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Revista JRG de Estudos Acadêmicos

ISSN: 2595-1661

ARTIGO

Página da revista:
https://revistajrg.com/index.php/jrg

ISSN: 2595-1661
Revista JRG de Estudos Acadêmicos

Aplicabilidade das técnicas de gerenciamento de riscos em problemas de engenharia

Applicability of risk management techniques in engineering problems

DOI: 10.55892/jrg.v8i19.2743
ARK: 57118/JRG.v8i19.2743

Recebido: 24/11/2025 | Aceito: 29/11/2025 | Publicado *on-line*: 30/11/2025

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Resumo
Dentre os diversos estudos que abordam a temática de Gestão de Riscos, a ideia proposta neste trabalho consiste em mostrar a importância da utilização de ferramentas de gerenciamento e controle de riscos na prevenção de acidentes de trabalho que possam orientar métodos para antecipação, o reconhecimento, a avaliação e o controle dos riscos. Risco é todo evento futuro e incerto que possa comprometer a realização de um ou mais objetivos do projeto. A Gestão de Riscos aplicada consiste na identificação, classificação e quantificação dos riscos, bem como na definição, planejamento e gerenciamento das ações de resposta a estes riscos. Sendo assim, pode-se dizer que os principais benefícios da Gestão de Riscos são a minimização da probabilidade da ocorrência de eventos adversos aos objetivos dos projetos, ampliando assim as chances de sucesso destes, o que é vital no mercado competitivo de hoje e o diferencial para a realização de projetos de excelência.

Palavras-chave: riscos, gerenciamento, ferramentas, gestão de riscos.

Abstract
There are many studies involving the theme Risk Management, and the main purpose of these works is to show the importance of the risk management tools utilization for preventing work accidents that may guide to apply anticipation, recognizing, evaluation and control of these risks. Risk is all uncertain and future events that can harm one or more design objectives. Applied Risk Management consists in the identification, classification and quantification of the risks, and the planning and management of feedback actions to these risks. Thus, we can say that the main benefit of risk management is the minimization of the probability of harming events for the design,

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increasing the possibility of being successful, which is important nowadays and may be the difference to making a well-done design.

Keywords: *risks, management, tools, risk management.*

1. Introduction

In general, accidents occur due to a lack of awareness of workplace risks, noncompliance with legislation, the use of inappropriate tools, and, most importantly, a lack of planning, logistics, and systematic prevention activities. According to Bentes et al. (2018), the different risks are associated with the working conditions existing in each production process. A workplace accident generates consequential losses that affect both employers and workers. For the company, the costs involve much more than just production shutdowns, including damage to the company's image, construction embargoes, and/or equipment bans by tax authorities. Workers face physical and psychological injuries, in addition to trauma and ongoing expenses for medication and rehabilitation treatments.

Due to the high number of workplace accidents, companies have been urged to implement more effective prevention methods that reduce the likelihood of accidents. Bentes et al. (2017) understand that “workplace accidents represent a large part of the material and human losses in today's companies.” Thus, we need to understand the risks from the project. Zhao and Bai (2010) explain that identifying and mitigating project risks are crucial steps in managing successful projects.

An accident prevention system includes identifying high-risk points, emergency plans, checklists, safety reports, risk assessments, monitoring, inspections, maintenance, and repairs, as well as worker training and supervision by a qualified professional. The benefits of risk management include minimizing the likelihood of events that are averse to project objectives, thus increasing the chances of success. This is vital in today's competitive market and a key factor in achieving excellent projects (BENTES, 2007).

Several tools are used to manage and control risks in a workplace. Risk control involves developing risk management strategies based on risk management techniques. Zeng et al. (2010) understand that “a structured risk management approach also enhances and encourages the identification of greater opportunities for continuous improvement”.

