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Modeling the Relationship Between Psychosocial Stressor Exposure and Safety Compliance in a Developing Economy Construction Industry

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Abstract

Psychosocial hazards are established antecedents of psychological strain among construction personnel, yet whether that strain transmits exposure to safety compliance or exposure acts on compliance directly has rarely been tested with criteria sensitive to construct redundancy. This study tested these competing accounts in Pakistan, where construction carries about twice its workforce share of occupational injuries. A questionnaire survey obtained 196 responses, of which 157 were retained after screening for unengaged and duplicate cases. Partial least squares structural equation modeling was applied, with discriminant validity assessed by the heterotrait–monotrait ratio, mediation evaluated through specific indirect effects, and predictive relevance assessed out of sample. Four construct pairs exceeded the discriminant criterion before remediation, one at unity. Psychosocial stressor exposure predicted perceived strain-related safety impairment ($\beta = 0.676$) and compliance maintained under strain ($\beta = -0.301$), whereas impairment did not predict compliance and the indirect effect spanned zero under both reflective and formative specifications of exposure. Role and employment insecurity predicted compliance positively ($\beta = 0.600$), contrary to expectation. Contractors and site managers can monitor workload, scheduling, and communication conditions as early indicators of non-compliance without clinical assessment, regulators should treat work organization and employment security as safety determinants, and compliance observed under job insecurity should not be read as internalized safety commitment.

Keywords: construction safety; psychosocial hazards; safety compliance; psychological distress; job insecurity; structural equation modeling

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1. Introduction

Construction remains among the most hazardous industries. At least 108,000 workers are killed on construction sites each year, about 30% of all fatal occupational injuries, and in developing countries the risks associated with construction work may be three to six

times greater than those of other occupations [1]. In Pakistan, the construction sector accounted for 19.7% of employed persons who suffered an occupational injury or disease in 2020–21, against a 9.5% share of total employment [2], so the sector carries about twice its share of the national injury burden. Safety on such sites depends on more than physical site conditions [3,4]. Production pressure, role ambiguity, and weak supervisory support are now treated as antecedents of safety behavior [5,6]. Impaired psychological states degrade the processes on which hazard detection depends [7,8]. Subjective appraisal governs whether awareness becomes protective action [9]. Mental ill health is accordingly an explicit target of safety research [10,11].

The exposures shaping construction workers' mental health are well documented. Chan et al. [12] reviewed 16 studies and identified 32 risk factors, with working hours above 60 per week ranked first. Tijani et al. [13] extracted 49 stressors from 38 papers across organizational, task, personal, and physical categories. Comparable exposures appear among bricklayers [14] and among professional staff, for whom long hours predicted stress [15]. Sun et al. [16] pooled 48 studies covering 13,083 workers and reported a correlation of 0.28 with mental health problems, rising to 0.41 for role conflict and 0.32 across Asian samples.

Evidence that psychological strain transmits stressor exposure to unsafe outcomes spans two decades. Siu et al. [17] found psychological distress mediating safety attitudes and accident rates among 374 workers, and Goldenhar et al. [18] related 10 of 12 stressors to injury and near-miss outcomes among 408 laborers. Li et al. [19] routed demands and resources to injuries through emotional exhaustion. An important qualification followed. Wang et al. [20] reported that safety-related stress reduced participation ($\beta = -0.192$) while leaving compliance unaffected ($\beta = -0.028$), an asymmetry consistent with meta-analytic evidence on participation [21], with support predicting compliance and control predicting participation [22], and with the small indirect effects reported by Jung et al. [23].

Risk perception supplies the cognitive step between psychological state and behavior. Pandit et al. [24] showed hazard recognition mediating safety climate and risk perception across 280 workers at 57 workplaces. Degraded states impair appraisal directly, since mental fatigue reduced hazard detection among operators [25] and induced fatigue raised error rates in manual handling [26]. Measurement remained weak until Man et al. [27] developed a 13-item scenario-based instrument on 469 workers, which was later extended into a screening index [28] and separated from risk-taking behavior [29].

Organizational conditions govern whether hazards are voiced. Hall et al. [30] established psychosocial safety climate as a measurable upstream resource, and Manapragada and Bruk-Lee [31] showed that safety silence follows identifiable motives. Job insecurity degrades reporting and compliance [32], while supervisory enforcement predicts how far incidents go unrecorded [33]. These conditions intensify where enforcement is uneven. Mohamed et al. [34] linked national culture to unsafe behavior in Pakistan, Zahoor et al. [35] cross-validated a 24-item safety climate scale on 40 Pakistani projects, and Khan et al. [36] attributed persistent hazards to equipment and training costs.

Analytical practice has advanced in parallel. Variance-based structural equation modeling handles composite constructs and mediation [37,38], yet Henseler et al. [39] showed by simulation that the Fornell–Larcker criterion and cross-loadings detect genuine discriminant validity failures in as few as 0.3 and 0.0% of cases, whereas the heterotrait–monotrait ratio is reliable. Predictive assessment is benchmarked out of sample against linear models [40,41]. Construction applications predict injury type, site risk, and fatality from incident records [42,43], and the behavior scales show measurement equivalence across languages [44].

It therefore remains unknown whether psychosocial stressors reduce safety compliance through psychological strain or act on it directly, because three weaknesses in the existing work prevent this question from being answered. First, studies of psychosocial exposure stop at a mental health outcome, whereas studies of safety behavior begin from climate, so the full sequence from stressor to behavior is rarely estimated in one specification. Second, discriminant validity is routinely assessed by criteria that lack sensitivity, so reported separations between psychological constructs may not survive a stricter test. Third, predictive work draws on incident records, so no procedure identifies workers at risk from their psychosocial profile in advance. These weaknesses converge in developing economies such as Pakistan, where construction carries twice its share of occupational injuries, enforcement is uneven, and local instruments are rarely applied.

This study addresses one research question: does psychosocial stressor exposure reduce safety compliance among construction personnel by impairing their perceived capacity to work safely, or does it act on compliance directly? The question is treated as a test between two competing accounts rather than as confirmation of a presumed pathway, so an absent indirect effect is as informative as a present one. One structural model links psychosocial stressor exposure and role and employment insecurity to safety compliance through perceived strain-related safety impairment, using indicators adapted from established sources and screened for unengaged responding among construction personnel in Pakistan. Discriminant validity is assessed by the heterotrait–monotrait ratio, and failing construct pairs receive the prescribed remediation rather than being set aside. Mediation is tested through specific indirect effects, and predictive relevance is evaluated out of sample against a linear benchmark using Q^2predict, so the claims rest on measured indicators rather than on model-derived scores. The answer indicates whether prevention in developing economy construction should target the organization of work or the psychological condition of individual workers.

2. Significance, Novelty, and Contribution

The contribution of this study is positioned against 10 recent investigations of psychosocial influences on construction safety behavior, set out in Table 1. Psychological state across that set is represented most often by a single construct such as resilience, thriving, or empathy, and only Jung et al. [23] applied established clinical instruments for depression and anxiety. One study applied variance-based structural equation modeling, none reported the heterotrait–monotrait ratio, and none evaluated predictive performance on held-out cases, so no comparison study establishes that its construct separations withstand a sensitive test or that its estimates generalize beyond the estimation sample.

Against this set, the present study analyzes five research dimensions within one specification, each corresponding to a column of Table 1. The first is context: nine of the 10 studies drew their samples from China or South Korea, whereas the present sample of 157 construction personnel in Pakistan represents a South Asian workforce employed predominantly on contract or daily wage terms. The second is pathway structure: psychosocial stressor exposure, role and employment insecurity, perceived strain-related safety impairment, and safety compliance are estimated together, so the direct and mediated routes from exposure to behavior are tested against each other rather than in separate models. The third is construct validity: discriminant validity is assessed by the heterotrait–monotrait ratio with bootstrap confidence intervals, and failing construct pairs are remediated, a procedure reported by none of the comparison studies. The fourth is the behavioral outcome: only two of the 10 studies separated compliance from discretionary participation, and the present study isolates compliance maintained under strain, the facet that the asymmetry reported by Wang et al. [20] predicts to be least responsive to strain. The fifth is prediction:

performance is evaluated on held-out observations against naive and linear benchmarks and through screening classification against a majority-class baseline, a dimension absent from all 10 comparison studies.

Table 1. Comparison of the present study with 10 recent investigations of psychosocial determinants of construction safety behavior.

