Risk Management Process In Innovation Projects

Processo De Gestão De Risco Em Projectos De Inovação

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ABSTRACT
According technological development advances in many industrial sectors and organizations looking for innovative products to be diferent themselves, due market challenge and competition through technological innovation projects.It´s necessary mapping and planning the risk response to arising the uncertaities of innovation enables more management control, avoinding the resources waste to meet the requirements of stakeholders in the Project. In this paper, the authors developed a risk management process integrated with TRL (Technology Readiness Level) metric, to analyze internal and external threats in the assessment of thechnological maturity. Finally, the process was applied to three innovation projects at an Institute of Science and Technology (IST) that develops innovation projects. 45 risks were identified, classified and monitored between TRL 1 and TRL3 in the categories: management risks, technical risks, safety and environmental risks. It was found that of the 45 risks found, 22% were security risks that affected TRL3. Technical risks were identified regarding the adaptation of technology to the development life cycle from TRL 1 to TRL 3. This process was accepted and implemented by the Project Management Office as a standard to be used in IST innovation projects.

Keywords: Technological Innovation, Development, Risk management, TRL.

RESUMO
Conforme o avanço do desenvolvimento tecnológico em diversos setores da indústria, as organizações buscam desenvolver produtos e processos inovadores para se diferenciarem perante a concorrência de mercado, por meio de projetos de inovação tecnológica. Mapear

e planejar a resposta aos riscos decorrentes das incertezas da inovação possibilitam maior controle da gestão evitando o desperdício de recursos para atender aos requisitos das partes interessadas no projeto. Neste trabalho, os autores desenvolveram um processo de gestão de riscos integrado ao uso da métrica TRL (*Technology Readiness Level*), para análise das ameaças internas e externas na avaliação da maturidade tecnológica. Por fim, o processo foi aplicado em três projetos de inovação em um Instituto de Ciência e Tecnologia que desenvolve projetos de inovação. Foram identificados, classificados e monitorados 45 riscos divididos entre as TRL1 e TRL3 nas categorias: Riscos de Gestão, Riscos Técnicos, Riscos de Segurança e de Meio Ambiente. Verificou-se que dos 45 riscos encontrados, 22% eram riscos de Segurança que afetavam a TRL3. Foram identificados riscos técnicos referente a adaptação da tecnologia com o ciclo de vida do desenvolvimento desde a TRL 1 a TRL 3. Esse processo foi aceito e implementado pelo Escritório de Gerenciamento de Projetos como padrão para ser utilizado nos projetos de inovação da ICT.

Palavras-chave: Desenvolvimento de Inovação Tecnológica, Gestão de Riscos, TRL.

1 INTRODUCTION

Technological innovation in Brazil is encouraged through the national Science and Technology system to contribute and strengthen innovative activities in the country, however, in recent years efforts have been intensified to consolidate the National Innovation System (NIS), to expand the support for Science, Technology and Innovation (TURCHI, 2017). Innovation can only be brought to the market if it meets the requirements of technical standards and regulations, whether of a technical, social and environmental nature, fundamental since the formation of partnerships between companies and Institutes of Science and Technology (IST) in the process of development of activities to the final stages of the innovation chain at all stages of the product cycle (TURCHI, 2017). This is because, technological innovation development projects are characterized by a high degree of uncertainty due to the novelty of the scope, and it is necessary to adopt mechanisms and tools for assessing the risks inherent in the nature of the technology to be developed (MENDES, 2017; OLIVEIRA, 2018).

Uncertainty is the state, even if partial, of the deficiency of information related to an event, its understanding, its knowledge, its consequence or its probability, and the risk is the effect of this uncertainty on the objectives of the activity (ISO31000, 2009). The risk is often expressed as a combination of the consequence of an event (including changes in circumstances) and the probability associated of it occurrence (ISO31000, 2009).

