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Developing a Safety Framework for Construction Health & Safety in the Kurdistan Region: A Systems Approach

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Table S1. Workforce distribution and chi-square analysis in the Kurdistan region of Iraq’s construction industry.

Variable	Classification	Private Sector (N, %)	Public Sector (N, %)	Chi-Square	p-value
Gender	Male	265 (62.8%)	50 (11.8%)	84.088	0.000**
	Female	41 (9.7%)	66 (15.6%)		
Age	<35	127 (30.1%)	26 (6.2%)	18.083	0.001**
	35-44	120 (28.4%)	55 (13.0%)		
	45-54	43 (10.2%)	31 (7.3%)		
	55-64	12 (2.8%)	3 (0.7%)		
	>=65	4 (0.9%)	1 (0.2%)		
Qualifications	Diploma	48 (11.4%)	1 (0.2%)	36.942	0.000**
	BSc	159 (37.7%)	92 (21.8%)		
	High Diploma	11 (2.6%)	5 (1.2%)		
	MSc	36 (8.5%)	12 (2.8%)		
	PhD	9 (2.1%)	3 (0.7%)		
	Other	43 (10.2%)	3 (0.7%)		

(Table S1) contd....

Variable	Classification	Private Sector (N, %)	Public Sector (N, %)	Chi-Square	p-value
Type of Work	Engineer	194 (46.0%)	105 (24.9%)	31.987	0.000**
	Electrician	14 (3.3%)	1 (0.2%)		
	Technician	21 (5.0%)	5 (1.2%)		
	Foreman	18 (4.3%)	1 (0.2%)		
	Skilled Labourer	11 (2.6%)	0 (0.0%)		
	Labourer	35 (8.3%)	3 (0.7%)		
	Other	13 (3.1%)	1 (0.2%)		
Specialization	Architectural	24 (5.7%)	20 (4.7%)	62.012	0.000**
	Civil	128 (30.3%)	37 (8.8%)		
	Electrical	66 (15.6%)	14 (3.3%)		
	Software	4 (0.9%)	10 (2.4%)		
	Water Resources	5 (1.2%)	7 (1.7%)		
	Geomatics (Survey)	6 (1.4%)	3 (0.7%)		
	Mechanical	12 (2.8%)	19 (4.5%)		
Other	61 (14.5%)	6 (1.4%)			
Role in Project	Engineer	125 (29.6%)	96 (22.7%)	64.26	0.000**
	Client	8 (1.9%)	3 (0.7%)		
	Contractor	22 (5.2%)	0 (0.0%)		
	Owner	21 (5.0%)	1 (0.2%)		
	Project Manager	28 (6.6%)	7 (1.7%)		
	Other	102 (24.2%)	9 (2.1%)		
Construction Project	Residential Houses	132 (31.3%)	19 (4.5%)	102.146	0.000**
	High-rise Buildings	79 (18.7%)	3 (0.7%)		
	Oil Industry Projects	16 (3.8%)	2 (0.5%)		
	Infrastructure Project	29 (6.9%)	36 (8.5%)		
	Other	50 (11.8%)	56 (13.3%)		
Region	Erbil	133 (31.5%)	56 (13.3%)	11.462	0.022*
	Duhok	58 (13.7%)	26 (6.2%)		
	Sulaymaniyah	77 (18.2%)	14 (3.3%)		
	Halabja	28 (6.6%)	18 (4.3%)		
	Other	10 (2.4%)	2 (0.5%)		
Employment Duration (Current Employer)	1-5 years	154 (36.5%)	10 (2.4%)	123.805	0.000**
	6-10 years	81 (19.2%)	15 (3.6%)		
	11-15 years	36 (8.5%)	24 (5.7%)		
	>=16 years	35 (8.3%)	67 (15.9%)		
Employment Duration (Construction industry (1-5 years	69 (16.4%)	6 (1.4%)		
	6-10 years	72 (17.1%)	16 (3.8%)		
	11-15 years	57 (13.5%)	19 (4.5%)		
	>=16 years	108 (25.6%)	75 (17.8%)		

Note: o *Significant at level (p<0.05).
o ** Significant at level (p<0.01).

Table S2. Health and safety context-specific framework for construction industry in the emerging economies. (Organized by Project Phases, Stakeholder Roles, and RACI Matrix).

