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Structural analysis of factors that influence the perception and effectiveness of occupational health and safety policies in the university environment

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Abstract

This study examines Occupational Health and Safety (OHS) at a Peruvian public university, recognizing its importance as a key component of workplace well-being and institutional quality. The objective of this study was to analyze the factors influencing safety perceptions and the perceived effectiveness of OHS policies using a structural equation model estimated through partial least squares (PLS-SEM), complemented by an importance–performance map analysis (IPMA). The sample included 178 civil servants, 13 members of the OHS Committee, and 82 brigade members (teachers and students). The results reveal that regulatory compliance, OHS knowledge, and institutional safety culture significantly contribute to explaining safety perceptions and the effectiveness of OHS policies. Although training was highly rated, its impact on perceived safety and policy effectiveness was limited. The results underscore the need to prioritize knowledge about OHS and a culture of preventive safety as key factors for university well-being and sustainable institutional development, in line with the Sustainable Development Goals, in particular SDG 3 (Good Health and Well-being) and SDG 4 (Quality Education).

Keywords: Occupational health and safety, Preventive culture, Regulatory compliance, Safety perception, Higher education.

1. Introduction

Occupational Health and Safety (OHS) dates back to industrialization [1] when workers began recognizing occupational hazards and fought for better conditions, leading to strikes and demands for protection [2]. It was in 1919 that the World Health Organization (WHO) included OHS as a fundamental principle, with the first recommendations focused on the prevention of specific diseases and accidents [2], [3], which led to the first "occupational accident prevention report" in the 1960s [4]. Subsequently, the creation of specialized agencies and the promulgation of laws such as the Occupational Safety and Health Act of 1970 in the USA institutionalized labor protection [5], [6].

The International Labor Organization (ILO) [7] maintains that the protection of workers from illnesses, diseases, and injuries arising from employment is a fundamental element of social justice: since OHS is a basic right, ultimately, decent work is safe work [8]. Occupational health is conceived as the highest level of physical, mental, and social well-being of workers in all occupations, implying a dynamic and continuous balance between the individual and their work environment [9], [10]. Industrial development (Industries 4.0 and 5.0) has driven the adaptation of OHS to new technological risks, automation, and changes in work organization [11], [12]; OHS not only includes the prevention of accidents and illnesses, but also the promotion of mental health and job satisfaction [13], [14], integrating occupational risk management and ergonomic adaptation of jobs, as well as the implementation of preventive strategies and effective protection measures [6]; in this way, not only are physical and chemical risks addressed [15] but now also addresses organizational, psychosocial, and overall well-being factors [16].

In Peru, the Occupational Health and Safety Act, establishes a preventive approach that promotes a culture of preventing occupational risks through the active participation of employees and workers [17]. This regulation is complemented by the approved regulation through Decreto Supremo N° 005-2012-TR [18] and other provisions, such as those which detail the rights and obligations of the actors involved. Peru has also ratified relevant international conventions, such as Convention N° 155 of the International Labour Organization, which requires the State to formulate coherent OHS policies [19].

In the educational sector, such as public universities, with the support of teachers, students, and staff, they seek to promote safe learning environments that contribute to institutional sustainability [20], however, they are places where different risk profiles exist, depending on the activities they carry out, both due to their organizational structure and infrastructure [21]. Integrating OHS into education is key to preventing risks, improving well-being, and training conscious professionals [22], committed to economic and social development, to guarantee institutional sustainability and the well-being of the university community [20], [23]. OHS education promotes a preventive, not just reactive, culture aligned with the Sustainable Development Goals (SDGs), especially SDG 4 (Quality Education) [20], [22], [23]. Ongoing OHS practices protect workers and students [24] and encourage inclusion in the curricula by offering ongoing training to teachers and students, under the concept of awareness [25].

However, despite the existing legal framework, there is evidence of limited compliance and a weak institutional perception regarding OHS, especially in public sector entities [26], the implementation of OHS management systems shows in multiple institutions, the lack of active joint committees, the lack of accident records, and the scarce implementation of training [27]. Furthermore, in public university contexts, a formalist vision of OHS persists, where actions focus on meeting documentary requirements rather than generating a real preventive culture [28]. Non-compliance with OHS regulations is due to a series of interrelated causes that have a direct impact on accident rates [29]. At the organizational level, 85% of fatal fall incidents among Hispanic workers are due to the failure to use personal protective equipment (PPE) [30]. In the construction sector, non-compliance with OHS standards is due to poor supervision (56%), inadequate risk perception (55%), and lack of adaptation of PPE to the thermal environment (54%) [31]. Furthermore, in the informal sector, only 62.9% of workers use PPE, and only 54.4% maintain proper order in the workplace, reflecting low levels of training, supervision, and resources [32]. In Colombia, 90.3% stated that they comply with OHS standards, but only 9.4%

show a lack of knowledge and communication [33]. Therefore, effective safety communication plays a vital role in reducing employee incidents in the workplace [34].

According to the ILO and the WHO, approximately 2.78 million work-related deaths are recorded each year, and 374 million workers suffer non-fatal injuries [35]. The ILO in 2023 indicated that 2.6 million workers die each year due to inadequate work-related procedures, with the three leading causes of death being circulatory problems, malignant neoplasms, and respiratory problems [36], [37]. In Latin America and the Caribbean, more than 76% of countries have implemented accident registration systems, but these are still incomplete and unreliable [30]. Workplace stress affects 83% of workers in the U.S. and is associated with 120,000 deaths annually from related causes (cardiovascular, cerebrovascular, and suicide) [38]. Additionally, working more than 55 hours a week increases the risk of stroke by 35% and the probability of death from heart disease by 17% [38], [39]. A study showed that occupational injuries and illnesses covered by workers' compensation result in lost work time in Australia equivalent to more than 41,000 full-time jobs [40].

Despite growing concern about working conditions in higher education institutions, there remains a notable shortage of research that specifically analyzes OHS in public universities, particularly in Latin American contexts [41], [42]. This restriction can be attributed to the limited prioritization of the topic, budgetary restrictions for applied research, or the absence of a monitoring system that integrates occupational risk data in the academic field [43], [44]. In response to this gap, this study seeks to generate empirical evidence on the actual conditions of OHS at a public university, considering structural factors such as the perceptions of administrative staff, faculty, and students. The goal is to provide relevant information that will guide the development of more effective internal policies and promote a culture of prevention in university settings that have traditionally lagged in this area. In response to this gap, the objective was to analyze the factors that influence safety perceptions and the effectiveness of OHS policies using a structural model estimated with PLS-SEM, complemented by an importance–performance mapping analysis (IPMA).