Study	Context and Sample	Psychosocial Exposure	Psychological State	Risk Perception	Safety Outcome	Design & Analysis	Out-of-Sample Prediction
Wang et al. [20]	China; 359 workers	Safety role ambiguity, role conflict, interpersonal conflict	Psychological capital (moderator)	No	Compliance and participation	Cross-sectional; hierarchical regression	Not performed
Jung et al. [23]	South Korea; 399 workers, 29 sites	Job demand, control, support, reward, justice	Depression (CES-D); trait anxiety (STAI)	No	Compliance and participation	Cross-sectional; SEM	Not performed
Zhao and Li [45]	China; 381 workers	Psychosocial safety climate; safety-related stress	Psychological resilience	No	Safety behavior	Cross-sectional; cross-level analysis	Not performed
Liang et al. [46]	China; over 500 workers	Job insecurity and organizational conditions	Stress; empathy	No	Safety participation	Cross-sectional; SEM and regression	Not performed
Cong et al. [47]	China; 293 workers	Challenge and hindrance job stressors	Not modeled	No	Informal safety communication	Cross-sectional; stepwise regression	Not performed
Ma et al. [48]	China; 218 young workers	Resilient safety culture; supervisor, coworker support	Job crafting	No	Safety performance	Cross-sectional; SEM and simulation	Not performed
Martin et al. [49]	United Kingdom; construction workers	Financial loss; quality of life	Anxiety; worry; dread	Yes	Risk perception and well-being	Cross-sectional; PLS-SEM	Not performed
Huang and Li [50]	China; 275 workers	Challenge and hindrance time pressure	Not modeled	No	Safety behavior	Two-wave; SEM	Not performed
Long et al. [51]	China; 208 workers	Family–work conflict; coworker safety support	Thriving at work; workplace anxiety	No	Safety behavior	Three-wave; mediation analysis	Not performed
Li et al. [52]	China; 513 workers	Foreman safety leadership	Attachment avoidance	No	Safety behavior	Cross-sectional; SEM	Not performed
Present study	Pakistan; 157 workers	Time pressure, workload, job control, communication, role and interpersonal conflict, production pressure, risk normalization, silence	Perceived strain-related safety impairment	Merged with strain after HTMT	Compliance	Cross-sectional; PLS-SEM with HTMT and indirect effects	Yes, against a linear benchmark

3. Methodology

3.1. Theoretical Framework and Hypothesis Development

3.1.1. Psychosocial Exposure and Employment Insecurity

Safety behavior is treated here as the terminal element of a sequence originating in the organization of work and passing through the psychological condition of the individual. Two complementary formulations inform this sequence. The Job Demand–Control–Support model holds that strain arises where psychological demands are elevated and decision latitude and social support are limited [53,54], a proposition supported by meta-analytic evidence on the interrelationships among these characteristics [55]. The Job Demands–Resources formulation generalizes this structure by classifying any working condition as a demand or a resource and by separating a health impairment process from a motivational one [56,57]. Later statements clarify that demands deplete regulatory capacity, while resources buffer that depletion and sustain discretionary effort [58,59]. Both formulations are retained, since the control and support constructs of the earlier model correspond to resources in the latter one, while the later model accommodates organizational conditions lying outside the task itself.

Psychosocial exposure in construction has been characterized consistently across systematic reviews, which identify time pressure, quantitative workload, restricted job control, deficient communication, role and interpersonal conflict, and production pressure as recurrent conditions [12,13,60]. Pooled estimates place the association between such exposures and psychological outcomes in the moderate range, with somewhat larger values for Asian samples [16]. Where hazards are tolerated as routine and concerns go unvoiced, the same conditions persist without correction, so normalization of risk and reticence in raising hazards are treated as elements of exposure rather than as separate outcomes [31,61]. These conditions are represented collectively as psychosocial stressor exposure. Role ambiguity and fear of adverse consequence for refusing hazardous work are specified separately as role and employment insecurity, since anticipatory threat to continuity of employment operates through a distinct mechanism and has been shown to affect reporting and compliance rather than psychological condition alone [32,62].

3.1.2. Strain and the Appraisal of Hazards

The psychological consequence of exposure is represented as perceived strain-related safety impairment, denoting the extent to which a worker judges their own hazard detection, concentration, and risk appraisal to deteriorate under conditions of strain. This construct combines symptom-level distress with the appraisal deficits attributed to it, a combination adopted on empirical rather than preferential grounds and justified in Section 3.5.2. Resource depletion is associated with attentional narrowing and with substitution of expedient routines for prescribed procedures, a mechanism supported by longitudinal evidence linking exhaustion to occupational injury [63] and by experimental work in construction relating induced fatigue to error and to degraded hazard detection [25,26]. Integrative reviews place individual appraisal alongside workgroup and organizational influences while noting that its mediating position remains inconsistently specified [64].

3.1.3. Safety Compliance as the Behavioral Outcome

Safety compliance denotes adherence to prescribed procedure and is distinguished in the established formulation from discretionary activity beyond formal requirements [65]. Compliance is itself multifaceted, spanning adherence to procedure, use of protective equipment, and the correct operation of equipment, and it differs in the depth with which rules are internalized rather than displayed for observation [66]; validated instruments accordingly represent it with several items within a two-factor structure of compliance and

participation [67,68]. The instrument administered in this study captures a narrower facet. Its two indicators record whether a worker continues to follow safety protocols and to use protective equipment when under stress, corresponding to the procedural and protective equipment content of the established compliance formulation [65], so the construct is interpreted throughout as compliance maintained under strain, and correct equipment operation, hazard reporting, and discretionary participation lie outside its scope. This restriction bears directly on the expected magnitude of effects. Meta-analytic evidence reports a stronger association between organizational climate and discretionary behavior than between climate and compliance [21], leadership behaviors have been shown to motivate the two components through separate routes [69], and work characteristics drawn from the demand–control–support tradition predict them differentially [22]. Most directly, safety-related stress has been found to reduce discretionary participation while leaving compliance largely unaffected, an asymmetry attributed to the protection of enforced in-role obligation under conditions of limited energy [20]. Effects on compliance are accordingly hypothesized as directional but modest, and the possibility that impairment fails to transmit to enforced behavior is treated as an outcome of interest rather than as a failure of the model.

The specification comprises two exogenous constructs, one mediating construct, and one behavioral outcome. Six hypotheses are advanced, of which five concern direct associations and one concerns mediation. The hypotheses, their theoretical basis, and the expected direction of each association are set out in Table 2, and the corresponding path structure is depicted in Figure 1. Given the cross-sectional design, directional language throughout denotes hypothesized rather than demonstrated causal ordering.

Table 2. Hypothesized associations and their theoretical basis.

	Hypothesized Association	Theoretical Basis
H1	Psychosocial stressor exposure is positively associated with perceived strain-related safety impairment	Health impairment process of the Job Demands–Resources model
H2	Psychosocial stressor exposure is negatively associated with safety compliance	Depletion of the regulatory capacity required for consistent rule following
H3	Role and employment insecurity is positively associated with perceived strain-related safety impairment	Anticipated threat to continuity of employment as a chronic demand
H4	Role and employment insecurity is negatively associated with safety compliance	Ambiguity regarding safety obligation impedes consistent adherence
H5	Perceived strain-related safety impairment is negatively associated with safety compliance	Degraded appraisal and attention acting on in-role behavior
H6	Perceived strain-related safety impairment mediates the association between psychosocial stressor exposure and safety compliance	Health impairment process extended to behavior, tested against a direct-exposure alternative

3.2. Research Design

A quantitative, cross-sectional design was executed in three sequential stages. The first established the constructs and candidate indicators from the literature and fixed the measurement instrument. The second collected primary data through a structured questionnaire administered to construction personnel in Pakistan. The third estimated the structural model, evaluated mediation, and assessed predictive performance on withheld observations. The three stages and their principal outputs are represented in Figure 2. This sequence follows comparable investigations of psychosocial influences on construction safety behavior, which have combined questionnaire measurement with covariance-based

or variance-based structural modeling [23,46,49]. The design does not permit temporal separation of predictor and outcome measurement, a constraint addressed procedurally in Section 3.5.4.

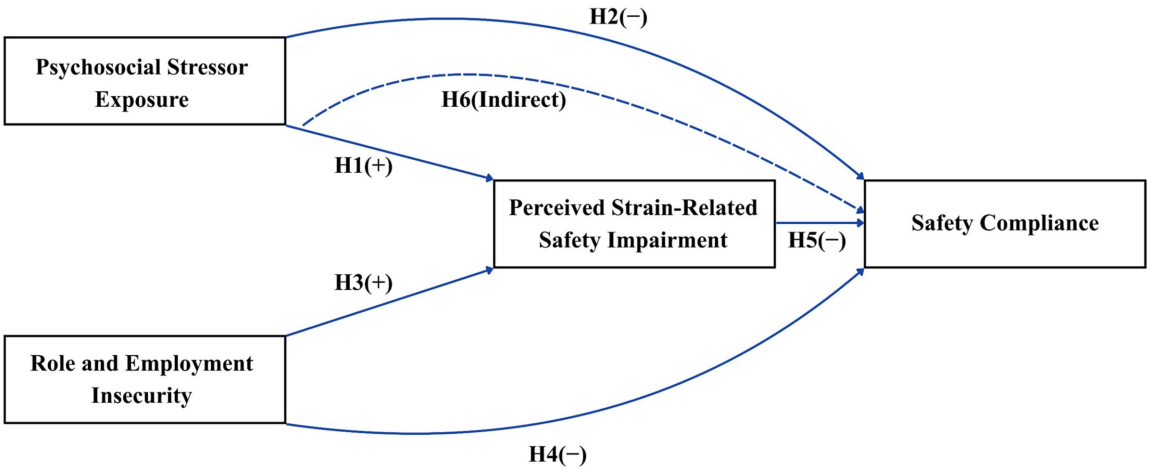


Figure 1. Hypothesized structural model relating psychosocial stressor exposure and role and employment insecurity to safety compliance through perceived strain-related safety impairment.

