Supplementary Materials

Women Engineers' Occupational Safety in Iraq's Construction Sector: Site Exposure, Gender-Responsive Working Conditions, and Digital Safety Reporting

Table S1. Dunn post-hoc pairwise comparisons following significant Kruskal-Wallis tests

Construct	Group 1	Group 2	z	Raw p	BH-adjusted p	Significant after BH
OS: Exposure Risk	Office	Occasional/monthly	-1.569	0.1166	0.1399	No
	Office	Weekly/high	-4.444	<0.0001	<0.0001	Yes
	Office	Site-based	-4.109	<0.0001	0.0001	Yes
	Occasional/monthly	Weekly/high	-3.766	0.0002	0.0003	Yes
	Occasional/monthly	Site-based	-3.340	0.0008	0.0013	Yes
	Weekly/high	Site-based	0.990	0.3222	0.3222	No
OS: Preparedness	Office	Occasional/monthly	-0.973	0.3305	0.3966	No
	Office	Weekly/high	0.630	0.5285	0.5285	No
	Office	Site-based	4.024	<0.0001	0.0002	Yes
	Occasional/monthly	Weekly/high	1.448	0.1477	0.2215	No
	Occasional/monthly	Site-based	5.695	<0.0001	<0.0001	Yes
	Weekly/high	Site-based	2.692	0.0071	0.0142	Yes
OS: Safety Concern	Office	Occasional/monthly	-1.682	0.0926	0.1389	No
	Office	Weekly/high	1.176	0.2396	0.2876	No
	Office	Site-based	2.236	0.0254	0.0507	No
	Occasional/monthly	Weekly/high	2.599	0.0094	0.0281	Yes
	Occasional/monthly	Site-based	4.267	<0.0001	0.0001	Yes
	Weekly/high	Site-based	0.684	0.4943	0.4943	No
Reporting Barriers	Office	Occasional/monthly	3.785	0.0002	0.0009	Yes
	Office	Weekly/high	3.452	0.0006	0.0017	Yes
	Office	Site-based	0.733	0.4636	0.4636	No
	Occasional/monthly	Weekly/high	0.964	0.3352	0.4023	No
	Occasional/monthly	Site-based	-2.791	0.0053	0.0079	Yes
	Weekly/high	Site-based	-2.792	0.0052	0.0079	Yes
Gender Barriers	Office	Occasional/monthly	-1.508	0.1317	0.2633	No
	Office	Weekly/high	1.249	0.2118	0.3177	No
	Office	Site-based	0.670	0.5029	0.5029	No
	Occasional/monthly	Weekly/high	2.547	0.0109	0.0652	No
	Occasional/monthly	Site-based	2.248	0.0246	0.0737	No
	Weekly/high	Site-based	-0.677	0.4985	0.5029	No
Improvement Priorities	Office	Occasional/monthly	-1.835	0.0666	0.0799	No
	Office	Weekly/high	-2.022	0.0432	0.0664	No
	Office	Site-based	2.012	0.0443	0.0664	No
	Occasional/monthly	Weekly/high	-0.857	0.3916	0.3916	No
	Occasional/monthly	Site-based	4.150	<0.0001	0.0002	Yes
	Weekly/high	Site-based	3.645	0.0003	0.0008	Yes

Note. Dunn pairwise tests were conducted only for constructs with a significant omnibus Kruskal-Wallis test retained in the revised construct-level analysis. Benjamini-Hochberg (BH) adjustment was applied to the six pairwise comparisons within each construct. Statistical inference is based on the BH-adjusted p-value; BH-adjusted $p < 0.05$ was considered significant. Office = office only/no site visits (n = 44); Occasional/monthly = occasional or monthly site visits (n = 109); Weekly/high = weekly or high-frequency site visits (n = 22); Site-based = almost daily/site-based work (n = 40).