1.1. Literature review

The WHO [8] defines OHS as the promotion and maintenance of the highest level of physical, mental, and social well-being of workers in all occupations, rather than merely the absence of disease or infirmity. OHS involves protecting the physical and mental integrity of workers from the risks arising from their work activities and ensuring a healthy and safe environment [6], [10], [45]. The ILO [7], meanwhile, points out that OHS is a fundamental right and an essential pillar for decent, safe, and healthy work. OHS encompasses occupational risks defined as any hazard experienced in the workplace and includes chemical, physical, biological, and psychosocial hazards, which constitute a major public health problem [6]. It also refers to any activity, material, process, or situation that may cause an accident or illness at work [46]. While improvements have been observed in developed countries, the same cannot be said for developing countries [47]. For example, in Peru, OHS is a growing issue, especially relevant given the economic growth and expansion in sectors such as construction, manufacturing, and the high rate of informal employment [48].

The WHO defines a healthy work environment as a complex system with four interdependent avenues of influence: the physical environment, the psychosocial environment, personal resources, and community participation [49]. The physical environment refers to the tangible conditions of the workspace, such as air quality, lighting, and machinery safety, subject to proper management essential to minimize toxic, ergonomic, and accident risks [50]. The psychosocial environment encompasses organizational culture, work structures, interpersonal relationships, and factors such as workload, control, and support, which directly influence the development of stress, burnout, and mental disorders [51]. Additionally, personal resources refer to access to health services, training programs, and promotional activities, strengthening the worker's self-management capacity in caring for their well-being [52]. Finally, community engagement refers to effective collaboration among employers, workers, their families, and the broader community, thereby expanding the positive impact of OHS actions. This systemic approach is also based on a continuous improvement process (CIRP) that drives the effectiveness and sustainability of preventive and promotional initiatives [53].

OHS is widely addressed in industrial and business sectors; however, in the context of public universities, studies remain scarce and fragmented [41], [42]. Authors such as Vitrano & Micheli [54] conducted an integrative review of the literature on OHS and found limited empirical evaluation of its effectiveness, especially in complex institutional environments such as higher education. Similarly, [55] in their study on regulatory compliance in the South African mining sector, they warn that a lack of training, resources, and a culture of prevention are the main limitations. Magalhães et al. [55] noted that the success of OHS interventions depends largely on the organizational context and the active participation of all stakeholders. However, Kim et al. [56] proposed a model for evaluating organizational interventions in health based on three components: context, process, and outcome, while Bollans & Preece [57] emphasized the need to consider the institutional environment as an active element in the effectiveness of preventive actions.

In the academic field, where hours in front of a screen and intellectual pressure coexist daily, subtle but constant ergonomic threats emerge [58]. Recent research, such as the study of Avila et al. [59] shows how prolonged sitting in static positions in front of computers significantly increases musculoskeletal disorders of the neck, shoulders, and back. According to Escribano [60] these discomforts, although not always visible, gradually erode physical well-being and teaching performance. In addition, inquiries into Horowitz et al. [61] and Liu et al. [62] reveal that more than 60% of staff who use computers show symptoms compatible with repetitive stress injuries, directly linked to inadequate furniture and prolonged sessions without breaks. This scenario for Liu et al. [62] underlines the urgency of incorporating proactive ergonomic measures, from adjustable furniture and active breaks to training in healthy postures. At universities in Gelisim and Gaziantep, Türkiye, the existence of a laboratory for conducting practical courses at the university, where students are trained in OHS, and the fact that their parents are employers, positively suggests an understanding of OHS. This analysis is crucial for assessing students' views of occupational safety culture regarding legal regulations on occupational health and safety under ILO guidelines, and for expressing their views on the effectiveness of occupational health and safety education [63].

The institutional perception of OHS in Peruvian universities, such as San Marcos National University of (UNMSM), is based on organizational culture and shared values regarding workplace well-being [64]. In response to the growing need to promote comprehensive well-being, UNMSM and the Universidad Peruana Cayetano Heredia (UPCH) are promoting specialized OHS programs with a proactive approach [65]. This TWH approach promotes protection against occupational hazards, along with active health promotion [19], [66]; it also promotes intersectoral collaboration networks that strengthen participation in OHS, intending to transform university spaces into safe, healthy, and sustainable environments that protect the physical and mental health of their community [51], [67].

Classic occupational health models such as Demand Control Support (DCS) and Effort Reward Imbalance (ERI) offer a theoretical framework to understand how the combination of high demand, low control, and poor recognition generates burnout syndrome, anxiety, and depression [68], [69]. Studies in Europe and the United Kingdom confirm that an imbalance between effort and reward is associated with chronic diseases and lower well-being [70]; likewise, the lack of autonomy and limited support increase job stress, which in the long-term damages both mental health and institutional commitment [51].

Job Demands and Resources (JD-R) theory offers a robust framework for understanding well-being and motivation in academic settings [71], [72]. For Juarez [73], high work demands, such as overload, pressure from publications, and intense administrative tasks, overload workers' energy and can trigger burnout processes accompanied by absenteeism and low institutional commitment. According to Dirik & Özdoğan [74], job resources such as social support, autonomy, and continuous feedback act as buffers and sources of motivation that promote engagement and superior performance.

OHS management models such as ISO 45001:2018 and the ILO guide-OHS 2001 promote a structured approach based on the PDCA cycle (Plan, Do, Check, Act) [75]. The ISO 45001 [76] provides an international regulatory framework that enables organizations to systematically identify risks, implement controls, and evaluate

performance with a view to continuous improvement; in addition, ILO [66] it highlights the need to involve senior management, define clear roles and responsibilities, and establish effective inspection, measurement, and feedback systems. The increasing use of predictive models based on data mining and machine learning methods to predict occupational accidents and illnesses in university and public settings [77], [78]. These predictive models have proven their worth in predicting occupational risk trends, enabling universities to implement prevention-focused strategies and maximize available resources.

The Total Worker Health (TWH) approach seeks to integrate workplace protection policies, promotion of healthy habits, and behavioral well-being, thereby reducing absenteeism and improving employee engagement [79]. Likewise, the University of Massachusetts Lowell implemented the Healthy Workplace Participatory Program, based on TWH, which encouraged the creation of joint OHS committees and the co-creation of worker-centered solutions, generating effective and sustainable interventions over time [79], [80]. This type of model is considered highly viable in organizations because it combines risk prevention and the active promotion of personal and collective well-being [81], [82]. Deeper integration of artificial intelligence, the Internet of Things (IoT), and augmented reality for real-time surveillance is anticipated [83], [84], detection of dangerous situations, and customization of OHS training in public and private higher education universities.

2. Research method

2.1. Place of study and Methodology

The research was conducted at the headquarters of the National University Toribio Rodriguez of Mendoza of Amazonas (UNTRM), located in the city of Chachapoyas, Amazonas region, Peru.

A quantitative, non-experimental, cross-sectional design was used. Data were collected during May and June, subsequently analyzed using descriptive statistics and the structural equation model, to measure the influence of variables. Figure 1 describes the methodological design using the structural equation technique. The proposed model represents causal relationships between latent variables: knowledge about OHS, university safety culture, OHS training, compliance with regulations, effectiveness of OHS policies, and perceived safety. Each construct is composed of its respective observable indicators (P1–P24). The one-way arrows reflect the hypotheses of influence between constructs, and the model structure allows for the evaluation of the direct and indirect effects of each variable on perceived safety, which acts as the main dependent variable of the study.

