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Risk management and its effect on welders' health and the work environment of shipyard industries

Nur Yanu Nugroho[1*], Amin Setyo Leksono[2], Gatot Ciptadi[3], Fadillah Putra[4]
[1]Department of Environmental Science, Postgraduate School, University of Brawijaya, East Java, Indonesia; nur.yanu@hangtuah.ac.id (N.Y.N.).
[2]Faculty of Mathematics and Natural Sciences, University of Brawijaya, East Java, Indonesia.
[3]Faculty of Animal Science, University of Brawijaya, East Java, Indonesia.
[4]Faculty of Administrative Sciences, University of Brawijaya, East Java, Indonesia.

Abstract: This study examines the influence of risk management implementation on occupational health and the work environment in welding activities within shipyard industries. Using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, the research identifies key factors affecting the effectiveness of risk management practices. The results indicate that welders' competency, facility availability, internal communication, and workers' knowledge and persuasion significantly enhance risk management implementation through the development of safe and professional work behavior. In contrast, company policy and work motivation show no significant effects, implying that formal regulations have not been fully embedded in the organizational culture. The study concludes that strengthening knowledge-sharing culture and communication systems is essential to improve risk awareness and proactive safety behavior. Practically, the findings highlight the importance of integrating continuous learning, competency development, and participatory communication into occupational safety programs to achieve a sustainable and healthy work environment.
Keywords: *Occupational health, PLS-SEM, Risk management, Shipyard industry, Welding safety, Work behavior.*

1. Introduction

In the shipbuilding industry, both for new construction and repair work, welding operators and materials are essential components, along with appropriate welding methods for joining processes. The development of modern steel construction technology, together with advances in welding processes and equipment, plays a crucial role in determining structural integrity and repair effectiveness. Therefore, operator skills and process control are critical factors [1]. Welded joints in steel structure fabrication require strict quality control and compliance with welding procedures, as the quality of the joints depends heavily on the welder's skills and the control of process parameters [2]. The application of welding techniques in steel construction is extensive, encompassing bridges, high-rise buildings, pipeline industries, pressure vessels, transportation, and shipbuilding [3].

A welder is a person who performs welding work in accordance with an approved welding procedure and has been qualified through testing as specified by classification regulations [4]. According to ISO 9606-1, a welder is defined as a person who performs manual or semi-automatic welding using a qualified welding procedure [5]. The DNV Rules for Classification - Part 2, Chapter 3 state that a welder is an individual approved to perform welding operations in accordance with a Welding Procedure Specification (WPS) [6]. Similarly, the American Bureau of Shipping (ABS) defines a welder as a person qualified to perform welding work under approved conditions and in compliance with applicable procedures [7]. Therefore, a welder can be defined as a skilled worker who possesses the necessary competence and official certification to carry out welding processes in accordance with an

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* Correspondence: nur.yanu@hangtuah.ac.id

approved Welding Procedure Specification (WPS), having successfully passed qualification tests administered by a recognized classification society.

Risk management is an activity undertaken to develop strategies for managing risks through the processes of identifying, analyzing, assessing, and ensuring that potential hazards are minimized or, where possible, eliminated altogether [8]. The existence of a formal risk management policy within a company enables risks arising during the production process to be properly managed and controlled, thereby preventing potential losses to the organization [9]. Several factors can influence the implementation of risk management, including welder competency, the presence of clear policies, the availability of facilities and infrastructure, and the emergence of work motivation [10]. These four factors are interrelated and can serve as important evaluation criteria for corporate risk management policies, as they directly influence welders' work behavior, which in turn determines the success of efforts to ensure welder health, occupational well-being, and a safe work environment. Welders who engage in welding operations daily are exposed to a high level of occupational health risks as well as environmental health hazards in the workplace [11].

Findings by Karimi Zeverdegani et al. [12] indicate that welding fumes consist of various metal oxides, particulate matter, and gases that can cause multiple health issues, including adverse effects on welders' reproductive health [12]. Welders exposed to metal-containing fumes experience alterations in reproductive hormones and oxidative stress levels, both of which may impair male reproductive function. Exposure to welding fumes has been associated with a significant increase in blood concentrations of several heavy metals, such as aluminum (Al), lead (Pb), and manganese (Mn), which are strongly correlated with reproductive disorders, including decreased IIEF-5 scores, reduced libido, and premature ejaculation. Moreover, welders often experience oxidative stress conditions resulting from decreased levels of antioxidant enzymes such as superoxide dismutase (SOD), along with hormonal disturbances affecting reproductive health. In relation to welding work, it is recommended that welders adopt comprehensive preventive measures, including the implementation of proper ventilation infrastructure, limitation of overexposure, regular monitoring of heavy metal levels, periodic health examinations, and the provision of adequate respiratory protective equipment.

According to Tsuji et al. [13], several studies conducted in Japan have reported a relationship between exposure to welding fumes and neurological dysfunction. In her research, Tsuji examined the association between manganese (Mn) exposure originating from welding fumes and neurological behavior among welders and non-welders working in the same environment. The study found a significant correlation between elevated Mn concentrations in the blood of welders and the occurrence of neurological dysfunction symptoms after long-term exposure. Furthermore, it was also suggested that non-welders in the same industrial setting might be exposed to Mn from welding fumes, although at lower concentrations [13].

The study conducted by Jönsson et al. [14] monitored the health conditions of welders by examining symptoms reported in their daily logs, particularly those related to eye and respiratory tract disorders under varying exposure conditions. The objective was to clarify the potential causes of health disturbances experienced by welders. Observations were carried out by identifying symptoms among welders who worked daily, with data collected three times every two weeks over the course of one year. The amount of respirable dust (RD) inhaled by each welder was measured during every monitoring period. The findings indicated that welders who were continuously exposed in the workplace faced an increased risk of developing various health symptoms, including eye irritation, nasal problems, dry cough, asthma, and/or dyspnea. The study concluded that the existing Occupational Exposure Limit (OEL) standards were insufficient to protect welders from exposure to welding particles that can cause eye and respiratory disorders [14].

2. Methods

This study employed a quantitative research method, which aims to address the research questions that have been formulated. The quantitative approach relies on numerical data to assist in analysis and interpretation.

in drawing conclusions based on empirical findings [15]. The rationale for adopting this method lies in its robust analytical tools and instruments that enable numerical data processing and mathematical analysis through the application of statistical techniques [16].