Phase	Stakeholder	Study Finding	Proposed Actions	Objective	RACI Matrix	WHO Guidelines	
Phase 1: Initiation & Design	Designers	1. Unsafe design decisions	1.1. Assess design for potential construction risks (falls, access constraints, high-risk zones). 1.2 apply principles of inherently safe design (elimination of hazards, use of safety barriers, minimization of configurations). 1.3 Implement peer reviews with a focus on constructability and safety.	Mitigate construction risks arising from design; guarantee safe constructability.	R: Designers A: Project Manager C: Safety Officer, Client I: Contractors	Safe Design in Construction	
		2. Poor integration of emergency features	2.1 Incorporate fire exits, evacuation routes, emergency access and refuge positions into the design. 2.2 Certify effectiveness of emergency capabilities with Certified Project Managers and safety officers. 2.3 Introduce explicit annotations and instructions into design diagrams.	Enhance efficient emergency response and evacuation; safeguard personnel and occupants.	R: Designers A: Project Manager C: Safety Officer, CPMs, Client I: Contractors	Emergency Preparedness and Response in Workplaces	
		3. Lack of constructability checks	3.1 Work with the Construction Project Managers making sure the designs are build-able and provide safety for construction. 3.2 Identify differences between design standards and the safety legislation as it applies to sites. 3.3 Revise the configuration to eliminate critical construction sequence.	Guarantee that designs are practical and secure for on-site implementation; prevent hazardous behaviors.	R: Designers, CPMs A: Project Manager C: Safety Officer, Client I: Contractors, Client	Occupational Health and Safety - Risk Assessment	
		4. Unsafe material or system specifications	4.1 Recognize materials and systems that mitigate hazards (nontoxic, fire resistant, low dust). 4.2 Review supplier information with regard to compliance with safety regulations. 4.3 Determine materials that may be considered hazardous to remedy during construction.	Avoid exposure to toxic substances and risky systems on-site.	R: Designers A: Project Manager C: Safety Officer, Client I: Contractors, Client	Chemical and Material Safety in Workplaces	
		5. Lack of accountability for design safety	5.1 Assign safety responsibility for the critical design aspects. 5.2 Include safety compliance evaluations as part of the design review process. 5.3 Safety checks by the designer responsible for drafting the document.	Ensure designers are responsible for the safety implications of their ideas.	R: Designers A: Project Manager C: Senior Management I: Safety Officer, Client	Occupational Health and Safety	
	Government	6. Lack of clear safety regulations	6.1 Develop and amend the laws, regulations, and standards on national construction safety. 6.2 Publish code which is universally accessible by all the stakeholders in the construction industry. 6.3 Ensure compliance with global safety regulations.	Establish a legislative framework for secure construction procedures.	R: Ministry of Labor A: Ministry of Labor C: Professional Bodies, Unions I: Contractors, Designers, Client	Occupational Health and Safety Guidelines	
		7. Lack of mandatory training /certification	7.1 Mandate obligatory HSE certification for CPMs, Designers, Contractors, and personnel. 7.2 Approve authorized training programs. 7.3 Oversee the documentation of training completion.	Verify that all construction people possess proficiency in safety protocols.	R: Ministry of Labor, Training Boards A: Ministry of Labor C: Professional Bodies, Contractors I: Workers, Designers, Client	Worker Training and Education for Safety	
	Professional Bodies	8. Lack of professional HSE competence	8.1 Implement mandatory HSE competence requirements for registration / licensing. 8.2 Present approved safety training programs and certificates. 8.3 Require evidence of safety competence for continued membership or re-licensing.	Ensure that professionals (engineers, designers, project managers) have sufficient HSE expertise.	R: Professional Bodies A: Professional Bodies C: Training Providers I: Government, Contractors, Client	Worker Training and Education for Safety	
		9. Lack of collaboration with other stakeholders	9.1 Work with governmental agencies, labor organizations, insurers and industry associations to develop safety initiatives. 9.2 Participate in national safety programs and advisory committees. 9.3 Suggest improvements to regulatory frameworks.	Encourage collaboration among several stakeholders to enhance systemic safety results.	R: Professional Bodies A: Professional Bodies C: Government, Unions, Client I: Contractors, Designers, Client	Multi-Stakeholder Collaboration	
	Registration Boards	10. Lack of verification of professional qualifications	10.1 Authenticate educational and professional qualifications prior to registration. 10.2 Verify that applicants fulfill the minimal safety and health, safety, and environmental competency criteria. 10.3 Ensure the accuracy of registration records.	Ensure that only qualified professionals engage in practice to mitigate harmful activities resulting from ineptitude.	R: Registration Boards, HR/Verification Departments A: Registration Boards C: Professional Bodies I: Project Stakeholders, Client	Worker Training and Education for Safety	
