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Culture Of Safety In Innovation: An Analysis From The Pulp And Paper Industry

Cultura De Segurança Na Inovação: Uma Análise A Partir Da Indústria De Papel E Celulose

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Abstract: This article aims to assess the influence of safety culture practices on innovation. The research is characterized by being quantitative and descriptive whose method used for the treatment and analysis of data was canonical correlation analysis. The sample consisted of 198 respondents, belonging to the pulp and paper segment, from a survey, being collected for accessibility and convenience. The research showed that safety culture practices and innovation are correlated, as the strength of association between the dimensions showed a high and significant coefficient variation (0.749 - p-value of 0.000), a canonical R^2 of 0.5610 considerable and a Wilks's Lambda (0.341) close to zero. It was also observed, in a more expressive way, that the lesser the participation of employees in safety culture practices, the less innovative the organization. The use of a single company and market segment considering a transversal view can be considered a limitation of the

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study, as the data may not express the results that would be obtained if analyzed in different companies and market segments. The study allows managers from different areas to understand which safety culture practices should be prioritized to influence innovation, thus contributing to the creation of safer and healthier environments, for a lasting innovation development process. This study allows organizations to measure practices of excellence and those that should be improved in the management of the safety culture, building a framework for the development of strategies aimed at innovation.

Keywords: Safety culture. Innovation. Pulp and paper industry.

Resumo: Este artigo tem como objetivo avaliar a influência das práticas de cultura de segurança na inovação. A pesquisa caracteriza-se por ser quantitativa e descritiva cujo método utilizado para o tratamento e análise dos dados foi a análise de correlação canônica. A amostra foi composta por 189 respondentes, pertencentes ao segmento de celulose e papel, a partir de uma *survey*, sendo coletada por acessibilidade e conveniência. A pesquisa evidenciou que as práticas de cultura de segurança e inovação estão correlacionadas, pois a força de associação entre as dimensões apresentou um coeficiente de variação alto e significativo (0,749 – *p-value* de 0,000), um R^2 canônico considerável de 0,5610 e um Lambda de Wilks (0,341) próximo de zero. Observou-se também, de forma mais expressiva, que quanto menor a participação dos funcionários nas práticas de cultura de segurança, menor a condição inovadora da organização. A utilização de empresa e segmento de mercado único considerando uma visão transversal pode ser considerada uma limitação do estudo, pois os dados podem não expressar os resultados que seriam obtidos se analisados em empresas e segmentos de mercado díspares. O estudo permite que gestores de diferentes áreas entendam quais práticas de cultura de segurança devem ser priorizadas para influenciar a inovação, contribuindo assim para a criação de ambientes mais seguros e saudáveis, para um processo duradouro de desenvolvimento da inovação. Este estudo permite às organizações mensurar as práticas de excelência e as que devem ser aprimoradas na gestão da cultura de

segurança, construindo um referencial para o desenvolvimento de estratégias voltadas para a inovação.

Palavras-chave: Cultura de segurança. Inovação. Indústria de celulose e papel.

INTRODUCTION

Organizations currently operate under simultaneous pressures to ensure high standards of safety while maintaining competitiveness through continuous innovation. In industrial environments, particularly those characterized by complex operations and technological intensity, safety and innovation must coexist. Understanding how these two dimensions interact has therefore become increasingly relevant for both scholars and practitioners (Demirarslan *et al.*, 2025; Zwetsloot *et al.*, 2023).

Culture plays a key role in organizations, influencing and being influenced by formal structures, daily processes, and interactions between individuals and work systems. When safety becomes an integral part of these interactions, a "safety culture" is established (Guldenmund, 2018; Le Coze and Dupré, 2022). Over time, the recognition of safety as a strategic priority has been reinforced by legislative adjustments that place responsibility on organizations to identify and properly manage risks generated by their activities (Carvalho and Santos, 2018; Oh and Lee, 2024). In this context, occupational health and safety have become embedded in individual, team, and organizational responsibilities, supported by government regulations, employee attitudes, and managerial practices (Khoo *et al.*, 2018; Quaigrain *et al.*, 2024).

At the same time, ongoing technological transformations have demanded increasingly innovative processes within organizations (Illiashenko *et al.*, 2023; Prato Neto *et al.*, 2018). Innovation involves the development or improvement of processes, services, products, and operational methods and depends on multidimensional factors such as knowledge, leadership, people, and organizational structure (Dereli, 2015; Veselica Celić, 2025). In industrial settings, however, innovation must occur within regulated environments, where safety requirements are central to operational continuity.

Previous studies suggest that safety culture practices may positively influence organizational performance and even foster innovation (Demirarslan *et al.*, 2025; Fu *et al.*, 2014; Le Coze and Dupré, 2022; chultz *et al.*, 2016). Strategies aimed at strengthening safety culture can contribute to a more favorable organizational climate, characterized by shared perceptions regarding policies, practices, and expected behaviors (Asad *et al.*, 2022), which may also support innovative dynamics (Güven and Doğan, 2025; Jilcha and Kitaw, 2017). However, despite these indications, empirical evidence directly examining the relationship between safety culture practices and innovation remains limited. Several authors highlight the

need for a more integrated understanding of safety and innovation cultures, particularly through empirical investigation (Arvidsson *et al.*, 2006; Demirarslan *et al.*, 2025; Khushrushahi, 2012; Otaverina and Sunaryo, 2025; Rollenhagen, 2010; Waring, 2019).

This gap becomes particularly relevant in industrial sectors that combine operational risk, strict regulatory environments, and strong pressure for technological advancement. The Brazilian pulp and paper sector represent a strategic context in this regard. Composed of approximately 220 companies, the sector generates around 128,000 direct jobs and 640,000 indirect jobs. Brazil is the fourth largest pulp producer in the world, accounting for 11.3% of global production (25 million tons), and ranks ninth in paper production worldwide (ABTCP, 2024; IBÁ, 2023). In addition to its economic relevance, the sector operates in complex industrial plants, where safety management and continuous process improvement are essential to maintain competitiveness in international markets. Thus, it offers a suitable empirical setting to investigate how safety culture practices may influence innovation.

Given the above, this study aims to assess the influence of safety culture practices on innovation within organizations in the Brazilian pulp and paper sector. By empirically examining this relationship, the study contributes to advancing the understanding of how safety-oriented organizational practices may coexist with and potentially foster innovation, addressing a gap identified in the literature and integrating two fields that are often analyzed separately.

THEORETICAL REFERENCE

Safety Culture

The concept of "safety culture" appears in 1988, in the first technical report carried out by the International Nuclear Safety Advisory Group [INSAG], with an approach to organizational factors in the analysis of the accident of Chernobyl nuclear plant in Ukraine in 1986 (AIEA, 1991). The concept of safety culture was elaborated as: "the set of characteristics and attitudes of organizations and individuals, which guarantees that the safety of a nuclear plant, due to its importance, will have the highest priority" (INSAG, 1988, p.84).

The safety culture, according to Pidgeon (1991) and Turner *et al.* (1989), expresses a specific set of organizational functions, norms, beliefs and values, formed by people and their social relationships inside and outside organizations (Richter and Koch, 2004), which is a predictor for improving the performance of work occupations (Blair and O'Toole, 2010; Gonçalves Filho, 2011), encouraging people to be concerned about their attitudes and actions that affect the physical world and other people (Turner, 2019).

For Cooper (2000) the safety culture management can interact with other perspectives present in the organizational culture, through team practices, organizational structure and basic assumptions and values, thus forming the safety culture (Figure 1). The dynamic interactions between these aspects can vary in intensity and time. Glendon and Stanton (2000) and Silva and Lima (2004) define the safety culture as being a part of the organizational culture.

Figure 1.
Aspects of dynamic safety culture interactions
Source: adapted from Cooper (2000, p.118).

Contemporary studies argue that safety culture is continuously shaped by interactions between people, technologies, organizational arrangements, and external pressures, especially in contexts characterized by complexity, innovation, and digitalization (Le Coze and Dupré, 2022; Hollnagel, 2018). This updated perspective reinforces the idea that safety culture is not static, but evolves from daily work practices, decision-making processes, and organizational learning mechanisms (Karachalios and Adjekum, 2025).

