

Supplementary Materials (S1–S7)

These Supplementary Materials provide definitions and state mappings for 85 indicators, the stage–indicator activation matrix, parameterization questionnaires, elicited root-node judgments from the ten-member parameter-calibration panel (all ten members, E1–E10, completed Questionnaires 2 and 3), transition-rate tables, case-evidence coding, and reproducibility scripts. Section S2 reports general baseline priors, whereas Table 11 in the main text reports case-specific priors; these are not interchangeable. FPS is consistently obtained by centroid defuzzification of trapezoidal fuzzy numbers. The worked linear-CPT example, root-node prior calculations, and the back-calculation of λ and μ from the reported d(8 h) and r(8 h) values can be reproduced from the equations and tables provided here. Reproducing the complete five-node *NSRI* sequence and internal noisy-OR settings requires the accompanying stage-network files.

Transferability note: X1–X69 are common whole-process indicators, X70–X72 are regional-background indicators, and X73–X85 are stage-specific indicators. The stage–indicator activation matrix activates only the technical group required for the current operation. Sections S3 and S6 contain framework-level materials; the parameters in S2 and S4 should be recalibrated when the framework is transferred to other regions, building types, or rescue teams. Section S5 applies only to the Mandalay case.

S1. Indicator System: Definitions, State Classification, and Activation Matrix

S1.1. Complete indicator definitions (85 indicators)

This section reports the final 85 indicators retained after Round 2 (Table S1-1). The main text summarizes the revision from 96 candidates in Round 1 to 85 indicators in Round 2; this supplement does not provide an item-by-item record of deletions, mergers, or revisions.

Table S1-1. Definitions of the 85 indicators

Dimension	Criterion	Indicator (code)	Definition
Personnel (rescuers) B1	Personnel qualifications and experience C1	Certified-position coverage (X1)	Proportion of the duty positions required by the approved operation plan that are filled by personnel holding the corresponding valid certification, assessed per shift; the adverse state is incomplete coverage, in particular of a safety-critical position.
Personnel (rescuers) B1	Personnel qualifications and experience C1	Rescue-operator experience (X2)	Accumulated field deployments and independently executed operations of the same task type completed by the personnel assigned to rope work, breaching, and shoring at this node; the adverse state is an operator without prior experience of the assigned task type.
Personnel (rescuers) B1	Personnel qualifications and experience C1	Structural-expert qualifications and experience (X3)	Qualification grade and number of comparable post-earthquake assessments completed by the structural specialist responsible for on-site damage and stability assessment; the adverse state is the absence of a specialist of the required grade on site or reachable within the reassessment interval.
Personnel (rescuers) B1	Personnel qualifications and experience C1	Commander/decision-maker qualifications and experience (X4)	Command grade of the person exercising command at this node, number of earthquake or collapse operations previously commanded, and command-qualification training completed; the adverse state is command being exercised by a person below the required grade or being left unassigned.
Personnel (rescuers) B1	Personnel qualifications and experience C1	Safety-officer qualifications and experience (X5)	Safety qualification grade, earthquake-rescue deployments, and formally delegated stop-work authority of the field safety officer assigned to this node; the adverse state is the absence of a qualified officer or the assignment of an officer without documented stop-work authority.
Personnel (rescuers) B1	Language and communication C2	Multilingual communication capability (X6)	Availability, at each operating face, of personnel able to conduct task communication in the languages actually present at the site, including those of the trapped persons and of local authorities; the adverse state is an operating face lacking that capability where victim contact or inter-team coordination requires it.
Personnel (rescuers) B1	Language and communication C2	Cross-cultural communication capability (X7)	Availability of personnel with prior cross-region or international deployment experience together with an agreed liaison protocol for working with local actors; the adverse state is coordination conducted without either.
Personnel (rescuers) B1	Language and communication C2	Multi-agency communication and coordination (X8)	Capability of the team to exchange task-critical information with fire, medical, police, armed-police, and local-government units, expressed as designated liaison, shared channel, and closed-loop confirmation of transmitted safety information. Scope: a personnel capability; the command structure itself is X55 and inter-team dispatch is X61.
Personnel (rescuers) B1	Training and drills C3	Drill frequency and quality (X9)	Number and assessed pass rate of routine earthquake and collapse-rescue drills completed by the deployed team in the 12 months preceding deployment; the adverse state is a frequency or pass rate below the team training standard.

Personnel (rescuers) B1	Training and drills C3	Special-environment drill frequency and quality (X10)	Number and assessed pass rate of drills completed in each special-environment class present at the current site — confined space, extreme heat or cold, hypoxia, chemical protection, inclined collapse; the adverse state is a class present at the site for which no drill was completed within the preceding 12 months.
Personnel (rescuers) B1	Physical/psychological fitness and professionalism C4	Physical endurance and recovery (X11)	Current physical working condition of the deployed personnel, expressed as continuous and cumulative working time against the prescribed limit together with completion of the prescribed rest interval, re-assessed at each time point as a persistent state. Scope: the observed condition of the personnel; whether the rotation regime is implemented is X69.
Personnel (rescuers) B1	Physical/psychological fitness and professionalism C4	Physiological load tolerance and environmental adaptability (X12)	Acclimatization status of the deployed personnel to the thermal, humidity, and hypoxic conditions present, together with any heat-, cold-, or hypoxia-related symptom recorded during the shift; propagated as a persistent state. Scope: the personnel's tolerance; the ambient conditions themselves are X46–X48.
Personnel (rescuers) B1	Physical/psychological fitness and professionalism C4	Psychological resilience and emotion regulation (X13)	Screening result and observed stress reactions of the deployed personnel under high-pressure, high-risk, and casualty exposure; the adverse state is a stress reaction impairing task performance, or assignment of personnel with below-standard screening results to high-exposure tasks.
Personnel (rescuers) B1	Physical/psychological fitness and professionalism C4	Social responsibility and professional ethics (X14)	Adherence of personnel to mandatory reporting obligations, in particular reporting an identified hazard and reporting one's own unfitness for duty; the adverse state is a known hazard or unfitness condition not reported through the prescribed channel.
Personnel (rescuers) B1	Operational safety and emergency response C5	Procedural violations by rescue personnel (X15)	Count of observed departures from the approved operating procedure per shift, normalized by the number of monitored operations. Scope: a knowing departure from a known procedure; unintended execution failures are X16.
Personnel (rescuers) B1	Operational safety and emergency response C5	Operational errors by rescue personnel (X16)	Count of observed execution failures per shift attributable to insufficient technical proficiency or to unclear task information, normalized by the number of monitored operations. Scope: unintended failures only; knowing departures are X15.
Personnel (rescuers) B1	Operational safety and emergency response C5	Risk recognition and emergency response capability (X17)	Measured reaction time of on-site personnel from the appearance of a structural anomaly, collapse indication, or aftershock signal to evacuation, report, or response; the adverse state is a reaction exceeding the prescribed time, or a recognized signal not acted upon through the prescribed channel.
Personnel (rescuers) B1	Operational safety and emergency response C5	Basic medical-aid skills (X18)	Proportion of personnel at each operating face certified in bleeding control, immobilization, and cardiopulmonary resuscitation; the adverse state is coverage below the team standard at a face where a casualty is to be reached. Scope: rescuer self- and buddy-aid capability; casualty treatment and transfer coordination is X83.
Equipment B2	Rescue tools and equipment C6	Equipment quantity adequacy (X19)	Available units per equipment class as a proportion of the quantity the approved plan requires for the current stage; the adverse state is a shortfall in any class the stage requires.
Equipment B2	Rescue tools and equipment C6	Equipment-type suitability (X20)	Proportion of the equipment classes required by the current stage for which a type compatible with the task conditions is on site; the adverse state is a task executed with a substitute outside its specified application range.
Equipment B2	Rescue tools and equipment C6	Equipment integrity and reliability (X21)	Serviceability of the deployed units under current task conditions, expressed as pre-use inspection results, maintenance-interval status, and in-service failures, re-assessed at each time point as a persistent state. Scope: whether the unit itself functions; the functioning of its status-indication system is X27.
Equipment B2	Rescue tools and equipment C6	Critical-equipment redundancy (X22)	Number of serviceable spare units per critical class — breaching tools, jacks, rescue-shoring systems — against the redundancy the plan requires; the adverse state is the absence of an immediate replacement for a single-point failure.
Equipment B2	Personal protective equipment C7	PPE provision adequacy (X23)	Proportion of personnel entering the operating area who have been issued the complete PPE set required for that area, covering head, body, foot, and respiratory protection; the adverse state is any entry with an incomplete set.
Equipment B2	Personal protective equipment C7	PPE spare redundancy (X24)	Stock of spare PPE sets and consumable components against the replacement rate the operation is expected to require over its remaining duration; the adverse state is insufficient stock to sustain that rate.
Equipment B2	Personal protective equipment C7	PPE performance suitability for the environment (X25)	Proportion of the hazard classes present at the site — impact, chemical, thermal, water, cut, respiratory load — for which the issued PPE meets the corresponding performance rating; the adverse state is an uncovered hazard class, or PPE bulk preventing compliant use in the confined space to be entered.