In research studies, the quantitative approach focuses on establishing theoretical foundations and hypotheses to be empirically tested, whereas the qualitative approach emphasizes theory and hypothesis development based on observed phenomena [17]. The present study was conducted using a survey method, with a structured questionnaire employed as the primary data collection instrument. A total of 130 responses were collected from 185 welders qualified in Shielded Metal Arc Welding (SMAW) and Flux-Cored Arc Welding (FCAW) at PT. Adiluhung Sarana Segara Indonesia (ASSI), a shipyard industry located in Madura, East Java, Indonesia, during the year 2025. The sample size in this study meets the minimum criteria recommended by Hair et al. [18]. In studies utilizing Partial Least Squares–Structural Equation Modeling (PLS-SEM), an adequate sample size is generally determined based on the number of indicators (observed variables), with a rule of thumb of 5–10 respondents per indicator, or at least 100–200 respondents for complex structural models [18].

The sampling technique used in this study was purposive sampling, which is a non-probability sampling method in which respondents are selected based on specific criteria determined by the researcher [19]. The selection criteria were established according to the research objectives, namely, individuals who actively work as welders or welding operators with a minimum of one year of professional experience in the welding field. The use of purposive sampling ensured that data were obtained from respondents who fully understood the context of the research problem, thereby increasing the accuracy and representativeness of the findings [20]. Data collection was conducted by visiting workshops and welding project sites at the shipyard, where researchers either interviewed welders directly or distributed questionnaires to those present at the time of data collection. Respondents completed the questionnaires independently by selecting the most appropriate responses based on their own experiences.

The survey instrument consisted of measurement scales designed to assess several latent constructs, including characteristics of welder competence, company policy, facilities, infrastructure, and information channels, job motivation, welder knowledge, implementation of corporate risk management, and indicators of welder behavior. These indicators were developed based on theoretical frameworks and empirical findings derived from previous studies, as well as insights obtained from preliminary field observations. Respondents were asked to complete the questionnaire honestly, providing their perceptions using a five-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5).

The collected data were then analyzed using Confirmatory Factor Analysis (CFA) to validate the measurement model and to test the structural (inner) model comprising the variables: welder competence characteristics (X1), company policy (X2), facilities, infrastructure, and information channels (X3), job motivation (X4), welder knowledge (X5), implementation of corporate risk management (Y1), and indicators of welder behavior (Y2). The analysis employed the Partial Least Squares-Structural Equation Modeling (PLS-SEM) approach, which was chosen for its ability to handle complex models and relatively small sample sizes.

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Table 1.
Exogenous, Endogenous, and Manifest Variables in the PLS-SEM Model.

Latent Variable / Construct	Manifest Variable / Indicator	Code
Welder Competence Characteristics		X1
	Has a high level of discipline	X1.1
	Has good accuracy and precision	X1.2
	Understands welding safety procedures	X1.3
	Understands welding quality standards	X1.4
	Possesses adequate welding skills	X1.5
Company Policy		X2
	Availability of occupational safety, health, and environmental (OSHE) policies for welders	X2.1
	Dissemination of company policies to welders	X2.2
	Continuous implementation of policies	X2.3
	Implementation of a welder career development system	X2.4
Facilities, Infrastructure, and Communication Channels		X3
	Availability of adequate welding equipment	X3.1
	Existence of interpersonal/local communication and discussion	X3.2
	Existence of cosmopolitan/external communication using electronic media	X3.3
	Existence of cosmopolite/external communication using print media	X3.4
Work Motivation within the Company's Social System		X4
	Actively participates in worker organizations	X4.1
	Actively participates in socialization activities	X4.2
	Actively participates in training activities	X4.3
Knowledge and Persuasion		X5
	Awareness and understanding of welding job risks	X5.1
	Interest in and active search for information about welding job risks	X5.2
	Mentoring process in understanding welding job risks	X5.3
Implementation of Corporate Risk Management		Y1
	Establishment of OSHE policies	Y1.1
	Planning of OSHE policies	Y1.2
	Implementation of OSHE programs	Y1.3
	Monitoring and evaluation of OSHE performance	Y1.4
	Review and improvement of OSHE performance	Y1.5
Indicators of Welder Behavior		Y2
	Welder's welfare level	Y2.1
	Welder's health condition	Y2.2
	Workplace health and environmental conditions	Y2.3

The data analysis process was carried out by eliminating latent variables and constructs that were not statistically significant until the final research model was obtained. The validity of the model was determined based on the factor loading values in the outer model using Partial Least Squares-Structural Equation Modeling (PLS-SEM). The next stage involved testing the structural model of the study, which examined the hypotheses regarding the influence of the five variables (X1 to X5) on the *implementation of risk management* (Y1) as a mediating variable, and its relationship with the *indicators of welder behavior* (Y2).

Data analysis in this study employed the variance-based PLS-SEM approach. The PLS-SEM model consists of three main components: the structural model, the measurement model, and the weighting scheme [21]. The research variables in the variance-based Structural Equation Modeling (SEM) framework comprise both latent and manifest variables. Latent variables, also referred to as constructs, are those that cannot be directly measured within the SEM model [22]. The model modification process was performed by eliminating non-significant latent variables and constructs until the final model was achieved. The validity of this final model was confirmed through the factor loading values of the outer model in the PLS-SEM analysis.

The path diagram in the PLS-SEM model was employed to examine the influence of *characteristics of welder competence* (X1), *company policy* (X2), *facilities, infrastructure, and information channels* (X3), *job motivation* (X4), and *welder knowledge* (X5) through *implementation of risk management* (Y1) on the *indicators of welder behavior* (Y2). These variables were constructed using a reflective indicator approach, as indicated by the directional arrows pointing from the latent variables to their corresponding constructs. The use of reflective indicators for these variables was based on the assumption that the indicators represent reflections of the latent constructs they measure. This approach aligns with the perspective of Fornell and Bookstein, who emphasize that when indicators are reflections of a construct, particularly in contexts related to attitudes and personality traits, the reflective measurement model should be applied [23].

In processing the questionnaire data, a Goodness of Fit analysis was also conducted to measure the extent of influence of *characteristics of welder competence* (X1), *company policy* (X2), *facilities, infrastructure, and information channels* (X3), *job motivation within the company's social system* (X4), and *knowledge and persuasion* (X5) through *implementation of corporate risk management* (Y1) on *welder behavior* (Y2). The model's adequacy or goodness of fit was assessed using the R-square (R^2) values of the dependent latent variables, which are interpreted similarly to those in regression analysis. In addition, the Q-square (Q^2) predictive relevance value was used to evaluate how well the structural model is capable of predicting observed values and estimating the existing parameters [24].