In this regard, recent approaches grounded in resilience engineering and Safety-II have broadened the traditional focus on accident prevention by emphasizing how organizations successfully manage variability and uncertainty in daily operations (Bhattacharjee *et al.*, 2024; Hollnagel, 2018; Vlachokyriakou, 2024). From this standpoint, a positive safety culture supports continuous learning not only from incidents

and failures, but also from normal work activities, strengthening adaptability, collective sensemaking and long-term organizational sustainability (Protasenko and Ivashura, 2024).

Management practices have also received renewed attention in contemporary research on safety culture, highlighting the central role of leaders in shaping shared perceptions of safety priorities through communication, encouraging participation, and exemplary behavior (Asad *et al.*, 2022). Evidence from meta-analyses further confirms that leadership styles and supervisory practices exert a significant influence on attitudes, behaviors, and engagement in safety, reinforcing the relevance of managerial commitment and worker participation already highlighted in classic models (Lyubykh *et al.*, 2022).

In parallel, the increasing adoption of digital technologies and innovative systems has introduced new challenges for security management, indicating that digital transformation can either strengthen or weaken the security culture, depending on how technologies are incorporated into organizational routines and human-centered practices (Bozkus, 2023; Milea, 2024). Thus, contemporary approaches emphasize the need to align technological innovation with cultural, organizational, and behavioral dimensions, ensuring that security remains a strategic value in changing contexts (Bozkus, 2023).

Building on these conceptual developments, safety culture can be understood as a set of shared characteristics that reflect how organizations approach occupational safety in relation to their goals, demands and operational contexts (Morrow and Coplen, 2017; Buffon *et al.*, 2018). Alves (2014) and Mustapha *et al.* (2023) emphasizes that safety culture is constructed through formal and informal organizational arrangements, linking values and beliefs to structures, processes and work environments.

Reason (2016) synthesizes these discussions by defining safety culture as a configuration of shared values and beliefs that interact with organizational structures and control systems to shape behavioral norms. The author highlights four key dimensions: (I) reporting culture, in which people perceive the importance and confidence of reporting accidents that occur in their routine; (II) continuous learning culture; (III) culture of justice, which generates trust for people to freely report abnormal occurrences that may occur; and, finally, (IV) flexibility, which translates into the organization's ability to consider a horizontal structure providing more autonomy.

In operational terms, Rodrigues (2011) identifies essential elements for the development and maintenance of an effective safety culture, including: Management commitment; Communication; Employee participation; Training and information; Motivation; Compliance with safety procedures; Learning organization; and Management to preserve the safety culture (Table 1).

Table 1.
Key aspects of the safety culture

Key Aspects	Description
Commitment of management to safety	Effective leadership and commitment of managers to ensure compliance with policies, procedures and regulations on occupational health and safety, in addition to ensuring the availability of essential resources for their execution;
Communication about safety aspects	Occupational health and safety must be part of the daily routine of all stakeholders who are part of the business, listening and providing necessary feedback in order to develop safe behaviors;
Employee participation in health and safety initiatives	Ensure the participation of everyone involved in matters related to occupational health and safety, sharing responsibilities and knowledge;
Employees training and information about safety	Ensure the necessary training, based on occupational health and safety policies, procedures and regulations, for the development of all work activities;
Motivation for elimination of existing risks	Encourage people to work preventively, with the main objective of eliminating or minimizing existing risks;
Observation of security procedures	Contribute to the elaboration, understanding, implementation and execution of established occupational health and safety policies, procedures and regulations;
Organization learning about safety	Provide the necessary methods and tools to implement the continuous improvement of the safety culture;
Management to preserve safety culture	Establish risk management strategies, policies and indicators to preserve the safety culture in a sustainable and perennial manner.

Source: adapted from Rodrigues (2011, p.44).

Guldenmund *et al.* (2018) and Siuta *et al.* (2022) reinforce the relevance of these elements, indicating that the evolution of the maturity of the safety culture reflects the organization's ability to integrate leadership, learning, and risk management practices in a consistent and sustainable way. Organizations need to continually balance safety culture with operational and business demands, especially in contexts marked by innovation and technological transformation (Bourrier, 2018).

From this perspective, the implementation of methods that transform ideas into real value, as well as new technologies, must be accompanied by deliberate cultural strategies in order to ensure that safety principles are incorporated into daily practices and organizational decision-making processes (Stojiljković, 2017; Antonsen *et al.*, 2021). According to Bourrier (2018) and Le Coze and Dupré (2022), safety culture functions as an enabling infrastructure that supports innovative practices, particularly in contexts of digital transformation and organizational change, where the balance between reliability and innovation becomes a critical management challenge.

Innovation

Historically, innovation has been conceived as a central driver of economic development and organizational transformation. From a classical perspective, Schumpeter (1982) defined innovation based on five fundamental forms: the introduction of new goods or services; the implementation of new production methods; the opening of new markets; the discovery of new sources of raw materials; and the creation of new organizational or market structures. This approach laid the groundwork for understanding

innovation as a process of disruption and renewal, directly linking it to competitiveness and economic growth. Later, Freeman and Soete (2012) reinforced this view by relating innovation to economic rationality, highlighting the financial returns from new products, processes, and procedures.

From this classic framework, the literature has expanded the concept of innovation, incorporating organizational and behavioral dimensions. Authors such as Kim (1997), Kuratko *et al.* (2018) and Hurley and Hult (1998) have emphasized innovation as an organizational capacity to create knowledge and successfully implement new ideas. In a complementary way, Dektyareva (2023) and Tidd *et al.* (2008) conceived of innovation as a structured process of transforming opportunities into applicable solutions, while Busch *et al.* (2026) and Trott (2012) highlighted the need to systematically manage all the activities involved, from the generation of ideas to their introduction to the market. These contributions have solidified the understanding of innovation as a continuous, collective phenomenon dependent on favorable organizational contexts.

Coccia (2017) and Davila *et al.* (2007) mention that not all innovations are created in the same way, or present the same risks and generate the same returns. In order to design and perpetuate an innovative culture in organizations, Wikhamn and Wikhamn (2011) mention the need to understand certain key aspects, such as: Innovation and flexibility; External focus; and Reflexibility.

Table 2 describes some key aspects that contribute to building an innovation culture in organizations.

Table 2.
Key Innovation Aspects

Key Aspects	Description
Innovation and flexibility	It refers to organizational readiness and responsiveness to new ideas, changes, and challenges, including flexibility in work processes, support for experimentation, and tolerance for incremental adjustments (De la Gala-Velásquez *et al.*, 2023; Wikhamn and Wikhamn, 2011).
External focus	This refers to the organization's ability to orient its actions towards the external environment, especially customers, users, and the market, seeking to identify opportunities, trends, and emerging demands (Ehls *et al.*, 2020; Wikhamn and Wikhamn, 2011).
Reflexibility	It is defined as the degree to which individuals and teams continuously review their practices, routines, and assumptions, promoting adjustments and learning that enable opportunities for innovation (Farnese *et al.* 2016; Oh and Lee (2024); Wikhamn and Wikhamn, 2011).
Innovative behavior	It encompasses both the exploration of opportunities and the generation of creative ideas, as well as the effective implementation of changes through the application of new knowledge and process improvement (Hughes *et al.*, 2018; Newman *et al.*, 2018).

Source: elaborated by the authors.

In contemporary times, innovation has been predominantly approached as a dynamic capability, essential for the adaptation of organizations in environments characterized by uncertainty, complexity, and rapid technological change. Innovation is not limited to technological results, but involves the ability to integrate, reconfigure and renew organizational resources continuously, sustaining competitiveness in the

long term (Pundziene *et al.*, 2022; Veselica Celić, 2025). This perspective shifts the focus from innovation as a one-off event to a logic of ongoing organizational learning.

For AlQudah (2023) and Arsawan *et al.* (2022), innovative organizations are those capable of creating, sharing, and applying knowledge in a systematic way, promoting environments that encourage experimentation, collaboration, and critical reflection on existing practices. In this sense, innovation emerges as a socially constructed phenomenon, dependent on the interactions between individuals, teams, and organizational structures.

