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Methodological Guide for Improving Risk Management Using the HAZOP Method Applied to Multifamily Housing Projects

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Abstract **-** Construction projects carried out using traditional methods involve different risks that are not anticipated or were not considered during the planning of multifamily housing projects. According to various studies, the absence of a risk management plan leads to project delays, poor project performance, and stakeholders' dissatisfaction with project delivery. Therefore, this study provides a set of procedures for risk management in the planning stage of multifamily housing projects based on the method called Hazard and Operability Study (HAZOP), which identifies risks that may cause problems in project operations. The contribution of this research is to demonstrate that the method can improve risk management in multifamily housing projects in the province of Huancayo.

Keywords**:** Project management, HAZOP, Multi-family housing, planification, risk management

1. Introduction

Project management includes various tasks aimed at ensuring the delivery of these projects in an acceptable and functional manner. According to Al-Mafrachi, Abdulrahman & Naimi, Sepanta [1], it is essential to implement effective management and planning methodologies in the construction sector to avoid slowdowns and delays, which can lead to serious economic losses and ultimately customer dissatisfaction. However, a common problem in many projects is the lack of interest in innovating or adopting efficient management methods. In addition, in some cases, adequate time is not allocated for project management, especially regarding risk management. This situation negatively affects the efficiency and success of construction projects, underlining the need for specific and effective methodological approaches in the planning and execution of multi-family housing projects.

Ahmed Muneer Abdulrahman [2] considers project risk management to be a fundamental aspect that allows for the identification of uncertain events in the execution of construction projects. The author highlights the importance of good risk management to identify potential events that affect the performance of construction execution operations.

However, poor risk management negatively impacts different processes and decreases the reliability in the delivery of construction projects. Rehman [3] pointed out that cost overruns in these projects are mainly due to the risks inherent in the development of the work, such as instability in the availability of labor, safety problems on site, quality and delivery of materials, and unforeseen weather conditions, factors that directly affect the budget and deadlines, generating cost overruns and affecting the efficiency of the project. Likewise, Idris [4] emphasizes that organizational efficiency in construction is evidenced by the ability to effectively manage these risks, highlighting that construction delays, late payments, lack of funds, and inadequate communication between the parties significantly impact project performance. According to Renault [5], risk management in construction projects is essential, highlighting as critical factors the use of defective materials, insufficient financial resources by the contractor, and lack of effective communication between the parties involved. Hasan [6] adds that, in developing countries, where the environment is uncertain, projects require effective risk management to mitigate the effects of incidents that can cause delays or increases in costs. Likewise, Obondi [7] emphasizes that the lack of adequate risk monitoring and control practices contributes to cost overruns and delays, as insufficient monitoring of identified risks causes significant losses. His study in the Dallas-Fort Worth area shows that practices such as risk reassessment, audits,

contingency reserve analysis, and risk status meetings are positively related to project success, as they allow for early intervention and increase the likelihood of meeting time, cost, and quality objectives.

This article presents the application of the HAZOP (Hazard and Operability Study) method as an effective alternative to optimize risk management in multi-family housing projects developed in the province of Huancayo, Peru. The research outlines a series of processes during the risk management and planning phase in which the method will seek to identify, assist, and propose alternative solutions to possible risks that may arise in the execution of works in multi-family housing buildings in the province of Huancayo. The main purpose of this article is to demonstrate the viability of the method in the construction sector, given that the HAZOP method is well-known in other industries beyond the construction sector, such as the petrochemical, pharmaceutical, and industrial industries.

2. Materials/tools and Methodology

In this section, the materials and/or tools necessary for the integration of the HAZOP method in risk management will be defined. A HAZOP table is fundamentally needed in which the possible risks that may occur during the execution of the methodological guide will be written. The table consists of different items that will be analyzed in one of the procedures for the preparation of the methodological guide. These items are the following: node to be analyzed, assignment of keywords, identified risk, cause, consequence and countermeasure. These items will be placed in the main row of the table. Finally, in the main column, each risk analyzed will only be differentiated by a defined node. The following table will be a reference table of how the HAZOP table should be prepared:

