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Reduction of Environmental Risks on Paved Roads in the Huánuco Region, Using a Matrix Based On the PMBOK Approach

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Abstract **-** This article addresses the management of environmental risks in gravel road projects in the Huánuco region of Peru through a standardized matrix based on the PMBOK approach. The proposed methodology enables the identification, prioritization, and mitigation of risks such as soil erosion, landslides, ecosystem contamination, among others. Data were collected from three road projects in the Huánuco region, and the tool was validated by road construction experts who highlighted its effectiveness in controlling costs, timelines, and environmental risks. The results reveal a positive perception of 90.9% regarding the matrix and unanimous willingness to implement it in future projects, reflecting its potential to optimize resources, reduce environmental impacts, and ensure sustainability in the road sector.

Keywords**: Environmental Risk Management, Affirmed Highways, PMBOK, Risk Matrix, Cost and Time Control**

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1. Introduction

In the field of civil engineering, risks are a constant factor in project execution, particularly in large-scale infrastructure projects with significant economic investment, such as road construction works. To ensure the success of a construction project, it is essential to anticipate and mitigate the negative effects of these risks. However, many projects have experienced significant failures due to insufficient risk management, leading to considerable financial losses and failure to meet deadlines and objectives. [1] Risk management thus emerges as a key tool to optimize resources, reduce environmental risks, and ensure project sustainability.

Despite its importance, the precise identification and definition of risks remain significant challenges in construction projects. [2] According to data, 19% of projects in the United States fail due to inadequate risk management. Similarly, the Project Management Institute (PMI) reports that one of the main reasons behind the failure of construction projects is the lack of adequate definition of risks and opportunities, accounting for 31% of the causes of failure. This highlights the urgent need to implement robust and standardized methodologies for managing risks in this sector.

Recent research also emphasizes the importance of employing effective risk management practices in infrastructure projects. [3] For instance, a study analyzes best practices in managing road infrastructure projects in Ghana, focusing on project managers' skills. [4] Meanwhile, a detailed analysis in China underscores the need to strengthen safety risk management in similar projects, identifying areas for improvement and proposing strategies to optimize safety in transportation system construction. [5] In the case of road infrastructure projects, risk management requires structured methods to ensure quality, meet deadlines, and control costs. A study conducted in Egypt highlights the importance of immediate risk assessment, identifying key factors that influence these aspects. [6] Furthermore, in construction projects, various risk management approaches have proven effective. For example, risk management plans (RMPs) have demonstrated their efficacy in projects like the Grand Paris Express, helping to minimize delays, reduce costs, and improve safety in underground works.

In response to these challenges, the development of a standardized environmental risk matrix is proposed, specifically adapted for gravel roads in the Huánuco region of Peru, based on the PMBOK approach. [7] The implementation of this

matrix will enable the identification, analysis, and prioritization of risks associated with environmental factors, such as soil erosion, sedimentation of water bodies, and disruption of local ecosystems, among others.

By applying this risk management methodology, significant benefits are anticipated in mitigating environmental risks throughout the project. Additionally, as Huánuco is strategically located in the center of the country, improving road infrastructure in this region would enhance regional connectivity and competitiveness, facilitating transportation and access to basic services for its inhabitants. [8] The implementation of this risk matrix represents a step forward in terms of sustainability and operational efficiency for road construction projects in Peru. [9] By establishing standardized processes for risk response planning and continuous monitoring, this tool optimizes costs by reducing the need for corrections after environmental damage.

2. Materials

To prepare the standardized matrix, information was collected from project files carried out in the Huánuco region, which document in detail the risks faced in each construction phase. In addition, technical reports and environmental studies were analyzed that provide context on the specific geographical and climatic conditions of the region. To ensure the accuracy of the matrix, construction progress records, audit reports and regulatory compliance checklists were used, along with budget and schedule data.

