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Evaluating the Relationship between Health, Safety, and Environment Culture (HSEC) and Occupational Health and Safety Literacy (OHS Literacy): A Comparison of Two Structural Equation Modeling Approaches

ABSTRACT

Background and Objectives: Health, Safety, and Environment Culture (HSEC) shapes employees' awareness, attitudes, and behaviors toward occupational risks. Occupational Health and Safety Literacy (OHSL) is a key determinant of accident prevention, well-being, and regulatory compliance. Understanding the HSEC–OHSL relationship is essential for organizational performance and worker safety. Structural Equation Modeling (SEM) offers tools to investigate such relationships; however, researchers face the choice between covariance-based SEM (CB-SEM) and partial least squares SEM (PLS-SEM). By contrasting these approaches, this study contributes to the theoretical understanding of safety culture and literacy and informs methodological decisions in occupational health research.

Materials and Methods: We conducted a cross-sectional survey of personnel at Shahid Hasheminejad Gas Refining Company (Khangiran) (n = 410) using cluster sampling. Instruments included demographic checklists and validated HSEC and OHSL questionnaires. Data were analyzed with PLS-SEM (SmartPLS) and CB-SEM (AMOS) to compare approaches in estimating relationships and underlying factor structures. Model fit, factor loadings, (R2), and predictive relevance were evaluated.

Results: Mean scores were 78.66 ± 20.73 for HSEC and 74.67 ± 12.94 for OHSL (0–100 scale). Both SEM approaches showed a significant positive association: (rPLS=0.68) and (rCB=0.70). In PLS-SEM, factor loadings were higher than in CB-SEM. Based on loadings and (R2), the most influential OHSL facet was the use of health and safety information; for HSEC, on-the-job training and human factors were prominent. In CB-SEM, the communications factor had the highest loading.

Conclusion: Our findings support a positive HSEC–OHSL interrelationship, contributing to workplace safety and organizational performance. Overall, high levels of HSEC and OHSL suggest a foundation for promoting safe practices and continuous safety-management improvement. Enhancing both culture and literacy may yield synergistic effects for a safer, more productive work environment.

Paper Type: Research Article

Keywords: Structural Equation Modeling; Partial Least Squares Structural Equation Modeling; Covariance-Based Structural Equation Modeling; Health, Safety, and Environment Culture; Occupational Health and Safety Literacy.

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Introduction

While industry growth offers numerous benefits, it also introduces significant risks. Traditional safety measures—centered solely on accident analysis and failure modes are often inadequate in complex industries, such as nuclear power, chemical processing, and aerospace, which are classified as high-risk systems requiring tight integration of technical and human factors (1).

Annual accident incidents impose considerable financial, human, and environmental costs globally. Studies of complex systems reveal that human error is a leading contributing factor, responsible for approximately 83%-95% of accidents (2-8). Consequently, a robust Health, Safety, and Environment culture (HSEC) is deemed critical for predicting and preventing accidents, fostering an organization's capacity to perform optimally during incidents. In 1985, the British Health and Safety Executive described HSE culture as the product of individual and collective values, attitudes, skills, and behavior patterns influencing organizational safety commitment and effectiveness (9). Measurement of HSE culture often relies on qualitative techniques—including interviews, observations, and questionnaires—although challenges persist in ensuring these tools accurately reflect the true organizational culture (10). The importance of cultivating a positive HSE culture was underscored by the Chernobyl disaster, where the absence of such a culture contributed to catastrophic failure (11, 12). A strong safety culture encourages all personnel—regardless of position—to engage actively in safety practices, thus reducing the likelihood of accidents.