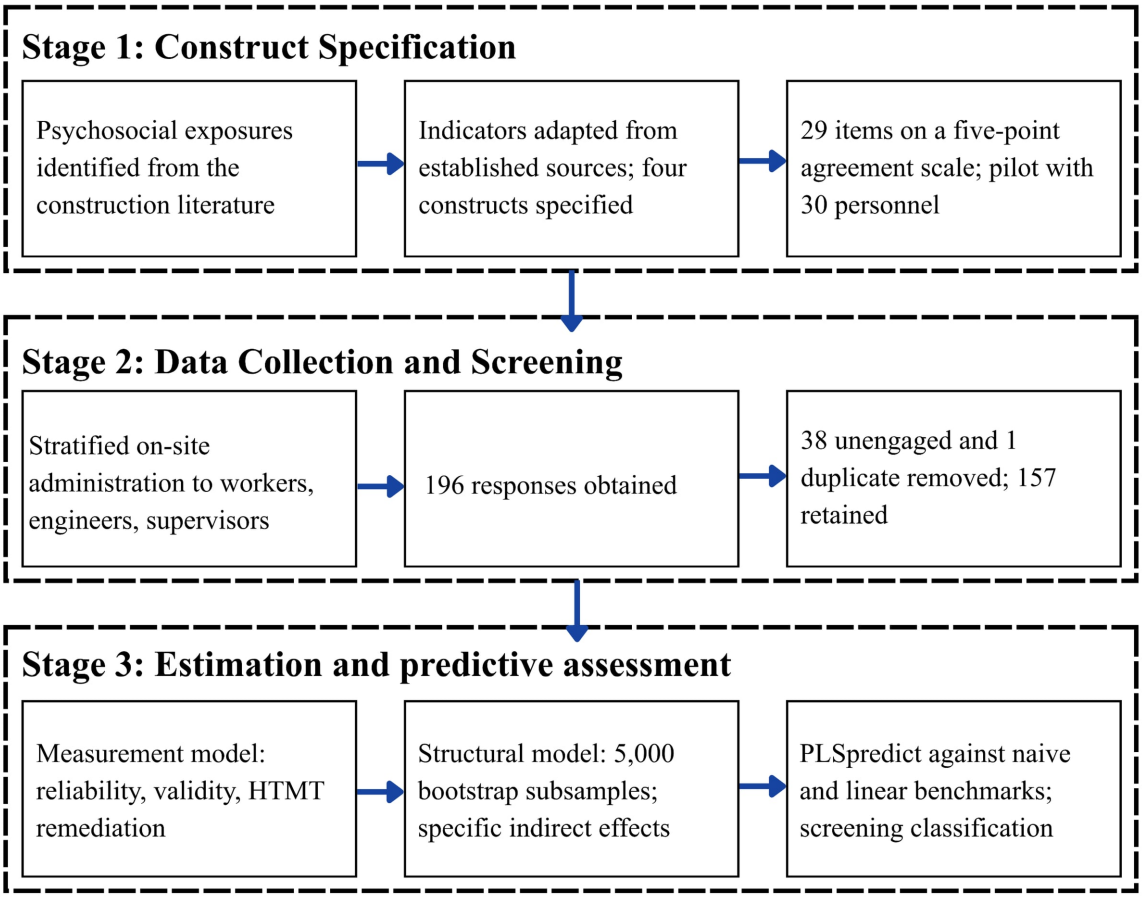


Figure 2. Three-stage research design comprising construct specification, questionnaire administration and screening, and model estimation with predictive assessment.

3.3. Instrument and Measurement

3.3.1. Construct Operationalization and Item Sources

The questionnaire comprised a demographic section and 29 attitudinal items rated on a five-point agreement scale anchored at strongly disagree and strongly agree. Items were adapted from established sources rather than composed for this study. Indicators of time pressure, workload, and restricted job control follow the demand and latitude constructs of the demand-control tradition [53,54]; indicators of communication deficiency, role conflict, and interpersonal conflict follow psychosocial work environment measurement in construction populations [14,60]; indicators of production pressure and risk normalization follow organizational climate measurement [30]; and the indicator of reticence in raising hazards follows the safety silence formulation [31]. Symptom-level indicators of distress and the appraisal deficits attributed to it were drawn from construction mental health measurement [12,28], and compliance indicators follow the established in-role formulation [65]. The constructs, their indicator composition, item counts, and sources are set out in Table 3.

Table 3. Constructs, indicator composition, item counts, and measurement sources.

Construct	Indicator Composition	Items	Source
Psychosocial stressor exposure	Time pressure; quantitative workload; restricted job control; communication deficiency; role conflict; interpersonal conflict; production pressure; risk normalization; safety silence	9	[14,30,31,53]
Role and employment insecurity	Ambiguity regarding personal safety responsibility; fear of adverse employment consequence for refusing hazardous work	2	[32,62]
Perceived strain-related safety impairment	Distress attributed to work conditions; impairment of hazard detection, concentration, motivation, and protective equipment focus; underestimation of risk and propensity to expedient shortcuts under strain	8	[12,28]
Safety compliance	Continued adherence to safety protocols under stress; continued use of protective equipment under stress (compliance maintained under strain)	2	[65]

Note: The 29 attitudinal items were administered on a five-point agreement scale, and 21 are retained in the specification above. Eight were excluded, comprising five items not assigned to any construct at the design stage, one risk-taking item eliminated on empirical grounds, and two belief items removed as lying outside the behavioral outcome. Item wording and retention status are reported in Table A1 (Appendix A).

3.3.2. Questionnaire Development, Pilot Testing, and Administration

The questionnaire was developed in four stages. Candidate items were first identified from the literature on construction mental health, psychosocial work environment, risk perception, and safety behavior and were adapted to the construction setting rather than composed anew, so that the wording of each item is traceable to the sources listed in Table 3. The instrument was then organized into three sections: a demographic section recording age, occupational role, construction experience, educational attainment, marital status, project type, and employment status; a section of 14 items on psychosocial conditions at the respondent's site; and a section of 15 items on psychological state, risk appraisal, and safety behavior. All 29 attitudinal items used a five-point agreement scale from strongly disagree (1) to strongly agree (5), and the full wording, code, and retention status of every item are reported in Table A1 (Appendix A). The draft was reviewed for clarity by the research team and piloted with 30 construction personnel drawn from site worker, engineer,

and supervisory roles, who completed the questionnaire and commented on the clarity, relevance, and length of the items. Cronbach alpha exceeded 0.70 for every construct in the pilot, and minor revisions to wording were made, whereas the construct structure and response format required no alteration.

The final instrument was administered in person by the research team during site visits, with responses recorded on a structured electronic form, and items were read aloud where literacy was limited, given that a substantial proportion of the target population holds primary or secondary schooling only. Participation was voluntary and confidential and was preceded by informed consent. Respondent names recorded on the form were removed before analysis so that no identifying information was retained in the analytic file. Completion required approximately 10 min, and the screening applied to the returned forms is described in Section 3.4.

3.4. Sampling, Data Collection, and Response Screening

The target population comprised personnel engaged on building and infrastructure projects in Pakistan. Stratification was applied by occupational group so that site workers, site engineers, and supervisory staff were each represented, with site workers forming the majority on the grounds of their exposure to the hazards under study. Within strata, participation depended on availability during site visits, so the realized sample is not a probability sample; this constraint is common to site-based construction research and is acknowledged rather than obscured. In total, 196 responses were obtained. Two screening procedures were then applied, following the protocol used in a prior Pakistani construction sample [35]. Responses giving an identical answer to at least 80% of the 24 indicators assigned to constructs at the design stage were removed as unengaged, and verbatim duplicate response vectors were removed beyond their first occurrence. On these grounds, 39 responses were excluded, leaving an analytic sample of 157. Screening was performed before any construct was scored so that exclusion decisions could not be informed by the associations subsequently estimated.

3.5. Analytical Procedure

3.5.1. Rationale for Variance-Based Structural Equation Modeling

Partial least squares structural equation modeling was selected over covariance-based estimation for three reasons. The analytic sample is modest relative to the number of indicators, a condition under which variance-based estimation retains statistical power [70]. The distributional assumptions of maximum likelihood estimation are unlikely to hold for five-point responses drawn from an occupationally heterogeneous sample. Most importantly, the study is causal–predictive in orientation rather than strictly confirmatory, and variance-based estimation supports assessment of out-of-sample performance alongside explanatory fit [41]. Estimation was performed in SmartPLS [71] using the path weighting scheme, with reporting following current guidance on composite model specification and evaluation [40,72].

3.5.2. Measurement Model Evaluation and Construct Remediation

Reflective measurement was assessed through indicator loadings, internal consistency, and average variance extracted. Discriminant validity was assessed by the heterotrait–monotrait ratio of correlations rather than by the Fornell–Larcker criterion or by inspection of cross-loadings, since simulation evidence indicates that the latter two procedures detect genuine discriminant validity failures at rates approaching zero under loading patterns and sample sizes typical of this literature [39]. Where the ratio exceeded the criterion for a construct pair, the prescribed remediation sequence was followed rather than the

finding set aside: indicators correlating more strongly with an opposing construct than with their own were reassigned or eliminated, and construct pairs that remained empirically indistinguishable were merged into a more general construct supported by measurement theory [39]. Merging on this basis produced the combined impairment construct described in Section 3.1.2, which subsumes symptom-level distress and the appraisal deficits attributed to it. Item retention and the discriminant validity values obtained before and after remediation are reported in Section 4, since they constitute results rather than procedure.

The specification of psychosocial stressor exposure as a reflective construct requires justification, since its nine indicators describe conditions that differ in content, a configuration that can also be represented formatively or as a higher-order construct [73]. Reflective specification was retained on conceptual and empirical grounds. Conceptually, the indicators are treated as manifestations of a single site-level condition, the general intensity of psychosocial pressure under which work is organized, so that a change in that condition is expected to shift all indicators together and any one indicator is substitutable for another, which is the defining property of reflective measurement [73]. Empirically, dimensionality was evaluated by parallel analysis, which retains only those components whose eigenvalues exceed the corresponding eigenvalues of random data of the same dimensions [74]. A formative alternative was estimated by Mode B weighting, with indicator collinearity, outer weights, and outer loadings assessed against the criteria established for composite measurement [75]. Each of the nine conditions is represented by a single indicator, so a higher-order specification with single-indicator lower-order components reduces to a first-order composite of the same indicators, and the Mode B estimate therefore represents the formative and higher-order alternatives jointly [76].

