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Factors Affecting the Well-Being at Work and Risk Perception of Construction Workers: A Validated Interpretative Structural Modeling (VISM) Approach

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Abstract: Despite increased safety investments in the civil construction sector, high accident rates persist, often due to workers' intentional unsafe behaviors influenced by poorly understood psychological factors. This study utilized validated interpretative structural modeling (VISM), an innovative technique, to investigate factors impacting the well-being and risk perception of construction workers in the Brazilian Amazon. The VISM model was developed through five steps: (1) identification of indicators; (2) definition of constructs; (3) identification of relationships between constructs; (4) validation of these relationships; and (5) creation of the model. The results underscore the effectiveness of VISM in crafting complex models with robust statistical validity, even in studies with sample limitations and intricate or circular relationships among constructs. The research identified various factors in this phenomenon, such as the importance given by management to workplace safety, job dissatisfaction, work-related stress, turnover intention, work–family balance, alcohol and cigarette use, physical health, perception of accident risks at work, and education and training in workplace safety. Another significant contribution lies in the model's ability to discern both direct and indirect relationships among these well-being factors. This insight enables the formulation of strategies to enhance worker well-being and reduce workplace accidents, particularly those stemming from intentional unsafe behaviors.

Keywords: civil construction; safety at work; well-being at work; unsafe acts

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Citation: Santana, W.; Moreira, F.; Maués, L.M.; Nery, L.M.; Silva, J. Factors Affecting the Well-Being at Work and Risk Perception of Construction Workers: A Validated Interpretative Structural Modeling (VISM) Approach. *Buildings* **2023**, *13*, 2906. https://doi.org/10.3390/buildings13122906

Academic Editor: Ahmed Senouci

Received: 26 September 2023
Revised: 1 November 2023
Accepted: 6 November 2023
Published: 22 November 2023

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1. Introduction

Investing in workplace safety is crucial in protecting the health, well-being, and physical integrity of workers. It also contributes to the efficiency and sustainability of industry operations. Data obtained by the main occupational health and safety health authorities estimate that there are approximately 2.78 million deaths per year attributed to work-related causes. Among these figures, about 380,500 fatal accidents occur annually, which equates to roughly 1000 deaths each day. This figure does not include non-fatal occupational accidents, which amount to a staggering 374 million per year [1]. The global cost of injuries, illnesses, and accidents at work is a considerable aspect, as it consumes up to 4% of the world's gross domestic product (GDP) [2]. This issue is gaining increasing importance as part of the 2030 agenda, as it is fundamental for sustainable development; it emphasizes the promotion a safe and healthy work for all [3].

This scenario is evident in civil construction. The International Labour Organization (ILO) emphasizes the potential for accidents in this sector, as employees in developed countries are three to four times more prone to experiencing a fatal accident compared to other industries, while in developing countries, this figure increases to six times the

likelihood of accidents [4,5]. Compounding the issue, the ILO also underscores that 60% of the workforce employed is not adequately safeguarded against workplace accidents [2].

In Brazil, the civil construction sector has been steadily increasing its investment in the safety of its workers. According to the Brazilian Association of Real Estate Developers—ABRAINC [6], in the period from December 2021 to May 2023, there were noteworthy developments: an increase in the average investment in collective protection equipment (CPE), rising from USD 923.45 to USD 2548.47 per employee; an increase in average monthly training hours, rising from 6.9 to 7.2; and an increase in the average monthly investment in personal protective equipment (PPE), increasing from USD 41.51 to USD 47.08 per worker. However, it is important to highlight that in 2021 alone, 34,219 accidents at work were recorded in the Brazilian construction sector, with it ranking as the fifth highest in terms of work-related accidents in the country [7].

These data clearly indicate that to decrease the number of accidents in the construction industry, it is insufficient to solely invest in planning, training, and protective equipment for workers. Other factors may be influencing the construction sector as a high-risk activity. This is possibly due to the fact that most accidents at work result from unsafe actions by workers [8]. While unintentional unsafe acts can be attributed to the workers' safety skills (WS), intentional unsafe acts are explained by psychological factors [9].

In this context, various studies explore how psychological factors may influence the occurrence of workplace accidents. These factors include: social influence [8,10]; the work environment [8,10–12]; job satisfaction [11]; the perception of the inefficiency of security measures [10,13]; stress at work [14,15]; professional exhaustion or burnout [16]; physical and mental health [8,11,14,15,17]; and even optimism about job security [18]. This issue is so important that the US National Institute for Occupational Safety and Health (NIOSH) created the Total Worker Health (TWH) program, which deals with a set of safety practices and policies to prevent injuries and illnesses at work with the promotion of well-being, in which the worker's life is assessed, including the psychological factors that may affect their behavior at work [19,20].

In construction, many of these psychological factors are encompassed by the concept of well-being at work. However, there are certain aspects related to this theme that are not adequately addressed. It is essential to recognize that a proportion of an individual's life is spent in the workplace [21]. Therefore, employment and the work environment influence the formation of happiness for individuals and communities worldwide [22], including in civil construction. Therefore, researchers are working to develop methods and practices that consider not only health and safety but also promote well-being at work, as can be seen in the latest works [23–26], with a few exceptions [27].

Indeed, the construction industry is renowned for its challenging and often unhealthy working conditions [28]. It exhibits high rates of work-related illnesses and has detrimental impacts on the mental well-being of its own workers [29]. Characteristics such as long working hours, physical and job insecurity, and conflicts between work and family [30,31], in addition to workers' lack of qualifications and less healthy lifestyles, such as the use of alcohol and smoking [32,33], due to the itinerant nature of the sector [34], contribute to making construction one of the most stressful occupations [35]. Other challenges include the predominance of male cultural stigmas [31,36], high rates of absenteeism and turnover [37,38], low productivity [39–41], and the organizational commitment of workers [42]. These peculiarities reinforce the complexity and risks associated with the construction industry.

It is clear that there are numerous aspects related to well-being at work that could be influencing the incidence of accidents, especially those resulting from intentional unsafe actions.

In this sense, from the perspective of construction workers in the Brazilian Amazon, what are the workplace well-being factors that affect their perception of accident risks? To address this question, this research aims to develop a conceptual model to investigate the influence of factors related to the well-being and perception of the risk of accidents

among construction workers. With this, this research seeks to identify the interrelationships between these factors in order to guide welfare intervention strategies of well-being in construction with effective potential to effectively reduce work accidents stemming from intentional unsafe acts.

2. Literature Review

2.1. Well-Being at Work

Presently, well-being has gone from a popular perception to a measure of global interest, which is currently included in human development analyses [43]. Furthermore, it has emerged as a top priority in the agendas of governments, international organizations, healthcare companies, and research institutions [44].