The nature of innovative projects is characterized by levels of complexity and uncertainties that are specific to each scope. In this sense, Shenhar and Wideman (2000), developed a classification system both for the technological content, referred to as Project Uncertainty, and for the scope management in projects and programs referred to as Complexity. These concepts were addressed to classify the innovation of the projects that participated in this research. Technological uncertainty can be classified as: Low uncertainty, when the technology for the most part is already established, Traditional uncertainty when it is executed through the use of existing technologies; Medium Uncertainty if existing technologies are adapted, some new technology or new characteristic; Advanced Uncertainty, if there is integration between several new or existing technologies and Highly Advanced Uncertainty, exploratory or Super hi-tech when integrating essential technologies that did not exist at the beginning of the project. The advanced and high levels of technological uncertainty can be seen as examples of fundamental technological changes that require a transition from one technological paradigm to another and, therefore, are not only less likely to occur and are also associated with greater uncertainty than innovation in a determined trajectory (SHENHAR et al., 1995; SHENHAR AND WIDEMAN, 2000).

Regarding the level of complexity, it can be approached as: Low or Level 1, these are simple projects, consisting of simple assembly units; Average or Level 2 referring to complex projects with interactive elements by systems; High or Level 3, referring to a program or series of projects (SHENHAR AND WIDEMAN, 2000).

Innovation projects are often exposed to risks related to their activities, methods, employees and the process involved in each development (GRUBISIC, 2009). Knowing and controlling these risks avoids damages that affect the project to reach the goals of cost, deadline and compliance with requirements (MATSUMOTO, 2010).

The development of technical standards, regulations and practices to guarantee the quality of technological innovations has grown with an interest in knowing and controlling these risks, even if it is in an international dynamic, also with an interest in social, health, safety and social sustainability demands, among others (TURCHI, 2017). In order to guarantee quality in technological innovation projects, the Technology Qualification (TQ) process is a practice that provides evidence that the technology under development will work within the specified operational limits, with an acceptable level of reliability (DNVGL, 2007).

TQ is a process that ensures that a technology will be inserted in a system based on some factors such as: maturity, functionality, readiness of the environment and ability to integrate into the intended system (DNVGL, 2007). These factors can be classified and evaluated by some metrics, within the TQ process, such as the TRL (Technology Readiness Level) metric. Initially, TRL was prepared on a 7-point scale by NASA, based on experience from previous projects, on which performance depended on technological maturity and in 1989 the metric was extended to a 9-point scale (OLECHOWSKI, 2016). Since then, TRL has been adopted to assist leaders in integrating a technology into a larger system, being adopted by organizations from various segments, including: Science and Engineering Development, Software Development, Medical Science and Health, Department of Safety, Oil and Gas Industry (YASSERI, 2016). Table 1 presents a summary of each level of the TRL, its definitions and milestones (ISO16290, 2015). The second column describes the milestone in each TRL presenting the description of the information to be documented to allow an appropriate assessment of each level.

In addition to the practice of evaluating and validating the technological maturity of technological development projects, it is necessary to understand to be monitored and address the sources of risks to ensure the prevention of negative impacts on the project's internal and external environmental factors such as management, safety and environment. (SOUZA; BEAL, 2019). What is perceived is the need to assess both TQ and risks and their impacts, in an integrated way. These Risk Management (RM) processes will allow project managers and other interested parties to be able to monitor and address negative risks so that they do not affect project objectives.

Table 1. Summary of TRL milestones

TRL	Marco alcançado pelo elemento
TRL 1: Basic principles observed and reported	Potential applications are identified after basic observations, but the element concept is not yet formulated
TRL2: Concept and / or application of technology formulated	Formulation of potential applications and preliminary concept of the element. No proof of concept yet.
TRL 3: Analytical and experimental proof of concept of the critical function and / or characteristic	The concept of the element is elaborated and the expected performance is demonstrated through analytical models supported by experimental data / characteristics.
TRL 4: Functional verification in the laboratory of the component and / or model	The functional performance of the element is demonstrated by model tests in a laboratory environment.
TRL 5: Verification in relevant environment of the critical function of the component and / or model	. Models, not necessarily in real scale, are built to verify performance through tests in a relevant environment, subject to scale effects.

TRL 6: Model demonstrating critical element functions in a relevant environment	The critical functions of the element are checked and performance is demonstrated in a relevant environment with representative models in configuration and function format.
TRL 7: Model demonstrating element performance for the operating environment	A representative model, fully reflecting all aspects of the project, is built and tested with adequate safety margins to demonstrate performance in the operational environment.
TRL 8: Completed and accepted real system	The product model is qualified and integrated into the final production-ready system
TRL 9: Real system demonstrated through successful mission operations	The technology is fully mature. The element is in service, for the designated mission, in the actual operating environment.