TABLE 1
TYPICAL HAZOP TABLE

Node	**HAZOP analysis of potential risks**				
	Keyword to use	***Risk***	***Causes***	***Consequences***	***Countermeasure***
Node 1	Keyword 1	Risk 1 + Keyword 1	Cause of risk 1	Consequence associated with risk 1	Countermeasure associated with risk 1
Node 2	Keyword 2	Risk 2 + Keyword 2	Cause of risk 2	Consequence associated with risk 2	Countermeasure associated with risk 2
Node 3	Keyword 3	Risk 3+ Keyword 3	Cause of risk 3	Consequence associated with risk 3	Countermeasure associated with risk 3

In addition, an index table of the keywords to be used in risk management will be needed. These keywords are intended to complement and formulate sentences that better identify the identified risks. The following table will show the keywords to be used in the methodological guide and the meaning that corresponds to them according to what the HAZOP method indicates.

TABLE 2
KEYWORD TABLE OF THE HAZOP METHOD

Keyword	**HAZOP Method Keyword Table**
	Meaning and/or use
More	Identify and analyze that you have or find more of something
Less	Identify and analyze that you have or find less of something
No	Identify and analyze that there is an absence of something
Part of	Identify and analyze what would happen if only part of a process is completed
Other	Identifies that there is another process running that is completely different from the original process

According to these tables that will be used in the risk analysis of multi-family housing projects carried out in the province of Huancayo, the procedures for executing the method in a risk management plan are described.

A. Define the members that will make up the risk management group: Those involved must be professionals closely related to the construction project that is planned to be built. It is recommended that the members of the group be professionals with the greatest possible experience in the planning and development of multi-family housing projects. Finally, a moderator will be appointed to direct the risk management procedures using the HAZOP method. This moderator must know and understand how to use the method's tools so that it can be applied in the meeting.

B. Identify the sequence of project nodes: The nodes, according to the HAZOP method, are stages, teams or processes within a project. For the correct implementation and delimitation of these nodes in multi-family housing construction projects, the nodes will represent the milestones that sequence their construction. Such as earthworks, foundations, structures for each floor, architecture and finally facilities, among others. These nodes must be sequenced in an orderly manner one on top of the other.

C. Explanation of the tools to be used in management and analysis of project risks: It will begin with the meeting, after grouping those involved in the project, defining the moderator and identifying the project nodes. At this stage, the 2 tables will be applied during the meeting. Table I will be the main means where the possible risks associated with each node will be identified and discussed. The process is to identify a risk within a node, then one of the key words from Table II will be used to formulate a phrase that associates the possible risk. The purpose is for the identified risks to have a quantified description since these key words are quantifiable measurements of each risk. Finally, having the risks identified for each node, the causes, consequences and possible countermeasures for each risk evaluated will be analyzed.

D. Risk documentation: After identifying the potential risks of these nodes, a data table is created so that each potential risk that may occur can be identified and solved in the manner planned. This data table must be present at each stage of the project and must be reviewed periodically to verify whether any risk was detected during the execution of the project.

Below is a flow chart of the steps applied in the methodology.

