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Risk Management in Rehabilitation of Structures

João Parreira [1]
Vítor Cóias [2]

ABSTRACT

The problems related to the durability of materials and constructed assets have deserved special attention due to the evident consequences both in terms of safety and costs arising from inadequate performance over time. Given the high frequency of unfortunate premature failures there is an increased interest to assess the risk of undertaking extended rehabilitation interventions and preventive actions to maintain the integrity of structures over the long-term.

In the rehabilitation of structures this problem is perhaps more acute given the difficulty in resolving problems that normally involve many causes, as well as, the uncertainty in the long-term performance.

The present study is intended to provide evidence on the current performance of structural interventions. A database was developed integrating all pertinent information allowing a diagnosis of the interventions and from which a risk management plan for the implementation of the interventions can be made. The database provides information about the verification of failures and anomalies, the degree of success of the corrective action and the durability of the structural systems under repair.

KEYWORDS

Risks, Rehabilitation of civil infrastructures, Inspections.

[1] Stap, sa, Lisboa, PORTUGAL, jcparreira@stap.pt
[2] Stap, sa, Lisboa, PORTUGAL, vitorcoias@gestip.pt

1 INTRODUCTION

Recent events made it clear that effective risk management is a critical element for success, and indeed, for long term survival, not only for industrial firms, but also for construction firms. The world is filled with all manner of risks, and so risk management must be extended far beyond the use of standard directive instruments in routine edging applications.

Construction companies take big risks associated to project mistakes, incorrect execution, wrong utilization, lack of maintenance and the inexistence of monitoring and controlling risk plans. Due to this, an information system that allows collecting information needed to manage risk and assess the performance of construction rehabilitation projects was developed.

The main objective consists of evaluating the present state of the rehabilitated infrastructures by the company since 1980 (during thirty years of activity). Another objective is to analyze the performance of the techniques used along with the structural behaviour, and also to detect the recurrence of anomalies of structural nature.

2 STATE OF THE ART

According to the Project Management Institute in the guide PMBOK [page 273], risk management involves six processes:

1. Plan Risk Management [P1] - The process of defining how to conduct risk management activities for a project;
2. Identity Risks [P2] - The process of determining which risks may affect the project and documenting their characteristics;
3. Perform Qualitative Risk Analysis [P3] - The process of prioritizing risks for further analysis or action by assessing and combining their probability of occurrence and impact;
4. Perform Quantitative Risk Analysis [P4] - The process of numerically analyzing the effect of identified risks on overall project objectives;
5. Plan Risk Responses [P5] - The process of developing options and actions to enhance opportunities and to reduce threats to project objectives;
6. Monitor and Control Risks [P6] - The process of implementing risk response plans, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating risk process effectiveness throughout the project.

Each process occurs at least once in every project and occurs in one or more of the project phases.
Risk is an uncertain event or condition that, if it occurs, has an effect on at least one project objective. This can include scope, schedule, cost, and quality. A risk may have one or more causes and, if it occurs, it may have one or more impacts. A cause may be a requirement, assumption, constraint, or condition that creates the possibility of negative or positive outcomes.

Project risk has its origins in the uncertainty present in all projects. Known risks are those that have been identified and analyzed, making it possible to plan responses for those risks. Specific unknown risks cannot be managed proactively. Organizations perceive risk as the effect of uncertainty on their project and organizational objectives. Organizations and stakeholders are willing to accept varying degrees of risk. This is called risk tolerance. Risks that are threats to the project may be accepted if the risks are within tolerances and are in balance with the rewards that may be gained by taking the risks. Individuals and groups adopt attitudes towards risk that influence the way they respond. These risk attitudes are driven by perception and tolerances which should be made explicit wherever possible.

A consistent approach to risk should be developed for each project, and communication about risk and its handling should be open and honest. Risk responses reflect an organization's perceived balance between risk taking and risk avoidance.

To be successful, the organization should be committed to address risk management proactively and consistently throughout the project. A conscious choice must be made at all levels of the organization to actively identify and pursue effective risk management during the life of the project. Moving forward on a project without a proactive focus on risk management increases the impact that a realized risk can have on the project and can potentially lead to project failure.

3 RISK MANAGEMENT PLAN

1. **Enterprise environmental factors** both internal and external that0 influence the project's success. These factors come from all of the enterprises involved. Includes:
    - Organizational culture, structure, and processes;
    - Government or industry standards;
    - Stakeholder risk tolerances;
    - Organization's established communications channels;
2. **Design and implement system information** to contain all the information necessary;
3. **Discussion with stakeholders** to select the projects based on factors like probability, monetary value, patrimonial value and structural safety impacts.
4. **Field inspections** and status report of the infrastructure rehabilitation projects.
5. **Perform qualitative risk analysis;**
6. **Plan risk responses**.