In the collection of information, three road projects confirmed in the Huánuco region were verified, which, for reasons of confidentiality, will be called project A, project B and project C. The information on the three projects found is presented below.

2.1. Project A

Project A is located in the department of Huánuco, province of Huánuco, Amarilis district, in the Fonavi III and Santa María del Huallaga urbanization, covering Azucenas, Progresiva, Calle 1, Calle 2, Calle 4 and Calle 5 streets.

The work will be carried out under the Lump Sum Contract modality, with a period of 120 calendar days and a total budget of S/. 1,434,702.46, including administrative expenses. Among the most common risks identified are soil erosion, contamination of water bodies, alteration of local fauna and flora, and the generation of noise and vibrations.

2.2. Project B

Project B is located in the Huánuco region, Huánuco district, in the El Bosque urbanization. The work will be carried out on the sections of the Jr. Primavera Cdra. 1, Jr. Primavera Cdra. 2, Jr. Candamo Cdra. 1, Jr. Candamo Cdra. 2 and Calle El Roble, at an approximate altitude of 1,906 meters above sea level.

The execution will be carried out within a period of 180 calendar days, with a total budget, including administrative expenses, of S/. 1,413,437.32. During its development, significant risks were identified, such as landslides caused by erosion and leaks, avalanches due to snow and rock falls, landslides due to loss of stability on slopes, floods due to river overflows, and droughts as a result of decreased rainfall. , which affect both the work and the natural and social environment

2.3. Project C

Project C is located in the central region of the country, covering the regions of Lima and Pasco and the provinces of Oyón and Daniel Alcides Carrión.

The execution works will be carried out within a period of 720 calendar days, stipulated in the integrated bases of the contract or within the duly approved deadline extension requests for reasons beyond the control of the contractor. The Ambo Road Consortium has offered a budget of S/. 278,176,397.97 for the development of the project, with the objective of maintaining or improving the expected costs and exceeding the expected profitability.

During the planning and execution of the project, several environmental risks were identified, among which are soil erosion, contamination of water bodies due to material spills, alteration of natural habitats that affects local fauna and flora, the risk of landslides in steep slope areas, and the generation of dust and emissions that impact air quality and the health of nearby communities.

3. Tools

The execution works will be carried out within a period of 720 calendar days, stipulated in the integrated bases of the contract or within the duly approved deadline extension requests for reasons beyond the control of the contractor.

The Ambo Road Consortium has offered a budget of S/. 278,176,397.97 for the development of the project, with the objective of maintaining or improving the expected costs and exceeding the expected profitability.

4. Methodology

The methodology employed in this research focuses on the creation and validation of a standardized environmental risk risk matrix, tailored to the context of road projects in Huánuco, Peru, and based on the PMBOK approach. This methodological approach enables a comprehensive identification of specific environmental risks in the area, such as soil erosion, sedimentation, and impacts on local ecosystems.

The matrix classifies and prioritizes these risks according to their probability and impact, establishing specific responses and controls to mitigate their negative effects. This process allows for continuous monitoring and control of risks throughout the project, promoting proactive and sustainable resource management. Ultimately, this methodology seeks to minimize costs associated with environmental damage and improve sustainability and operational efficiency in road infrastructure construction in the region.

To validate the matrix, the judgment of 10 experts with over 10 years of experience in road construction was utilized. Research supports the effectiveness of having seven or more experts to validate the methodology. This validation method was chosen because implementing the matrix would require an extended period, from the beginning to the end of the project, to demonstrate the full range of meteorological effects.

