

RESEARCH TITLE

Evaluation of Occupational Safety and Health Practices in the Construction Industry: A Case Study of Port Sudan, Sudan

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Abstract

Background: The construction industry in low- and middle-income countries faces persistent occupational safety challenges due to weak regulatory frameworks, resource constraints, and limited safety culture. This study evaluates Occupational Safety and Health (OSH) practices in Port Sudan, Sudan, using an integrated Likert scale quantitative analysis and SWOT strategic assessment framework.

Methods: A structured 100-item questionnaire using a 5-point Likert scale was administered to 312 construction stakeholders. Data were analyzed using: (1) Descriptive statistics and Weighted Average Index (WAI) for compliance measurement; (2) Relative Importance Index (RII) for factor prioritization; (3) Cronbach's alpha and Exploratory Factor Analysis for instrument validation; (4) One-way ANOVA and Pearson correlation for group comparisons and relationships; and (5) Quantitative SWOT analysis with Strategic Position and Action Evaluation (SPACE) matrix for strategic recommendations.

Results: Overall OSH compliance scored moderate-low (WAI = 2.74/5.00; 54.8%). Highest compliance was observed in Training & Competency (WAI = 3.12), while lowest scores occurred in Incident Reporting (WAI = 2.44) and PPE Infrastructure (WAI = 2.59). RII identified "management commitment" (RII = 0.89) and "safety audit frequency" (RII = 0.86) as most critical success factors. ANOVA revealed significant perceptual gaps between management and frontline workers ($F = 11.24, p < 0.001$). SWOT analysis identified 12 strengths, 18 weaknesses, 9 opportunities, and 14 threats, with strategic positioning in the "Conservative" quadrant of the SPACE matrix, recommending defensive-improvement strategies.

Conclusions: The integrated Likert-SWOT framework provides a practical, replicable methodology for OSH evaluation in resource-constrained settings. Findings underscore the need for leadership-driven safety culture enhancement, targeted training investment, and systematic incident reporting mechanisms. Strategic recommendations align with ISO 45001 and support evidence-based policy formulation for Sudan's construction sector.

Key Words: Occupational Safety and Health; Construction Industry; Likert Scale Analysis; SWOT Analysis; Weighted Average Index; Relative Importance Index; Port Sudan; Strategic Management; Safety Climate.

تقييم ممارسات السلامة والصحة المهنية في صناعة البناء والتشييد: دراسة حالة مدينة بورتسودان، السودان

المستخلص

الخلفية: تواجه صناعة البناء والتشييد في الدول منخفضة ومتوسطة الدخل تحديات مستمرة في مجال السلامة المهنية، وذلك نتيجة ضعف الأطر التنظيمية، ومحدودية الموارد، وضعف ثقافة السلامة. تهدف هذه الدراسة إلى تقييم ممارسات السلامة والصحة المهنية في مدينة بورتسودان، السودان، باستخدام إطار متكامل يجمع بين التحليل الكمي بمقياس ليكرت والتقييم الاستراتيجي وفق تحليل SWOT.

المنهجية: تم تطبيق استبانة منظمة مكونة من 100 فقرة باستخدام مقياس ليكرت الخماسي على عينة شملت 312 من أصحاب المصلحة في قطاع البناء والتشييد. وقد تم تحليل البيانات باستخدام: (1) الإحصاءات الوصفية ومؤشر المتوسط المرجح لقياس مستوى الامتثال؛ (2) مؤشر الأهمية النسبية لترتيب العوامل حسب أولويتها؛ (3) معامل ألفا كرونباخ والتحليل العاملي الاستكشافي للتحقق من صدق وثبات الأداة؛ (4) تحليل التباين الأحادي ومعامل ارتباط بيرسون للمقارنات بين المجموعات ودراسة العلاقات؛ و(5) تحليل SWOT الكمي مع مصفوفة تقييم الموقع الاستراتيجي والعمل SPACE لتقديم التوصيات الاستراتيجية.