Equipment B2	On-site real-time monitoring equipment/systems C8	Real-time debris-displacement monitoring equipment (X26)	Serviceable instruments and monitoring-point coverage available for tracking debris and shoring movement — vibration monitors, laser displacement sensors, inclinometers, simple displacement gauges — against the monitoring plan. Scope: hardware availability and deployment; the monitoring regime as executed is X57 and delivery of the data is X63.
Equipment B2	On-site real-time monitoring equipment/systems C8	Rescue-tool/equipment sensing systems (X27)	Proportion of critical units, such as hydraulic devices and shoring systems, whose specified load, pressure, or displacement indication is present and functioning; the adverse state is a critical unit operated without its specified indication.
Equipment B2	On-site real-time monitoring equipment/systems C8	Environmental monitoring equipment (gas, temperature, humidity) (X28)	Serviceable and in-calibration instruments available for the atmospheric parameters the plan requires to be monitored, together with configuration of the prescribed alarm thresholds. Scope: instrument availability and readiness; the measured values are X39–X41.
Environment B3	Structural stability of earthquake-damaged buildings C9	Structural stability state (X29)	Current load-bearing condition of the residual structure at the assessment time point, expressed as the structural specialist's stability grade together with measured tilt, displacement, and crack-development rates, propagated as a persistent state. Scope: the structure's present state; its pre-earthquake vulnerability is X70 and the seismic input is X72.
Environment B3	Structural stability of earthquake-damaged buildings C9	Controllability of dominant debris damage pattern (X30)	Extent to which the identified dominant collapse pattern — leaning, V-shaped, A-shaped, hanging, pancake, or composite — can be stabilized and worked on using the shoring and access measures available; the adverse state is a pattern that those measures cannot control for the planned operation.
Environment B3	Structural stability of earthquake-damaged buildings C9	Rescue-passageway stability (X31)	Current condition of the passage opened or in use, expressed as passage stability grade together with measured clear-height loss, sectional deformation, and debris-fall events, propagated as a persistent state. Scope: the passage; the surrounding residual structure is X29.
Environment B3	Rescue-site accessibility and entrapment conditions C10	Relative entrapment position (X32)	Complexity of the trapped person's location within the collapsed structure, expressed as position within the collapse, number of intervening structural layers, and the approach direction they impose; the adverse state is a position requiring a non-standard approach or additional structural intervention.
Environment B3	Rescue-site accessibility and entrapment conditions C10	Burial depth (X33)	Thickness of overburden between the working surface and the trapped person, expressed in metres and as a depth class; the adverse state is a depth class at which the planned access method requires additional shoring, staged excavation, or extended working time.
Environment B3	Rescue-site accessibility and entrapment conditions C10	Access-construction difficulty (X34)	Effort required to create or enlarge the rescue passage, expressed as estimated construction time classified as no construction required, up to 2 h, 2–8 h, over 8 h, or not achievable, together with assessed procedural complexity; the adverse state is the over-8-h class, or access that is judged not achievable by the planned method with no alternative route demonstrated.
Environment B3	Rescue-site accessibility and entrapment conditions C10	Space-configuration safety (X35)	Geometry of the working and transit space, expressed as minimum clear cross-section, number of direction changes, number of vertical levels, and availability of a second means of egress; the adverse state is any quantity beyond the limit for the planned operation or for stretcher transport.
Environment B3	Rescue-site accessibility and entrapment conditions C10	Visibility (X36)	Distance over which working details can be discerned at the operating face under the prevailing lighting, smoke, and dust conditions; the adverse state is a discernible distance shorter than that required for the planned task, with the available lighting or dust-suppression measures unable to restore the required visibility.
Environment B3	Rescue-site accessibility and entrapment conditions C10	Inundation risk (X37)	Depth and inflow rate of water present or accumulating at the working level of the site or passage; the adverse state is water beyond the limit for the planned operation. Scope: water already at or entering the working level; an external flood source is X52 and the meteorological condition is X48.
Environment B3	Rescue-site accessibility and entrapment conditions C10	Fall risk (X38)	Number of identified fall-exposure points at the operating face — elevation differences, unprotected openings, inadequate edges — and the proportion protected to the prescribed standard; the adverse state is an unprotected point with no fall-arrest measure in use.
Environment B3	Gaseous and chemical hazards in the rescue space C11	Oxygen condition (X39)	Measured oxygen concentration at the operating face and its deviation from the prescribed safe range, covering both deficiency and enrichment, propagated as a persistent state. Scope: the measured value; instrument availability is X28.
Environment B3	Gaseous and chemical hazards in the rescue space C11	Combustible-gas concentration (X40)	Measured combustible-gas concentration at the operating face as a percentage of the lower explosive limit, propagated as a persistent state. Scope: the measured atmospheric value; the ignition-source and fuel configuration is X53 and the integrity of gas lines is X44.
Environment B3	Gaseous and chemical hazards in the rescue space C11	Excess toxic/hazardous gases (X41)	Measured concentration of the monitored toxic gases, such as carbon monoxide and hydrogen sulfide, at the operating face relative to the applicable occupational exposure limit, propagated as a persistent state. Scope: airborne concentration; the integrity of chemical containment is X42.

Environment B3	Gaseous and chemical hazards in the rescue space C11	Hazardous-chemical leakage risk (X42)	Hazardous-chemical containment units identified within the influence range of the operation, together with their observed integrity; the adverse state is a unit showing loss of integrity, or one whose integrity cannot be confirmed before entry. Scope: the source; the resulting airborne concentration is X41.
Environment B3	Gaseous and chemical hazards in the rescue space C11	Biological-hazard risk (X43)	Biological-exposure sources identified at the worksite — pathogens in debris, body decomposition, contaminated water — together with the coverage of the prescribed protection and disinfection measures. Scope: exposure at the worksite; a declared regional epidemic condition is X49.
Environment B3	Gaseous and chemical hazards in the rescue space C11	Utility-line rupture risk (X44)	Gas, water, sewer, and cable-duct lines within the working envelope that are ruptured or of unverified status, together with their isolation status; the adverse state is such a line that has not been isolated and confirmed to be depressurized or de-energized before work proceeds. Scope: line integrity and isolation; electrical energization specifically is X54.
Environment B3	Special rescue environments C12	High altitude (X45)	Elevation class of the worksite and the acclimatization and equipment-derating requirements it triggers; the adverse state is an elevation class requiring those measures without them in place.
Environment B3	Special rescue environments C12	High temperature (X46)	Measured temperature and heat-stress index at the working face, including residual fire heat, against the permissible exposure time; the adverse state is a value exceeding the limit for the planned exposure without rotation or cooling in place. Scope: the ambient condition; the personnel's tolerance of it is X12.
Environment B3	Special rescue environments C12	Extreme cold (X47)	Measured temperature and wind chill at the working face, together with observed cold-related degradation of required equipment; the adverse state is a value below the limit for the planned exposure, or a cold-related failure of equipment the plan requires.
Environment B3	Special rescue environments C12	High humidity, heavy rainfall, and typhoons (X48)	Observed and forecast precipitation, wind speed, and humidity against the operating limits for the planned window. Scope: the meteorological condition; water present at the working level is X37 and an external flood source is X52.
Environment B3	Special rescue environments C12	Infectious-disease outbreak (X49)	Declared epidemic status applying to the site, together with the coverage of the prescribed protection, screening, and isolation measures; the adverse state is a declared condition with those measures not fully in place. Scope: the regional public-health condition; biological exposure at the worksite is X43.
Environment B3	Special rescue environments C12	Security environment (X50)	Assessed security level of the site under conditions of violent conflict or severe public-security instability, together with the presence of the escort and withdrawal arrangements that level requires; the adverse state is such a level without those arrangements in place.
Environment B3	Secondary-hazard impacts C13	Geological-hazard risk (X51)	Landslide, debris-flow, and slope-collapse bodies identified within the influence range of the operation, together with observed movement indications and monitoring status; the adverse state is such a body showing movement, or one left unmonitored where the plan requires monitoring. Scope: an active hazard body; the static site condition is X71.
Environment B3	Secondary-hazard impacts C13	Flooding risk (X52)	External flooding source identified upstream of the worksite — flash flood, river surge, dam or dike failure, barrier-lake breach — together with forecast arrival time and inundation depth; the adverse state is an arrival time within the planned window, or the absence of a monitored warning and withdrawal arrangement for that source. Scope: an external source; water at the working level is X37.
Environment B3	Secondary-hazard impacts C13	Fire/explosion risk (X53)	Coexistence of an ignition source with a fuel accumulation or an above-threshold gas concentration at the operating face, together with the coverage of the prescribed control measures. Scope: the ignition-and-fuel configuration; the measured gas concentration is X40 and chemical containment is X42.
Environment B3	Secondary-hazard impacts C13	Electrical-leakage/electrocution risk (X54)	Electrical sources within the working envelope that are energized or of unverified status — damaged lines, energized equipment, conductive standing water — together with their isolation status; the adverse state is such a source that has not been isolated and verified as de-energized before work proceeds.
Management and operation control B4	Safety and risk-control measures C14	Field-command system adequacy (X55)	Documented and communicated assignment of the command chain, position responsibilities, and coordination mechanism for the current node; the adverse state occurs when any of these elements is undocumented or not communicated to the operating teams. Scope: the command structure of this operation; coordination between separate teams is X61.
Management and operation control B4	Safety and risk-control measures C14	Emergency mechanism for secondary hazards (X56)	Proportion of the identified secondary hazards — aftershock, landslide, flood, fire — for which a documented response, a withdrawal route, and an alarm signal exist and have been communicated and rehearsed; the adverse state is an identified hazard lacking any of these.