3.5.3. Structural Estimation, Mediation, and Predictive Assessment

Structural relationships were estimated with bootstrapping using 5000 subsamples, two-tailed, at the 5% level, with percentile confidence intervals reported alongside path coefficients and effect sizes. Mediation was evaluated through specific indirect effects rather than inferred from the pattern of direct coefficients, since a comparison of direct paths does not identify the transmission route [38]. Predictive performance was assessed on observations withheld from estimation using the PLSpredict procedure with 10 folds and 10 repetitions, evaluated against two benchmarks: the indicator means of the training sample, through the $Q^2_{predict}$ statistic, and a linear regression model estimated on the same indicators [40,41]. Comparison against a linear benchmark rather than against the explanatory statistics of the model itself is necessary, since explanatory power in a composite model does not establish predictive relevance. The cross-validated predictive ability test provided an inferential comparison of average prediction error between competing specifications [77]. A secondary classification analysis supports practical screening: the observed compliance composite, rather than any model-derived score, was dichotomized at a threshold justified by its empirical distribution, following the precedent of a screening index developed for construction workers on comparable grounds [28], and classified under stratified partitioning against the majority-class baseline. The partitioning scheme and predictive workflow are represented in Figure 3, and the criteria applied at every stage are collected in Table 4.

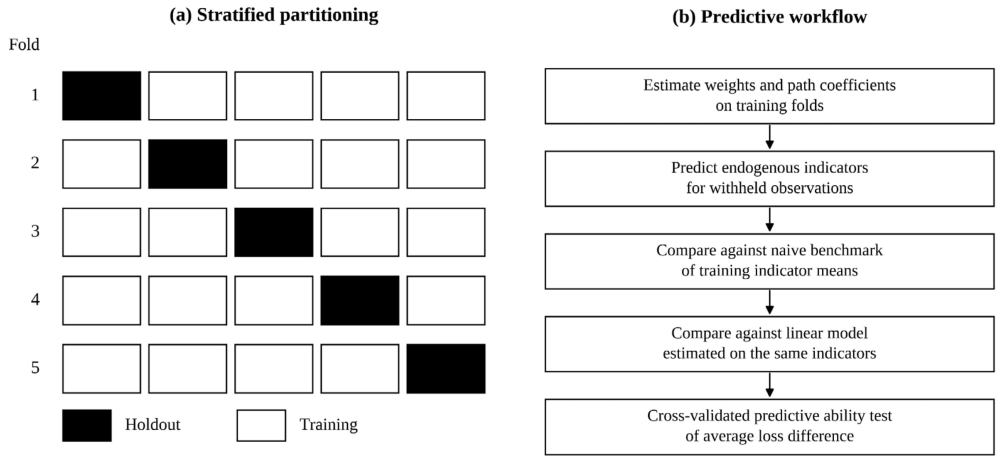


Figure 3. Predictive assessment procedure, showing (**a**) stratified partitioning of the analytic sample into training and holdout folds, and (**b**) the workflow for estimation, prediction on withheld observations, and benchmarking against the naive and linear model benchmarks.

Table 4. Evaluation criteria, decision rules, and supporting sources applied at each analytical stage.

Stage	Criterion	Decision Rule	Source
Reflective measurement	Indicator loading	At or above 0.708; retention between 0.40 and 0.708 conditional on convergent validity and reliability	[40]
	Internal consistency	Cronbach alpha and composite reliability between 0.70 and 0.95	[70]
	Convergent validity	Average variance extracted at or above 0.50	[40]
	Discriminant validity	Heterotrait–monotrait ratio below 0.85; remediation by reassignment, elimination, or merging where exceeded	[39]
Structural model	Collinearity	Inner variance inflation factor below 3.3	[72]
	Path significance	Percentile bootstrap with 5000 subsamples, two-tailed, at the 5% level	[72]
	Effect size	Values of 0.02, 0.15, and 0.35 interpreted as small, medium, and large	[40]
	Mediation	Specific indirect effects with bootstrap confidence intervals; direct coefficients not used for inference	[38]
Predictive assessment	Predictive relevance	Q^2predict above zero against training-sample indicator means	[41]
	Predictive power	Root-mean-square error and mean absolute error below the linear model benchmark	[40]
	Model comparison	Cross-validated predictive ability test, average loss difference with confidence interval	[77]
	Screening classification	Balanced accuracy and area under the curve exceeding the majority-class baseline	[28]
Method variance	Common method variance	Procedural separation of predictor and outcome items; collinearity examination across all constructs	[78]

3.5.4. Common Method Variance

All constructs were obtained by self-report from a single instrument on a single occasion, a configuration under which common method variance may inflate observed associations [78]. Confidentiality was assured and identifying information was removed before analysis, reducing incentives toward socially desirable responding, and predictor and outcome items were separated within the questionnaire. The instrument nonetheless employed a uniform agreement format throughout, which affords no protection against a consistent response set, and the screening procedure described in Section 3.4 was adopted partly for this reason. Statistical assessment through collinearity examination across all constructs, together with item-level evidence bearing on acquiescent responding, is reported in Section 4.

4. Results and Analysis

4.1. Sample Characteristics

Of the 196 responses obtained, 38 were removed as unengaged and one as a verbatim duplicate, retaining 157 for analysis. The composition of the retained sample is set out in Table 5. Site workers accounted for two-thirds of respondents, with site engineers and supervisory staff forming the remainder, and contract-based and daily wage employment together accounted for more than nine in ten. The workforce was young and comparatively inexperienced, with 79% aged between 20 and 30 years and 68% reporting three years of construction experience or less. Educational attainment was concentrated at primary and secondary level, which is consistent with the profile reported for frontline construction personnel in other developing economies [79]. Commercial and residential projects accounted for 83% of the sample. The distribution of employment status is relevant to the interpretation that follows, since the predominance of contract and daily wage arrangements implies limited protection against the consequences of refusing hazardous work.

Table 5. Demographic and occupational characteristics of the analytic sample (N = 157).

Variable	Category	Frequency	Percentage
Age group	20 to 30 years	124	79.0
	31 to 40 years	27	17.2
	Below 20 years	6	3.8
Occupational role	Site worker (laborer, skilled tradesperson)	104	66.2
	Other roles	26	16.6
	Site engineer	23	14.6
	Site supervisor	4	2.5
Construction experience	1 to 3 years	72	45.9
	4 to 6 years	36	22.9
	Less than 1 year	34	21.7
	More than 6 years	15	9.6

Table 5. *Cont.*

Variable	Category	Frequency	Percentage
Educational attainment	Primary or secondary schooling	70	44.6
	Bachelor's degree	40	25.5
	Diploma or technical certification	20	12.7
	No formal education	15	9.6
	Other	12	7.6
Project type	Commercial	70	44.6
	Residential	60	38.2
	Industrial	10	6.4
	Infrastructure	10	6.4
	Other	7	4.4
Employment status	Contract-based	81	51.6
	Daily wage	63	40.1
	Permanent	10	6.4
	Other	3	1.9

Note: Percentages are computed on the analytic sample of 157 retained responses and may not total 100 owing to rounding.

4.2. Measurement Model Evaluation

4.2.1. Indicator Reliability, Internal Consistency, and Convergent Validity

Outer loadings for the retained specification are reported in Table 6. Loadings ranged from 0.684 to 0.926, and all but one exceeded the 0.708 criterion; the exception, an indicator of production pressure loading at 0.684, was retained under the conditional rule declared in Table 4, since its removal would not have raised average variance extracted above the threshold already attained. Cronbach alpha ranged from 0.717 to 0.904 and composite reliability from 0.874 to 0.922, with every value inside the 0.70 to 0.95 interval, indicating adequate internal consistency without the redundancy that values above 0.95 would suggest. The Dijkstra–Henseler coefficient fell between these two bounds for every construct, ranging from 0.751 to 0.907. Average variance extracted ranged from 0.567 to 0.855, so each construct accounted for more than half the variance of its indicators. Convergent validity was therefore established for all four constructs.

Table 6. Indicator loadings, internal consistency, and convergent validity of the retained measurement model.

Construct	Indicators	Loading Range	Cronbach Alpha	rho A	Composite Reliability	AVE
Psychosocial stressor exposure	9	0.684 to 0.808	0.904	0.907	0.922	0.567
Role and employment insecurity	2	0.924 to 0.926	0.831	0.831	0.922	0.855
Perceived strain-related safety impairment	8	0.699 to 0.847	0.897	0.902	0.917	0.582
Safety compliance	2	0.849 to 0.913	0.717	0.751	0.874	0.777

Note: All loadings are significant at $p < 0.001$. Criteria as declared in Table 4.

The reflective specification of psychosocial stressor exposure was supported by the dimensionality evidence reported in Table A2 (Appendix B). Only the first eigenvalue of

the nine-indicator correlation matrix, at 5.107, exceeded the 95th percentile of eigenvalues obtained from 2000 random data sets, whereas the second, at 0.763, fell well below its random counterpart of 1.338; the first component accounted for 56.7% of indicator variance, inter-item correlations ranged from 0.357 to 0.641, and sampling adequacy reached 0.914. The original grouping of these indicators into work intensity demands and organizational stressors returned a heterotrait–monotrait ratio of 0.947 (Table 7), so the lower-order dimensions that a higher-order specification would require were not empirically distinguishable. Under Mode B estimation, indicator variance inflation factors ranged from 1.664 to 2.352, below the 3.3 criterion; the outer weights of communication deficiency and risk normalization were significant, and every outer loading was at least 0.629 and significant, which satisfies the retention rule for formative indicators whose weights are non-significant [75]. The formative and reflective composites correlated at 0.969, and every structural conclusion was unchanged, as reported in Table A3 (Appendix B). Exposure was associated with impairment at 0.702 and with compliance at −0.311, insecurity with compliance at 0.605, and impairment with compliance at 0.123 with an interval spanning zero, while the specific indirect effect, at 0.086 with an interval from −0.069 to 0.283, remained non-significant. The substantive findings therefore do not depend on the measurement specification adopted for exposure.

Table 7. Heterotrait–monotrait ratios before and after construct remediation.