Source: Adapted ISO16290 (2015).

2 METHODOLOGY

The scenario used in this research was the engineering department of a Science and Technology Institution (STI), whose focus is related to technological innovation in the development of new industrial products for application in national and / or international Market. The process was structured in 2 phases, according to the steps: Planning - Data collection from participants in innovation projects; Elaboration and implementation of the process in innovation projects. The details of the steps can be checked below

2.1 PLANNING - DATA COLLECTION FROM PARTICIPANTS IN INNOVATION PROJECTS

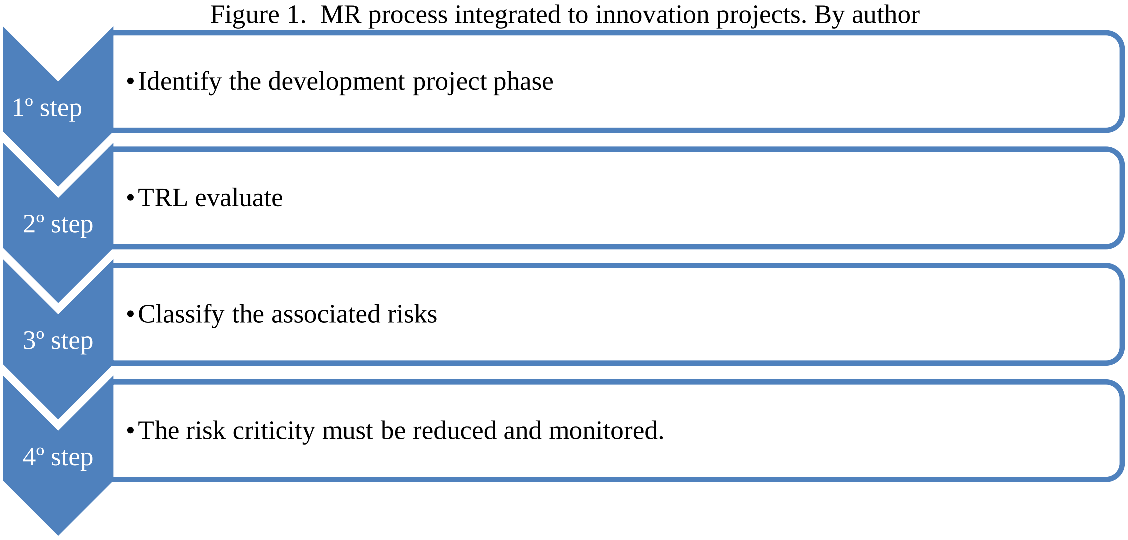
To understand the main technological development activities, the complexity of each project and its relationship with the tools adopted in the assessment of TQ and risk management. In this stage, there was the participation of managers from the technological areas and project managers. Was possible to observe some improvement opportunities, as follows: RM approach only for management and technical risks without assessing the impacts on the environment and safety; Need to knowledge in the TQ process for proper application; The need to integrate risk management with the TRL metric, as the technological limitations and risks in the planning and execution of the tests to prove the technology were not observed in the RM; Training on the TRL metric for project members; To emphasize the importance of the multidisciplinary team brainstorming at risk meetings; Start the development of an integration process between the evaluation of TRL metrics and risk management.

2.2 ELABORATION AND IMPLEMENTATION PROCESS IN INNOVATION PROJECTS

RM is a fundamental task for the project organization, but it often does not add value to the process as they only represent how to manage a failure mode (WILLUMSEN, 2019). As the objective of the process is precisely to identify the risks that represent threats to TQ and to evaluate the impact factors (environment, safety, management and technical risks), it was important to consolidate data and information so that the team can identify, classify, treat and to monitor possible risks and their impacts. The integration between RM and TRL is a process that must be led by the project manager. However, it is important to note that, to achieve the objective of this process, the leadership of the project manager and team leaders is an essential factor for improvement results. Excel was choosen as a platform for the elaboration of the process because it allows the use of formulas and other integrations with the user. The structure of the process considered the alignment between: the stage of development, the technological assessment and the associated risks. The details of the steps can be seen in figure 1.