Management and operation control B4	Safety and risk-control measures C14	Safety-monitoring measures (X57)	Proportion of the monitoring items the plan requires — structural stability, atmospheric conditions, equipment status, personnel location — that are active at the prescribed interval. Scope: the monitoring regime as executed; instrument availability is X26 and X28, and delivery of the data to decision makers is X63.
Management and operation control B4	Safety and risk-control measures C14	Exclusion-zone and evacuation management (X58)	Proportion of the prescribed exclusion zones that are physically delineated and access-controlled, together with unauthorized entries recorded during the node; the adverse state is an undelineated or uncontrolled zone, or a recorded unauthorized entry.
Management and operation control B4	Communication and information C15	Rescue-operation documentation (X59)	Proportion of the prescribed record items completed for the node with attributable time, operator, and evidence source; the adverse state is a missing item, or one that cannot be attributed. Scope: the operation record; information passed at handover is X60 and physical field marking is X62.
Management and operation control B4	Communication and information C15	Shift-handover information transfer (X60)	Proportion of shift and stage handovers completed against the prescribed handover checklist with receipt confirmed by the incoming shift; the adverse state is a handover without the checklist or without confirmed receipt, or a hazard known to the outgoing shift not transferred.
Management and operation control B4	Communication and information C15	Multi-team coordination and information sharing (X61)	Existence of a single dispatch authority, joint coordination at the prescribed interval, and a shared situation record among teams working on interacting structures or shared resources; the adverse state is the absence of any of these. Scope: between teams; the internal command structure is X55 and the capability to work with external agencies is X8.
Management and operation control B4	Communication and information C15	Standardized use of a unified marking system (X62)	Proportion of the required markings on structures, searched areas, and victim locations that are applied in accordance with the adopted standard and remain legible under field conditions; the adverse state is a missing, non-standard, or illegible marking, or two teams applying different conventions on the same structure.
Management and operation control B4	Communication and information C15	Receipt and transmission of field-monitoring data (X63)	Measured latency from acquisition of structural-monitoring, atmospheric-monitoring, and life-detection data to receipt by the decision maker, together with the proportion of transmissions confirmed as received; the adverse state is latency beyond the prescribed interval, or an unconfirmed transmission.
Management and operation control B4	Resource allocation and logistics C16	Storage management of tools/equipment/shoring materials (X64)	Proportion of the items the plan requires that carry a unique identifier, a current inspection status, and a recorded storage location; the adverse state is an item whose serviceability cannot be established before use. Scope: identification and traceability; quantity is X19 and spares are X22.
Management and operation control B4	Resource allocation and logistics C16	Resource allocation and dispatch efficiency (X65)	Measured time from request to arrival at the operating face for the critical resources — personnel, equipment, vehicles — against the interval the plan assumes; the adverse state is an arrival time beyond that interval with no documented substitute arrangement.
Management and operation control B4	Resource allocation and logistics C16	Logistics support under extreme conditions (X66)	Days of stocked supply of the critical consumables — food, water, medicines, thermal protection — against the projected operation duration; the adverse state is stock below that duration with no confirmed resupply arrangement.
Management and operation control B4	Rescue planning and execution C17	Rescue-plan soundness and technical feasibility (X67)	Completion and pass rate of the prescribed technical review of the node's plan, covering technical route, safety measures, and resource matching; the adverse state is a node proceeding without that review, or with an unresolved review finding affecting a safety-critical step.
Management and operation control B4	Rescue planning and execution C17	Dynamic adjustment of the rescue plan (X68)	Measured time from recognition of a trigger condition defined in the plan to approval of the corresponding adjustment, together with the proportion of adjustments passing review; the adverse state is work continuing under the superseded plan beyond the prescribed interval.
Management and operation control B4	Rescue planning and execution C17	Shift-rotation implementation (X69)	Proportion of shifts executed within the prescribed working-hour and rotation limits, together with maintenance of the rotation schedule throughout the node. Scope: the organizational control as implemented; the resulting condition of the personnel is X11.
Environment B3	Regional site characteristics C18	Building structural type and construction standard (X70)	Structural system, construction period, and seismic-design level of the earthquake-damaged building, expressed as structural-type class together with seismic-fortification-intensity rating; a parentless background indicator fixed for the site rather than re-assessed per node. Scope: pre-earthquake vulnerability; the current structural state is X29.
Environment B3	Regional site characteristics C18	Site geology and terrain conditions (X71)	Site class, slope grade, and access-width class of the location, covering liquefaction, soft soil, sloping ground, and narrow streets; a parentless background indicator fixed for the site. Scope: the static site condition; an active geological hazard body is X51.
Environment B3	Regional site characteristics C18	Aftershock intensity and frequency (X72)	Aftershock count per unit time and maximum-magnitude class at the site, updated on a rolling basis from seismic-network observation; the adverse state is a level at which the plan requires reassessment or suspension. Scope: the seismic input; the structural response to it is X29.

Management and operation control B4	Technical operation control C19 (shoring group, activated in S1)	Shoring-system selection and load verification (X73)	Pass rate of design-compliance checks on the selected shoring configuration, together with verification coverage of the load cases the stage requires; the adverse state is a unit installed without a successful check, or a required load case left unverified.
Management and operation control B4	Technical operation control C19 (shoring group, activated in S1)	Jacking capacity and synchronization (X74)	Load safety factor of the jacking arrangement against the demanded load, together with measured synchronization deviation in millimetres across multi-point lifting; the adverse state is a factor below the prescribed value, or a deviation beyond the prescribed limit during jacking.
Management and operation control B4	Technical operation control C19 (shoring group, activated in S1)	Shoring-system monitoring, review, and secondary reinforcement (X75)	Monitoring-point coverage and review frequency applied to the installed shoring, together with measured response time for secondary reinforcement after a review finding; the adverse state is coverage or frequency below the plan, or a response time beyond the prescribed interval.
Management and operation control B4	Technical operation control C19 (slab-breaching group, activated in S2)	Breaching-method suitability (X76)	Pass rate of compatibility checks between the selected breaching method and the component's material, thickness, and reinforcement arrangement and the victim's location; the adverse state is breaching proceeding on a component for which the compatibility check has failed or has not been performed.
Management and operation control B4	Technical operation control C19 (slab-breaching group, activated in S2)	Breaching vibration and structural-disturbance control (X77)	Measured peak particle velocity at the control point, in millimetres per second, against the prescribed limit during breaching; the adverse state is a value at or above the limit, or breaching without vibration monitoring where the plan requires it. Scope: operation-induced vibration; earthquake-induced input is X72.
Management and operation control B4	Technical operation control C19 (slab-breaching group, activated in S2)	Dust and spark control (X78)	Pass rate of checks on the wet-operation, dust-shielding, and spark-control measures, together with measured dust concentration at the operating face; the adverse state is a prescribed measure that is absent or ineffective, or a concentration beyond the prescribed limit.
Management and operation control B4	Technical operation control C19 (slab-breaching group, activated in S2)	Breaching-opening location and dimensions (X79)	Deviation of the executed opening from its planned location, its encroachment on primary load-bearing members or on the trapped person, and its dimensional compliance with the rescue-access requirement; the adverse state is a deviation beyond tolerance, an encroachment, or an opening with undersized dimensions.
Management and operation control B4	Technical operation control C19 (debris-removal group, activated in S3)	Lifting plan and lifting-point selection (X80)	Pass rate of the plan review covering lifting sequence, lifting-point layout, and assessment of component interconnections, together with records of the prescribed trial lift; the adverse state is a lift proceeding without a successful review, without the interconnection assessment, or without the trial lift.
Management and operation control B4	Technical operation control C19 (debris-removal group, activated in S3)	Machine–human coordination and blind-spot control (X81)	Compliance with the machine–human coordination procedure, together with the number of blind-spot intrusion alarms recorded during mechanical operation; the adverse state is an omitted procedure step, or a recorded intrusion.
Management and operation control B4	Technical operation control C19 (debris-removal group, activated in S3)	Removal sequence and unloading control (X82)	Compliance with the prescribed layered and sectional removal sequence, together with the measured debris displacement rate in millimetres per hour; the adverse state is removal executed out of sequence, or a rate beyond the prescribed control limit.
Management and operation control B4	Technical operation control C19 (casualty-transport group, activated in S4)	Medical coordination and crush-syndrome management (X83)	Timing of medical intervention relative to extrication, compliance with the prescribed crush-syndrome prevention procedure, and confirmation of the onward-transfer arrangement; the adverse state is extrication without the prescribed pre-decompression intervention, or an omitted treatment step. Scope: casualty treatment; rescuer self- and buddy-aid capability is X18.
Management and operation control B4	Technical operation control C19 (casualty-transport group, activated in S4)	Casualty-condition monitoring and communication (X84)	Continuity of casualty vital-sign monitoring and frequency of support communication against the prescribed intervals throughout the rescue; the adverse state is a gap in either activity beyond the prescribed interval.
Management and operation control B4	Technical operation control C19 (casualty-transport group, activated in S4)	Transport, evacuation, and site-handover organization (X85)	Compliance of the transport route, stretcher-team assignment, equipment-withdrawal sequence, and site handover with the contingency plan, together with the pass rate of withdrawal checks; the adverse state is transport or withdrawal proceeding without a compliant arrangement, or with an unpassed check at handover.