	Project Sponsor / Project Manager / H&S Officer	11. Health & Safety Policy Development (Resistance from contractors, delays in policy approval, lack of clarity in roles.)	11.1 Formulate a formal Health and Safety policy tailored to the project, explicitly delineating objectives, duties, and dedication to employee welfare. 11.2 Incorporate health and safety provisions into agreements with contractors and subcontractors. 11.3 Ensure the policy encompasses site layout, working hours, personal protective equipment standards, welfare amenities, and medical assistance.	Establish H&S as a core project requirement	R: Project Sponsor, Project Manager, H&S Officer A: Project Sponsor, Client C: Legal/Contract Team, Client I: Contractors	Occupational Health: Guidelines for Safe Work Environments	
		12. Stakeholder & Worker Engagement (Language barriers, low engagement, cultural differences, misinformation.)	12.1 Conduct preliminary health and safety seminars with clients, designers, contractors, workers, and community representatives. 12.2 Gather input regarding potential problems (traffic, noise, dust, public safety). 12.3 Disseminate information regarding grievance channels (hotlines, site office contacts). 12.4 Establish a communication strategy for continuous safety updates.	Culture of shared responsibility & early safety buy-in	R: Project Manager, H&S Officer A: Project Manager C: Contractor Reprs., Client I: Workers, Community, Client	Community Engagement for Health & Safety Planning	
		13. Early Risk Assessment (Incomplete data, unanticipated hazards, underreporting of risks.)	13.1 Perform baseline hazard identification for the location (e.g., unstable terrain, utility infrastructure, adjacent residential zones). 13.2 Evaluate occupational hazards: falls, heavy machinery operation, noise, silica dust, chemical exposure. 13.3 Employ standardized instruments (e.g., checklists, Job Hazard Analysis templates, digital risk applications). 13.4 Document risks in a "Risk Register" for oversight.	Early structured hazard mitigation	R: H&S Officer, Risk Management Team A: H&S Officer C: Environmental Consultants, Client I: All stakeholders	Risk Assessment and Management in Occupational Health	
		14. Define Roles & Responsibilities (Role overlap, unclear reporting lines, staff turnover.)	14.1 Develop a Health and Safety Responsibility Matrix delineating accountability for inspections, reporting, toolbox discussions, and training. 14.2 The Employer shall appoint an experienced Health & Safety Officer full time for the Project. 14.3 The contractor and sub-contractor shall each have a Health and Safety focal point. 14.4 Define escalation plans (to whom does each report during incidents).	Accountability and fast decision-making	R: Project Sponsor, Project Manager A: Project Sponsor C: Legal/Contract Team, Client I: Contractors, Client	Roles & Responsibilities in Project Planning	
		15. Emergency Preparedness	15.1 Establish a site specific Emergency Response Plan (ERP) that includes evacuation routes, fire assembly points and spill response actions. 15.2 Identify the closest hospitals, clinics and medical emergency services and added to the ERP system. 15.3 Purchase first aid kits, fire extinguishers and emergency contact lists. 15.4 Arrange for training exercises (at least one before the site is established).	Ensure readiness and minimize fatalities/injuries	R: H&S Officer A: Project Manager C: Local Authorities, Client I: Contractors, Workers, Client	Emergency Preparedness in Occupational Settings	
		16. Resource Allocation for H&S (Budget constraints, delayed procurement, resource mismanagement.)	16.1 Provide money for Health and Safety (PPE, training, first aid, welfare facilities, signage). 16.2 Arranging supplies necessary for safe site set-up (fence; lights at night; control of access, sanitation facilities). 16.3 Identify medical/first aid staff before deployment and follow through. 16.4 Conduct monitoring ensuring the exchange and sustain of resources.	Make safety funded and operationalized	R: Project Sponsor, Finance Team, H&S Officer A: Project Sponsor, Client C: Contractors I: Workers, Client	Resources for Occupational Health Systems	
		17. Compliance & Legal Review (Conflicting regulations, changing laws, lack of enforcement knowledge.)	17.1 Examine local occupational safety regulations and labor statutes (working hours, welfare criteria). 17.2 Assess against WHO and ILO criteria. 17.3 Develop a compliance checklist and include the information in project governance documentation. 17.4 Nominate a member of the legal/ health and safety team to look at changes in legislation that have been implemented while the project is running.	Prevent fines, align with best practice	R: Legal Team, H&S Officer A: Project Manager C: Regulatory Authority, Client I: Contractors, Client	Compliance with Occupational Health Standards	
		18. Worker Engagement	18.1 Participate in H&S workshops 18.2 Provide feedback on risks 18.3 Represent workers in safety committees	Build trust, inclusion, and communication	R: Worker Reprs A: Unions C: H&S Officer, Project Manager I: Workers, Client	Occupational Health for Vulnerable Workers	
		Legal / Contract Team					
		Worker Representatives / Unions					

(Table S2) cont.....

