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"Seeing is believing": the importance of proof of concept in robotics projects

"Ver para crer": a importância da prova de conceito em projetos com robôs

"Ver para creer": la importancia de la prueba de concepto en proyectos con robots

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KEYWORDS
Project Management. Proof of Concept. Robotics.

Abstract: The implementation of projects with robots not only enables the execution of dangerous, repetitive, or physically demanding industrial tasks but also reduces the risk of injuries to workers, promoting health and safety in the workplace. This study emerges in response to the growing global demand for innovative technologies, specifically the implementation of robots, which brings significant challenges to project management. The research objective is to analyze how proof of concept influences the implementation of projects with robots. To achieve this, a qualitative approach was employed, conducting a case study with data collected through semi-structured interviews and document analysis. The implementation of a Proof of Concept Laboratory demonstrated positive results for the studied company, such as risk mitigation, increased stakeholder confidence, improved project specifications, better final performance, and reduced time to market. This study contributes to scientific knowledge by mitigating risks in projects involving innovative technologies of Industry 4.0 and reinforcing stakeholder confidence.

PALAVRAS-CHAVE
Gerenciamento de Projetos. Prova de Conceito. Robótica.

Resumo: *A implementação de projetos com robôs não apenas possibilita a execução de tarefas industriais perigosas, repetitivas ou fisicamente exigentes, mas também reduz o risco de lesões para os trabalhadores, promovendo a saúde e segurança no trabalho. Este estudo surge em resposta à crescente demanda global por tecnologias inovadoras, no caso, a implementação de robôs, que traz para o gerenciamento de projetos desafios significativos. O objetivo da pesquisa é analisar como a prova de conceito influencia a implementação de projetos com robôs. Para tanto, por meio da abordagem qualitativa, foi realizado um estudo* *de caso, tendo a coleta de dados ocorrida por meio de entrevistas semiestruturadas e análise de documentos. A implementação de um Laboratório de Prova de Conceito demonstrou resultados positivos para a empresa estudada, como a mitigação de riscos, o aumento da confiança dos stakeholders, a melhoria na especificação de projetos, o melhor desempenho final e a redução no tempo de venda. Este estudo contribui para o conhecimento científico ao mitigar riscos em projetos de tecnologias inovadoras da Indústria 4.0 e reforçar a confiança das partes interessadas.*

PALABRAS CLAVE
Gestión de proyectos.
Prueba de concepto.
Robótica.

Resumen: *La implementación de proyectos con robots no solo permite la ejecución de tareas industriales peligrosas, repetitivas o físicamente exigentes, sino que también reduce el riesgo de lesiones para los trabajadores, promoviendo la salud y seguridad en el trabajo. Este estudio surge en respuesta a la creciente demanda global de tecnologías innovadoras, en este caso, la implementación de robots, lo que presenta desafíos significativos para la gestión de proyectos. El objetivo de la investigación es analizar cómo la prueba de concepto influye en la implementación de proyectos con robots. Para ello, a través de un enfoque cualitativo, se llevó a cabo un estudio de caso, con la recopilación de datos realizada mediante entrevistas semiestructuradas y análisis de documentos. La implementación de un Laboratorio de Prueba de Concepto demostró resultados positivos para la empresa estudiada, como la mitigación de riesgos, el aumento de la confianza de los stakeholders, la mejora en la especificación de proyectos, el mejor desempeño final y la reducción en el tiempo de venta. Este estudio contribuye al conocimiento científico al mitigar riesgos en proyectos de tecnologías innovadoras de la Industria 4.0 y reforzar la confianza de las partes interesadas.*

Introduction

With the advancement of robotics, the global business scenario is close to an imminent change, providing support to organizations to improve their operations strategies (Vido, Scur, Massote & Lima, 2020). Although the literature emphasizes the importance of creating, developing and maintaining advantages, new manufacturing technologies have influenced organizations' strategies and capabilities (Vido et al., 2020). Thus, in the last 50 years, the use of robots in the manufacturing industry has increased, and they have replaced humans in several tasks, relieving workers from repetitive tasks, unhealthy or dangerous work (Robla-Gómez et al., 2017).

The spread of COVID-19 has slowed the expansion of the use of industrial robots, with around 435,000 new units implemented globally in the last year (Insper, 2022). It is expected that, by 2024, the number of new robots in operation will reach a record of half a million for the first time (Insper, 2022). In this context, the estimate suggests that, by 2025, Industry 4.0 could generate approximately US$ 3.7 trillion in value for manufacturers and suppliers, offering the potential to drive a new revolution in manufacturing (Garms, Jansen, Schmitz, Hallerstede & Tschiesner, 2019).