S1.2. State classification and evidence-mapping rules

All root nodes are binary (normal/failure). Table S1-2 defines state criteria and evidence-mapping rules for six indicator categories.

Table S1-2. State classification and evidence-mapping rules

Indicator category	Covered indicators	Failure-state criterion	Evidence source/type
Quantitative monitoring	X26–X28, X74, X77, X78, X82	At or above equipment-manufacturer limits, structural-expert-approved operating limits, or team warning levels; task-specific thresholds are recorded in the operational plan.	Field monitoring streams (hard evidence; updated with monitoring).

Qualification and capability records	X1–X10	Applicable regulatory, position-qualification, or training requirements are not met.	Team qualification files and training records (entered at task initiation).
Condition survey	X29–X38, X70–X72	The structure or passage is assessed as metastable or unstable, or entrapment/accessibility reaches an adverse level defined in the operational plan.	Structural-expert survey and UAV/3D-model outputs (hard evidence + expert judgment).
Environmental detection	X39–X54	Gas, temperature/humidity, or secondary-hazard measurements reach control values specified by applicable confined-space, fire-safety, or team procedures.	Gas detectors, environmental monitoring, and seismic-network information (hard evidence).
Management checks	X19–X25, X55–X69, X73, X75–X76, X79–X81, X83–X85	A critical checklist item fails, e.g., plan not reviewed, exclusion zone absent, incomplete handover, missing technical review, or equipment/PPE provision not meeting the requirement stated in the operational plan.	Operational records/checklists (hard evidence) + safety-officer judgment (soft evidence).
Personnel state	X11–X18	Work-hour/rotation limits are exceeded, vital signs are abnormal, or procedural violations/operational errors occur.	Rotation records, wearable monitoring, and safety-officer observation (hard + soft evidence).

S1.3. Stage–indicator activation matrix (full grouping and field-use version)

Table S1-3. Stage–indicator activation matrix

Indicator group	S0	S1	S2	S3	S4	Notes
Common personnel X1–X18	Always active	Always active	Always active	Always active	Always active	Used throughout inference.
Common equipment X19–X28	Always active	Always active	Always active	Always active	Always active	Used throughout inference.
Common environment X29–X54	Always active	Always active	Always active	Always active	Always active	Used throughout inference.
Common management X55–X69	Always active	Always active	Always active	Always active	Always active	Used throughout inference.
Regional site X70–X72	Background	Background	Background	Background	Background	Assigned at task initiation; X72 updated with seismic-network monitoring.
Shoring/bracing X73–X75	Dormant	Active	Dormant	Dormant	Dormant	Reactivated when S1 is repeated.
Slab breaching X76–X79	Dormant	Dormant	Active	Dormant	Dormant	Same rule for repeated S2.
Debris removal X80–X82	Dormant	Dormant	Dormant	Active	Dormant	Same rule for repeated S3.
Casualty transport X83–X85	Dormant	Dormant	Dormant	Dormant	Active	—

In Table S1-3, “Always active” means that the group remains in the active evidence set at every node; it does not mean that the group belongs to the persistent-state set. The eight variables propagated across nodes by CTMC transitions are X11, X12, X21, X29, X31, and X39–X41. Each node expands only the common indicators, regional-background indicators, and the technical group corresponding to the current stage. When a stage is repeated, its technical group is reactivated. Concurrent operations require prior assessment of shared structures, resources, and evidence dependencies.

S2. Fuzzy Parameters, Expert Information, and Raw Judgments

S2.1. Seven-level linguistic scale, fuzzy numbers, and λ -cuts

Table S2-1. Seven-level linguistic terms, trapezoidal fuzzy numbers, and λ -cuts

Linguistic term	Trapezoidal fuzzy number	λ -cut
Very Low (VL)	$f_{VL} = (0, 0, 0.1, 0.2)$	$f_{\lambda VL} = [0, 0.2 - 0.1\lambda]$
Low (L)	$f_L = (0.1, 0.2, 0.2, 0.3)$	$f_{\lambda L} = [0.1\lambda + 0.1, 0.3 - 0.1\lambda]$
Mildly Low (ML)	$f_{ML} = (0.2, 0.3, 0.4, 0.5)$	$f_{\lambda ML} = [0.1\lambda + 0.2, 0.5 - 0.1\lambda]$
Middle (M)	$f_M = (0.4, 0.5, 0.5, 0.6)$	$f_{\lambda M} = [0.1\lambda + 0.4, 0.6 - 0.1\lambda]$
Mildly High (MH)	$f_{MH} = (0.5, 0.6, 0.7, 0.8)$	$f_{\lambda MH} = [0.1\lambda + 0.5, 0.8 - 0.1\lambda]$
High (H)	$f_H = (0.7, 0.8, 0.8, 0.9)$	$f_{\lambda H} = [0.1\lambda + 0.7, 0.9 - 0.1\lambda]$

Linguistic term	Trapezoidal fuzzy number	λ -cut
Very High (VH)	$f_{VH} = (0.8, 0.9, 1, 1)$	$f_{\lambda VH} = [0.1\lambda + 0.8, 1]$

S2.2. Expert background, scoring, and individual weights

(a) Background of the ten parameter-calibration experts. These experts were recruited separately and are not part of the 33-expert sample described in S7.1; the S7.1 sample includes neither experts with engineering-series professional titles nor an expert with a total Table 6 score of 16.

Table S2-2. Background of the ten parameter-calibration experts

Expert	Education	Professional title/technical grade	Background note
E1	Ph.D.	Associate Research Fellow	Scoring details and weights are provided in Table S2-3.
E2	Master's	Engineer	Scoring details and weights are provided in Table S2-3.
E3	Ph.D.	Research Fellow	Scoring details and weights are provided in Table S2-3.
E4	Ph.D.	Research Fellow	Scoring details and weights are provided in Table S2-3.
E5	Master's	Associate Senior Engineer	Scoring details and weights are provided in Table S2-3.
E6	Master's	Assistant Engineer	Scoring details and weights are provided in Table S2-3.
E7	Ph.D.	Research Fellow	Scoring details and weights are provided in Table S2-3.
E8	Master's	Research-Grade Senior Engineer	Scoring details and weights are provided in Table S2-3.
E9	Bachelor's	Associate Senior Engineer	Scoring details and weights are provided in Table S2-3.
E10	Ph.D.	Associate Research Fellow	Scoring details and weights are provided in Table S2-3.

(b) Detailed scores and individual weights obtained by applying the five criteria in Table 6 of the main text to the experts described in (a). Individual weights in Table S2-3 are normalized over the full ten-member panel (sum of Table 6 totals = 185). Questionnaires 2 and 3 were returned by all ten panel members E1–E10; accordingly, every quantity derived from those instruments (Tables S2-4 to S2-6) uses the ten-member weights $w = (0.0919, 0.0865, 0.1027, 0.1081, 0.0973, 0.0811, 0.1189, 0.1189, 0.0973, 0.0973)$ based directly on scores (17, 16, 19, 20, 18, 15, 22, 22, 18, 18) and a panel total of 185, without subgroup renormalization, so that the weights entering Eq. (C3) sum to unity.

Table S2-3. Scores and individual weights of the ten parameter-calibration experts

Expert	Professional title	Experience	Education	Rescue missions	Professional category	Total score	Weight
E1	4	2	5	2	4	17	0.092
E2	3	2	4	2	5	16	0.086
E3	5	3	5	2	4	19	0.103
E4	5	3	5	3	4	20	0.108
E5	4	3	4	2	5	18	0.097
E6	2	2	4	2	5	15	0.081
E7	5	4	5	4	4	22	0.119
E8	5	3	4	5	5	22	0.119
E9	4	3	3	3	5	18	0.097
E10	4	2	5	3	4	18	0.097

S2.3. Raw linguistic judgments and general baseline priors for X1–X69 from experts E1–E10

Table S2-4. Raw linguistic judgments and general baseline priors for X1–X69 (experts E1–E10)

Node	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Prior probability
X1	L	L	L	ML	L	ML	L	ML	L	L	4.559×10^{-4}
X2	ML	ML	ML	L	L	L	L	ML	ML	L	6.594×10^{-4}
X3	L	L	L	L	ML	ML	L	ML	L	L	4.458×10^{-4}
X4	ML	L	L	L	L	L	L	L	ML	L	3.526×10^{-4}