In recent years, the concept of literacy, particularly health and safety literacy, has gained prominence in HSE research. Assessing occupational health literacy is a crucial step in mitigating work-related hazards, as low literacy levels are linked to higher incidence rates of occupational diseases and injuries (13, 14). The World Health Organization (WHO) defines occupational health literacy as an individual's capacity to access, comprehend, evaluate, and apply health and safety information in work and daily contexts to make informed decisions that enhance safety and well-being(15) The integration of HSEC with occupational health and safety literacy (OHSL) is increasingly recognized as a critical determinant of workplace safety outcomes. OHSL encompasses knowledge, motivation, and skills to navigate health and safety information effectively—aiming to promote healthier workplaces and improve overall quality of life (16). The relationship between HSEC and OHSL is symbiotic: while a positive safety culture creates an enabling environment for knowledge dissemination and safe behaviors, adequate literacy ensures that workers can interpret and act upon safety information effectively. Research suggests that low health and safety literacy is associated with higher occupational risks, accidents, and reduced compliance with safety protocols (17, 18). Conversely, organizations that embed safety literacy within their culture foster improved hazard awareness, reporting behavior, and compliance, ultimately contributing to better health and safety outcomes(19). Structural

Equation Modeling (SEM) provides a robust methodological framework to analyze the complex and multidimensional relationship between HSEC and OHSL. Prior studies have emphasized that SEM can uncover underlying causal mechanisms in occupational safety research, where traditional regression models may fall short (20). For example, a strong organizational safety culture (HSEC) may influence workers' safety literacy both directly—through knowledge-sharing practices—and indirectly—by shaping safety communication channels and peer learning. Given Iran's significant reliance on the oil and gas industry—one of the most hazardous sectors globally—improving OHSL among workers is vital. This industry's exploration, extraction, refining, and transportation activities expose personnel to substantial occupational risks. Enhancing OHSL can empower industry managers to reduce accidents and occupational diseases, fostering safer work environments.

Therefore, this study aims to compare the relationship between HSE culture and OHSL using SEM at Shahid Hasheminejad Gas Refinery.

Materials and Methods

Study Design and Setting

This cross-sectional, descriptive-analytical study was conducted on 410 participants in 2023 among personnel at the Shahid Hasheminejad Gas Refinery Company located in Sarakhs, Razavi Khorasan Province, and Northeastern Iran.

Sampling method

Data were collected from using cluster sampling, with job categories serving as clusters. Among the refinery job categories, 13 job categories (Operator, Security, Driver, Administrative, Firefighter, Mechanic, HSE, Repair, Construction, Service, Technician, Rigger and Laboratory) were randomly selected and a random sample was selected based on the proportion of employees in each job.

Inclusion and exclusion criteria:

The samples consisted of individuals who had an employment relationship with Shahid Hasheminejad Gas Refinery and were willing to participate in the study. Questionnaires that did not answer at least 50% of the questions were eliminated.

Sample size:

For advanced statistical models, such as structural equation models, there is no statistical closed formula. In such cases, rules of thumb are used. Tabachnick and Fidell (2019) suggest that a minimum of 300 cases is generally required to obtain stable solutions in SEM (21). Similarly, Boomsma and Hoogland (2001) and Kline (2015) emphasize that samples above 200 are typically adequate for covariance-based SEM (22, 23), while Hair et al. (2019) note that PLS-SEM performs reliably with samples greater than 300 (24).

Data Collection Tools

Two validated questionnaires were employed:

1- OHSL Questionnaire

This questionnaire adapted from Suthakorn's (2020) study was translated and validated by Noori specifically for Iranian industrial workers. The impact score, CVR and CVI of the questionnaire were 3.51, 0.96 and 0.91, respectively. The internal consistency of the questionnaire was (α=0.923), and repeatability (ICC= 0.98) which were within the acceptable range (25, 26). This questionnaire comprised 34 items distributed across four dimensions: access to occupational health and safety information (OHSL_D1), perception of occupational health and safety information (OHSL_D2), evaluation of occupational health and safety information (OHSL_D3), and use of occupational health and safety information (OHSL_D4). Responses were recorded using a 5-point Likert scale, with ratings ranging from 1 (never) to 5 (always). Scores obtained from the questionnaire were categorized as follows: Low (1–33.33), Moderate (33.34–66.67), and High (>66.68).

2- HSEC Questionnaire

This instrument, translated and validated into Persian by Gharib et al., comprises 34 items assessing Health, Safety, and Environment (HSE) culture on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The average impact score, validity ratio, and validity index were 3.81, 0.82, and 0.92, respectively (α =0.94 and ICC=0.975), which was within the acceptable range (27). It was developed based on the guidelines provided by the International Association of Oil & Gas Producers (OGP), encompassing dimensions pertinent to safety culture within industrial settings. Scoring followed the same methodology as the OHSL questionnaire. OHSL Questionnaire consists of six dimensions: observable commitment of HSE management (HSEC_D1), competence and awareness of the position (HSEC_D2), communications (HSEC_D3), on-the-job training and human factors (HSEC_D4), accident management (HSEC_D5), and HSE evaluation and auditing (HSEC_D6).

