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Workforce retention in the forest industry: a structural equation modeling analysis of perceived safety risk, job satisfaction, job stress, and work engagement

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Introduction: Forest-based industries face chronic labor shortages and an aging workforce, raising concerns about workforce sustainability in safety-critical and physically demanding work settings. While physical risks in forestry are well documented, less is known about how perceived safety appraisals and psychosocial conditions jointly relate to turnover intention. Grounded in the Job Demands–Resources (JD–R) framework, this study examined the structural relationships among perceived safety risk, job satisfaction, job stress, work engagement, and turnover intention within a five-variable structural equation model.
Methods: Using pooled cross-sectional survey data from 1,822 workers across six major forestry sectors in South Korea (2022–2024), we estimated the model and tested indirect pathways using bias-corrected bootstrapping (5,000 resamples). PSR was assessed as a perceived accident-likelihood item. To support robustness of the measurement structure, the CFA specification was re-estimated in two stratified split-half subsamples, yielding comparable fit indices across subsamples.
Results: In the structural model, PSR was associated with lower job satisfaction and higher job stress and showed a positive association with turnover intention, whereas its direct association with work engagement was not supported. Job satisfaction exhibited an "indirect-only" pattern: it was not directly associated with turnover intention but was linked to turnover intention through pathways involving lower stress and higher engagement; work engagement was inversely associated with turnover intention. Group comparisons further indicated that less favorable profiles clustered in the Forest Product Production sector and field-site contexts, where higher perceived safety risk and less favorable psychosocial conditions co-occurred.
Discussion: These findings suggest that workforce sustainability may benefit from a dual emphasis on safety-centered modernization in field operations and organizational practices that mitigate psychosocial strain and support engagement-related resources. Addressing these human dimensions may be important for maintaining the continuity of forest operations and supporting sustainable forest management goals.

KEYWORDS
forest industry workforce, forest management, job demands–resources model, perceived safety risk, structural equation modeling, turnover intention, workforce retention, workforce sustainability

1 Introduction

Across several countries, forest-based industries face persistent labor shortages and an aging workforce, increasing the importance of workforce retention for sustainable forest operations and ecosystem management (Lee and Kim, 2022; Statistics Korea, 2022; Korea Forest Service, 2024). From a forest management perspective, workforce stability is widely considered important for maintaining forest operations and implementing long-term management plans. In addition, forest work is characterized by physically demanding and safety-critical tasks, suggesting that workers' perceptions of accident likelihood may be related to their psychological states and turnover intention (i.e., intentions to stay or leave) (Jiang et al., 2026). Understanding how these experiences translate into turnover intention (TI) is therefore relevant to both organizational practice and public policy. Prior organizational research has repeatedly linked job satisfaction (JS), job stress (JStr), and work engagement (WE) to turnover intention (TI) (Griffeth et al., 2000; Aziri, 2011; Mazzetti et al., 2023). However, evidence specific to forest industry workers remains limited (Mylek and Schirmer, 2015; Best et al., 2021), and studies rarely model simultaneous and mediated relationships within an integrated framework. In particular, the interplay between strain (stress), motivational resources (engagement), and attitudinal evaluations (satisfaction)—together with safety-related appraisals—has seldom been tested in a single model for this occupational group.

To address this gap, we applied structural equation modeling (SEM) to examine the structural links among JS, JStr, WE, TI and a safety-related appraisal (perceived safety risk; PSR) in the forest industry workforce. SEM enables the explicit modeling of latent constructs while accounting for measurement error (including turnover intention), simultaneous estimation of interdependent paths, and quantification of indirect (mediation) effects that are theoretically expected but often overlooked in regression-based designs (Bollen, 1989; Leth-Steensen and Gallitto, 2016; Kline, 2023). Grounded in the job demands-resources (JD-R) framework, we conceptualized job stress as a job demand contributing to strain, while job satisfaction and work engagement function as motivational resources that may buffer turnover intention (Demerouti and Bakker, 2011; Bakker et al., 2014; Bakker and Demerouti, 2017). Furthermore, we incorporated perceived safety risk (PSR)—operationalized as workers' perceived likelihood of industrial accidents— as a safety-related contextual appraisal positioned upstream in the hypothesized model, and examined its associations with these work-related psychological states (Rundmo, 1992, 1995; Melià et al., 2008). Based on this framework, we expected that JS would be associated with lower JStr and higher WE; that JStr would be associated with lower WE and higher TI; and that WE would be associated with lower TI (Lazarus and Folkman, 1984; Demerouti et al., 2001; Cabrera-Aguilar et al., 2023; Zhu et al., 2023; Üngüren et al., 2024). We further posited that JS is positively associated with WE as a motivational resource (Mazzetti et al., 2023).

Accordingly, we specified a structural model linking PSR, JS, JStr, WE, and TI. Specifically, we hypothesized that JS would be negatively associated with JStr and positively associated with WE; that JStr would be negatively associated with WE and positively associated with TI; and that WE would be negatively associated with TI (Zhu et al., 2023; Üngüren et al., 2024). Moreover, we included paths where PSR was positioned upstream of the psychosocial constructs and where JS was associated with WE as a motivational resource (Rundmo, 1992, 1995; Le Blanc et al., 2008; Mazzetti et al., 2023). We tested whether the associations of PSR and JS with TI are transmitted via indirect pathways involving JStr and WE, including serial configurations. Using a field survey of forest workers in South Korea, we validated the measurement model, estimated structural relationships, and evaluated specific indirect effects via bias-corrected bootstrapping (Bollen and Stine, 1992). By clarifying these mechanisms within an integrated SEM framework, the study contributes to discussions on workforce sustainability and safety management in the forest sector.

2 Materials and methods

2.1 Study design and participants

This study employed a pooled cross-sectional survey design targeting workers in the South Korean forest industry. Stratified sampling was applied based on the six major sectors defined by the Korean Forest Industry Special Classification: (1) Input Industry, (2) Forest Product Production, (3) Processing and Manufacturing, (4) Wholesale, Retail, and Transportation, (5) Recreation and Service, and (6) Support Services.

Data were collected via face-to-face interviews using a structured questionnaire. The survey was administered in three waves: July 2022 (n = 654), August–September 2023 (n = 500), and May–June 2024 (n = 668). Participants were independently recruited in each wave (i.e., not a longitudinal panel). Given the target population and sampling procedures were consistent across the three waves, the data were pooled for analysis. The final analytic sample comprised 1,822 respondents after excluding incomplete questionnaires. Participant characteristics and the distribution across the six industry sectors are presented in Table 1.

2.2 Measures

The survey instrument assessed perceived safety risk (PSR), job satisfaction (JS), job stress (JStr), work engagement (WE), and turnover intention (TI). Items were administered in Korean. For scales originally developed in English, a translation and expert review process was conducted to support conceptual and linguistic equivalence. The composition of each measure and its sources is summarized in Table 2.