In the era of Industry 4.0, emerging technologies arise, such as autonomous mobile robots (AMR), which are considered intelligent robots that allow for improving the performance of production systems in industry in terms of productivity, flexibility and costs (Fragapane, Ivanov, Peron, Sgarbossa & Strandhagen, 2022).

In this context, the dissemination of the Industrial Internet of Things (IIoT) is occurring at high speed due to the advances brought by Industry 4.0 (I4.0), a term that emerged in 2011 at the Hannover fair, in Germany, to describe a new revolution with the potential to significantly modify global manufacturing chains and meet the new consumer profile (Kumar, Gorshy & Abdelgadir, 2017). The idea of consistent digitalization and linking of all production units in an economy is increasingly present and to support this concept several technological areas are needed: horizontal and vertical systems integration, big data analysis, cloud, industrial internet of things, cybersecurity, simulation, additive manufacturing (3D printing), augmented reality and autonomous robotics (Albertin, Elienesio, Pontes & Aragão Junior, 2017; Choi, Kumar, Yue & Chan, 2022).

Industry 4.0 combines traditional technologies with new areas of digitalization and this brings challenges for organizations that need to assess this diversity of development using methods and systems to achieve their objectives (Schmidt et al., 2015; Xu, Xu & Li, 2018). Technological infrastructure risk was found to have a significant impact on all Industry 4.0 technologies, regardless of their stage of maturation (Dixit & Verma, 2022). In this way, several risk management studies based on the contingency approach have been identified and suggest that the success of a project depends on how it deals with environmental uncertainties, making adjustments to risk exposure and the project management profile (Carvalho & Rabechini Jr., 2014). Thus, risk mitigation involves a decrease in the probability of the risk or the impact of the risk (Teller & Kock, 2013).

This technological article discusses an environment for implementing robotics projects in the manufacturing process. Success in implementing industrial robots depends on comprehensively resolving challenges in engineering, management, organization, and human resources, but neglect of human aspects in design often leads to lower-than-expected productivity gains, with a reported failure rate of up to 75% (Das, 2001). Research by McKinsey (2020), going back more than a decade, indicates that around 70% of these initiatives, which include robotics, fail to achieve their objectives. Thus, with possible risks associated with the implementation of these projects, the importance of using Proof of Concept (PoC) can be seen.

In the construction industry, the implementation of autonomous robots, despite initial costs and complex infrastructure, is economical for large projects as it reduces associated risks (Rane, Potdar & Rane, 2021). Innovations can improve safety, but adherence to safety technologies is limited, especially in developing countries, where improvements in health, project visualization and digital technologies such as automation and robotics stand out, as well as accident prevention (Dobrucali, Demirkesen, Sadikoglu, Zhang & Damci, 2022; Yap, Skitmore, Lam, Lee & Lew, 2024; Akinlolu, Haupt, Edwards & Simpeh, 2022).

Risk management must be balanced and include traditional risk-sharing strategies (Hall, Whyte & Lessing, 2020).

The contributions of individuals, organizations and projects to improving digital innovation (Papadonikolaki, Krystallis & Morgan, 2022; Bhattacharya & Chatterjee, 2022). Quality and punctuality are essential for the success of projects (Kanski & Pizon, 2023), while high supplier turnover hinders the stability and consistency of solutions (Marion & Fixson, 2021; Bhattacharya & Momaya, 2021). A PoC, according to Silva (2014), makes it possible to validate in practice the methodology and technological concepts that will be used in implementing the project. According to PMBOK (2021), in predictive approaches, PoC can be used to explore options, especially projects that have similar models.

Physical proof-of-concept experiments, which validate simulation results, prove the effectiveness of reinforcement learning techniques for robotic systems (López-Guede, Estévez, Garmendia & Graña, 2018). Furthermore, these proofs of concept are fundamental for the development of robust systems, capable of being implemented in different situations and industries; it is worth noting the contributions of Nguyen et al. (2012). In addition, the study by Klein et al. (2019) emphasizes that these initiatives not only highlight the potential but also the significant challenges involved in implementing robotic automation.