3. Results

The Goodness of Fit (GoF) measurement in this study aimed to evaluate the extent to which the proposed structural model fits the empirical data. The Standardized Root Mean Square Residual (SRMR) represents the average standardized difference between the observed covariances and the covariances predicted by the model. SRMR indicates the magnitude of the discrepancy between the actual data and the data predicted by the model. A smaller SRMR value signifies a better model fit, and generally, an SRMR value of ≤ 0.08 is considered to indicate a good fit. The estimated model refers to the model that conforms to the hypothesized structural relationships in the study, meaning that not all constructs are connected; only those supported by the theoretical framework. The SRMR value of the estimated model reflects how well the actual research model fits the empirical data. The results of the analysis show that the SRMR values for both the saturated model and the estimated model were 0.118, which is slightly above the ideal threshold (≤ 0.10). However, the model fit can still be categorized as reasonably acceptable (see Table 2).

Table 2.
Goodness of Fit (GoF) Measurement.

Fit Index	Estimated Model
SRMR (Standardized Root Mean Square Residual)	0.118
d_ULS (Unweighted Least Squares Discrepancy)	5.275
d_G (Geodesic Discrepancy)	2.041
Chi-Square (χ^2)	1250.002
NFI (Normed Fit Index)	0.619
RMSEA (Root Mean Square Error of Approximation)	0.168

The Normed Fit Index (NFI) was used to assess the degree of model fit between the hypothesized research model (estimated model) and the baseline model (null model), which assumes no relationships among the constructs. In this study, the NFI value of 0.619 indicates that the model demonstrates a relatively moderate level of fit. This suggests that the hypothesized structural relationships in the research model are not substantially different from the maximum level of fit that could be achieved. In general, NFI values range from 0 to 1, where values closer to 1 represent a better model fit. An NFI value of 0.619 falls within the moderate category, meaning that the model achieves an acceptable level of fit, although not yet optimal. Within the context of exploratory research, this value is still considered acceptable, as it implies that the model is capable of empirically explaining a substantial portion of the relationships among the latent variables.

The Root Mean Square Error of Approximation (RMSEA) is one of the key Goodness of Fit (GoF) indices used in structural model analysis to evaluate how well a theoretical model fits the observed data. RMSEA measures the degree of approximation error per degree of freedom in the model; in other words, it indicates how effectively a model with a given number of parameters represents the actual population data. Unlike other fit indices, RMSEA accounts for model complexity, meaning that a more complex model is not necessarily considered superior. Therefore, the RMSEA value reflects the extent to which the model approximates the true data structure while considering potential estimation errors. A smaller RMSEA value indicates a better fit between the model and the empirical data. In this study, the RMSEA value of 0.168 suggests a relatively high level of approximation error. Based on the established *goodness-of-fit* criteria, an RMSEA value exceeding 0.10 indicates a poor model fit. Thus, the proposed structural model does not adequately represent the empirical data and requires modification or re-specification of the relationships among variables to achieve a better model fit.

In the PLS-SEM–based data analysis, the Goodness of Fit (GoF) value is calculated as the square root of the product of the Average Variance Extracted (AVE) and the R^2 value of the endogenous variables. A higher GoF value indicates a better overall model fit [25, 26]. In addition, model adequacy was further evaluated through the assessment of reliability, construct validity, and predictive relevance, as recommended by Hair et al. [18]. The convergent validity test can be evaluated using two main criteria: the outer loading coefficients and the Average Variance Extracted (AVE) values. A reflective indicator is considered to have a strong relationship with the construct it measures if its loading factor exceeds 0.70 [27]. However, according to Jonathan [21], an outer loading value of 0.60 may still be regarded as acceptable. The results of this analysis are presented in Table 3.

Table 3.
Outer Loading Values for the Welder Competence Characteristics Variable (X1).

Indicator	Loading Factor	P-Value
Has a high level of discipline ← Welder Competence Characteristics	0.875	0.000
Has good accuracy and precision ← Welder Competence Characteristics	0.881	0.000
Understands welding safety procedures ← Welder Competence Characteristics	0.890	0.000
Understands welding quality standards ← Welder Competence Characteristics	0.884	0.000
Possesses adequate welding skills ← Welder Competence Characteristics	0.921	0.000

Table 3 presents the outer loading results for the *Welder Competence Characteristics* variable (X1). It is observed that all five indicators have outer loading values greater than 0.7, with p-values less than 0.05. Therefore, all indicators of the *Welder Competence Characteristics* variable (X1) meet the criteria for convergent validity, indicating that these indicators are capable of accurately measuring the latent construct of *Welder Competence Characteristics.*

Table 4.
Outer Loading Values for the Variable *Company Policy (X2)*.

Indicator	Loading Factor	P-Value
Existence of occupational health, safety, and environmental policies for welders ← Company Policy	0.822	0.000
Dissemination of policies to welding workers ← Company Policy	0.834	0.000
Continuous implementation of company policies ← Company Policy	0.840	0.000
Implementation of the welder career path system ← Company Policy	0.567	0.000

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Table 4 presents the outer loading results for the *Company Policy (X2)* construct. Among the four indicators, one indicator (X2.4) exhibits an outer loading value below the recommended threshold of 0.7, while the other three indicators demonstrate acceptable loading values above 0.7, all with p-values less than 0.05. Although most indicators meet the criterion for convergent validity, the relatively low loading of X2.4 suggests a weaker contribution to the overall construct, indicating that the measurement of the *Company Policy (X2)* variable may require further refinement.

Table 5.
Outer Loading Values for the Variable *Facilities, Infrastructure, and Information Channels (X3).*

Indicator	Loading Factor	P-Value
Availability of adequate welding equipment ← Facilities, infrastructure, and information channels	0.625	0.000
Existence of interpersonal/local communication through discussion ← Facilities, infrastructure, and information channels	0.693	0.000
Existence of cosmopolitan communication/outside local systems using electronic media ← Facilities, infrastructure, and information channels	0.836	0.000
Existence of cosmopolitan communication/outside local systems using printed media ← Facilities, infrastructure, and information channels	0.816	0.000

Table 5 presents the outer loading results for the *Facilities, Infrastructure, and Information Channels (X3)* variable. The findings indicate that two indicators (X3.1 and X3.2) have outer loading values below 0.7 with *p*-values less than 0.05, while the other two indicators (X3.3 and X3.4) have outer loading values above 0.7 with *p*-values less than 0.05. Thus, these four indicators are considered to insufficiently meet the criteria for convergent validity, suggesting that the indicators are less capable of adequately representing the *Facilities, Infrastructure, and Information Channels (X3)* construct.

Table 6.
Outer Loading Values for the Variable *Job Motivation within the Company's Social System (X4).*

Indicator	Loading Factor	P-Value
Actively participates in existing worker organizations ← Job Motivation within the Company's Social System	0.713	0.000
Actively participates in socialization activities ← Job Motivation within the Company's Social System	0.739	0.000
Actively participates in training activities ← Job Motivation within the Company's Social System	0.839	0.000

Table 6 presents the outer loading results for the variable *Job Motivation within the Company's Social System (X4)*, showing that all three indicators have outer loading values above 0.7 with p-values less than 0.05. Therefore, all indicators are considered to meet the criteria for convergent validity, indicating that these indicators are capable of effectively measuring the construct of *Job Motivation within the Company's Social System (X4).*

Table 7.
Outer Loading Values for the Variable Knowledge and Persuasion (X5).