Phase	Stakeholder	Study Finding	Proposed Actions	Objective	RACI Matrix	WHO Guidelines
Phase2: Planning & Mobilization	Contractors	1. Lack of HSE competency	1.1 Ensure that all employees and site supervisors' hold HSE training and certification. 1.2 Conduct recurring training and toolbox discussions. 1.3 Assess understanding of safety protocol before allowing work on site.	Guarantee that the personnel are proficient and cognizant of safety protocols.	R: Contractors, Safety Officer A: Contractors C: HR, Union I: Workers, Client	Worker Training and Education for Safety
		2. Unsafe site practices	2.1 Complete daily site inspections to identify hazards. 2.2 Implement road-safety measures (guard rails, barriers, and signs). 2.3 Maintain a list of risks in the register and control them quickly.	Mitigate accidents and hazardous activities on-site.	R: Site Supervisors A: Contractors C: Safety Officer I: Workers, Client	Risk Assessment Guidelines
		3. Poor PPE compliance	3.1 Make all efforts to provide PPE for all staff. 3.2 Train staff in appropriate use, storage and maintenance. 3.3 Observe PPE rules and take corrective action for violations.	Safeguard employees from physical, chemical, and environmental risks.	R: Contractors, Safety Officer A: Contractors C: Site Supervisors I: Workers,	PPE Guidelines
		4. Unsafe subcontractor management	4.1 Prequalification of Subcontractors based on Safety Performance. 4.2 Review subcontractor safety plans before work begins. 4.3 Perform daily supervision of subcontractor work through the enforcement of quality and safety standards.	Ensure uniform safety standards are upheld across all teams.	R: Contractors A: Project Manager C: Safety Officer, Client I: Subcontractors, Client	Contractor Safety Management Guidelines
		5. Poor emergency preparedness	5.1 Develop site-specific emergency response plans. 5.2 Emergency responsibilities should be outlined and practiced regularly. 5.3 Work directly with public safety and share protocols across all staff.	Facilitate prompt, systematic reactions in emergencies; mitigate injuries.	R: Safety Officer A: Contractors C: Local Authorities, Client I: Workers, Client	Emergency Preparedness and Response
	Government	(see above; also applies to Planning & Mobilization)				
Phase3: Construction	Contractors	1. Environmental hazards	1.1 Monitor the dust, noise vibration and waste levels. 1.2 Take measures to mitigate the impacts (dust suppression, barriers, personal protection equipment). 1.3 Garbage should be removed in environmentally-sensitive manner.	Safeguard employees and the adjacent environment; adhere to regulations.	R: Environmental Officer A: Contractors C: Safety Officer I: Workers, Local Authorities	Environmental Safety
		2. Lack of accountability in HSE	2.1 Define Key Performance Indicators for safety of contractors and supervisors. 2.2 Monitor the adherence to safety procedures and incident. 2.3 Regularly audit, and take remedial action as appropriate if discrepancies are found.	Ensure accountability and continuous improvement in safety performance	R: Senior Management A: Contractors C: Safety Officer I: Workers	Occupational Health and Safety
		3. Unsafe material handling	3.1 Provide suitable procedures of storing, stacking and marking. 3.2 Supply hoisting gear and mechanical aid. 3.3 Instruct staff in the proper procedures for handling & in ergonomic principles.	Avert injuries and property damage.	R: Site Supervisors A: Contractors C: Safety Officer I: Workers	Manual Handling & Equipment Safety
		4. Poor site hygiene/sanitation	4.1 Ensure availability of toilets, handwashing facilities and clean water. 4.2 Develop a schedule for the cleaning of site offices, canteens and communal areas. 4.3 Introduce hygiene regulations for staff.	Mitigate disease risk; sustain a healthful occupational environment.	R: Hygiene Officer A: Contractors C: Safety Officer I: Workers	Hygiene & Sanitation Guidelines
	Project Manager / H&S Officer / BIM Coordinator	5. Digital Safety Documentation	5.1 Replace paper with cloud/BIM solutions; upload procedures/checklists; QR codes at work zones.	Up-to-date, live safety documents	R: Project Manager, H&S Officer, BIM Coordinator A: Project Manager C: IT Dept I: Workers	Digital Health in Workplace Safety
	IT/Tech Team / H&S Officer	6. Smart Monitoring & Reporting	6.1 Drones/AI cameras for unsafe acts; wearables for fatigue/noise/heat; integrate into H&S system.	Real-time safety intelligence.	R: Project Sponsor, IT/Tech Team, H&S Officer A: Project Sponsor C: Contractors, Client I: Workers	Innovation in Worker Health Monitoring