Thus, we sought to answer the following research question: How can proof of concept influence the implementation of projects that use robots? Based on the information previously discussed about the implementation of projects that use new technologies, this study aims to analyze the influence of proof of concept on the implementation of projects involving robots. The study seeks to examine how Proof of Concept (PoC) can influence specific aspects of project management, focusing on mitigating risks associated with the project, enhancing the project specification, improving overall performance, enable customers to visualize the proposed solution and reduce the time needed to complete the sale of the project. It is important to understand the best practices for implementing Proofs of Concept (PoCs) in robotics projects, thus ensuring that it effectively contributes to innovation and optimization of technological development.

In this context, practical contributions are expected to the implementation of projects with robots that perform industrial tasks considered dangerous, repetitive or physically demanding, reducing the risk of injuries for workers and increasing health and safety at work. It should be noted that the PoC used in the implementation of robotics projects in this study belongs to a large automation company, developed to support customers' projects that use robots.

This technological article was prepared following the proposal of Martens, Pedron and Oliveira (2021). Therefore, this article is organized as follows: in Section 2, the Theoretical elements of the research that will address questions about Proof of Concept and Robots: one of the technologies of Industry 4.0; in Section 3, the Methodological elements of the research; in Section 4, Presentation and discussion of results; Section 5 presents the Obtained Results and Analysis. In the last section, final considerations are presented.

Theoretical elements of the research

The manufacturing industry plays an essential role in the economy and in creating jobs, but faces relevant challenges for management and projects related to Industry 4.0 (Kanski & Pizon, 2023). In the same way, projects become an important activity for the strategic competitiveness of organizations (Patanakul & Shenhar, 2012). An adequate assessment of risk management resulting from identification makes it possible to prevent negative results from project implementation. In this initial identification phase, it is necessary to check all possible threats to the organization's business and the implementation of the project (Stosic, Mihic, Milutinovic & Isljamovic, 2017).

Organizations must correctly manage innovation projects in order to avoid failures, however, not interrupting innovation (Kupeshova, Lazanyuk & Kareke, 2019). Thus, investments in actions for technical definition and requirements are positively correlated with project implementation (Dvir, Raz & Shenhar, 2003). In this context, the risk of innovation must be defined, as it is a negative factor in the approach to new technologies, with the purpose of managing and facilitating their implementation (Cole & Matsumiya, 2008).

Proof of Concept

Proof of Concept (PoC) is a term that has been frequently used in project proposals and in the validation of new technologies (Kendig, 2016; Bajic et al., 2023). Proof of concept describes early-stage research at the forefront of new applications or technologies defined within a given context or field of study such as, but not limited to, pharmacology, biochemistry and business (Kendig, 2016; Bajic et al., 2023).

According to the National Science Foundation (2023), a PoC must perform a certain method to validate its technological parameters. According to Silva (2014), PoC makes it possible to validate in practice the methodology and technological concepts that will be used in the implementation of the project and must be implemented in the management of projects where the scope is not well understood. In this context, companies can create and validate scientific results, from the initial stages of innovation projects, making it possible to reduce technological and market deficiencies (Passarelli, Landi, Cariola & Sciarelli, 2020).

With the Industry 4.0 scenario, the adoption of augmented reality (AR) is accelerated, and new opportunities arise offered by this innovative technology. However, small organizations are often afraid to make large investments in AR without a proof of concept due to the risk of failures (Dieck & Jung, 2017). For digital technologies, developers create robust proofs of concept by combining pre-existing software, and generate innovation and technological production (Floyd, Jones, Rathi & Twidale, 2007; Maaradji, Hacid & Soukane, 2023). From this perspective, the development process in the PoC phase requires each organization to have specific knowledge, skills and abilities, and allows them to acquire external knowledge, combine resources and promote new proofs of concept (Chesbrough, 2006; Albats, Podmetina & Vanhaverbeke, 2021).

Another relevant factor to be analyzed is the type of knowledge offered by organizations and the place where technology is shared. An empirical analysis demonstrates that it is more important to focus on the social and cognitive aspect of PoC, rather than the physical distance between those involved in the context (Breschi & Lissoni, 2009; Hidalgo, 2021). Among those involved we have stakeholders who are individuals, groups or institutions with an interest in the project, and who can affect its outcome (Littau, Jujagiri & Adlbrecht, 2010). Thus, stakeholder trust is fundamental to the success of the project, promoting constructive relationships and allowing the balance of conflicts and common problems (Pinto, Slevin & English, 2009).