Indicator	Loading Factor	P-Value
Awareness and understanding of welding job risks ← Knowledge and Persuasion	0.878	0.000
Interest and active information seeking about welding job risks ← Knowledge and Persuasion	0.369	0.000
Assistance in the process of understanding welding job risks ← Knowledge and Persuasion	0.858	0.000

Table 7 presents the outer loading results for the *Knowledge and Persuasion (X5)* variable. The findings indicate that among the three indicators, one indicator (X5.2) has an outer loading value below 0.7 with a p-value less than 0.05, while the other two indicators have outer loading values above 0.7

with p-values less than 0.05. Therefore, these three indicators are considered to insufficiently meet the criteria for convergent validity, suggesting that the indicators are less effective in adequately representing the *Knowledge and Persuasion (X5)* construct.

Table 8.
Outer Loading Values for the Variable Corporate Risk Management Implementation (Y1).

Indicator	Loading Factor	P-Value
Establishment of OHS policy ← Corporate Risk Management Implementation	0.881	0.000
Planning of OHS policy ← Corporate Risk Management Implementation	0.888	0.000
Implementation of OHS policy ← Corporate Risk Management Implementation	0.844	0.000
Monitoring and evaluation of OHS performance ← Corporate Risk Management Implementation	0.835	0.000
Review and improvement of performance ← Corporate Risk Management Implementation	0.766	0.000

Table 8 presents the outer loading results for the *Corporate Risk Management Implementation (Y1)* variable. The findings indicate that all five indicators have outer loading values greater than 0.7, with p-values less than 0.05. Therefore, these indicators are considered to meet the criteria for convergent validity, implying that they effectively measure the *Corporate Risk Management Implementation (Y1)* construct.

Table 9.
Outer Loading Values for the Welder Behavior Indicator Variable (Y2).

Indicator	Loading Factor	P-Value
Welder's welfare level ← Welder behavior indicator	0.940	0.000
Welder's health condition ← Welder behavior indicator	0.946	0.000
Health and environmental condition ← Welder behavior indicator	0.951	0.000

Table 9 presents the outer loading results for the *Welder Behavior Indicator (Y2)* variable. The findings reveal that all three indicators have outer loading values above 0.7, with p-values less than 0.05. Therefore, these indicators meet the criteria for convergent validity, indicating that they effectively measure the *Welder Behavior Indicator (Y2)* construct.

Table 10.
Average Variance Extracted (AVE).

Variable	Average Variance Extracted (AVE)
Welder Competency Characteristics (X1)	0.793
Company Policy (X2)	0.599
Facilities, Infrastructure, and Communication Channels (X3)	0.559
Work Motivation within the Company's Social System (X4)	0.586
Knowledge and Persuasion (X5)	0.548
Implementation of Corporate Risk Management (Y1)	0.712
Indicators of Welder Behavior (Y2)	0.894

Table 10 presents the output results from data processing using SmartPLS, showing that the Average Variance Extracted (AVE) values for all constructs are above 0.5. Therefore, it can be concluded that the constructs *Welder Competency Characteristics (X1)*, *Company Policy (X2)*, *Facilities, Infrastructure, and Communication Channels (X3)*, *Work Motivation within the Company's Social System (X4)*, *Knowledge and Persuasion (X5)*, *Implementation of Corporate Risk Management (Y1)*, and *Indicators of Welder Behavior (Y2)* are included in a well-fitting model. Consequently, all constructs in the estimated model have satisfied the criteria for discriminant validity [25].

Table 11.
Composite Reliability.

Variable	Composite Reliability
Welder Competency Characteristics (X1)	0.950
Company Policy (X2)	0.854
Facilities, Infrastructure, and Communication Channels (X3)	0.833
Work Motivation within the Company's Social System (X4)	0.808
Knowledge and Persuasion (X5)	0.766
Implementation of Corporate Risk Management (Y1)	0.925
Indicators of Welder Behavior (Y2)	0.962

A model is considered to have good composite reliability when its value exceeds 0.70 [18]. Based on the results presented in Table 11, all constructs in the model exhibit composite reliability values greater than 0.70. Therefore, it can be concluded that the measurement model (outer model) with reflective indicators demonstrates a high level of reliability. According to Chin and ewsted [28], in exploratory research, loading factor values ranging from 0.5 to 0.6 are considered acceptable [28]. Consequently, it can be inferred that all indicators within the variables, *Welder Competency Characteristics (X1)*, *Company Policy (X2)*, *Facilities, Infrastructure, and Communication Channels (X3)*, *Work Motivation within the Company's Social System (X4)*, *Knowledge and Persuasion (X5)*, *Implementation of Corporate Risk Management (Y1)*, and *Indicators of Welder Behavior (Y2)*, exhibit strong consistency in representing their respective latent variables. Thus, the research model fulfills the criteria for composite reliability.

Table 12.
Construct Reliability (Cronbach's Alpha).

Construct	Cronbach's Alpha
Welder Competency Characteristics (X1)	0.935
Company Policy (X2)	0.773
Facilities, Infrastructure, and Communication Channels (X3)	0.732
Work Motivation within the Company's Social System (X4)	0.650
Knowledge and Persuasion (X5)	0.584
Implementation of Corporate Risk Management (Y1)	0.898
Indicators of Welder Behavior (Y2)	0.943

Construct Reliability (Cronbach's Alpha) is used to assess the internal consistency or reliability of a construct or latent variable. A construct is considered reliable if its value exceeds 0.70. However, in exploratory research, reliability values between 0.5 and 0.6 are deemed acceptable to support the validity of research findings [29].

Based on the results presented in Table 11, the Cronbach's Alpha values for the variables are as follows: *Welder Competency Characteristics (X1)* = 0.935, *Company Policy (X2)* = 0.773, *Facilities, Infrastructure, and Communication Channels (X3)* = 0.732, *Work Motivation within the Company's Social System (X4)* = 0.650, *Knowledge and Persuasion (X5)* = 0.584, *Implementation of Corporate Risk Management (Y1)* = 0.898, and *Indicators of Welder Behavior (Y2)* = 0.943.

These results indicate that variables X4 and X5 have reliability values below 0.70, while the remaining variables exhibit reliability values above 0.70. Therefore, all variables in the research model, *Welder Competency Characteristics (X1)*, *Company Policy (X2)*, *Facilities, Infrastructure, and Communication Channels (X3)*, *Work Motivation within the Company's Social System (X4)*, *Knowledge and Persuasion (X5)*, *Implementation of Corporate Risk Management (Y1)*, and *Indicators of Welder Behavior (Y2)*, demonstrate adequate construct reliability [29]. This indicates that each latent variable in the model has strong internal consistency, confirming that the research model meets the construct reliability criteria sufficiently.