With this growing interest, concepts related to the topic have been expanded and directed to different areas over time, with one of them being the work environment [45,46]. One of the notable advantages of understanding well-being in the context of work is that the relationships between well-being and antecedents inherent to work tend to be strong. This can provide a better understanding of how the characteristics of work impact the well-being of employee [47].

In organizations, the perceived benefits resulting from workplace health programs are diverse. They increase employees' motivation [48], improve productivity (throughout the day and also throughout their career) [49], reduce absenteeism, and improve the work climate and contribute to the positive promotion of organizational image [50], increasing organizational citizenship behavior [51].

According to an interview involving 32,000 individuals conducted by the iOpener Institute, the researchers concluded that happy workers (a) take just one-tenth as much leave as less happy workers, (b) are six times more energized, (c) intend to stay twice as long in their job, and (d) are twice as productive [52]. Additionally, the study showed that employees who are happiest at work report being on task 80% of the work week, whereas employees who are truly unhappy at work only spend 40% of their time on task.

In fact, it is expected that workers who have high well-being will bring several benefits to organizations. From a more human perspective, the individual benefits resulting from this well-being are essential to a healthy life. Therefore, the search for prosperous work environments that promote the well-being of employees becomes a priority for both individuals and organizations.

2.2. Well-Being at Work for Construction Workers

In this context, organizations that are characterized by intensive use of labor have great potential in developing activities aimed at the well-being of their employees. This includes the construction industry, which, despite technological advancements, continues to rely on a substantial workforce. The construction industry, in general, is notably hazardous due to high numbers of on-site or commuting accidents [53]. Additionally, work-related illnesses in construction rank among the highest across all occupational groups [28]. This reality poses a challenge in effectively promoting occupational health in this industry [54].

In Brazil, the work environment for construction workers exhibits unique characteristics such as limited technological development, a high percentage of workers with low educational levels, low wages, and significant social deprivation [55,56]. Additionally, high job turnover prevents workers from having financial security, and negligence in enforcing safety standards, particularly among smaller, less regulated companies, is also prevalent, especially concerning fall protection [57]. Furthermore, workers often resist using personal protective equipment (PPE) [58].

To quantify accidents in the construction sector in the country, the Ministry of Social Security publishes the Statistical Yearbook of Workplace Accidents (AEAT), categorizing accidents into three main groups: (1) typical accidents, occurring during work, whether the worker is on the company premises or on duty elsewhere, (2) Commuting accidents, occurring during the journey between home and the workplace and vice versa, and (3) oc-

cupational diseases, caused as a consequence of work-related activities. Accidents between 2019 and 2021 are detailed in Table 1.

Table 1. Number of workplace accidents in the Brazilian civil construction industry between 2016 and 2021.

Year	Reason			
	Typical	Commuting	Occupational Diseases	Total
2016	25,640	5359	431	31,430
2017	20,921	4403	346	25,640
2018	21,059	4435	295	25,789
2019	22,313	4172	322	26,807
2020	21,348	3068	296	24,712
2021	25,188	4606	384	30,178

Note: Data obtained from [53].

Table 1 indicates accident rates between 2016 and 2021, demonstrating that accidents classified as typical remain high, with only minimal reductions in those related to occupational diseases. This highlights that occupational safety is a crucial factor to consider in the Brazilian construction industry, with workers being subjected to stressful situations.

Regarding work-related stress, professionals who work in this niche are exposed to several stressful factors [59,60], which have negative impacts on their mental well-being and reflects on individuals and organizations [29], including: long hours and high workload, role conflict, insecurity (both physical and job), dissatisfaction, high pressure, and conflict between work and family [30,31]. For Jebelli et al. [35], psychologically and physiologically demanding tasks carried out in dangerous work environments make construction one of the most stressful occupations, which affects productivity, safety, individual well-being, and the quality of work performed by the employees.

Other characteristics inherent to the construction sector further corroborate its uniqueness and risk: it has an itinerant in nature, it encourages workers to adopt less healthy lifestyles [34]; its workers lack proper qualifications [41,61] and are susceptible to drinking alcohol and smoking [32,33]; it is cyclical due to its dependence on economic factors [62]; it is male-dominated and characterized by predominantly male stigmas and cultures [31,36]; and it has a high rate of absenteeism and turnover [37,38]; on the other hand, it has a low productivity index [39–41] as well as organizational commitment [42].

Although there are initiatives to encourage increased well-being in workplaces in the construction industry, few interventions address the topic in a complete or global way [63]. Studies on psychosocial factors have primarily examined the negative effects on health, as well as focusing on the results of occupational accidents [64]. Therefore, it is important to carry out research to determine the extent of well-being problems, that is, studies that can assess well-being through the use of well-established diagnostic tools, since there is no empirical research with such an approach [30].

In a general context, there is a wave of interest in measuring and providing WBW, which is the main target of training and interventions in business organizations [65]. Despite this, Sender and Fleck [66] state that studies on happiness at work consist of a large number of studies that are dispersed, divergent and therefore not very conclusive, creating difficulties for the evolution of research on this topic (these authors sought concepts concerning happiness stemming from work within organizations).

In fact, the definitions of WBW are still not clear and differ significantly between authors, who choose both positive and negative concepts to represent it, as well as affective and cognitive dimensions. Therefore, there is a need for convergence in the literature, as current approaches do not allow for a full and integrated vision [66,67].

Many studies that claim to study this topic deal with issues such as stress, emotional exhaustion [68], interpersonal relationships, environment, nature of the task [69], engagement, and burnout [70], for example. On the other hand, terms such as satisfaction, involvement,

commitment, engagement, state of flow, motivation, and well-being are the main ones found in academia that are linked to the construct [66]. In this work, well-being at work will be treated as the degree of satisfaction, interest, and excitement with the construction company, job and opportunities offered by the worker's current job.

2.3. Aspects Related to the Safety Climate of Civil Construction Workers

Among the aspects related to WBW, the safety climate is frequently addressed in research [18,71,72]. According to these studies, the safety climate can be considered as people's perception of safety in their work environment and is normally measured through abstract indicators related to the organization's safety culture [71]. This fact is corroborated by Dedobbeleer and Béland [72], who demonstrate that the safety climate comprises factors such as management concerns, safety-related activities carried out by management, and employees' perception of risk.

Furthermore, the safety climate has a close connection with initiatives aimed at the quality of work life in organizations [73]. The question to be answered revolves around the impact that the feeling of security that an individual has on their WBW.

In an effort to clarify this impact, Couto and Paschoal [74] conducted a correlation study between the safety climate and WBW, and they discovered that factors linked to quality of life at work are negatively related to the negative affect component of WBW. According to the actors, the stronger an individual's perception of the positive impact of activities aimed at improving quality of life at work, the less negative effect they experience. In practice, it is believed that these activities do not necessarily increase well-being, but rather help prevent discomfort.