Project performance criteria, such as cost, time and scope, are not enough to guarantee success, so the relationship between project manager and project stakeholders has become more emphasized (Oliveira & Rabechini Jr., 2019; Eskerod & Larsen, 2018). According to Cartwright et al. (2010), the Proof of Concept (PoC) marks the initial stage in the development of a drug product, standing out as a “reasonably likely” indicator that the essential attributes for success are present and the main causes of failure are absent. Challenges to the success of PoC include the shortage of qualified personnel, the inability to integrate multiple subjects and information, and the requirement for certainty from organizations (Cartwright et al., 2010; Cummings, Feldman & Scheltens, 2019).

The project can be successfully developed and demonstrated in industrial practices, as proven by the case study of a PoC prototype of an ABB IRB 120 robot system with digital twin (Anh et al., 2023). One of the emerging areas of smart manufacturing and Industry 4.0 aimed to develop and demonstrate the concept of a digital twin of a robotic system (Anh et al., 2023).

Several Industry 4.0 technologies use PoC for validation, such as the case study to repair and update sensors in an IoT ecosystem (Ben Hlima, Kacem & Gharsallah, 2023). Many IoT applications, such as those present in automotive or military companies, require a backlash-free system (Ben Hlima et al., 2023). In the study by Ben Hlima et al. (2023), PoC was used to find a solution and reduce network downtime, which allowed continuous operation for this type of ecosystem.

Over the last decade, researchers have focused on digital technologies within Industry 4.0, however, the euphoria surrounding it has not met the sector's expectations, due to several implementation challenges (Bajic et al., 2023). Today, Industry 5.0 proposes a human-centered approach to implementing sustainable digital technologies focused on smart quality improvement (Bajic et al., 2023). Thus, the study by Bajic et al. (2023) demonstrated that the key element to the success of these implementations has been the execution of proofs of concept, as evidenced in a big data project in the process industry, in which the proof of concept allowed the reduction of data by 99.73% without losing significant information, thus demonstrating the feasibility and effectiveness of the proposed model.

Robots: one of the technologies of Industry 4.0

Considering a historical perspective, several industrial revolutions have emerged. The First Industrial Revolution was born with steam mechanization; the Second Revolution evolved with electricity and mass production; and the Third Industrial Revolution included electronics and information technology (IT) (Lunelli & Cecconello, 2019). The Fourth Industrial Revolution arises with new concepts and digital technologies, which can be divided into three groups: physical, digital and biological (Lima & Gomes, 2021). According to the authors, physical technologies include, but are not limited to, autonomous vehicles, additive manufacturing, advanced robotics and new materials; digital technologies comprise the Industrial Internet of Things, big data and blockchain; and biological technologies comprehend biotechnology and genetics.

Regardless of all the benefits that accompany the implementation of the enabling pillars of Industry 4.0, several companies find challenges and barriers to its adoption (Cugno, Castagnoli & Büchi, 2021). Possible barriers that could make the implementation of Industry 4.0 technologies unfeasible are: poor value chain integration, cybersecurity challenges, doubts about the real economic benefits, lack of qualified labor, high investment requirements, poor infrastructure, task interruptions, challenges in data management and quality, lack of security standards and regulations, and opposition to change (Kumar, Bhamu & Sangwan, 2021). Thus, the use of industrial robots has been going on for many decades in industry, but in this recent context they have become an important pillar in Industry 4.0 and for intelligent manufacturing (Oesterreich & Teuteberg, 2016).

The term "robot" was coined by the novelist Karel Capek in 1921 and was later popularized by Isaac Asimov. This term means forced work or work that people do not like to do (Burgard et al., 1999). The first industrial robot was Unimates, developed in the early 1960s by George Devol and Engelberger. The patent belongs to Devol, but Engelberger presented himself earlier in the market and became known as the "father of robotics" (Islam & Rahman, 20 13). According to the authors, during this period robots did not have economic viability, a situation that ended up changing in the 80s.

The definition of robot used in this technical report is based on the international standard ISO 8373 "Vocabulary", also used by the IFR (International Federation of Robotics), with a robot defined as "a programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning", an industrial robot defined as a "automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or fixed to a mobile platform for use in automation applications in an industrial environment" and a mobile robot is a "robot able to travel under its own control". In addition to autonomous operation, a mobile robot can have capabilities to be controlled remotely. In this way, the implementation of robotics in organizations can improve productivity, safety, quality, profitability and competitive advantage (Soska, 1988; Vali-Chivuţa & Angela, 2019).