Table 13.
Construct Reliability (Rho_A).

Construct	Rho_A
Welder Competency Characteristics (X1)	0.943
Company Policy (X2)	0.812
Facilities, Infrastructure, and Communication Channels (X3)	0.754
Work Motivation within the Company's Social System (X4)	0.678
Knowledge and Persuasion (X5)	0.728
Implementation of Corporate Risk Management (Y1)	0.904
Indicators of Welder Behavior (Y2)	1.016

According to Dijkstra and Henseler [23], the development of rho_A in the PLS-SEM (Partial Least Squares Structural Equation Modeling) approach serves as a measure of construct reliability that is considered more accurate than Cronbach's Alpha or Composite Reliability. This is because rho_A accounts for the true relationships between indicators and latent constructs, providing a more precise assessment of internal reliability.

Rho_A reflects the internal consistency of the indicators forming a latent variable (construct). It indicates the extent to which the indicators within a single latent variable consistently measure the same concept. The higher the Rho_A value (≥ 0.7), the greater the reliability of the construct in the SEM model. The advantage of Rho_A lies in its ability to combine the strengths of Cronbach's Alpha and Composite Reliability, making it highly recommended as it approximates true reliability most closely.

Table 13 shows that the rho_A values for the variables are as follows: Welder Competency Characteristics (X1) = 0.943, Company Policy (X2) = 0.812, Facilities, Infrastructure, and Communication Channels (X3) = 0.754, Work Motivation within the Company's Social System (X4) = 0.678, Knowledge and Persuasion (X5) = 0.728, Implementation of Corporate Risk Management (Y1) = 0.904, and Indicators of Welder Behavior (Y2) = 1.016.

These results indicate that only variable X4 has a reliability value below 0.70, while all other variables show reliability values above 0.70. Therefore, all variables in the research model, Welder Competency Characteristics (X1), Company Policy (X2), Facilities, Infrastructure, and Communication Channels (X3), Work Motivation within the Company's Social System (X4), Knowledge and Persuasion (X5), Implementation of Corporate Risk Management (Y1), and Indicators of Welder Behavior (Y2), demonstrate adequate construct reliability [23]. This indicates that each latent variable in the model possesses strong internal consistency, confirming that the research model meets the construct reliability criteria satisfactorily.

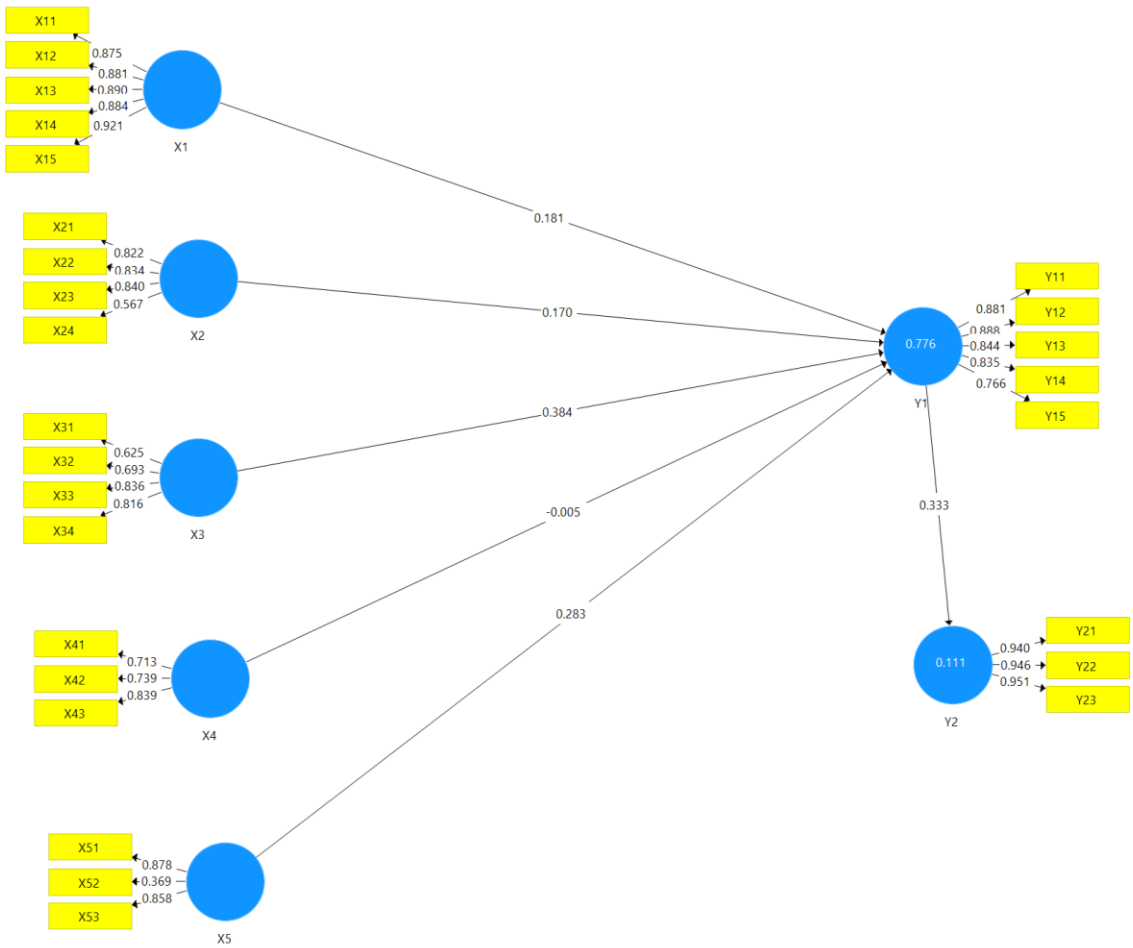

Figure 1.
Outer Model of the Study.

3.1. Direct Effect of Exogenous Variables on Endogenous Variables

The direct effect of exogenous variables on endogenous variables refers to the causal relationship between two types of variables within a research model. Exogenous variables act as independent variables, representing factors that influence or cause changes in other variables. Endogenous variables function as dependent variables, representing factors that are directly affected or are the direct outcomes of exogenous variables [18]. In other words, the direct effect of exogenous variables on endogenous variables indicates the magnitude of the contribution or impact that the independent variables have on the dependent variables within the research model. The results of the data analysis examining the direct effect of exogenous variables on endogenous variables are presented in Table 14.

Table 14.
Direct Effect of Exogenous Variables on Endogenous Variables.