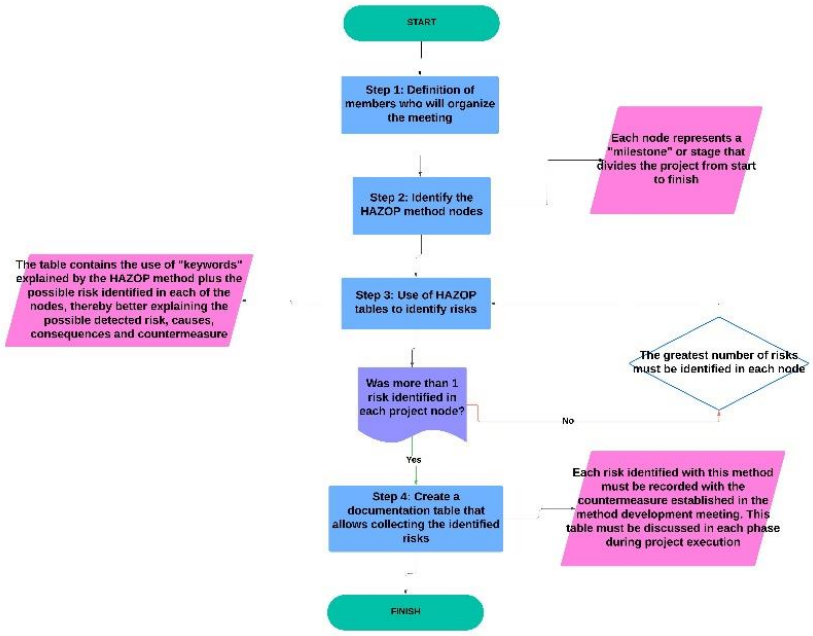

Fig. 1: Flow chart of the activities of the HAZOP method

Similarly, a table of indicators has been made that can measure the problem of this research:

TABLE 3
TABLE OF INDICATORS FOR MEASUREMENT OF THE PROBLEM

Table of measurement indicators		
Indicator	**Unit of Measure**	**Description**
Coverage of critical risks	Number of risks addressed/ Total risks identified	Evaluates what percentage of critical risks are covered by the methodological guide.
Realism in estimated time	Average duration of the appropriate analysis stage (in days)	Analyze whether the estimated time to implement the methodology is considered adequate by experts.
Number of unresolved risks	Number of unresolved risks in the project/total risks found in the project	It measures the amount of unresolved risks since countermeasures to these risks were not proposed before executing the project.

3. Validation of the methodological guide:

To validate the "Methodological guide for improving risk management using the HAZOP method applied to multi-family housing projects in the Province of Huancayo, Peru", it was decided to use expert judgment through a questionnaire designed in Google Forms. This questionnaire provided detailed feedback on the clarity, applicability and feasibility of the proposed methodology, as well as on its structure and content. A total of 10 experts in the construction field were surveyed.

TABLE 4
TABLE OF SURVEY RESPONDENTS

Experts	**Actual role**	**Years of experiencie**
Julio Gabriel Casaverde García	Resident engineer	10-13 Years

Sergio Lipa Vilca	Resident engineer	10-13 Years
Paolo Aníbal Zuta Gómez	Resident engineer	14-16 Years
Eduardo Sanchez Rodriguez	Resident engineer	14-16 Years
Luis Araujo Ramos	Resident engineer	10-13 Years
Nadinne Flores Tintaya	Production engineer	14-16 Years
Piero Ruiz Castillo	General manager	More than 16 years
Mauro Huaman Montoya	Resident engineer	10-13 Years
Valeria Rivera Guzman	Production engineer	10-13 Years
Miguel Luis Córdova Gonzales	General manager	More than 16 years

The questions asked were the following:

I. Do you think the proposed method for risk management in multi-family housing projects is clear and easy to apply?

This question sought to obtain a general evaluation of the clarity of the HAZOP method and its ease of implementation.

II. Do you think that the methodological guide adequately addresses the most critical risks in this type of project?

For this question, the indicator used was the number of risks covered out of the total risks identified, allowing to quantify how many of the critical risks relevant to multi-family housing projects have been considered in the guide.

III. Do you think that the estimated time to implement this methodology is sufficient and realistic?

For this question, the indicator was based on the average time considered adequate by the experts, analyzing whether the estimated time to implement the HAZOP methodology is realistic and sufficient to effectively apply the risk management process in practice.

IV. Do you think that the steps in the methodological guide will allow you to identify effective countermeasures that help mitigate potential risks, thereby reducing the number of unresolved risks in the future?

This question assessed the ability of the methodological guide to propose practical and effective solutions that allow you to minimize the identified risks, ensuring more efficient management and reducing the likelihood of unresolved risks remaining in projects.