Improving competitiveness through innovations in industrial processes, such as robotics, requires greater attention to initial use activities to assess buyers' perception of benefits, enabling the implementation of incremental innovation strategies (Meyers, Sivakumar & Nakata, 1999; Moeketsi & Letaba, 2022). Even with all the benefits noted, implementing robot projects requires communication with organized labor, setup of a robotics team, understanding of robotic technology, familiarity with commercially available equipment, manufacturing operations and process knowledge, detailed engineering project and cost/benefit analysis (Soska, 1988; Vali-Chivuţa & Angela, 2019). In this context, a strategic partnership with high-tech companies may be an appropriate method to overcome challenges in implementing robotics (Yahya et al., 2019).

Methodological elements of the research

This technological article used a qualitative approach, through a single case study. The essence of the case study is investigation through data collection from multiple sources, whether direct observation, interviews, documents and archival records (Yin, 2018). The single case study is relevant when it represents a decisive case or a rare case or brings some specificities that it justifies as complexity (Yin, 2018).

This method allows for a deep and holistic investigation of complex phenomena within their real contexts, which would be impractical or unfeasible through more quantitative or varied approaches (Yin, 2018). Judicious case selection depends not only on representativeness or typicality, but also on the case's ability to shine a light on research questions and reveal insights at depths not accessible through conventional research methods (Yin, 2018). This approach is a comprehensive methodological strategy, and particularly valuable when the boundaries between the phenomenon and the context are not clearly defined, thus allowing the researcher to explore the complexity and peculiarities inherent to the case in question.

The case study was carried out in a Japanese company that provides innovative solutions within the scope of Industry 4.0 and robotics, and has a Proof of Concept (PoC) laboratory in Brazil. The chosen company is the only one in the private sector that manufactures and supplies advanced technologies in all categories of robotics, such as: collaborative robots, autonomous mobile robots and industrial robots. Additionally, the company has a complete portfolio of Industry 4.0 technologies, including: Artificial Intelligence, Internet of Things, Virtual Simulation, Connectivity and Big Data, Integrated Systems and Information Security. All of these technologies are available in the company's Proof of Concept Laboratory to validate customer projects.

The first stage of the research involved seeking theoretical foundations to support and deepen the topic. This study covered the following topics: proof of concept, industry 4.0 and robots.

The second stage consisted of conducting and analyzing interviews guided by a semi-structured data collection script. Five interviews were carried out with company employees who directly participate in the sale of solutions that involve implementations of robotics projects. These interviews took place online, and were recorded and transcribed using the software Microsoft Teams. The interviews lasted an average of 14 minutes each. Table 1 shows the profile of the interview participants, with the average age of the interviewees being 35 years old, the average time of experience in the market being 15 years and the period of work in the company studied being approximately 10 years. All interviewees have an engineering background and only one of them have a "*lato sensu* postgraduate" degree.

All interviewees were already at the company before the laboratory was set up, which makes them knowledgeable about aspects before and after the implementation of this validation. Furthermore, the selection considered the technical knowledge and practical experience of the interviewees, ensuring a comprehensive and detailed view of the impact of Industry 4.0 technologies and robotics on efficiency, quality, security and digital integration within the company.

The third stage consisted of carrying out a technical survey of data from the Proof of Concept Laboratory in relation to the projects. Data from the studied company corresponding to the implementation of robot projects were also collected, such as the number of units implemented and revenue obtained from the sale of robots.

Table 1
Profile of interview participants (education and in years)

	Role	Education	Age	Time of experience in the market	Period of work at the studied company
Interviewee 1	Product Specialist	Electrical and Electronic Engineering	27	9	5
Interviewee 2	Technical Support, Training and Proof of Concept Coordinator	Mechatronics Engineering	39	17	12
Interviewee 3	Application Engineer	Mechatronics Engineering	27	8	5
Interviewee 4	Application Engineer	Postgraduate Degree in Strategic Management Electrical and Electronic Engineering	37	19	12
Interviewee 5	Application Engineering Manager	Electrical Engineering	42	22	14

Source: Prepared by the authors.

In the fourth stage, one of the researchers conducted a non-participant observation in a proof-of-concept laboratory. This approach provides valuable insight into the process of validating new ideas or technologies, allowing the observer to maintain distance and impartiality (Yin, 2018). During this experiment, the researcher recorded the participants' interactions and reactions as they tested and explored the concept. This methodology was essential for identifying challenges, gaps or areas for improvement, contributing to the success of the proof of concept. Furthermore, it enabled an objective analysis of the concept's performance in a controlled environment, including tests and customer visits to the PoC laboratory.

During this experiment, the researcher recorded the participants' interactions and reactions as they tested and explored the concept. This methodology was essential for identifying challenges, gaps or areas for improvement, contributing to the success of the proof of concept. Furthermore, it enabled an objective analysis of the concept's performance in a controlled environment, including tests and customer visits to the PoC laboratory.