PSR was assessed using a single item developed for this study. Respondents rated the perceived likelihood of industrial accidents in their current job on a five-point scale.

JS was measured with 12 items informed by Herzberg's two-factor theory and the Job Characteristics Model (Herzberg, 1959; Hackman and Oldham, 1976), covering intrinsic and extrinsic aspects of satisfaction. JStr was assessed using the short form of the Korean Occupational Stress Scale (KOSS), comprising 24 items across seven domains (Chang and Koh, 2005). Among these domains, the "authoritarianism and inequality" domain captures organizational-culture stressors (e.g., hierarchical climate, inconsistent instruction, perceived unfairness), alongside domains capturing workload-related stressors. WE was assessed using 12 items adapted from prior engagement literature (Kahn, 1990; Schaufeli et al., 2002). The items were intended to capture motivational facets of engagement, and their dimensionality was examined empirically using the item-screening and EFA procedures described in Section 2.4. TI was assessed using four items adapted from turnover models and prior studies in the Korean forestry workforce (Mobley et al., 1979; Kim et al., 2009); in SEM analyses, TI was specified as a latent construct indicated by these four items.

Across all multi-item scales, higher scores indicate higher levels of the construct; negatively worded items were reverse-coded prior to the 0–100 standardization described in Section 2.3.

TABLE 1 Demographic characteristics and distribution of the study sample by industry sector.

Characteristics	Category	*n*	%
Gender	Male	927	50.9
	Female	895	49.1
Age group	20s	181	9.9
	30s	487	26.7
	40s	530	29.1
	50s	451	24.8
	60s or older	173	9.5
Employment type	Regular	1,620	88.9
	Non-regular	202	11.1
Workplace	Office	973	53.4
	Field site	849	46.6
Industry sector (stratification)	Input industry	273	15.0
	Forest product production	357	19.6
	Processing and manufacturing	426	23.4
	Wholesale, retail, and transportation	253	13.9
	Recreation and service	251	13.8
	Support services	262	14.4

2.3 Score standardization and data quality control

Likert-type items were linearly transformed to a 0–100 scale. Scores were standardized using the formula $(x - 1)/(k - 1) \times 100$, where (x) denotes the observed response and (k) denotes the maximum response category (4 or 5). Negatively keyed items in the multi-item scales were reverse-coded prior to transformation. This linear transformation was applied to facilitate interpretability across measures with different Likert ranges; as a monotonic rescaling, it preserves relative ordering and does not affect inferences based on standardized relationships. Data were screened for completeness and consistency prior to analysis. Multivariate normality was examined using the critical ratio of multivariate kurtosis reported by AMOS. Bootstrap procedures were used for indirect-effect inference, as described in Section 2.4 (Kline, 2023).

2.4 Statistical analysis

Analyses were conducted using IBM SPSS Statistics 26.0 and AMOS 26.0. The analytic workflow included group comparisons, measurement evaluation, and structural equation modeling. First, reliability and exploratory factor analysis (EFA) were conducted for the multi-item scales (JS, JStr, WE, and TI). Internal consistency was evaluated using Cronbach's α. Item screening was performed using corrected item-total correlation (CITC) and Cronbach's α if item deleted (CAID); items with corrected item–total correlations below 0.30 were removed (Norušis, 1993). EFA was conducted using principal component analysis (PCA) with Varimax rotation (Kaiser, 1958; Abdi and Williams, 2010). Sampling adequacy and factorability were assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity (Bartlett, 1951; Kaiser, 1974). Factors were retained based on eigenvalues greater than 1.0, and items with factor loadings of at least 0.40 were retained (Stevens, 2002). Multicollinearity was

TABLE 2 Composition of the survey instrument.

Category	Variable	Content/sub-factors	No. of items	Source
General characteristics	Demographics	Gender, age, education, income, marital status	–	–
	Job characteristics	Tenure, workplace type, employment type	–	–
Job attitudes/perceptions	Perceived safety risk	Perceived likelihood of industrial accidents in the current job	1	Developed for this study
	Job satisfaction	Overall satisfaction, intrinsic factors, extrinsic factors	12	Herzberg (1959) and Hackman and Oldham (1976)
	Job stress	Job demand, insufficient job control, interpersonal conflict, job insecurity, organizational system, lack of reward, occupational climate	24	Chang and Koh (2005)
	Work engagement	Vigor, dedication, absorption	12	Schaufeli et al. (2002) and Kahn (1990)
	Turnover intention	Intention to quit, search for alternatives	4	Mobley et al. (1979) and Kim et al. (2009)

screened using Pearson correlation coefficients and variance inflation factors (VIFs).

Group differences across industry sectors and demographic characteristics were examined using independent-samples *t*-tests and one-way ANOVA (Field, 2024). Homogeneity of variance was assessed using Levene's test (Levene, 1960). When variances were unequal, Welch's *t*-test or Welch's ANOVA was applied, followed by Games–Howell *post-hoc* comparisons; otherwise, Scheffé's test was used for *post-hoc* comparisons (Welch, 1951; Scheffé, 1953; Games and Howell, 1976; Delacre et al., 2017).

Second, SEM was performed using the two-step approach (Anderson and Gerbing, 1988). A confirmatory factor analysis (CFA) was used to evaluate the measurement model and to assess convergent and discriminant validity. The structural model was then estimated to test hypothesized paths among PSR, JS, JStr, WE, and TI. Model fit was evaluated using the Chi-square (χ^2) statistic, Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean square Residual (SRMR), interpreted using commonly applied guidelines (Tucker and Lewis, 1973; Bentler, 1990; Browne and Cudeck, 1992; Hu and Bentler, 1999). Indirect effects were evaluated using bias-corrected bootstrapping with 5,000 resamples and 95% confidence intervals (Bollen and Stine, 1992). This procedure was implemented using the phantom-variable approach in AMOS to obtain estimates for specific indirect pathways. Finally, as a stability check, the CFA measurement model was re-estimated in two stratified random split-half subsamples by industry sector.

3 Results

3.1 EFA and reliability

Consistent with the analysis plan (Section 2.4), psychometric evaluation focused on the multi-item scales (JS, JStr, WE, and TI); PSR, assessed with a single item, was not included in factor-analytic procedures. Item analysis was conducted to refine the measurement scales using pre-specified item-screening criteria (CITC < 0.30 and alpha-if-item-deleted diagnostics). Six items were removed from the job stress scale (Supplementary Table S1), whereas all items for JS, WE, and TI were retained. The removed items included content related to creativity and skill demands, decision latitude, future uncertainty, fairness of personnel systems, and dining-culture discomfort. These aspects may be less salient or more heterogeneously interpreted in this workforce than in the general working populations for which the original instrument was developed. Potential implications for domain coverage are addressed in the limitations. Subsequently, EFA using PCA with Varimax rotation was performed on the refined items. The KMO measures and Bartlett's tests supported the suitability of the data for factor analysis (see Supplementary Table S2 for details). The analysis identified distinct factor structures corresponding to specific dimensions: (1) JS (4 factors): Job & Performance, Reward & Support, Relationship & Recognition, and Autonomy & Balance; (2) JStr (4 factors): Lack of Growth & Autonomy, Lack of Support & Rest, Authoritarianism & Inequality, and Work Overload; (3) WE (2 factors): Job Identity and Psychological Empowerment; (4) TI (1 factor): Single-factor structure.