X5	ML	L	L	L	ML	L	L	ML	L	L	4.559×10^{-4}
X6	L	L	L	L	ML	L	L	L	ML	L	3.569×10^{-4}
X7	ML	ML	MH	M	MH	MH	ML	M	MH	MH	6.022×10^{-3}
X8	ML	L	ML	L	ML	L	L	ML	L	ML	6.726×10^{-4}
X9	ML	M	ML	ML	M	M	ML	ML	M	M	2.715×10^{-3}
X10	MH	H	MH	H	H	MH	MH	H	H	MH	2.176×10^{-2}
X11	M	M	M	M	L	L	M	M	L	ML	2.376×10^{-3}
X12	L	ML	ML	ML	M	M	ML	L	M	M	1.859×10^{-3}
X13	L	L	ML	M	M	ML	ML	M	L	ML	1.591×10^{-3}
X14	ML	L	M	L	ML	ML	M	ML	L	L	1.158×10^{-3}
X15	M	M	ML	ML	ML	M	ML	ML	M	M	2.698×10^{-3}
X16	MH	H	MH	H	H	H	H	MH	H	H	2.588×10^{-2}
X17	ML	L	ML	ML	ML	L	L	ML	ML	ML	9.587×10^{-4}
X18	ML	ML	L	ML	L	L	L	ML	ML	L	6.659×10^{-4}
X19	M	M	L	ML	ML	L	ML	ML	L	M	1.473×10^{-3}
X20	ML	ML	ML	ML	L	L	ML	L	ML	ML	9.419×10^{-4}
X21	ML	ML	ML	L	L	L	ML	L	ML	L	6.594×10^{-4}
X22	L	L	ML	ML	ML	L	ML	ML	L	L	7.202×10^{-4}
X23	L	L	ML	L	ML	L	L	L	ML	ML	5.427×10^{-4}
X24	L	M	M	ML	M	L	L	M	M	ML	1.983×10^{-3}
X25	ML	MH	H	H	MH	H	M	MH	H	H	1.598×10^{-2}
X26	L	ML	ML	L	ML	M	ML	ML	ML	L	1.073×10^{-3}
X27	L	ML	ML	L	ML	L	ML	L	L	ML	6.659×10^{-4}
X28	ML	ML	L	ML	L	ML	L	ML	ML	ML	9.089×10^{-4}
X29	L	L	ML	ML	M	L	ML	L	L	M	9.672×10^{-4}
X30	L	ML	L	L	ML	L	ML	L	L	L	4.508×10^{-4}
X31	L	L	ML	ML	ML	ML	L	ML	ML	ML	9.419×10^{-4}
X32	MH	H	H	MH	VH	H	H	H	H	MH	2.839×10^{-2}
X33	VH	VH	VH	H	H	VH	VH	H	VH	VH	6.636×10^{-2}
X34	MH	H	MH	H	MH	VH	MH	MH	H	VH	2.410×10^{-2}
X35	H	H	MH	H	MH	H	H	H	MH	MH	2.391×10^{-2}
X36	H	MH	H	MH	MH	H	H	MH	MH	H	2.143×10^{-2}
X37	L	ML	VL	ML	L	L	ML	ML	VL	VL	3.561×10^{-4}

X38	MH	H	MH	VH	MH	MH	H	MH	H	MH	2.154×10^{-2}
X39	ML	L	ML	M	ML	L	L	L	M	M	1.278×10^{-3}
X40	L	L	L	M	ML	L	M	L	L	L	7.271×10^{-4}
X41	ML	ML	L	L	ML	ML	ML	L	ML	ML	8.926×10^{-4}
X42	VL	VL	VL	L	VL	L	VL	L	VL	VL	2.996×10^{-5}
X43	VH	VH	MH	VH	VH	H	H	H	VH	VH	5.302×10^{-2}
X44	L	M	ML	M	ML	ML	ML	L	M	M	1.900×10^{-3}
X45	L	VL	VL	L	L	L	VL	L	L	L	1.081×10^{-4}
X46	H	H	VH	VH	VH	VH	VH	H	VH	VH	6.833×10^{-2}
X47	L	L	VL	VL	VL	VL	VL	L	VL	VL	2.862×10^{-5}
X48	ML	ML	ML	M	L	ML	M	ML	L	ML	1.555×10^{-3}
X49	VL	VL	VL	L	VL	L	VL	L	VL	VL	2.996×10^{-5}
X50	MH	MH	H	H	MH	MH	H	MH	MH	MH	1.835×10^{-2}
X51	ML	ML	ML	VL	VL	L	ML	ML	VL	VL	3.580×10^{-4}
X52	ML	ML	VL	VL	VL	VL	L	VL	L	L	1.132×10^{-4}
X53	ML	ML	ML	ML	M	L	ML	ML	ML	ML	1.520×10^{-3}
X54	H	MH	MH	MH	M	M	MH	H	M	M	1.151×10^{-2}
X55	L	L	ML	ML	ML	ML	ML	L	ML	ML	9.419×10^{-4}
X56	ML	ML	L	L	ML	ML	ML	L	ML	ML	8.926×10^{-4}
X57	ML	ML	ML	L	ML	L	L	ML	ML	ML	9.253×10^{-4}
X58	L	L	L	ML	ML	ML	L	ML	ML	L	6.659×10^{-4}
X59	ML	ML	ML	ML	L	ML	ML	ML	L	ML	1.110×10^{-3}
X60	L	L	L	ML	L	L	L	L	ML	L	3.656×10^{-4}
X61	ML	ML	MH	MH	MH	MH	MH	MH	ML	M	7.173×10^{-3}
X62	ML	ML	ML	L	L	L	ML	L	ML	L	6.594×10^{-4}
X63	ML	L	L	L	ML	L	ML	L	L	L	4.559×10^{-4}
X64	MH	M	MH	ML	MH	L	MH	M	MH	L	5.234×10^{-3}
X65	L	L	ML	ML	ML	ML	L	ML	ML	ML	9.419×10^{-4}
X66	MH	MH	VH	H	H	H	MH	MH	VH	VH	2.963×10^{-2}
X67	MH	L	ML	ML	ML	ML	L	ML	ML	MH	1.886×10^{-3}
X68	L	L	ML	ML	ML	ML	L	ML	ML	ML	9.419×10^{-4}
X69	ML	L	ML	L	L	L	L	ML	L	L	4.610×10^{-4}

Note: The prior probabilities in Table S2-4 were computed from the linguistic judgments listed in the same rows using Eqs. (C2)–(C4) with the ten-member weights of Table S2-3 (0.0919, 0.0865, 0.1027, 0.1081, 0.0973, 0.0811, 0.1189, 0.1189, 0.0973, 0.0973). The procedure is identical to that used for Table S2-5: weighted endpoint aggregation of the trapezoidal fuzzy numbers in Table S2-1, centroid defuzzification to obtain FPS, and the Onisawa transformation $P = 10^{-K}$ with $K = 2.301[(1-FPS)/FPS]^{1/3}$. Intermediate FPS values are therefore reproducible row by row from the reported judgments and weights.

S2.4. Raw linguistic judgments and general baseline priors for X70–X85 from experts E1–E10

Table S2-5. Raw linguistic judgments and general baseline priors for X70–X85 (experts E1–E10)

Node	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	FPS	Prior probability
X70	MH	MH	H	MH	M	MH	H	M	MH	MH	0.651	1.35×10^{-2}
X71	M	M	MH	M	ML	M	MH	ML	MH	ML	0.501	5.03×10^{-3}
X72	MH	M	MH	MH	M	MH	M	MH	MH	MH	0.605	1.01×10^{-2}
X73	L	ML	L	L	ML	L	ML	L	L	L	0.245	4.51×10^{-4}
X74	ML	L	ML	ML	L	ML	ML	L	ML	ML	0.305	9.34×10^{-4}
X75	L	L	ML	L	L	ML	L	ML	L	L	0.245	4.51×10^{-4}
X76	M	L	M	L	ML	L	ML	M	L	L	0.326	1.18×10^{-3}
X77	ML	M	ML	L	M	ML	M	M	L	L	0.368	1.75×10^{-3}
X78	M	L	ML	L	ML	L	L	L	M	ML	0.301	9.01×10^{-4}
X79	L	ML	L	L	L	ML	ML	L	L	L	0.243	4.36×10^{-4}
X80	ML	M	ML	ML	L	ML	M	L	L	M	0.348	1.46×10^{-3}
X81	ML	ML	M	L	ML	ML	ML	ML	ML	ML	0.349	1.47×10^{-3}
X82	L	ML	ML	L	ML	L	L	ML	L	ML	0.275	6.66×10^{-4}
X83	L	L	ML	L	L	L	L	L	L	ML	0.230	3.61×10^{-4}
X84	L	L	L	VL	L	ML	VL	L	ML	L	0.200	2.21×10^{-4}
X85	VL	L	L	VL	L	L	VL	L	L	L	0.162	1.05×10^{-4}

S2.5. Raw combined-weighting matrices for X76–X78 (example in Section 3.3 of the main text)

The AHP judgment matrices from the ten calibration experts (E1–E10) are reported in Table S2-6 (row order: X76, X77, X78):