Structure Equation Modeling (SEM)

Multivariate analysis is a pivotal method utilized across various fields, including behavioral sciences, social sciences, medicine, and management. Among the primary techniques in this domain is Structural Equation Modeling (SEM), which enables the simultaneous examination of multiple dependent and independent variables. This approach facilitates the exploration of relationships between latent constructs and their interactions with observed variables.

SEM, employing appropriate estimation methods, can quantify measurement errors in observed indicators, ensuring that models of latent variable regression are not biased by these errors (28). There are three main approaches to SEM: Covariance-Based SEM (CB-SEM), Variance-Based SEM (VB-SEM), and Generalized Structured Component Analysis SEM (GSCA-SEM), with the first two being the most widely used (29). Partial Least Squares SEM (PLS-SEM) is a prominent technique within VB-SEM.

In CB-SEM, parameter estimation is achieved by minimizing the difference between the empirical covariance matrix and the model-implied covariance matrix. Conversely, PLS-SEM employs linear combinations of indicators as proxies for latent variables and estimates the model parameters accordingly. The selection of the appropriate approach depends on research objectives, model complexity, and data characteristic (30).

CB-SEM often requires strict assumptions, including multivariate normality and sufficiently large sample sizes. When these assumptions are violated or when the focus is on prediction rather than confirmation, PLS-SEM emerges as a more suitable alternative. Generally, when measurement issues or model constraints restrict the use of CB-SEM, PLS-SEM offers a practical solution.

Tenenhaus et al. (2008) compared these approaches and concluded that the quality of the measurement model influences the results, with both methods capable of yielding similar outcomes when appropriate criteria and data are employed. Consequently, understanding the specific purposes of each method is vital for selecting the most appropriate approach (31).

Numerous studies have contrasted these methods across different domains. For example, Richter and colleagues (2016) analyzed six prominent journals over 24 years, finding that 89% of studies relied on CB-SEM, likely due to its longer history and more established application in social sciences. They emphasized that research objectives and theoretical foundations should guide the choice between PLS-SEM and CB-SEM, as PLS-SEM is particularly valuable in exploratory analyses (32).

Further comparative analyses, such as Astrachan et al. (2014), highlight the advantages of PLS-SEM, including higher factor loadings, better reliability and construct validity, and its aptitude for small samples and complex models (33). A study involving 466 respondents from India, Saudi Arabia, South Africa, and the U.S. indicated that variance-based methods often produced higher loadings and superior validity assessments, although CB-SEM provided better model fit indices (34).

Statistical Analysis

The data were analyzed using both PLS-SEM and CB-SEM to examine the relationship between HSEC and OHSL.

Both analyses were performed using SmartPLS (for PLS-SEM) and AMOS (for CB-SEM). Model fit indices such as χ^2/df, Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) were evaluated in CB-SEM. In PLS-SEM, R^2 values, path coefficients, and bootstrapping with 5000 resamples were used to assess the significance and predictive relevance of the model. Construct validity was verified through Composite Reliability (CR), Average Variance Extracted (AVE), and discriminant validity checks using the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio.

The R2 value was considered to be in three categories based on the study of Hair et al.: weak (0.25), moderate (0.5), and good (0.75) (35). Rho_A, also known as the consistent reliability coefficient, is a measure of internal consistency reliability for composite scales, particularly in the context of PLS-SEM. It's considered a more appropriate reliability measure for PLS than Cronbach's alpha, especially when dealing with formative constructs or when loadings are not consistent. All analyses were conducted at a significance level of 0.05. Standardized coefficients and p-values were reported, with $p < 0.05$ indicating statistical significance.

Results

The study included participants with a mean and standard deviation age of 39.92 ± 7.62 years and an average work experience of 13.29 ± 8.16 years. The majority were married

(92.1%) and held a bachelor's degree (37.4%). A detailed demographic breakdown is provided in Table 1.