Researchers used content analysis to explore data from interviews, documents, observations and interactions, in order to identifying relevant patterns, themes and relationships (Yin, 2018). Data coding and categorization played a key role in extracting important insights, allowing researchers to understand in detail how PoC influenced the results of specifications, tests and validation of projects using robots. This analytical approach provided a holistic view and comprehensive understanding of the PoC laboratory, contributing to the generation of knowledge and valuable learning in the context of the study.

Finally, the result of implementing robots was analyzed, verifying the consequence of using the proof of concept. This approach allowed detailed observation of the development process, providing learning for scientific knowledge. The case study method was chosen appropriately taking into account the characteristics of the case studied, in accordance with the precepts of Yin (2018). Also according to Yin (2018), a single case study may be appropriate when the research objective is to deepen the understanding of a complex phenomenon in its real context. For the proof of concept study, this approach can be advantageous because it allows for a detailed, in-depth investigation of a single case, providing deep insights into how the proof of concept was designed, implemented, and what results were achieved. In situations where the phenomenon is unique, complex, or rare, a single case study may be the best choice, enabling a holistic analysis of the issue in question.

Presentation and discussion of results

This topic will present the characteristics of the company and the characteristics of the Proof-of-Concept (PoC) Laboratory implementation project. In this way, we will highlight the scenario before and after the implementation of this laboratory.

Company characteristics

The company under study is of Japanese origin and provides innovative solutions within the scope of Industry 4.0. With an annual revenue of 6.8 billion dollars, more than 30,000 employees, and a global presence, this multinational has been present in Brazil for more than 40 years. The company provides automation equipment and high-value-added solutions and has qualified staff intending to deliver the best results to customers in the most diverse segments, such as: automotive, food and beverage, digital, infrastructure, pharmaceutical, and cosmetics.

Seeking to provide complete automation solutions, the company acquired other technology companies to expand its portfolio. As an example, the incorporation of an industrial safety products unit in 2006 and traceability products in 2017, resulting from the acquisition of other companies.

Project characteristics

The company analyzed in this case study has a global presence and was founded in 1933 in Kyoto, Japan. The company initially produced X-ray timers, but quickly expanded into other electronic components such as relays and switches. The company is recognized worldwide for the quality of its products and works in state-of-the-art automation, always challenging itself to improve processes and solve complex problems. Therefore, 7% of annual revenue is allocated to Research and Development (R&D).

With each passing year, the company under study invests in research and development, seeking to deliver solutions that improve speed, increase productivity rates and improve operator safety. The challenge or problem began in 2016, with the incorporation of robots into the portfolio. Even with all the benefits of implementing projects with robots, such as increased production capacity and quality, creation of more technological products, greater safety, production scalability and standardization, robotics projects involve a high added value for their implementation. In 2018, the company invested in the construction of a Proof-of-Concept Laboratory at its unit in São Paulo, seeking to establish a global standard, as in the company's other units around the world, for validating projects that use robots. In this context, the researchers examined the influence of proof of concept on the sales prospecting process of the company under study, in order to understand how this phenomenon influenced the process.

Type of intervention and adopted mechanisms

Intending to improve the performance of implementing robot projects for its customers, the company under study opened a Proof-of-Concept Laboratory in 2018. According to PMBOK (2021), some predictive approaches can use proof of concept developments to assess choices, but the project must have its plan mostly developed at the beginning. Many times, projects that use the PoC approach have similarities in the model of previous projects. Thus, this Laboratory has several industrial automation technologies, to demonstrate the most advanced Industry 4.0 technologies, and presents several robots from the company's portfolio, which are integrated with vision systems and conveyors, as shown in Figure 1.

In this context, Proof of Concept has robotic cells composed exclusively of products from the company studied. It is possible to demonstrate the integration and connectivity between the levels of Information Technology (IT) and Automation Technology (AT).

Full integration between modules occurs through robotics, security, control, movement, vision systems, industrial networks, and sensing products.