On the other hand, despite the constant need for progress and inspection, the strict current safety legislation and the collective awareness of workers and management make construction sites safer. Some recent case studies indicate significant adherence by construction employees to the companies' safety policy (between 81% and 89%) and also safe behavior by the employees themselves—around 93% [75]. Others indicate a high level of compliance with regulatory safety standards for the construction sector, particularly NR-18. Out of 10 workers surveyed, 9 had a compliance rate of 80% with the standard [76].

In this situation, to some extent, safe practices may have become a standard requirement for employees, who do not see them as an aspect that provides well-being but rather as an obligation that any company has. Therefore, the feeling of security does not really seem to add to job satisfaction or positive affect.

In another analysis, in the construction industry, there are strong correlations between work stress and physical safety outcomes. It is also been found that the safety climate has the potential to reduce this stress, indicating that it can impact not only the physical health of employees but also their psychological health [77]. Thus, by mitigating negative aspects, the safety climate contributes to reducing negative effects on the work environment. These analyses highlight the importance of the safety climate as a crucial factor in promoting the well-being and safety of workers in the construction industry, highlighting the importance of continuous measures to improve the perception of safety and the organizational culture focused on safety in the sector.

In this context, conceptually, this research explores factors related to workplace well-being and the safety climate, wherein the perception of workplace accident risks is one of the components encompassed within the safety climate concept.

3. Methodology

To build the conceptual model of the factors that affect well-being at work and the perception of the risk of accidents among construction workers, this research used the validated interpretive structural modeling approach. This modeling technique, known as validated interpretative structural modeling (VISM), was presented by Santana et al. [78] and proves to be a powerful tool for modeling experimental research based on data obtained in survey research. VISM was chosen because it allows the construction of conceptual

models with strong statistical support from a reduced number of interviews, even in situations where the sample exhibits non-normal data distribution [78], as is the case in this research.

Furthermore, the relationship between well-being and the perception of occupational accident risks is still not well understood due to the complexity of these interactions. In this context, VISM emerges as a technique capable of combining the explanatory power for complex phenomena of interpretative structural modeling (ISM) with the statistical validity of structural equation modeling–partial least squares (PLS-SEM), enabling the creation of complex models with strong statistical support, even in non-linear models containing circular and/or cross-relations among constructs [78].

Following VISM procedures, the research methodology was developed in five stages: (1) identification of indicators of the safety climate and well-being at work for construction workers; (2) definition of constructs; (3) identification of the relationship between constructs; (4) validation of relationships between constructs; and (5) creation of the conceptual model.

Figure 1 summarizes the procedures used to build the model using the VISM modeling technique.

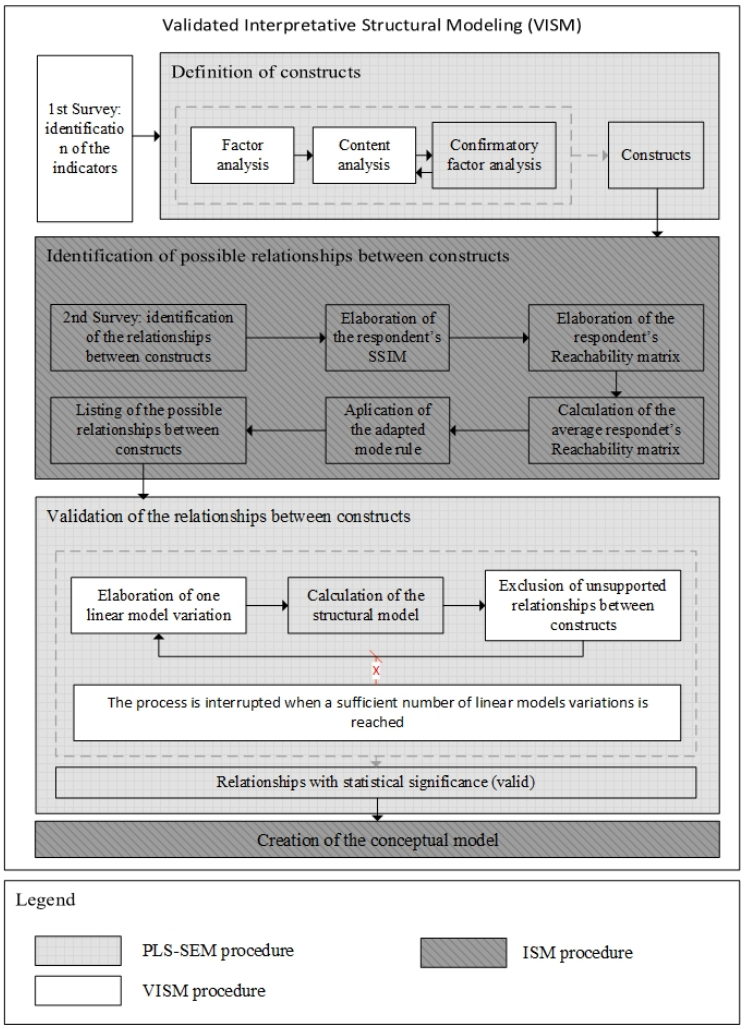


Figure 1. Flowchart for constructing the VISM model of factors that affect well-being at work and the perception of the risk of accidents among construction workers.

The procedures used to execute each step of the developed model will be detailed below.

3.1. Identification and Measurement of the Safety Climate and Well-Being Indicators at Work for Civil Construction Workers

To identify indicators of well-being and workplace safety climate related to workers in the construction industry, a systematic review of the literature was carried out. A systematic literature review is a scientific search technique that aims to establish a clear and replicable method for data collection [79], which results in a broad set of results, ideally containing all studies relevant to the topic being researched [80].

In this research, ten search bases were chosen because they contain scientific publications related to the construction industry: EBSCO, ProQuest, PubMed, Scopus, Web of Science, Cochrane Library, SciELO, Emerald, PsycINFO and Engineering Village. The following search terms were used: ("safety climate" OR "safety culture" OR "safety perception") AND ("well-being" OR "wellbeing" OR "well being") AND ("civil construction" OR "construction industry" OR "construction sector" OR "construction sites" OR "civil construction workers").

Initially, 988 articles were obtained in the searches. In the selection stage, 166 articles showed strong adherence to the topic, with them being accepted for the next stage. In the extraction stage, 74 studies were rejected and were 92 accepted, in which indicators related to the safety climate and well-being at work of construction workers were extracted.

As a result, 26 indicators were identified, as shown in Table 2. The next step involved measuring these indicators. This survey was conducted using a questionnaire developed based on models adopted by various renowned authors in the research field, as indicated in Table 2; the goal was to maintain them entirely in their original form to prevent distortions in their application and the responses obtained. To ensure response variability consistent with PLS-SEM, a 5-point Likert scale was adopted, where 1 = strongly disagree, 2 = disagree, 3 = partially agree, 4 = agree, and 5 = strongly agree. Regarding the questionnaire classification, it can be considered structured and closed, as it contains questions with pre-defined answers [81].