النتائج: أظهرت النتائج أن مستوى الامتثال العام لممارسات السلامة والصحة المهنية كان متوسطاً منخفضاً، حيث بلغ مؤشر المتوسط المرجح 2.74 من 5.00، بنسبة 54.8%. وسُجل أعلى مستوى امتثال في محور التدريب والكفاءة بمتوسط مرجح بلغ 3.12، بينما ظهرت أدنى الدرجات في الإبلاغ عن الحوادث بمتوسط مرجح بلغ 2.44، وفي بنية معدات الوقاية الشخصية بمتوسط مرجح بلغ 2.59. كما حدد مؤشر الأهمية النسبية أن «التزام الإدارة» بواقع 0.89 و«تكرار تدقيق السلامة» بواقع 0.86 يمثلان أهم عوامل النجاح الحرجة. وكشف تحليل التباين الأحادي عن وجود فجوات إدراكية ذات دلالة إحصائية بين الإدارة والعاملين في الخطوط الأمامية، حيث بلغت قيمة $F = 11.24$ عند مستوى دلالة $p < 0.001$ وحدد تحليل SWOT عدد 12 نقطة قوة، و18 نقطة ضعف، و9 فرص، و14 تهديداً، كما أظهر التوضع الاستراتيجي في الربع «المحافظ» من مصفوفة SPACE، مما يشير إلى الحاجة إلى تبني استراتيجيات دفاعية وتحسينية.

الخلاصة: يوفر الإطار المتكامل القائم على مقياس ليكرت وتحليل SWOT منهجية عملية وقابلة للتكرار لتقييم السلامة والصحة المهنية في البيئات محدودة الموارد. وتؤكد النتائج الحاجة إلى تعزيز ثقافة السلامة المدفوعة بالقيادة، والاستثمار الموجه في التدريب، وإنشاء آليات منهجية للإبلاغ عن الحوادث. كما تتسجم التوصيات الاستراتيجية مع معيار ISO 45001، وتدعم صياغة سياسات قائمة على الأدلة لتطوير قطاع البناء والتشييد في السودان.

الكلمات المفتاحية: السلامة والصحة المهنية؛ صناعة البناء والتشييد؛ تحليل مقياس ليكرت؛ تحليل SWOT؛ مؤشر المتوسط المرجح؛ مؤشر الأهمية النسبية؛ بورتسودان؛ الإدارة الاستراتيجية؛ مناخ السلامة.

1. Introduction

1.1 Background and Problem Statement

The construction industry globally accounts for approximately 20% of occupational fatalities despite employing only 6–7% of the formal workforce (ILO, 2021). In Sudan, and particularly in Port Sudan—the nation's primary maritime and economic hub—construction activities have intensified amid urban expansion and infrastructure rehabilitation. However, occupational safety and health (OSH) practices remain fragmented due to limited regulatory enforcement, informal labor arrangements, and inadequate safety infrastructure.

Existing OSH evaluations in similar contexts often rely on qualitative assessments or basic descriptive statistics, limiting their capacity to generate prioritized, actionable insights. There is a methodological gap in applying structured quantitative scaling (e.g., Likert-based indices) combined with strategic analytical frameworks (e.g., SWOT) to translate survey data into implementable safety improvement strategies.

1.2 Research Objectives

1. To evaluate the current state of OSH practices in Port Sudan's construction industry using a validated 100-item Likert scale questionnaire.
2. To quantify compliance levels across seven OSH dimensions using Weighted Average Index (WAI) and Relative Importance Index (RII).
3. To assess perceptual differences among stakeholder groups using inferential statistics (ANOVA, correlation).
4. To conduct a quantitative SWOT analysis to identify strategic priorities for OSH improvement.
5. To propose evidence-based, strategically aligned recommendations for policymakers and practitioners.

1.3 Research Questions

1. What is the level of OSH compliance across policy, risk assessment, training, PPE, incident reporting, and safety culture dimensions?
2. Which factors are perceived as most critical for improving safety performance (per RII ranking)?
3. Do perceptions of OSH practices differ significantly by occupational role, experience, or firm size?
4. What are the internal strengths/weaknesses and external opportunities/threats affecting OSH in Port Sudan?
5. What strategic posture and action priorities emerge from the integrated SWOT-SPACE analysis?

1.4 Significance and Innovation

This study contributes methodologically by:

- Demonstrating the application of Likert-based composite indices (WAI, RII) for OSH benchmarking in LMIC contexts.
- Integrating quantitative SWOT analysis with survey data to bridge diagnostic assessment and strategic planning.

- Providing a replicable, low-cost analytical framework suitable for resource-constrained regulatory agencies.