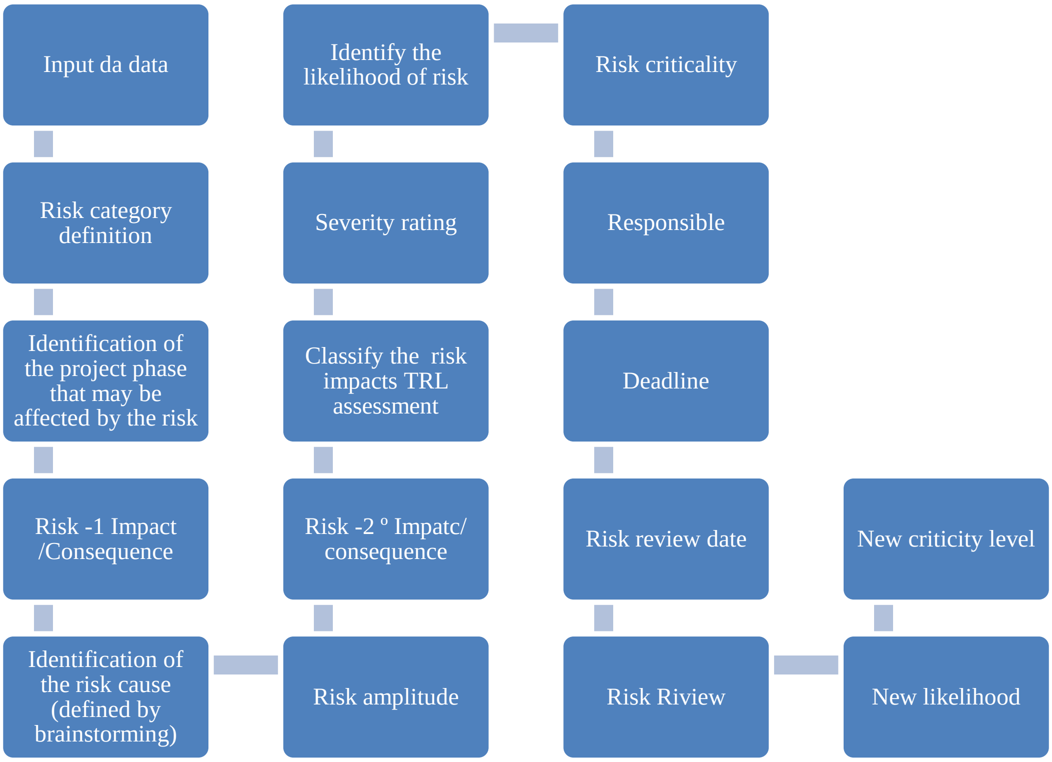
As shown in figure 1, the process involves four stages. **First step**: the team must evaluate the product development phase (it can be the current or the next phases), allowing for a better planning and approach to the phase deliveries in a preventive way. The factors that contribute to the complexity of product development, consist of a long-term development cycle, participation of countless partners and contractors from various countries and the fluid nature of the technology considering the dynamism of the external environment (KARDES et al, 2013).

Figure 1. MR process integrated to innovation projects. By author



Second stage: the team do assessement the technological maturity level ot the development phase. For this step, a specific flow was developed with questions that enable the team to assess the risks int the planning, execution and validation process of each TRL. Third and fourth stage: the possible risks identified int he planning, execution of the Project activities

Figure 2. Risk record sheet – Risk Identification, Classification, Treatment and Monitoring. By the author



The proposed process implementation occurred between May 2019 and February 2020 in 3 innovation projects according the steps: The scope of the process was presented to project managers and leaders; the project team started to participate in risk meetings, according to the frequency established by the project leaders; project teams were able to evaluate and contribute to improvements in the process interface (excel), as well as adaptation to current projects. The process was implemented on a constant basis, through regular meetings on projects with varied complexities

To evaluate the effectiveness of the process, a specific questionnaire was used, according to: Time optimization in Risk Management meetings, effectiveness and robustness by the project teams. Respondents rated the level of service: Not attending (NA); Meets Partially (AP); Totally Attends (AT); I can't say anything (NCO), at different stages of EM (Identification, Classification and Treatment and Resolution of Risk).