The mean and standard deviation OHSL score was 78.66 ± 20.73 (out of 100), reflecting a generally good level of OHSL among refinery workers. The mean and standard deviation scores for the respective dimensions were as follows: OHSL_D1: 68.75±20.73, OHSL_D2: 84.42±11.57, OHSL_D3: 74.95±19.49, and OHSL_D4: 76.48±14.72.

Similarly, the mean and standard deviation HSE culture score was 74.67 ± 12.94 (out of 100), indicating a positive safety culture within the refinery. The scores across various dimensions of HSE culture were: HSEC_D1: 73.09±17.33, HSEC_D2: 89.41±11.57, HSEC_D3: 71.05±18.63, HSEC_D4: 74.70±15.21, HSEC_D5: 69.89±18.36, and HSEC_D6: 70.59±16.88.

Table 1. Distribution of Demographic Variables of Participants

	Demographic Variable	Frequency	Percentage
Marital Status	- Married	387	92.1%
	- Single	33	7.9%
Education Level	- Less than diploma	20	4.8%
	- High school diploma	90	21.4%
	- Associate degree	81	19.3%
	- Bachelor's degree	157	37.4%
	- Master's degree	67	16.0%
	- Doctorate	5	1.2%
Job Title	- Operators	87	20.7%
	- Guards	48	11.4%
	- Drivers	27	6.4%
	- Administrative Staff	49	11.7%
	- Firefighters	31	7.4%
	- Mechanics	14	3.3%
	- HSE Department Staff	18	4.3%
	- Machinery Maintenance Workers	32	7.6%
	- Construction Workers	37	8.8%
	- Service Staff	35	8.3%
	- Skilled Workers	22	5.2%
	- Riggers*	10	4.2%
	- Laboratory Staff	10	4.2%
Working Hours	- 8 hours	222	52.9%
	- 12 hours	198	47.1%
Work Accident History	- Yes	57	13.6%
	- No	363	86.4%

*Note: Riggers are trained personnel capable of relocating frequently without incidents in coordination with crane drivers.

Results of SEM Approaches

Factor Loadings and Predictive Power

The outcomes of the two SEM fitting approaches are presented in Figure 1, Figure 2 and Table 2.

Table 2 indicates that all factor loadings in both approaches exceeded the threshold of 0.4. Notably, the loadings were higher in the PLS-SEM approach compared to CB-SEM. Based on the factor loadings and R^2, the most influential factor in the OHSL questionnaire is namely the use of occupational health and safety information and in the HSEC questionnaire, the factor is on-the-job training and human factors. The communications factor had the highest factor loading in the CB-SEM. Both models revealed a significant statistical relationship between OHSL and HSEC, with path coefficients of 0.70 (CB-SEM) and 0.68 (PLS-SEM) ($p < 0.001$).

Table 3 presents the measures of construct validity, including Composite Reliability (CR) and Average Variance Extracted (AVE), for both approaches. These indicators confirm the internal consistency and convergent validity of the constructs in each model.

Table 4 presents the model fit indices for both SEM approaches. Based on multiple fit metrics, the models can be considered acceptable, indicating an adequate fit to the data.