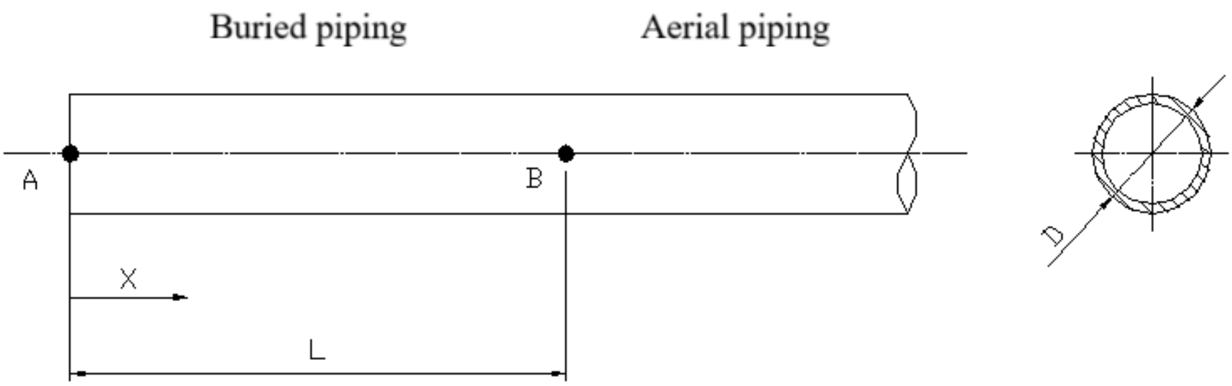
One such tool is Preliminary Hazard Analysis (PHA). It is typically used during project design, especially when there is limited information about the associated risks. Another technique is Failure Modes and Effects Analysis (FMEA). According to Liu et al. (2024) “FMEA method is widely used in the fields of aerospace, mechanical engineering, and medical management”. In this approach, failure modes are identified, followed by analysis and evaluation of their respective effects. Based on the FMEA, intervention measures are adopted with the goal of mitigating the causes and consequences associated with the risks.

Hazard and Operability Studies (HAZOP) were developed for the detailed study of variables related to a given process. This methodology can be understood as a systematic way to identify potential equipment failures or improper operating procedures. Guide words are used and assigned to process variables. Based on individual analyses of these variables, operational deviations are obtained and analysed in terms of potential consequences and possible causes. prescribed. Siddiqui et al. (2014) describe that HAZOP system helps the companies to identify deviations from the design intent. Galante et al. (2014) understand that HAZOP can be defined as a systematic application of management policies, procedures and practices.

2. Methodology

We illustrate bellow a situation involving an anchored pipeline that will represent the problem under study. Next, we list the hypotheses adopted for the problem, the equation that determines the anchor length, and the pipeline data, describing all parameters.

Figure 1 – Problem illustration.



The following assumptions are adopted:

- To the left of point A, the pipeline is prevented from moving axially.
- Between point A and point B, the pipeline moves subject to a frictional force against the ground (slip).
- To the right of point B, the pipeline is no longer subject to axial friction (overhead pipeline).
- The pipeline has no manufacturing discontinuities.
- The pipeline has no dents.
- The pipeline has no planar deformities, or volumetric deformities.
- There are no failures due to soil action (geologically stable soil).
- The pipeline is not susceptible to stress corrosion cracking (SCC).
- The pipeline is not subject to cyclic fatigue stresses.

The equation that determines the design anchorage length for the model is given by the expression below:

$$L = \frac{A}{f_a}\left(\frac{(0{,}5-\nu)PD}{2t} + E\alpha\Delta T\right) \quad \text{(Equation 1)}$$

The analyzed pipeline data are illustrated below:

Table 1 - Problem data.

Parameter	Dimension
Duct outside diameter (*D*)	30”
Thickness (*t*)	0,5”
Assembly Temperature (T_o)	26 °C
Yield Strength (σ_y)	482,63 MPa
Modulus of Elasticity (*E*)	200 GPa
Poisson’s ratio (ν)	0,3
Coefficient of Thermal Expansion (α)	12.10^{-6} ºC^{-1}
Ground Friction Force (f_a)	10
Internal pressure (*P*)	4,90 MPa
Fluid temperature (T_f)	80 °C

An acceptance criterion can be established if the variation in anchorage length is considered. Thus:

$$\Delta L = L_P - \frac{A}{f_a}\left(\frac{(0{,}5-\nu)PD}{2t} + E\alpha\Delta T\right) \qquad \text{(Equation 2)}$$

The calculated design anchorage length is L_p= 483,40. Logo:

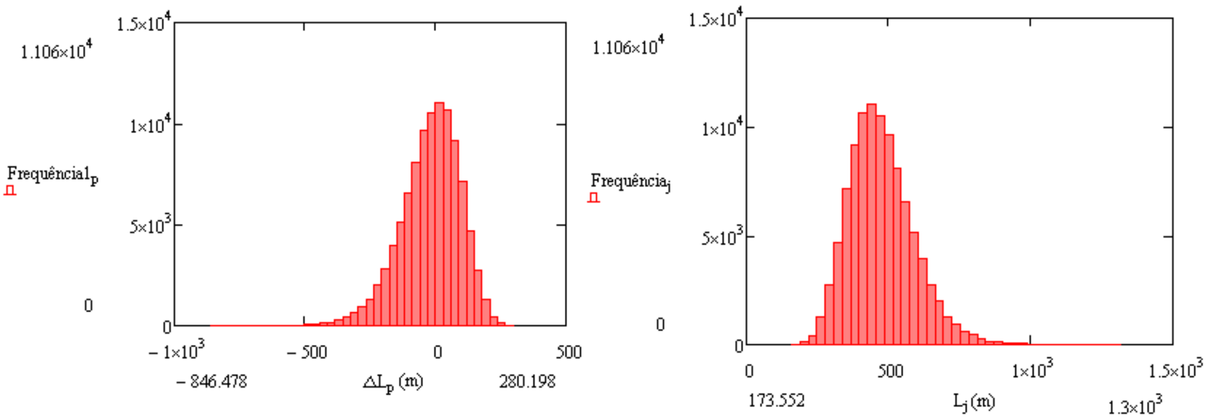
$$\Delta L = 483{,}40 - \frac{A}{f_a}\left(\frac{(0{,}5-\nu)PD}{2t} + E\alpha\Delta T\right) \qquad \text{(Equation 3)}$$

There is then an acceptance criterion, such that:

$$\begin{cases} \text{If } \Delta L \geq 0 & \text{there will be no problem} \\ \text{If } \Delta L < 0 & \text{outside the design conditions} \end{cases}$$

Below we can see the distribution for ΔL and L for the analized problem.

Figure 2 – Distribution for ΔL and L.



3. Results and discussion

3.1. Preliminary Hazard Analysis – PHA

At this stage of the work, the Preliminary Risk Analysis is carried out for the problem variables based on the data obtained from the correlation of dependence of each variable with the variation in the anchoring length ΔL. It is worth noting that the Preliminary Risk Analysis also considers the difficulty of controlling the variable, which may influence the responsible party to classify it as more critical, even if with a lower correlation dependence. This includes the variables thickness (t) and modulus of elasticity (E), which have control limitations primarily related to the high cost of technological and inspection equipment (e.g., probing and testing equipment).

Table 2 - Preliminary Hazard Analysis.

SYSTEM IDENTIFICATION: Buried pipeline (lateral confinement) with outcrop point SUBSYSTEM IDENTIFICATION: Pipeline RESPONSIBLE: Flavio Maldonado Bentes				
HAZARD	CAUSE	LEVEL	CORRELATION (%)	PREVENTIVE MEASURES
Increase in Diameter	Material out of specification	IV	-51,2	Quality control inspections upon receipt
Decrease in friction with the ground	Modification of the soil variable	IV	44,4	Periodic field inspections
Temperature variation	Failure in controlling the temperature variable	III	-35,4	Redundant control of temperature variation
Variation in thickness	Material out of specification	IV	-35,2	Quality control inspections upon receipt
Coeficiente de Expanão Térmica	Material out of specification	III	-35,1	Quality control inspections upon receipt
Variation in E	Material out of specification	IV	-34,8	Quality control inspections upon receipt
Variation in v	Material out of specification	II	11,7	Quality control inspections upon receipt
Increase in internal pressure	Failure in controlling the pressure variable	II	-8,3	Redundant control of the pressure variable

The risk category classification is summarized below:

- Negligible (I): The failure will not result in major system degradation.
- Marginal (II): Indicates that the failure will harm the system to some extent.
- Critical (III): The failure will harm the system, resulting in material or harmful.
- Catastrophic (IV): The failure will harm the system, resulting in material or harmful losses, or a total loss.