	Workers' Union	7. Lack of worker representation	7.1 Ensure staff are represented on safety committees and at site meetings. 7.2 Advocate for the health and safety concerns of workers with management. 7.3 Take part in risk assessments and site visits with management.	Facilitate the expression of workers' perspectives; enhance safety-related decision-making.	R: Union Rep A: Union Rep C: Safety Officer I: Workers	Worker Participation in Committees
		8. Poor hazard communication	8.1 Deliver safety updates, warnings and other announcements to all members. 8.2 Hold safety briefings and training for all employees. 8.3 Help workers understand procedures for reporting of hazards.	Enhance hazard recognition and guarantee prompt reporting of harmful conditions.	R: Union Rep A: Union Rep C: Safety Officer I: Workers	Communication Guidelines
		9. Unsafe conditions ignored	9.1 Site circumstances are evaluated for compliance with safety legislation. 9.2 Report unsafe conditions to the manager or regulation agency. 9.3 Promote measures that are curative when risks have been identified.	Safeguard employees from hazardous conditions; diminish incidents.	R: Union Rep A: Union Rep C: Safety Officer I: Management	Risk Assessment Guidelines
		10. Lack of HSE training	10.1 Ensure that all staff receive appropriate HSE training. 10.2 Provide refresher training in newly introduced or revised procedures, where appropriate. 10.3 Work with contractors and CPMs to coordinate on-site training sessions.	Ensure that employees possess competence and understanding regarding safety protocols.	R: Union Rep A: Union Rep C: Safety Officer, HR I: Workers, Client	Worker Training Guidelines
		11. Reluctance to report incidents	11.1 The culture of safety and fear-free reporting shall be promoted. 11.2 Implement anonymous reporting procedures where appropriate. 11.3 Monitor and ensure follow up actions taken on reported hazards or incidents.	Enhance the documentation of dangers and near misses; promote proactive hazard mitigation.	R: Union Rep A: Union Rep C: Safety Officer I: Workers	Incident Reporting Guidelines
		12. Advocacy for worker health	12.1 Campaign for medical examination, health surveillance and Occupational health. 12.2 Communicate employees fears of being tired, sanity or unsafe in here. 12.3 Address workers' health complaints without delay.	Ensure a robust workforce; mitigate workplace ailments and fatigue-induced incidents.	R: Union Rep A: Union Rep C: HR, Safety Officer I: Workers, Client	Health Monitoring Guidelines
		13. Enforcement of safety rights	13.1 Explain for employees the law related to safety: regarding working processes, machinery or equipment. 13.2 Lobby contractors and CPMs, or regulators if rights aren't preserved. 13.3 Carry out inspections or audits to determine compliance.	Guarantee the enforcement of labor rights; enhance the culture of compliance.	R: Union Rep A: Union Rep C: Regulatory Authorities I: Workers	Worker Rights Guidelines
	Registration Boards	14. Workers not properly recorded	14.1 Implement compulsory sign-in/sign-out procedures via registration boards at all ingress/egress locations.	Maintain precise documentation of all employees and visitors for safety and accountability.	R: Site Manager, Safety Officer A: Registration Boards C: Security I: All site personnel	Administrative controls & traceability
		15. Boards poorly located	15.1 Install boards at each site access point, ensuring they are located in well-lit and distinctly defined places.	Enhance visibility and accessibility for all employees and visitors.	R: HSE Officer A: Registration Boards C: Site Manager I: Workers, Visitors	Risk communication
		16. Rules/instructions missing or outdated	16.1 Exhibit revised safety protocols, emergency contact information, and personal protective equipment requirements on registration boards.	Furnish explicit, comprehensible, and current safety information.	R: Safety Officer, Emergency Coordinator A: Registration Boards C: HSE Officer I: All site personnel	Hazard communication
		17. Manual boards delay emergency accountability	17.1 Implement digital or electronic registration systems utilizing badge, swipe, or biometric access methods.	Facilitate rapid roll-call and emergency headcount.	R: IT Dept, HSE Officer A: Registration Boards C: Site Manager I: All personnel	Emergency preparedness

(Table S2) cont.....