With the respondents shown in the table above, the results of the survey will be determined based on the questions asked. First, the years of experience of the experts were collected and summarized in the following graph:

Results of question 1:

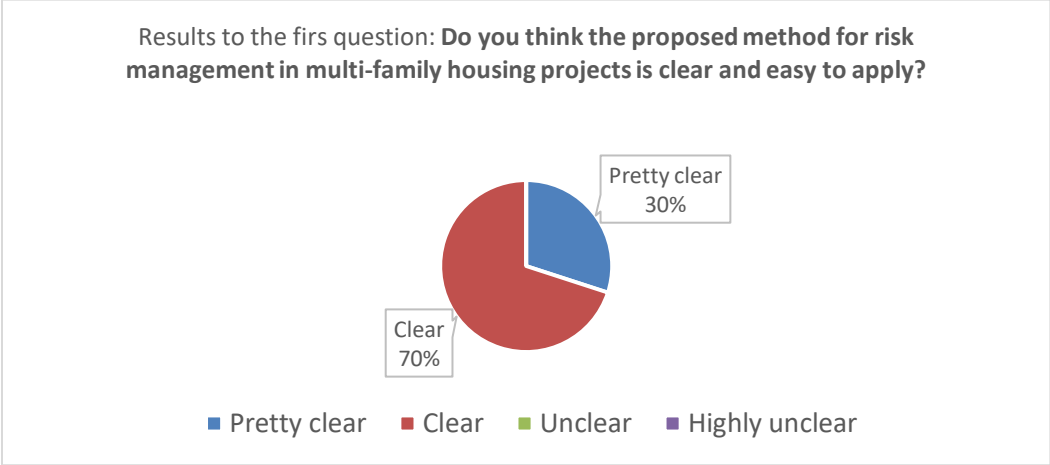

Fig. 2: Respondents' perception of method clarity and ease of application

Most experts (70%) considered the method to be "Clear" and 30% rated it as "Very clear". This suggests that the method is perceived as comprehensible and applicable.

Results of question 2:

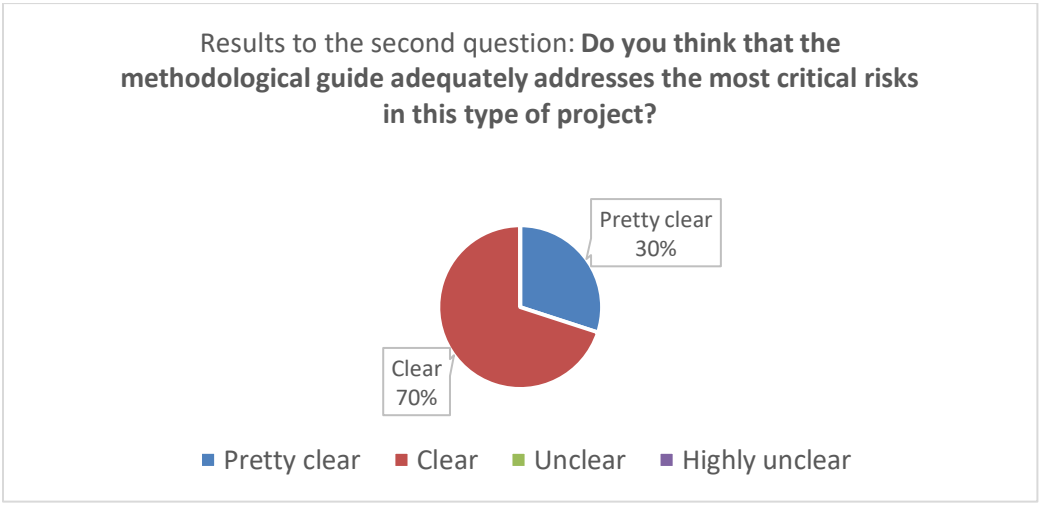

Fig. 3: Respondents' perception on adequacy of the methodological guide in addressing critical risks

70% of the experts agreed and 30% strongly agreed that the methodological guide covers the most critical risks of these projects, which reflects a favourable assessment of the coverage of relevant risks in the guide.

