Likely-D, and Almost Certain-E)	Impact: Costs Overrun (Light-1, Mediocre-2, Severe-3, and Critical-4)	Matrix Combination
Construction Risks	RC1	B	1	
	RC2	B	1	
	RC3	B	2	
	RC4	C	4	
	RC5	A	1	
	RC6	A	1	
	RC7	D	2	
	RC8	D	2	
	RC9	E	2	
	RC10	E	1	
	RC11	D	3	
Performance Risks	RP1	A	2	
	RP2	A	1	
	RP4	A	1	
Demand Risks	RD1	B	1	
Other Risks	RO1	C	3	
	RO4	A	1	

After carrying out the risk analysis, as illustrated above, it was found that seven risks led to the request for the implementation of corrective action plans for risk mitigation both urgently (orange: medium) or immediately (red: high): RC4, RC7, RC8, RC9, RC10, RC11, and RO1. For the presented case study, only three types of risks falling into the high risk of occurrence (red: high) have been selected to be calculated: RC4, RC9, and RC11.

To monetize the selected risks, five deviation classes corresponding to the different levels of increase, previously used for the risk matrix study, have been identified. The deviation classes with their associated percentage of cost increase (Increase Level—*i*) are defined as follows:

(a) None, with an Increase in Value (IV_a) = 0.0%
(b) Slight, with an Increase in Value (IV_b): [0%,5%]
(c) Moderate, with an Increase in Value (IV_c): [5%,10%]
(d) Significant, with an Increase in Value (IV_d): [10%,20%]
(e) Grave, with an Increase in Value (IV_e): [20%,∞]

This study, aiming to estimate and quantify cost overruns, monetized the value of the selected risk associated with each type of increment. To monetize these risks, we introduce Table 4, which contains the various parameters involved in the evaluation, where the following terms apply:

- Increase Level (*i*) is defined above;
- Increase in Value (IV_i) represents the deviation class, which falls within a defined percentage range that defines its increment on estimated costs. These intervals have been described above, and, in this table, we associated to each level a specific percentage increase, which corresponded to the arithmetic average of the interval. However, for the IV_e, since there is no higher limit (+∞), we decided to apply a 50% increase to estimated costs. This percentage is considered quite critical in the literature, as the 20–40% range is deemed the maximum threshold of acceptability for valuation accuracy [26,52,53]. Therefore, we have chosen a slightly higher percentage to highlight the critical nature of this Level of Increase.

- Increased Costs (IC_i): in this column, the base value amplified with the associated percentage (IV_i) for each corresponding increment type (i) has been calculated, where IC_a is the Estimated Base Cost in 2017 (CC_{2017}) for that specific Cost Item as reported in Table 5.
- Cost Impact (CI_i) was calculated by subtracting from the Increased Cost (CI_i) the Increased Cost associated to the previous Increase Level (CI_{i-1}). In the Increase Level$_a$, IV_a is equal to 0.0% and the corresponding CI_a is equal to 0.
- Probability (P_i) represents the probability of occurrence associated with each type of Increase Level for each risk. This probability has been estimated considering the matrix reported in Table A2.
- Risk Value (RV_i) is calculated by multiplying the Cost Impact (CI_i) of each Increased Level by its corresponding Probability (P_i). The sum of the RV_i values corresponds to the Estimated Risk Value for each single risk, which has been analyzed.

Table 4. Risk value assessment per five levels of increase (i).

Increase Level (i)	Increase in Value (IV_i)	Increased Cost (IC_i)	Cost Impact (CI_i)	Probability (P_i)	Risk Value (RV_i) = (CI_i) × (P_i)
a	IV_a = 0.0%	IC_a	0	P_a	RV_a
b	IV_b = 2.5%	$IC_b = IC_a \times (1 + IV_b)$	$IC_b - IC_a$	P_b	RV_b
c	IV_c = 8.0%	$IC_c = IC_a \times (1 + IV_c)$	$IC_c - IC_b$	P_c	RV_c
d	IV_d = 15.5%	$IC_d = IC_a \times (1 + IV_d)$	$IC_d - IC_c$	P_d	RV_d
e	IV_e = 50.0%	$IC_e = IC_a \times (1 + IV_e)$	$IC_e - IC_d$	P_e	RV_e

Table 5. Project costs: comparison between CC_{2017} and CC_{2019}.