Furthermore, Hughes *et al.* (2018) and Newman *et al.* (2018) highlight that organizational culture and leadership practices exert a direct influence on innovative capacity. According to the authors, leadership styles that promote autonomy, trust, and support for learning encourage employee engagement in innovative behaviors, expanding both the generation and implementation of new ideas. Thus, innovation comes to be understood as a result of values, norms, and practices shared within the organizational environment.

Contemporary approaches, such as the Industry 5.0 perspective, reinforce a human-centered vision of innovation, in which well-being, sustainability, and organizational resilience play a central role. In this conception, innovation must generate economic and social value, while promoting safe working conditions and the empowerment of individuals in production processes (European Commission, 2021; Rubio-Andrés *et al.*, 2022; Wang, 2022).

In light of this, the relationship between innovation and safety culture has gained increasing attention in recent literature, indicating that organizations with a consolidated safety culture tend to create psychologically safe environments in which employees feel encouraged to report failures, propose improvements, and actively participate in change processes. These conditions favor organizational learning and responsible experimentation, essential elements for the development of sustainable innovation (Leape, 2021; Zwetsloot *et al.*, 2023).

Therefore, innovation should not be understood merely as the introduction of new technologies or processes, but also as a mechanism capable of strengthening safe behaviors and improving organizational safety performance. The implementation of innovations in production processes and risk prevention technologies can foster more responsible and conscious practices among workers, reinforcing norms, routines, and values associated with a safety culture. Thus, psychologically safe environments not only encourage the proposal of improvements but also enhance the effective adoption of innovations that directly impact safety behaviors and the reduction of incidents (Naevestad *et al.*, 2024; Taqwa *et al.*, 2025).

Furthermore, evidence from high-reliability sectors, such as aviation, indicates that strengthening a safety culture requires both technological innovations aimed at controlling tangible risks and innovative solutions capable of addressing intangible risks, particularly those related to human error. Initiatives such as applications designed to promote safety culture illustrate how innovation can function as a mechanism for continuous organizational learning, fostering awareness, engagement, and collective responsibility (AswathySreenivasan *et al.*, 2019). From this perspective, a culture of innovation can be understood as an extension of a learning-oriented safety culture, as it encourages systematic reflection, continuous improvement, and the integration of new knowledge into organizational practices (Naevestad *et al.*, 2024).

In line with this argument, the relationship between safety culture and innovation has been explicitly explored in the literature. Rollenhagen (2010) suggests that combining the concepts of safety culture and innovation provides a valuable starting point for advancing research in this field. Similarly, Arvidsson *et al.* (2006) demonstrated that even in highly regulated and structured environments, such as air traffic control, organizational contexts characterized by a strong safety culture may also be conducive to innovation.

Corroborating this perspective, studies indicate that employees' commitment to reducing work-related injuries, reflecting a favorable safety culture, is directly associated with innovation processes (Güven and Doğan, 2025; Jilcha and Kitaw, 2017). Continuous improvement and innovation are more likely to occur in organizations where employees share the understanding that safety is a collective responsibility and are committed to the goal of zero harm (Leape, 2021).

Based on the literature review, the researchers proposed the following research structure, as illustrated in Figure 2. In the proposed structure, this study suggests that the safety culture will influence innovation processes.

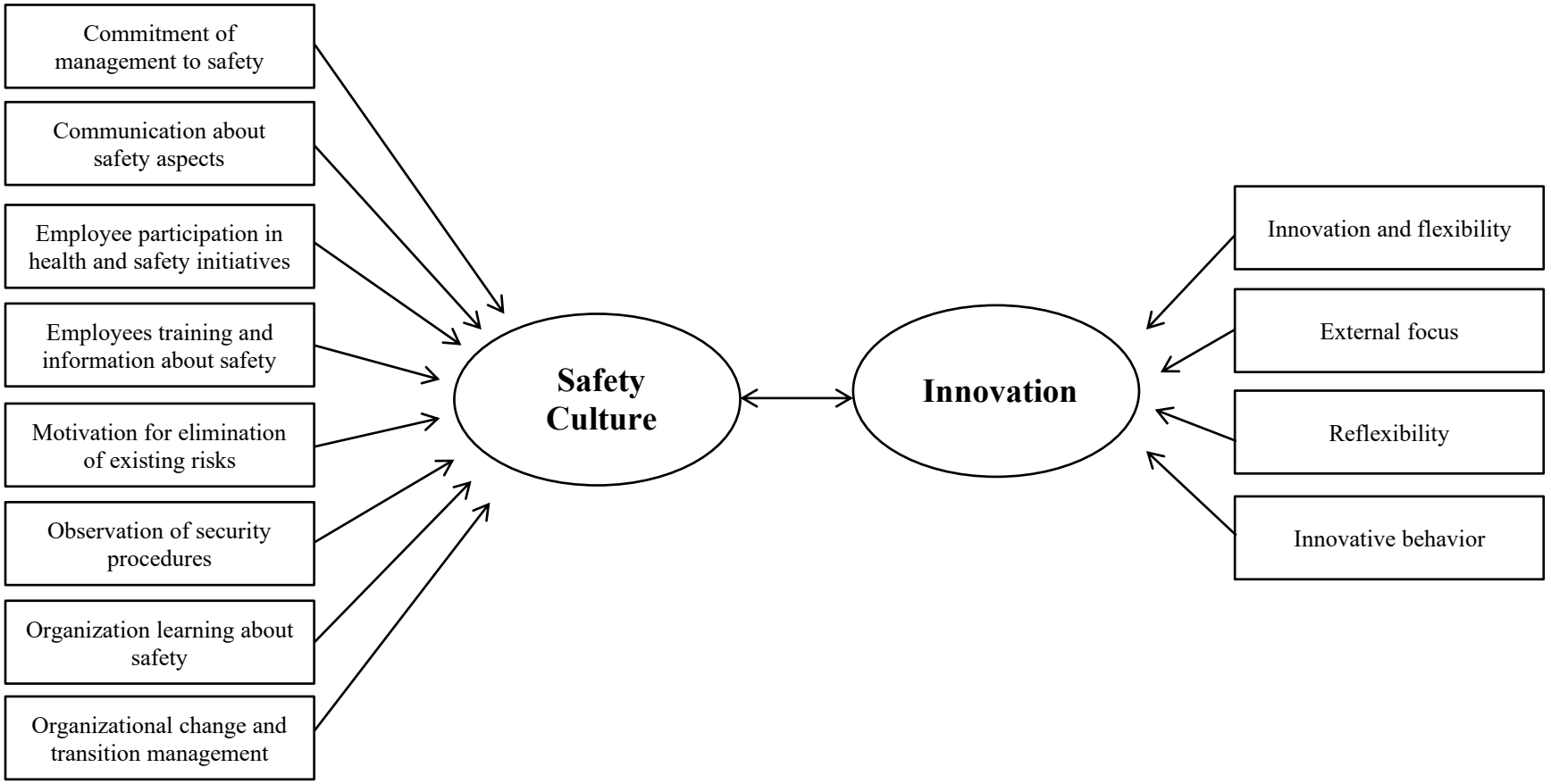

Figure 2.
Conceptual structure
Source: elaborated by the authors.

In view of the reflections on safety culture and innovation, based on the theoretical framework, the following hypothesis was created:

H: Favorable safety culture practices influence innovation.

Based on the theoretical framework discussed above, this hypothesis is empirically tested in the following section.

METHODOLOGY

The research is characterized as quantitative by using indicators to analyze dimensions, through the collection of data that indicate the functioning of institutions (Lindfelt *et al.*, 2018). The quantitative research design was adopted to examine the relationship between safety culture practices and innovation through measurable indicators and statistical testing. In accordance with the criteria of completeness, clarity and credibility (Zhang and Shaw, 2012), the methodological procedures ensure transparency in data collection, measurement and analysis. Following Eisenhardt (1989), the study clarifies why the phenomenon was investigated (influence of safety culture on innovation), what was measured (dimensions of safety culture and innovation), how it was operationalized (validated questionnaires and statistical techniques), and the analytical implications derived from the findings.