3.2. Hazard and Operability Studies – HAZOP

At this stage of the work, the Hazard and Operability Studies are carried out for the problem variables based on the data obtained from the correlation of dependence of each variable with the variation in the anchorage length ΔL. Although the HAZOP technique is not intended to classify risks into a specific category, as is done in the previously analysed PHA, it rather provides a snapshot of what must be done to control and minimize deviations. It is worth noting that the study of hazards and operability can also consider the difficulty of controlling the variable, such as choosing a variable to be treated as a priority, as well as the control mechanisms to mitigate the occurrence and/or continuation of the deviation(s).

Table 3 - Hazard and Operability Studies.

Object of analysis: modelling of problems with industrial pipelines				
Variable	Desviation	Causes	Correlation	Control
D	Increase in D	Material out of specification	-0,512	Quality control inspections upon receipt
f_a	Decrease in f_a	Modification of the soil variable	0,444	Periodic field inspections
ΔT	Temperature variation	Failure in controlling the temperature variable	-0,354	Redundant control of temperature variation
T	Decrease in *t*	Material out of specification	-0,352	Quality control inspections upon receipt
A	Increase in α	Material out of specification	-0,351	Quality control inspections upon receipt
E	Increase in E	Material out of specification	-0,348	Quality control inspections upon receipt
N	Increase in v	Material out of specification	0,117	Quality control inspections upon receipt
P	Increase in P	Failure in controlling the pressure variable	-0,830	Redundant control of the pressure variable

3.3. Failure Modes and Effects Analysis – FMEA

The Failure Mode and Effect Analysis is carried out for the problem variables, considering the Risk Index, which is calculated as the result of the product of the severity (S), occurrence (O) and Detection (D) indices. Severity indices were determined by establishing the proportionality criterion for the correlation between the variable and its respective severity. Regarding occurrence levels, the conservative principle (moderate occurrence) was adopted for all cases. For detection levels, a detection system was assumed to exist where the failure will likely be detected for almost all variables, except for friction force (f_a), thickness (t), and modulus of elasticity (E), which were classified with a detection index of 8 due to the difficulty of controlling this parameter. It is worth noting that an index of 8 indicates that the failure will likely not be detected.

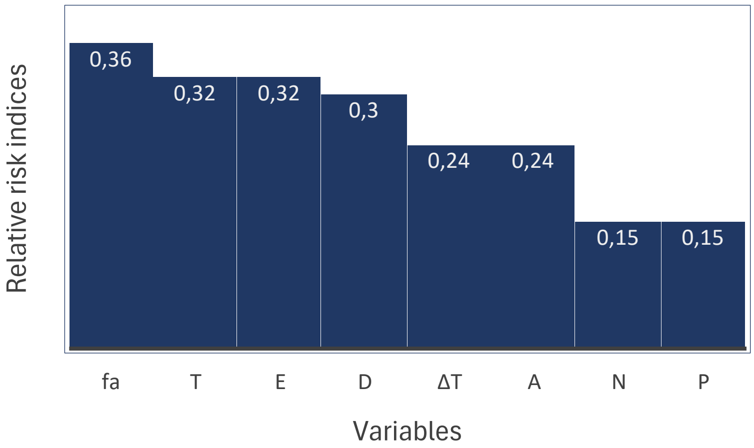
Table 4 shows the analysis using FMEA.

Tabela 4 – Analysis using FMEA.

Variável	S	O	D	I_R	I_{RR}
D	10	5	6	300	0,30
f_a	9	5	8	360	0,36
ΔT	8	5	6	240	0,24
T	8	5	8	320	0,32
A	8	5	6	240	0,24
E	8	5	8	320	0,32
N	5	5	6	150	0,15
P	5	5	6	150	0,15

Figure 3 shows the relative risk indices for each variable in the problem.

Figure 3 - Relative risk indices.



The determination of the Relative Risk Index took into account the product of the respective severity, occurrence and detection indices divided by 1000, which would be the most critical situation when the three indices would be equal to 10.

4. Conclusions

As noted, the use of risk management methods offers several advantages, including not only a better understanding of the potential risks involved in the facility, but also the possibility of systematically managing them to prevent potentially damaging accidents from occurring, which would inevitably result in losses for both the workers involved and the company itself. If analysed as a whole, the accident itself can have an even more drastic impact, considering the effects on reduced family income, social security, environmental impacts, and more.