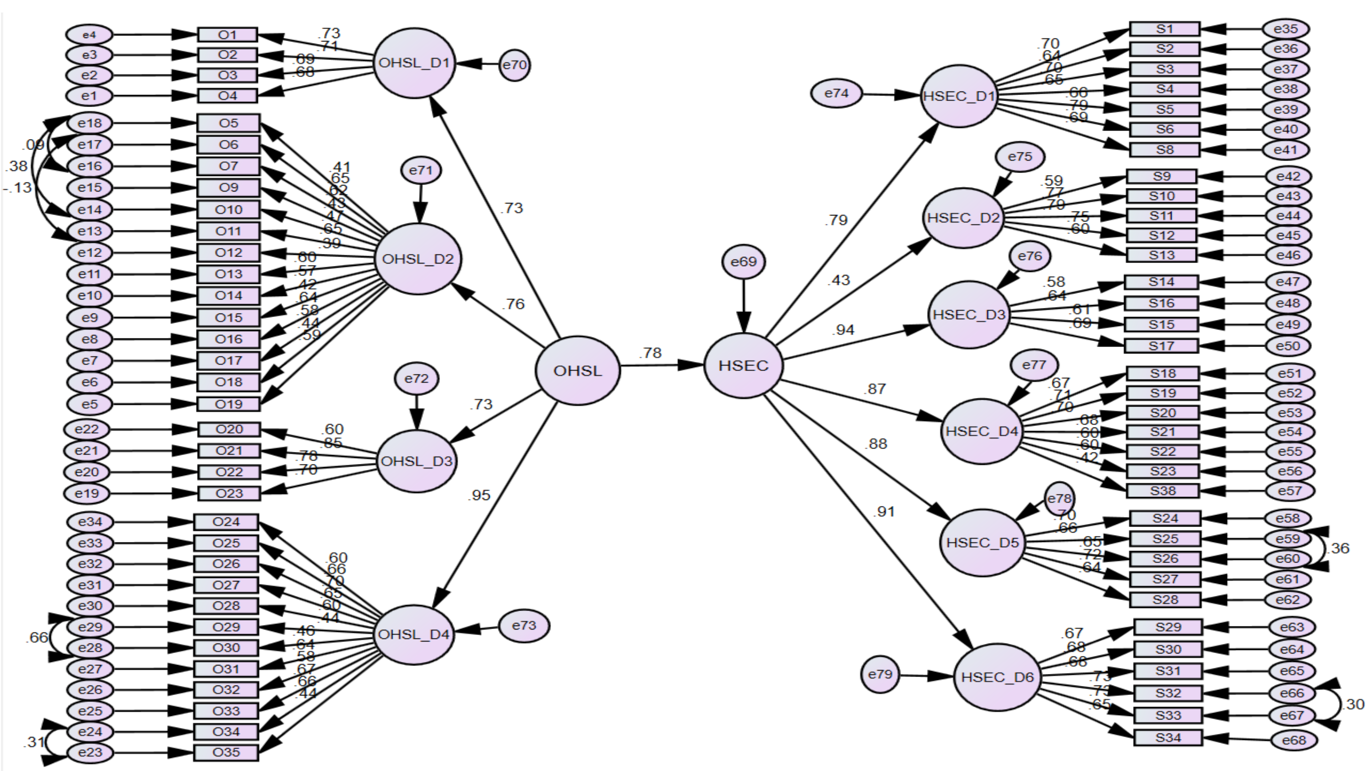

Figure 1. CB-SEM to Evaluating the Relationship between HSEC and OHSL

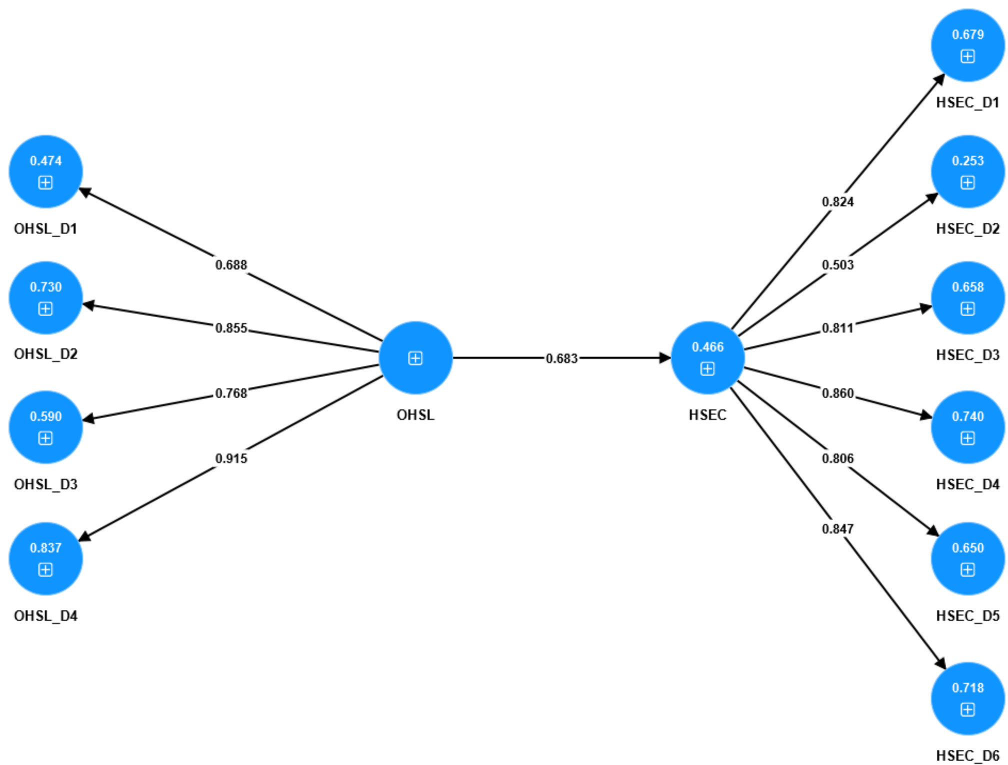

Figure 2. PLS-SEM to Evaluating the Relationship between HSEC and OHS

Table 2. Standardized Factor Loadings in Two Structural Equation Modeling Approaches

Construct and Dimensions	Item	CB-SEM	PLS-SEM
OHSL_D1 Access to Occupational Health and Safety Information R2 CB-SEM =0.69, $\lambda = 0.73$ R2 PLS-SEM =0.474, $\lambda = 0.69$	O1	0.73	0.80
	O2	0.71	0.80
	O3	0.69	0.78
	O4	0.68	0.78
OHSL_D2 Perception of Occupational Health and Safety Information R2 CB-SEM =0.85, $\lambda = 0.76$ R2 PLS-SEM =0.730, $\lambda = 0.85$	O5	0.41	0.50
	O6	0.65	0.67
	O7	0.62	0.65
	O9	0.43	0.48
	O10	0.47	0.54
	O11	0.65	0.67
	O12	0.39	0.45
	O13	0.60	0.64
	O14	0.57	0.62
	O15	0.42	0.46
	O16	0.64	0.69
	O17	0.58	0.62
	O18	0.44	0.49
	O19	0.59	0.62
OHSL_D3 Evaluation of Occupational Health and Safety Information R2 CB-SEM =0.77, $\lambda = 0.73$ R2 PLS-SEM =0.590, $\lambda = 0.77$	O20	0.60	0.72
	O21	0.85	0.87
	O22	0.78	0.81
	O23	0.72	0.79

OHSL_D4 Use of Occupational Health and Safety Information R2 CB-SEM =0.91, $\lambda = 0.95$ R2 PLS-SEM =0.837, $\lambda = 0.91$	O24	0.60	0.62
	O25	0.66	0.70
	O26	0.70	0.72
	O27	0.65	0.68