To measure the safety culture, a questionnaire (Appendix 1) consisting of 39 statements was used, structured by a set of eight dimensions, namely: Commitment of management to safety; Communication about safety aspects; Employee participation in health and safety initiatives; Employees training and information about safety; Motivation for elimination of existing risks; Observation of security procedures; Organization learning about safety; and Management to preserve safety culture; and the Innovation dimension, composed of 27 assertions, consisting of four dimensions: Innovation and flexibility; External focus; Reflexibility; and Innovative behavior. The questionnaire used was developed based on Rodrigues (2011) to measure safety culture and on Wikhamn and Wikhamn, (2011), González-Romá (2008) and De Jong and Den Hartog (2008) to determine innovation.

The selection of these instruments is grounded in their prior empirical validation and theoretical alignment with the constructs investigated. Rodrigues (2011) provides a structured and multidimensional approach to measuring safety culture practices within organizational environments. The innovation scales proposed by Wikhamn and Wikhamn (2011), González-Romá (2008), and De Jong and Den Hartog (2008) capture both contextual and behavioral dimensions of innovation, including flexibility, external orientation

and innovative work behavior. Their combined use allows a comprehensive assessment of innovation at the organizational and individual levels, consistent with the objectives of this study.

The Likert scale was adopted for the questionnaire, which expresses a favorable or unfavorable attitude towards a given subject, measuring the degree of agreement and disagreement in relation to a given statement (Curado, Teles, and Marôco, 2014). Each question in that questionnaire contains 5 answer options, ranging from (1) Strongly Disagree to (5) Strongly Agree.

In order to establish the sample size, the recommendations made by Ringle, Silva and Bido (2014) regarding the use of the G*Power software, version 3.1.9.2, were taken as a basis. According to the authors, this software concerns a free power analysis program for a variety of commonly used statistical tests in social, behavioral and biomedical sciences (Faul *et al.*, 2009; Memon *et al.*, 2020). Ringle, Silva and Bido (2014) recommend that, initially, the construct or VL that receives the highest number of arrows or has the highest number of predictors should be evaluated, observing two parameters: the test power (Power = 1 – β error prob) and effect size (f^2). The authors suggest the use of at least twice the value obtained in the calculation to define a more consistent model. Cohen (1988) and Hair Jr. *et al.* (2021) indicate as a test power parameter a value of 0.80 and a median f^2 of 0.15. They add that a model should receive at least two arrows, as a suitable parameter.

Following the previously established criteria, the calculation of the software indicated a total sample size of 85, which, adjusted to the recommended (double) becomes 170 respondents. Considering that the questionnaires received for this research, 222 questionnaires were collected and 198 validated, with complete data, without filling errors, low variance or incompleteness, which is the final size of the research sample, where the number of answers was considered representative for application of exploratory factor analysis [EFA] techniques (Hair Jr. *et al.*, 2014). The research involved employees from companies in the Brazilian pulp and paper sector, including operational, technical and managerial staff, ensuring representation across hierarchical levels. These organizations operate in highly regulated, technology-intensive industrial environments, which are appropriate for examining the relationship between safety culture practices and innovation. For confidentiality reasons, the companies are not identified.

To obtain the data, a descriptive cross-sectional survey was carried out using structured questionnaires available for filling out via the web, through the site specialized in data collection Google Forms. The survey link was distributed electronically via corporate communication channels to employees of the participating companies. Data collection took place over a three-month period in the year 2025, ensuring sufficient time for participation. Participation was voluntary and responses were anonymous. Then

the data were tabulated in a Microsoft Excel® spreadsheet and imported into the SPSS® Statistical Software (Statistical Package for the Social Sciences) version 28.

Regarding the statistical technique used for data processing and analysis, descriptive research was used, indicated for detailing specific situations, in which it is developed and structured to measure the characteristics of occurrences found in a scientific study (Hair Jr. *et al.*, 2009). The comparison between the mean values obtained by function surveyed was performed using the Wilcoxon-Mann-Whitney test (U test). According to Campbell and Skillings (1985) the Wilcoxon-Mann-Whitney test (U test) is indicated to test the difference between two unpaired groups.

Then, Cronbach's alpha reliability test was performed. According to Hair Jr. *et al.* (2009) this indicator measures reliability in a variance from 0 to 1, with values from 0.60 to 0.70 being considered the lower limit of acceptability. We also applied the canonical correlation analysis. This analysis technique that allows the evaluation of the relationship between multiple dependent variables with multiple independent variables, metric or non-metric. The analysis can be used without the metric variables necessarily showing normality (Fávero and Belfiore, 2021). The use of canonical correlation analysis aligns with the study's objective of examining the multivariate association between two sets of observed variables. Unlike other methods, such as structural equation modeling, which requires specifying causal relationships between latent constructs, canonical correlation focuses on identifying and measuring the shared variance between groups of variables. Since the present study does not aim to test a structural causal model, but rather to evaluate the general relationship between the constructs, canonical correlation analysis is methodologically appropriate.

The combination of reliability testing, non-parametric comparison tests and canonical correlation analysis strengthens the robustness of the findings by examining both internal consistency of the scales and multivariate relationships between constructs. This methodological triangulation enhances the credibility of the results and supports the analytical interpretation of the relationship between safety culture practices and innovation. Once the methodological procedures have been completed, the analysis of the results found in the next section is presented.

RESULTS AND DISCUSSIONS

This section presents and analyzes the research results. In order to characterize the sample, we investigated demographic aspects. Table 3 shows a predominance of male respondents (69.7%) among the research participants. Regarding the distribution of respondents by area of work, it appears that 48.5% are

working in the production area. Most of the survey participants (84.8%) have higher and secondary education as their educational background.

Table 3.
Distribution of respondents

Gender	**Male**			**Female**	
	138	69.7		60	30.3
Education	Frequency	Percent	**Work area**	Frequency	Percent
Postgraduate studies	8	4.0	Administrative	21	10.6
University education	22	11.1	Forestry	3	1.5
High school	146	73.7	Logistics	36	18.2
Elementary School	22	11.1	Maintenance	42	21.2
-	-	-	Production	96	48.5
Total	**198**	**100.0**	**Total**	**198**	**100.0**

Source: authors'own findings.

It is noteworthy that the average length of stay of respondents in the organization is 6.07 years, while the average length of stay in the current position is 4.28 years. Of the survey participants, 64.1% are married and 35.9% are single.

After the analysis of the distribution of respondents was completed, a descriptive analysis of the sample was performed. Table 4 shows the mean values of each dimension by work area. As we can see, the highest total average value obtained among the Safety Culture practices is the Organization learning about safety with an average value of 4.53, while the lowest average score of 3.97 belongs to the Communication about safety aspects dimension. With regard to Innovation, it appears that the total average score obtained comprises the innovation and flexibility dimension with an average value of 3.96, while the lowest average score of 3.47 belongs to the innovative behavior dimension.

Table 4.
Descriptive analysis

	Dimension	Administrative		Forestry		Logistics		Maintenance		Production		Total	
		Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Safety Culture	Commitment of management to safety	4.22	0.710	3.61	1.058	4.07	0.701	3.98	0.776	4.30	0.602	4.17	0.688
	Communication about safety aspects	3.98	0.753	3.67	1.155	3.87	0.807	3.91	0.731	4.04	0.753	3.97	0.760
	Employee participation in health and safety initiatives	4.02	0.871	3.56	0.962	3.97	0.864	3.79	0.835	4.27	0.691	4.08	0.798
	Employees training and information about safety	4.38	0.613	3.67	1.155	4.19	0.808	4.21	0.603	4.39	0.672	4.31	0.690

	Motivation for elimination of existing risks	4.25	0.720	3.67	1.155	4.22	0.800	4.26	0.580	4.46	0.608	4.34	0.669
	Observation of security procedures	4.32	0.809	3.62	1.072	4.27	0.729	4.18	0.671	4.35	0.651	4.28	0.694
	Organization learning about safety	4.65	0.372	3.67	1.155	4.36	0.822	4.45	0.690	4.63	0.570	4.53	0.654
	Management to preserve safety culture	4.31	0.766	3.67	1.155	4.28	0.766	4.13	0.725	4.47	0.623	4.33	0.706
	Total	4.24	0.609	3.63	1.095	4.13	0.677	4.08	0.578	4.34	0.542	4.22	0.600
Innovation	Innovation and flexibility	4.20	0.486	4.13	0.115	3.91	0.442	3.77	0.524	4.01	0.403	3.96	0.459
	External focus	4.10	0.427	3.60	0.529	3.87	0.468	3.86	0.487	3.97	0.459	3.93	0.467
	Reflexibility	4.06	0.457	3.80	0.346	3.82	0.390	3.77	0.464	3.84	0.433	3.84	0.437
	Innovative behavior	3.76	0.695	3.33	0.643	3.44	0.523	3.35	0.665	3.47	0.530	3.47	0.585
	Total	4.02	0.408	3.67	0.378	3.74	0.349	3.68	0.464	3.83	0.336	3.80	0.386
Number of Respondents		21		3		36		42		96		198	

Source: authors'own findings.