Practically, findings offer prioritized, actionable insights for Sudan's Ministry of Labor, construction contractors, and international development partners to align safety interventions with ISO 45001 and UN Sustainable Development Goal 8.8.

2. Literature Review and Theoretical Framework

2.1 Likert Scale Applications in OSH Research

Likert scales are widely employed in safety climate and OSH perception studies due to their reliability, ease of administration, and compatibility with parametric and non-parametric statistics (Zohar, 1980; Neal & Griffin, 2006). Composite indices derived from Likert items—such as Weighted Average Index (WAI) and Relative Importance Index (RII)—enable ranking of factors and benchmarking across contexts (Ameyaw et al., 2022). However, applications in Sudanese and North African construction research remain limited.

2.2 SWOT Analysis in Safety Management

SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, originally developed for strategic business planning, has been adapted for OSH governance to systematically evaluate internal capabilities and external contextual factors (Helms & Nixon, 2010). Quantitative SWOT approaches assign Likert-weighted scores to factors, enabling mathematical prioritization via matrices such as IE (Internal-External) or SPACE (Strategic Position and Action Evaluation) (David & David, 2017). Integration of survey-derived SWOT factors enhances empirical grounding and strategic relevance.

2.3 Theoretical Integration

This study anchors its framework in:

- **Safety Climate Theory** (Zohar, 1980): Guides Likert item development for measuring shared perceptions of safety policies and leadership.
- **Resource-Based View (RBV)**: Informs SWOT categorization of internal organizational capabilities (strengths/weaknesses).
- **Institutional Theory**: Frames external opportunities/threats related to regulatory, economic, and socio-cultural contexts.

3. Methodology

3.1 Research Design

A quantitative cross-sectional survey design was employed, supplemented by qualitative validation of SWOT factors through expert focus groups (n = 12). The study adhered to STROBE guidelines for observational research.

3.2 Study Area and Population

Port Sudan, Red Sea State, Sudan, was selected due to its concentration of construction activity and documented OSH challenges. The target population included construction workers, supervisors, safety officers, project managers, and contractors operating within the city limits.

3.3 Sampling Strategy

Stratified random sampling ensured representation across:

- **Occupational roles:** Laborers, skilled workers, supervisors, safety officers, managers

- **Firm types:** Local contractors, national firms, international/joint ventures, subcontractors
- **Construction zones:** Port Industrial, Residential Expansion, Commercial Center, Infrastructure Corridor

Sample size was determined using Cochran's formula (95% confidence level, 5% margin of error, $p = 0.5$), yielding $n = 384$. Accounting for an anticipated 20% non-response rate, 480 questionnaires were distributed. Valid responses: $N = 312$ (response rate = 65%).

3.4 Instrument Development: 100-Item Likert Questionnaire

3.4.1 Structure and Scaling

The questionnaire comprised seven sections:

Section	Items	Construct	Scale
A	1–10	Demographics & Occupational Profile	Categorical
B	11–25	OSH Policy & Management System	5-point Likert (1=SD to 5=SA)
C	26–40	Risk Assessment & Hazard Control	5-point Likert
D	41–55	Training & Competency Development	5-point Likert
E	56–70	PPE & Infrastructure	5-point Likert
F	71–85	Incident Reporting & Emergency Response	5-point Likert
G	86–100	Safety Culture & Worker Participation	5-point Likert

3.4.2 Validity and Reliability

- **Content Validity:** Expert panel ($n = 10$) rated item relevance; Aiken's $V \geq 0.82$ for all items.
- **Construct Validity:** Exploratory Factor Analysis (EFA) with Varimax rotation; $KMO = 0.84$, Bartlett's $\chi^2 = 4,812$ ($p < 0.001$); seven factors extracted explaining 68.3% variance.
- **Reliability:** Cronbach's alpha for overall scale = 0.91; subscales ranged 0.78–0.93.
- **Test-Retest:** ICC = 0.84 ($n = 50$, 3-week interval).

3.5 Data Analysis Methods

3.5.1 Likert Scale Analytical Techniques

1. Weighted Average Index (WAI):

$$WAI = \frac{\sum(w_i \times f_i)}{N \times k}$$

Where: w_i = weight of response category (1–5), f_i = frequency of response, N = total respondents, k = maximum scale value (5). Interpretation: 1.00–1.80 = Very Low; 1.81–2.60 = Low; 2.61–3.40 = Moderate; 3.41–4.20 = High; 4.21–5.00 = Very High.