Cost Code	Cost Item	Estimated Costs in 2017	Actual Costs in 2019	Cost Difference (€)	Delta 2019–2017 (%)
		CC(2017)	CC(2019)	CD = CC(2019) − CC(2017)	De = CD/CC(2017)
CC1	Construction Costs	45,609,732 €	43,482,988 €	−2,126,744 €	−4.66%
CC2	Construction Site Security	2,420,342 €	4,164,468 €	1,744,126 €	72.06%
CC3	Engineering Fees	395,158 €	878,737 €	483,579 €	122.38%
CC4	Surveys	24,000 €	24,000 €	-	0.00%
CC5	Interferences	210,000 €	1,089,803 €	879,803 €	418.95%
CC6	Contingencies	1,422,630 €	-	−1,422,630 €	−100.00%
CC7	Eminent Domain	1,500,000 €	5,415,645 €	3,915,645 €	261.04%
CC8	General Office Overhead	183,179 €	93,327 €	−89,852 €	−49.05%
CC9	Energy Efficiency	223,453 €	223,453 €	-	0.00%
CC10	Taxes	3664 €	-	−3664 €	−100.00%
CC11	Marketing	32,000 €	32,000 €	-	0.00%
CC12	Testing and Inspections	522,102 €	522,102 €	-	0.00%
CC13	Financial Costs	8,478,189 €	8,478,189 €	-	0.00%
TOTAL		61,024,448 €	64,404,711 €	3,380,263 €	5.54%
TOTAL (CC1 + CC2 + CC5 + CC7)		49,740,074 €	54,152,904 €	4,412,830 €	8.87%

To be able to calculate the Risk Value (RV_i), we need to calculate CI_i as the difference between two IC_i values of subsequent levels (i). To do so, we need to know the base cost (IC_a) associated with each selected risk. The base cost to be associated with the three above-selected risks, as estimated in 2017 (CC_{2017}), corresponds to different Cost Items and Cost Codes, presented in Table 5. The costs (CC_{2017}) associated with RC4 sum to EUR 48,030,074 (CC1-Construction Costs + CC2-Construction Site Security); the costs associated with RC9 sum to EUR 1,500,000 (CC7-Eminent Domain); and the costs associated with RC11 sum to EUR 210,000 (CC5-Interferences); see Table 5.

As shown in Table 5, the Total Estimated Costs, which correspond to the cost developer's schedule, estimated ex ante in 2017 (CC_{2017}), amounted to EUR 61,024,448, of which only EUR 49,740,074 (81.51% of the overall costs) is attributable to the selected costs associated with the selected risks (CC1 + CC2, CC5, and CC7), and EUR 1,422,630 corresponds to the estimated Contingencies (CC6), or 2.33% of the overall costs. For the Actual Costs (in 2019, CC_{2019}), the total project costs increased by 8.87%, with a 5.54% increase attributed to the selected costs (CC1 + CC2 + CC5 + CC7).

Calculating the Risk Value (RV_i) through Table 4, we obtain a Total Estimated Risk Value of EUR 3,706,184, of which EUR 113,475 corresponds to the Estimated Risk Value for Eminent Domain Risk (RC9), with EUR 14,469 attributable to Risk of Interference (RC11) and EUR 3,578,240 to the risk of inaccurate assessment of construction costs and project timelines (RC4); see Table 6. As per Table 6, the overall Estimated Risk Value sums to EUR 3,706,184, which corresponds to 7.45% of the Estimated Costs in 2017 of the associated costs (CC1 + CC2 + CC5 + CC7 in 2017). As expected, considering our previous risk analysis (Table A2), the three selected risks associated with the four above-mentioned costs highly impacted the overall cost, causing an increase in costs in 2019 of 8.87%; see Table 5. Per the Developer's Costs Schedule, the Contingencies (CC6) were estimated to be only EUR 1,422,630, or 2.86% of the selected costs. Our tool was instead able to forecast, as previously mentioned, an increase in costs of approximately EUR 3.7 millions, which corresponds to an increase by 7.45% of the selected costs in 2017 (Figure 5).

Table 6. Risk value estimation for RC4, RC9, and RC11.

	Increase Level (i)	**Increase in Value (IV_i)**	**Increased Cost (IC_i)**	**Cost Impact (CI_i)**	**Probability (P_i)**	**Estimated Risk Value (RV_i) = (CI_i) × (P_i)**	**Estimated Risk Value (%) (ERV_i) = (RV_i)/(IC_a)**
RC9 (CC7)	*a*	0.0%	1,500,000 €	-	1%	-	0.00%
	b	2.5%	1,537,500 €	37,500 €	3%	1125 €	0.08%
	c	8.0%	1,620,000 €	82,500 €	80%	66,000 €	4.40%
	d	15.5%	1,732,500 €	112,500 €	9%	10,125 €	0.68%
	e	50.0%	2,250,000 €	517,500 €	7%	36,225 €	2.42%
					RC9 Risk Value	113,475 €	7.57%
RC11 (CC5)	*a*	0.0%	210,000 €	-	10%	-	0.00%
	b	2.5%	215,250 €	5250 €	20%	1050 €	0.07%
	c	8.0%	226,800 €	11,550 €	51%	5891 €	0.39%
	d	15.5%	242,550 €	15,750 €	11%	1733 €	0.12%
	e	50.0%	315,000 €	72,450 €	8%	5796 €	0.39%
					RC11 Risk Value	14,469 €	6.89%
RC4 (CC1 + CC2)	*a*	0.0%	48,030,074 €	-	10%	-	0.00%
	b	2.5%	49,230,826 €	1,200,752 €	30%	360,226 €	24.02%
	c	8.0%	51,872,480 €	2,641,654 €	25%	660,414 €	44.03%
	d	15.5%	55,474,735 €	3,602,256 €	25%	900,564 €	60.04%
	e	50.0%	72,045,111 €	16,570,375 €	10%	1,657,038 €	110.47%
					RC4 Risk Value	3,578,240 €	7.45%
					Total Risk Value	3,706,184 €	7.45%