It was also verified whether there is an alternation between the dimensions through the average values attributed to safety culture practices and innovation per work area. Data were tested for normality using the Kolmogorov-Smirnov test, but the results revealed that they do not have a normal distribution (p-value of 0.000 for all dimensions). According to Hair *et al.* (2009), when data are measured by ordinal or nominal scales, the assumption that the data are normal is not always valid. In these cases, the use of non-parametric tests is suggested.

Thus, the Wilcoxon-Mann-Whitney nonparametric test [U test] was used for two independent samples. The Wilcoxon-Mann-Whitney test was used to determine whether differences in mean values attributed to safety culture practices and innovation are statistically significant. In the Wilcoxon-Mann-Whitney test, p-values less than 0.05 demonstrate that the groups are significantly different.

It can be seen in Table 5, through the analysis carried out in pairs, that the practices of safety culture and innovation, mostly demonstrate similarity and/or equality between the average values presented, thus establishing a uniformity of the concepts established between both practices across all work areas. The process of modifying, adapting and consolidating people in relation to established concepts, according to Bley (2011) is constituted essentially through people's behavior and attitudes linked to organizational guidelines reciprocally. It is evident that mean values significantly different between the work areas represent the tenth part of the total analysis performed.

Table 5.
Wilcoxon-Mann-Whitney test: dimension by researched work area

Wilcoxon-Mann-Whitney		Macro Dimension											
		Safety Culture Dimension								Innovation Dimension			
		Commitment of management to safety	Communication about safety aspects	Employee participation in health and safety	Employees training and information about safety	Motivation for elimination of existing risks	Observation of security procedures	Organization learning about safety	Management to preserve safety culture	Innovation and flexibility	External focus	Reflexibility	Innovative behavior
Administrative and Forestry	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV
	p-value	0.403	0.454	0.334	0.309	0.377	0.253	0.149	0.376	0.928	0.403	0.454	0.334
	U test	22.000	23.000	20.500	20.000	21.500	18.500	16.000	21.500	30.500	22.000	23.000	20.500
Administrative and Logistics	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≠ AV	≅ AV	≅ AV	≅ AV
	p-value	0.335	0.578	0.771	0.563	0.926	0.745	0.565	0.933	0.009	0.335	0.578	0.771
	U test	320.000	344.500	360.500	343.500	372.500	358.500	345.500	373.000	225.000	320.000	344.500	360.500
Administration and Maintenance	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≠ AV	≅ AV	≠ AV	≠ AV
	p-value	0.177	0.809	0.260	0.183	0.779	0.235	0.502	0.187	0.001	0.137	0.010	0.017
	U test	349.000	424.500	364.000	350.500	422.000	360.000	397.500	351.500	216.000	340.000	269.000	279.500
Administration and Production	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≠ AV	≠ AV
	p-value	0.723	0.751	0.276	0.647	0.195	0.723	0.558	0.355	0.057	0.398	0.017	0.018
	U test	958.500	963.500	855.500	944.500	830.000	958.500	933.500	880.500	748.500	891.000	677.000	679.000
Forestry and Logistics	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV
	p-value	0.341	0.634	0.443	0.424	0.422	0.232	0.260	0.331	0.160	0.424	0.850	0.871

Forestry and Maintenance	U test	36.000	45.000	39.500	39.000	39.000	31.500	34.000	36.000	28.000	39.000	50.500	51.000
	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV
	p-value	0.493	0.631	0.616	0.435	0.268	0.283	0.223	0.490	0.061	0.359	0.963	0.836
Forestry and Production	U test	48.000	52.500	52.000	46.000	39.000	39.500	37.500	48.000	23.000	43.000	62.000	58.500
	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV
	p-value	0.229	0.505	0.133	0.285	0.204	0.199	0.102	0.251	0.349	0.213	0.788	0.618
Logistics and Maintenance	U test	85.500	111.500	71.000	92.500	83.500	81.500	72.000	89.000	99.500	84.000	131.000	120.000
	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV
	p-value	0.680	0.817	0.317	0.575	0.796	0.423	0.953	0.211	0.366	0.964	0.906	0.964
Logistics and Production	U test	715.000	733.000	656.500	700.500	730.500	676.500	750.500	633.000	668.500	751.500	744.500	751.500
	Result	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV	≅ AV
	p-value	0.085	0.263	0.084	0.195	0.142	0.758	0.153	0.399	0.119	0.262	0.718	0.418
Maintenance and Production	U test	1393.50	1510.00	1391.50	1478.00	1447.50	1668.00	1474.50	1566.50	1431.50	1511.50	1658.50	1572.00
	Result	≠ AV	≅ AV	≠ AV	≠ AV	≅ AV	≅ AV	≅ AV	≠ AV	≠ AV	≅ AV	≅ AV	≅ AV
	p-value	0.018	0.327	0.002	0.033	0.051	0.122	0.122	0.004	0.005	0.230	0.653	0.503
	U test	1509.50	1805.00	1335.00	1560.00	1602.50	1683.50	1710.50	1409.00	1427.00	1760.00	1920.50	1873.50

Caption: ≠ (Difference); ≅ (Similarity and/or equality); AV (Average Value).
Source: authors'own findings.

Dimension reliability was assessed using Cronbach's Alpha test (Table 6). Alpha Cronbach is a useful statistic for investigating the internal consistency of the questionnaire scale. According to Hair Jr. *et al.* (2009), this indicator measures reliability in a variance from 0 to 1, with values from 0.600 to 0.700 being considered the lower limit of acceptability. In this research, the values were considered as having good reliability of the data with coefficients $\alpha \geq 0.600$.

Table 6.
Reliability Analysis

Macro Dimensions	***Cronbach's Alpha***	**No. of items**
Safety Culture	0.961	39
Innovation	0.824	27

Source: authors'own findings.

Through the Kaiser-Meyer-Olkin test – Measure of Sampling Adequacy [KMO], which determines the sample adequacy with regard to the degree of partial correlation, ranging from 0 to 1, it is clear that KMO close to 1 indicates that it is very adequate to use of the Factor Analysis technique [FA]. On the other hand, values close to 0 reflect a weak correlation between dimensions. It is noteworthy that for the correct use of factor analysis, the KMO must be at least 0.6 (Fávero and Belfiore, 2021; Hair Jr. *et al.*, 2009). Therefore, the KMO test denoted reasonable explanatory power (0.874), as highlighted in Table 7. In turn, the Bartlett's sphericity test presented a p-value of 0.001, indicating that there is a correlation between the dimensions, thus it is advisable to use of FA. It is evident that for the p-value to be significant it must be below 0.05 (Fávero and Belfiore, 2021; Hair Jr. *et al.*, 2009).

Table 7.
KMO and Bartlett Tests from Dimensions 1 to 12

KMO and Bartlett Test		
Kaiser-Meyer-Olkin measure of sampling adequacy.		.874
Bartlett's sphericity test	Approx. chi square	1680.250
	Df.	66
	Sig.	.001

Source: authors'own findings.