2. Relative Importance Index (RII):

$$RII = \frac{\sum w}{A \times N}$$

Where: w = weight (1–5), A = highest weight (5), N = total respondents. Range: 0–1; higher values indicate greater perceived importance.

3. **Descriptive Statistics:** Mean, standard deviation, frequency distributions for all items and constructs.
4. **Inferential Statistics:**
 - One-way ANOVA with Tukey HSD post-hoc for group comparisons (role, experience, firm size)
 - Pearson correlation coefficients for relationships between constructs
 - Multiple regression for predicting overall OSH compliance
5. **Factor Analysis:** EFA for dimensionality confirmation; factor loadings ≥ 0.50 retained.

3.5.2 Quantitative SWOT Analysis Protocol

1. **Factor Identification:** SWOT factors extracted from:
 - Literature review (global and regional OSH studies)
 - Open-ended questionnaire responses ($n = 312$)
 - Expert focus group validation ($n = 12$)
 2. **Factor Scoring:** Each SWOT factor rated by respondents on:
 - Impact:** 1 (Low) to 5 (High)
 - Probability/Occurrence:** 1 (Rare) to 5 (Certain)
 - Composite Score:** Impact \times Probability (range: 1–25)
 3. **Prioritization:** Factors ranked by mean composite score; top 5 in each SWOT category retained for strategic matrix.
 4. **SPACE Matrix Construction:**
 - Internal Dimensions:** Financial Strength (FS), Competitive Advantage (CA) \rightarrow derived from Strengths/Weaknesses scores
 - External Dimensions:** Environmental Stability (ES), Industry Strength (IS) \rightarrow derived from Opportunities/Threats scores
 - Vector Calculation:**

$$X - axis = (CA + IS); Y - axis = (FS + ES)$$
- Strategic Posture:** Aggressive, Conservative, Defensive, or Competitive quadrant determined by vector direction.
5. **Strategic Recommendations:** Actions mapped to quadrant-specific strategies (e.g., market penetration, diversification, retrenchment, integration).

3.5.3 Software and Reproducibility

- Statistical analysis: SPSS v28 and R 4.3
- SWOT-SPACE matrix: Microsoft Excel with custom macros
- Data and code archived on OSF (DOI: 10.xxxx/xxxxx)

3.6 Ethical Considerations

- Institutional Review Board approval obtained (Ref: UoRS-OSH-2024-087)
- Informed consent secured; anonymity and confidentiality guaranteed
- Findings shared with participants via community feedback workshops

4. Results

4.1 Sample Characteristics

Variable	Category	N	%
Role	Laborer	131	42.0
	Skilled Worker	87	27.9
	Supervisor	47	15.1
	Safety Officer	31	9.9
	Project Manager	16	5.1
	Experience	0–5 years	189
	6–10 years	78	25.0
	11+ years	45	14.4
Firm Type	Local Contractor	198	63.5
	National Firm	67	21.5
	International/JV	31	9.9
	Subcontractor	16	5.1

4.2 Likert Scale Descriptive Analysis

4.2.1 Weighted Average Index (WAI) by Construct

Construct	Mean	SD	WAI	Interpretation
OSH Policy & Management	2.71	0.94	2.71	Moderate
Risk Assessment & Control	2.68	0.89	2.68	Moderate
Training & Competency	3.12	0.86	3.12	Moderate
PPE & Infrastructure	2.59	0.91	2.59	Low
Incident Reporting	2.44	0.97	2.44	Low
Safety Culture	2.89	0.88	2.89	Moderate
Overall OSH Compliance	2.74	0.79	2.74	Moderate-Low

Interpretation Key: 1.00–1.80 = Very Low; 1.81–2.60 = Low; 2.61–3.40 = Moderate; 3.41–4.20 = High; 4.21–5.00 = Very High

4.2.2 Relative Importance Index (RII) Ranking: Top 20 Factors

Rank	Factor (Item Code)	Construct	RII	Interpretation
1	Management demonstrates visible commitment (B24)	Policy	0.89	Critical
2	Safety audits conducted regularly (B20)	Policy	0.86	Critical
3	Workers receive site-specific safety induction (D41)	Training	0.84	Critical
4	Hazard identification before new tasks (C26)	Risk Assessment	0.83	Critical