Construction workers from the cities of Belém, Ananindeua, Castanhal, and Abaetetuba were defined as a sample group, with the aim of achieving maximum diversity. These cities also had the highest number of ongoing construction projects in the state during the study period, between April and May 2019. Moreover, these cities shared the same labor relations, with them being governed by the same employers' and workers' unions and adhering to the same employment contract statutes. To ensure data quality, participants were randomly selected based on their availability and willingness to participate. The chosen data collection method was face-to-face, whereby the interviewer explained the questions and addressed any concerns [81]. Interviewee anonymity was preserved, and the interviews were conducted spontaneously and individually, with them lasting between twelve to fifteen minutes.

Table 2. Constructs and indicators developed.

Constructs		Indicators	References
1—Stress at work	SW1	Competition in my workplace has left me in a bad mood	[82,83]
	SW2	Lack of understanding of my responsibilities in this job has caused irritation	
	SW3	The lack of autonomy in carrying out my work has been exhausting	
	SW4	I have felt uncomfortable with my superior's lack of trust in my work	
	SW5	I feel irritated by the lack of exposure about organizational decisions	
	SW6	I am happy about the company that I work for	

Table 2. *Cont.*

Constructs		Indicators	References
2—Use of alcohol or cigarettes	UAC1	How many drinks are my average weekly alcohol intake?	[84]
	UAC2	I drink more than four drinks on one occasion	
	UAC3	I smoke cigarettes	
3—Importance given by management to worker's safety	IMWS1	How important are worker safety practices to your company's managers?	[72]
	IMWS2	How much do supervisors and other high-level managers seem to care about your safety?	
	IMWS3	How much emphasis does the responsible one put on safety practices in the workplace?	
4—Turnover intention	TI1	I think about leaving the company I work for	[83]
	TI2	I have plans of leaving the company I work for	
	TI3	I want to leave the company where I work	
5—Work and family relationship	WFR1	The demands of my work interfere with my family life	[85]
	WFR2	Due to the amount of time I dedicate to my work, I have difficulty fulfilling my family responsibilities	
	WFR3	My work duties cause me to change my plans for family activities	
	WFR4	Because of the demands of my job, I cannot do the things I want to do at home	
	WFR5	The pressures generated by my work restrict the freedom to plan my family activities	
6—Physical health	PH1	In general, what you would say your health is excellent	[86]
	PH2	I am as healthy as any other person that I know	
	PH3	I think my health will get worse	
	PH4	My health is excellent	
7—Task dissatisfaction	TD1	The way tasks are distributed in my area has been making me nervous	[82]
	TD2	I have felt uncomfortable working on tasks below my skill level	
	TD3	Not having enough time to complete my workload makes me nervous	
8—Education and training in worker's safety	ETWS1	When you were hired by your current employer, were you briefed on the company's security policy and security requirements?	[72]
	ETWS2	Are there regular workplace safety meetings at your current workplace?	
9—Accident risk perception	ARP1	How likely are you to be injured at work in the next 12 months?	[72]
10—Well-being at work	WBW1	I am satisfied with the understanding between me and my boss	[83]
	WBW2	I am proud of the company I work for	
	WBW3	I am satisfied with the opportunities to be promoted in this company	
	WBW4	I am excited about the company I work for	
	WBW5	I am interested in the company I work for	
	WBW6	I am satisfied with my salary compared to my efforts at work	
	WBW7	I'm excited about the company I work for	

3.2. Definition of Constructs

The constructs are the basis of the model structure and are explained by the indicators measured from the data obtained with the first survey of the research. To create the constructs, a rigorous cycle procedure based on the study by Santana and Maués [87] was used, detailed below.

First, the indicators were grouped according to the literature review conducted in Section 3.1, forming the constructs. Subsequently, confirmatory factor analysis (CFA) was conducted to assess their coherence, obtained from the rules presented in Table 3. However, as in the study by Santana and Maués [87], the constructs at this first stage did not show statistical consistency and had to go through a rigorous procedure of two more stages. In this procedure, carried out in cycles, the adequacy of the indicators to the constructs was verified through content analysis, and the constructs were modified, or other constructs were created until their content and a confirmatory factor analysis indicated their adequacy to the objectives of the research and the statistical rigor necessary for the measurement model [87,88].

Table 3. Confirmatory factor analysis rules.

	Rules	Guidelines
Construct	Composite reliability	The composite reliability of the construct should be greater than 0.708.
	Convergent validity	The average variance extracted (AVE) of the construct should exceed 0.5.
	Discriminant validity	The square root of the AVE for each construct should be greater than its correlations with all other constructs.
Indicator		The outer loading of the indicator with its construct should be higher than the outer loading with all other constructs.
	Indicator reliability	The outer loading of the indicator should be greater than 0.708. The indicators with outer loadings between 0.4 and 0.7 can be considered for exclusion only if they result in an increase in the construct's AVE above 0.5.

Note: adapted from Hair et al. [88].

3.3. Identification of Possible Relationships between Constructs

According to the VISM technique, the relationships identified in this stage are possible, but not guaranteed, and will only be true if they are validated in the subsequent stage. Aiming to identify the possible relationships between the constructs, a second survey was carried out to obtain the structural self-interaction matrix (SSIM).

Basically, in the SSIM, the respondents of this second survey were asked about the existence and direction of the relationship between each construct by assigning one of the following symbols: "V" for a direct relationship in the sense of the construct from left to right; "A" for a direct relationship in the sense of the construct from right to left; "X" for a cross-relationship; and "0" for a lack of a relationship between the evaluated constructs.

To develop the SSIM, a second questionnaire was created and emailed to accredited experts in the field of occupational safety and construction engineering in Brazil, including researchers and on-site engineers. The snowball sampling technique was employed for data collection, wherein the questionnaire was sent to one person, who then recommended other individuals to participate based on the sample criteria, until the research requirements were met [89]. The data for the second survey were collected from July to August 2019.

Based on the responses obtained from the second survey, the average accessibility matrix was created, allowing the identification of possible relationships between constructs. To do this, the mode rule was used. According to the mode rule, relationships that present values above 0.5 in the average accessibility matrix can be considered [78,90].

3.4. Validation of Relationships between Constructs

Once possible relationships between constructs have been identified, these relationships are checked for statistical significance. This is a key step in the VISM technique and aims to add the reliability of PLS-SEM models to ISM models. To achieve this, linear models will be constructed containing the potential relationships between constructs and then tested for statistical significance using bootstrapping procedures, following Santana et al.'s [78] guidelines. According to the author, we should adopt the following five condi-

tions for the creation and testing of linear models used to validate relationships between constructs:

1. The linear variations developed should show as many relations between constructs as possible;
2. Possible unsupported relations should be deleted;
3. A good test of a possible relation is one, in which, in the same linear variation, all existing relations between the constructs that precede it are tested;
4. If possible, as many linear variations should be developed as the possible relations to be tested allow, otherwise, and there is no clear limit on the maximum number of linear variations to be tested, a sufficient number of linear variations should be tested (as in rule 5 shown below);
5. A sufficient number of linear variations developed is one in which each relation is tested a number of times equal to the number of constructs. For example, if a model has ten constructs, each possible relation should be tested at least ten times.