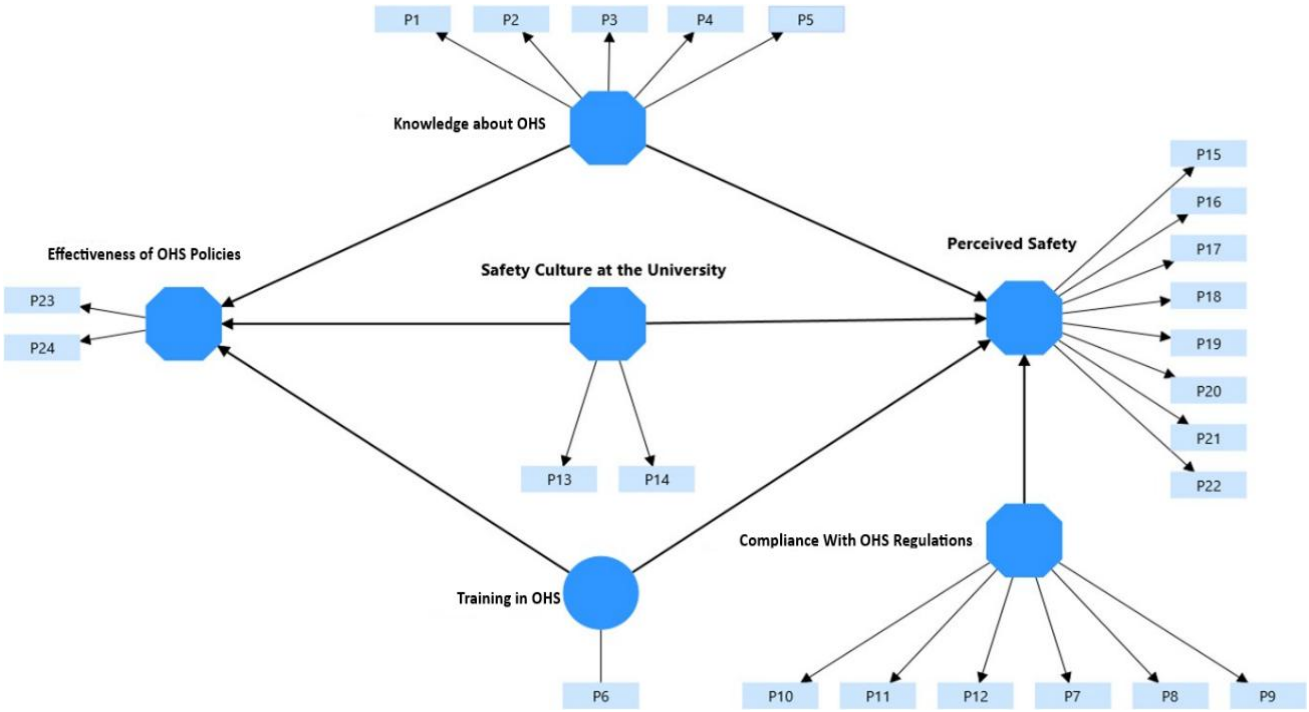

Figure 1. Research design

Based on this, the following hypotheses were put forward:
H1: Compliance with OHS regulations positively influences perceived safety.
H2: Knowledge about OHS positively influences the perceived effectiveness of OHS policies.
H3: Knowledge about OHS positively influences perceived safety.
H4: The safety culture at the university positively influences the effectiveness of OHS policies.
H5: The safety culture at the university positively influences perceived safety.
H6: OHS training positively influences the effectiveness of OHS policies.
H7: OHS training positively influences perceived safety.

2.2. Study population

Data were collected using a structured questionnaire administered to a sample selected through non-probability convenience sampling, choosing respondents based on their accessibility and availability during the study period. This approach was considered appropriate as it allowed the inclusion of key actors directly involved in occupational safety and health at the university, ensuring the relevance and pertinence of the information gathered.

In this regard, the population consisted of civil servants from the UNTRM, members of the OHS Committee, and professors and student OHS brigade members. The sample comprised 178 civil servants (teachers and administrators), 13 members of the OHS Committee, and 82 brigade members (teachers and students).

Inclusion criteria: Civil servants and students of both sexes who agreed to participate voluntarily through informed consent.

Exclusion criteria: Civil servants and brigade members who belonged to the decentralized headquarters of the UNTRM.

2.3. Data collection

The survey was administered virtually via Google Forms and distributed through institutional email. The data collection instrument consisted of a Likert-scale questionnaire structured around six key variables related to OHS in the university context. These variables include: OHS knowledge, which assesses the degree of familiarity with current policies and regulations; OHS training, which measures the training received by participants; compliance with OHS regulations, which reflects institutional adherence to legal provisions; the university's safety culture, understood as participation, awareness, and proactive attitude toward risk prevention; perceived safety, which captures the general perception of the environment as safe or unsafe; and the effectiveness of OHS policies, which expresses the level of compliance with institutional procedures in this area. The first four were defined as independent variables, while the last two were established as dependent variables, all measured on an ordinal scale. This approach enabled analysis of the influence of institutional and cognitive factors on safety perceptions and the effectiveness of preventive policies implemented at the university.

The questionnaire was validated by three experts in OHS, who assessed the relevance and clarity of each item. To ensure internal consistency, Cronbach's alpha test was applied, yielding a coefficient of 0.900, indicating an excellent level of reliability and supporting the psychometric soundness of the questionnaire used in the study. The questionnaire was administered virtually using the Google Forms platform. The link was distributed via institutional emails; this method facilitated the participation of the various groups involved, ensuring secure access, data protection, and compliance with the ethical standards established for the research.

All participants provided their written informed consent prior to the administration of the instrument. They were clearly and comprehensively informed about the objectives of the study, the voluntary nature of their participation, and the confidentiality of the information collected. They were also assured that their responses would be used exclusively for academic and research purposes and that their identity would remain completely

anonymous at all times. Furthermore, the research has the favorable opinion of the Institutional Research Ethics Committee (CIEI), in accordance with Evaluation Certificate CIEI N° 00173.

2.4. Data processing

The analysis was developed using SmartPLS version 4 software, which allows estimations using partial least squares structural equation modeling (PLS-SEM), recommended for exploratory and predictive models with moderate sample sizes, complex relationships among latent variables, and without strict distributional assumptions [85]. The model is based on theoretical frameworks related to organizational safety culture [86] and regulatory compliance in work environments [87], which highlight the importance of knowledge, training, and institutional policies as key factors in the perception of security and preventive behavior.

For the descriptive analysis of the general survey data, R-Studio software was used to generate frequency tables that allowed for the examination of variables such as age, sex, faculty, educational level, and prior experience in OHS. This initial analysis characterized the sample and provided a contextual framework for the subsequent interpretation of the structural model. Table 1 presents a detailed overview of the sociodemographic profile of the respondents who participated in the study. This characterization is essential for understanding the perceptions and level of knowledge about OHS within the university environment. It also constitutes a key input for the validation of the PLS-SEM model used to analyze the relationships between the latent variables.