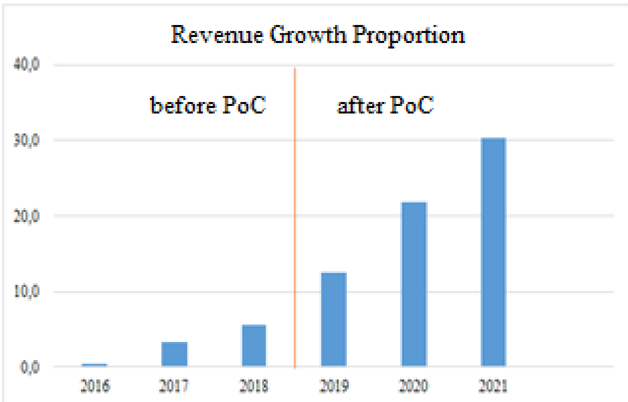
Figure 1
Proof-of-Concept Laboratory

Source: Company archive

Obtained Results and Analysis

To better understand the result of the intervention, some indicators related to the periods before and after the implementation of the Proof-of-Concept Laboratory were used. Starting with the number of robot sales revenues, it is possible to see that the number of implementations increased after the proof of concept (PoC) was set up in 2018. This indicator is measured by the revenue in Brazilian reais of the analyzed company, as shown in Figure 2.

Figure 2
Proportion of the company's revenue growth analyzed by the sale of robots before and after the proof of concept



Source: Prepared by the authors with data provided by the company.

According to data collected in the interviews, the average time to implement projects with robots can take from 1 to 3 years to complete.

Interviewees I2, I3 and I4 addressed this topic and described the importance of PoC to reduce the sale time of the project with a robot. I2, mechatronics engineer and technician responsible for the Proof-of-Concept Laboratory, states: “We can close the deal in 3 to 6 months, this is not a response to what we can provide with confidence in the trusted brand of what the customer wants when investing in a robot that is not cheap, it is not”. This corroborates the study by Bajic et al. (2023) who demonstrated that the key element to the success of these implementations has been the execution of proofs of concept.

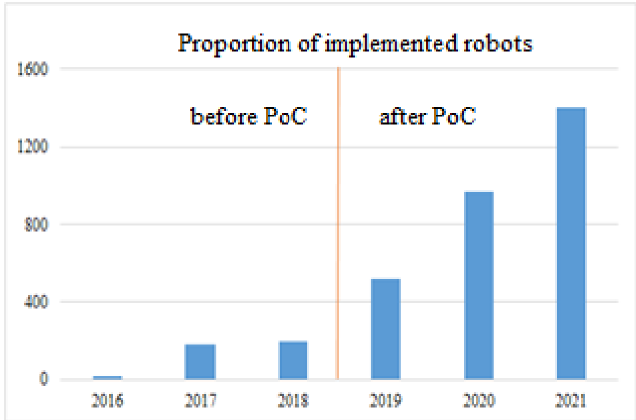
Interviewees I1, I2, and I5 report the importance of presenting the PoC to the decision-makers responsible for defining the project. Seeing the proof of concept in operation, demonstrating the solution and project performance was important for the continuity of the opportunity. I5, application engineering manager, states: “OK? So, it is essential for them to be able to really see that what they are putting in is an investment. It will achieve, mainly in terms of speed, quality, and reliability of the process. So, little is essential to be able to demonstrate this and give confidence to continue with the investment”. This evidence demonstrates that proof of concept helps to understand a project scope that is not well understood, helping those involved to understand and clarify the necessary requirements and supporting stakeholders' confidence in the success of the project (Silva, 2014; Pinto et al., 2009).

Another “before and after” indicator used is the number of robots implemented per year in the studied company. It is possible to observe that in 2018 there was no evolution. However, in 2019, after the launch of the Proof-of-Concept Laboratory, the number of projects with robots grew again, as seen in Figure 3. According to data collected in the interviews, the proof of concept allows us to evaluate the portfolio and understand the best robot solution for the client's project. The emphasis on the importance of proof of concept was evident for interviewees I1, I3 and I5, highlighting its relevance in improving the specification of projects involving robots. The interviews highlighted proof of concept as a fundamental tool, providing a clearer understanding of specific needs, resulting in more accurate specifications. This convergence of perspectives highlights the universality of recognizing proof of concept as an important component in maximizing the effectiveness of robot projects.

Interviewee 1, a product specialist at the studied company, states: “PoC contributes positively so that I can validate that specification and mitigate risks”. Interviewee 3, application engineer, addresses the importance of proof of concept for security in the specification, as it is possible to see the entire system working, and he states: “So it passes confidence to the customer, it passes confidence to the engineers too because it's one thing to rely on simulations, it's another thing to see that all your knowledge is there. It was really right, it was working, and it also gives you confidence in its specification”. Thus, the study by Anh et al. (2023) proved that a project can be successfully developed and demonstrated in industrial practices, as proved by the case of a robot system PoC prototype.