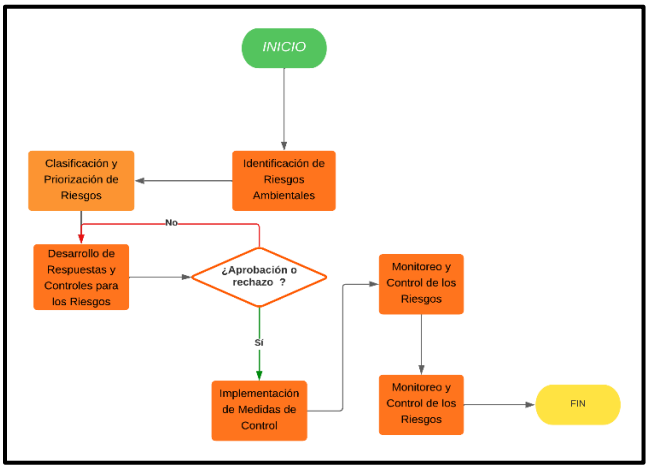

Fig. 1: Flowchart of the research procedure.

Figure captions and table headings should be sufficient to explain the figure or table without needing to refer to the text. Figures and tables not cited in the text should not be presented. Refer to the tale below for a sample.

5. Results

To validate the risk matrix with the PMBOK approach in road construction projects in Huánuco, a survey was conducted among experts with more than 10 years of experience in road construction. Using Google Forms, the survey provided insight into how risks affect project timelines and costs, providing a solid foundation to adjust and improve the procedure in future implementations. Below are the questions contained in the survey:

The high level of confidence in the proposed matrix is evident, as the majority of respondents consider it essential to mitigate environmental risks related to deadlines in construction projects. With a 90.9% positive perception, the matrix with a PMBOK approach is seen as a solid solution to face these challenges. However, a 9.1% indifference suggests that some believe the procedure may not be effective enough in certain cases or may need adjustments for specific contexts.

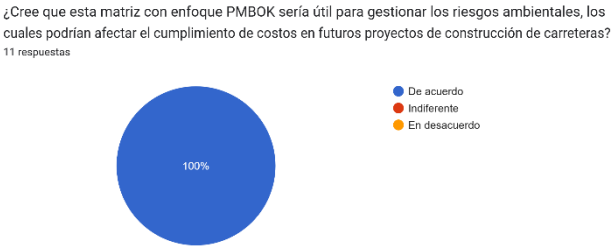

Fig. 2: Pie chart showing the effectiveness of the matrix for meeting deadlines in highway projects.

100% of the professionals surveyed perceive that the matrix with a PMBOK approach can effectively manage environmental risks and contribute to reducing costs, thus showing a positive perception about their capacity for financial control in projects. This indicates that the majority have experienced or anticipate cost risks and believe that the matrix will help mitigate cost overruns.

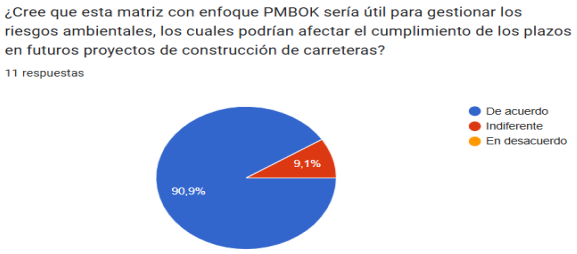

Fig. 3: Pie chart showing the effectiveness of the matrix for cost compliance in highway projects

81.8% of respondents indicate that environmental risk assessments have been carried out on road projects in the Huánuco region, reflecting a growing awareness of the importance of managing these risks. This data is positive, since it suggests that the majority of professionals have participated in projects with preventive measures. However, the 18.2% who indicate that no evaluations have been done point to areas for improvement, which could be due to resource limitations and inadequate procedures.

Fig. 4: Pie chart showing the previous risk assessment in road projects.

The graph shows that the majority of the professionals surveyed identified between 0 and 10 environmental risks (36.4%), while 27.3% identified between 10 and 20. 9.1% reported between 20 and 30 environmental risks, and another 9.1% between 30 and 40. These results indicate variability in the identification of environmental risks, with the majority detecting a moderate number of risks in highway projects.