In Figure 5, we have graphically represented the impact of the Contingency category (in green) on CC_{2017}, as estimated ex ante in 2017, the actual cost overrun that occurred in 2019 (second column), and our contingency forecast as estimated applying the proposed risk management tool. It can be observed that by calculating the Risk Value associated with the three most critical risks, the ex ante estimation of the possible cost overruns would have reduced the actual cost overruns to only EUR 706,645, which corresponds to a delta between our estimate and the 2019 costs of only 1.32%, highly increasing the ex ante estimation accuracy. These preliminary results confirm our initial hypothesis that an ex ante evaluation of risks through the proposed risk assessment matrix and their monetization could potentially be an effective tool for estimating possible cost overruns in large and complex infrastructure projects.

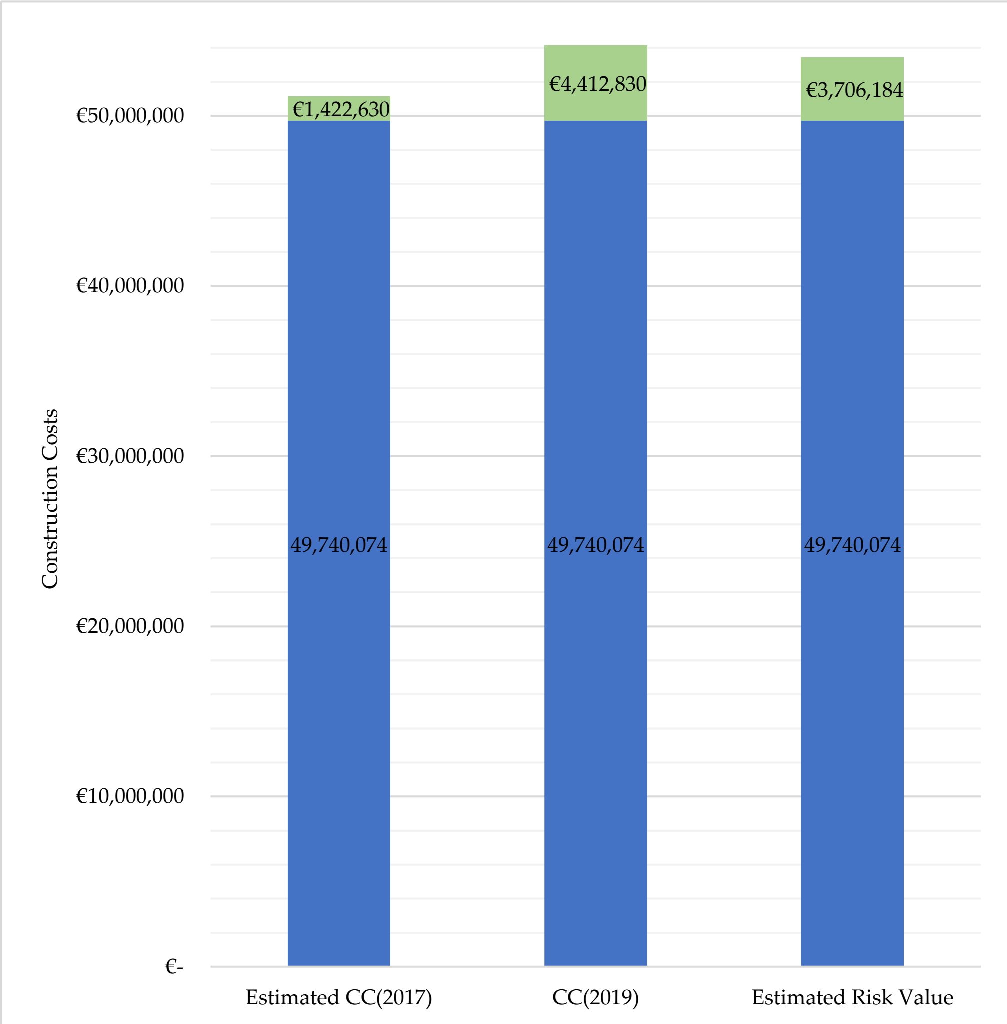

Figure 5. Comparison between CC_{2017}, CC_{2019}, and the Estimated Risk Value. In blue: base costs including only CC1, CC2, CC5, and CC7, in green: 2017 Contingencies estimation (EURO 1,422,630), 2019 cost overruns (EURO 4,412,830), Estimated Risk Value per Table 6 (EURO 3,706,184).