While carrying out the work, it was also observed that it is not an easy task to anticipate and implement adequate measures aimed at meeting all requirements and preventing possible losses. However, when tools that provide optimal levels of management are used, a system is created in which losses are minimized, and it can even be said that they are brought to levels close to zero.

The methodology of a risk management program must have a preventive vision, which means that the manager must adopt a posture of anticipating everything that may in some way be contrary to what is actually expected in a normal project situation and contrary to what laymen consider to be ideal by the well-known phrase: “it is by making mistakes that we learn”, it is preferable to adopt a more technical one: “it is by learning that we do not make mistakes”.

In addition to the fact that, as was well perceived throughout the work, risk management provides a range and wealth of information that enriches the project in such a way that, from its implementation onwards, failures can be prevented from occurring and causing substantial losses.

Risk Management's role in projects, in our case involving an anchored pipeline, has been demonstrated to be extremely important, as it assists in planning and managing response actions to the most diverse risks identified at various priority levels. Among the benefits of Risk Management is minimizing the likelihood of adverse events affecting project objectives, which consequently increases the chances of success.

It is important to highlight that these tools contribute considerably to the anticipation and recognition, evaluation and implementation of control measures and provide optimal conditions for better monitoring and management of risks and operability. If there is continuous management together with a systematization process, the process will inevitably converge in a trend of continuous improvement, which, as very well highlighted, is the foundation of PDCA.

It was observed that the use of redundancies in the system allows the project to be provided with higher levels of reliability, by allowing that even if a failure occurs at a given point, this does not lead to the interruption of activities, which in turn would be compared to the most critical situation in which there are the greatest losses.

The importance of the mechanical engineer can be affirmed, as he is a key player and must help with his technical background to prevent an apparently small risk from spreading and reaching larger proportions, being aware of constant monitoring and proposing effective control measures when any deviations are present.

It is worth highlighting the importance of teamwork and the managerial vision of continuous improvement, as suggested throughout the work, since risk management is intrinsically related to the fact of minimizing risks, which in a way is a dynamic process that involves the closing of a chain and the beginning of another, always aiming to correct the failure and consequently reduce the risk.

References

Bentes, F. M. Risk Management Program for Industrial Pipelines. **Master's Dissertation. University of Brasilia.** 2007.http://repositorio.unb.br/handle/10482/3112

Bentes, F. M.; Teixeira, E. M.; Viaro, R. S. Perspectives on integrated actions in the field of prevention. **Revista Augustus**. Rio de Janeiro, v. 21, n. 42, p. 120–126. 2017. http://dx.doi.org/10.15202/19811896.2016v21n42p120

Bentes, F. M.; Teixeira, E. M.; Marques, A. C. G. Prevention as a strategy in work environments. **Revista Tecnológica da Universidade Santa Úrsula**, Rio de Janeiro, v. 1, n. 1, p. 142–150. 2018. https://revistas.icesp.br/index.php/TEC-USU/article/view/453

Galante, E.; Bordalo, D.; Nobrega, M. Risk assessment methodology: quantitative HazOp. **Journal of Safety Engineering**, v. 3, n. 2, p. 31-36. 2014. https://doi.org/10.5923/j.safety.20140302.01

LIU, Peide et al. An improved FMEA method based on the expert trust network for maritime transportation risk management. **Expert Systems with Applications**, v. 238, p. 121705. 2024. https://doi.org/10.1016/j.eswa.2023.121705

Siddiqui, D. N. et al. Risk management techniques HAZOP and HAZID study. **Int J Occup Health Saf, Fire Environ Allied Sci**, v. 1, n. 1, p. 5-8. Int J OHSFE-Allied Sci./Vol. 1/Issue 1/July-Sept,2014/005-008. 2014. https://www.researchgate.net/publication/319979143_Risk_Management_Techniques_HAZOP_HAZID_Study

Zeng, S. X.; Tam, C. M.; Tam, V. W. Y. Integrating safety, environmental and quality risks for project management using a FMEA method. **Engineering Economics**, v. 66, n. 1. 2010. https://inzeko.ktu.lt/index.php/EE/article/view/11645/6327

Zhao, X.; Bai, X. The application of FMEA method in the risk management of medical device during the lifecycle. In: **2010 2nd international conference on e-business and information system security**. IEEE. p. 1-4. 2010. https://doi.org/10.1080/10429247.2004.11415263