Table 1. Sociodemographic, occupational, and training profile of the participants in OHS

Variables		Frequency	Percentage
Gender			
	Female	160	58.6
	Male	113	41.4
Age			
	18 to 25	71	26.0
	26 to 35	75	27.5
	36 to 45	64	23.4
	46 to 55	43	15.8
	56 to 65	16	5.8
	66 and over	4	1.5
Role in the university			
	Teaching brigade member	10	3.7
	Student brigade member	72	26.3
	Teaching	53	19.4
	Member of the COHS	13	4.8
	Administrative worker	125	45.8
Time of connection with the university			
	1 to 3 years	91	33.3
	3 to 5 years	48	17.6
	More than 5 years	102	37.4
	Less than 1 year	32	11.7
Knowledge of the OHS Law (Law N° 29783)			
	Quite	50	18.3
	A lot	11	4.0
	Nothing	21	7.7
	Bit	191	70.0
OHS Training			
	No	129	47.3
	Yes	144	52.7

Note. OHS = Occupational Safety and Health

The population is predominantly young adults, with more than half of the respondents between 18 and 35 years old (53.5%), which is significant because this age group typically requires greater awareness of occupational hazards. Regarding the institutional role, administrative workers (45.8%) stand out, followed by teachers (19.4%) and brigade members (26.4%, including students and teachers), representing a diverse functional distribution with operational knowledge of the regulations. Institutional seniority is significant, with 37.4% having more than five years of experience, providing an experienced perspective on the evolution of OHS at the university. However, there is a significant gap in regulatory knowledge: 70.0% reported having "little" knowledge of Law N° 29783, and only 4.0% reported having "a great deal" of knowledge of it. Although 52.7% received training, this percentage shows that training efforts have not yet reached full coverage, which limits the institutional impact of preventive policies.

2.5. SEM model evaluation

This study employs a complex research model that includes observable variables and latent constructs related to knowledge, regulatory compliance, safety perception, and the effectiveness of Occupational Safety and Health (OHS) policies. For its analysis, Partial Least Squares Structural Equation Modeling (PLS-SEM) was used, an approach well-suited for exploratory studies with predictive models and multidimensional structures [88]. The software tool applied was SmartPLS 4, recognized for its intuitive interface and advanced functionalities such as the combined importance–performance map analysis (IPMA), which helps prioritize key managerial actions [88], [89].

The model evaluation followed the two classic stages of PLS-SEM. The first stage corresponds to the measurement model, whose purpose is to validate the reliability and validity of the indicators representing each construct. At this stage, basic psychometric properties are reviewed to ensure that each latent variable is properly operationalized. The second stage corresponds to the structural model, which analyzes the hypothetical relationships among latent variables, contrasting the network of links proposed in the theoretical framework to test the robustness of the study's hypotheses [90].

Within the measurement model, three main aspects are assessed: internal consistency reliability, convergent validity, and discriminant validity. Internal consistency reliability is determined using Cronbach's alpha, composite reliability (CR), and the rho A coefficient, all of which are recommended to exceed 0.70 [91], [92]. Convergent validity is verified through the Average Variance Extracted (AVE), with a minimum acceptable value of 0.50, indicating that the construct explains more than half of the variance of its indicators [92]. Discriminant validity is tested using the Fornell–Larcker criterion and, preferably, the Heterotrait–Monotrait (HTMT) ratio, which should be below 0.85, or under 0.90 in cases of high communality, to avoid conceptual overlap among constructs [91].

Once the quality of the measurement model has been confirmed, the analysis proceeds to the structural model, which examines the significance and strength of the relationships between the latent constructs. Before testing the hypotheses, an indicator refinement is carried out: items with outer loadings below 0.40 are removed, and those with loadings between 0.40 and 0.70 are reviewed for potential exclusion based on their impact on convergent validity and composite reliability. This procedure follows recent guidelines to ensure the quality and robustness of the model [92].

Table 2. Factor loadings of the final model

	Compliance With OHS Regulations	Effectiveness of OHS Policies	Knowledge about OHS	Perceived Safety	Safety Culture at the University	Training in OHS
P11	0.717					
P13					0.906	
P14					0.705	
P15				0.805		
P16				0.785		

	Compliance With OHS Regulations	Effectiveness of OHS Policies	Knowledge about OHS	Perceived Safety	Safety Culture at the University	Training in OHS
P17				0.853		
P20				0.743		
P21				0.782		
P22				0.701		
P23		0.915				
P24		0.899				
P3			0.760			
P4			0.916			
P6						1.000
P7	0.811					
P8	0.803					
P9	0.744					

In the context of this research, the initial analysis revealed that several items had outer loadings below the desired threshold (see Table 2). Following theoretical criteria, these indicators were removed to improve the psychometric quality of the model. As a result, the final model retained only indicators with loadings above 0.70, ensuring a more precise and reliable measurement of the latent variables and establishing a solid foundation for the analysis of the structural model and the testing of the proposed hypotheses.

3. Results

The results obtained through partial least squares structural equation analysis (PLS-SEM) allow us to evaluate both the validity of the measurement model and the structural relationships between the constructs that comprise the university's OHS system. The reliability and validity of the constructs, standardized path coefficients, R^2 values, model fit indices, and complementary analyses such as confidence intervals, predictive power, and multicollinearity assessment are detailed. In addition, a graphical importance-performance analysis (IPMA) is incorporated, which facilitates the practical interpretation of the results, identifying those variables that have the greatest impact on the model's results and those that require prioritization for improvement.

The results in Table 3 show that all constructs in the model meet the minimum criteria established for a valid and reliable measurement. Regarding internal reliability, all Cronbach's alpha values exceed the recommended minimum threshold of 0.70 [85], [92], indicating adequate internal consistency. Likewise, the composite reliability (rho_c) ranged between 0.792 and 0.903, indicating adequate homogeneity between the items of each construct. Regarding convergent validity, the AVE of all constructs is greater than 0.50, meeting the criteria for Fornell & Larcker [93], confirming that each construct explains more than 50% of the variance in its indicators. These findings validate the robustness of the measurement model and that the instruments used adequately assess levels of knowledge, compliance, perception, and effectiveness in OHS.