Results of question 3:

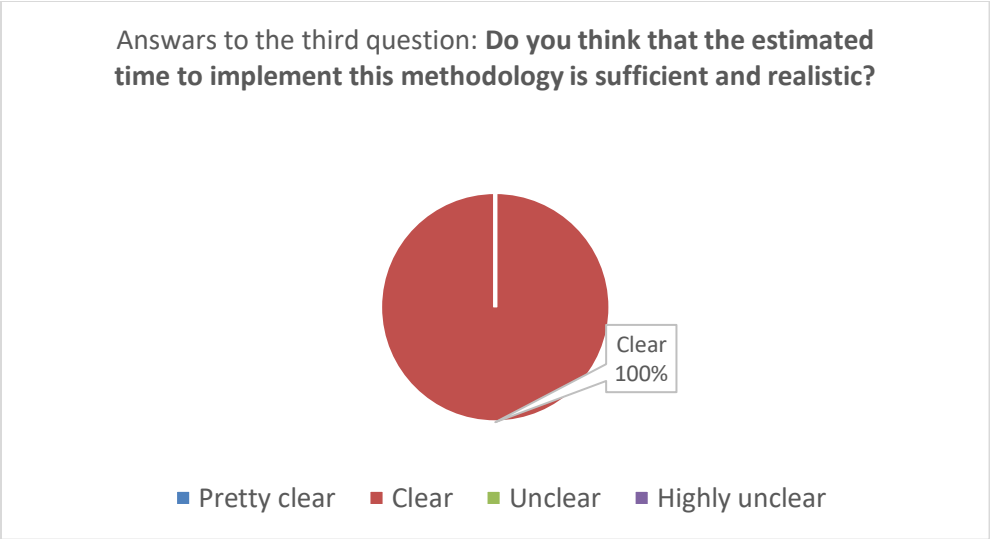

Fig. 4: Respondents' perception on time implementation of the methodological guide

100% of the experts "Agreed" that the estimated time to implement the methodology is sufficient and realistic, which demonstrates unanimous acceptance regarding the temporal viability of its application.

Results of question 4:

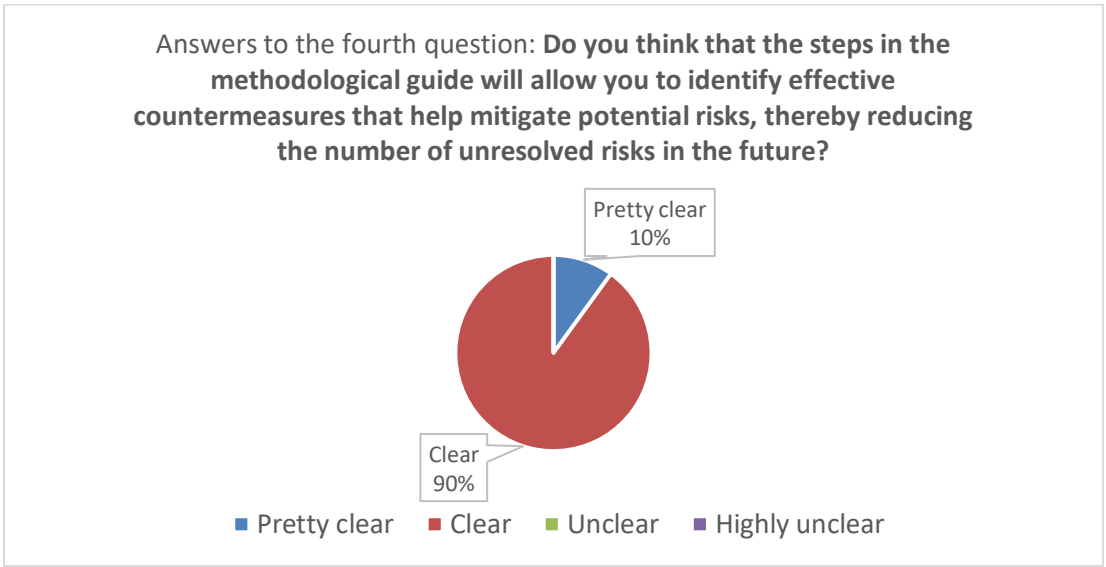

Fig. 5: Respondents' perception of the guide's effectiveness in identifying countermeasures and reducing unresolved risks

90% of experts “Agree” and 10% “Strongly Agree” that the structure and steps of the methodology will allow identifying most of the potential risks in the construction of multi-family housing, which reflects high confidence in the effectiveness of the guide for this purpose.