Construct Pair	Ratio	Outcome
Before remediation: seven-construct specification		
Work intensity demands and organizational stressors	0.947	Exceeds criterion
Distress and stress-related risk-taking	1.019	Exceeds criterion
Distress and mental health beliefs	0.919	Exceeds criterion
Stress-related risk-taking and mental health beliefs	0.925	Exceeds criterion
All remaining pairs before remediation	below 0.85	Within criterion
After remediation: four-construct specification		
Psychosocial stressor exposure and Role and employment insecurity	0.108 [−0.109, 0.327]	Within criterion
Psychosocial stressor exposure and Perceived strain-related safety impairment	0.738 [0.623, 0.839]	Within criterion
Psychosocial stressor exposure and Safety compliance	−0.215 [−0.433, 0.023]	Within criterion
Role and employment insecurity and Perceived strain-related safety impairment	0.035 [−0.177, 0.234]	Within criterion
Role and employment insecurity and Safety compliance	0.735 [0.552, 0.908]	Within criterion
Perceived strain-related safety impairment and Safety compliance	−0.098 [−0.341, 0.144]	Within criterion

Note: Values in brackets are 95% percentile bootstrap confidence intervals from 5000 subsamples. Every interval in the remediated specification excludes unity.

4.2.2. Discriminant Validity and Construct Remediation

Discriminant validity was first evaluated for the seven-construct specification implied by the original item assignment, and four construct pairs exceeded the criterion, as reported in the upper panel of Table 7. Work intensity demands and organizational stressors returned a ratio of 0.947, while distress and stress-related risk-taking returned 1.019, a value at unity indicating that the two were not empirically separable. The belief indicators concerning the general relationship between mental health and safety exceeded the criterion against both distress and risk-taking, at 0.919 and 0.925 respectively. Remediation followed the sequence

declared in Section 3.5.2. One risk-taking indicator was eliminated, since it correlated more strongly with the belief indicators than with its own block, at 0.663 against 0.610; the belief indicators were removed as a construct lying outside the behavioral outcome of interest; and the two remaining offending pairs were merged. In the resulting four-construct specification, reported in the lower panel of Table 7, the largest ratio was 0.738, and every bootstrap confidence interval excluded unity. Of the 29 administered indicators, 21 were retained.

4.3. Structural Model

4.3.1. Direct Effects and Explanatory Power

Path coefficients and their bootstrap standard errors, confidence intervals, and effect sizes are reported in Table 8, and the estimated structure is depicted in Figure 4. Inner variance inflation factors ranged from 1.009 to 1.845, so collinearity did not threaten the estimates. Psychosocial stressor exposure was strongly associated with perceived strain-related safety impairment, at 0.676 with a confidence interval from 0.584 to 0.772 and an effect size of 0.829, supporting H1. This magnitude exceeds the pooled correlation of 0.28 reported across 48 construction studies and the Asian subgroup estimate of 0.32 [16], a divergence considered in Section 5. Exposure was also negatively associated with safety compliance, at −0.301 with an interval from −0.495 to −0.111, supporting H2, though the effect size of 0.080 places this influence in the small range. Role and employment insecurity showed no association with impairment, at −0.032, so H3 was not supported. Its association with compliance was substantial but positive, at 0.600 with an effect size of 0.584, so H4 was not supported in the direction hypothesized. Impairment showed no association with compliance, at 0.109 with an interval spanning zero, so H5 was not supported. The model accounted for 45.4% of variance in impairment and 38.9% in compliance, with adjusted values of 0.447 and 0.377.

Table 8. Direct effects, effect sizes, and explanatory power of the structural model.

	Path	Coefficient	SE	t	*p*	95% CI	f-Squared	Outcome
H1	Exposure to Impairment	+0.676	0.049	13.899	<0.001	[+0.584, +0.772]	0.829	Supported
H2	Exposure to Compliance	−0.301	0.099	3.056	0.002	[−0.495, −0.111]	0.080	Supported
H3	Insecurity to Impairment	−0.032	0.066	0.492	0.623	[−0.166, +0.092]	0.002	Not supported
H4	Insecurity to Compliance	+0.600	0.064	9.423	<0.001	[+0.473, +0.722]	0.584	Not supported
H5	Impairment to Compliance	+0.109	0.119	0.911	0.362	[−0.117, +0.346]	0.011	Not supported

Note: Coefficients are standardized. Bootstrap with 5000 subsamples, two-tailed. R-squared is 0.454 for perceived strain-related safety impairment and 0.389 for safety compliance, with adjusted values of 0.447 and 0.377. Inner variance inflation factors ranged from 1.009 to 1.845. H4 was significant but opposite in sign to the hypothesis.

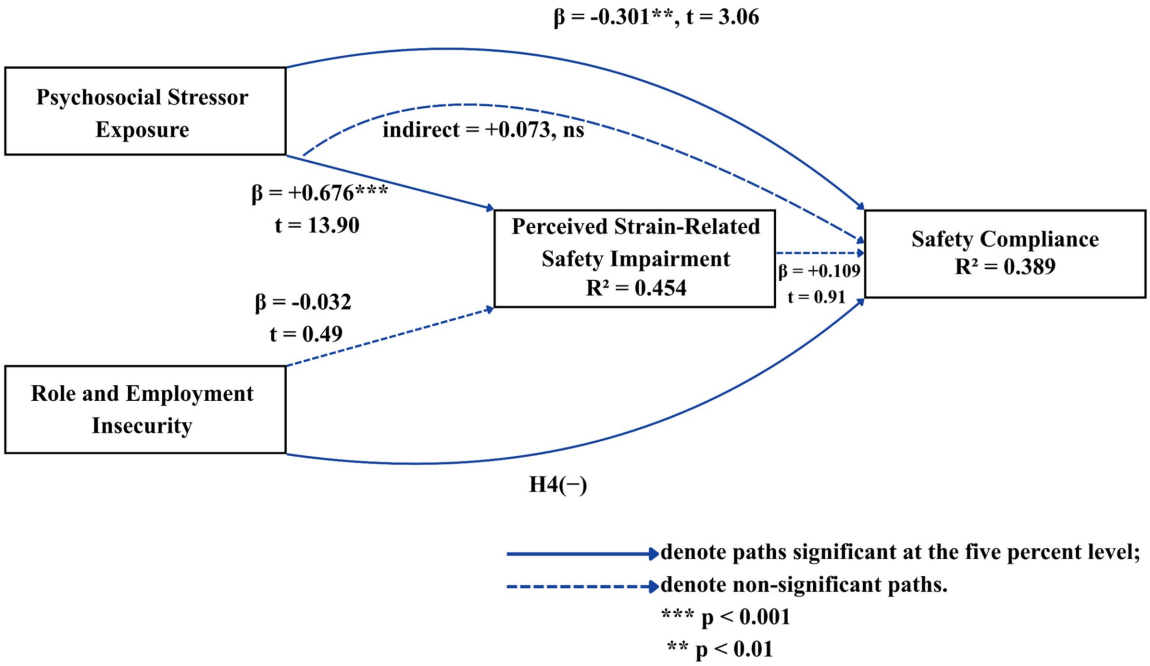


Figure 4. Estimated structural model showing standardized path coefficients, t-statistics, and explanatory power for each endogenous construct.

4.3.2. Mediation

The specific indirect effect running from exposure through impairment to compliance is reported in Table 9. Its point estimate was 0.073 with a bootstrap confidence interval from −0.079 to 0.242, which includes zero, so H6 was not supported. The absence of mediation follows directly from the non-significant second segment of the pathway, since a serial route is unable to transmit an effect through a link that itself carries none. The relationship between exposure and compliance was therefore direct rather than mediated. This pattern is consistent with the finding that safety-related stress reduced discretionary participation while leaving compliance essentially unaffected, at −0.028, in a sample of 359 construction workers [20], and with the small total indirect effects of depression and trait anxiety on compliance, at −0.044 and −0.090, reported among 399 Korean construction workers [23]. Comparable null or weak transmissions to in-role behavior have been reported where the mediator is attitudinal rather than behavioral [47,80].

Table 9. Specific indirect effect of psychosocial stressor exposure on safety compliance.

	Pathway	Effect	SE	t	*p*	95% CI	Outcome
H6	Exposure to impairment to compliance	+0.073	0.083	0.883	0.377	[−0.079, +0.242]	Not supported

Note: The confidence interval includes zero, so mediation is not established. The direct effect of exposure on compliance reported in Table 8 remains significant, indicating a direct rather than a mediated association.

4.4. Predictive Assessment

4.4.1. Out-of-Sample Prediction of Endogenous Indicators

Predictive performance across 10 folds and 10 repetitions is reported in Table 10. Every endogenous indicator returned a positive statistic against the naive benchmark of training-sample indicator means, with values ranging from 0.178 to 0.346, establishing predictive relevance. Against the linear model benchmark, nine of the 10 indicators returned a lower

root-mean-square error, the exception being a single distress indicator exceeding the benchmark by 0.015. Under the decision rule declared in Table 4, this pattern corresponds to high predictive power. The cross-validated predictive ability test confirmed both comparisons inferentially: average loss was lower than the indicator-average benchmark by 0.266 and lower than the linear model by 0.054, each at p below 0.001. The advantage over the linear benchmark, while statistically reliable, is modest in absolute terms, which is expected where a composite model and a saturated regression draw on the same indicator set.

Table 10. Out-of-sample predictive performance of endogenous indicators against the naive and linear model benchmarks.