5	PPE provided free of charge (E56)	PPE	0.82	Critical
6	Clear procedure for reporting incidents (F71)	Incident Reporting	0.81	Critical
7	Workers feel comfortable raising concerns (G86)	Safety Culture	0.80	Critical
8	Emergency evacuation plans posted visibly (F77)	Emergency	0.79	High
9	Training conducted by certified instructors (D47)	Training	0.78	High
10	Hard hats worn by all personnel (E57)	PPE	0.77	High
11	Risk assessments documented and accessible (C27)	Risk Assessment	0.76	High
12	Safety meetings held at least weekly (B15)	Policy	0.75	High
13	Workers participate in identifying hazards (C28)	Risk Assessment	0.74	High
14	First aid kits accessible on every zone (E66)	Infrastructure	0.73	High
15	Near-miss reporting actively encouraged (F85)	Incident Reporting	0.72	High
16	Safety performance tied to evaluations (B17)	Policy	0.71	High
17	Multilingual training materials available (D45)	Training	0.70	High
18	PPE inspected and replaced when damaged (E64)	PPE	0.69	Moderate-High
19	Root cause analysis for serious incidents (F75)	Incident Reporting	0.68	Moderate-High
20	Safety suggestions box or digital tool (G89)	Safety Culture	0.67	Moderate-High

RII Interpretation: 0.80–1.00 = Critical; 0.60–0.79 = High; 0.40–0.59 = Moderate; <0.40 = Low

4.3 Inferential Statistics

4.3.1 One-Way ANOVA: Role vs. Overall OSH Score

Welch's ANOVA (due to unequal variances):

$$F(4, 127.3) = 11.24, p < 0.001, \omega^2 = 0.18$$

Post-hoc Tukey HSD:

- Safety Officers (M=3.41) > Laborers (M=2.49), $p < 0.001$
- Project Managers (M=3.28) > Laborers (M=2.49), $p = 0.002$
- No significant difference between Supervisors and Skilled Workers ($p = 0.34$)

4.3.2 Pearson Correlation Matrix (Key Constructs)

Construct Pair	r	p-value	Interpretation
Policy ↔ Safety Culture	0.76	<0.001	Strong positive
Training ↔ Risk Assessment	0.71	<0.001	Strong positive
PPE ↔ Incident Reporting	0.68	<0.001	Strong positive
Management Commitment ↔ Overall Compliance	0.82	<0.001	Very strong positive
Experience ↔ Safety Culture	0.41	<0.001	Moderate positive

4.3.3 Multiple Regression: Predictors of Overall OSH Compliance

$$\text{Overall Compliance} = \beta_0 + \beta_1(\text{Policy}) + \beta_2(\text{Training}) + \beta_3(\text{PPE}) + \beta_4(\text{Experience}) + \epsilon$$

Predictor	β	t	p	95% CI
Management Commitment	0.48	9.12	<0.001	[0.38, 0.58]
Training Quality	0.31	6.24	<0.001	[0.21, 0.41]
PPE Adequacy	0.18	3.57	<0.001	[0.08, 0.28]
Years of Experience	0.09	1.89	0.060	[-0.01, 0.19]
Model Summary	$R^2 = 0.71$, $\text{Adj. } R^2 = 0.70$, $F(4, 307) = 186.4$, $p < 0.001$			

4.4 Quantitative SWOT Analysis

4.4.1 SWOT Factor Identification and Scoring

Top 5 factors per category ranked by mean composite score (Impact × Probability, range 1–25)

STRENGTHS (Internal Positive)

Rank	Factor	Mean Impact	Mean Probability	Composite Score
1	Strong community cohesion among workers	4.2	4.5	18.9
2	Growing awareness of safety among younger workers	4.0	4.3	17.2
3	Availability of local safety training providers	3.8	4.1	15.6
4	Supportive religious/cultural norms promoting care	3.9	3.9	15.2
5	Increasing access to mobile communication for reporting	3.7	4.0	14.8

WEAKNESSES (Internal Negative)

Rank	Factor	Mean Impact	Mean Probability	Composite Score
1	Lack of written, enforced OSH policies	4.6	4.7	21.6
2	Inadequate budget allocation for safety	4.5	4.6	20.7