5. Conclusions

The importance of a robust and well-maintained infrastructure system for a country's economic and environmental progress cannot be understated. However, the persistent decline in infrastructure spending, particularly in the transportation sector, raises concerns about governments' ability to meet the demands of a growing economy. This study delves into the critical issue of infrastructure investment and, more specifically, the looming problem of cost overruns in transportation projects.

The application of the risk assessment tool proposed by the National Anti-Corruption Authority (ANAC) offers valuable insights into potential risks associated with project costs and their valuation. The proposed risk matrix, associating selected risks with a possible probability of occurrence and potential impact, was useful in this case study to identify the most sensitive and relevant risk categories. It served as a preliminary guide to identify the cost categories most likely to be sensitive to cost increases and was thus used as a basis for selecting our risks to calculate potential cost overruns. The calculated

Risk Value, when compared to the ex ante cost estimates and ex post results, was, in this specific case, able to reduce the actual cost overrun to 1.32%, decreasing it by 4.52%. These preliminary results, when applied to this specific case study, suggest the potential efficacy of the risk assessment method employed, though further application is needed to validate the model. The results underscore the importance of integrating risk management strategies into the planning and execution phases of infrastructure projects to mitigate the impact of unforeseen events and enhance the likelihood of project success. While the study provides valuable insights, it is essential to acknowledge its limitations. The specific focus on a single case study, SSv-51, and the utilization of ANAC's risk assessment tool, may limit the generalizability of the findings. Future research endeavors should aim to expand the scope by including a broader range and a larger sample of projects. Increasing the case studies can help support the preliminary results obtained here from a single application, and it can validate or adjust, for example, the percentage increases considered in our model. Another limitation of the current research is assuming that the experts and the local administrators involved, tasked with completing the risk matrix, are capable of foreseeing and estimating with an acceptable degree of approximation the project risks and their probability of occurrence. Finally, the last limitation of the current application is that only the construction cost overruns have been considered, without considering possible time overruns or the cost overruns associated with the project's management phase either. Therefore, a possible further application of this tool might involve considering both the costs that occur in the management phase, and the time overruns that the developer faces during the design and the construction phases. In conclusion, this study contributes to the ongoing discourse on infrastructure investment, providing a preliminary framework for mitigating and monetizing the risks associated with cost overruns. As Italy and other nations navigate the complexities of infrastructure development, embracing proactive risk management practices becomes imperative. Utilizing simple risk management tools, such as the one introduced in this research, presents a significant advantage for local administrations in effectively overseeing their infrastructure projects. Through meticulous risk assessment and mitigation strategies, these tools offer a pathway to mitigating the likelihood of cost overruns, thereby enhancing the financial feasibility and sustainability of the projects. By curbing both cost and time overruns, the economic efficacy of the project is fortified, ensuring a streamlined implementation that bolsters its long-term viability and the overall project's resilience.

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Appendix A

Table A1. Risk matrix according to ANAC Guidelines.

Risk Type	Probability of Risk Occurrence (Percentage or Qualitative Values)	Impact: Higher Costs and/or Delays (Percentage or Quantitative Values in € or Days)	Risk Mitigation Tools
Planning/Design Risk			
Discrepancy Risk			
Risk of increase in production costs			
Risk of inaccurate assessment of construction costs and project timelines			
The risk of suppliers and subcontractors failing to meet their contractual obligations			
Risk of unreliability and inadequacy of the used technology			
Commissioning risk			
Administrative risk			
Eminent domain risk			
Environmental and/or archaeological risk			
Risk of interference			
Risk of extraordinary maintenance			
Performance risk			
Risk of unavailability			
Risk of technical obsolescence			
Risk of contraction in market demand			
Risk of contraction in specific demand			
Planning-regulatory risk			
Financial risk			
Risk of insolvency			
Residual value risk			

Table A2. Risk matrix applied to the 2017 executive project.