Table 3. Composite reliability, Cronbach's alpha, and convergent validity (AVE)

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Compliance with OHS Regulations	0.771	0.776	0.853	0.593
Effectiveness of OHS Policies	0.785	0.788	0.903	0.822
Knowledge about OHS	0.706	0.799	0.828	0.708
Perceived Safety	0.870	0.873	0.903	0.608
Safety Culture at the University	0.716	0.793	0.792	0.659

Table 4 presents the HTMT values, a modern and robust criterion for assessing discriminant validity in PLS-SEM models. This indicator estimates the ratio between heterotrait-heteromethod and monotrait-heteromethod correlations, with acceptable values below 0.85 [93], [94]. In this study, values ranging from 0.22 to 0.888 were observed. The highest relationships were found between "Compliance with OHS Regulations" and "Perceived Safety" (0.888), and between "Effectiveness of OHS Policies" and "Perceived Safety" (0.858), without exceeding the critical threshold, indicating adequate discrimination between the constructs. These results indicate that, despite the conceptual relationship between perceived safety and regulatory compliance or perceived effectiveness, the variables represent empirically distinct constructs. Thus, it can be stated that the model presents solid discriminant validity, which is key to ensuring that structural inferences are not distorted by conceptual overlap between the measured factors [95].

Table 4. Matrix Heterotrait-monotrait ratio (HTMT) for discriminant validity

	Compliance with OHS Regulations	Effectiveness of OHS Policies	Knowledge about OHS	Perceived Safety	Safety Culture at the University	Training in OHS
Compliance with OHS Regulations						
Effectiveness of OHS Policies	0.831					
Knowledge about OHS	0.775	0.622				
Perceived Safety	0.888	0.858	0.68			
Safety Culture at the University	0.793	0.798	0.713	0.799		
Training in OHS	0.246	0.371	0.275	0.352	0.672	

Table 5 presents the matrix of the Fornell-Larcker criterion, which assesses discriminant validity by comparing the square root of the AVE of each construct (diagonal values) with the correlations between the constructs (off-diagonal values). According to Fornell & Larcker [93], the square root of the AVE must be greater than the correlations with the other constructs. In this study, all constructs meet this criterion. For example, “Effectiveness of OHS Policies” has a square root of AVE of 0.907, which is greater than its correlation with “Compliance with OHS Regulations” (0.648) or with “Knowledge about OHS” (0.455). These results reinforce the discriminant validity of the model and complement the HTMT analysis, confirming that the constructs are empirically distinguishable [96].

Table 5. Discriminant validity according to the Fornell-Larcker criterion

	Compliance with OHS Regulations	Effectiveness of OHS Policies	Knowledge about OHS	Perceived Safety	Safety Culture at the University	Training in OHS
Compliance with OHS Regulations	0.77					
Effectiveness of OHS Policies	0.648	0.907				
Knowledge about OHS	0.543	0.455	0.841			
Perceived Safety	0.739	0.717	0.516	0.779		
Safety Culture at the University	0.537	0.519	0.416	0.565	0.812	
Training in OHS	0.221	0.33	0.22	0.325	0.424	1

In Table 6, the R^2 values show the proportion of variance explained by the independent constructs relative to the dependent variables in the model. The adjusted R^2 for "Perceived Safety" was 0.60, indicating that the model explains 60% of its variability, a value considered high in social research [97]. For its part, "Effectiveness of OHS Policies" presented an adjusted R^2 of 0.342, which is acceptable and suggests that a significant portion of the perception of effectiveness is explained by exogenous variables. These results support the predictive utility of the model and show that knowledge, safety culture, and training contributed significantly to safety perception and the perceived effectiveness of OHS policies.

Table 6. Coefficient of determination R^2 of the dependent constructs

Variable	R-square	R-square adjusted
Effectiveness of OHS Policies	0.350	0.342
Perceived Safety	0.606	0.600

Figure 2 shows the structural diagram of the final PLS-SEM model, which visualizes the latent constructs, validated indicators (items), and standardized path coefficients between variables. This model integrates both direct relationships and the direction of influence between constructs, allowing the most significant paths to be observed within the system of variables studied. It is notable, for example, that the highest path coefficient is found between "Compliance with OHS Regulations" and "Perceived Safety" (β = 0.561), which supports the centrality of the normative dimension in shaping perceived safe environments. Likewise, the paths from "Safety Culture" to "Effectiveness" (β = 0.350) and to "Perceived Safety" (β = 0.172) reflect the weight of organizational cultural aspects in perceived effectiveness.

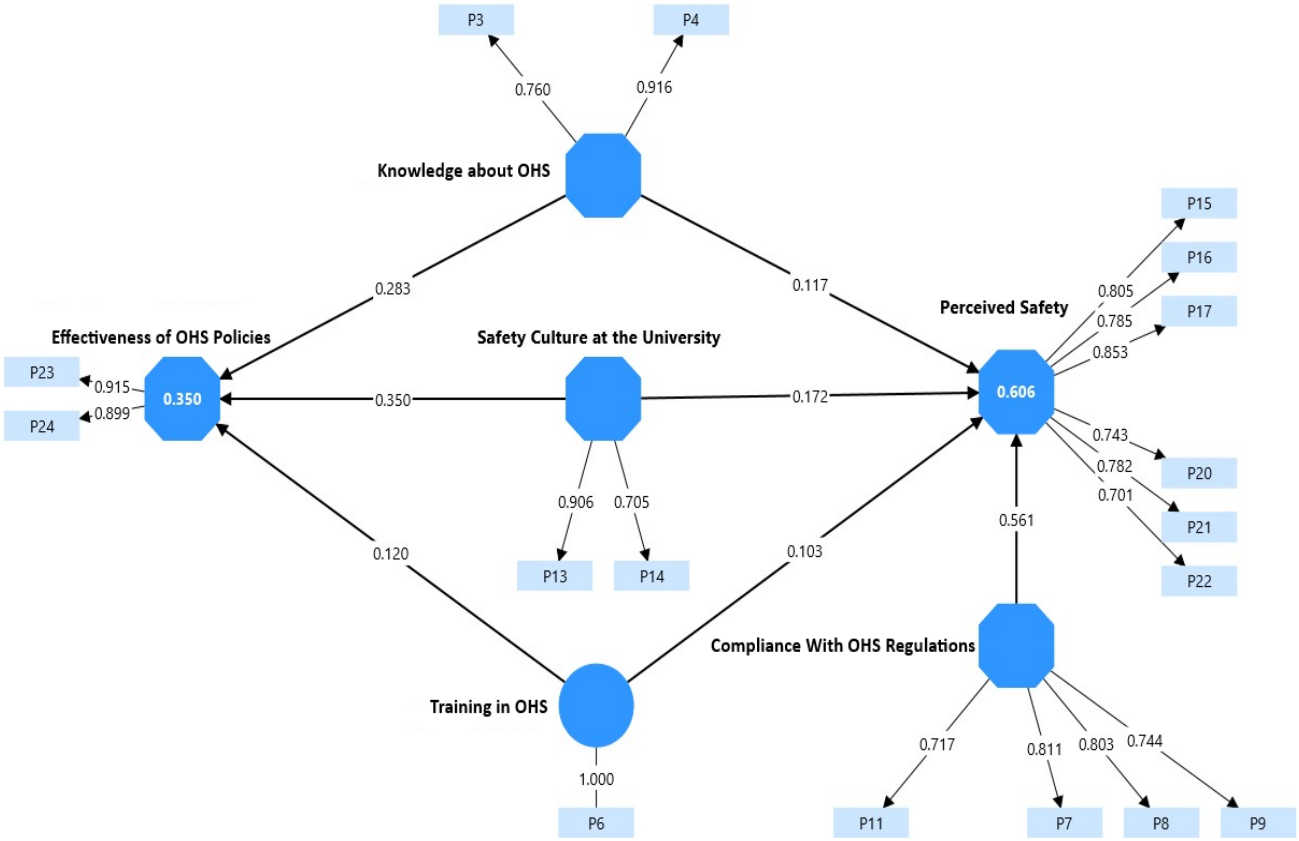

Figure 2. Structural model estimated using PLS-SEM with standardized path coefficients.