Table S2. Item-to-construct mapping and literature basis for the questionnaire

Construct/domain	Item	English item wording	Analytical treatment	Literature basis*
OS: Exposure Risk	ER1	The nature of my work brings me into direct or indirect contact with project sites.	Included as scored	[1-5,11]
	ER2	I am exposed to occupational safety risks during site visits or field follow-up.	Included as scored	[1-5,11]
OS: Preparedness	PR1	Entrances and walkways at project sites are usually safe and suitable for women engineers.	Included as scored	[2,3,5,12,24]
	PR2	Safety instructions are explained before or during a site visit.	Included as scored	[2,3,5,12,24]
OS: Safety Concern	SC1	Poor housekeeping and site order affect my sense of safety during a visit.	Included as scored	[1-5]
	SC2	The movement of machinery, vehicles, and materials within the site is a source of safety concern.	Included as scored	[1-5]
	SC3	I sometimes avoid entering certain areas of a site because they appear unsafe.	Included as scored	[1-5]
PPE Barriers	PPE1	Suitable personal protective equipment is available when visiting project sites.	Reverse-coded	[12,13,24,25]
	PPE2	The sizes and designs of the available personal protective equipment are generally suitable for women engineers.	Reverse-coded	[12,13,24,25]
	PPE3	Unsuitable personal protective equipment may reduce a woman engineer's ability to work safely on site.	Included as scored	[12,13,24,25]
	PPE4	I have experienced difficulty obtaining suitable personal protective equipment during field visits.	Included as scored	[12,13,24,25]
	PPE5	Some women engineers may avoid certain field tasks because suitable personal protective equipment is not available.	Included as scored	[12,13,24,25]
Welfare/Mobility Barriers	WM1	Project sites usually provide suitable sanitary facilities for women engineers.	Reverse-coded	[14,15]
	WM2	The lack of suitable sanitary facilities affects women engineers' willingness to visit project sites.	Included as scored	[14,15]
	WM3	Safe waiting or rest areas are available during field visits.	Reverse-coded	[14,15]
	WM4	Site arrangements take account of women engineers' privacy and comfort.	Reverse-coded	[14,15]
	WM5	Remote or distant sites create additional concerns for women engineers.	Included as scored	[14,15]
	WM6	Transportation to and from project sites affects women engineers' sense of safety.	Included as scored	[14,15]
Reporting Barriers	RB1	I feel comfortable reporting unsafe conditions at the workplace.	Reverse-coded	[15,16,26-29]
	RB2	Women engineers can report inappropriate conduct without fear of negative consequences.	Reverse-coded	[15,16,26-29]
	RB3	Management takes women engineers' safety concerns seriously.	Reverse-coded	[15,16,26-29]
	RB4	Clear channels are available for reporting harassment, inappropriate conduct, or unsafe working conditions.	Reverse-coded	[15,16,26-29]
	RB5	I would feel supported if I refused to enter an unsafe area on site.	Reverse-coded	[15,16,26-29]
	RB6	Reporting safety problems may expose a woman engineer to embarrassment or blame.	Included as scored	[15,16,26-29]
Gender Barriers	GB1	Women engineers may sometimes be excluded from certain field activities because they are women.	Included as scored	[6-11,19-24,28]
	GB2	The male-dominated nature of the site affects a woman engineer's sense of safety or comfort.	Included as scored	[6-11,19-24,28]
	GB3	Women engineers may be excluded from some informal discussions or communications on site.	Included as scored	[6-11,19-24,28]
	GB4	Some workers or supervisors question the technical authority of a woman engineer on site	Included as scored	[6-11,19-24,28]
	GB5	Inappropriate comments or conduct may affect a woman engineer's comfort during field work.	Included as scored	[6-11,19-24,28]
	GB6	Social expectations affect the types of tasks assigned to women engineers in the construction sector.	Included as scored	[6-11,19-24,28]
	GB7	Gender-related barriers may reduce women engineers' opportunities to gain field experience.	Included as scored	[6-11,19-24,28]
Digital and AI-Enabled Safety Support	AI1	Anonymous digital reporting systems could help report safety risks.	Included in four-item support index	[17,18,30-32]
	AI2	Mobile safety applications could improve communication during field visits.	Included in four-item support index	[17,18,30-32]
	AI3	AI-based complaint analysis could help organizations detect recurring problems.	Included in four-item support index; explicitly AI-enabled	[17,18,30-32]
	AI4	Digital dashboards could help management prioritize improvements in women engineers' safety and the work environment.	Included in four-item support index	[17,18,30-32]

Construct/domain	Item	English item wording	Analytical treatment	Literature basis*
Privacy-related digital reporting	AI5	I would use a digital reporting system if privacy were guaranteed.	Reported individually; not combined into a governance construct	[15,17,18,28,29,31]
	AI6	Women engineers may hesitate to use digital reporting systems if they fear that their identity could be disclosed.	Reported individually; not combined into a governance construct	[15,17,18,28,29,31]
Improvement Priorities	IP1	Provide suitable personal protective equipment for women engineers.	Importance item	[12-15,26,29,30,32]
	IP2	Provide suitable sanitary facilities at project sites.	Importance item	[12-15,26,29,30,32]
	IP3	Provide safe waiting or rest areas during site visits.	Importance item	[12-15,26,29,30,32]
	IP4	Establish clear protocols for women engineers' visits to project sites.	Importance item	[12-15,26,29,30,32]
	IP5	Provide safe transportation to remote or distant sites.	Importance item	[12-15,26,29,30,32]
	IP6	Establish confidential channels for reporting safety problems or inappropriate conduct.	Importance item	[12-15,26,29,30,32]
	IP7	Train site managers and supervisors to address women engineers' safety issues professionally.	Importance item	[12-15,26,29,30,32]
	IP8	Increase women engineers' participation in safety committees or project safety decisions.	Importance item	[12-15,26,29,30,32]
	IP9	Use anonymous digital reporting systems to enhance women engineers' safety.	Importance item	[12-15,26,29,30,32]
	IP10	Require contractors and consultants to provide suitable conditions for women engineers working on site.	Importance item	[12-15,26,29,30,32]

Note. Items were administered in Arabic. The English wording shown here is provided for transparent construct mapping and reporting. Reverse-coded items were recoded so that higher composite scores consistently indicate stronger barriers where applicable. The AI5 and AI6 privacy-related items are retained as individual items in the revised analysis rather than combined into the former two-item governance composite. *Reference numbers correspond to the reference list in the main manuscript and indicate the literature domains used to inform item development; the questionnaire was literature-informed rather than adopted from a single standardized scale.