4 INFORMATION SYSTEM (IS)

The design of the IS allows the collection of technical and administrative data. To achieve this objective Windows MS Office/ Access was used. In Figure 1 one of the interfaces to input the data into the system is illustrated.

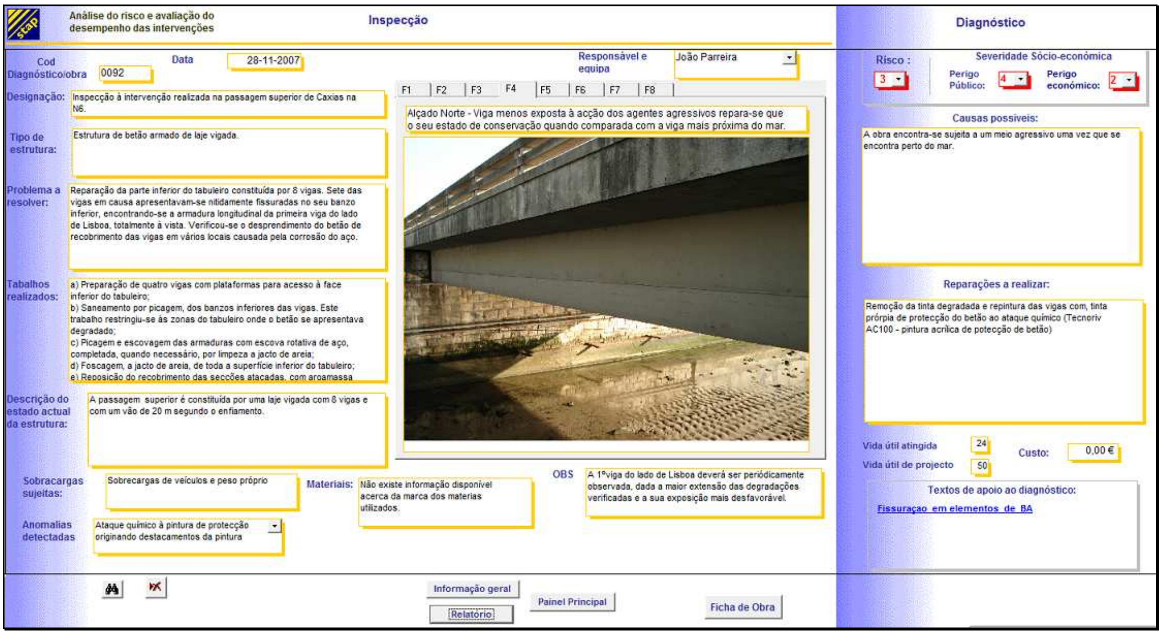

Figure 1. System Form - Field inspections and risk assessment.

As a result, this system allows several reports to be obtained by the management, by assessing the performance of the enterprise's project risks and planning strategies.

5 METHODOLOGY

Identifying Risks [P2] is an iterative process because new risks may evolve or become known as the project/product progresses through its lifecycle. Stakeholders outside the project, also provide additional objective information.

According to the *"Guide to the Maintenance, Repair and Monitoring of Reinforced Concrete Structures"* [page 691] published by the American Concrete Institute (ACI), a structured approach to identifying risk exposures will produce the best results. Having identified the risk exposures and, if possible, quantified their potential impact, it is useful to prioritise them [P3]. Risk exposures are ranked by order of impact, being determined by:

Risk = Probability (P) x Impact (I)

Risk solutions are identified with the aim of either eliminating or reducing the impact of risk exposure. The inspection and maintenance appear as solutions for high risks with the objective to eliminate or reduce their probability of occurrence, even for any risks that do not directly involve the company. In Table 1 is an example of specific risks for a structural reinforcement solution.

Table 1. Example of risk solution exercise for a reinforced concrete structures using steel plate bonding.

Risk	Success criteria	Solutions/risk reduction
Debonding of steel plates and loss of transmission of tensions to the element of reinforcement.	Full bonding action and polymerisation of epoxy resin	Routine inspection and maintenance repair
Diminishing resistance.	Lack of steel plates and fasteners.	Routine inspection and maintenance repair
Corrosion, concrete delamination.	Non-existence of concrete cracking	Routine inspection and maintenance repair

Evaluating the consequence and cost of a given risk will be determined on a case-by-case basis. Each infrastructure presents its own unique characteristics, for this reason the guidance notes do not seek to provide calculations for given risk exposures and each structure must be considered separately.