Risk Category	Risk Type	Risk Code	Description	Probability of Risk Occurrence *	Impact: Costs Overrun **	Matrix Combination	Risk Mitigation Tools
Construction Risks	Planning/Design Risk	RC1	The level of design currently reached (2019) is developed on the basis of the final project that had already been improved in terms of its integration into the territory, as suggested by the Superintendence for Architectural and Landscape Heritage in 2005.	B	1		Acquire opinions, authorizations, approvals. Attach further explanatory tables to the project even if they are not mandatory.
	Discrepancy Risk	RC2	The current design level is feasible for construction, following numerous investigations and studies, so the risk of discrepancies is minimal.	B	1		Perform a precise and accurate design analysis.
	Risk of increase in production costs	RC3	This risk is exacerbated for the project by two factors: the increase in construction material prices that occurred during the pandemic and post-pandemic period, and the extended timelines that occurred between project delivery and the start of construction.	B	2		Prepare the project based on the updated regional price list. In the case of an integrated contract, verify in advance with suppliers the updated price lists and the availability of materials in the market. Pay particular attention to the easy availability of construction materials.
	Risk of inaccurate assessment of construction costs and project timelines	RC4	This level of design specifies the construction costs in the estimate and defines the detailed schedule of work. For large projects, it must be considered that the design is very complex, and often, as in the case of tunnel construction, it is not possible to rely on precise outcomes of conducted investigations. This entails the risk of encountering unforeseen circumstances that affect the overall cost.	C	4		Consult updated regional price lists. Seek opinions, authorizations, approvals in order to avoid extending the project schedule due to administrative procedures. Include thorough soil knowledge analyses and conduct them at multiple points. Additionally, gather information from historical data and works of the same category carried out in nearby areas.
	The risk of suppliers and subcontractors failing to meet their contractual obligations	RC5	The contract in question is an integrated contract, and the winning company is responsible for drafting the executive project and carrying out the construction work, with the aim of minimizing the risk of non-compliance.	A	1		Select subcontractors carefully by verifying in advance their compliance with requirements, including Chamber of Commerce records and ANAC files, to assess if there are any past contract resolutions. Request the subcontractor to provide a surety bond. Clearly define the contractual obligations and include penalties for non-compliance with these obligations.

Table A2. *Cont.*

Risk Category	Risk Type	Risk Code	Description	Probability of Risk Occurrence *	Impact: Costs Overrun **	Matrix Combination	Risk Mitigation Tools
Construction Risks	Risk of unreliability and inadequacy of the used technology	RC6	The project presented has undergone several changes over the years, taking into account that technological design solutions have evolved, and as a result, the project has been adapted accordingly.	A	1		Implement parallel control and safety systems to allow, in the event of a component failure, the other systems to function. Stay updated on the latest technologies in use.
	Commissioning risk	RC7	The project has been the subject of numerous investigations and protests from the local community regarding issues related to expropriations, potential environmental impact, and the proposed project route.	D	2		Evaluate possible design alternatives in advance, estimating their associated costs and environmental impact. Prepare administrative documents related to expropriations with great care and involve the community through meetings and roundtable discussions to share project details.
	Administrative risk	RC8	This risk is associated with the duration of the administrative procedures.	D	2		Obtain opinions, authorizations, and approvals in advance. Attach to the project all additional documents that may be necessary to demonstrate a comprehensive assessment of the context and the relative compatibility of the work, even if not mandatory.
	Eminent domain risk	RC9	This risk can result in both delays and costs increase.	E	2		Evaluate design alternatives that minimize the need for expropriation and, if possible, prioritize expropriations that do not involve the demolition of buildings. Prepare administrative documents related to expropriations with great care to ensure there are no loopholes that expropriated individuals could use to claim a higher compensation while also prolonging the expropriation and administrative timelines.

Table A2. *Cont.*

Risk Category	Risk Type	Risk Code	Description	Probability of Risk Occurrence *	Impact: Costs Overrun **	Matrix Combination	Risk Mitigation Tools
Construction Risks	Environmental and/or archaeological risk	RC10	The project is located in the vicinity of the ecclesiastical district of St. Andrew, already known for archaeological findings dating back to the 6th century.	E	1		Include comprehensive soil knowledge analyses and conduct them at multiple points. Additionally, gather information from historical data and works of the same category carried out in nearby areas. Preemptively verify archaeological interest. Plan archaeological investigations before project implementation and allocate resources for archaeological support during the works.
	Risk of interference	RC11	This type of risk is mainly associated with the presence of above and below-ground utilities of various types (e.g., water, gas, fiber optics, etc.). In the absence of updated plans, it is possible that during excavation, pipes may be inadvertently damaged or cables may be cut.	D	3		Retrieve updated plans of the underground services, possibly in dwg extension. Make use of BIM design systems.
Performance Risks	Risk of extraordinary maintenance	RP1	This level of design requires, among the documents, the drafting of the Maintenance Plan for the work, whose purpose is to plan and schedule maintenance activities in order to "sustain over time the functionality, quality characteristics, efficiency, and economic value" (Article 38 D.P.R. 207/2010).	A	2		Prepare the Maintenance Plan of the Work accurately.
	Performance risk	RP2	The road design was based on traffic volumes obtained from the previous detailed project in 2004 by projecting municipal traffic data to 2010. It is realistic to assume that these traffic volumes are likely to increase over the years, further reinforcing the reasons that led to the request for this project, making it increasingly important in addressing the traffic issue in the historical center.	A	1		Accurate identification of traffic volumes.
	Risk of technical obsolescence	RP4	This project, which is realized after numerous design phases, must take into account that over the years, technological design solutions have certainly changed, and therefore the project needs to be adapted.	A	1		Anticipate a design level updated to technical and technological evolution.