Table 7 presents the standardized path coefficients (β), effect sizes (f^2), standard errors, p-values, and significance levels for the hypothesized relationships posed in the structural model. Of the seven hypotheses evaluated, six show statistically significant relationships ($p < 0.05$), allowing for their acceptance, while one was rejected for not reaching statistical significance.

Table 7. Testing structural hypotheses

Hypothesis	Original sample (O)	f-square	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P-values
Compliance with OHS Regulations -> Perceived Safety	0.561	0.468	0.560	0.060	9.275	0.000
Knowledge about OHS -> Effectiveness of OHS Policies	0.283	0.101	0.288	0.059	4.779	0.000
Knowledge about OHS -> Perceived Safety	0.117	0.024	0.117	0.053	2.209	0.027
Safety Culture at the University -> Effectiveness of OHS Policies	0.350	0.134	0.350	0.072	4.879	0.000
Safety Culture at the University -> Perceived Safety	0.172	0.045	0.175	0.058	2.943	0.003
Training in OHS -> Effectiveness of OHS Policies	0.120	0.018	0.120	0.068	1.754	0.080
Training in OHS -> Perceived Safety	0.103	0.022	0.101	0.044	2.314	0.021

H1 (Compliance with OHS Regulations → Perceived safety): Accepted, with a coefficient $\beta = 0.561$ ($p < 0.001$), indicating a strong and significant positive effect of regulatory compliance on perceived safety. The effect size $f^2 = 0.468$ suggests a substantial impact.

H2 (Knowledge about OHS → Effectiveness of OHS policies): is accepted ($\beta = 0.283$; $p < 0.001$), with a moderate magnitude effect ($f^2 = 0.101$), showing that greater knowledge is associated with greater perceived effectiveness in policy implementation.

H3 (Knowledge about OHS → Perceived safety): Accepted, with a positive, albeit weak, effect ($\beta = 0.117$; $p = 0.027$), indicating that knowledge contributes to perceived safety, although to a lesser extent ($f^2 = 0.024$).

H4 (Safety culture → Effectiveness of OHS policies): Accepted, with a significant effect ($\beta = 0.350$; $p < 0.001$) with a moderate effect size ($f^2 = 0.134$), reflecting that a strong organizational culture drives the perception of effectiveness in OHS.

H5 (Safety culture → Perceived safety): It is accepted with a positive effect ($\beta = 0.172$; $p = 0.003$), although of lesser magnitude ($f^2 = 0.045$), demonstrating the relevance of the cultural environment in the perception of the safe environment.

H6 (OHS training → OHS policy effectiveness): Rejected because it does not reach statistical significance ($\beta = 0.120$; $p = 0.080$), and its confidence interval includes zero. This suggests that, in this study, training did not have a significant impact on perceived effectiveness.

H7 (OHS training → Perceived safety): It is confirmed, although with a weak effect ($\beta = 0.103$; $p = 0.021$; $f^2 = 0.022$), which suggests that the training received contributes, although modestly, to a greater perception of safety in the university environment.

The predictive Q^2 values (Table 8) for the dependent variables show a medium to high predictive power ($Q^2 = 0.320$ for Effectiveness and 0.589 for Perceived Safety), which indicates that the model has a good ability to predict new observed values [98]. This reinforces the practical utility of the model in real-life institutional contexts, such as improving OHS programs at public universities.

Table 8. Predictive power of the model

Variable	Q^2 predict	RMSE	MAE
Effectiveness of OHS Policies	0.320	0.833	0.646
Perceived Safety	0.589	0.648	0.503

Figure 3 shows the final structural model estimated using PLS-SEM, complemented by the importance-performance map analysis (IPMA), in which each construct is represented by a hexagon containing its mean performance value on a scale of 0 to 100. These values allow for identifying priorities for improvement in OHS within the university. The compliance with OHS regulations construct shows moderate performance (55.384) and a substantial impact on safety perception (β = 0.561), which positions it as a strategic component that should be maintained and strengthened. For its part, knowledge about OHS presents a lower performance (48.615), consistent with the descriptive data indicating that 70% of participants declared having "little" knowledge of Law N° 29783. Despite this, this construct significantly influences policy effectiveness (β = 0.283) and perceived safety (β = 0.117), justifying its prioritization as a critical area of institutional intervention. In contrast, training in OHS obtained the highest level of performance (79.670), although its effect on the dependent variables was smaller (β = 0.103 and β = 0.120), with only marginal significance. This finding does not imply that training is irrelevant, but rather that its current impact on the perception of effectiveness or safety is still limited, possibly due to methodological or coverage aspects.