Phase	Stakeholder	Study Finding	Proposed Actions	Objective	RACI Matrix	WHO Guidelines
PHASE 3B: Occupational Hazards and Accidents	Contractors, H&S Officer/Safety Officer, Supervisors, Workers	18. Falls from Height (unsafe scaffolds, ladders, roofs; rushing jobs; weak supervision)	18.1 Provide guardrails, mid-rails, and toe boards on all edges open to removal or access of floors before work is begun. 18.3 Use complete safety harnesses attached to lifelines or anchor points, and also develop sensibiles fall-arrest devices that sound the alarm when a worker falls. 18.3 Require that scaffolds be put up only by licensed scaffolders, and that all such structures be inspected every day, tagged and listed on a computerized system." 18.4 Provide staff with training in Virtual Reality simulations to experience high-risk events in complete safety. 18.5 Introduce a "100% tie-off" rule where workers need to have some form of protection at all times when working above 2 m from the ground.	Preventing from Falls	R: H&S Officer, Site Engineer A: Contractors C: Supervisors I: Workers, Client	Falls Prevention in Occupational Safety
		19. Noise Exposure (machinery, jackhammers, generators; lack of hearing protection)	19.1 Perform Noise survey to find out the areas where noise levels exceeds hazardous limits (85 dB). 19.2 Install noise-monitoring equipment in areas throughout the site, which would trigger flashing lights when noise levels are greater than allowable levels. 19.3 Provide your personnel with appropriately fitted hearing protection, whether this is custom molded earplugs or earmuffs, and train them in how and when to use and maintain it. 19.4 Rotate jobs to limit the exposure of employees to loud areas. 19.5 Conduct regular aural evaluations to detect signs of early hearing loss and assist in medical referrals.	Preventing Noise Exposure	R: H&S Officer, Equipment Manager A: Contractors C: Medical Team I: Workers	Occupational Noise Exposure
		20. Dust & Airborne Particles (cutting, drilling, demolition; respirator non-use)	20.1 Replace dry cutting and grinding with wet methods to reduce dust from dusty surfaces at its source. 20.2 Provide local exhaust ventilation systems in close proximity to dust-producing equipment. 20.3 Provide only respiratory protection approved for the job (disposable or reusable respirators with replaceable safe filters) and ensure that workers are fit tested to assure a good seal. 20.4 Use real-time dust monitors with air quality readings posted on visual boards. 20.5 Provide decontamination stations with showers and locker room facilities to reduce transfer of dust from clothing to the home setting. 20.6 Provide regular health evaluation of the employee's lungs.	Controlling Dust and Airborne Particles	R: H&S Officer, Supervisors A: Contractors C: Medical Team I: Workers	Air Quality & Worker Respiratory Health
		21. Chemical Hazards (exposure to solvents, adhesives, paints, fuels; poor labeling/storage)	21.1 Maintain an up-to-date list of chemical items and have Safety Data Sheets available for all hazardous materials. 21.2 Keep chemicals in well-ventilated fire-resistant cabinets or clearly mark containers with warning signs. 21.3 Replace toxic substances with less toxic or nontoxic ones whenever possible (e.g., use of water-based paints instead of solvent-based). 21.4 Instruct employees in the proper method of handling, mixing and disposing of chemicals. 21.5 Provide gloves, aprons and chemical-resistant goggles. 21.6 Place spill kits at staff locations and educate individuals to deal immediately with a leak or spill.	Preventing Chemical Hazards	R: H&S Officer, Store Manager A: Contractors C: Supervisors I: Workers	Chemical Safety at Work
		22. Manual Handling & Ergonomic Risks (lifting, bending, awkward postures)	22.1 Provide mechanical lifting equipment (e.g., forklift trucks, hoists, trolleys or powered exoskeletons) to reduce manual strain. 22.2 Provide staff with information about safe lifting and talk to them about the need for team lifts when an object is too large, etc. 22.3 Modify workstations to decrease awkward posture and repetition. 22.4 Rotate employees from heavy work to light work to reduce fatigue. 22.5 Enable timely access to physical therapy and ergonomic health programs.	Mitigating Manual Handling & Ergonomic Risks	R: Supervisors, H&S Officer A: Contractors C: HR I: Workers	Occupational Ergonomics