For the significance test of the possible relations, the bootstrapping procedure will be used, a powerful tool of the PLS-SEM method for testing hypothetical relationships in complex models [88]. As a criterion to determine the validity of possible relationships, significance in the sample will be adopted at a 10% confidence level, that is, when the t value is above or equal to 1.65 [78,88].

3.5. Creation of the Conceptual Model

Once the valid relationships between the constructs have been identified, the conceptual model is drawn up. In this research, the standard conceptual model of the ISM technique will be used, containing the constructs and their relationships, represented by arrows. In this method, first, an SSIM is constructed containing the valid relationships between the constructs obtained in Section 3.4. Then, the influences between constructs are translated into relationships and represented by arrows. Finally, the constructs and their relationships are organized into a structure containing the model's constructs and their interconnections. This model presentation format will be used as it highlights the interpellations between the model factors; therefore, it allows a more detailed analysis of the specific ways in which the safety climate and well-being at work of construction workers are related.

4. Results

4.1. Safety and Well-Being Climate Indicators at Work for Construction Workers

Table 2 presents the indicators adopted and the references that supported them, obtained from the systematic review of the literature developed. In Table 2 it can be seen that 26 indicators were used, which were later grouped into 10 constructs.

With the application of the first survey, 376 responses were obtained. The preponderant characteristics of the individuals who participated in this study are: (a) male (98.9%), (b) marital status married or friends (67.3%), (c) completed high school (31.6%), (d) aged between 29 and 38 years old, (e) with one to three children (72.6%), (f) time with the company up to 6 months (31.9%), and (h) have their own employment relationship with the construction company (83%). Despite the group being heterogeneous, no significant variations in the obtained responses were observed when statically utilizing the PLS-SEM procedure.

Once the research indicators were measured, it was possible to define the constructs that made up the developed model, according to the following topic.

4.2. Results of the of the Constructs Definition

To create the constructs, the rigorous three-step procedure developed by Santana and Maués [87] was adopted. As a result, several cycles were necessary, and Table 4 presents the constructs and results of the confirmatory factor analysis of the last creation cycle.

Table 4. Results of the evaluation of the mensuration model.

	SW	WBW	UAC	IMWS	TI	WFR	PH	TD	ETWS	ARP
Stress at work	**0.734**									
Well-being at work	0.486	**0.766**								
Use of alcohol or cigarettes	0.183	0.207	**0.728**							
Importance given by management to worker's safety	0.19	0.415	0.222	**0.773**						
Turnover intention	0.421	0.596	0.123	0.234	**0.922**					
Work and family relationship	0.454	0.231	0.079	0.107	0.224	**0.86**				
Physical health	0.329	0.295	0.172	0.127	0.156	0.318	**0.718**			
Task dissatisfaction	0.629	0.429	0.113	0.145	0.419	0.383	0.269	**0.735**		
Education and training in worker's safety	0.116	0.215	0.215	0.399	0.081	0.068	0.031	0.133	**0.847**	
Accident risk perception	0.173	0.071	0.029	0.023	0.081	0.258	0.189	0.203	0.12	**1**
Composite reliability	0.854	0.917	0.771	0.816	0.945	0.934	0.808	0.779	0.835	1
Average variance extracted (AVE)	0.539	0.587	0.531	0.597	0.85	0.74	0.515	0.54	0.717	1

Note: values highlighted on the diagonal line are the square root of the AVE. The abbreviations in the columns represent, in sequence, the constructs listed in the rows. For example, SW stands for stress at work and ARP stands for accident risk perception.

Confirmatory factor analysis aims to test whether the arrangement of indicators in constructs is coherent with the factor model [91]. In Table 4, we can observe the cross-loadings between the constructs obtained through the measurement model of PLS-SEM. In Table 4, one can be see that the internal consistency of the factors is satisfactory, as the composite reliability presented values above 0.708 for all constructs [88]. Likewise, the convergent validity of the model was confirmed, given by the AVE greater than 0.5 and the square roots of the AVE (in bold on the diagonals) greater than the correlations of the constructs with the others.

Another method of checking discriminant validity is by examining cross-loadings between indicators. In this case, all indicators must have higher loadings with their associated construct [88]. Table 5 presents the cross-loadings between indicators and constructs; it can be seen that the discriminant validity rule was satisfied.

In addition to the internal consistency and discriminant validity of the constructs, it is important to verify the consistency of the indicators in explaining their respective constructs [91]. Regarding the consistency of the indicators, the reliability of the indicators (loadings above 0.5 with their construct) and discriminant validity were confirmed, as all indicators showed higher loadings with their construct than with the others [88].

Once the constructs were defined, the next step was the identification of possible relationships between constructs.

4.3. Results of the Identification of Possible Relationships between Constructs

According to VISM, at this stage a second survey is carried out to identify possible relationships between constructs. As a result, five responses were obtained, a number equivalent to other surveys [78,92,93], and deemed sufficient, given that potential relationships would still be tested for statistical significance in the study. Among the respondents, all of them have more than twenty-five years of experience in the area of building construction, including three civil engineers, one occupational safety specialist, and one psychologist.

Table 6 presents the accessibility matrix containing the average of the responses obtained. According to Santana et al. [78], all relationships that present values greater than 0.5 are considered possible relationships between constructs, and they were statistically tested by the bootstrapping procedure of the PLS-SEM for their adherence in relation to the data from the first survey.

Table 5. Cross-loadings between constructs and indicators.