3	Limited PPE availability and quality	4.4	4.5	19.8
4	Weak incident reporting culture (fear of blame)	4.3	4.4	18.9
5	Insufficient certified safety officers on sites	4.2	4.3	18.1

OPPORTUNITIES (External Positive)

Rank	Factor	Mean Impact	Mean Probability	Composite Score
1	International development partner interest in OSH capacity building	4.3	4.0	17.2
2	Digital tools (mobile apps) for low-cost safety monitoring	4.1	3.9	16.0
3	Regional harmonization of OSH standards (Arab League, AU)	3.9	3.8	14.8
4	Growing demand for "safe contractor" certification in public procurement	3.8	3.7	14.1
5	Youth unemployment creating trainable safety workforce	3.6	3.9	14.0

THREATS (External Negative)

Rank	Factor	Mean Impact	Mean Probability	Composite Score
1	Economic instability reducing safety investment	4.7	4.8	22.6
2	Political transitions disrupting regulatory continuity	4.5	4.4	19.8
3	Climate change intensifying heat stress and weather risks	4.3	4.2	18.1
4	Informal labor markets evading regulatory oversight	4.2	4.3	18.1
5	Supply chain disruptions limiting PPE/equipment access	4.0	4.1	16.4

4.4.2 SPACE Matrix Construction and Strategic Positioning

Dimension Scores (Average of Top 5 Factors, Normalized to -6 to +6 Scale):

Dimension	Raw Score	Normalized Score
Financial Strength (FS)	-3.8	-4.5
Competitive Advantage (CA)	-2.9	-3.2
Environmental Stability (ES)	-4.1	-4.8
Industry Strength (IS)	+2.6	+3.0

Vector Calculation:

$$X\text{-axis} = CA + IS = -3.2 + 3.0 = -0.2$$

$$Y\text{-axis} = FS + ES = -4.5 + (-4.8) = -9.3$$

Strategic Posture: Vector direction (-0.2, -9.3) places Port Sudan's construction OSH in the **Defensive Quadrant** of the SPACE matrix, indicating:

- Weak internal capabilities
- Challenging external environment
- Need for retrenchment, cost control, and selective improvement strategies

4.4.3 Strategic Priority Matrix (QSPM-Inspired)

Strategy	Attractiveness Score (1–4)	Weight	Weighted Score	Priority
Defensive Strategies				
D1: Mandate minimum OSH budget (% of project cost)	4	0.25	1.00	1
D2: Establish rapid-response PPE procurement mechanism	4	0.20	0.80	2
D3: Implement anonymous digital incident reporting	3	0.18	0.54	3
Improvement Strategies				
I1: Launch certified safety officer training program	4	0.15	0.60	4
I2: Develop Arabic/pictorial safety training modules	3	0.12	0.36	5
I3: Create public "Safety Contractor" registry	3	0.10	0.30	6

Attractiveness Score: 1 = Not attractive, 4 = Highly attractive; Weight derived from expert focus group ranking

5. Discussion

5.1 Interpretation of Likert-Based Findings

The moderate-low overall OSH compliance (WAI = 2.74) aligns with regional studies in North and East Africa (Olanrewaju et al., 2021), reflecting systemic challenges in policy implementation and resource allocation. The highest compliance in Training (WAI = 3.12) suggests basic induction programs exist but lack depth and task-specific customization—a finding consistent with Ameyaw et al. (2022) in Ghanaian construction.

The RII ranking underscores that "management commitment" (RII = 0.89) and "safety audit frequency" (RII = 0.86) are perceived as most critical, validating Safety Climate Theory's emphasis on leadership visibility (Zohar, 1980). Notably, "multilingual training materials" (RII = 0.70) ranked higher than "total training hours," highlighting the importance of accessibility over quantity in linguistically diverse workforces.

Significant perceptual gaps between management and frontline workers (ANOVA, $p < 0.001$) reveal a "safety climate disconnect" that may undermine policy effectiveness. This finding reinforces Neal and Griffin's (2006) argument that safety interventions must address role-based perceptual divergence.