Table S2-6. Raw combined-weighting matrices for X76–X78

Expert	Judgment matrix	$\lambda_{\max}$	CR
E1	(1,1/2,1; 2,1,2; 1,1/2,1)	3.000	0
E2	(1,1/2,1; 2,1,1; 1,1,1)	3.054	0.046
E3	(1,1,1; 1,1,2; 1,1/2,1)	3.054	0.046
E4	(1,1/2,2; 2,1,2; 1/2,1/2,1)	3.054	0.046
E5	(1,1/2,1; 2,1,2; 1,1/2,1)	3.000	0
E6	(1,1,1; 1,1,2; 1,1/2,1)	3.054	0.046
E7	(1,1/2,1; 2,1,1; 1,1,1)	3.054	0.046
E8	(1,1/2,1; 2,1,2; 1,1/2,1)	3.000	0
E9	(1,1/2,2; 2,1,2; 1/2,1/2,1)	3.054	0.046
E10	(1,1,1; 1,1,2; 1,1/2,1)	3.054	0.046

The AHP judgment matrices above (Module D) were aggregated using the ten-member weights from Table S2-3 to obtain the subjective ranking weights $W_A = (0.2863, 0.4561, 0.2576)$. The consequence-severity score matrices (Module C, 1–10 scale) were E1(6,7,7), E2(7,9,6), E3(8,8,7), E4(7,9,6), E5(6,6,7), E6(8,8,5), E7(6,6,7), E8(8,9,7), E9(8,9,6), and E10(6,7,5). Column-wise min–max normalization followed by expert-weighted entropy proportions (Eq. C7) yielded the score-dispersion weights $W_B = (0.4832, 0.2720, 0.2448)$. Game-theoretic combination of W_A and W_B , with combination coefficients (0.4318, 0.5682), yielded $W^* = (0.3982, 0.3515, 0.2503)$. W_B represents only dispersion in expert scores and is sensitive to the normalization method. Note that W_A ranks X77 first (0.4561) whereas W_B ranks X76 first (0.4832), so the combination reverses the elicited importance ordering of X76 and X77. The reversal is small — the combined coefficients differ by 0.047 — and does not change the sensitivity ordering of the branch, which is governed by the root priors and remains $X77 > X76 > X78$ (Section 3.4 of the main text). Analyses that require the elicited importance ordering to be preserved exactly should use W_A alone; the rationale for retaining the dispersion term is given in Section 2.4.2 of the main text.

S3. Questionnaire Texts and Version–Sample Mapping

Table S3-1. Mapping of questionnaire versions, samples, and uses

Instrument	Valid sample	Round/module	Primary use	Boundary relative to other instruments
Questionnaire 1	20	Two rounds: 96→85 indicators	Indicator screening, CVR, Kendall's W	Both rounds covered all 19 criteria, including C18 and C19.
Questionnaire 2	10 (E1–E10, the full ten-member calibration panel)	Modules A–D	Indicator likelihood, consequence severity, AHP matrices	Generates general baseline priors and within-slice CPT inputs.
Questionnaire 3	10 (E1–E10, the full ten-member calibration panel)	Variable group $\times$ stage $\times$ 8 h	Deterioration/recovery likelihood and CTMC rates	Used for case parameters; distinct from the 1-h three-state questions in Review Module E.
Review Modules A–F	33	Background, review, weighting, direction, scenarios	Criterion-level review and cross-scenario ranking consistency	Do not directly replace indicator-level parameterization for the 85 indicators.

S3.1. Questionnaire 1: Relevance of rescue-operation risk indicators (two-round Delphi)

Background items covered professional role, years of experience, number of major rescue operations, professional title/qualification, educational background, and age.

The main questionnaire used five-point relevance ratings for indicators under the 19 criteria and included an open-ended item at the end of each dimension.

Question 7: When assessing rescue-operation risk in earthquake-damaged buildings from the "Personnel (rescuers)" dimension and the "Personnel qualifications and positions" aspect, how appropriate is each of the following indicators? (coverage of certified personnel / staffing completeness / qualifications and experience of structural experts / qualifications and experience of commanders / qualifications and experience of safety officers; each rated on a five-point scale).

Question 14 (open-ended): What additional indicators, if any, should be included under the "Personnel" dimension? (Enter "none" if not applicable.)

Questionnaire 1 was administered in two rounds: 96 indicators in Round 1 and 85 indicators in Round 2, including C18 and C19. This study reports the final 85 definitions and round-level statistics; S1.1 is not an item-by-item 96→85 revision log. The subsequent Review Modules A–F, completed by 33 experts, were organized by the 19 criteria and served a different purpose from Round 2 of Questionnaire 1.

S3.2. Questionnaire 2: Indicator likelihood and consequence severity (structure)

Module A recorded case background; Module B elicited the likelihood that each of the 85 indicators contributes to operational risk using the seven-level VL–VH scale; Module C rated consequence severity on a 1–10 scale; and Module D used a 1–9 scale for pairwise comparisons within each criterion.

S3.3. Questionnaire 3: Stage-specific transition calibration of persistent states (proposed in this study; expert modal judgments over a standard 8-h window)

Each cell uses VL/L/ML/M/MH/H/VH to rate the likelihood of a normal → failure or failure → normal transition within a standard 8-h window. Table S3-2 reports the modal linguistic judgments across the ten calibration experts (E1–E10) as a directional consistency check. Model calculations use the calibrated d(8 h) and r(8 h) values in Table S4-2; the linguistic modes are not treated as a direct numerical mapping and therefore do not independently reconstruct those probabilities. Document-level reproducibility covers the CTMC back-calculation of λ and μ from the reported d and r values, while the intermediate elicitation-to-probability calibration is part of the adopted parameter set. For the structural group in S2 and S3 and the gas group in S2, the modal net tendency differs from the conditional ordering of d and r. This is not a logical contradiction because deterioration and recovery are conditioned on different initial states. Section 3.4 of the main text additionally reports a structural S2 bounding check with $\mu = 0$, for which the node ranking is unchanged.

Table S3-2. Modal linguistic judgments for stage-specific transitions of persistent-state groups (standard 8-h window)

Persistent-state group	S1 deterioration	S1 recovery	S2 deterioration	S2 recovery	S3 deterioration	S3 recovery	S4 deterioration	S4 recovery
Structural (X29, X31)	VL	MH	ML	L	ML	L	VL	L
Gas (X39–X41)	L	ML	M	ML	ML	ML	L	L
Personnel state (X11–X12)	ML	MH	M	M	ML	M	ML	MH
Equipment state (X21)	L	MH	ML	M	ML	M	VL	MH

S4. Complete CPT Construction Parameters and Transition-Rate Calibration

S4.1. Three CPT construction rules

Balanced “OR-type” factor groups use weighted linear CPTs; designated strongly coupled factors use a noisy-OR formulation with interaction terms; and serial-failure links use deterministic AND gates or AND gates with a leak term. The four coefficients W_b of the top node Y are score-based CPT parameters elicited from the ten parameter-calibration experts (E1–E10) using the procedure in Section 2.4.2 of the main text. The coefficient vector is fixed across the M0–M4 stage networks and is contained in the accompanying stage-network files. The direct 100-point dimension weights from the 33 experts in S7.3 are used only as a robustness comparison and do not enter network inference.

S4.2. Calibration of noisy-OR branches

The noisy-OR parameters comprise the individual parent risk intensity q_u , the leak term π_0 , and the interaction term q_{uv} . Table S4-1 reports only the strongly coupled factor pairs, mechanistic rationale, and interaction adjustment factors; $\pi_0 = 1.0 \times 10^{-3}$. Because this supplement does not list each q_u , q_{uv} , or the internal mapping from the interaction-adjustment factor to q_{uv} , Eq. (17) is excluded from the independently reproducible items in S6.5. Full reproduction requires the accompanying stage-network files. These parameters are model settings and are not interpreted as accident frequencies.

Table S4-1. Strongly coupled factor pairs and interaction adjustment factors for noisy-OR branches

Strongly coupled factor pair	Mechanistic basis	Interaction adjustment factor
X77 breaching vibration × X29 structural stability	Vibration applied to a metastable structure; a recurrent mechanism in secondary-collapse cases.	1.30

Strongly coupled factor pair	Mechanistic basis	Interaction adjustment factor
X40 combustible-gas concentration × X78 spark-control failure	Coupled ignition conditions.	1.25
X33 burial depth × X34 access-construction difficulty	Deep burial combined with constrained access prolongs exposure.	1.15

S4.3. Full transition-rate calibration for four variable groups × four stages (standard 8-h window; λ and μ back-calculated from the CTMC)

Table S4-2. Transition-rate calibration for four variable groups × four stages (standard 8-h window)