	SW	WBW	UAC	IMWS	TI	WFR	PH	TD	ETWS	ARP
SW1	0.697	0.278	0.147	0.084	0.289	0.34	0.192	0.478	0.066	−0.092
SW2	0.766	0.334	0.148	0.126	0.273	0.341	0.28	0.53	0.112	−0.097
SW3	0.707	0.314	0.123	0.121	0.269	0.293	0.218	0.503	0.055	−0.136
SW4	0.763	0.465	0.105	0.195	0.393	0.352	0.287	0.403	0.07	−0.109
SW5	0.733	0.387	0.149	0.17	0.319	0.338	0.225	0.394	0.122	−0.205
WBW1	0.467	0.885	0.221	0.349	0.534	0.214	0.245	0.37	0.16	−0.031
WBW2	0.479	0.684	0.122	0.315	0.425	0.163	0.172	0.337	0.15	−0.067
WBW3	0.311	0.758	0.162	0.316	0.457	0.082	0.207	0.296	0.26	−0.093
WBW4	0.232	0.548	0.099	0.307	0.313	0.165	0.165	0.28	0.239	−0.118
WBW5	0.413	0.888	0.207	0.354	0.524	0.195	0.286	0.369	0.096	−0.047
WBW6	0.42	0.863	0.167	0.304	0.53	0.198	0.241	0.375	0.163	−0.03
WBW7	0.205	0.523	0.062	0.223	0.276	0.187	0.179	0.254	0.139	−0.007
WBW8	0.359	0.875	0.182	0.358	0.517	0.21	0.291	0.324	0.15	−0.049
UAC1	0.183	0.202	0.801	0.183	0.069	0.082	0.105	0.087	0.184	−0.008
UAC2	0.089	0.083	0.741	0.13	0.053	0.026	0.076	0.038	0.085	0.016
UAC3	0.103	0.132	0.633	0.155	0.13	0.049	0.173	0.101	0.165	−0.056
IMWS1	0.18	0.3	0.142	0.742	0.152	0.09	0.039	0.137	0.307	0.02
IMWS2	0.133	0.265	0.162	0.788	0.131	0.107	0.161	0.084	0.306	−0.051
IMWS3	0.131	0.386	0.205	0.787	0.247	0.057	0.096	0.115	0.313	−0.022
TI1	0.415	0.552	0.088	0.196	0.915	0.183	0.169	0.388	0.036	−0.087
TI2	0.362	0.547	0.131	0.232	0.918	0.199	0.121	0.38	0.096	−0.043
TI3	0.388	0.55	0.121	0.22	0.933	0.236	0.141	0.393	0.092	−0.093
WFR1	0.402	0.226	0.04	0.102	0.224	0.822	0.253	0.335	0.099	−0.311
WFR2	0.386	0.189	0.061	0.074	0.175	0.88	0.28	0.288	0.046	−0.25
WFR3	0.339	0.163	0.058	0.022	0.172	0.848	0.244	0.308	0.028	−0.148
WFR4	0.362	0.202	0.091	0.138	0.191	0.851	0.285	0.321	0.032	−0.17
WFR5	0.449	0.208	0.089	0.116	0.197	0.899	0.301	0.385	0.078	−0.222
PH1	0.169	0.235	0.172	0.135	0.059	0.128	0.727	0.206	0.02	−0.136
PH2	0.346	0.235	0.072	0.039	0.18	0.309	0.691	0.217	0.003	−0.125
PH3	0.174	0.148	0.168	0.101	0.118	0.179	0.641	0.131	0.1	−0.123
PH4	0.267	0.218	0.076	0.081	0.104	0.315	0.802	0.212	−0.026	−0.157
TD1	0.506	0.288	0.039	0.104	0.308	0.356	0.194	0.728	0.003	−0.165
TD2	0.414	0.373	0.122	0.114	0.263	0.213	0.236	0.741	0.195	−0.129
TD3	0.46	0.29	0.095	0.103	0.35	0.266	0.166	0.736	0.108	−0.151
ETWS1	0.099	0.191	0.239	0.34	0.018	0.038	0.105	0.118	0.865	−0.077
ETWS2	0.098	0.172	0.119	0.337	0.125	0.08	−0.061	0.106	0.828	−0.129
ARP1	−0.173	−0.071	−0.029	−0.023	−0.081	−0.258	−0.189	−0.203	−0.12	1

Table 6. Accessibility matrix containing the average responses from the second survey.

ID	Constructs	ST	UAC	IMWS	TI	WFR	PH	TD	ETWS	ARP	WBW
1	Stress at work	1	0.8	0.2	1	0.8	0.4	0.2	0.4	0.4	1
2	Use of alcohol or cigarettes	0.2	1	0.2	0.2	0.6	1	0	0.2	0.4	0
3	Importance given by management to Work's safety (WS)	0.4	0.4	1	0.4	0.8	0.6	0.6	1	1	0.6
4	Turnover intention	0	0	0.2	1	0.2	0	0.6	0.4	0	0.4
5	Work and family relationship	0.8	0.8	0.4	0.8	1	0.2	0.2	0.4	0.4	0.8
6	Physical health	0.2	0.4	0.4	0.4	0.4	1	0.2	0	0.6	1
7	Task dissatisfaction	0.8	0.2	0.6	1	0.6	0.4	1	0.2	0.2	1
8	Education and training in WS	0.6	0.6	0.6	0.6	0.6	0.4	0.2	1	1	0.6
9	Accident risk perception	0.6	0.2	0.6	0.4	0.4	0.6	0.2	0.4	1	0.6
10	Well-being at work	0.6	0.4	0.2	1	0.8	0.4	0.6	0.6	0.2	1

4.4. Results of the Validation of Relationships between Constructs

At this stage, possible relationships between constructs will be tested for their statistical significance, as according to VISM, only validated relationships will be used to create the model. For this, the bootstrapping procedure was used in order to obtain the significance

of possible relationships according to linear variations of the model, generated based on the five VISM conditions developed by Santana et al. [78].

The results of the linear variations developed are presented in Tables 7 and 8. The possible relationships are presented in the columns, referring to the identifications of the constructs in Table 6; therefore, for example, the relationship 1-2 means a possible relationship of the construct SW in the sense of the UAC construct. In the lines of Tables 7 and 8, the results of the t- and *p*-values (significance) for the linear variations (LV) developed by VISM are presented.

Twenty linear variations were created to investigate the relationships between the model's constructs. In this process, twenty-three valid relationships were identified among the forty possible relationships tested. In Table 8, it is possible to observe that all seventeen rejected relationships were excluded up to the fourth linear variation as they were not significant in the sample at a 10% confidence level [78,88]. Furthermore, to meet VISM condition five, which requires that each possible relationship be tested a number of times equal to the number of constructs in the model, each relationship was tested at least ten times, as evidenced in the last row of Table 7 [78].

4.5. Conceptual Model

After identifying the relations between constructors, it was possible to create the conceptual model highlighting these relations. The resulting conceptual model is presented in Figure 2.