All retained items exhibited factor loadings greater than 0.40 (see Supplementary Table S2 for the full factor loading matrix). Internal consistency coefficients (Cronbach's α) for the final constructs were 0.907 (JS), 0.877 (JStr), 0.893 (WE), and 0.844 (TI).

3.2 Descriptive statistics and group differences

Descriptive statistics and bivariate associations among the study variables are presented in Table 3. All variables were standardized to a 0–100 scale (PSR: higher scores indicate higher perceived accident likelihood). In the bivariate correlations, turnover intention (TI) was negatively associated with job satisfaction (JS) and work engagement (WE) and positively associated with job stress (JStr). PSR was positively associated with TI and JStr and negatively associated with JS and WE; ranges by sub-dimensions are reported in Table 3, with the full sub-factor correlation matrix provided in Supplementary Table S3. Given the pooled cross-sectional design, these coefficients are interpreted as descriptive associations and do not support causal inferences.

Sectoral differences across the six industry sectors were examined using Welch's ANOVA with Games–Howell *post-hoc* comparisons (Table 4). Significant differences were observed across sectors for PSR, JS, JStr, WE, and TI. *Post-hoc* comparisons indicated that the Forest Product Production sector reported higher PSR alongside higher JStr and TI, and lower JS and WE, relative to several other sectors (Table 4).

Group differences by demographic and job characteristics are summarized in Table 5, with additional comparisons reported in Supplementary Table S4. PSR varied significantly across age and tenure groups, whereas WE and TI did not differ by age. Differences by tenure were observed across PSR, JS, JStr, WE, and TI (Table 5). By employment type, regular employees reported higher JS and WE and lower TI than non-regular employees, while PSR and JStr did not differ materially between these groups. Workplace type also showed differences in PSR, JS, and TI: field-site workers reported higher PSR and TI, whereas office workers reported higher JS (Table 5).

3.3 Measurement model assessment

Following the two-step approach (Section 2.4), CFA was conducted to evaluate the measurement model for the four latent constructs (JS, JStr, WE, and TI) using the refined indicators retained after the pooled-sample item screening and EFA procedures; PSR (0–100; higher scores indicate higher perceived accident likelihood) was treated as an observed single-item variable and was allowed to correlate with the latent constructs. The model demonstrated an acceptable fit to the data (χ^2 = 932.081, df = 81, CFI = 0.940, TLI = 0.923, RMSEA = 0.076, SRMR = 0.044). All standardized factor loadings were statistically significant ($p < 0.001$) and ranged from 0.513 to 0.890 (JS: 0.658–0.879; JStr: 0.513–0.866; WE: 0.778–0.890; TI: 0.722–0.778), supporting convergent validity. To assess the stability of the measurement structure, the same CFA specification (based on the pooled-sample refined indicators) was re-estimated in two stratified random split-half subsamples by industry sector; fit indices were comparable across the two subsamples and the pooled model (Supplementary Table S5). In the subsequent structural model, PSR was specified as an exogenous observed predictor with structural paths to the psychosocial constructs (and TI), rather than being modeled only as a correlated observed variable.

TABLE 3 Descriptive statistics and sub-factor correlation ranges among study variables.

Variable	Mean ± SD	α	PSR	JS	JStr	WE	TI
Perceived safety risk	36.87 ± 25.69	–	1				
Job satisfaction	66.24± 16.17	0.907	−0.149 to −0.203	1			
Job stress	38.50± 12.17	0.877	0.110–0.220	−0.294 to −0.654	1		
Work engagement	63.71±15.70	0.893	−0.159 to −0.216	0.502–0.756	−0.250 to −0.684	1	
Turnover intention	29.92 ±19.75	0.844	0.161	−0.232 to −0.408	0.242–0.487	−0.329 to −0.452	1

$N = 1,822$. All correlations are significant at $p < 0.001$. α = Cronbach's alpha. Correlation entries for JS, JStr, and WE represent the range of correlations across sub-factors (see Supplementary Table S3). PSR is a single-item measure (0–100); higher scores indicate higher perceived accident likelihood (higher perceived safety risk).

TABLE 4 Differences in key variables by industry sector.

Industry sector	PSR (M ± SD)	JS (M ± SD)	JStr (M ± SD)	WE (M ± SD)	TI (M ± SD)
(a) Input industry	29.94 ± 23.15	67.61 ± 13.88	35.99 ± 10.80	68.37 ± 13.26	28.70 ± 17.46
(b) Forest product production	52.12 ± 25.18	61.92 ± 15.36	41.82 ± 10.44	57.85 ± 15.25	32.89 ± 20.98
(c) Processing & Mfg.	43.90 ± 26.59	65.27 ± 15.68	39.41 ± 11.94	62.32 ± 15.26	30.68 ± 19.18
(d) Wholesale & retail	24.21 ± 17.09	68.67 ± 18.14	34.37 ± 11.50	67.36 ± 17.27	25.20 ± 17.19
(e) Recreation & service	37.75 ± 21.37	66.43 ± 18.25	39.20 ± 15.04	64.79 ± 17.28	32.40 ± 22.39
(f) Support services	21.56 ± 21.16	70.17 ± 14.50	38.01 ± 12.13	65.37 ± 13.04	27.77 ± 19.52
Welch *F*	88.31***	11.50***	17.50***	21.29***	6.80***
Post-hoc (Games–Howell)	b > c, e, a, d, f c > e, a, d, f e > a, d, f a > d, f	f > c, b d, a, e, c > b	b > c, f, a, d c > a, d e, f > d	a, d > c, b f, e, c > b	b > f, d e, c > d

$N = 1,822$. ***$p < 0.001$. Letters in the *post-hoc* row indicate significant differences between sectors.

3.4 Structural model assessment

Based on the validated measurement model, the structural relationships among perceived safety risk (PSR), job satisfaction (JS), job stress (JStr), work engagement (WE), and turnover intention (TI) were estimated (Table 6 and Figure 1). Model fit indices and standardized path coefficients are reported in Table 6.

Following the ordering of paths in Table 6, PSR was negatively associated with JS and positively associated with JStr. PSR also showed a positive direct association with TI, whereas its direct association with WE was not statistically significant.

Next, JS was negatively associated with JStr and positively associated with WE. The direct path from JS to TI did not show a statistically significant association.

Finally, JStr was negatively associated with WE and positively associated with TI, and WE was negatively associated with TI (Table 6). As a sensitivity check, we compared the proposed model with two nested alternative specifications (PSR → WE constrained to zero; PSR → TI constrained to zero), and comparative fit statistics are reported in Supplementary Table S6.