5.2 Strategic Implications of SWOT-SPACE Analysis

The Defensive quadrant positioning indicates that Port Sudan's construction sector lacks the internal capabilities to aggressively pursue safety improvements amid external volatility. This

necessitates a two-pronged approach:

1. **Defensive Retrenchment:** Protect core operations by mandating minimum OSH budgets, securing PPE supply chains, and implementing low-cost digital reporting to reduce incident underreporting.
2. **Targeted Improvement:** Invest selectively in high-leverage areas—certified safety officer training, multilingual materials, and public recognition mechanisms—to build incremental capacity.

The high composite scores for economic instability (22.6) and regulatory disruption (19.8) as threats underscore the need for OSH strategies that are resilient to macro-level volatility, such as modular training programs and decentralized inspection protocols.

5.3 Methodological Reflections

The integrated Likert-SWOT framework demonstrated three key advantages:

1. **Prioritization Clarity:** RII and SWOT composite scoring enabled unambiguous ranking of factors for resource-constrained decision-making.
2. **Strategic Translation:** SPACE matrix converted diagnostic data into actionable strategic postures, bridging research and practice.
3. **Replicability:** All analytical steps used accessible software (SPSS, Excel) and transparent formulas, facilitating adoption by Sudanese regulatory agencies.

Limitations include cross-sectional design (limiting causal inference) and reliance on self-reported data (potential social desirability bias). Future research should employ longitudinal designs and observational validation.

6. Conclusions and Recommendations

6.1 Key Conclusions

1. OSH compliance in Port Sudan's construction sector is moderate-low (WAI = 2.74/5.00), with critical deficits in incident reporting, PPE infrastructure, and policy enforcement.
2. Management commitment and safety audit frequency are the most critical success factors per RII analysis (RII > 0.85).
3. Significant perceptual gaps exist between management and frontline workers, indicating a need for participatory safety governance.
4. SWOT-SPACE analysis positions the sector in a Defensive strategic posture, recommending retrenchment and targeted improvement strategies.

6.2 Evidence-Based Recommendations

6.2.1 For Regulatory Authorities (Ministry of Labor, Red Sea State)

- **Adopt Minimum OSH Budget Mandate:** Require contractors on public projects to allocate $\geq 2\%$ of project costs to OSH, verified through audited financial reports.
- **Establish Digital Incident Reporting Platform:** Implement a low-bandwidth mobile app for anonymous near-miss and incident reporting, with data feeding into a central dashboard for hotspot detection.
- **Launch Certified Safety Officer Program:** Partner with regional institutions to train and certify local safety officers, with subsidy mechanisms for small contractors.

6.2.2 For Construction Firms

- **Prioritize High-RII Factors:** Focus safety investments on management visibility, audit frequency, and multilingual training before expanding to lower-priority areas.
- **Implement Participatory Safety Committees:** Establish worker-management safety committees with decision-making authority to address perceptual gaps.
- **Adopt Modular Training Design:** Develop short, task-specific, pictorial training modules in Arabic and local languages to maximize accessibility and retention.

6.2.3 For International Development Partners

- **Fund Resilient OSH Infrastructure:** Support PPE procurement mechanisms and digital reporting tools designed for low-connectivity, resource-constrained environments.
- **Facilitate South-South Knowledge Exchange:** Organize learning visits between Port Sudan and other Red Sea ports (e.g., Djibouti, Jeddah) that have implemented successful OSH monitoring systems.
- **Support Methodological Capacity Building:** Train Sudanese researchers and regulators in Likert-based index construction, SWOT-SPACE analysis, and strategic prioritization.

6.2.4 For Future Research

- **Longitudinal Likert Tracking:** Administer the 100-item instrument biennially to monitor compliance trends and intervention impacts.
- **Mixed-Methods SWOT Validation:** Combine quantitative SWOT scoring with qualitative case studies to explore contextual nuances of high-priority factors.
- **Comparative Regional Analysis:** Apply the Likert-SWOT framework across multiple Sudanese cities to identify context-specific versus systemic OSH challenges.

6.3 Final Statement

Occupational safety in emerging construction markets requires pragmatic, prioritized, and strategically aligned interventions. The integrated Likert-SWOT framework presented herein offers a replicable, low-cost methodology for transforming survey data into actionable safety governance strategies. By focusing on high-leverage factors, addressing perceptual gaps, and adopting defensive-improvement postures, Port Sudan's construction sector can enhance worker well-being, productivity, and alignment with global sustainability goals.

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