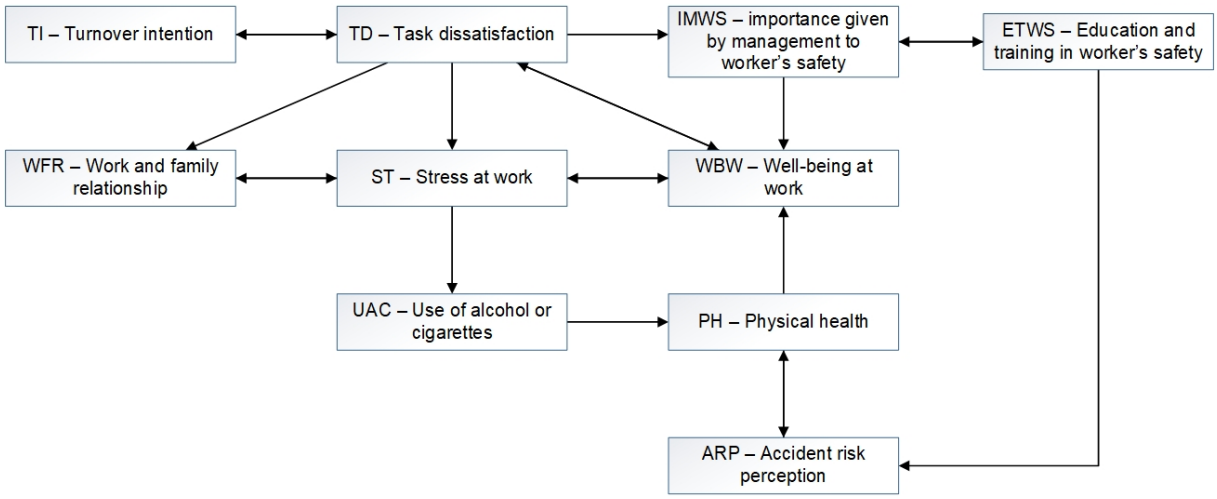


Figure 2. Conceptual model of factors that affect the well-being and risk perception of construction workers.

After creating the model using the VISM methodology, its findings and contributions are elaborated upon in the following discussion section.

Table 7. Results of the significance test of possible relationships between constructs (only valid relationships).

Linear Variation		1-2	1-5	1-10	2-6	3-6	3-8	3-10	4-7	5-1	6-9	6-10	7-1	7-3	7-4	7-5	7-10	8-2	8-3	8-9	9-6	10-1	10-4	10-7
1	*t*	3	9	4	3	2	8	6	8		4	3					3	3		2				
	p	0	0	0	0	0	0	0	0		0	0					0	0		0				
2	*t*	3			3	2				5			8	2	2	6		3	7	2	3	5	9	10
	p	0			0	0				0			0	0.1	0	0		0	0	0	0	0	0	0
3	*t*	3	5	7		3	7	7	4		3	3				2		3		2			15	5
	p	0	0	0		0	0	0	0		0	0				0		0		0.1			0	0
4	*t*	3			3	2		6		5			8	2	4	7	9	4	7	2	3	5	10	
	p	0			0	0		0		0			0	0.1	0	0	0	0	0	0	0	0	0	
5	*t*	3	5	4	3	2	8	7	9		3	2	16	3		2	3	4		2				
	p	0	0	0	0	0	0	0	0		0	0	0	0		0	0	0		0.1				
6	*t*	3								5		6	9	2	4	7		3	8	2	3	5	10	10
	p	0								0		0	0	0.1	0	0		0	0	0	0	0	0	0
7	*t*	3	5				8					6	10	3	4	2		4			3	5	10	10
	p	0	0				0					0	0	0	0	0		0			0	0	0	0
8	*t*	3		4	3	2		7	9	5	3	2	11				3	4	7	2				
	p	0		0	0	0		0	0	0	0	0	0				0	0	0	0				
9	*t*	3		4	2	2	8	7	9	5		2	11	3		7	3	4		2	3			
	p	0		0	0	0	0	0	0	0		0	0	0		0	0	0		0	0			
10	*t*	3	5		3	2		9			3		10		4	2		4	8	2		5	10	10
	p	0	0		0	0		0			0		0		0	0		0	0	0.1		0	0	0
11	*t*	3	5	7	3	2	8	7	4			3				2		3		2	3		15	5
	p	0	0	0	0	0	0	0	0			0				0		0		0	0		0	0
12	*t*	3			3	2		7		5	3		8	2	4	7	9	4	7	2		5	10	
	p	0			0	0		0		0	0		0	0.1	0	0	0	0	0	0.1		0	0	
13	*t*	3	5		3	2	8	7	9				10	3		2	9	4		2	3	5		
	p	0	0		0	0	0	0	0				0	0		0	0	0		0	0	0		
14	*t*	3		8	3	2		7		9	3	3			4			4	8	2			10	10
	p	0		0	0	0		0		0	0	0			0			0	0	0.1			0	0
15	*t*	3	5			2	8	8	4			5	10			2		3		2	3	5	15	5
	p	0	0			0	0	0	0			0	0			0		0		0	0	0	0	0
16	*t*	3		4	3	2	8	7		5	3	2	11	3	4	7	3	4		2			10	
	p	0		0	0	0	0	0		0	0	0	0	0	0	0	0	0		0.1			0	

Table 7. *Cont.*

Linear Variation		1-2	1-5	1-10	2-6	3-6	3-8	3-10	4-7	5-1	6-9	6-10	7-1	7-3	7-4	7-5	7-10	8-2	8-3	8-9	9-6	10-1	10-4	10-7
17	*t*	3	5				8				3	6	10	3	4	2		4		2		5	10	10
	p	**0**	**0**				**0**				**0**	**0**	**0**	**0**	**0**	**0**		**0**		**0.1**		**0**	**0**	**0**
18	*t*	3		4	2	2		7	9	5		2	11	2		7	3	4	7	2	3			
	p	**0**		**0**	**0**	**0**		**0**	**0**	**0**		**0**	**0**	**0.1**		**0**	**0**	**0**	**0**	**0**	**0**			
19	*t*				3	2		7	9	5		3	8	2		7	7	4	4	7	2	3		
	p				**0**	**0**		**0**	**0**	**0**		**0**	**0**	**0.1**		**0**	**0**	**0**	**0**	**0**	**0**	**0**		
20	*t*	3	5	7	3	2		7			3	3			4	2		4	8	2			10	10
	p	**0**	**0**	**0**	**0**	**0**		**0**			**0**	**0**			**0**	**0**		**0**	**0**	**0.1**			**0**	**0**
No. Tests		19	10	10	15	17	10	16	10	10	10	15	15	12	10	17	10	20	10	19	10	10	13	10

Note: the values in black are the t (strength)-values of the possible relationships for each linear variation. The values in green are the *p*-values that were significant at 10% of the sample.

Table 8. Results of the significance test of possible relationships between constructs (only non-significant relationships).

Linear Variation		8-10	10-8	1-4	5-2	9-1	9-3	10-5	2-5	3-5	3-7	3-9	5-4	5-10	8-1	8-4	8-5	9-10
1	*t*	2		7					0	0	1	1	1	1	1	1	0	1
	p	**0**		**0**					**0.9**	**0.7**	**0.4**	**0.4**	**0.5**	**0.4**	**0.5**	**0.6**	**0.8**	**0.3**
2	*t*		4	1	0	0	1	1										
	p		**0**	**0.2**	**0.9**	**0.8**	**0.4**	**0.2**										
3	*t*		1															
	p		**0.2**															
4	*t*	1																
	p	**0.6**																

Note: the values in black are the t (strength)-values of the possible relationships for each linear variation; the values in green are the *p*-values that were significant at 10% of the sample. The values in red are the *p*-values that were not significant in 10% of the sample.