To address the assessment and validation, standards and guidelines were used: TRL - Metric for Assessment of Technological Maturity - Developed by NASA, used as a standard in EMBRAPII (TRL), ISO16025, ANP, ICTs and other organizations internationally; PMBOK 6th Edition - Guide to Good Practices in Project Management; ISO 31000 - International Risk Management Standard; ISO14001- International Environmental Management Standard (Safety Guidelines); ISO 9001- International Quality Standard (Guidelines for the Development of Industrial Products); DNVGL- Recommended Practice- Technology Qualification; API RP - Recommended Practice- Subsea equipment qualification.

3 RESULTS AND DISCUSSIONS

The IST innovation projects that implemented the RM process developed in this work, had different characteristics, as detailed in figure 3. In order to classify the technological innovation of these projects, analyzes of the project scopes were carried out, together with the teams (Project Manager). Project, Technical Leader, engineers and technicians), using the approach developed by Shenhar and Wideman (2000), regarding the classification of innovation.

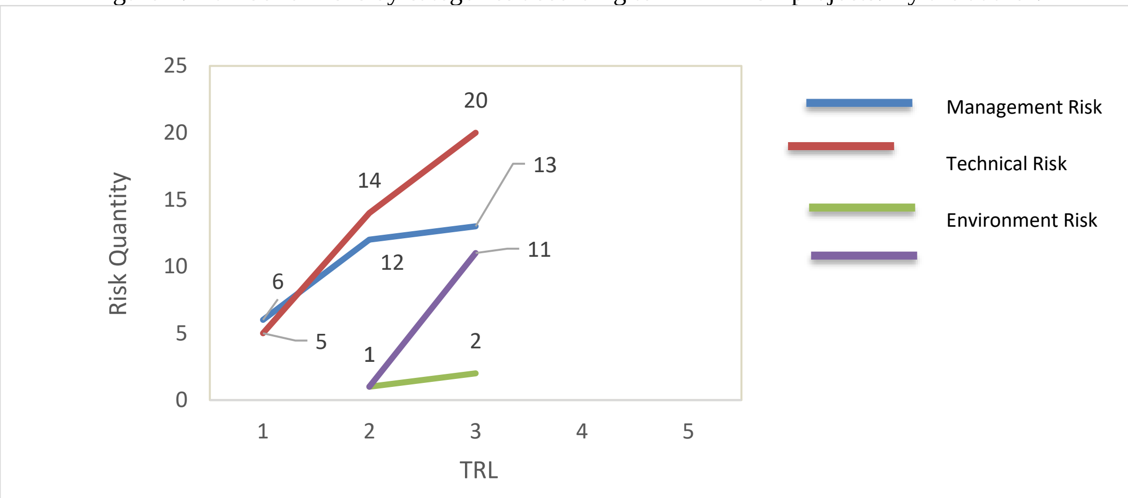
46 relevant risks were identified in the 3 innovation projects, using the proposed process. It can be seen in figure 4 that in the initial TRLs, risks with impacts on the Environment and Safety were not identified, however these were identified in the planning phase of proof of concept (TRL 3). As technological maturity increases, previously unidentified risks become more evident. In these specific cases, for projects 1 and 2, the proofs of concepts were planned in a simulated environment with natural scale. During the preparation of the operation manuals, the assembly sequences were analyzed and defined and, therefore, safety risks, due to the size of the parts, volume and conditions of the tests, as well as risks to the environment were identified. With this preventive approach, it was possible to plan the necessary training to avoid accidents, as well as assessing responsible teams and possible damage to the environment.

Regarding technical risks, after selecting concepts, TRL 2, the teams were able to identify possible risks related to the availability of technology in the environment necessary for the project.