Exogenous Variable → Endogenous Variable	Path Coefficient (Direct Effect)	*P-Value*
Welder Competency Characteristics (X1) → Implementation of Corporate Risk Management (Y1)	0.181	0.017
Company Policy (X2) → Implementation of Corporate Risk Management (Y1)	0.170	0.124
Facilities, Infrastructure, and Communication Channels (X3) → Implementation of Corporate Risk Management (Y1)	0.384	0.000
Work Motivation within the Company's Social System (X4) → Implementation of Corporate Risk Management (Y1)	-0.005	0.957
Knowledge and Persuasion (X5) → Implementation of Corporate Risk Management (Y1)	0.283	0.000
Implementation of Corporate Risk Management (Y1) → Indicators of Welder Behavior (Y2)	0.333	0.000

The estimation results of the inner model indicate that the direct effect of *Welder Competency Characteristics (X1)* on the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.017, which is below the significance level of 0.05. This shows a significant and positive direct effect between *Welder Competency Characteristics (X1)* and the *Implementation of Corporate Risk Management (Y1)*, with a path coefficient of 0.181. The positive relationship implies that higher levels of *Welder Competency Characteristics (X1)* lead to an increase in the *Implementation of Corporate Risk Management (Y1)*. Conversely, a decrease in *Welder Competency Characteristics (X1)* will result in a reduction in the *Implementation of Corporate Risk Management (Y1)*. Therefore, it can be concluded that enhancing welder competency characteristics can improve the implementation of risk management within the company.

The estimation results of the inner model indicate that the direct effect of *Company Policy (X2)* on the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.124, which is greater than the significance level of 0.05. Therefore, the direct effect is not statistically significant, although it is positive, with a path coefficient of 0.170. The positive relationship suggests that higher levels of *Company Policy (X2)* are associated with an increase in the *Implementation of Corporate Risk Management (Y1)*, whereas a decrease in *Company Policy (X2)* would correspond to a reduction in Y1. Based on the non-significant p-value, it can be concluded that *Company Policy* does not yet have a direct impact on the implementation of risk management.

The estimation results of the inner model indicate that the direct effect of *Facilities, Infrastructure, and Information Channels (X3)* on the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.000, which is below the significance level of 0.05. Therefore, there is a significant and positive direct effect, with a path coefficient of 0.389. This positive relationship suggests that higher levels of *Facilities, Infrastructure, and Information Channels (X3)* lead to an increase in the *Implementation of Corporate Risk Management (Y1)*. Conversely, a decrease in X3 would result in a reduction in Y1. It can thus be concluded that adequate facilities, infrastructure, and communication channels strengthen the implementation of risk management.

The estimation results of the inner model indicate that the direct effect of *Job Motivation within the corporate social system (X4)* on the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.957, which exceeds the significance level of 0.05. Consequently, there is an insignificant and negative direct effect, with a path coefficient of -0.005. This negative relationship suggests that higher levels of *Job Motivation (X4)* are associated with a slight decrease in the *Implementation of Corporate Risk Management (Y1)*, while a decrease in X4 would slightly increase Y1. Based on the non-significant p-value, it can be concluded that *Job Motivation* within the corporate social system does not have a direct effect on the implementation of risk management in the company.

The estimation results of the inner model indicate that the direct effect of *Knowledge and Persuasion (X5)* on the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.000, which is below the significance level of 0.05. Therefore, there is a significant and positive direct effect, with a path coefficient of 0.283. This positive relationship suggests that higher levels of *Knowledge and Persuasion (X5)* lead to an increase in the *Implementation of Corporate Risk Management (Y1)*, whereas a decrease in X5 would result in a reduction in Y1. Thus, it can be concluded that Knowledge and Persuasion positively contribute to enhancing risk management implementation in the company.

The inner model estimation also shows that the direct effect of the *Implementation of Corporate Risk Management (Y1)* on *Welder Behavior Indicators (Y2)* has a p-value of 0.000, which is below the significance level of 0.05. Therefore, there is a significant and positive direct effect, with a path coefficient of 0.333. This positive relationship indicates that higher levels of Y1 are associated with an increase in Y2, while a decrease in Y1 would reduce Y2. Hence, it can be concluded that the implementation of corporate risk management positively affects welder behavior indicators.

Based on the analysis of the direct effects of exogenous variables on endogenous variables, several conclusions can be drawn: the *Implementation of Corporate Risk Management (Y1)* is significantly influenced by *Welder Competence Characteristics (X1)*, *Facilities, Infrastructure, and Information Channels (X3)*, and *Knowledge and Persuasion (X5)*. In contrast, *Job Motivation within the corporate social system (X4)* and *Company Policy (X2)* do not have a significant direct effect on Y1. Furthermore, Y1 significantly influences the *Welder Behavior Indicators (Y2)*.

3.2. Indirect Effect of Exogenous Variables on Endogenous Variables

The indirect effect reflects the strength of the relationship between exogenous and endogenous variables that occurs through the involvement of a mediating variable in the research model. An indirect effect arises when an exogenous variable influences an endogenous variable through another variable acting as a mediator. In this context, the endogenous variable serves as the dependent variable, which is indirectly affected by the exogenous (independent) variable [30].

The results of the data analysis examining the indirect effect of exogenous variables on endogenous variables are presented in Table 15.

Table 15.
Indirect Effect of Exogenous Variables on Endogenous Variables.

Path	Coefficient of Indirect Effect	P-Value
Welder Competence Characteristics (X1) → Implementation of Corporate Risk Management (Y1) → Welder Behavior Indicators (Y2)	0.060	0.079
Company Policy (X2) → Implementation of Corporate Risk Management (Y1) → Welder Behavior Indicators (Y2)	0.056	0.157
Facilities, Infrastructure, and Information Channels (X3) → Implementation of Corporate Risk Management (Y1) → Welder Behavior Indicators (Y2)	0.128	0.002
Work Motivation in the Company's Social System (X4) → Implementation of Corporate Risk Management (Y1) → Welder Behavior Indicators (Y2)	-0.002	0.955
Knowledge and Persuasion (X5) → Implementation of Corporate Risk Management (Y1) → Welder Behavior Indicators (Y2)	0.094	0.004

The inner model estimation results indicate that the indirect effect of *Welder Competence Characteristics (X1)* on *Welder Behavior Indicators (Y2)* through the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.079, which is greater than the significance level of 0.05. Therefore, the indirect effect is positive but not statistically significant, with a coefficient of 0.060. This positive relationship suggests that better *Welder Competence Characteristics (X1)* can contribute to an increase in the *Implementation of Corporate Risk Management (Y1)*, which in turn could enhance *Welder Behavior Indicators (Y2)*. Conversely, lower competence characteristics would reduce the *Implementation of Corporate Risk Management (Y1)*, potentially leading to a decrease in *Welder Behavior Indicators (Y2)*. In conclusion, the effect of *Welder Competence Characteristics* on *Welder Behavior Indicators* is not significantly mediated by the *Implementation of Corporate Risk Management*.