		23. Vibration Hazards (use of drills, jackhammers, heavy vehicles; poor tool maintenance)	23.1 Utilize vibration reduced equipment and tools. 23.2 Service equipment to avoid free vibrations. 23.3 Reduce worker exposure using job rotation and breaks. 23.5 Provide operators with antivibration gloves and padded chairs. 23.5 Conduct health checks as routine to identify early risks of hand-arm vibration syndrome or back problems.	Preventing Vibration Hazards	R: H&S Officer, Equipment Manager A: Contractors C: Supervisors I: Workers	Occupational Vibration Safety
		24. Heat Stress & Weather Hazards (outdoor work, dehydration, fatigue)	24.1 Provide shaded rest areas or airconditioned shelters in hot weather and heat shelters when cold weather occurs. 24.2 Supply free drinking water outlets at various site locations. 24.3 Adjust working hours to correlate with the cooler parts of the day in the summer, and provide protective warm clothing in winter. 24.4 Use personal electronics capable of recording body temperatures, heart rates and hydration levels. 24.5 Train workers to recognize the symptoms of heat stroke, dehydration, and hypothermia.	Preventing Health Stress and Weather Hazards	R: H&S Officer, Supervisors, HR A: Contractors C: Site Manager I: Workers	Environmental Health at Work
		25. Electrical Hazards (contact with live wires, poor lockout/tagout, faulty tools)	25.1 Use ground-penetrating radar to locate buried cables before digging. 25.2 Ensure that strict lockout and tagout procedures are in place to ensure electrical circuits are completely de-energized before starting work. 25.3 Fit automatic power cut-out systems (RCDS) on all circuits." 25.4 Train workers in arc flash prevention and provide insulated gloves, boots, and face shields. 25.5 Perform daily examinations of portable electrical tools and extension cords.	Preventing Electrical Hazards	R: Site Engineer, Electricians, H&S Officer A: Contractors C: Supervisors I: Workers	Electrical Safety at Work
		26. Machinery & Equipment Hazards (struck-by, crushed, poor signaling)	26.1 Fit reversing cameras and detectors to heavy plant in order to reduce blind spots. 26.2 Designate traffic-free paths on the premises and separate them from vehicular areas through fencing. 26.3 Use wearable proximity alarms that alert workers and operators if they come too close together. 26.4 Employ and appoint competent spotters (banksmen) to control vehicle and crane movement. 26.5 Conduct rigorous machines maintenance checkup.	Preventing Machinery and Equipment Hazards	R: Equipment Manager, H&S Officer A: Contractors C: Supervisors I: Workers	Safe Use of Work Equipment
		27. Fire & Explosion Risks (fuels, gases, welding sparks, poor hot work control)	27.1 Mandate permits for all hot work operations (e.g., welding, grinding, or cutting). 27.2 Designate trained fire observers for hot work tasks. Store combustible substances in ventilated, fire-resistant storage facilities. 27.3 Provide and maintain extinguishers and suppression systems adjacent to high-risk areas. 27.4 Conduct regular fire drill with staff.	Mitigating Fire and Explosion Risks	R: Fire Safety Officer, H&S Officer A: Project Manager C: Contractors I: Workers	Emergency Preparedness
		28. Psychosocial Hazards (stress, fatigue, bullying)	28.1 Introduce electronic systems to monitor hours worked and crack down on overtime abuse. 28.2 Provide confidential ways for underreporting of workplace bullying, harassment and stress. 28.3 Establish worker welfare zones with areas for rest, eating and socializing. 28.4 Train managers to recognize signs of stress and fatigue. 28.5 Ease of access to mental health providers.	Preventing Psychosocial Hazards	R: HR Manager, H&S Officer A: Contractors C: Worker Rep., Client I: Workers	Mental Health at Work Framework
		29. Discrimination & Inequality (gender, pay, harassment, exclusion)	29.1 Embed specific anti-discrimination and equal opportunity clauses into contracts. 29.2 Make diversity, equity, and inclusion training mandatory for all staff at all levels. 29.3 Establish a culture group with workforce members to generate diversity committee action items. 29.4 Provide safe and appropriate facilities, such as separated latrines and changing facilities for women. 29.5 There must be personal protection equipment available to fit both male and female personnel. 29.6 Set up anonymous complaint processes and track workforce demographics to ensure fairness.	Mitigating Discrimination and Inequality	R: HR Manager, Project Sponsor A: Contractors C: Worker Rep., Client I: Workers	Healthy Workplaces: Equity & Inclusion Framework

(Table S2) contd.....