Table A2. *Cont.*

Risk Category	Risk Type	Risk Code	Description	Probability of Risk Occurrence *	Impact: Costs Overrun **	Matrix Combination	Risk Mitigation Tools
Demand Risks	Risk of contraction in market demand	RD1	This project has undergone numerous studies on vehicular traffic with the aim of freeing the historical center from car traffic in order to preserve its characteristics, bringing a significant impact to the area.	B	1		Draft the project based on updated studies on vehicular traffic.
Other Risks	Planning-regulatory risk	RO1	The project has an extensive development timeline that has witnessed changes in regional price lists (regional price lists from 2006 to the present are available on the Veneto Region's website).	C	3		Allocate adequate amounts available to the contracting authority under the 'unforeseen' item, update the project to the current regional price list. Include, where possible and in compliance with current regulations, appropriate contractual clauses regarding price revisions.
	Residual value risk	RO4	The road and infrastructure design was based on traffic volumes derived from the previous 2004 detailed project by projecting municipal traffic data to 2010. It is realistic to assume that these traffic volumes are likely to increase over the years, further reinforcing the reasons that led to the request for this project, making it increasingly important in addressing the traffic issue in the historical center.	A	1		To plan for a design level updated to technological and technical evolution.

* Minimum-A, Extemely Low-B, Low-C, Medium-D, High-E, ** Light-1, Mediocre-2, Severe-3, Critical-4.