3.5 Mediation effects

To estimate indirect effects, bias-corrected bootstrapping with 5,000 resamples was conducted using the phantom-variable approach. The specified indirect pathways are illustrated in Figure 2 (PSR pathways) and Figure 3 (JS pathways), and Table 7 reports the estimated indirect effects with bias-corrected 95% confidence intervals.

For perceived safety risk (PSR), the total indirect effect on turnover intention (TI) was statistically significant (i.e., the 95% bias-corrected confidence interval excluded zero). Among the specific indirect effects, significant pathways were observed through job satisfaction (JS) and job stress (JStr), including serial pathways involving work engagement (WE), as well as pathways operating via JStr.

For job satisfaction (JS), the total indirect effect on TI was also statistically significant (i.e., the 95% bias-corrected confidence interval excluded zero). Significant specific indirect effects were observed via JStr, via WE, and via the serial pathway through JStr and WE.

Additional indirect pathways were estimated; however, pathways whose 95% bias-corrected confidence intervals including zero are omitted from Table 7 for clarity.

4 Discussion

4.1 Five-variable framework and primary structural associations

Using a five-variable model, this study examined perceived safety risk (PSR), job satisfaction (JS), job stress (JStr), work engagement (WE), and turnover intention (TI) within a single structural framework. As summarized in Table 6, PSR was linked to less favorable

TABLE 5 Differences in key variables by demographic and job characteristics.

Variable	Category	n	PSR (M ± SD)	JS (M ± SD)	JStr (M ± SD)	WE (M ± SD)	TI (M ± SD)
Age group	(a) 20s	181	25.41 ± 24.79	69.13 ± 15.79	36.26 ± 13.08	64.33 ± 16.48	31.66 ± 20.88
	(b) 30s	487	34.70 ± 24.42	67.90 ± 16.24	38.04 ± 12.32	64.19 ± 15.51	29.84 ± 20.33
	(c) 40s	530	38.77 ± 25.05	64.40 ± 16.35	40.35 ± 11.90	62.01 ± 15.67	30.87 ± 19.83
	(d) 50s	451	41.02 ± 26.50	65.45 ± 15.28	38.19 ± 11.98	64.73 ± 14.85	29.18 ± 19.14
	(e) 60s or older	173	38.29 ± 26.07	66.24 ± 17.35	37.33 ± 11.46	64.28 ± 17.32	27.31 ± 17.98
	F-value		14.22***	4.76***	5.29***	2.28	1.57
	Post-hoc		d > b, a c, e, b > a	a > c	c > a	–	–
Tenure	(a) <1 year	170	29.56 ± 26.18	63.69 ± 17.18	41.94 ± 11.83	59.38 ± 16.72	31.85 ± 21.57
	(b) 1–5 years	671	36.33 ± 25.38	66.03 ± 15.48	39.16 ± 11.17	62.74 ± 15.03	29.24 ± 19.15
	(c) 6–10 years	513	40.06 ± 25.50	65.81 ± 16.28	38.61 ± 12.51	63.49 ± 15.60	31.21 ± 20.07
	(d) 11–15 years	254	41.73 ± 26.50	68.27 ± 15.14	36.28 ± 12.29	67.25 ± 14.26	30.73 ± 18.47
	(e) 16–20 years	105	32.62 ± 24.05	70.95 ± 16.48	33.39 ± 13.92	69.53 ± 15.91	28.89 ± 19.26
	(f) ≥21 years	109	29.36 ± 22.53	64.27 ± 18.96	38.71 ± 12.84	63.68 ± 18.53	24.10 ± 21.30
	F-value		9.04***	3.67**	7.77***	8.72***	2.98*
	Post-hoc		d > e, a, f, c b > a, f	e > c, a	a > c, d, e b > d, e f, c > e	e, d > c, a, b	a, c > f
Emp. type	(a) Regular	1,620	36.71 ± 26.06	66.60 ± 15.68	38.39 ± 11.73	64.20 ± 14.98	28.89 ± 19.28
	(b) Non-regular	202	38.12 ± 22.47	63.30 ± 19.46	39.45 ± 15.26	59.79 ± 20.21	38.13 ± 21.55
	t-value		−0.82	2.32* (a > b)	−0.96	3.00**	−5.806***
	Direction			a > b		a > b	b > a
Work place	(a) Office	973	26.18 ± 22.25	67.64 ± 15.52	38.23 ± 11.49	64.14 ± 14.97	28.02 ± 20.24
	(b) Field site	849	49.12 ± 23.84	64.63 ± 16.76	38.82 ± 12.91	63.23 ± 16.49	32.10 ± 18.94
	t-value		−21.13***	3.98***	−1.03	1.22	−4.42***
	Direction		b > a	a > b	–	–	b > a

Comparisons were made using independent *t*-tests or ANOVA. $N = 1,822$. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. *Post-hoc* tests: Scheffé or Games–Howell. "–" indicates non-significant results. "Direction" indicates which group has a significantly higher mean. See Supplementary Table S4 for full comparisons, including gender, education, income, and employment type.

psychosocial profiles (lower JS and higher JStr) and showed a positive association with TI, while the direct PSR–WE path was not supported.

Among the psychosocial variables, the pattern was consistent with the JD–R framing: stress- and engagement-related processes were most closely aligned with TI, and JS related to TI primarily via its associations with lower stress and higher engagement (Demerouti et al., 2001).

4.2 Indirect pathways linking PSR and JS to turnover intention

The mediation analysis further clarified how PSR and JS relate to TI through indirect pathways (Table 7 and Figures 2, 3). For PSR, the total indirect effect on TI was statistically significant (i.e., the 95% bias-corrected confidence interval excluded zero), with supported specific pathways operating through JS and JStr, including serial configurations involving WE. For JS, the total indirect effect on TI was also statistically significant, with supported specific pathways via JStr, via WE, and via the serial pathway through JStr and WE (Table 7). This configuration is consistent with mediation typologies that distinguish indirect-only patterns from direct effects in models with multiple mediators (Zhao et al., 2010). Other estimated indirect pathways whose bias-corrected confidence intervals included zero are omitted from Table 7 for clarity.

4.3 Descriptive patterns from sub-dimensions and group comparisons

Bivariate associations and sub-dimension correlations provide descriptive context for interpreting the model (Table 3; Supplementary Table S3). The sub-dimension patterns suggest that relational/structural stressors (e.g., authoritarian climate and perceived inequality) may be more closely aligned with TI than workload-related indicators, while identification-related aspects of WE may be salient correlates of TI. In addition, group comparisons indicated heterogeneity in PSR and psychosocial variables across sectors and workplace settings (Tables 4, 5). The Forest Product Production sector and field-site workers showed profiles characterized by higher PSR and less favorable psychosocial outcomes relative to several comparison groups (Tables 4, 5). These descriptive patterns are consistent with the interpretation that safety appraisals and psychosocial conditions co-occur in specific production- and field-oriented contexts.