5. Discussion

As observed by the model developed, the connection between the importance given by construction company management to workplace safety and education and training in safety at work is evident. According to the research findings, a construction company in which the managers responsible for setting goals and guidelines for workers are concerned about their safety is highly likely to provide a more extensive range of courses and instructive measures on workplace safety (WS) for the workers.

To the same extent, the model highlights the influence of education and training in WS on the perception of accident risks. These findings align with other studies [12,18,94], and demonstrate the importance of training workers to deal with insecure situations as a fundamental risk management tool in construction projects.

Furthermore, these results indicate that the positive attitude of the construction company's management towards WS education and training activities has a beneficial impact on the workers' perception of accident risks at work. This highlights the importance of not only offering WS training to workers but also actively engaging those responsible for management and promoting safety-conscious behaviors as a strategy to decrease accidents, enhancing the safety climate and potentially reducing acts of workers' insecurity. Previous studies support these findings, highlighting the influence of superiors' WS attitude in mitigating unsafe behaviors among construction workers [12,18,71].

According to these studies, the imposition of penalties such as fines and infraction points to those who commit unsafe acts at work can serve as a deterrent [94]; however, a more humane approach may prove to be more advantageous. After all, studies demonstrate that the recognition of good behavior in WS [18], the strengthening of monitoring in WS at the construction site [95], the certification of training in WS [18], and even the presence and encouragement of management when providing courses and training in WS for employees have the potential to favor a reduction in unsafe acts at work [12,71]. Therefore, the model developed infers that promoting a culture of safety in the workplace, valuing the commitment of workers to adopt safe practices, and investing in their training represent an effective approach to enhancing the safety and well-being of workers in the construction industry.

Concerning the perception of accident risks, the model developed highlights its connection with the physical health of the worker, suggesting that workers who feel less susceptible to workplace accidents, due to education and training in WS, tend to possess a better perception of their health and, as a result, experience improved well-being at work. These findings align with those of Na et al. [9], which suggest that the unsafe behaviors of workers responsible for workplace accidents are linked to deliberate attitudes. Its relatively accepted that workers with good perception about risks at work positively influences construction workers' risk-taking behavior [18]. In this context, the developed model suggests that workers with a diminished perception of their risk of accidents, physical health, and well-being have a propensity to commit unsafe acts due to dissatisfaction with well-being at work or a feeling that risk is part of the activities carried out and, therefore, cannot be avoided.

When it comes to factors associated with workplace stress, the model clarifies the ways in which dissatisfaction with tasks and turnover intention affect worker well-being. These findings are in line with the existing literature [27] and go further, helping to clarify how happens. According to the model, turnover intention is closely related to dissatisfaction with tasks, and dissatisfaction with tasks stands out as one of the main factors with a direct relationship with construction worker stress at work. Additionally, the model highlights one of the perverse ways in which stress at work can affect such a worker, as stress at work can harm the work–family relationship, as well as favor the use of alcohol and cigarettes, with damage to their physical health and negative consequences for their well-being.

6. Conclusions

In this study, an innovative modeling technique developed by Santana et al. [78] was employed, known as validated interpretative structural modeling (VISM). The results underscore the effectiveness of VISM in crafting complex models with robust statistical validity, even in exploratory research scenarios characterized by sample limitations and intricate or circular relationships among constructs. This represents a significant contribution, as many contemporary modeling techniques struggle to effectively address such complexities.

The developed model aimed to investigate the influence of factors affecting the well-being and accident risk perception of construction workers. The research identified various factors in this phenomenon, such as the importance given by management to workplace safety, job dissatisfaction, work-related stress, turnover intention, work–family balance, alcohol and cigarette use, physical health, perception of accident risks at work, and education and training in workplace safety.

Moreover, the primary contribution of the research lies in the formulation of the proposed model, which surpasses prior studies in the field. Previous research often identified only a few factors without exploring the intricate relationships between the elements influencing the well-being of construction workers. The developed model has the potential to assist researchers, construction enterprises, and practitioners by aiding in the formulation of strategies and the adoption of measures to enhance worker well-being and reduce workplace accident risks, especially those related to intentional unsafe acts.

As per the developed model, factors like the importance given by management to workplace safety, job dissatisfaction, work-related stress, and physical health directly impact the well-being of construction workers. Therefore, these factors should be prioritized. Simple strategies such as investing in training programs and adopting humane practices can significantly improve the safety climate and the overall well-being of the workforce.

Additionally, other factors indirectly affect the well-being of construction workers. For instance, job dissatisfaction and turnover intention are linked to work-related stress among laborers. Stress can negatively impact employees' well-being, harming work–family relationships and increasing the use of alcohol and cigarettes. Furthermore, the significance given by management to safety influences education and training in safety, affecting accident risk perceptions, physical health, and ultimately the well-being of workers. These findings highlight how intentional unsafe acts can stem from dissatisfaction or a sense that risks are inherent in their work, prompting workers to engage in unsafe practices.

Despite the contributions, certain limitations should be acknowledged for future research. Firstly, workers from other countries with different cultures, climates, education levels, and behaviors might yield distinct models and, consequently, different relationships between constructs and strategies to enhance worker well-being. Secondly, the developed model represents the reality of building construction workers in the Brazilian Amazon context. Therefore, workers from infrastructure, port, or industrial construction sites might produce different results due to the application of advanced construction technologies and equipment, which could favor worker well-being. Thirdly, although PLS-SEM allows for the influence of demographic characteristics through multi-group analysis, no significant variations were identified in the results according to the 95% confidence interval, demonstrating the homogeneity of the findings. Future studies using alternative modeling methods or different samples could yield diverse analyses or compare different models to assess variations in relationships involving factors influencing construction workers' well-being.

Author Contributions: Conceptualization, W.S. and L.M.M.; methodology, W.S.; software, W.S.; validation, W.S.; formal analysis, W.S.; investigation, W.S. and F.M.; resources, W.S. and F.M.; data curation, F.M.; writing—original draft preparation, W.S., F.M., L.M.N. and J.S.; writing—review and editing, W.S., L.M.M., L.M.N. and J.S.; visualization, W.S.; supervision, L.M.M.; project administration, W.S. and L.M.M.; funding acquisition, L.M.M. All authors have read and agreed to the published version of the manuscript.

Funding: The authors received no financial support for the research but did receive financial support for the publication of this article from PROPESP/PAPQ/UFPA. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível (CAPES) (Coordination for the Improvement of Higher Education Personnel)-Brazil-Finance Code 001.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to the need to protect the privacy of the research respondents.

Conflicts of Interest: The authors declare no conflict of interest.

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