Indicator	Q-Squared Predict	RMSE	RMSE, Linear Model	Difference	MAE	MAE, Linear Model
MH1	0.297	0.893	0.909	−0.016	0.693	0.694
MH2	0.208	0.845	0.881	−0.036	0.644	0.682
MH3	0.307	0.832	0.838	−0.006	0.644	0.647
MH4	0.193	0.864	0.849	+0.015	0.679	0.668
MH5	0.178	0.936	0.965	−0.029	0.768	0.776
RP1	0.195	0.884	0.908	−0.024	0.687	0.711
RP2	0.326	0.802	0.834	−0.032	0.647	0.668
RP3	0.244	0.857	0.897	−0.040	0.686	0.703
SC1	0.200	0.972	1.039	−0.067	0.751	0.794
SC2	0.346	0.960	1.014	−0.054	0.719	0.744

Note: Results are based on 10 folds and 10 repetitions. A negative difference indicates lower prediction error than the linear model benchmark. The cross-validated predictive ability test returned an average loss difference of −0.266 against the indicator-average benchmark ($t = -30.36$, $p < 0.001$) and −0.054 against the linear model ($t = -12.03$, $p < 0.001$).

4.4.2. Screening Classification

The observed compliance composite, with a mean of 3.105 and a standard deviation of 0.998, was dichotomized at the scale midpoint of 3.00, a cut point falling close to the sample mean and separating respondents who endorsed continued adherence under strain from those who did not. The resulting distribution, presented in Figure 5, comprised 101 compliant and 56 non-compliant cases, giving a majority-class baseline of 0.643. Classification performance under stratified 10-fold partitioning is reported in Table 11. Logistic regression attained an accuracy of 0.803 and a balanced accuracy of 0.767, exceeding the baseline by 16 percentage points, with an area under the curve of 0.814. The support vector classifier and random forest performed somewhat better, attaining balanced accuracies of 0.814 and 0.838 and areas under the curve of 0.893 and 0.891. Training and validation performance by fold, presented in Figure 6, remained closely aligned throughout, with mean validation accuracy of 0.803 against training accuracy of comparable magnitude, indicating that the models did not overfit. The confusion matrix for the logistic classifier, presented in Figure 7, shows 90 compliant and 36 non-compliant cases correctly identified, against 11 and 20 misclassifications respectively. The asymmetry is consequential for screening, since the 20 non-compliant workers classified as compliant represent the cases a screening instrument would fail to flag.

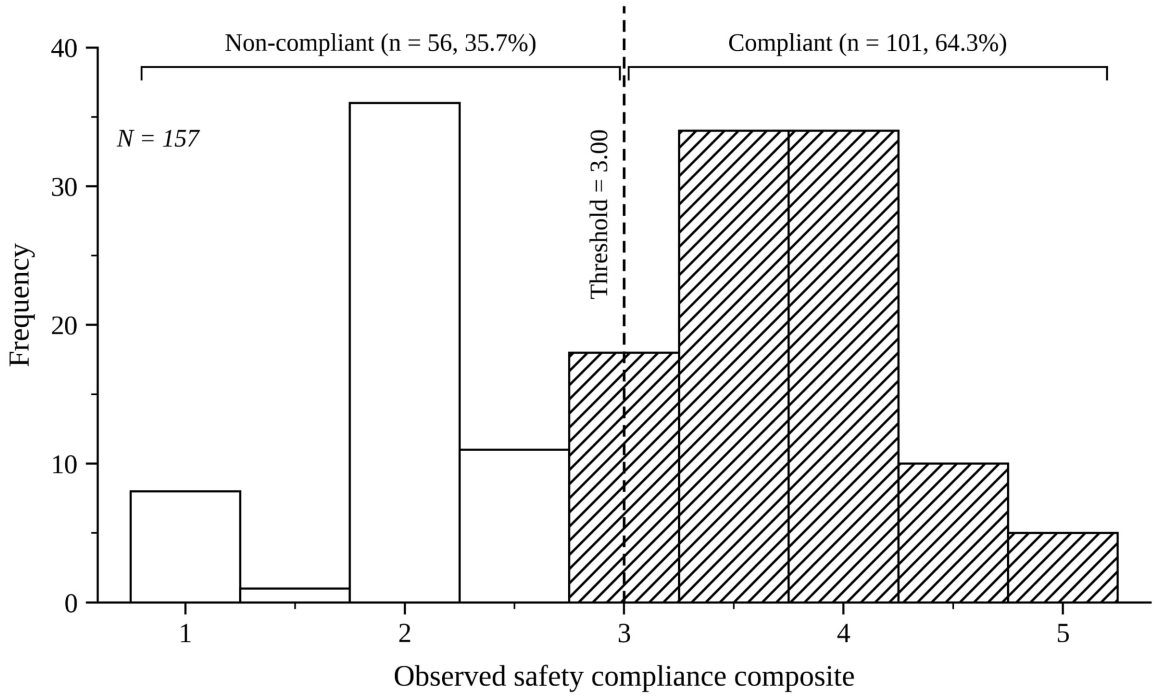


Figure 5. Distribution of the observed safety compliance composite with the classification threshold at the scale midpoint.

Table 11. Classification performance for safety compliance under stratified 10-fold partitioning.

Classifier	Accuracy	Balanced Accuracy	AUC	F1	Precision	Recall	Log Loss
Majority-class baseline	0.643	0.500	0.500	0.783	0.643	1.000	n/a
Logistic regression	0.803	0.767	0.814	0.853	0.818	0.891	0.498
Support vector classifier	0.847	0.814	0.893	0.887	0.847	0.931	0.377
Random forest	0.854	0.838	0.891	0.887	0.882	0.891	0.408

Note: The outcome is the observed safety compliance composite dichotomized at 3.00, not a model-derived score. Baseline values are those obtained by assigning every case to the majority class. Predictors are the observed composites for psychosocial stressor exposure, role and employment insecurity, and perceived strain-related safety impairment.

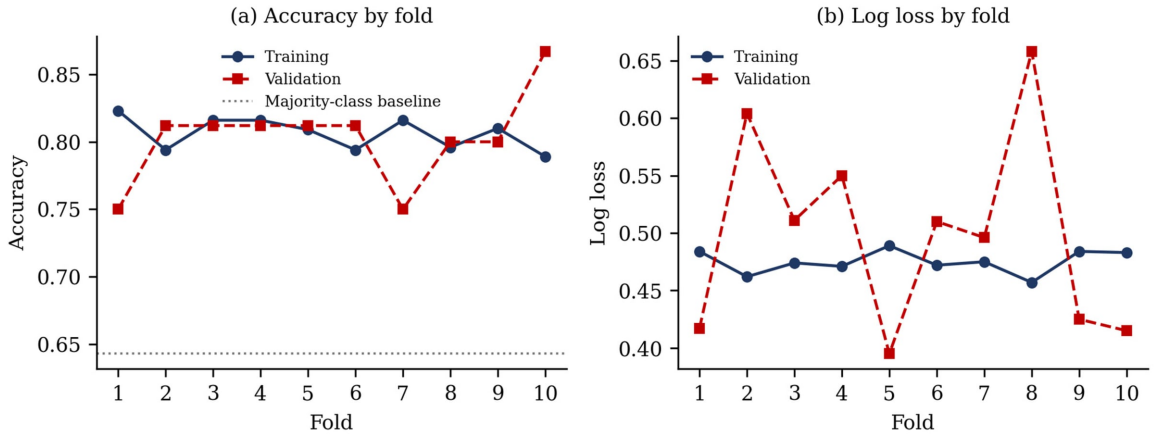


Figure 6. Classification performance across 10 folds, showing (**a**) training and validation accuracy against the majority-class baseline and (**b**) training and validation log loss.

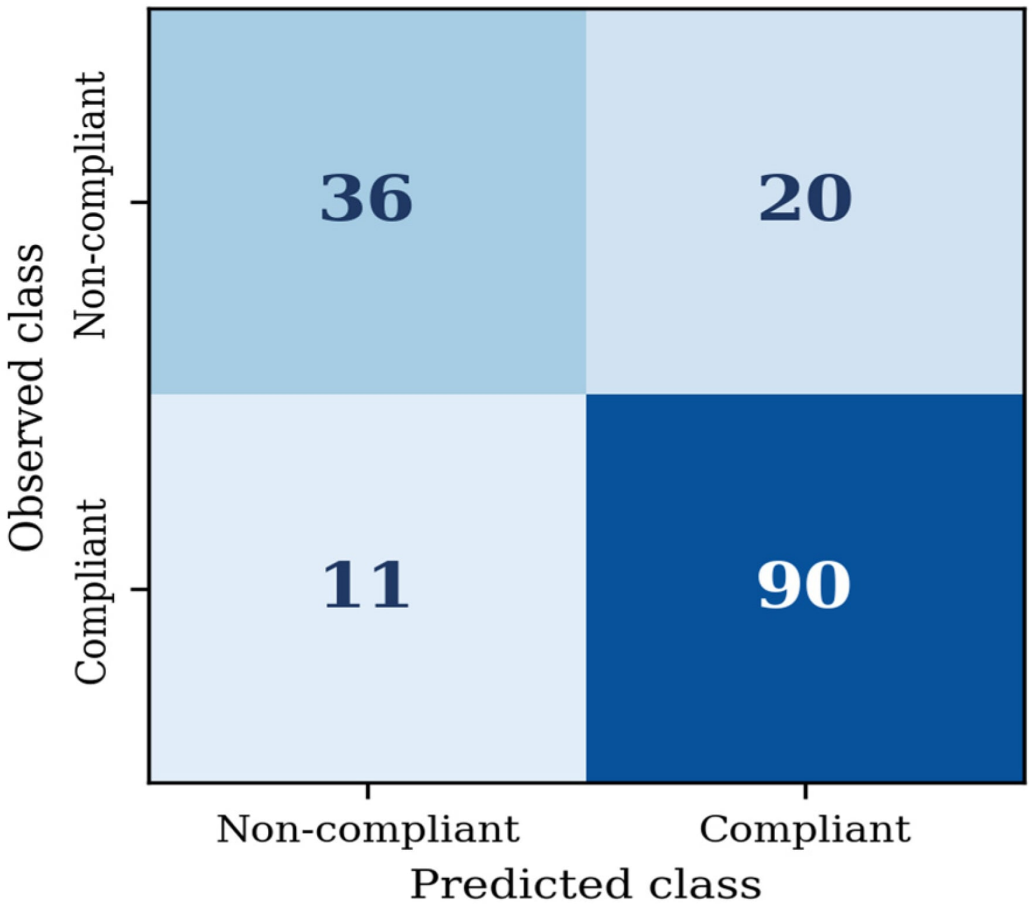


Figure 7. Confusion matrix for the logistic classifier under stratified 10-fold partitioning.