TABLE 6 Standardized path coefficients of the structural model.

Path	Unstd. *B*	S.E.	Std. *β*	*p*
Perceived safety risk → job satisfaction	−0.135	0.015	−0.223	<0.001
Perceived safety risk → job stress	0.028	0.010	0.050	0.005
Perceived safety risk → work engagement	0.009	0.009	0.015	0.316
Perceived safety risk → turnover intention	0.039	0.017	0.055	0.019
Job satisfaction → job stress	−0.808	0.022	−0.860	<0.001
Job satisfaction → work engagement	0.728	0.046	0.743	<0.001
Job satisfaction → turnover intention	0.259	0.158	0.221	0.102
Job stress → work engagement	−0.241	0.048	−0.232	<0.001
Job stress → turnover intention	0.576	0.095	0.462	<0.001
Work engagement → turnover intention	−0.383	0.170	−0.319	0.024

N = 1,822. Unstd. *B*, unstandardized coefficient; S.E., standard error; Std. *β*, standardized coefficient. Model fit indices: χ^2 = 932.081 (*df* = 81, $p < 0.001$), CFI = 0.940, TLI = 0.923, RMSEA = 0.076, SRMR = 0.044.

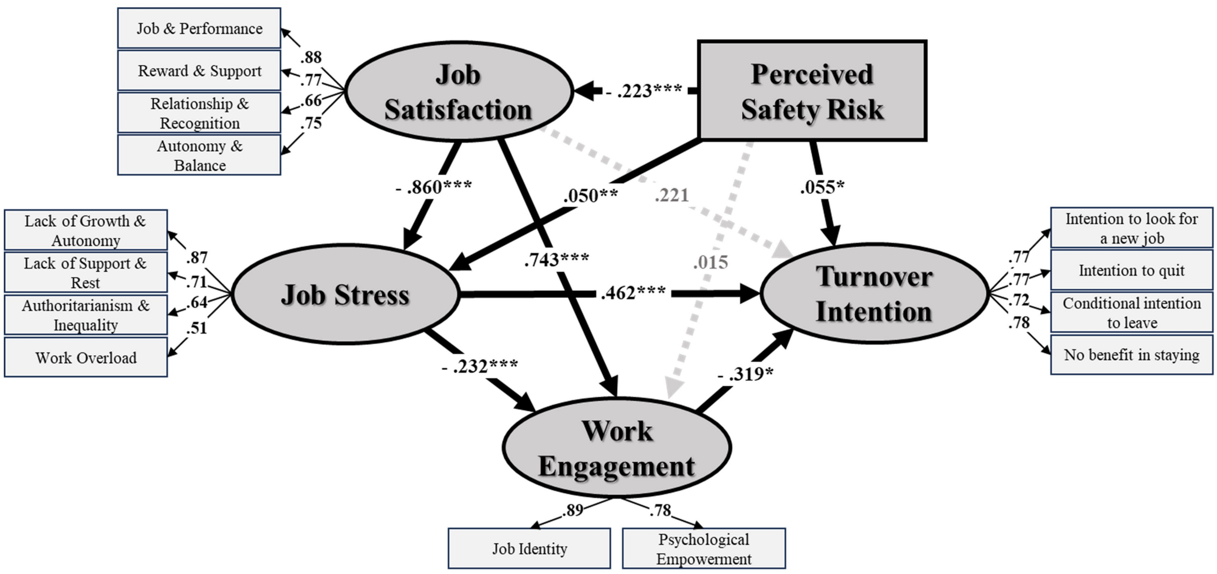

FIGURE 1
Final five-variable structural equation model linking perceived safety risk (PSR), job satisfaction (JS), job stress (JStr), work engagement (WE), and turnover intention (TI). Values on structural paths are standardized coefficients (*β*); solid arrows indicate statistically significant paths and dashed gray arrows indicate non-significant paths. Measurement links show standardized factor loadings for the indicators/sub-factors of each latent construct (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

4.4 Practical implications

The results suggest several practical considerations for workforce sustainability. First, safety management may be relevant not only for accident prevention but also for turnover-related attitudes insofar as PSR is associated with psychosocial variables and TI within the model (Tables 6, 7). Second, the descriptive sub-dimension patterns indicate that organizational fairness, communication, and supervisory practices may complement workload-oriented approaches (Supplementary Table S3). Third, strengthening job identity (e.g., role clarity, recognition, and professional meaning) may be relevant for engagement-related components inversely associated with TI. From a forest management perspective, stabilizing the workforce is not merely a human resource concern but a strategic consideration for maintaining operational continuity and implementing long-term management plans effectively.

4.5 Limitations and future research

Several limitations should be considered. First, the cross-sectional design does not support causal inference; the directional paths represent theory-consistent associations. Accordingly, reverse causality (e.g., higher strain shaping satisfaction) and omitted variable bias (e.g., unmeasured organizational or personal factors) cannot be ruled out, and the estimated paths should be interpreted as theory-consistent associations rather than causal effects. Second, measures were self-reported, which may introduce common method variance. Third, PSR was assessed using a single item; future studies could employ