The inner model estimation results indicate that the indirect effect of *Company Policy (X2)* on *Welder Behavior Indicators (Y2)* through the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.157, which is greater than the significance level of 0.05. Therefore, the indirect effect is positive but not statistically significant, with a coefficient of 0.056. This positive relationship suggests that better *Company Policy (X2)* may contribute to an increase in the *Implementation of Corporate Risk Management (Y1)*, which in turn could enhance *Welder Behavior Indicators (Y2)*. Conversely, poorer *Company Policy (X2)* would reduce the *Implementation of Corporate Risk Management (Y1)*, potentially leading to a decrease in *Welder Behavior Indicators (Y2)*. In conclusion, the effect of *Company Policy* on *Welder Behavior Indicators* is not significantly mediated by the *Implementation of Corporate Risk Management*.

The inner model estimation results indicate that the indirect effect of *Facilities, Infrastructure, and Information Channels (X3)* on *Welder Behavior Indicators (Y2)* through the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.002, which is less than the significance level of 0.05. This indicates that the relationship between these variables is statistically significant and positive, with a coefficient of 0.128. The positive relationship suggests that better *Facilities, Infrastructure, and Information Channels (X3)* lead to an increase in the *Implementation of Corporate Risk Management (Y1)*, which in turn enhances *Welder Behavior Indicators (Y2)*. Conversely, suboptimal *Facilities, Infrastructure, and Information Channels (X3)* would reduce the *Implementation of Corporate Risk Management (Y1)*, subsequently lowering *Welder Behavior Indicators (Y2)*. Therefore, it can be concluded that the effect of *Facilities, Infrastructure, and Information Channels* on *Welder Behavior Indicators* is significantly mediated by the *Implementation of Corporate Risk Management*, indicating that this indirect pathway is effective within the research model.

The inner model estimation results show that the indirect effect of *Job Motivation in the Corporate Social System (X4)* on *Welder Behavior Indicators (Y2)* through the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.955, which is greater than the significance level of 0.05, with a negative coefficient of -0.002. This indicates that the effect is negative but not statistically significant. The coefficient of -0.002 reflects a negative relationship between these variables, suggesting that an increase in *Job Motivation in the Corporate Social System (X4)* does not meaningfully reduce *Welder Behavior Indicators (Y2)* via the *Implementation of Corporate Risk Management (Y1)*. Conversely, lower levels of *Job Motivation in the Corporate Social System (X4)* do not significantly increase *Welder Behavior Indicators (Y2)* through Y1. Therefore, it can be concluded that the mediating variable does not effectively bridge the relationship between *Job Motivation in the Corporate Social System* and welder behavior, implying that the observed effect is weak and not empirically meaningful.

Based on the inner model estimation results, the indirect effect of *Knowledge and Persuasion (X5)* on *Welder Behavior Indicators (Y2)* through the *Implementation of Corporate Risk Management (Y1)* has a p-value of 0.004, which is below the significance level of 0.05. This indicates that the relationship between these variables is significant and the effect is positive, with a coefficient of 0.094. The positive direction of this relationship suggests that higher levels of *Knowledge and Persuasion (X5)* tend to enhance the *Implementation of Corporate Risk Management (Y1)*, which in turn can increase *Welder Behavior Indicators (Y2)*. Conversely, if *Knowledge and Persuasion (X5)* are suboptimal, it may reduce the *Implementation of Corporate Risk Management (Y1)*, ultimately lowering *Welder Behavior Indicators (Y2)*. Therefore, it can be concluded that the effect of *Knowledge and Persuasion* on *Welder Behavior Indicators* is significantly mediated by the *Implementation of Corporate Risk Management*.

4. Discussion

The PLS (Partial Least Squares) method does not assume any specific distribution for parameter estimation, and therefore significance testing of parameters does not require a parametric approach [28]. Consequently, the PLS model assessment emphasizes non-parametric predictive capabilities. In the case of measurement models (outer models) using formative indicators, evaluation of convergent validity and discriminant validity is not required, nor is composite reliability testing of the indicator blocks necessary. The assessment of outer models with formative indicators is based on substantive content, which involves comparing relative weights and testing the significance of these weights [28].

Meanwhile, the inner model or structural model is evaluated by examining the proportion of variance explained, using the R^2 values of the dependent latent constructs and the Stone-Geisser Q^2 test [31] while also considering the magnitude of the path coefficients. The outer model represents the relationships between latent variables and their indicators. In other words, the outer model illustrates how each indicator is associated with the latent variable it represents [21]. The output of the PLS analysis for the complete model presents the outer loading values for each variable. This measurement model demonstrates the extent to which indicators contribute to reflecting the latent variable being measured or how well they capture the relationship between the construct and its constituent indicators [32]. The highest outer loading value within a variable identifies the indicator that is most representative of that variable.

The results of the study indicate that the Composite Reliability (CR) and Average Variance Extracted (AVE) values for the constructs of *Characteristics of Welder Competence (X1)*, *Company Policy (X2)*, *Facilities, Infrastructure, and Information Channels (X3)*, *Job Motivation (X4)*, and *Welder Knowledge and Persuasion (X5)* through the *Implementation of Risk Management (Y1)* on *Indicators of Welder Behavior (Y2)* demonstrate that all constructs meet the criteria for adequate reliability and validity. Although the *Welder Knowledge and Persuasion* construct (X5) has the lowest reliability value ($\alpha = 0.584$), this value remains within an acceptable tolerance range, and therefore, its indicators were retained in the model. The measurement model assessment (outer loading) shows that nearly all indicators have loading values above 0.70, indicating that convergent validity has been achieved [18]. However, indicator X5.2, namely "interested in and actively seeking information on welding job risks," exhibits a relatively low loading value (0.369), warranting further attention as it may potentially reduce the convergent validity of the welder knowledge and persuasion construct.

The low outer loading of indicator X5.2, namely "interest in and actively seeking information on welding job risks," suggests that the individual initiative component in seeking risk-related information has not yet emerged as a strong dimension of the Welder Knowledge and Persuasion construct. This condition may be attributed to limited access to occupational safety information, a lack of a knowledge-sharing culture, and insufficient organizational support in promoting proactive safety behavior. These findings are consistent with the Theory of Planned Behavior, which posits that individual behavior is influenced by attitudes, subjective norms, and perceived behavioral control [33]. The low contribution of indicator X5.2 indicates that, although welders possess a basic understanding of risk management, their internal motivation to seek additional information remains limited. This also reflects weak motivational and social factors shaping risk-aware behavior in the workplace.