In the Innovation macro dimension, six assertions were loaded in each of the Innovation and Flexibility and External Focus dimensions, five assertions in the Reflexibility dimension and ten assertions in the Innovative Behavior dimension. Regarding the safety culture macro dimension, six assertions were uploaded in Commitment of management to safety, five assertions in Communication about safety aspects, six assertions in Employee participation in health and safety initiatives, five assertions in Employees

training and information about safety, four assertions in Motivation for elimination of existing risks, seven assertions in Observation of security procedures, three statements in Organization learning about safety and four statements in Management to preserve safety culture.

The factorial analysis of the statements confirmed five components for the variable people management and eight components for the variable safety culture. The analysis produced two factors depicted in Table 8. The first factor is mostly composed of safety culture components, representing the behavior and commitment of people and the organization with the established safety culture; the second factor is mostly made up of innovation components, representing the contribution of innovation practices. The two joint factors in this study contributed to 68.8% of total variance.

Table 8.
Rotating Component Matrix

	Factors		Variance	
	1	2	Variance (%)	Accumulated (%)
Observation of security procedures	0.893		51.713	51.713
Motivation for elimination of existing risks	0.865			
Employees training and information about safety	0.843			
Employee participation in health and safety initiatives	0.839			
Management to preserve safety culture	0.838			
Communication about safety aspects	0.795			
Organization learning about safety	0.764			
Commitment of management to safety	0.759			
Innovation and flexibility		0.864	17.116	68.829
External focus		0.844		
Reflexibility		0.770		
Innovative behavior		0.567		

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.
Source: authors'own findings.

In Table 9 we present a matrix with Pearson's correlation coefficients. In this analysis, the values can vary from (-1 to 1). A value of (-1) suggests a perfect negative correlation, a value of (0) indicates no correlation and (1) indicates a perfect positive correlation (Hair Jr. *et al.*, 2009). Based on Franzblau (1958), it is highlighted that 36.3% of the correlations were considered strong correlations (If $0.60 < | \rho | < 0.80$, the correlation is strong), 19.7% were considered moderate correlations (If $0.40 < | \rho | < 0.60$, the correlation is moderate) and the others were classified as weak corrections.

Table 9.
Correlation between dimensions

Dimension	Commitment of management to safety	Communication about safety aspects	Employee participation in health and safety	Employees training and information about safety	Motivation for elimination of existing risks	Observation of security procedures	Organization learning about safety	Management to preserve safety culture	Innovation and flexibility	External focus	Reflexibility	Innovative behavior
Commitment of management to safety	1											
Communication about safety aspects	0.675	1										
Employee participation in health and safety initiatives	0.621	0.713	1									
Employees training and information about safety	0.641	0.622	0.694	1								
Motivation for elimination of existing risks	0.639	0.654	0.707	0.729	1							
Observation of security procedures	0.619	0.625	0.714	0.741	0.744	1						
Organization learning about safety	0.531	0.565	0.590	0.683	0.581	0.649	1					
Management to preserve safety culture	0.598	0.583	0.638	0.645	0.679	0.806	0.657	1				
Innovation and flexibility	0.284	0.181	0.174	0.182	0.081	0.064	0.220	0.140	1			
External focus	0.493	0.394	0.583	0.515	0.469	0.486	0.449	0.445	0.346	1		
Reflexibility	0.132	0.066	0.078	0.096	-0.011	0.010	0.115	0.023	0.243	0.604	1	
Innovative behavior	0.285	0.227	0.221	0.289	0.211	0.170	0.195	0.229	0.398	0.702	0.599	1

**. The correlation is significant at the 0.01 level (2 ends).
*. The correlation is significant at the 0.05 level (2 ends).
Source: authors'own findings.

In order to identify the existence, or not, of a relationship between the dimensions surveyed, a canonical correlation analysis was performed for each dimension, considering the innovation dimensions as dependent variables and the safety culture dimensions as independent variables.

Table 10 shows the canonical correlations obtained, the canonical R^2, Wilks' Lambda, Eigenvalue and the significance test performed. It is observed that the canonical functions 1 and 2 were significant. However, even with the p-value < 0.05, due to the low explained variance (15.3%) and the high value of Wilks' Lambda (0.777), the canonical function 2 will be disregarded in this research. The other canonical functions are not statistically significant, as their p-values are greater than the significance level adopted in this work, which is 5%.

In view of this, the model manages to explain 82.6% of data variance with only one discriminant (Eigenvalue = 1,277) through the canonical function 1. The eigenvalue indicates the degree of superiority between functions (Corrar *et al.*, 2014).

The canonical correlation has the same explanatory power as the R^2 of a regression analysis, which, when the value is squared, measures the explanatory power of the referred Function (Corrar *et al.*, 2014). According to Corrar *et al.* (2014) a high result of the canonical correlation (0.749) reveals a high explanatory power of the discriminant function. The squared value corresponds to 56.1%, therefore, the degree of reliability of the function is considerable.

To test the level of significance of the discriminant function, that is, whether the model is able to separate and classify the groups well, the Wilks Lick test was performed, also shown in Table 10. With the result of 0.341 for Wilks Lambda and a p-value of < 0.000, we can say that the discriminant function is highly significant. The closer to zero the Wilks Lambda test value is, it implies that the two data sets are well correlated (Corrar *et al.*, 2014).

Table 10.
Canonical correlation analysis

Canonical Function	Canonical Correlation	R^2 Canonical	Wilks' Lambda	Eigenvalue	p-value
1	0.749	0.5610	0.341	1.277	0.000
2	0.391	0.1529	0.777	0.181	0.001
3	0.278	0.0773	0.918	0.084	0.212
4	0.073	0.0053	0.995	0.005	0.965

Source: authors'own findings.

Figure 3 shows the cross canonical loads for canonical function 1. The higher the canonical load, the more important the variable for deriving the canonical statistical variable (Hair Jr. *et al.*, 2009). It is

assumed that the first canonical function approximates the results of multiple regression, and the independent statistical variable represents the set of dimensions that best predicts the four dependent dimensions, in particular the dimension innovation and flexibility.

The canonical loading of the first independent statistical function has a similar pattern, where the loadings vary from -0.470 to -0.704. The canonical loads that correspond to canonical function 1, in the first set, show a tendency for the dimension of employee participation (-0.704) to have the greatest influence on the model association, showing that the lower the involvement of employees in the practices that they establish a favorable safety culture, such as active involvement of employees through the promotion of health and safety in the actions of the Internal Commission for the Prevention of Accidents [CIPA], joint work, audits and continuous improvement programs applied to health and safety, less will be the innovative condition of the organization. Eeckelaert *et al.* (2012) mention in their research that the strong participation of employees contributes to a favorable safety culture, where innovation and safety culture must be systematically developed over the long term (Sang. 2020).

The second-best canonical load (-0.622) observed was that of the Observation of security procedures dimension, demonstrating that organizations that do not have written health and safety procedures associated with risks, and do not carry out training and fundamental audits in these, the smaller the capacity of innovation of the organization. For Dereli (2015) innovations must be managed through appropriate strategies and properly regulated healthy and safe working environments.

Regarding the Motivation for elimination of existing risks dimension (canonical load of -0.594), it can be observed that not creating stimuli that direct people's behavior towards risk prevention can considerably reduce quick responses (flexibility) to constant market changes and, consequently, the development of new ideas. According to Korbelak and Kozioł (2021), the safety culture must also be managed from a subjective perspective, directly associated with behavior, level of motivation and the individual understanding of the work context by employees. For the authors, the effectiveness of innovation systems depends on a safety culture and vice-versa.

With regard to the education and information dimension (canonical load of -0.590), it is evident that the lower the level of information and specific training on health and safety at work, the level of flexibility to develop new instruments, techniques or methods of work may be excessively reduced. According to Antonsen (2017), it is essential to develop activities aimed at capacity building and training focused on a safety culture, as the innovation process involves the design and improvement of processes, services, products and operating methods (Forsman and Temel. 2011), the which need a healthy work environment.

In the second set, the innovation and flexibility dimension (-0.637) has the greatest influence on the model association and, in second place, the innovative behavior dimension.