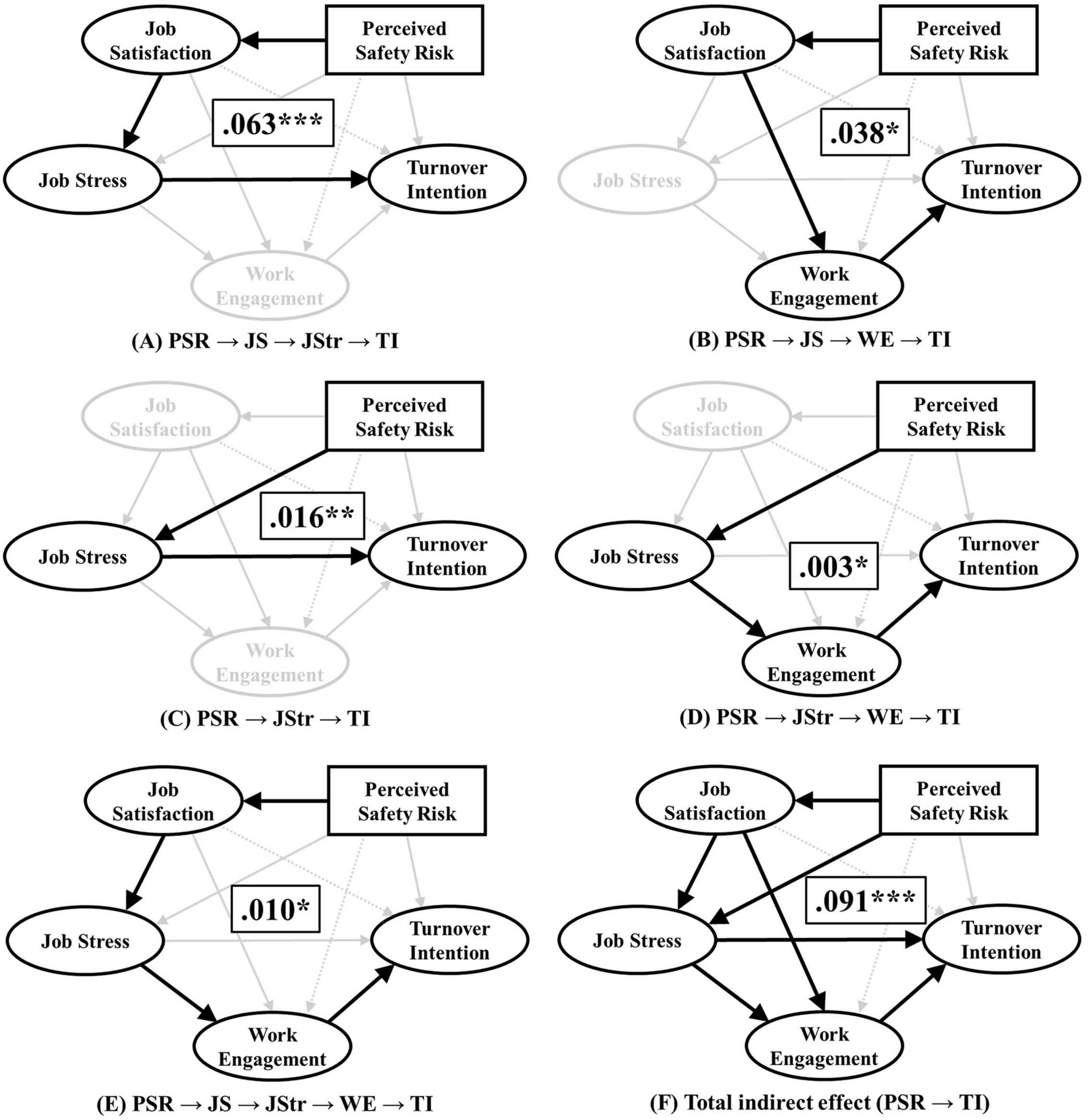

FIGURE 2
Significant indirect pathways from perceived safety risk (PSR) to turnover intention (TI) estimated using bias-corrected bootstrapping (5,000 resamples) (Table 7). In each panel, the focal pathway is highlighted in bold and remaining model paths are shown in light gray for context; values indicate unstandardized indirect-effects estimates. Panels **(A–E)** present the supported specific indirect routes and **(F)** reports the total indirect effect. Indirect effects are considered statistically significant when the 95% bias-corrected bootstrap confidence interval excludes zero.

multi-item measures capturing safety climate and related dimensions. Fourth, item screening for the job stress scale improved internal consistency in this sample but may have narrowed content coverage relative to the full KOSS domains; future work should confirm the retained structure in an independent sample and evaluate domain coverage with alternative stress measures. Finally, psychometric refinement was conducted using pooled-sample item screening and EFA for established scales, followed by CFA; to address concerns about capitalization on chance, a stratified split-half stability check was conducted and yielded comparable fit indices across subsamples (Supplementary Table S5). Additionally, because the dataset is not publicly available due to institutional regulations, independent reproducibility may be constrained; access is subject to the process described in the Data availability statement. Future studies could combine survey data with administrative indicators and multi-item safety measures to evaluate whether perceived risk aligns with objective safety conditions. Longitudinal or repeated-measures designs and independent-sample validation would further help assess temporal ordering and the stability of the measurement and structural relations across survey waves and subpopulations.

5 Conclusion

This study clarifies the structural pattern linking perceived safety risk (PSR), job satisfaction (JS), job stress (JStr), work engagement (WE), and turnover intention (TI) among forest industry workers. Rather than reiterating individual coefficients, the overall results indicate that turnover intention is most coherently understood through stress- and engagement-related processes, with job satisfaction contributing primarily via indirect pathways.

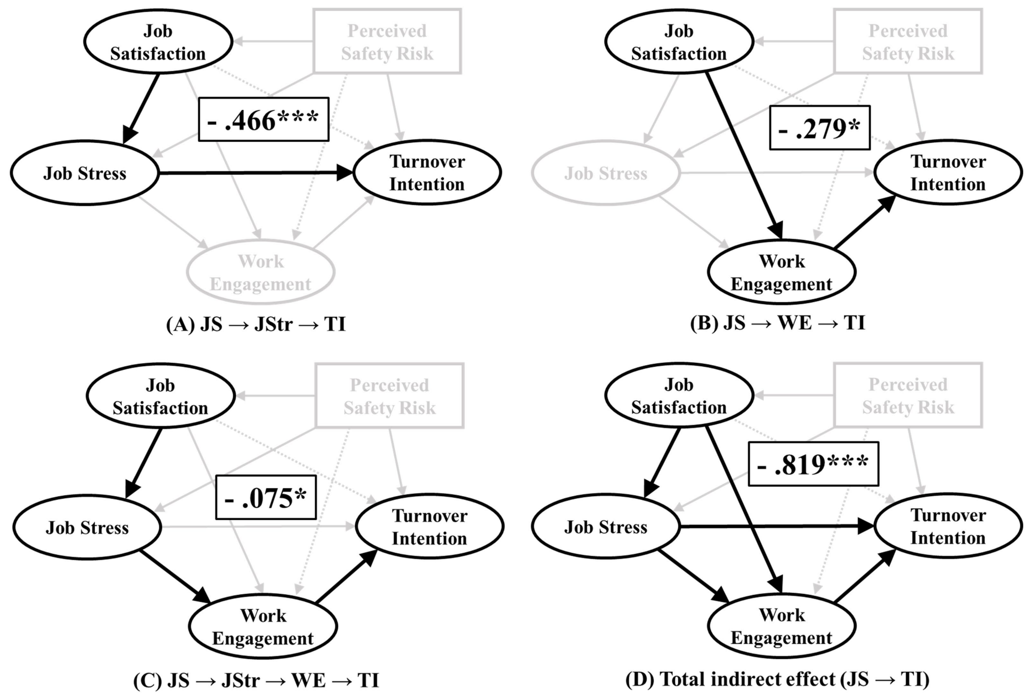

FIGURE 3
Significant indirect pathways from job satisfaction (JS) to turnover intention (TI) estimated using bias-corrected bootstrapping (5,000 resamples) (Table 7). The focal pathway is emphasized in each panel and other paths are shown in light gray; values indicate unstandardized indirect-effects estimates. Panels **(A–C)** present the supported specific indirect routes and **(D)** reports the total indirect effect. Indirect effects are considered statistically significant when the 95% bias-corrected bootstrap confidence interval excludes zero.

TABLE 7 Analysis of mediation effects.