4.5. Common Method Variance

Full collinearity variance inflation factors, computed by regressing each construct on all others, ranged from 1.601 to 1.994 and remained below the 3.3 criterion, so no construct was substantially explained by the remainder. This statistical evidence is qualified by the screening record. A total of 38 responses, amounting to 19% of those collected, gave an identical answer to at least 80% of the indicators, so the possibility that part of the association between exposure and impairment reflects shared method is retained [78] and examined in Section 5.3. The independence of the compliance indicators from the exposure and impairment blocks, evident in the ratios reported in Table 7, indicates that this concern does not extend to the behavioral outcome.

5. Discussion

5.1. Direct Transmission of Exposure to Compliance

The pathway hypothesized to carry exposure into behavior did not operate. Psychosocial stressor exposure was associated with perceived strain-related safety impairment at 0.676 and with safety compliance at −0.301, yet impairment showed no association with compliance, and the specific indirect effect of 0.073 spanned zero. Two readings are available, and the evidence does not fully separate them. The first attributes the pattern to the enforced character of the outcome: compliance is monitored, procedurally specified, and subject to sanction, so it should be the behavior least responsive to internal state and most responsive to external condition, a distinction reflected in the differential prediction of climate-linked safety outcomes reported by Beus et al. [81] and in the divergent antecedents of behavior among temporary construction personnel identified by Seo et al. [82]. The sec-

ond attributes it to the referent of the impairment indicators, which elicit a judgment about how strain affects safety rather than a record of behavior under strain. Judgments of this kind are systematically discounted when applied to the self, since construction workers rate their own vulnerability to hazards below that of colleagues performing identical work [83]. Under either reading, the practical implication is the same: exposure influences compliance without requiring an intervening deterioration in perceived functioning.

The null transmission sits within a divided body of evidence. Strain-based mediation has been confirmed where the outcome is broad or where distress is measured with clinical instruments: psychological distress mediated the effect of psychosocial safety climate on compliance among 190 oil and gas production workers in Malaysia [84], psychological strain mediated the association between role stressors and unsafe behavior among 600 Chinese construction employees [85], and anxiety and depression reduced compliance among 274 mineworkers [86]. Studies closer to the present configuration report the opposite pattern. Among 204 Iranian construction workers, the direct effect of mental health on safety behavior was not significant and operated only through work ability and sleep quality [87], and burnout showed no significant effect on safety behavior assessed by direct observation on Iranian construction projects [88]. The most informative comparison is a three-wave study of 466 elevator technicians in 61 teams, in which distress mediated the association of workload, lack of autonomy, and role ambiguity with safety behavior, yet the indirect effects ceased to be significant under a strong team safety climate [89]. Situational strength of this kind, in which supervision and procedure constrain behavior regardless of internal state, supplies a mechanism consistent with the present null result, since compliance in the sampled setting is monitored through supervisory observation of a predominantly contingent workforce. The divergence across studies therefore appears to follow the strength of the behavioral setting and the referent of the strain measure rather than the presence or absence of strain itself.

5.2. Employment Insecurity as a Compliance-Enforcing Condition

The association between role and employment insecurity and compliance was substantial and positive at 0.600, opposite in sign to the hypothesis and second only to the exposure pathway in effect size. The composition of the sample offers a plausible account. Contract-based and daily wage arrangements together accounted for 92% of respondents, so continuation of employment depends on day-to-day supervisory judgment rather than on contractual protection. Where a worker anticipates adverse consequences for declining hazardous work, visible adherence to procedure becomes the behavior through which continued engagement is secured, and compliance is precisely the safety behavior that supervisors observe. Insecurity would then raise conspicuous rule-following while leaving unmonitored protective action untouched, a divergence consistent with the elevated exposure and constrained agency documented among temporary and migrant construction workforces [82,90] and with the deference to hierarchy reported in construction settings marked by steep authority gradients [91,92]. Compliance obtained under this mechanism is contingent rather than internalized and would not be expected to persist once the employment threat is removed.

The positive association contrasts with the prevailing direction of evidence. Job insecurity reduced both compliance and participation among 349 coal miners in a time-lagged design, with emotional exhaustion as a partial mediator and a stronger effect on participation than on compliance [93]. Those miners were drawn from three mines of a single coal group, whereas 92% of the present respondents held contract or daily wage positions, and the difference in employment structure supplies a plausible basis for the reversal. Stress appraisal research offers a second mechanism: among 308 frontline employees in high-risk

industries, work task stress raised compliance through challenge appraisal while lowering it through hindrance appraisal [94], so a demand perceived as a threat to continued engagement may be appraised as a reason to display adherence. The distinction between deep and surface compliance clarifies what such adherence represents. Among 239 Australian construction workers, safety communication and safety knowledge increased deep compliance while communication reduced surface compliance, the form of rule following performed for observation with minimal commitment [95]. The present indicators do not separate the two forms, and the insecurity effect is most plausibly read as an increase in surface compliance, a reading that an instrument distinguishing the forms would allow future work to test directly.

5.3. Magnitude of Associations and the Influence of Measurement

The exposure to impairment coefficient of 0.676 exceeds by a wide margin the pooled correlation of 0.28 obtained across 48 construction studies and the corresponding Asian subgroup estimate of 0.32 [16]. Meta-analytic syntheses of construction safety relationships report associations of comparable modesty between organizational conditions and safety outcomes [96,97], so the present magnitude warrants explanation rather than emphasis. Three features of the instrument bear on it. Responses agreeing with at least 80% of the indicators amounted to 19% of those collected and were excluded, indicating a pronounced agreement tendency in the population sampled. The indicators forming exposure and impairment share a phrasing template asserting that a stressor degrades safety, which invites endorsement as a general proposition irrespective of personal experience, a wording concern of the kind that has led safety climate measurement to replace negatively worded items with positively worded alternatives validated through a time-lagged design [98]. The discriminant validity failures documented before remediation, reaching unity between distress and stress-related risk-taking, arose entirely among indicators sharing that template. Part of the observed association is therefore likely to reflect shared method rather than shared substance, and the estimate should be read as an upper bound.

5.4. Implications for Practitioners, Safety Professionals, and Regulators

The findings carry distinct implications for three groups. For contractors and site managers, the screening component performed above the majority-class baseline of 0.643 across all three classifiers, reaching balanced accuracies between 0.767 and 0.838 and areas under the curve between 0.814 and 0.893, which is sufficient to prioritize attention among crews rather than to determine individual status. The retained instrument comprises 21 items on a single response format, is completed in approximately 10 min, and was administered orally where literacy was limited, so it imposes no requirement for written competence in a workforce where 45% hold primary or secondary schooling only, and its predictors are organizational conditions rather than clinical states, so no diagnostic capability or medical confidentiality obligation is presupposed. Compliance merits this attention, since low compliance was associated with an adjusted odds ratio of 2.32 for self-reported injury among 1203 workers on 22 large building sites in Ethiopia [99]. For safety professionals, intervention should target exposure directly, since its influence on compliance did not pass through psychological condition; expert consensus on construction mental health similarly favors organizational restructuring over individual-level provision [100], and in Pakistan construction safety leadership predicted compliance at 0.35 among 237 engineers in a time-lagged design [101], which identifies supervisory practice as the channel through which work organization reaches enforced behavior. For regulators and policymakers, the positive insecurity effect indicates that compliance recorded on sites dominated by contract and daily wage employment may be secured by threat rather than commitment, so inspection regimes

that count observed adherence should be complemented by protection against dismissal for refusing hazardous work. Periodic administration would allow the instrument to function as a leading indicator alongside behavior-based observation [102] and, on larger projects, alongside physiological monitoring where such systems are already installed [103,104].

5.5. Limitations and Future Directions

Five limitations bound these findings, each with a specific route to resolution. The design is cross-sectional, so the ordering of exposure, impairment, and compliance is assumed rather than demonstrated; longitudinal evidence indicates that associations of this kind attenuate substantially when temporal separation is imposed [105], and multi-wave administration of the kind used to establish climate as a precursor to psychological outcomes would permit the sequence to be tested [106,107]. All measures derive from one self-report instrument on a single occasion with a uniform agreement format, so the exposure to impairment estimate remains vulnerable to shared method; replication with reverse-worded items and separated response formats would establish how much of it survives. The behavioral outcome rests on two indicators of compliance maintained under strain, so correct equipment operation, hazard reporting, the depth of compliance, and the discretionary component of safety performance are unobserved despite prior evidence locating the strongest strain effects in the discretionary component; a multidimensional instrument such as the 22-item, three-dimension safety behavior scale validated for industrial workplaces [108], combined with a participation scale, is the change most likely to alter the substantive conclusions. Each of the nine exposure conditions is represented by a single indicator, which precludes estimation of distinct lower-order dimensions; multi-item measurement of each condition would allow the higher-order structure to be tested directly. Finally, the sample is a non-probability sample drawn from a young and comparatively inexperienced workforce, which constrains generalization to established personnel and to firms with formalized safety systems [109,110]. Replication using clinically validated distress measurement, scenario-based risk perception, and objective incident records would establish whether the direct pathway reported here reflects a property of the setting or of the instrument [111,112].