Figure 3

Proportion of robots implemented in automation projects before and after proof of concept



Source: Prepared by the authors with data provided by the company.

Another point raised by interviewees E1, I2, I3 and I5 is in relation to proactive interventions, continuous risk analysis and contingency strategies to mitigate risks in projects. I3 states that the proof of concept helps mitigate risks and goes beyond these points, and he affirms: “It's totally like that, look, I think it ends up being more than that, it even ends up giving the customer confidence, because the customer goes to the PoC and sees the application running, they say, 'look, my product is working', it's different when you have a prototype there at reach and you're able to handle it. And the guy sees you handling one of his products. So it gives confidence to the customer, it gives confidence to the company's engineers too, because it's one thing to rely on simulations, to rely on honor.” In this way, risk management is the process of understanding uncertainties, allowing to reduce and mitigate risks, through their identification and analysis. Later, it can be adjusted, controlled or even plans can be drawn up to use it as an advantage in the project environment (Macedo & Salgado 2015; Kupeshova et al., 2019). In this initial identification phase, it is necessary to check all possible threats to the organization's business and the implementation of the project (Stosic et al., 2017).

Witnessing the robot solution in full operation during PoC provides a practical, tangible understanding of the technology's potential. This experience goes beyond mere theoretical descriptions, allowing a realistic assessment of the solution's performance, effectiveness and integration. Directly viewing the robot in action not only validates technical feasibility, but also offers valuable insights into usability, operational efficiency and potential impact on the workplace. This practical experience is essential to support informed decisions and inspire confidence in implementing the robotic solution. In this context, interviewee 4 states: “Yes, I'm going to use the word marketing, but I don't think that would be ideal, right? But as a presentation or as a reference to have the products there for preview, as a proof of concept is it? And I think that's what we add most to this visualization in general, which shows that we have the products, to bring the director of the company, a manager. People at this level, which is the decision-making level, is who I think is appropriate for us to have there”. For digital technologies, developers create robust proofs of concept by combining pre-existing software, generating innovation and technological production (Floyd et al., 2007; Maaradji et al., 2023).

In Table 2, we can see the grouping of points raised by the five interviewees from the company that implemented the PoC to validate projects with robots.

In this context, the proposed implementation of a Proof-of-Concept Laboratory provided benefits in mitigating project risks, increasing the confidence of stakeholders and customers when visualizing the solution, improving the specification of projects with robots, improving the performance of the final project, and reducing project sales time, all of which converted into positive results for the study company.

Table 2
Grouping of influences analyzed in the interviews

Item	I1	I2	I3	I4	I5
Mitigate risks	X	X	X		X
Improve project specification	X		X		X
Project performance	X	X			X
Solution visualization by the Customer	X	X	X	X	
Reduce product sales time		X	X	X	

Source: prepared by the authors.

Final Considerations

This work’s objective was to analyze how proof of concept can influence the implementation of projects with robots in a company providing innovative technology solutions.

Through the implementation of the Proof-of-Concept Laboratory, the company can overcome some barriers that make Industry 4.0 technologies unfeasible, such as: poor integration of the value chain, cybersecurity challenges, doubts about the real economic benefits, lack of qualified labor, high investment requirements, poor infrastructure, task interruptions, challenges in data management and quality, lack of security standards and regulations and opposition to change (Kumar et al., 2021). According to Keding (2016), proof of concept has been widely used in project proposals and validation of new technologies. In this context, the success of a project depends on environmental uncertainties, making adjustments to exposure to risk and failures, correctly managing innovation projects so as not to interrupt them (Carvalho & Rabechini Jr., 2014; Kupeshova et al., 2019).

This technological article is relevant for robotics companies and robotic systems integrators that aim to expand their market operations, in order to manage the risks of robot implementation projects. The case reported allows us to realize the advantages of adding a Proof-of-Concept (PoC) Laboratory in the risk management of robot implementation projects, resulting in increased sales and meeting risk mitigation theories in projects. This study presented evidence about what happened after the implementation of the Proof-of-Concept Laboratory for robotics projects. Thus, the new robot implementation projects had an increase in performance in several factors: mitigating project risks, increasing the confidence of stakeholders and customers when visualizing the solution, improving the specification of projects with robots, improving the performance of the final project, and reducing project sales time, which converted into positive results for the study company.

This technological article was limited to reporting the case of a private technology company, with a small number of interviewees. It is suggested that future studies analyze a greater number of institutions, public or private, that have adopted proof of concept for implementing projects with robots.

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