Phase	Stakeholder	Study Finding	Proposed Actions	Objective	RACI Matrix	WHO Guidelines
PHASE 4: Close-Out	Project Management, Contractors, Safety Officer	1. Incomplete documentation of incidents/hazards	1.1 Consolidate all event reports, near-miss records, danger logs. 1.2 Ensure that all corrective measures are completed and documented. 1.3 Maintain safety records for reference and legal compliance.	Furnish a comprehensive record of site safety history to ensure accountability and legal compliance.	R: Safety Officer A: CPM C: Contractors, Client I: All stakeholders	Incident Reporting Guidelines
		2. Lessons learned not captured	2.1 Organize a safety review meeting attended by all parties involved. 2.2 Document learning, increased safety and recommendations for future initiatives. 2.3 Share findings with professional communities, contractors and clients.	Enhance safety culture and protocols in forthcoming initiatives.	R: Safety Officer A: CPM C: Contractors, Designers, Client I: Workers, Professional Bodies, Clients	Continuous Improvement Guidelines
		3. Unsafe demobilization	3.1 Ensure temporary structures, scaffolds and equipment are dismantled securely. 3.2 Confirm hazardous materials are removed or disposed of as per appropriate standards. 3.3 Conduct final safety checks before the transfer to site.	Mitigate mishaps during site demobilization; provide a secure handover.	R: Safety Officer A: CPM C: Contractors, Client I: All stakeholders, Client (for handover acceptance)	Workplace Safety Guidelines
		4. Lack of evaluation of HSE performance	4.1 Carry out the last audit of HSE performance for the project. 4.2 Assess adherence to safety protocols, key performance indicators, and regulatory standards. 4.3 Prepare a closure report describing accomplishments, deficiencies and corrective action taken.	Assess the efficacy of safety management; pinpoint areas for enhancement.	R: Safety Officer A: CPM C: Contractors, Senior Mgmt., Client I: All stakeholders, Client (for final sign-off)	Performance Evaluation Guidelines
CROSS-PHASE / GENERAL	Applies to All Stakeholders /Phases	1. Socio-demographic factors (gender, age, migrant status, health, etc.)	1.1 Gender-sensitive facilities (No commonly shared restrooms, changing areas and rest areas). PPE should cater to men and women equally, and fair treatment for all employees from both genders. 1.2 Implement anti-harassment and equal opportunity policies; provide training and mentorship concerning gender sensitivity. 1.3 Provide interactive, multilingual safety training and signage that uses visual aids/pictures and pictograms. 1.4 Support worker well-being with health checks, medical support, fair remuneration and rest facilities. 1.5 Engage a variety of workers' representatives in safety decision-making and enhance their professional growth.	To foster a safer, more inclusive, and equitable workplace by promoting diversity (especially female participation), reducing accident risks for new employees, enhancing communication and inclusion for marginalized groups, and supporting comprehensive worker well-being.	R: HR Manager, H&S Officer, Project Manager, Unions A: Project Sponsor, Contractors, Client C: Worker Committees, Client I: All Workers, Client	Gender, Work, and Health; Protecting Young Workers; Vulnerable Workers; Global Plan of Action
		2. Continuous learning and safety culture	2.1 Organize and document participants in weekly toolbox talks led by supervisors on safety issues. 2.2 Integrated digital learning initiate a short training film allowing employees to view these on their mobile devices. 2.3 Recognize and reward those members of staff who are behaving safely well to encourage peer learning. 2.4 Maintain a record book of an individual employee's profile in order to automatically schedule refresher training.	Foster a culture of continuous safety education and accountability.	R: Supervisors, H&S Officer, HR Manager A: Project Manager, Client C: Contractors, Unions, Client I: Workers, Client	Workplace Learning and Skills Development

Note: o R = Responsible | A = Accountable | C = Consulted | I = Informed.