Table S3. Demographic and professional composition across site-exposure groups

Characteristic	Category	Office n=44	Occasional/monthly n=109	Weekly/high n=22	Site-based n=40	p	Cramér's V
Age	Less than 25	4 (9.1)	13 (11.9)	0 (0.0)	3 (7.5)	<0.001	0.258
	25-34	31 (70.5)	31 (28.4)	12 (54.5)	20 (50.0)		
	35-44	8 (18.2)	35 (32.1)	10 (45.5)	15 (37.5)		
	45 or above	1 (2.3)	30 (27.5)	0 (0.0)	2 (5.0)		
Experience	Less than 3 years	16 (36.4)	12 (11.0)	1 (4.5)	11 (27.5)	<0.001	0.382
	3-6 years	14 (31.8)	21 (19.3)	3 (13.6)	8 (20.0)		
	6-10 years	13 (29.5)	20 (18.3)	0 (0.0)	8 (20.0)		
	10-15 years	0 (0.0)	12 (11.0)	15 (68.2)	8 (20.0)		
	15 years or more	1 (2.3)	44 (40.4)	3 (13.6)	5 (12.5)		
Engineering discipline	Civil engineering	10 (22.7)	81 (74.3)	11 (50.0)	31 (77.5)	<0.001	0.327
	Mechanical engineering	9 (20.5)	14 (12.8)	0 (0.0)	0 (0.0)		
	Architectural engineering	8 (18.2)	2 (1.8)	5 (22.7)	0 (0.0)		
	Electrical engineering	2 (4.5)	5 (4.6)	0 (0.0)	0 (0.0)		
	Other discipline	15 (34.1)	7 (6.4)	6 (27.3)	9 (22.5)		
Organization type	Government department	21 (47.7)	83 (76.1)	14 (63.6)	9 (22.5)	<0.001	0.376
	University/educational institution	8 (18.2)	15 (13.8)	0 (0.0)	9 (22.5)		
	Contracting company	4 (9.1)	2 (1.8)	5 (22.7)	11 (27.5)		
	Other	11 (25.0)	2 (1.8)	0 (0.0)	7 (17.5)		
	Freelance/private office	0 (0.0)	7 (6.4)	0 (0.0)	0 (0.0)		
	Private design/supervision company	0 (0.0)	0 (0.0)	3 (13.6)	4 (10.0)		
Region	Southern governorates	29 (65.9)	52 (47.7)	16 (72.7)	37 (92.5)	<0.001	0.291
	Baghdad	15 (34.1)	40 (36.7)	0 (0.0)	0 (0.0)		
	Middle Euphrates governorates	0 (0.0)	7 (6.4)	4 (18.2)	0 (0.0)		
	Kurdistan Region	0 (0.0)	4 (3.7)	0 (0.0)	3 (7.5)		
	Other/not reported	0 (0.0)	6 (5.5)	2 (9.1)	0 (0.0)		

Note. Values are n (% within each site-exposure group). Because several contingency-table cells were sparse, statistical significance was evaluated using Monte Carlo tests of independence; all five associations were $p < 0.001$. Cramér's V is based on the corresponding contingency table and describes association magnitude. "Other discipline" combines the smaller discipline categories. "Other" organization includes other and consulting-office responses. "Other/not reported" region includes two responses from western governorates and six responses for which region was not reported.

Table S4. Adjusted sensitivity analysis of principal outcomes by site-exposure level

Outcome	Adjusted site-exposure F	df	p	BH-adjusted p	Interpretation
Preparedness	5.57	3, 195	0.001	0.002	Association retained
Safety Concern	6.84	3, 195	<0.001	<0.001	Association retained
Reporting Barriers	4.24	3, 195	0.006	0.008	Association retained
Gender Barriers	1.47	3, 195	0.224	0.224	Association not retained
Improvement Priorities	8.58	3, 195	<0.001	<0.001	Association retained

Note. N = 209 complete cases because six respondents did not report region. Heteroskedasticity-robust linear regression models with HC3 standard errors were used as sensitivity analyses. Site-exposure group was the principal predictor, with adjustment for age, professional experience, engineering discipline, organization type, and region. To reduce sparse-category instability, discipline was coded as civil versus other, organization type as government versus non-government, and region as southern versus non-southern. Benjamini-Hochberg adjustment was applied across the five adjusted site-exposure tests. These models supplement rather than replace the primary non-parametric comparisons.