In this study a method based on the following criteria, was adopted:
- infrastructure degradation;
- present utilization conditions;
- frequency of maintenance and inspection.

In Table 2 and 3 are the criteria impact and probability.

Table 2. Utilization conditions and impact scale.

Category	Description
Demolish	Demolition of the infrastructure represents a very low/null impact.
Inactive	The infrastructure is inactive and represents a low impact. If reactivated requires a new risk evaluation.
Modify	The system presents different functions from those for which it was designed. Impact varies according to a higher or lower exigency level (case by case evaluation).
Active	The system preserves the same functions for which it was designed. Impact varies from high to very high (case by case evaluation).

1 - Very low	2 - Low	3 - Moderate	4 - High	5 - Very high

Table 3. Probability classification.

Probability	**Description**
1 – Rare	Remains unaltered after the intervention. Anomalies are non-existent.
2 – Unlikely	The infrastructure presents symptoms to the occurrence of anomalies, but without compromising the structural performance or cause serious lesions.
3 – Possible	The infrastructure presents anomalies that do not represent a structural risk in the short term meanwhile at long term it can compromise its structural function.
4 - Likely	The infrastructure presents substantial anomalies and damages. Recurrence of the problems that originated the intervention.
5 – Certain	Eminent collapse resulting in infrastructure total loss.

Perform Qualitative Risk Analysis [P3]. In order to do this, a short list of previously identified risks was created. The shortlisted risks could be further analyzed in the quantitative risks analysis, but in this case we move directly to plan risk responses process.

The risk-rating rules are specified by the organization in advance of the project and included in organizational process assets. Risk-rating rules can be tailored to the specific project in the plan risk management process. Evaluation of each risk's importance and, consequently, priority for attention, was conducted using a probability and impact matrix (see Table 4). This type of matrix specifies combinations of probability and impact that lead to rating the risks as low, moderate, or high priority. The red area represents high risk, the gray area represents low risk, and the yellow/orange area represents moderate risk.

Table 4. Probability and impact matrix.

		Probability (P)				
		Rare	Unlikely	Possible	Likely	Certain
Impact (I)	Very high	5	10	15	20	25
	High	4	8	12	16	20
	Moderate	3	6	9	12	15
	Low	2	4	6	8	10
	Very low	1	2	3	4	5

This matrix is used to sort or rate risks to determine which ones deserve an immediate response and which should be put on the "watchlist". This analysis is usually a rapid and cost-effective means of establishing priorities for plan risk responses.

Plan Risk Response [P5]. Depending on the case, responses include doing one or all of the following for each risk:

- do something to eliminate the threats before they happen;
- Decrease the probability and/or impact of threats.

The following three strategies applied to risks that have a negative impact:
<u>Avoid</u> - Eliminate the threat by eliminating the cause;
<u>Mitigate</u> - Reduce the probability or the impact of the threat;
<u>Transfer</u> - Make another party responsible for the risk.

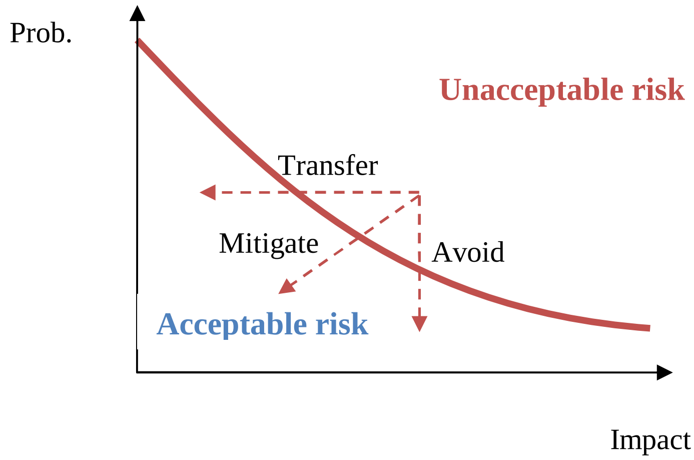

Figure 2. Risk response strategies.

6 CASE ESTUDY [CE]

More than forty jobs were selected, below are some examples:

Work 301 - The work on a school building involved using micro-piles and slope stabilization with sprayed concrete (1991). The performance appraisal conducted in 02-07-2008 found the structure presents anomalies that do not represent a structural risk in the short term. Meanwhile, in the long term it can compromise its structural function

Figure 3. Sprayed concrete - 1991.

Figure 4. Micro-piles head block - 2008.