Studies by Shin, Kim, and Kim (2021) demonstrate that effective strategies, policies, and practices in the areas of occupational health and safety have a significant impact on innovation. The authors also mention that the better people's awareness of health and safety regulations, the more efficient the innovation process is in organizations.

Khushrushahi (2012) and Waring (2019) present in their studies that establishing a culture of safety is one of the best long-term investments, thus resulting in a beneficial climate for innovation. For Fu *et al.* (2014) and Schultz. André and Sjøvold (2016) the development of strategies focused on safety culture can be sources of innovation.

The results presented in the research by Leisten *et al.* (2011) point out that the search for the continuous improvement of safety culture practices and the encouragement of people to expand the level of competences in occupational health and safety, provides the increase of the ability to innovation of the people and consequently of the organization.

Beyond the confirmatory associations observed, the findings suggest that safety culture may influence innovation through specific organizational mechanisms, particularly psychological safety. When employee participation and adherence to safety procedures are institutionalized, they create structured spaces for dialogue, voice, and shared problem-solving. Such environments reduce fear of negative consequences and stimulate proactive behaviors, which are central antecedents of innovative performance. Empirical evidence indicates that psychological safety fosters knowledge sharing and innovative behavior at individual and team levels (Bellibaş *et al.*, 2024; Vella *et al.*, 2024; Zhu *et al.*, 2022). Therefore, safety culture practices may operate not merely as compliance mechanisms, but as enabling conditions that support experimentation and the generation of new ideas.

A second explanatory mechanism relates to organizational learning processes. The dimensions of motivation for risk elimination and education and information suggest that safety-oriented practices institutionalize routines of reflection, feedback, and continuous improvement. These processes resemble the microfoundations of dynamic capabilities, as organizations systematically analyze failures, anticipate risks, and reconfigure processes in response to environmental demands. Recent studies emphasize that innovation capacity is closely linked to structured learning mechanisms that balance stability and adaptation (Brix, 2019; Oh and Lee, 2024). From this perspective, safety culture may strengthen innovation not despite its formalization, but because it embeds cycles of evaluation and improvement that enhance adaptive capacity.

However, the relationship between safety culture and innovation also involves inherent tensions. Safety management systems are typically associated with formalization, standardization, and risk control, whereas innovation requires flexibility, experimentation, and tolerance for ambiguity. This apparent contradiction reflects a broader organizational paradox between control and adaptability. Research on ambidexterity and paradox theory suggests that organizations capable of managing such tensions are better positioned to achieve sustained innovative outcomes (Linden *et al.*, 2025; Kornli, 2013; Zhao *et al.*, 2023). Thus, the findings should not be interpreted as indicating a purely linear relationship, but rather as highlighting the importance of balancing structured safety practices with flexibility and creative autonomy.

Finally, the results contribute to the theoretical debate by suggesting that safety culture can be interpreted as a dynamic organizational capability that supports long-term innovation. Rather than constraining innovation, well-developed safety practices may provide the stability necessary for adaptive performance and resilience. In high-reliability contexts, safety organizing has been associated with improved collective mindfulness and adaptive capacity (Abraçado *et al.*, 2025; Foster *et al.*, 2024; Garg, 2022). Accordingly, this study advances the argument that safety culture and innovation are not competing constructs, but mutually reinforcing dimensions that, when properly aligned, enhance sustainable organizational performance.

To enhance the clarity of the results, Table 11 summarizes the main safety culture dimensions and their relationships with innovation outcomes identified in the significant canonical function. The table synthesizes the central empirical associations observed in the analysis.

Table 11.
Main dimensions and their relationships identified in the canonical analysis

Main Safety Culture Dimensions	Related Innovation Outcomes	Relationship Identified
Employee participation in health and safety initiatives	Innovation and flexibility	Lower employee participation is associated with reduced adaptive and flexible innovation capacity.
Observation of security procedures	Innovative behavior	Weak formal safety procedures are associated with lower levels of proactive innovative behavior.
Motivation for elimination of existing risks	Innovation and flexibility	Limited preventive motivation reduces organizational responsiveness to change.
Education and information on safety	Innovation and flexibility	Insufficient training and safety information are associated with reduced innovation flexibility.

*Based on structural loadings of Canonical Function 1 ($r = 0.749$; $p < 0.001$)
Source: authors'own findings.

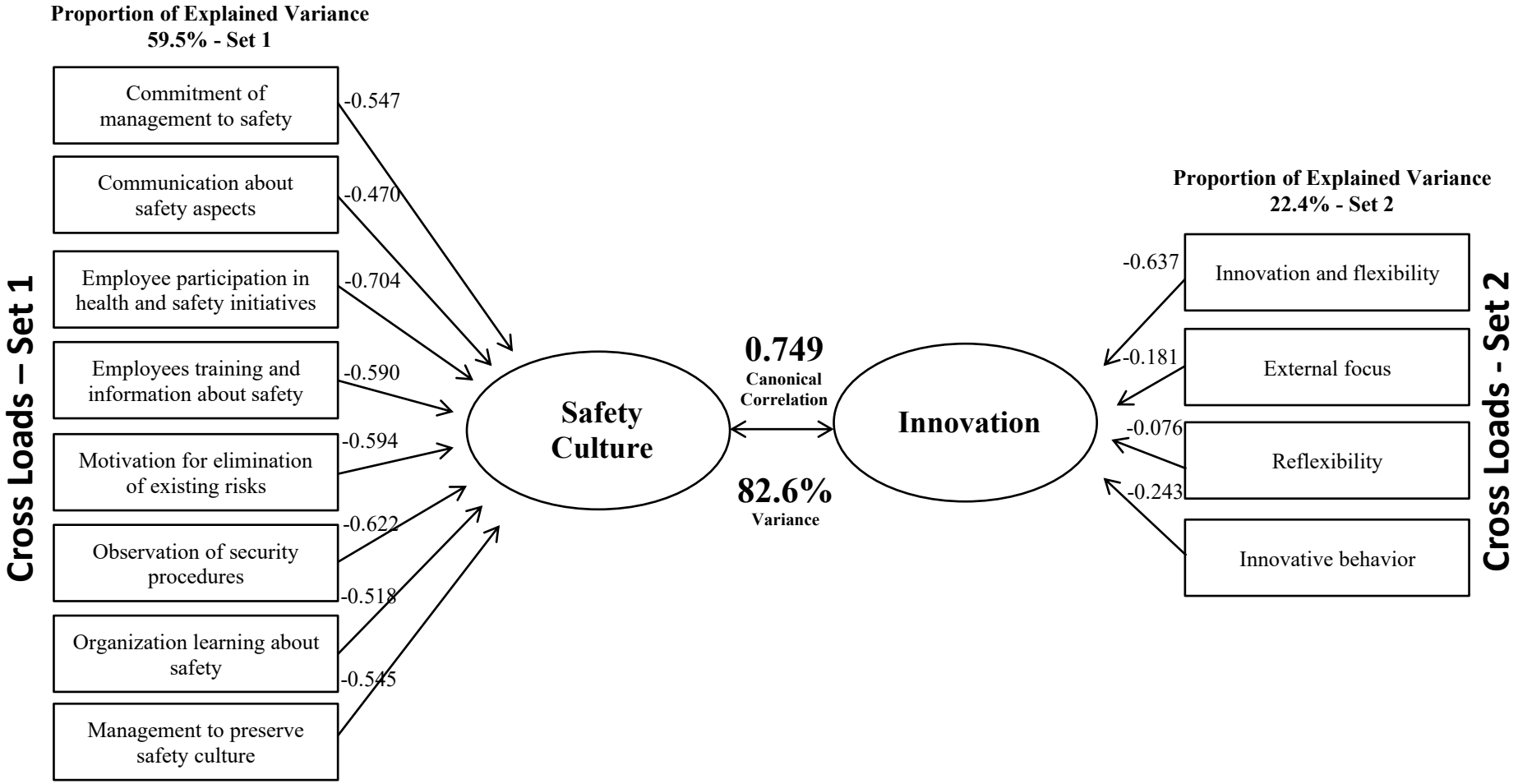

Figure 3.
The Path of Canonical Correlation Analysis
Source: authors'own findings.