Predictor	Specific indirect path	Effect	95% CI	*p*
Perceived safety risk (PSR)	PSR → JS → JStr → TI	0.063	[0.036, 0.095]	<0.001
	PSR → JS → WE → TI	0.038	[0.001, 0.088]	0.042
	PSR → JStr → TI	0.016	[0.004, 0.034]	0.006
	PSR → JStr → WE → TI	0.003	[0.000, 0.008]	0.022
	PSR → JS → JStr → WE → TI	0.010	[0.001, 0.026]	0.031
	Total indirect effect (PSR → TI)	0.091	[0.068, 0.116]	<0.001
Job satisfaction	JS → JStr → TI	−0.466	[−0.661, −0.268]	<0.001
	JS → WE → TI	−0.279	[−0.648, −0.004]	0.047
	JS → JStr → WE → TI	−0.075	[−0.191, −0.008]	0.031
	Total indirect effect (JS → TI)	−0.819	[−1.252, −0.486]	<0.001

Effects are unstandardized estimates. CI = bias-corrected bootstrap 95% confidence interval (5,000 resamples). Indirect effects are considered statistically significant when the 95% BC CI does not include zero. Confidence interval bounds are reported to three decimal places; values shown as 0.000 reflect rounding of positive estimates and do not indicate an exact zero.

Consistent with mediation typologies that distinguish "indirect-only" configurations in multi-mediator settings (Zhao et al., 2010), JS was not directly associated with TI, but its associations with reduced stress and enhanced engagement were aligned with lower turnover intention. In this sense, satisfaction appears to operate as a general evaluative resource whose relevance to retention depends on whether it is translated into lower strain and stronger motivational states, which is also compatible with the broader job demands–resources framing (Demerouti et al., 2001).

Beyond this indirect-only pattern for JS, incorporating PSR into the five-variable framework highlights the relevance of safety appraisals as an upstream contextual factor. The results suggest that PSR is intertwined with less favorable psychosocial conditions and is linked to turnover intention both directly and through supported indirect routes that involve satisfaction and stress-related processes. Importantly, these findings do not imply that safety perceptions affect retention through a single dominant route; instead, the evidence points to a coupled structure in which perceived risk, job attitudes, and strain/motivation processes co-vary within the same workforce ecosystem. The descriptive patterns additionally indicate that less favorable profiles tended to cluster in production- and field-oriented contexts, including the Forest Product Production sector, where higher safety risk appraisals and psychosocial stressors co-occurred—an observation that may be useful for prioritizing where retention-oriented interventions are likely to be most salient.

Taken together, the results motivate a dual emphasis for workforce sustainability efforts. First, safety-centered modernization and risk reduction in field operations may be relevant not only for accident prevention but also for stabilizing retention-relevant attitudes insofar as perceived risk aligns with the psychosocial processes captured in the model. Second, organizational practices that address psychosocial strain and support engagement-relevant resources—such as fairness, communication, and job identity—may complement equipment- and workload-oriented approaches by strengthening the conditions under which satisfaction relates to lower stress and higher engagement. At the same time, these implications should be interpreted cautiously given the pooled cross-sectional, self-reported design and the single-item measurement of PSR. Future studies using multi-item safety constructs (e.g., safety climate), independent-sample validation, repeated measures or longitudinal designs, and objective indicators (e.g., accident and turnover records) would help evaluate temporal ordering, reduce shared-method concerns, and test whether perceived risk tracks observable safety conditions across sectors and worksites.

Data availability statement

The raw data supporting the conclusions of this article are not publicly available due to institutional regulations regarding government data management and privacy protection. The dataset contains sector-specific information and is owned and managed by the National Institute of Forest Science. Requests to access the datasets should be directed to Kidong Kim, goldeast@korea.kr, subject to official review and approval.

Ethics statement

Ethical review and approval were not required for this study involving human participants in accordance with local legislation and institutional requirements. Specifically, under the Enforcement Rule of the Bioethics and Safety Act of the Republic of Korea (Article 2, Paragraph 2, Item 1), research conducted or commissioned by the national government to review or evaluate public welfare programs is exempt from IRB review. Written informed consent was not required from the participants in accordance with national legislation and institutional requirements. The survey was anonymous and conducted for public policy purposes.

Author contributions

CL: Writing – original draft, Methodology, Formal analysis, Visualization, Investigation, Conceptualization, Validation, Data curation, Writing – review & editing. KK: Supervision, Writing – review & editing, Project administration, Funding acquisition, Conceptualization, Resources.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffgc.2026.1763752/full#supplementary-material

References

Abdi, H., and Williams, L. J. (2010). Principal component analysis. *WIREs Comput. Stat.* 2, 433–459. doi: 10.1002/wics.101

Anderson, J. C., and Gerbing, D. W. (1988). Structural equation modeling in practice: a review and recommended two-step approach. *Psychol. Bull.* 103, 411–423. doi: 10.1037/0033-2909.103.3.411

Aziri, B. (2011). Job satisfaction: a literature review. *Manag. Res. Pract.* 3, 77–86.

Bakker, A. B., and Demerouti, E. (2017). Job demands–resources theory: taking stock and looking forward. *J. Occup. Health Psychol.* 22, 273–285. doi: 10.1037/ocp0000056

Bakker, A. B., Demerouti, E., and Sanz-Vergel, A. I. (2014). Burnout and work engagement: the JD–R approach. *Annu. Rev. Organ. Psychol. Organ. Behav.* 1, 389–411. doi: 10.1146/annurev-orgpsych-031413-091235

Bartlett, M. S. (1951). A further note on tests of significance in factor analysis. *Br. J. Stat. Psychol.* 4, 1–2. doi: 10.1111/j.2044-8317.1951.tb00299.x

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychol. Bull.* 107, 238–246. doi: 10.1037/0033-2909.107.2.238

Best, T., Visser, R., and Conradson, D. (2021). Stress, psychosocial factors and the New Zealand forest industry workforce: seeing past the risk of harm to the potential for individual and organisational wellbeing. *N. Z. J. For. Sci.* 51, 1–13. doi: 10.33494/nzjfs512021x93x

Bollen, K. A. (1989). *Structural equations with latent variables*. Oxford, England: John Wiley & Sons.

Bollen, K. A., and Stine, R. A. (1992). Bootstrapping goodness-of-fit measures in structural equation models. *Sociol. Methods Res.* 21, 205–229. doi: 10.1177/0049124192021002004

Browne, M. W., and Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociol. Methods Res.* 21, 230–258. doi: 10.1177/0049124192021002005

Cabrera-Aguilar, E., Zevallos-Francia, M., Morales-García, M., Ramírez-Coronel, A. A., Morales-García, S. B., Sairitupa-Sanchez, L. Z., et al. (2023). Resilience and stress as predictors of work engagement: the mediating role of self-efficacy in nurses. *Front. Psych.* 14:1202048. doi: 10.3389/fpsyt.2023.1202048

Chang, S.-J., and Koh, S.-B. (2005). Development of the Korean occupational stress scale (KOSS). *Korean J. Stress Res.* 13, 183–197.