References

1. CPT Settori. Agenzia per la Coesione Territoriale, Sistema dei Conti Pubblici Territoriali e Produzione di Statistiche, Indagini e Ricerche Sulla Conduzione Delle Politiche Pubbliche. 2023. Available online: https://www.agenziacoesione.gov.it/wp-content/uploads/2023/04/2-Spesa_CPT_Settori_Vol2_TRASPORTI-1.pdf (accessed on 23 November 2023).
2. European Commission. *Mobility and Transport Transport in the European Union Current Trends and Issues*; European Commission: Brussels, Belgium, 2019; p. 144.
3. Avotos, I. Cost-relevance analysis for overrun control. *Int. J. Proj. Manag.* **1983**, *1*, 142–148. [CrossRef]
4. Flyvbjerg, B.; Ansar, A.; Budzier, A.; Buhl, S.; Cantarelli, C.; Garbuio, M.; Glenting, C.; Holm, M.S.; Lovallo, D.; Lunn, D. Five things you should know about cost overrun. *Transp. Res. Part A Policy Pract.* **2018**, *118*, 174–190. [CrossRef]
5. Pehlivan, S.; Öztemir, A.E. Integrated Risk of Progress-Based Costs and Schedule Delays in Construction Projects. *Eng. Manag. J.* **2018**, *30*, 108–116. [CrossRef]
6. Love, P.E.D.; Ahiaga-Dagbui, D.D.; Irani, Z. Cost overruns in transportation infrastructure projects: Sowing the seeds for a probabilistic theory of causation. *Transp. Res. Part A Policy Pract.* **2016**, *92*, 184–194. [CrossRef]
7. Fan, C.F.; Yu, Y.C. BBN-based software project risk management. *J. Syst. Softw.* **2004**, *73*, 193–203. [CrossRef]
8. Kardes, I.; Ozturk, A.; Cavusgil, S.T.; Cavusgil, E. Managing global megaprojects: Complexity and risk management. *Int. Bus. Rev.* **2013**, *22*, 905–917. [CrossRef]
9. Valipour, A.; Yahaya, N.; Md Noor, N.; Kildienė, S.; Sarvari, H.; Mardani, A. A fuzzy analytic network process method for risk prioritization in freeway PPP projects: An Iranian case study. *J. Civ. Eng. Manag.* **2015**, *21*, 933–947. [CrossRef]
10. Canesi, R. Urban Policy Sustainability through a Value-Added Densification Tool: The Case of the South Boston Area. *Sustainability* **2022**, *14*, 8762. [CrossRef]
11. Anelli, D.; Tajani, F. Spatial decision support systems for effective ex-ante risk evaluation: An innovative model for improving the real estate redevelopment processes. *Land Use Policy* **2023**, *128*, 106595. [CrossRef]
12. Hillson, D. *Managing Risk in Projects*; Routledge: London, UK, 2009.
13. Floyd, M.K.; Barker, K.; Rocco, C.M.; Whitman, M.G. A Multi-Criteria Decision Analysis Technique for Stochastic Task Criticality in Project Management. *Eng. Manag. J.* **2017**, *29*, 165–178. [CrossRef]
14. Qazi, A.; Quigley, J.; Dickson, A.; Kirytopoulos, K. Project Complexity and Risk Management (ProCRiM): Towards modelling project complexity driven risk paths in construction projects. *Int. J. Proj. Manag.* **2016**, *34*, 1183–1198. [CrossRef]
15. Fang, C.; Marle, F. Dealing with project complexity by matrix-based propagation modelling for project risk analysis. *J. Eng. Des.* **2013**, *24*, 239–256. [CrossRef]
16. Demirkesen, S.; Ozorhon, B. Measuring Project Management Performance: Case of Construction Industry. *Eng. Manag. J.* **2017**, *29*, 258–277. [CrossRef]
17. Renigier-Biłozor, M.; Źróbek, S.; Walacik, M.; Borst, R.; Grover, R.; D'Amato, M. International acceptance of automated modern tools use must-have for sustainable real estate market development. *Land Use Policy* **2022**, *113*, 105876. [CrossRef]
18. Canesi, R. A multicriteria approach to prioritize urban sustainable development projects | Un approccio multicriteri per il ranking di progetti urbani sostenibili. *Valori E Valutazioni* **2023**, *2023*, 117–132. [CrossRef]
19. Afzal, F.; Yunfei, S.; Nazir, M.; Bhatti, S.M. A review of artificial intelligence based risk assessment methods for capturing complexity-risk interdependencies: Cost overrun in construction projects. *Int. J. Manag. Proj. Bus.* **2021**, *14*, 300–328. [CrossRef]
20. Islam, M.S.; Nepal, M.P.; Skitmore, M.; Attarzadeh, M. Current research trends and application areas of fuzzy and hybrid methods to the risk assessment of construction projects. *Adv. Eng. Inform.* **2017**, *33*, 112–131. [CrossRef]
21. Zhang, L.; Huang, Y.; Wu, X.; Skibniewski, M.J. Risk-based estimate for operational safety in complex projects under uncertainty. *Appl. Soft Comput. J.* **2017**, *54*, 108–120. [CrossRef]
22. Cárdenas, I.C.; Al-Jibouri, S.S.H.; Halman, J.I.M.; Van Tol, F.A. Modeling risk-related knowledge in tunneling projects. *Risk Anal.* **2014**, *34*, 323–339. [CrossRef]
23. Gabrielli, L.; Ruggeri, A.G.; Scarpa, M. Detecting information transparency in the Italian real estate market: A machine learning approach | Identificare la trasparenza informativa nel mercato immobiliare italiano: Un approccio machine learning. *Valori E Valutazioni* **2022**, *2022*, 33–48. [CrossRef]
24. D'Alpaos, C.; Moretto, M.; Rosato, P. Common-Property Resource Exploitation: A Real Options Approach. *Land* **2023**, *12*, 1304. [CrossRef]
25. Russo, F.; Maselli, G.; Vietri, M.; Nesticò, A. Urban Slum Upgrading: A Model for Expeditious Estimation of the Cost of Interventions. In *Computational Science and Its Applications—ICCSA 2023 Workshops*; Springer: Berlin/Heidelberg, Germany, 2023.
26. Hager, D.P.; Lord, D.J. The property market, property valuations and property performance measurement. *J. Inst. Actuar.* **1985**, *112*, 19–60. [CrossRef]
27. Flyvbjerg, B.; Holm, M.S.; Buhl, S. Underestimating Costs in Public Works Projects: Error or Lie? *J. Am. Plan. Assoc.* **2002**, *68*, 279–295. [CrossRef]
28. Flyvbjerg, B.; Skamris holm, M.K.; Buhl, S.L. What Causes Cost Overrun in Transport Infrastructure Projects? *Transp. Rev.* **2004**, *24*, 3–18. [CrossRef]
29. Park, Y.I.; Papadopoulou, T.C. Causes of cost overruns in transport infrastructure projects in Asia: Their significance and relationship with project size. *Built Environ. Proj. Asset Manag.* **2012**, *2*, 195–216. [CrossRef]