	O28	0.60	0.63
	O29	0.44	0.55
	O30	0.46	0.56
	O31	0.64	0.70
	O32	0.58	0.64
	O33	0.66	0.69
	O34	0.44	0.49
HSEC_D1 Observable Commitment of HSE Management R2 CB-SEM =0.82, $\lambda = 0.79$ R2 PLS-SEM =0.679, $\lambda = 0.82$	S1	0.70	0.76
	S2	0.64	0.71
	S3	0.07	0.75
	S4	0.65	0.70
	S5	0.66	0.71
	S6	0.79	0.82
	S8	0.69	0.74
HSEC_D2 Competence and Awareness of the Position R2 CB-SEM =0.50, $\lambda = 0.43$ R2 PLS-SEM =0.253, $\lambda = 0.50$	S9	0.59	0.82
	S10	0.77	0.81
	S11	0.79	0.80
	S12	0.75	0.67
	S13	0.60	0.73
HSEC_D3 Communications R2 CB-SEM =0.81, $\lambda = 0.94$ R2 PLS-SEM =0.658, $\lambda = 0.81$	S14	0.58	0.71
	S15	0.63	0.75
	S16	0.61	0.76
	S17	0.69	0.74
HSEC_D4 On-the-Job Training and Human Factors R2 CB-SEM =0.86, $\lambda = 0.87$ R2 PLS-SEM =0.740, $\lambda = 0.86$	S18	0.67	0.72
	S19	0.71	0.76
	S20	0.70	0.75
	S21	0.68	0.74
	S22	0.60	0.68
	S23	0.60	0.66
	S38	0.42	0.47
HSEC_D5 Accident Management R2 CB-SEM =0.81, $\lambda = 0.88$ R2 PLS-SEM =0.650, $\lambda = 0.81$	S24	0.70	0.77
	S25	0.66	0.78
	S26	0.65	0.78
	S27	0.72	0.75
	S28	0.64	0.71
HSEC_D6 HSE Evaluation and Auditing R2 CB-SEM =0.85, $\lambda = 0.91$ R2 PLS-SEM =0.718, $\lambda = 0.85$	S29	0.67	0.73
	S30	0.68	0.74
	S31	0.68	0.73
	S32	0.73	0.82
	S33	0.73	0.81
	S34	0.65	0.71