4. Results Analysis

According to the results obtained in the previous chapter, a summary of the results will be presented:

a. ***Question 1:***

70% of experts rated the method as "Clear" and 30% as "Very clear". This reflects that the methodology is perceived as comprehensible and accessible for practical implementation. The absence of negative or neutral opinions highlights the clarity in the design of the method, which is essential to ensure its acceptance and application by professionals involved in risk management.

b. ***Question 2:***

The results show that 70% of experts "Agree" and 30% "Strongly Agree" that the guide effectively addresses the most critical risks in multifamily projects. This finding reinforces the relevance and accuracy of the guide's contents, as it covers the most relevant risk areas, ensuring greater effectiveness in mitigating them.

c. ***Question 3:***

100% of experts "Agree" that the estimated time is sufficient and realistic. This absolute consensus underlines that the methodology does not present obstacles related to its duration, facilitating its adoption and application in the professional field. Time feasibility is key to ensure that teams can implement the guide without significant delays or complications.

d. ***Question 4:***

90% of experts "Agree" and 10% "Strongly Agree" that the guide will enable effective countermeasures to be identified and unresolved risks to be reduced. This result demonstrates high confidence in the ability of the steps outlined in the methodology to effectively address and mitigate risks, highlighting their applicability in practical scenarios and their alignment with risk management objectives.

Each question assesses critical aspects of the guide, and the results confirm the strength of its design and its potential to be successfully implemented in multifamily housing projects.

5. Conclusions

This research proposes a development of a methodological guide based on the HAZOP method, whith the primary objective of strengthening risk management during the planning phase of multi-family housing construction projects, a stage where risk identification is often overlooked, particularly in housing projects in the province of Huancayo. The main proposition is that the HAZOP method can be effectively adapted for the construction sector. Expert judgment, gathered through multiple responses, confirmed that the guide would be effective in identifying relevant construction risks. These findings suggest that integrating systematic risk identification tools into early planning could improve project outcomes and reduce common issues such as delays and cost overruns in the housing sector.

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References

[1] A. Al-Mafrachi and S. Naimi, "Losses Resulting from Exceeding the Specified Time for Completion and Its Impact on the Status of the Project and Delay in Utilizing Services," *Mathematical Modelling of Engineering Problems*, vol. 11, no. 2, pp. 404–412, Feb. 2024, doi: 10.18280/MMEP.110212.

[2] A. T. A. M. Abdulrahman, N. A. Bin Haron, A. H. Bin Ales, and L. T. Hua, "The applications of the risk management & quality function deployment in the Malaysian Construction Industry: A critical perspective," *Periodicals of Engineering and Natural Sciences*, vol. 10, no. 5, pp. 136–155, 2022, doi: 10.21533/PEN.V10I5.3330.

[3] M. A. Rehman and M. S. Bin Ishak, "Risk-Level Assessment of Construction Risk Management Among the Kingdom of Saudi Arabia Contractors," *Lecture Notes in Civil Engineering*, vol. 384, pp. 3–29, 2024, doi: 10.1007/978-981-99-6022-4_1.

[4] M. H. Idris, H. Adnan, H. E. A. Baharuddin, Z. A. M. Zaki, and W. N. W. Ismail, "Risk Factors on Civil Engineering Projects," *IOP Conf Ser Earth Environ Sci*, vol. 1067, no. 1, 2022, doi: 10.1088/1755-1315/1067/1/012064.
[5] B. Y. Renault and J. N. Agumba, "Critical risk factors in construction projects: Perspective of contractors in South Africa," *Transforming the Future of Infrastructure through Smarter Information - Proceedings of the International Conference on Smart Infrastructure and Construction, ICSIC 2016*, pp. 707–714, 2016, doi: 10.1680/TFITSI.61279.707.
[6] F. H. Shah, O. S. Bhatti, and S. Ahmed, "A Review of the Effects of Project Management Practices on Cost Overrun in Construction Projects †," *Engineering Proceedings*, vol. 44, no. 1, 2023, doi: 10.3390/ENGPROC2023044001.
[7] K. C. Obondi, "The utilization of project risk monitoring and control practices and their relationship with project success in construction projects," *Journal of Project Management (Canada)*, vol. 7, no. 1, pp. 35–52, 2022, doi: 10.5267/J.JPM.2021.7.002.