30. Paris, S.; Tajani, F.; Pennacchia, E.; Ranieri, R.; Di Liddo, F. A Methodological Approach for the Assessment of Parametric Costs of Sustainable Urban Roads: An Application to the City of Rome (Italy). In *Computational Science and Its Applications—ICCSA 2023 Workshops*; Springer: Berlin/Heidelberg, Germany, 2023.
31. Antoniucci, V.; Marella, G. Public works in north-east italy: An efficiency and risk allocation analysis. In *Appraisal and Valuation*; Springer: Berlin/Heidelberg, Germany, 2021.
32. Asiedu, R.O.; Adaku, E. Cost overruns of public sector construction projects: A developing country perspective. *Int. J. Manag. Proj. Bus.* **2020**, *13*, 66–84. [CrossRef]
33. Ghazal, M.M.; Hammad, A. Application of knowledge discovery in database (KDD) techniques in cost overrun of construction projects. *Int. J. Constr. Manag.* **2022**, *22*, 1632–1646. [CrossRef]
34. Shoar, S.; Yiu, T.W.; Payan, S.; Parchamijalal, M. Modeling cost overrun in building construction projects using the interpretive structural modeling approach: A developing country perspective. *Eng. Constr. Archit. Manag.* **2023**, *30*, 365–392. [CrossRef]
35. Jennings, W. Why costs overrun: Risk, optimism and uncertainty in budgeting for the London 2012 Olympic Games. *Constr. Manag. Econ.* **2012**, *30*, 455–462. [CrossRef]
36. Flyvbjerg, B. Survival of the unfittest: Why the worst infrastructure gets built—And what we can do about it. *Oxf. Rev. Econ. Policy* **2009**, *25*, 344–367. [CrossRef]
37. Dominic, A.D.D.; Smith, S.D. Rethinking construction cost overruns: Cognition, learning and estimation. *J. Financ. Manag. Prop. Constr.* **2014**, *19*, 38–54. [CrossRef]
38. Skitmore, R.M.; Ng, S.T. Forecast models for actual construction time and cost. *Build. Environ.* **2003**, *38*, 1075–1083. [CrossRef]
39. Ökmen, Ö.; Öztaş, A. Construction cost analysis under uncertainty with correlated cost risk analysis model. *Constr. Manag. Econ.* **2010**, *28*, 203–212. [CrossRef]
40. Love, P.E.D.; Edwards, D.J.; Irani, Z. Moving beyond optimism bias and strategic misrepresentation: An explanation for social infrastructure project cost overruns. *IEEE Trans. Eng. Manag.* **2012**, *59*, 560–571. [CrossRef]
41. Subramani, T. Causes of Cost Overrun In Construction. *IOSR J. Eng.* **2014**, *4*, 01–07. [CrossRef]
42. Flyvbjerg, B. Over Budget, Over Time, Over and Over Again: Managing Major Projects. In *The Oxford Handbook of Project Management*; Oxford Academic: Oxford, UK, 2011; pp. 321–344. [CrossRef]
43. Cantarelli, C.C.; Flybjerg, B.; Molin, E.J.E.; van Wee, B. Cost Overruns in Large-Scale Transport Infrastructure Projects. *Autom. Constr.* **2018**, *2*, 19.
44. Al-Hazim, N.; Salem, Z.A.; Ahmad, H. Delay and Cost Overrun in Infrastructure Projects in Jordan. *Procedia Eng.* **2017**, *182*, 18–24. [CrossRef]
45. Herrera, R.F.; Sánchez, O.; Castañeda, K.; Porras, H. Cost overrun causative factors in road infrastructure projects: A frequency and importance analysis. *Appl. Sci.* **2020**, *10*, 5506. [CrossRef]
46. Flyvbjerg, B.; Skamris holm, M.K.; Buhl, S.L. How common and how large are cost overruns in transport infrastructure projects? *Transp. Rev.* **2003**, *23*, 71–88. [CrossRef]
47. Cantarelli, C.C.; van Wee, B.; Molin, E.J.E.; Flyvbjerg, B. Different cost performance: Different determinants? The case of cost overruns in Dutch transport infrastructure projects. *Transp. Policy* **2012**, *22*, 88–95. [CrossRef]
48. Mišić, S.; Radujković, M. Critical Drivers of Megaprojects Success and Failure. *Procedia Eng.* **2015**, *122*, 71–80. [CrossRef]
49. Nabawy, M.; Khodeir, L.M. A systematic review of quantitative risk analysis in construction of mega projects. *Ain Shams Eng. J.* **2020**, *11*, 1403–1410. [CrossRef]
50. ANAC. Linee Guida n. 9. Attuazione del DL 18 aprile 2016, n. 50. In *Monitoraggio delle Amministrazioni Aggiudicatrici Sull'attività Dell'operatore Economico nei Contratti di Partenariato Pubblico Privato*; Autorità Nazionale Anticorruzione: Roma, Italy, 2018.
51. MIMS. *Linee Guida per la Valutazione Degli Investimenti*; Ministero delle Infrastrutture e della Mobilità Sostenibile: Roma, Italy, 2022.
52. Crosby, N. Valuation accuracy, variation and bias in the context of standards and expectations. *J. Prop. Investig. Financ.* **2000**, *18*, 130–161. [CrossRef]
53. Morano, P. Sul grado di approssimazione delle stime. *Genio Rural.* **2002**, *10*, 11–25.