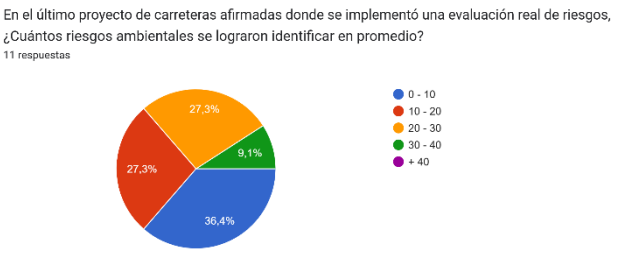

Fig. 5: Pie chart showing the number of risks identified without the matrix.

The graph shows that 27.3% of the professionals surveyed believe that the procedure allows the identification of between 30 and 40 risks on average. 54.5% estimate that more than 40 risks can be detected, while 9.1% consider it possible to identify between 20 and 30 risks and another 9.1% between 10 and 20 environmental risks. This reflects that the majority trust the procedure as an effective tool to identify a significant number of risks.

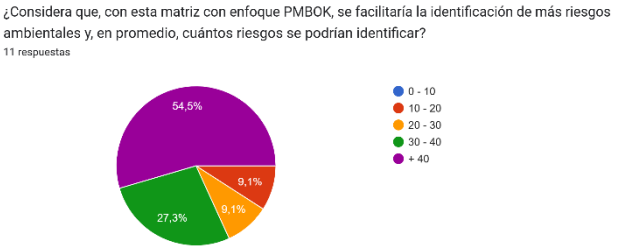

Fig. 5: Pie chart showing the number of risks identified with the matrix presented.

The pie chart indicates that all professionals surveyed are willing to apply the matrix with PMBOK approach to reduce environmental risks in future highway projects. This is due to the positive perception of its effectiveness in risk management, which demonstrates a high level of confidence in its ability to identify and mitigate potential problems in such projects.

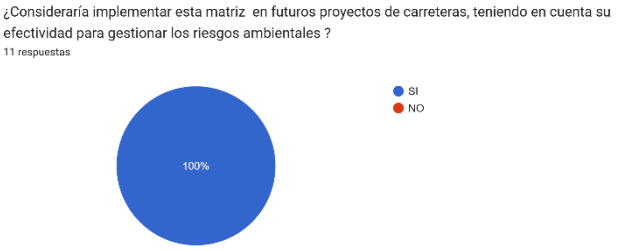

Fig. 7: Pie chart showing the effectiveness of the matrix in highway projects.

6. Analysis Of Results

6.1. Trust and Acceptance of the Matrix with PMBOK Approach

The survey shows a high level of confidence (90.9%) in the matrix with PMBOK approach as an effective tool to mitigate environmental risks in road construction projects. This perception is supported by the fact that 100% of those surveyed would be willing to implement it in future projects, indicating a consensus on its usefulness to face environmental risks on the roads

of Huánuco and other regions. Comparing this assessment with the three projects analyzed, it is observed that all present significant environmental risks (such as erosion, landslides, and ecosystem alteration), for which a management tool the PMBOK matrix could be especially beneficial. This suggests that professionals perceive that the matrix could address both current risks and challenges specific to each environment.

6.2. Environmental Risk Management and Cost and Time Control

Survey results and project data indicate that environmental risks are critical factors affecting both costs and timelines in highway projects. The professionals surveyed highlight the matrix with a PMBOK approach as an effective tool to manage these risks, which helps control additional expenses and reduce delays in works. 90.9% consider that the matrix mitigates cost overruns, and 100% are willing to implement it in projects. In projects like project C, with a high budget of S/. 278,176,397.97, the risks of landslides and mudslides generate cost overruns if they are not properly managed. Similarly, project B (S/. 1,413,437.32) is also affected by collapses and leaks, which increases costs if preventive measures are not taken. In addition to costs, environmental risks impact deadlines, as in project C, whose 720-day deadline is extended by adverse conditions such as rain or instability of the slopes. In project B, river overflows delay the schedule if corrective measures are not applied in time. The PMBOK matrix allows you to plan contingencies that help mitigate these risks, keeping costs and times under control. The majority of professionals consider the matrix essential for managing environmental risks in road projects, although a small percentage (9.1%) express doubts about its effectiveness in certain contexts, suggesting that some fear limitations in its implementation.