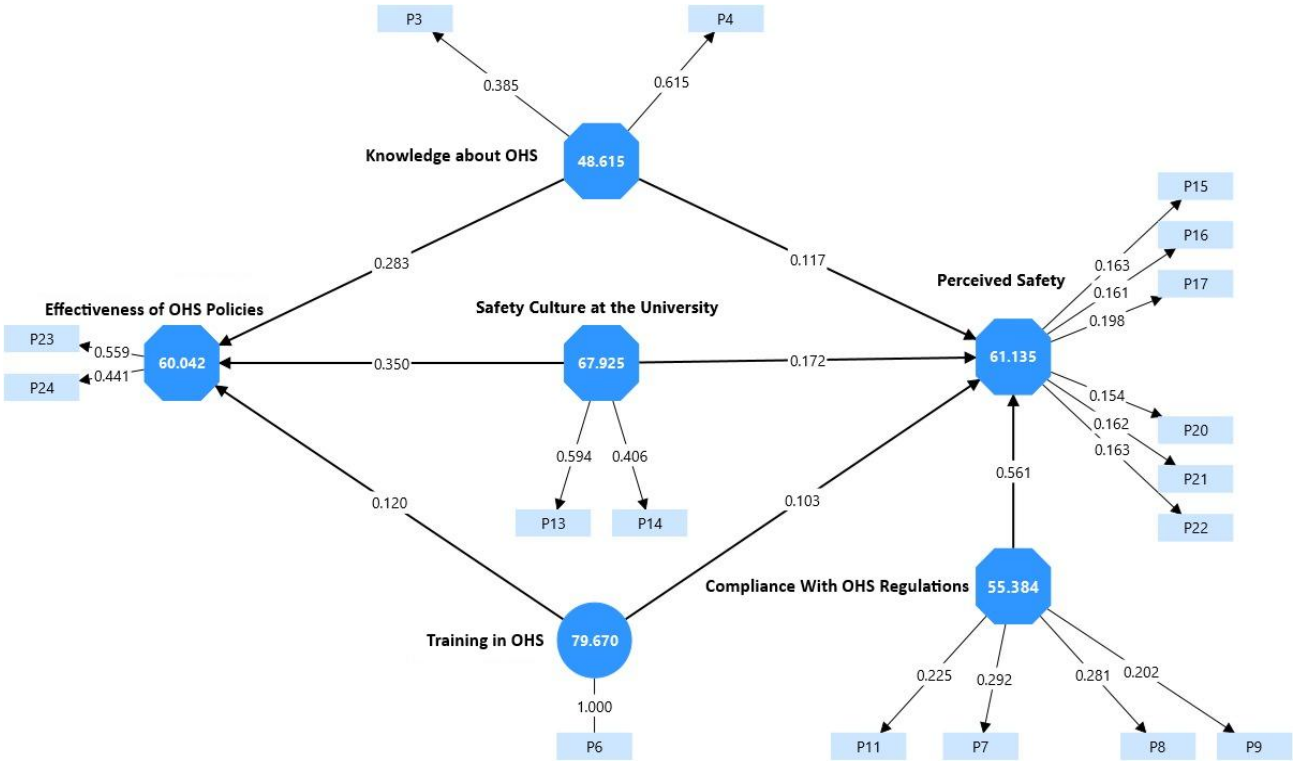

Figure 3. Latent construct in the IPMA (Importance-Performance Map Analysis) technique

4. Discussion

The study's findings reveal significant relationships between knowledge, compliance, organizational culture, and the perception of safety and effectiveness of OHS policies within the university environment, which is consistent with previous literature and reinforces the need to strengthen these components in public institutions. The positive effect was observed in the relationship between regulatory compliance and perceived safety, indicating that the effective presence of regulations and their enforcement promotes environments perceived as safe. This finding supports the ILO [7], [30] assertion that compliance with regulatory frameworks is

fundamental to decent work. Likewise, authors such as Sorensen et al. [6] and Duenas et al. [26] have noted that the effectiveness of OHS is closely linked to the institutional capacity to implement and enforce standards, which is also observed in this study.

In addition, knowledge about OHS was significantly related to both the perceived effectiveness of policies and perceived safety, although the effect was weaker in the latter case. This result is consistent with the approaches of Pllana [10] and Kamichi [48], who argue that ignorance of legal and preventive obligations creates implementation gaps. Furthermore, it aligns with studies such as those of Muthelo et al. [33] and Aurice et al. [32], which documents how low levels of training and knowledge negatively affect preventive culture and regulatory compliance.

Another notable finding was the impact of institutional security culture, which showed positive effects on both policy effectiveness and perceived security. This validates the approach proposed by Cooper [86] and Bollans & Preece [57] where the organizational environment, shared values, and active staff participation provide a solid foundation for the development of effective preventive systems. In the university context, actions can be perceived as merely formal [28].

From a Latin American perspective, these findings are consistent with previous evidence indicating that OHS systems in public institutions often exhibit structural weaknesses related to limited regulatory dissemination, fragmented implementation, and a predominance of formal compliance over the consolidation of a preventive culture. Empirical studies conducted in public organizations and higher education institutions across the region have reported similar patterns, particularly low levels of normative knowledge, uneven development of safety culture, and the limited effectiveness of training programs when these are not fully integrated into organizational practices or supported by institutional leadership [26], [32], [55], [99].

In this context, the Peru case analyzed in this study reflects shared regional challenges, but also contributes novel empirical evidence by structurally demonstrating how regulatory compliance, institutional safety culture, and OHS knowledge exert differentiated effects on perceived safety and policy effectiveness. The strong influence of regulatory compliance on perceived safety aligns with regional findings that emphasize the central role of enforceable norms in public sector environments [7], [30], while the modest impact of training highlights a persistent gap between training coverage and its practical translation into preventive behaviors, a recurring issue documented in Latin American public institutions where training frequently fulfills formal requirements without generating substantive behavioral change [25], [54].

The results obtained from the structural model and IPMA provide a more comprehensive understanding of the factors that influence safety perceptions and the effectiveness of OHS policies within the university. The cross-evaluation of impact (β) and performance (scale 0 to 100) offers a strategic approach for prioritizing evidence-based institutional interventions.

In contrast, OHS training, while highly effective (IPMA = 79.67), showed a significant but modest effect on perceived safety and no significant effect on policy effectiveness. This finding calls into question the depth or relevance of the training offered and is consistent with what was observed by Babalola et al. [25], who argue that the effectiveness of training programs depends on their methodological quality, frequency, and ability to adapt to the real needs of the environment. It could also reflect a disconnect between the training received and its practical application, as has been suggested by Vitrano & Micheli [54] in complex institutional contexts.

The compliance with OHS regulations construct showed a medium level of performance (55.384) and the greatest impact on perceived safety, constituting a central factor in the model. This relationship confirms that effective compliance with OHS regulations not only fulfills a regulatory function but also directly translates into the perception of protection by workers and students. In line with Politakis [3], Rosner & Markowitz [2], ILO [7], [30], legal compliance is considered a fundamental human right and a cornerstone of decent work. Previous studies, such as those of Mahfoudh et al. [27], Dabbagh & Yousefi [43], and Johnson [44] They warn that documentary compliance without real operationalization limits the transformative effect of OHS policies.

Thus, this finding reaffirms the approach of Sorensen et al. [6], which highlights the normative function as a guarantor of institutional well-being, especially in public environments where a formalist culture usually prevails [28].

Although the knowledge about the OHS construct obtained the lowest performance value (48.615), its significant influence on both policy effectiveness and perceived safety suggests that it constitutes a critical area for institutional intervention. This result is consistent with the descriptive data, where 70% of participants reported having "little" knowledge of Law N° 29783. According to Paprotny [47] and Kamichi [48], in developing countries like Peru, the lack of knowledge of legal frameworks is one of the structural barriers that prevent the consolidation of effective OHS systems. Similarly, Aurice et al. [32] show that a lack of training leads to low levels of practical compliance, especially in informal sectors. For their part, Vitrano & Micheli [54] point out that universities face challenges in institutionalizing normative knowledge as part of their academic practice. Consequently, improving knowledge would not only increase adherence to standards but also enhance the operational effectiveness of existing policies.

The safety culture at the University, with an intermediate performance (67.925), had a significant impact on both dependent variables, policy effectiveness and perceived safety. This result reinforces the approach of Cooper [86] and Bollans & Preece [57], who argue that organizational culture acts as a structural determinant in risk prevention. Furthermore, it aligns with the principles of the Total Worker Health (TWH) approach, which promotes collaborative and participatory environments as key to the sustainability of preventive strategies. Leso et al. [79] and Calsina [64] emphasize that building a preventive culture in the education sector requires the active commitment of authorities, teachers, and students, which appears to be incipient in this study. Institutional culture, therefore, must not only encompass shared values and norms but also translate into concrete practices of awareness, participation, and co-responsibility.