The effectiveness of safety behavior heavily depends on the interaction between individual knowledge and an organizational culture that supports learning from risks [34]. Accordingly, the low loading value of indicator X5.2 may signal that the company has not fully fostered an environment conducive to collective learning and the dissemination of risk-related information. To enhance the validity of the Welder Knowledge and Persuasion construct while strengthening the implementation of risk management, the company needs to undertake strategic interventions, including reinforcing internal communication, providing participatory-based training, and offering incentives to workers who demonstrate proactive behavior in seeking risk information. This strategy aligns with the view that construct validity and reliability are not solely statistical measures but also reflect the extent to which theoretical concepts are represented in empirical contexts [24]. By implementing these strategies, it is expected that the "knowledge-seeking" component will improve, thereby strengthening the influence of Welder Knowledge and Persuasion on safe work behavior and optimizing the effectiveness of the company's risk management system.

The analysis results indicate that the implementation of corporate risk management is significantly influenced by several key factors. First, the characteristics of welder competence play a crucial role in the effectiveness of risk management implementation. Enhanced technical skills, possession of certifications, and work proficiency have been shown to strengthen welders' ability to identify and control potential workplace hazards. This finding aligns with previous views suggesting that safety behavior is the outcome of interactions among individual, environmental, and organizational factors, where work competence forms the foundation for awareness and compliance with safety procedures [35]. Second, the availability of facilities and infrastructure, as well as the effectiveness of internal information and communication channels, are important factors supporting the successful implementation of a risk management system. Adequate infrastructure and smooth communication enable efficient processes for reporting, coordination, and problem-solving related to risks. This condition is consistent with prior findings stating that effective communication systems contribute to building a resilient organization, in which errors can be minimized through rapid and transparent feedback [34]. Third, knowledge and persuasion factors also contribute significantly to shaping welder behavior.

Awareness and understanding of the importance of risk management, coupled with the ability to persuade and influence colleagues, act as drivers for safe and professional work behavior. This finding is consistent with the Theory of Planned Behavior, which posits that an individual's intentions and behaviors are influenced by attitudes, subjective norms, and perceived behavioral control [33]. Meanwhile, company policy and work motivation within the organizational social system have not shown a dominant influence on the implementation of risk management. These findings suggest that formal policies have not been fully internalized into the work culture, and employee motivation may not yet be directed toward safety aspects. This situation can occur when an organization has not fully developed a strong safety culture, in which safety-related values and behaviors are embedded within the social system of the company [34].

This study supports previous findings by demonstrating that the implementation of risk management has a significant impact on improving the health and working environment in welding operations. Based on structural model analysis (PLS-SEM), the risk management variable was found to contribute positively to the effectiveness of worker protection and the reduction of potential hazards in welding areas. The findings indicate that the better the processes of risk identification, assessment, and control are implemented, the higher the level of occupational health and safety achieved. This is consistent with prior studies emphasizing that risk management in welding work must consider the combined effects of chemical and physical hazards, which can significantly affect welders' health [36]. Chronic exposure to metal dust particles, toxic gases, and heat radiation has been shown to cause various health disorders, including heavy metal intoxication, such as manganese, and potential carcinogenic effects. Therefore, the implementation of a comprehensive risk management system, including hazard source control, health risk assessment, and the application of adequate protective equipment and ventilation, is a crucial strategy to mitigate adverse health effects for welders and to sustain the quality of the welding work environment.

These findings are reinforced by previous studies, which also highlight the importance of implementing risk management and providing adequate safety training, given that many welders lack an understanding of the health risks associated with their work [37]. They emphasize that weak enforcement of safety standards, as well as insufficient training and supervision, constitute major obstacles in managing welding occupational risks. High morbidity rates among welders are closely related to low awareness of workplace hazards, inadequate safety training, and inconsistent use of personal protective equipment. This situation underscores the need to enhance both competency and safety culture as integral components of risk management implementation. Furthermore, these findings align with models suggesting that a systematic approach to risk management through the application of the hierarchy of controls and continuous monitoring plays a crucial role in creating a safe and sustainable work environment [38]. Therefore, this study not only reinforces previous theories and findings but also provides empirical evidence that risk management is a key determinant in safeguarding worker health and mitigating adverse impacts on the welding work environment.

Furthermore, the results indicate that welder behavior is directly influenced by the implementation of risk management. The application of effective risk management procedures can reinforce discipline, compliance with safety standards, and work professionalism. In addition, the impact of facilities, infrastructure, and internal communication on welder behavior is indirect, mediated through the effectiveness of risk management implementation. Knowledge and persuasion factors have been shown to shape positive behavior by increasing awareness and habituation toward the application of risk management principles, whereas welder competence characteristics contribute indirectly by enhancing the effectiveness of risk management execution. These findings support Hair et al. [24], who argue that in the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, direct and indirect relationships among constructs reflect the simultaneous influence of individual and organizational factors on behavioral performance [24]. Overall, the results underscore the importance of a holistic approach to strengthening a safety culture, where individual competence, communication systems, and organizational support must be integrated to create a safe, disciplined, and risk-preventive work environment.

5. Conclusion

The results of this study indicate that the implementation of risk management in welding occupational health and work environment is significantly influenced by several key factors, namely welder competence characteristics, the availability of facilities and infrastructure, the effectiveness of internal communication channels, and the level of worker knowledge and persuasion. These three factors were shown to contribute to the increased effectiveness of risk management system implementation, both directly and indirectly, through the development of safe and professional work behavior. In contrast, company policy and work motivation did not demonstrate a significant influence, suggesting that formal policies have not been fully internalized into the work culture and that welders' motivation has not yet been focused on occupational safety, health, and environmental aspects. The low outer loading value of the indicator "initiative in seeking risk-related information" indicates that the knowledge-seeking dimension remains a weak point in the Welder Knowledge and Persuasion construct. This condition reflects the need to enhance a knowledge-sharing culture and strengthen communication systems that support collective learning about occupational risks.

Based on the findings of this study, it is recommended to enhance welders' technical and non-technical competencies through certification programs, experience-based training, and continuous learning on risk management. Internal communication systems should be strengthened by establishing open, rapid, and two-way channels for reporting and learning about workplace risks. A participatory work culture should be developed by providing incentives for welders who actively share knowledge and demonstrate proactive behavior toward occupational health, safety, and environmental protection. Furthermore, occupational health, safety, and environmental policies should be integrated into the human resource management system, ensuring that safety, health, and environmental values and norms become an integral part of the social system within the shipbuilding company. The implementation of these recommendations is expected to sustainably improve the effectiveness of the company's risk management system, while simultaneously reinforcing a safe, disciplined, and risk-preventive work culture in the shipbuilding industry.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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