6. Conclusions

This study tested whether psychosocial stressor exposure reduces safety compliance among construction personnel in Pakistan by impairing their perceived capacity to work safely or by acting on compliance directly. A four-construct model relating psychosocial stressor exposure and role and employment insecurity to safety compliance through perceived strain-related safety impairment was estimated on 157 responses retained from 196 after removal of unengaged and duplicate cases. Construct composition was settled empirically under the heterotrait–monotrait criterion, and predictive relevance was assessed out of sample. The hypothesized mediation did not operate, since exposure reached compliance directly, insecurity raised it, and perceived impairment transmitted no effect, a configuration that held under both reflective and formative specification of exposure.

(1) In a developing economy construction workforce, psychosocial exposure lowers compliance maintained under strain without passing through perceived psychological impairment, so prevention belongs to the organization of work.
(2) Interventions directed solely at individual resilience act on a link that carried no effect in this setting, whereas reducing time pressure, workload, and production pressure reaches compliance directly.

(3) Where employment is contingent, insecurity raises visible compliance rather than depressing it, producing adherence secured by threat that is liable to lapse once the threat is withdrawn.
(4) Psychological constructs in this field require discriminant testing under sensitive criteria, since four construct pairs proved inseparable here before remediation, one of them at unity.
(5) Items asserting that a stressor degrades safety invite endorsement as a proposition, so instruments phrased in this way are likely to inflate the association between exposure and strain.

Replication with clinically validated distress measurement, reverse-worded items, a multidimensional compliance and participation outcome, and multi-wave administration would establish whether the direct pathway reported here is a property of the setting or of the instrument.

The study contributes to three audiences. For researchers, it supplies a tested direct-versus-mediated account of how psychosocial exposure reaches compliance, shows that construct separations in this field warrant re-examination under the heterotrait–monotrait criterion, and provides a 21-item instrument with documented retention decisions for South Asian construction settings. For policymakers and regulators, it indicates that occupational safety regulation in developing economies should address workload, scheduling, and employment protection as determinants of safety, and that compliance observed under insecure employment is an unreliable indicator of safety commitment. For construction practitioners, it provides a brief, orally administrable screening procedure based on working conditions rather than clinical status, which allows contractors and site managers to identify crews at elevated risk of non-compliance and to act on the conditions that produce it.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the National University of Sciences and Technology (NUST) (IRB No. 10-2025-IRB-A-116/116; meeting held on 22 September 2025).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

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

Appendix A. Questionnaire Items

Table A1 reports the wording of all 29 attitudinal items in the order of administration, together with the code and the retention status of each item in the final four-construct specification.

Table A1. Questionnaire items, codes, and retention status in the final specification.

Code	Item Wording	Status in Final Specification
PS1	I often feel I am not given enough time to do my job safely.	Retained, psychosocial stressor exposure
SS4	Management pressures workers to prioritize speed over safety.	Retained, psychosocial stressor exposure
PS2	I experience stress due to unrealistic deadlines or work overload.	Retained, psychosocial stressor exposure
U1	Co-workers create pressure to complete tasks quickly even when unsafe.	Excluded, not assigned at design stage
SS2	I experience conflicting instructions from different supervisors.	Retained, psychosocial stressor exposure
PS5	I have limited control over how and when I perform my tasks.	Retained, psychosocial stressor exposure
SS1	Poor communication from supervisors increases work stress.	Retained, psychosocial stressor exposure
SS3	I experience frequent arguments or tension with coworkers.	Retained, psychosocial stressor exposure
PS4	I fear job loss if I report unsafe conditions or refuse risky tasks.	Retained, role and employment insecurity
PS3	I often feel confused about my specific safety responsibilities.	Retained, role and employment insecurity
U2	I am expected to multitask dangerously to meet deadlines.	Excluded, not assigned at design stage
U3	Unsafe working conditions on site increase my daily stress.	Excluded, not assigned at design stage
SS6	I feel that workers' safety complaints are ignored by management.	Retained, psychosocial stressor exposure
SS5	There is a culture of accepting risk without proper controls on this site.	Retained, psychosocial stressor exposure
MH1	I frequently feel stressed, anxious, or depressed because of work conditions.	Retained, perceived strain-related safety impairment
U4	Stress at work lowers my ability to accurately detect hazards.	Excluded, not assigned at design stage
MH3	Anxiety affects my ability to concentrate on safety procedures.	Retained, perceived strain-related safety impairment
RP1	When I feel stressed, I sometimes underestimate safety risks.	Retained, perceived strain-related safety impairment
RP2	Stress and pressure make me more likely to take unsafe shortcuts.	Retained, perceived strain-related safety impairment
SC1	Even under stress, I strictly follow all safety protocols.	Retained, safety compliance
RP3	When I am anxious, I am more likely to make risky decisions at work.	Retained, perceived strain-related safety impairment
MH4	Depression decreases my motivation to participate in safety activities.	Retained, perceived strain-related safety impairment

Table A1. *Cont.*

Code	Item Wording	Status in Final Specification
MH5	Mental health issues (stress, anxiety, depression) reduce my focus on PPE use.	Retained, perceived strain-related safety impairment
SC2	I continue to use protective equipment even when under mental stress.	Retained, safety compliance
U5	Feeling anxious makes it harder for me to speak up about safety issues.	Excluded, not assigned at design stage
MH2	Stress negatively affects my ability to assess the severity of hazards.	Retained, perceived strain-related safety impairment
SC4	Workers experiencing mental stress often neglect minor safety rules.	Excluded, belief item outside the behavioral outcome
SC3	Good mental health support improves my ability to comply with safety policies.	Excluded, belief item outside the behavioral outcome
RP4	Lack of mental health support increases the risk of accidents on site.	Excluded, eliminated in discriminant validity remediation

Note: Items are listed in the order of administration; the first 14 formed the section on psychosocial conditions at the site and the remaining 15 the section on psychological state, risk appraisal, and safety behavior. All items were rated from strongly disagree (1) to strongly agree (5). Codes U1 to U5 denote items not assigned to a construct at the design stage, and construct-level sources are listed in Table 3.

Appendix B. Sensitivity of the Measurement Specification of Psychosocial Stressor Exposure

Table A2 reports the parallel analysis and the Mode B measurement evidence for psychosocial stressor exposure, and Table A3 compares the structural estimates obtained under the reflective and formative specifications.

Table A2. Dimensionality and formative measurement evidence for psychosocial stressor exposure ($n = 157$).

Component or Indicator	Observed Eigenvalue	95th Percentile of Random Eigenvalues	Decision
Panel A. Parallel analysis of the nine exposure indicators			
Component 1	5.107	1.503	Retained
Component 2	0.763	1.338	Not retained
Component 3	0.645	1.220	Not retained
Component 4	0.584	1.122	Not retained
Component 5	0.497	1.038	Not retained
Component 6	0.400	0.963	Not retained
Component 7	0.381	0.893	Not retained
Component 8	0.352	0.820	Not retained
Component 9	0.272	0.738	Not retained

Table A2. *Cont.*

Component or Indicator	Observed Eigenvalue	95th Percentile of Random Eigenvalues	Decision	
Panel B. Mode B (formative) estimation of psychosocial stressor exposure				
Indicator	Outer VIF	Outer weight [95% CI]	Outer loading [95% CI]	Condition
PS1	1.967	0.091 [−0.174, 0.300]	0.661 [0.474, 0.768]	Time pressure
PS2	2.352	0.013 [−0.294, 0.287]	0.696 [0.517, 0.800]	Quantitative workload
PS5	1.962	0.225 [−0.009, 0.476]	0.757 [0.560, 0.866]	Restricted job control
SS1	2.060	0.359 [0.041, 0.600]	0.815 [0.651, 0.886]	Communication deficiency
SS2	2.264	−0.016 [−0.283, 0.286]	0.684 [0.499, 0.798]	Role conflict
SS3	1.664	0.068 [−0.146, 0.310]	0.629 [0.428, 0.770]	Interpersonal conflict
SS4	2.311	0.099 [−0.167, 0.405]	0.769 [0.583, 0.868]	Production pressure
SS5	1.918	0.375 [0.155, 0.581]	0.823 [0.668, 0.897]	Risk normalization
SS6	1.927	0.075 [−0.167, 0.289]	0.691 [0.512, 0.793]	Safety silence

Note: Parallel analysis used 2000 random normal data sets of 157 cases and nine variables. The first component accounts for 56.7% of indicator variance; inter-item correlations range from 0.357 to 0.641; the Kaiser–Meyer–Olkin measure is 0.914. In Panel B, columns 2 to 4 report the variance inflation factor, outer weight, and outer loading, with percentile bootstrap intervals from 5000 subsamples; the header of Panel A applies to Panel A only.

Table A3. Structural estimates under reflective (Mode A) and formative (Mode B) specification of psychosocial stressor exposure.

Hypothesis	Path	Mode A, Coefficient [95% CI]	Mode B, Coefficient [95% CI]	Significant Under Mode B
H1	Exposure to impairment	0.676 [0.584, 0.772]	0.702 [0.624, 0.803]	Yes
H2	Exposure to compliance	−0.301 [−0.495, −0.111]	−0.311 [−0.537, −0.109]	Yes
H3	Insecurity to impairment	−0.032 [−0.166, 0.092]	−0.045 [−0.161, 0.081]	No
H4	Insecurity to compliance	0.600 [0.473, 0.722]	0.605 [0.476, 0.718]	Yes
H5	Impairment to compliance	0.109 [−0.117, 0.346]	0.123 [−0.097, 0.377]	No
H6	Exposure to impairment to compliance (indirect)	0.073 [−0.079, 0.242]	0.086 [−0.069, 0.283]	No
	R^2 of perceived strain-related safety impairment	0.454	0.488	
	R^2 of safety compliance	0.389	0.389	

Note: Mode A values are those reported in Tables 8 and 9. Mode B intervals are percentile bootstrap intervals from 5000 subsamples. The Mode A and Mode B composites of exposure correlate at 0.969.

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