Figure 3. Profile of inoovation projects that implemented and used the Risk Management Process proposed at IST. By the author

Project	Occupation area	Innovation Classification (SHENHAR E WIDEMAN, 2000)		Development steps
		Technology uncertainty	Scope Level	
1. Subsea Equipament	Oil and Gas	High Technology	System	Informational phase- basic research; conceptual phase- Development and validation of thecnology route.
2. Monitoring seísmic	Oil and Gas	High Technology	System	Development and validation of the technological route (prototyping)
3. Mining	Mining Company	Mean Tecnologia	System	Informational phase- basic research; conceptual phase- Development and validation of thecnology route.

Figure 1. Number of risks by categories according to TRL in IST projects. By the author.

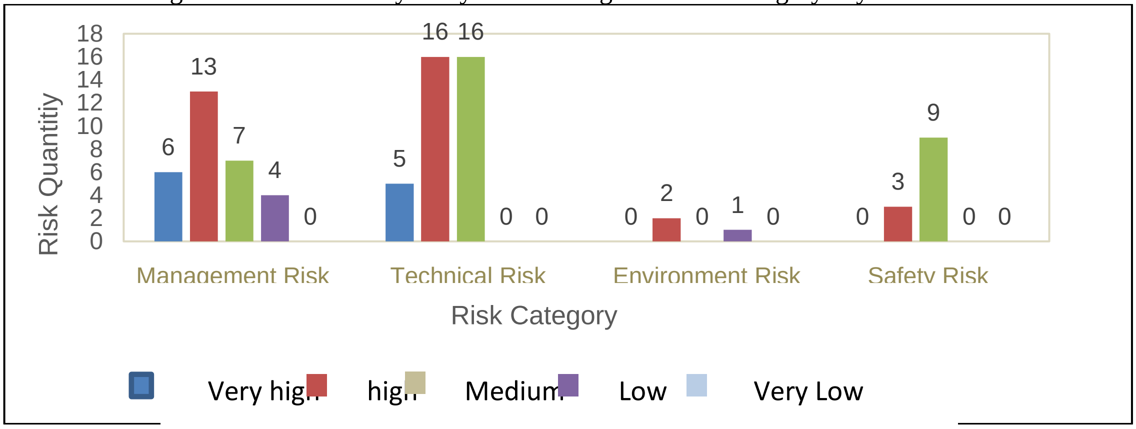


The process provided a systemic view of what is needed to advance TRL as well as the risks and impacts according to each project. Figure 5 shows that risks with high impact and high probability were identified in the management, technical and security categories.

It is recommended to use this process to assess risks to the environment in TRLs for concept validation and prototyping, as contact with the external environment and possible risks to these factors are increased. It was noticed that the RM Process integrated with TRL was easy to use in these projects even though they were projects of different scopes.

It is estimated that the proposed process, by integrating the evaluation of TRL with risk management, allowed to expand the spectrum of vision of managers and technical leaders of projects. New risks arise and must be identified dynamically during technological development. Updating the same risks identified only at the beginning of projects is a common failure. It was found that the process proposed in this work facilitates the identification of new risks continuously.

Figure 2. Risk criticality analysis according to the risk category. By the author.



In addition to the analysis of these results, the project teams in figure 3 assessed the effectiveness of the RM process integrated with TRL with respect to application to projects (adaptation to scopes), representation (clarity) and robustness (meeting norms and standards). 90% of the people who answered the questionnaire proposed for the evaluation of the process (as described in the methodology chapter) affirm that the tool is able to optimize the time used in the meetings due to the effectiveness in the treatment of risks, since the risk monitoring happens with the objective of evaluating the effectiveness of the action plan and reduction of the criticality.

The sample that answered the questionnaire is equivalent to 19% of the total population of IST projects (engineers, technicians, researchers and project managers). Following are the steps and responses to the questionnaire: Step 1 - Risk Identification - In this step, questions on how to identify the risks were assessed considering the impact on QT. Table 2 shows that there was no question or guideline evaluated as “Does not answer”. However, there is an opportunity for improvement in questions 3, 6 and 8, as some of the evaluators did not know or did not understand the process proposal regarding the item. Step 2 - Risk Classification: In the risk classification process, we sought to evaluate the criteria metric in the Risk Management tool, as shown in Table 3. To ensure the risk classification, the criterion adopted is to verify the severity and the probability of the risk occurring. The importance of this step results in the optimization of the team's time, because when the risk is classified as Very High or High, for example, it will hold more attention in the meetings, and consequently, the resources (time, budget, people) will be allocated in a understand risks with greater severity and probability. Step 3 - Risk Treatment and Resolution: The risk treatment and resolution stage also comprises the risk monitoring phase, as shown in Table 4.