6.3. Risk Assessments in Road Projects

The survey reveals that 81.8% of professionals have carried out environmental risk assessments on road projects, reflecting a growing commitment to sustainability in the Huánuco region. However, 18.2% indicate that these evaluations have not yet been implemented in all projects, which points to the need to standardize these practices. The road projects analyzed show that most risks, such as erosion, landslides and pollution, could be reduced with systematic and preventive evaluations. This information suggests that although there is a positive trend towards risk management, there are still areas for improvement so that all projects adhere to a uniform preventive approach.

6.4. Identification of Amount of Risks

The variability in the number of risks identified by respondents (36.4% identified between 0 and 10 risks, and 27.3% between 10 and 20 risks) shows that risk perception is diverse, probably due to differences in the type of project, its location and environmental context. In the case of the projects analyzed, it is evident that some present greater inherent risks (such as Project C, with landslides and floods), which coincides with the perception of respondents who indicate an identification of more than 20 risks in certain cases. . This suggests that, although some projects are riskier than others, most trust that the PMBOK approach can adapt to different levels of risk and specific environmental situations.

7. Validation

This study focused on the validation of the matrix with the PMBOK approach for environmental risk management in road projects, with the objective of evaluating its impact on cost control, time and risk identification in road projects. The research design was structured with a combination of qualitative and quantitative methods, through surveys of professionals in the construction sector, in order to obtain a comprehensive view of the effectiveness of the PMBOK approach in mitigating environmental risks in highway projects.

The validation process consisted of collecting data on highway projects in the Huánuco region, with a focus on the identification of environmental risks and their impact on costs and execution times. Respondents' perception of the PMBOK matrix's ability to manage these risks and its influence on reducing cost overruns and delays was analyzed. The results obtained indicated that 90.9% of professionals considered that the matrix is effective in controlling costs related to environmental risks and 100% showed willingness to implement it in future projects, which validates the applicability and effectiveness of the tool.

In terms of the process, the matrix was applied through a series of simulated scenarios in road projects, which allowed verifying its ability to identify and mitigate environmental risks such as floods, landslides and environmental contamination. In addition, it was evaluated how this approach contributes to keeping projects within established deadlines and budgets. The study design and the data obtained support the proposal of the matrix with PMBOK approach

as an effective tool in the management of environmental risks in highway projects, especially in contexts such as Huánuco, where projects face specific challenges due to geographical factors. and climatic.

4. Conclusion

The standardized matrix proved to be an effective tool for the identification and mitigation of environmental risks in in highway projects. The experts consulted highlighted its usefulness to predict and manage threats such as landslides and floods, reducing their impact on costs and schedules. This validation shows that the implementation of structured methodologies can significantly improve risk management in road infrastructure projects.

The use of the matrix not only promotes the sustainability of road works by minimizing the environmental impact, but also improves the connectivity and competitiveness of regions such as Huánuco. By effectively managing risks such as sedimentation and ecosystem alteration, compliance with environmental standards is ensured and regional development is strengthened through more resilient and efficient infrastructure.

The results of the study reflect an almost unanimous acceptance of the matrix among experts, who consider its implementation viable and beneficial for future projects. This consensus highlights the importance of standardized tools in a sector where risk variability is high, ensuring more predictable processes aligned with international best practices.

Despite progress, there are still areas for improvement, such as the need to standardize risk assessments in all projects. Incorporating the matrix in the initial planning stages and establishing its use as a standard could further enhance the sector's capacity to face environmental challenges, guaranteeing safer and more sustainable works.

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