The training in OHS construct achieved the highest level of performance (79.670), but showed weak effects on perceived safety and non-significant effects on policy effectiveness. This paradox between high performance and low impact could be explained by methodological limitations in the training offer, such as poor customization, low frequency, or lack of learning assessment, as noted by Babalola et al. [25] and Martínez & Balaguer [80] furthermore, the literature indicates that the effects of training depend on the organizational context, institutional leadership, and the integration of skills into the work routine [56], [73]. In this sense, current training may be meeting formal objectives without generating significant changes in the practices or perceptions of university staff.

The perceived safety construct showed the highest R^2 of the model, indicating that more than 60% of its variance is explained by the included variables. This result demonstrates that the perception of safety in university environments is a multifactorial construct, influenced by regulations, knowledge, culture, and, to a lesser extent, training. According to Bakker & De Vries [71] and Dirik & Özdoğan [74] work environments perceived as safe foster engagement, reduce burnout, and strengthen institutional commitment. This reinforces the relevance of the JD-R approach applied in this study and suggests that any improvement strategy must simultaneously consider multiple structural and cognitive dimensions [100]. Incorporating OHS into university curricula and providing ongoing training strengthens safety culture and equips future professionals for safer work environments.

The results obtained show that the relationship between current performance and the perceived impact of OHS components does not follow a linear pattern. Factors such as regulatory compliance and OHS knowledge, traditionally conceptualized as basic elements, emerge with a decisive influence despite exhibiting intermediate levels of performance. This pattern is consistent with evidence from other institutions that have reported similar difficulties in the implementation of integrated OHS policies, suggesting the presence of a systemic gap in university management. Likewise, institutional safety culture functions as a dynamic element that reinforces perceived effectiveness and generates synergies with other components. In contrast, OHS training, although positively assessed in terms of coverage, does not achieve the expected functional impact, indicating the need

to reconsider its methodological design and practical orientation. Taken together, these findings underscore the importance of moving toward more integrated and evidence-based approaches to university OHS policies, aligned with preventive management, organizational well-being, and sustainability principles.

In this context, the findings of this study provide relevant theoretical and practical implications for occupational health and safety in higher education. From a theoretical perspective, the validated PLS-SEM model offers empirical evidence on the central role of regulatory compliance, institutional safety culture, and OHS knowledge in shaping safety perceptions and the perceived effectiveness of preventive policies within a public university context, an area still underexplored in Latin America. From a practical perspective, the IPMA results identify regulatory compliance and OHS knowledge as high-impact priorities, suggesting that strengthening regulatory literacy, fostering participatory safety cultures, and better aligning training with daily work practices can enhance OHS effectiveness, university well-being, and sustainable institutional management.

5. Conclusions

This study provides empirical evidence supporting the usefulness of the structural model estimated using PLS-SEM, complemented by IPMA analysis, to explain safety perceptions and the effectiveness of OHS policies in university settings. This methodological combination has proven effective in identifying high-impact, low-performance areas, which is essential for formulating institutional strategies aimed at continuous improvement in preventive management. Among the factors analyzed, compliance with OHS regulations emerged as the main determinant of perceived safety. This finding reinforces the need to transcend the logic of formal compliance and move toward real, sustained, and consistent implementation of regulatory frameworks. The evidence gathered in this study validates the central role played by active compliance with legal provisions in creating safe institutional environments, aligned with the principles of decent work promoted by the ILO.

Knowledge about OHS is positioned as a strategic organizational resource, having shown significant effects on safety perceptions and policy effectiveness, despite its low level of performance. From a theoretical perspective, this result supports organizational and behavioral safety approaches that emphasize the role of cognitive and cultural factors in preventive effectiveness. At the same time, this identified gap reveals a concrete opportunity for institutional intervention: strengthening the regulatory literacy of university staff could translate into immediate improvements in the implementation of preventive policies. Furthermore, institutional safety culture emerges as a structuring factor for effectiveness, acting as an organizational support for the sustainability of OHS efforts, in line with approaches such as Total Worker Health.

On the other hand, OHS training, while highly implemented, fails to demonstrate a proportional impact on the variables analyzed. From an empirical perspective, this situation suggests a disconnect between formal training coverage and its functional effectiveness. These results indicate the need to critically review training design, methodologies, and scope, with greater emphasis on practical applicability, integration with daily work processes, and systematic monitoring of outcomes. Overall, safety perception proved to be a central construct, capturing the combined effect of the structural and cognitive dimensions of OHS in the university environment. Based on these findings, the study offers empirical foundations that can guide more integrated institutional policies. Universities would be in a position to redirect their efforts toward strengthening regulatory knowledge and consolidating an organizational culture focused on prevention. Similarly, it identifies the relevance of institutionalizing continuing education programs aligned with internal diagnostics, prioritizing participatory risk assessment mechanisms, and promoting shared responsibility among all levels in OHS management. These actions, more than external recommendations, are seen as necessary conditions for moving toward effective, sustainable, and consistent preventive systems in line with the principles of workplace well-being in public education.

While the results obtained provide a broad and relevant understanding, the study acknowledges limitations that must be considered. Since the analysis focused on a single public university and used a cross-sectional design, the findings cannot be generalized without reservation, nor can firm causal relationships be inferred. Future

research could expand the geographic and typological scope of the institutions evaluated, incorporate longitudinal measurements, and consider mediating or moderating variables that enrich the understanding of the mechanisms that underpin OHS in educational contexts. Furthermore, it is suggested that objective performance indicators be included and that the impact of specific institutional interventions be evaluated over time.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author contribution

Conceptualization, HCPR, SCHG, OCC, STM, and ACR; methodology, OCC, ESB and JACT; software, HCPR, SCHG, OCC, and STM; validation, HCPR, SCHG, OCC, STM, ESB and JACT; formal analysis, HCPR, OCC, ACR and ESB; investigation, HCPR, SCHG, OCC, STM, ACR, ESB and JACT; resources, JNAT; data curation, HCRP, SCHG, OCC, and STM; writing-original draft preparation, HCPR, SCHG, OCC, STM and ESB.; writing-review and editing, HCRP, SCHG, OCC, STM, ESB and JACT; visualization, HCPR, SCHG, OCC, STM, ACR, ESB and JACT; supervision, HCPR; project administration, STM; funding acquisition, JACT. All authors have read and agreed to the published version of the manuscript.

Ethical approval statement

The research has the favorable opinion of the Institutional Research Ethics Committee (CIEI), in accordance with Evaluation Certificate CIEI N° 00173.

Informed consent

All participants provided their written informed consent before the administration of the instrument. They were clearly and comprehensively informed about the objectives of the study, the voluntary nature of their participation, and the confidentiality of the information collected. They were also assured that their responses would be used exclusively for academic and research purposes and that their identity would remain completely anonymous at all times.

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