After inputting data in the IS and according to the tables described in this paper, the final result was:
P = 3
I = 5
Risk (P x I) = 15 (see Table 5)

Work 451 - The work on the Central Post Office building involved metallic reinforcement of beams and pillars and surface repair of damaged structural elements (1994). The performance appraisal conducted in 05-05-2008 found the structure to be generally well-preserved, exhibiting a very low degree of degradation and maintaining the function for which it was originally conceived.

Figure 5. Metallic reinforcement beams and pillars - 1991.

Figure 6. Reinforcement beams and pillars - 2008.

After inputting data in the IS and according to the tables described in this paper, the final result was:
P = 1
I = 5
Risk (P x I) = 5 (see Table 5)

Work 727 - Rehabilitation of the access viaduct to the oil terminal (1997 to 1999). This contract job was the first practical case of desalination treatment successfully applied to a road viaduct made of reinforced prestressed concrete. The performance appraisal conducted in 30-06-2008 found that the structure is generally well-preserved and exhibits a low degree of degradation. The electrochemical desalination of the viaduct seems to have been successful, having met the expectations in terms of the results obtained, the safety of its implementation and the elimination of the cause of deterioration of the concrete structure.

Figure 7. Norcure desalination system in operation - 1998.

Figure 8. Viaduct - 2008.

After inputting data in the IS and according to the tables described in this paper, the final result was:
P = 1
I = 5
Risk (P x I) = 5 (see Table 5)

7 CONCLUSION

In this CE, the evaluations of the risk focus on interventions that represent higher costs for the society and the patrimony. This system adopted by the company, allowed monitoring principal risks, alerting any anomalies. The consequences of the risks were determined case by case including its costs to avoid, mitigate and transfer.

The risk management is a determinant factor on the project's performance. All interventions have specific expositions, deserving a specific diagnosis in accordance with the criteria described in chapter 5.

Table 5. Risk classification and response in all evaluated jobs.

Risk [R]	R = P x I	Case Study Occurrence (%)	Response
Unacceptable	17 - 25	(0%)	Develop a rehabilitation project.
Significant	13 - 16	(35%)	Implement a maintenance plan.
Substantial	9 - 12	(24%)	Special attention - Plan fields inspection and reports.
Acceptable	5 - 8	(16%)	Attention - Plan fields inspection and reports.
Insignificant	1 - 4	(25%)	Monitor

The results demonstrate (Table 5) that none of the structures were classified as unacceptable, and, approximately 35 % of the structures present a significant risk. However, this result is classified as unacceptable and preventive and corrective actions were required. In 24% of the cases (substantial) no serious structural risk was detected, although, the anomalies detected could influence the structural function in the long term. Finally, acceptable and insignificant risks were detected in 41% of the cases, which simply require monitoring.

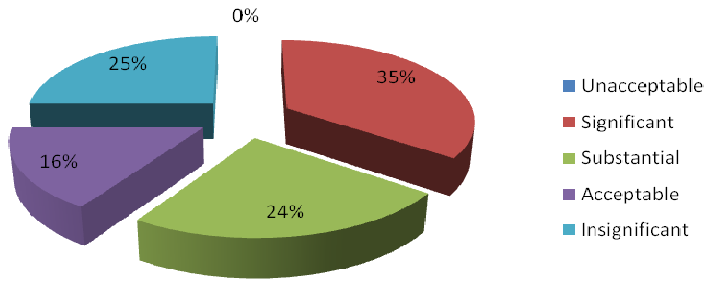

Figure 9. Risk classification

Based on the response plan defined to each of the risk groups, technical reports and diagnosis were elaborated in order to minimize associated risk in each intervention. In summary, inspections contribute to guarantee a good future performance, by alerting to the resolution of problems.

Infrastructure rehabilitation projects are even more sensitive to these questions and risk management allows response to risks and avoids their consequences. This CE had the aim of alerting all the stakeholders to the importance of risk management, especially in projects involving repair, strengthening, stiffening, protection, modification and demolition of structures.

REFERENCES

BRE DME D53 – Guide to the Maintenance, Repair and Monitoring of Reinforced Concrete Structures, in ACI, BRE, Concr. Society, ICRI - Concrete Repair Manual, 2.ª Edição, 2003, p. 691.

Cóias, Vítor – Inspecções e ensaios na reabilitação de edifícios;

Miguel, A. 2009. Gestão Moderna de Projectos: Melhores técnicas e práticas. FCA - Editora de Informática.

NP ISO 100006. 2006. Sistemas de Gestão da Qualidade. Linhas de orientação para a gestão da qualidade em projectos.

Project Management Institute. 2008. A Guide to Project Management Body of Knowledge (Fourth Edition).