Variable group	Stage	d(8 h)	r(8 h)	λ / h^{-1}	μ / h^{-1}
Structural	S1	8.0×10^{-4}	6.4×10^{-2}	1.03×10^{-4}	8.27×10^{-3}
Structural	S2	7.2×10^{-3}	1.1×10^{-2}	9.08×10^{-4}	1.39×10^{-3}
Structural	S3	5.6×10^{-3}	1.5×10^{-2}	7.07×10^{-4}	1.89×10^{-3}
Structural	S4	1.2×10^{-3}	9.0×10^{-3}	1.51×10^{-4}	1.13×10^{-3}
Gas	S1	1.5×10^{-3}	2.0×10^{-2}	1.90×10^{-4}	2.53×10^{-3}
Gas	S2	9.0×10^{-3}	1.6×10^{-2}	1.14×10^{-3}	2.03×10^{-3}
Gas	S3	4.0×10^{-3}	1.8×10^{-2}	5.06×10^{-4}	2.28×10^{-3}
Gas	S4	1.0×10^{-3}	1.2×10^{-2}	1.26×10^{-4}	1.51×10^{-3}
Personnel state	S1	2.5×10^{-3}	3.0×10^{-2}	3.18×10^{-4}	3.81×10^{-3}
Personnel state	S2	4.5×10^{-3}	2.0×10^{-2}	5.70×10^{-4}	2.53×10^{-3}
Personnel state	S3	4.0×10^{-3}	2.2×10^{-2}	5.07×10^{-4}	2.79×10^{-3}
Personnel state	S4	2.0×10^{-3}	2.8×10^{-2}	2.54×10^{-4}	3.55×10^{-3}
Equipment state	S1	1.0×10^{-3}	2.5×10^{-2}	1.27×10^{-4}	3.17×10^{-3}
Equipment state	S2	3.5×10^{-3}	2.0×10^{-2}	4.43×10^{-4}	2.53×10^{-3}
Equipment state	S3	3.0×10^{-3}	2.2×10^{-2}	3.80×10^{-4}	2.78×10^{-3}
Equipment state	S4	8.0×10^{-4}	2.4×10^{-2}	1.01×10^{-4}	3.04×10^{-3}

Mechanistic checks show that deterioration rates for all four variable groups are higher in S2 and S3 than in S1 and S4. Structural recovery is highest in S1, while personnel and equipment recovery rates are higher in S1 and S4. No persistent-state transition is applied in S0. The S4 recovery rate for the gas group ($1.51 \times 10^{-3} \text{ h}^{-1}$) is the lowest among the four stages, which is not fully consistent with the intuitive expectation of better ventilation or recovery during transport. Accordingly, this rate is excluded from the claim of mechanistic consistency and should be re-examined against the original judgments or justified by scenario-specific evidence before transfer. More generally, μ exceeds λ in all sixteen group-by-stage cells. This is not a statement that breaching or removal improves conditions: λ and μ are conditional on different initial states, and because node-start failure probabilities are of order 10^{-2} , the deterioration term dominates the propagated marginal even where $\mu > \lambda$. The propagated failure probability of X29 therefore rises across a 16-h S2 node, from 1.000×10^{-2} to 2.391×10^{-2} (Section 3.3 of the main text).

S5. Evidence Coding and Diagnostic Calculation Details

S5.1. Case-evidence coding

Table S5-1. Evidence coding for the Mandalay case

ID	Node	Evidence variable	Entered state	Type	Relative time	Source/nature
E01	M0	X72 aftershock sequence	Failure (active)	Hard	T0+0.5 h	Public seismic-network/case material
E02	M0	X46 high temperature	Adverse	Hard	T0+1 h	Field weather/case material
E03	M0	X29 structural stability	Soft evidence 0.7	Soft	T0+3 h	Structural-expert retrospective review
E04	M0	X32 relative entrapment position	Adverse	Soft	T0+4.5 h	Life detection and retrospective review
E05	M1	X73 shoring selection and load verification	Normal	Hard	T0+7 h	Plan record/retrospective review
E06	M1	X74 capacity and synchronization	Within plan limits	Hard	T0+11 h	Operational record/retrospective review
E07	M1	X75 monitoring review and secondary reinforcement	Normal	Hard	T0+16 h	Monitoring/review records
E08	M1	X36 visibility	Adverse	Soft	T0+10 h	Field retrospective review
E09	M2	X76 breaching-method suitability	Normal	Hard	T0+18 h	Plan/operational records
E10	M2	X77 vibration and structural-disturbance control	Soft evidence 0.65	Soft	T0+23 h	Monitoring and expert retrospective review
E11	M2	X78 dust and spark control	Normal	Hard	T0+20 h	Checklist record
E12	M2	X29 structural stability	Soft evidence 0.75	Soft	T0+26.3 h	Evidence recorded during pause/review
E13	M3	X80 lifting plan and lifting points	Normal	Hard	T0+35 h	Plan record/retrospective review
E14	M3	X81 machine–human coordination	Soft evidence 0.6	Soft	T0+41 h	Safety-officer retrospective review
E15	M3	X82 removal sequence and unloading control	Normal	Hard	T0+44 h	Operational record/retrospective review
E16	M4	X83 medical coordination and crush-syndrome management	Normal	Hard	T0+50 h	Medical/operational records
E17	M4	X84 casualty-condition monitoring and communication	Normal	Hard	T0+51 h	Medical/communication records
E18	M4	X85 transport, evacuation, and site handover	Normal	Hard	T0+56.7 h	Public record + case retrospective review

Table S5-1 records the timing and provenance of evidence entered at each node. Retrospectively coded soft evidence includes both categorical adverse states and confidence-coded labels of the form “0.x”. These labels document coding confidence and should not be interpreted as posterior probabilities or as software likelihood vectors. Network reproduction should use the virtual-evidence/likelihood parameters stored in the accompanying stage-network files. Time-locking constrains when each observation can enter the reconstructed sequence, while the retrospective coding itself remains outcome-aware; the main text therefore interprets the case as process-consistency evidence rather than prospective predictive validation.

S5.2. PRU calculation details for node M2 (θ : node-inference prior; ϕ : diagnostic posterior after adding $Y_2 = 1$; $PRU = \phi/\theta - 1$; indicators fixed as normal by hard evidence excluded)

Table S5-2. PRU calculation details for node M2

Node	Factor	θ	ϕ	PRU
M2	X77	1.75×10^{-3}	2.48×10^{-3}	0.412
M2	X29	2.39×10^{-2}	3.31×10^{-2}	0.386
M2	X31	8.02×10^{-3}	1.08×10^{-2}	0.341
M2	X33	3.55×10^{-2}	4.57×10^{-2}	0.287
M2	X57	1.05×10^{-3}	1.31×10^{-3}	0.243
M2	X26	7.40×10^{-4}	9.04×10^{-4}	0.221
M2	X17	5.40×10^{-4}	6.47×10^{-4}	0.198
M2	X68	8.90×10^{-4}	1.03×10^{-3}	0.153

Note: The diagnostic posterior ϕ is used only for within-node diagnosis and is not propagated across nodes. Cross-node propagation always uses the ordinary-evidence posterior $P(X_i=1|e;0)$. To avoid conflating the two posterior definitions, this table reports only M2 diagnostic results and is not used to construct M3 priors.

S5.3. Mutual-information ranking for the full M2 network

Table S5-3. Top 10 root factors by mutual information at M2

Rank	Factor	$I(X;R_2) / 10^{-3} \text{ bit}$
1	X77	4.74
2	X29	4.21
3	X31	3.66
4	X33	3.38
5	X76	3.20
6	X57	2.44
7	X26	2.10
8	X78	1.90
9	X17	1.72
10	X68	1.28

After X76 and X78 are excluded because hard evidence fixes them as normal, the top three M2 factors by PRU are X77, X29, and X31, identical to the top three by mutual information. Both metrics are derived from the same network and are used only as complementary internal diagnostics, not as independent validation.

S6. Reproducibility Materials: Proof, Software Implementation, and Scripts

S6.1. Detailed proof of Proposition B1

Let C denote the set of persistent-state variables and let the stage sequence σ be specified exogenously. At $k = 0$, M_0 coincides with the initial DBN slice. Assume that the two implementations yield identical marginal posteriors for the persistent variables at step $k-1$. The DBN prediction step is then equivalent to Eq. (15) in the main text. Under the marginal-independence approximation, the product of the predicted marginals forms the prior for the next node; applying the same within-slice structure, CPTs, and evidence update yields the same node posterior and NSRI. By induction, the result holds for all nodes. The proof applies only under the same approximation and does not claim equivalence to a full non-homogeneous DBN.

S6.2. Organization and workflow of the GeNIe stage-model files

The file package contains $M_0.xdsl$ – $M_4.xdsl$, `transfer.py`, `output_perturbation.py`, and `evidence.csv`. The workflow is as follows: enter the initial evidence in M_0 and export the ordinary posteriors of the persistent variables; use `transfer.py` to propagate them to the next node according to Eq. (15) and actual elapsed time; enter planned parameters for pre-task prediction; update evidence chronologically during operations; and repeat propagation after each node is completed. The ϕ posterior generated for PRU diagnosis must never be written to `transfer.py`. The X29 example reported in Section 3.3 of the main text can be checked directly from the case-specific prior in Table 11 and the structural S1 transition parameters in Table 9; the remaining full-network node states are reproduced from the accompanying stage-network files.