Table 2. Guidelines for identifying the risk integrated to QT in innovation projects

		Questions - Assess whether the process meets the requirements below	NA	AP	AT	NCO
RISK IDENTIFICATION	1	Projects of high variability and complexity, incur more uncertainties and risks, therefore, frequent identification of threats is necessary.	0	22%	78%	0
	2	As these are technological innovation development projects in an ICT, the function and performance of the components of the product or technology under development must be considered on a qualification scale.	0	0	100%	0
	3	The risk identification process enables higher quality in project deliveries due to the knowledge of the threats that exist at each stage of product development.	0	11%	89%	0
	4	The quality of integration between product components is considered, assessing regulatory requirements, function and performance.	0	11%	89%	0
	5	There is a process or flow that considers the stages of the assessment of technological maturity according to the phase, and what are the possible risks involved.	0	22%	78%	0
	6	The challenges and deliveries of each stage of technology or new product development are verified.	0	22%	78%	33%
	7	There is an approach on the internal and external conditions of the project considering the safety requirements of the tests and validations of the product development stages.	0	11%	89%	0
	8	The tool used in risk management must prioritize the most critical risks in a simple and dynamic way.	0	11%	89%	0
	9	The quality of information in the identification of risks is considered paramount for better prioritization and treatment, due to the impact of the project's objectives.	0	22%	78%	0

Source: By the author

Table 3. Guidelines for the classification of risk integrated to TQ in innovation projects

		Questions - Assess whether the process meets the requirements below	NA	AP	AT	NCO
RISK CLASSIFICATION	10	The risk classification with more than one impact is considered to be relevant in its criticality. Does the proposed process meet this requirement?	0	0	100%	0
	11	Factors related to the external environment of the project are considered in the risk classification process. Eg: Impact on the environment and safety. Does the proposed process meet this requirement?	0	11%	89%	0
	12	There are parameters for risk classification. Eg: Criticality = Probability X Severity of risk. Does the proposed process meet this requirement?	0	11%	78%	11%
	13	Qualitative, quantitative or quali-quantitative analysis is used in order to understand the risk factors and anticipate them according to the project phase. Ex. Risk matrix. Does the proposed process meet this requirement?	0	11%	78%	11%

Source: By the author

Table 4 Guidelines for the treatment and monitoring of risk integrated to TQ in innovation projects

		Questions - Assess whether the process meets the requirements below	NA	AP	AT	NCO
TREATMENT AND RESOLUTION	14	Criteria are used to prioritize risk at meetings. Ex .: 1 - The action plan deadline is checked; 2- The risk is critical. Does the proposed process meet this requirement?	0	10%	90%	0
	15	Risk treatment is indicated through the action plan with responsible and deadline. The Project Manager or responsible for the project, evaluates the progress in the action plan of the meetings to evaluate its effectiveness. Does the proposed process meet this requirement?	0	0	100%	0
	16	Improvements are expected in dealing with the threats identified in relation to the allocation of resources and decisions related to risk. Does the proposed process meet this requirement?	0	0	100%	0
	17	The impact on deliveries is taken into account, including the assessment of the technological maturity of the product. Does the proposed process meet this requirement?	0	11%	89%	0
	18	Factors that impact the quality and delivery of project objectives, such as cost, quality, schedule and customer requirements, are assessed according to risk. Does the proposed process meet this requirement?	0	11%	89%	0
	19	Deliveries of technological innovation projects have their importance identified in the treatment of risks. Ex .: Impact on technology maturity, impact on cost, schedule and meeting requirements. Does the proposed process meet this requirement?	0	0	89%	11%
	20	Risk monitoring takes place with the objective of evaluating the effectiveness of the action plan and reducing the level of criticality. Does the proposed process meet this requirement?	0	11%	89%	0

Source: By the author

Based on the evaluations by the technical teams of the projects, we sought to understand whether the execution of the tool in meetings is aligned with the guidelines on the relationship between the impact of risk on QT and the effectiveness of reducing the criticality of the effect of risk in the development stage. It was found that in the questions, 15, 19 and 20, 11% of the evaluators did not know how to give an opinion on the effectiveness of the risk action plan, in the meetings, in relation to the role of the project managers. According to the analysis of the applied questionnaire, a list of process improvement was elaborated and implemented, as shown in table 5.