Table 3. Validity and reliability check of two structural equation approaches

Construct	CB-SEM		PLS-SEM			
	CR	AVE	CR	AVE	Rho_A	Cronbach's Alpha
OHSL_D1	0.80	0.49	0.87	0.62	0.80	0.80
OHSL_D2	0.85	0.29	0.88	0.34	0.86	0.85
OHSL_D3	0.83	0.55	0.88	0.64	0.81	0.81
OHSL_D4	0.85	0.35	0.89	0.42	0.88	0.87
OHSL	0.95	0.37	0.93	0.30	0.93	0.93
HSEC_D1	0.86	0.48	0.90	0.55	0.87	0.86
HSEC_D2	0.83	0.05	0.88	0.59	0.83	0.83
HSEC_D3	0.72	0.04	0.73	0.55	0.73	0.73
HSEC_D4	0.82	0.04	0.83	0.48	0.83	0.81
HSEC_D5	0.81	0.45	0.82	0.58	0.82	0.82
HSEC_D6	0.84	0.48	0.85	0.57	0.85	0.85
HSEC	0.98	0.46	0.94	0.34	0.94	0.94

CR: Composite Ratability; AVE: Average Variance Extract

Table 4. Model fit indicators in two SEM approaches

Index	CB-SEM	PLS-SEM
CFI	0.93	-
IFI	0.93	-
TLI	0.92	-
NFI	0.83	-
RMSEA	0.06	-
CMIN/DF	2.74	-
AIC	6443.08	4660.05
BIC		4571.69
SRMR	-	0.11
d_ULS	-	108.89

CFI: Comparative Fit Index, IFI: Incremental Fit Index, TLI: Tucker-Lewis Index, NFI: Normed Fit Index, RMSEA: Root Mean Square Error of Approximation, CMIN/DF: Chi-Square divided by degrees of freedom, AIC: Akaike Information Criterion, BIC: Bayesian Information Criterion, SRMR: Standardized Root Mean Square Residual, d_ULS: Distance (Unweighted Least Squares discrepancy).

Discussion

Based on the data collected, OHSL within the Shahid Hasheminejad Gas Refinery in Sarakhs is at a commendable level. The most influential factor contributing to higher OHSL scores, as reported by respondents, was the use of occupational health and safety information (OHSL_D4).

The average HSEC score among personnel indicates a satisfactory level, which is consistent with the measures and annual programs implemented to promote HSE regulations within the oil and gas industry. According to participants' responses in the covariance SEM approach, the most impactful dimension for enhancing HSEC was communication (HSEC_D3). Conversely, the variance-based approach identified on-the-job training and human factors (HSEC_D4) as the key determinant.

Previous studies support these findings. For instance, Halvani's research among steel industry workers reported that 67% exhibited a positive safety culture (36). Effective participation in safety initiatives, teamwork, and collaboration significantly influence safety performance for both employers and employees. The results from both SEM approaches confirm a positive and statistically significant relationship between health literacy and safety culture, underscoring the importance of fostering a safety-oriented organizational environment.