Delacre, M., Lakens, D., and Leys, C. (2017). Why psychologists should by default use Welch's *t*-test instead of student's *t*-test. *Int. Rev. Soc. Psychol.* 30, 92–101. doi: 10.5334/irsp.82

Demerouti, E., and Bakker, A. B. (2011). The job demands-resources model: challenges for future research. *SA J. Ind. Psychol.* 37, 1–9. doi: 10.4102/sajip.v37i2.974

Demerouti, E., Bakker, A. B., Nachreiner, F., and Schaufeli, W. B. (2001). The job demands-resources model of burnout. *J. Appl. Psychol.* 86, 499–512. doi: 10.1037/0021-9010.86.3.499

Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. London: SAGE Publications.

Games, P. A., and Howell, J. F. (1976). Pairwise multiple comparison procedures with unequal N's and/or variances: a Monte Carlo study. *J. Educ. Stat.* 1, 113–125. doi: 10.3102/10769986001002113

Griffeth, R. W., Hom, P. W., and Gaertner, S. (2000). A meta-analysis of antecedents and correlates of employee turnover: update, moderator tests, and research implications for the next millennium. *J. Manage.* 26, 463–488. doi: 10.1177/014920630002600305

Hackman, J. R., and Oldham, G. R. (1976). Motivation through the design of work: test of a theory. *Organ. Behav. Hum. Perform.* 16, 250–279. doi: 10.1016/0030-5073(76)90016-7

Herzberg, F. (1959). *The motivation to work*. New York, NY: John Wiley & Sons.

Hu, L., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct. Equ. Model.* 6, 1–55. doi: 10.1080/10705519909540118

Jiang, L., Wang, S., and Li, Y. (2026). Forestry 5.0 and the human factor: a critical review of digital technologies in occupational safety and health management. *Front. For. Glob. Change* 9:1758933. doi: 10.3389/ffgc.2026.1758933

Kahn, W. A. (1990). Psychological conditions of personal engagement and disengagement at work. *Acad. Manag. J.* 33, 692–724. doi: 10.2307/256287

Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. *Psychometrika* 23, 187–200. doi: 10.1007/BF02289233

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika* 39, 31–36. doi: 10.1007/BF02291575

Kim, K., Jung, B. H., Kim, C. S., and Lee, J. H. (2009). A study on the job satisfaction and turnover of the forest workers. *J. Korean Soc. For. Sci.* 98, 690–695.

Kline, R. B. (2023). *Principles and practice of structural equation modeling*. New York, NY: Guilford Publications.

Korea Forest Service (2024). *Report on the 2023 Forest industry survey*. Daejeon: Korea Forest Service.

Lazarus, R. S., and Folkman, S. (1984). *Stress, appraisal, and coping*. New York, NY: Springer Publishing Company.

Le Blanc, P., De Jonge, J., and Schaufeli, W. (2008). Job stress and occupational health. *Introd. Work Organ. Psychol. Eur. Perspect.* (Malden, MA: Blackwell Publishing). 2, 119–147.

Lee, C., and Kim, K. (2022). Effects of the forest industry on the south Korean national economy: evidence from an input-output analysis based on the special classification for the forest industry. *For. Sci. Technol.* 18, 56–66. doi: 10.1080/21580103.2022.2075474

Leth-Steensen, C., and Gallitto, E. (2016). Testing mediation in structural equation modeling: the effectiveness of the test of joint significance. *Educ. Psychol. Meas.* 76, 339–351. doi: 10.1177/0013164415593777

Levene, H. (1960). *Contributions to probability and statistics: essays in honor of Harold Hotelling*. Palo Alto: Stanford University Press.

Mazzetti, G., Robledo, E., Vignoli, M., Topa, G., Guglielmi, D., and Schaufeli, W. B. (2023). Work engagement: a meta-analysis using the job demands-resources model. *Psychol. Rep.* 126, 1069–1107. doi: 10.1177/00332941211051988

Melià, J. L., Mearns, K. J., Silva, S. A., and Lima, M. L. (2008). Safety climate responses and the perceived risk of accidents in the construction industry. *Saf. Sci.* 46, 949–958. doi: 10.1016/j.ssci.2007.11.004

Mobley, W. H., Griffeth, R. W., Hand, H. H., and Meglino, B. M. (1979). Review and conceptual analysis of the employee turnover process. *Psychol. Bull.* 86, 493–522. doi: 10.1037/0033-2909.86.3.493

Mylek, M. R., and Schirmer, J. (2015). Beyond physical health and safety: supporting the wellbeing of workers employed in the forest industry. *Forestry* 88, 391–406. doi: 10.1093/forestry/cpv011

Norušis, M. J. (1993). *SPSS. Statistical data analysis*. Chicago, IL: SPSS Incorporated.

Rundmo, T. (1992). Risk perception and safety on offshore petroleum platforms—part II: perceived risk, job stress and accidents. *Saf. Sci.* 15, 53–68. doi: 10.1016/0925-7535(92)90039-3

Rundmo, T. (1995). Perceived risk, safety status, and job stress among injured and non-injured employees on offshore petroleum installations. *J. Saf. Res.* 26, 87–97. doi: 10.1016/0022-4375(95)00008-E

Schaufeli, W. B., Salanova, M., González-Romá, V., and Bakker, A. B. (2002). The measurement of engagement and burnout: a two sample confirmatory factor analytic approach. *J. Happiness Stud.* 3, 71–92. doi: 10.1023/A:1015630930326

Scheffé, H. (1953). A method for judging all contrasts in the analysis of variance. *Biometrika* 40, 87–104. doi: 10.2307/2333100

Statistics Korea (2022). *Population projections: 2020~2070*. Daejeon: Statistics Korea.

Stevens, J. P. (2002). *Applied multivariate statistics for the social sciences*. 4th Edn. Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Tucker, L. R., and Lewis, C. (1973). A reliability coefficient for maximum likelihood factor analysis. *Psychometrika* 38, 1–10. doi: 10.1007/BF02291170

Üngüren, E., Onur, N., Demirel, H., and Tekin, Ö. A. (2024). The effects of job stress on burnout and turnover intention: the moderating effects of job security and financial dependency. *Behav. Sci. (Basel).* 14:322. doi: 10.3390/bs14040322

Welch, B. L. (1951). On the comparison of several mean values: an alternative approach. *Biometrika* 38, 330–336. doi: 10.1093/biomet/38.3-4.330

Zhao, X., Lynch, J. G. Jr., and Chen, Q. (2010). Reconsidering baron and Kenny: myths and truths about mediation analysis. *J. Consum. Res.* 37, 197–206. doi: 10.1086/651257

Zhu, L.-L., Wang, H.-J., Xu, Y.-F., Ma, S.-T., and Luo, Y.-Y. (2023). The effect of work engagement and perceived organizational support on turnover intention among nurses: a meta-analysis based on the Price–Mueller model. *J. Nurs. Manag.* 2023:3356620. doi: 10.1155/2023/3356620