This finding seems to indicate that Innovation is favorably influenced by the uninterrupted pursuit of improving safety culture practices and also by the implementation of strategies, policies and indicators that minimize or eliminate potential risks. The strength of association between the dimensions presented a variation of the coefficient between ±0.71 to ±0.90 (0.749 – p-value of 0.000) considered by Hair Jr. *et al.* (2009) as Alta. Figure 3 shows that all the values that tested the cause relationship between the dimensions are within the parameters proposed by Hair Jr. *et al.* (2009), which confirms the hypothesis proposed in this study.

FINAL CONSIDERATIONS

Safety culture practices must be considered fundamental, ensuring an environment conducive to innovation, thus allowing people to consider themselves stimulated and motivated to carry out their activities in the best possible way. This study aimed to evaluate the influence of safety culture practices on innovation.

The result of the hypothesis test showed that safety culture practices and innovation are correlated, since the strength of association between the dimensions showed a high and significant variation of the coefficient (0.749 - p-value of 0.000), a canonical R^2 of 0.5610 considerable and a Wilks' Lambda (0.341) close to zero, confirming the influence of the safety culture on innovation (Table 10).

Regarding the main safety culture practices evidenced in the results obtained among the surveyed professionals, the Organization learning about safety dimension stands out, which obtained the highest average total value among all safety culture practices, mainly because employees have access to the different areas of the industrial park, the availability of information on the organizational guidelines aimed at the areas of occupational health and safety and also autonomy to contribute with necessary changes to improve the organization's work environments, thus making the activities safer and healthier.

It was noticed in our analyses, similarity and or equality, about the perception of the respondents in relation to the practices of safety culture and innovation, thus establishing a uniformity of the concepts established in all the researched work areas.

Despite the results observed in this research, we can infer that in order to guarantee a working environment conducive to innovation, it is necessary for managers to consider the health and safety of employees as a priority; that effective communication is essential for contributing to risk prevention and establishing a long-lasting safety culture; that the participation of collaborators in all processes that involve occupational health and safety is essential; that training on health and safety must be structured and ensured for all interest groups that involve the business; that the organization has methods and instruments to

stimulate the safety culture; and, finally, that the safety culture is linked to all the organization's operational processes.

Pragmatically, this research contributes by supporting organizational managers in selecting and structuring safety culture policies and practices that create conditions for employees to release their creative potential, that is, by investing in safe and innovation-friendly work environments. From a theoretical perspective, the study contributes to the literature by empirically demonstrating, through canonical analysis, the multidimensional relationship between safety culture practices and innovation, reinforcing the understanding that these constructs are structurally interconnected rather than isolated organizational phenomena. Methodologically, the adoption of canonical correlation analysis allowed the simultaneous examination of two complex sets of variables, offering a systemic analytical approach that advances empirical investigations in this field.

As a recommendation for further work, it is suggested to replicate this study in different industrial and cultural contexts, as the results found cannot be generalized. Future research may also explore mediating and moderating mechanisms in the relationship between safety culture and innovation, such as psychological safety, organizational learning processes, and adaptive capacity. Longitudinal designs could further examine potential nonlinear dynamics between control-oriented safety systems and flexibility-driven innovation processes, contributing to ongoing contemporary debates on organizational ambidexterity and resilience.

The results of this survey make contributions to researchers, professionals, organizations, universities and research institutions. These findings reinforce the strategic role of safety culture as a foundational element for sustainable organizational performance and long-term innovative capacity.

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Appendix 1. Descriptive analysis of the sample

Dimension	Subdimension	Code	Practice / Affirmative
Safety Culture	Commitment of management to safety	SC01	Safety is seen as part of the manager's priorities.
		SC02	The manager regularly travels to the work sites.
		SC03	The manager frequently talks to teams about health and safety when he is in the workplace.
		SC04	The manager practices what he advises about health and safety.
		SC05	The manager acts quickly and effectively on health and safety issues.
		SC06	There is trust in the manager in relation to health and safety.
	Communication about safety aspects	SC07	There is effective communication about health and safety between management and teams.
		SC08	Aspects of health and safety in the organization are discussed between the direct managers and the teams.
		SC09	The Environmental Risk Prevention Program [PPRA] is well known by employees.
		SC10	Employees are advised to inform the manager about health and safety issues.
	Employee participation in health and safety initiatives	SC11	Employees (all levels) effectively participate in health and safety matters.
		SC12	Employees communicate unsafe conditions or near misses.
		SC13	There is an active involvement of the Internal Commission for the Prevention of Accidents [CIPA] in promoting health and safety.
		SC14	There is an effective continuous improvement approach to health and safety.
		SC15	The manager performs internal health and safety audits in partnership with the employees.
		SC16	The organization promotes genuine cooperation regarding health and safety – working together with everyone in the organization.
	Employees training and information about safety	SC17	When the employee performs his work activities, he feels confident for having all the training necessary to perform them.
		SC18	The perception of the risks and dangers informed by the employee are considered by the organization.
		SC19	Training needs on health and safety are identified by the organization.
		SC20	Health and safety trainings meet the needs.
		SC21	All information on health and safety is accessible to employees.
	Motivation for elimination of	SC22	Managers act effectively in the prevention of risky behavior.
		SC23	Disciplinary actions relating to health and safety are fairly enforced.
		SC24	Employees feel safe and healthy in their workplace.
		SC25	Employees are proud of their organization as it relates to health and safety policies.
	Observation of security procedures	SC26	The procedures are described according to the environment and activities performed.
		SC27	Employees find reading the procedures helpful.
		SC28	Health and safety rules at your organization are described in the procedures.
		SC29	Employees receive sufficient training on the procedures.
		SC30	Procedures are periodically audited with due effectiveness.
		SC31	The script used in the procedures is easy to understand.
		SC32	The procedures are associated with risks.
	Organization learning about safety	SC33	The organization discloses the history of accidents, reporting of incidents, etc.
		SC34	The organization implements effective actions to eliminate or reduce accidents and reported incidents.
		SC35	The organization encourages continuous improvement in the areas/processes of health and safety.
	Management to preserve safety culture	SC36	The organization maintains an analysis process that identifies and details changes/adjustments to tasks/employees that may have an impact on the prevention of serious hazards.
		SC37	The risk analysis methodology is realistically oriented and has the confidence of employees.
		SC38	There is an Emergency Action Plan [PAE] in place.
		SC39	Performance indicators (health and safety) are managed during the risk transition process.

Innovation	Innovation and flexibility	IN01	At this company, ideas are accepted immediately.
		IN02	The company responds quickly when changes are required.
		IN03	The management of this company responds quickly when changes are shown to be necessary.
		IN04	Flexibility to changes and quick implementation of new procedures.
		IN05	Speed in developing new ideas.
		IN06	The people of this organization are always looking for new ways to approach problems.
	External focus	IN07	This company is quite introspective (self-centered); not concerned with what happens in the market (*).
		IN08	This company doesn't pay much attention to ways to improve customer service (*).
		IN09	This company considers that the customers' needs do not represent a main priority (*).
		IN10	This company is slow to respond to the needs of customers (*).
		IN11	This company is always looking for new opportunities in the market.
		IN12	This company has difficulties in incorporating ideas from outside (*).
	Reflexibility	IN13	In this company, people rapidly change the way they work together to improve performance.
		IN14	The methods used to achieve goals are often discussed.
		IN15	There are frequent discussions to see if people are actually working together.
		IN16	In this company the objectives are changed due to changing circumstances.
		IN17	In this company, due time is given for organizational requirements to be reviewed.
	Innovative behavior	IN18	Pay attention to matters that are not part of your day-to-day work.
		IN19	Just imagine how many things could be improved.
		IN20	Look for new tools, techniques or work methods.
		IN21	It generates original solutions to problems.
		IN22	Finds new ways to get my tasks done.
		IN23	I find new ways to do my tasks. I interest key members of the organization in innovative ideas.
		IN24	I try to convince people to support a new idea.
		IN25	Systematically introduce innovative ideas into work practices.
		IN26	Contribute to the implementation of new ideas.
		IN27	I make an effort to develop new things.

(*) These assertions were formulated in an inverted scale.