Despite Iran's high incidence of industrial accidents, literature on HSE culture, particularly concerning health literacy and occupational safety, remains scarce. Most existing studies emphasize safety culture but tend to overlook health and environmental aspects (37). Likewise, research on patient health literacy often focuses solely on individual behaviors, neglecting occupational and hazardous factors. Internationally, some studies have integrated occupational health literacy with factors such as accident rates, quality of life, and safety climate. For example, Ozaydin et al. (2021) found a significant correlation between occupational accidents and health literacy, as well as safety climate, among 250 employees in Turkey's Gemlik industrial zone (38). Similarly, Haghighi et al. reported good performance in HSEC among refinery personnel, supported by the Geller safety model (39).

Regarding model fit, the long-term lack of comprehensive fit indices for PLS-SEM has been a concern. Recent simulation studies suggest that even fully specified PLS models can achieve SRMR values of 0.06 or higher (40).

The results confirm that the theoretical model aligns well with the data. Notably, factor loadings in the variance-based approach (PLS-SEM) were higher than those in the covariance-based approach, consistent with findings by Dash et al. (34). Astrachan et al. (2014) emphasized that, despite analyzing similar measurement and structural models, PLS-SEM offers several advantages, especially in exploratory and predictive contexts (33). Furthermore, Choi's review advocates for PLS-SEM as a viable alternative to CB-SEM, given it's less stringent assumptions—particularly relevant in circumstances of small sample sizes or non-normal data distributions (41). In this study, PLS-SEM demonstrated higher validity and convergent validity indices, whereas CB-SEM yielded higher path coefficients, aligning with the empirical comparison by Amaro et al. (2015) (42).

Study Limitations and Strengths: This study has several limitations that should be acknowledged. The cross-sectional design restricts the ability to draw causal inferences between HSE culture and OHSL. Longitudinal studies are required to better understand how changes in safety culture may influence literacy levels over time. Additionally, the reliance on self-reported questionnaires introduces the potential for response bias, such as social desirability or inaccurate self-assessment. The study was conducted within a single industrial site, which may limit the generalizability of the findings to other industries or geographic regions. Furthermore, despite recent advancements, PLS-SEM still faces challenges in providing comprehensive model fit indices, which might impact the overall interpretation of the model's adequacy.

On the other hand, the study possesses several strengths. The combined use of covariance-based and variance-based SEM approaches provides a robust validation of the proposed theoretical model, enhancing the credibility of the results. The sizable sample of 410 participants also contributed to the statistical power and reliability of the findings. Another notable strength is the focus on occupational safety and health literacy in the context of Iran's industrial sector, an area that has received limited attention but holds significant practical importance. The insights gained from this research can inform targeted interventions aimed at improving safety culture and literacy, which are crucial steps toward reducing occupational risks and enhancing overall safety performance.

For future research, several avenues can be explored. Longitudinal studies would be beneficial to examine causal relationships and track how modifications in HSE culture influence occupational health literacy and safety outcomes over time. Expanding research to include multiple industries and diverse geographic regions would help enhance the generalizability of the findings. Incorporating qualitative methods, such as interviews or focus groups, could also provide richer, more in-depth insights into workers' perceptions, attitudes, and barriers related to safety culture and health literacy. Moreover, intervention-based studies that evaluate the effectiveness of specific training programs or organizational strategies aimed at boosting HSE culture and literacy could offer practical guidance for industry stakeholders. Finally, future research should consider employing multiple fit indices and emerging validation metrics, especially in PLS-SEM, to ensure more comprehensive assessment and model validity.

Conclusion

This study investigated the relationship between HSE culture and OHSL among personnel at the Shahid Hasheminejad Gas Refinery in Sarakhs, revealing generally positive levels of safety literacy and a conducive safety culture within the organization. The findings confirmed a significant and meaningful association between these two constructs, emphasizing the importance of enhancing safety communication, training, and information access to improve overall safety performance. The comparative analysis of SEM approaches demonstrated that, while both methods are valuable, the choice of the appropriate approach depends on the research objectives, model complexity, and data characteristics. Given PLS-SEM's ability to work effectively with a much wider range of sample sizes, increased model complexity, and more limited assumptions about the data, it can address a broader array of research problems than CB-SEM. Overall, these insights provide a solid foundation for developing targeted interventions to promote a safer work environment in the industrial sector and highlight the importance of choosing suitable analytical methods based on specific research needs.

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