Table 5. List of process improvements as assessed by the projects

List of Improvments
It was used as good practice, to mark the rounds of the shorter meetings, however, more frequent. Ex: 1 hour weekly or 1.5 hours fortnightly.
It was established that before the meetings, the leaders would provide an overview of the status of the project's work for new members at the meeting and which TRL to reach in the final project delivery.
Frequent meetings were established with the Safety Engineer of the ICT to survey the APR (Preliminary Risk Analysis) in the process of assembly, commissioning and operation of the project tests
The Matrices were presented at the Risk meetings showing possible risks and respective severities according to the impact factors: Environment, Safety, Technical and Management.
For each identified risk, it is checked whether or not it impacts the evolution of TRL (field in the form). Excel identification field included. More frequent training for new members of TRL projects.

Source:By the author

4 CONCLUSION

The IST Project Management Office also evaluated the Process proposed in this work to verify the level of complexity during the completion and its practical application in the projects. Knowledge on the TRL scale and the integrations between the phases of technology development were also evaluated, as they are necessary factors for the identification, classification and monitoring of risk. Thus, the process proposed by this work was adopted as a standard for 100% of ICT projects, in January 2020, in view of the constant assessment of risks in relation to the impact on TRL.

According to the proposed objective, the Risk Management Process uses three concepts that are already widely used in the scope of project management for technological innovation development, and also allows providing information for decision-making by Project Managers of this nature. The process integrates two concepts: the Risk Matrix and the metric TRL, as an analysis proposal for technological maturity. As demonstrated, the implementation of the process took place in three different innovation projects, in addition to having different scopes and levels of innovation uncertainty: Subsea Equipment; Seismic Monitoring and; Mining. It was noticed that in the months of use of the Process, 45 risks were identified, classified and monitored between TRLs 1 to 3, in the categories: Management Risks, Technical Risks, Safety and Environmental Risks. In addition to the classification of the categories, it was found that 22% of the risks were found in TRL 3 with a significant impact on safety.

As the range of TRLs assessed for innovation projects was TRL 1 to 3, it was assessed that there are risks from the lowest level of basic research (TRL1), whose impacts are more allocated to Management Risks (resource management, variation dollar exchange rate, turnover and communication between project members), until the development of proof of concept, TRL 3, where in addition to Security Risks, technical risks related to the adaptation of technology to the development life cycle were identified. A risk criticality relationship was verified, on a scale from Very High to Very Low for each category and impact during the TQ assessments. The proposal developed and applied, fulfilled its objective in the three projects, even though they are distinct, the RM Process integrated with TRL, because: it identified opportunities for improvement in IST's Risk Management and TQ, which were carried out at different times without any relationship between them ; developed an integrated Risk Analysis process with the assessment of technological maturity, in addition to providing information structured by the risk matrix to assist the team in meetings; finally, by assessing the effectiveness of the tool, improvements were still identified.

The use of the RM Process integrated with TRL enabled the identification of critical risks in the development stages that affected the qualification of the technology, with impacts on cost, schedule, physical integrity (safety), environment and customer satisfaction. It also shows assistance with the generation of indicators, highlighting the main areas with critical risks and which factors are influenced by risks in the technology qualification process. However, despite fulfilling the proposal, the RM Process presented some limitations, which are not critical, however they result in improvements, such as: validation sample of the proposed process limited to only 3 IST projects (due to the need to monitor the implementation and use of the IST). Process proposed in the projects), improve the interface of the risk registration spreadsheet with the user, enabling a more dynamic process through the development of a platform or software; propose the consolidation and dissemination of lessons learned by stage or deliverable according to risk. Finally, the RM Process integrated with TRL establishes standards for classifying and prioritizing risk, providing information for management decisions, as clear criteria are defined such as impact on the environment, TRL, safety and other critical factors in innovation projects.

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