S6.3. Cascading propagation script (Python)

```
import numpy as np

def ctmc_rates(d0, r0, T0=8.0):
    if d0 < 0 or r0 < 0 or d0 + r0 >= 1:
        raise ValueError("require d0>=0, r0>=0 and d0+r0<1")
    if d0 + r0 == 0:
        return 0.0, 0.0
    nu = -np.log1p(-(d0 + r0)) / T0
    return nu*d0/(d0+r0), nu*r0/(d0+r0)
```

```
def transition(lam, mu, dt):
    if lam < 0 or mu < 0 or dt < 0:
        raise ValueError("rates and duration must be non-negative")
    if lam + mu == 0:
        return np.eye(2)
    s = 1 - np.exp(-(lam+mu)*dt)
    d, r = lam/(lam+mu)*s, mu/(lam+mu)*s
    return np.array([[1-d, d], [r, 1-r]])
```

S6.4. Independent multiplicative perturbation of the output layer (Python)

```
import numpy as np
rng = np.random.default_rng(42)
risk = np.array([2.05, 1.62, 2.86, 2.21, 1.18])
N = 10_000
# Output-layer multiplicative perturbation only; not parameter-level Monte Carlo
R = risk * rng.uniform(0.8, 1.2, (N, 5))
print("P(peak at M2) =", (R.argmax(axis=1) == 2).mean())
print("P(M2 >= 2.5%) =", (R[:, 2] >= 2.5).mean())
```

The script applies independent $\pm 20\%$ multiplicative perturbations only to node-level NSRI values; it does not sample priors, CPTs, transition rates, evidence reliability, or network structure. It therefore represents a local output-layer stability analysis. With random seed 42, $P(\text{peak at M2}) = 0.9263$ and $P(M2 \geq 2.5\%) = 0.8169$.

S6.5. Audit of equations and independently reproducible numerical results

Items reproducible directly from the present documents include expert weights and fuzzy quantification of root nodes, the X76–X78 combined-weighting example, back-calculation of the 16 λ/μ pairs from the reported d(8 h) and r(8 h) values, Delphi statistics, Tables 9 and 11, and the output-layer perturbation script. Full network-level replication of internal noisy-OR parameters, soft-evidence likelihood vectors, the top-node coefficient vector, and the complete five-node *NSRI* sequence requires the accompanying .xdsl and evidence files. The reproducibility scope is therefore stated at two levels: equation-and-table calculations available in these documents, and full software replication using the accompanying network package.

S6.6. Within-slice network topology (full 85-indicator configuration)

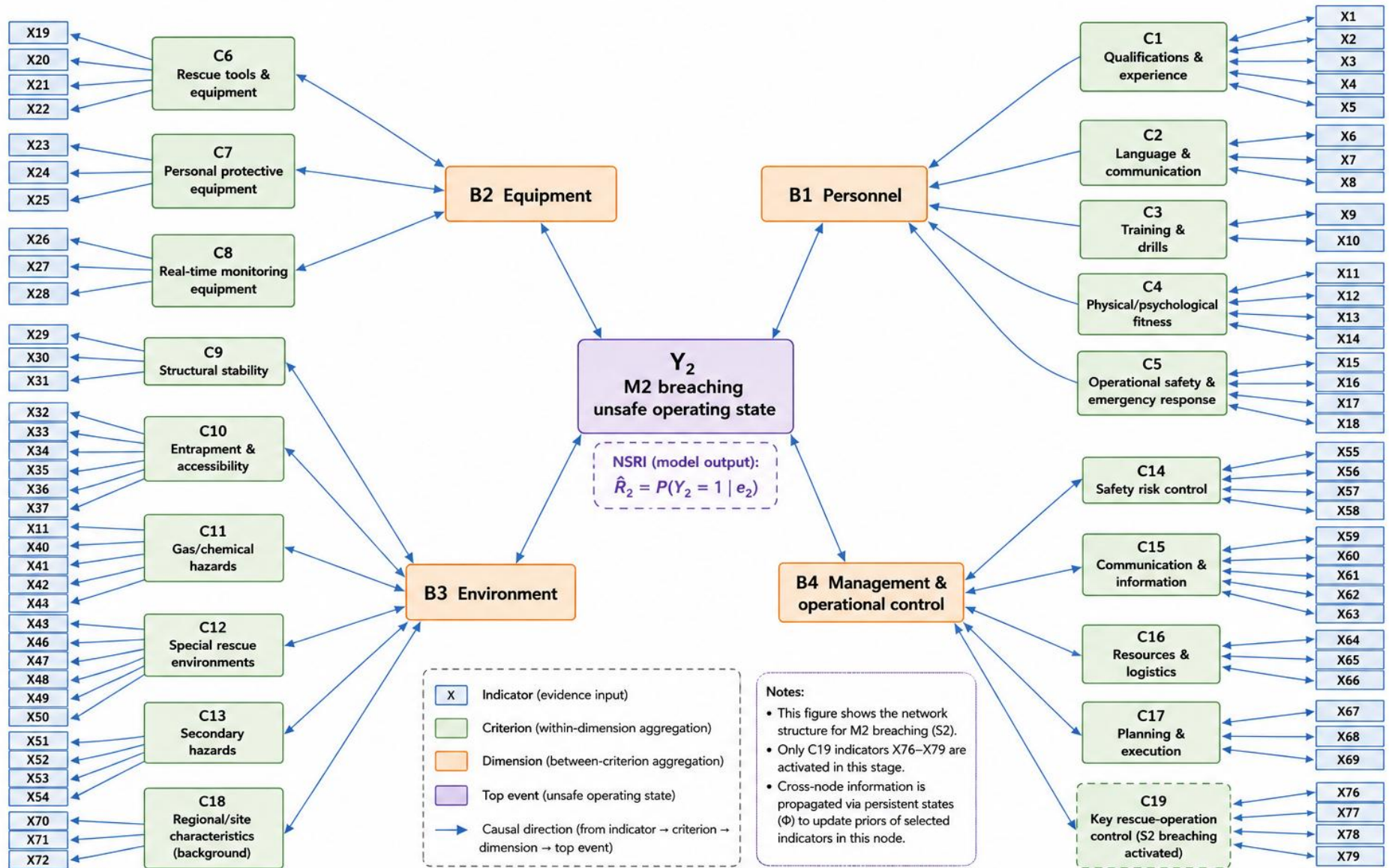
The full 85-indicator configuration of the S2 breaching model M2 is shown in Fig. S6-1, with technical indicators for other stages dormant. A vector version is provided separately as fig_m2_topology.svg; the figure below is a high-resolution raster image. Section S6.7 below defines the exact-joint benchmark referenced in Section 5.1 of the main text.

S6.7. Exact-joint benchmark for persistent-state factorization

The marginal factorization in Section 2.3.5 concerns only eight binary persistent states, so an exact-joint benchmark is feasible over $2^8 = 256$ configurations. For a specified stage-network parameterization, the benchmark runs the same node sequence twice: (i) propagating the eight marginal posteriors and reconstructing the next-node prior as their product, as in the main implementation; and (ii) carrying the full joint posterior over all 256 configurations. Under independent per-variable CTMC generators, the prediction kernels are identical in the two runs, so any difference is attributable to posterior dependence induced within a node by evidence shared across persistent states.

The comparison is defined in terms of node-wise *NSRI* differences, stability of node ranking and decision-band placement, and pairwise posterior dependence among the eight persistent states. No unreported numerical approximation-error estimate is used in the main-text results. With the complete stage-network parameterization, the exact-joint recursion provides a direct sensitivity benchmark for applications with dense shared instrumentation, repeated disturbance, or other conditions likely to strengthen posterior dependence.

The comparison script `joint_vs_marginal.py` is included in the file package. It reuses `ctmc_rates` and transition from S6.3, forms the stage generator for the joint state as the Kronecker sum of the eight single-variable generators, applies the within-node evidence through the same stage network, and returns both the joint posterior and its marginals at each node, so the two recursions differ only in what is carried forward.



Indicator range: X1–X72 (whole-process indicators common to all stages); X73–X85 (stage-specific indicators).
For M2 breaching (S2), only X76–X79 (in C19) are activated.

Fig. S6-1. Full 85-indicator configuration of the S2 breaching model M2

S7. Summary of the 33-Expert Survey (Review Modules A–F)

Review Modules A–F covered expert background, case registration, criterion-level review, 100-point weighting, stage-direction judgments, and standardized scenario probability estimates (Tables S7-1 to S7-5). They do not directly provide indicator-level priors, CPTs, or 8-h CTMC parameters for the 85 indicators.

S7.1. Expert background, Table 6 scores, and individual weights (n=33)

Table S7-1. Background, Table 6 scores, and individual weights of the 33 experts

I D	Primary roles (multi-select)	Experience	Major earthquakes	Professional title	Education	Table 6 total	Weight	Professional-category score
1	Structural engineering, Breaching/shoring operations, Research	8 years	5	Research Fellow	Ph.D.	20	0.0306	5
2	Field command, Structural engineering, Research	6 years	4	Professor	Ph.D.	20	0.0306	5
3	Structural engineering, Breaching/shoring operations	9 years	7	Associate Research Fellow	Ph.D.	20	0.0306	5
4	Field command, Structural engineering	7 years	6	Research Fellow	Ph.D.	20	0.0306	5
5	Safety officer, Structural engineering	8 years	5	Associate Professor	Master's	18	0.0276	5
6	Structural engineering	5 years	6	Associate Research Fellow	Ph.D.	19	0.0291	5
7	Field command, Structural engineering, Research	9 years	6	Professor	Ph.D.	20	0.0306	5
8	Structural engineering, Breaching/shoring operations, Equipment/logistics, Research	11 years	8	Research Fellow	Ph.D.	22	0.0337	5
9	Field command, Safety officer, Structural engineering	10 years	7	Research Fellow	Ph.D.	22	0.0337	5
10	Structural engineering, Research	6 years	4	Research Fellow	Ph.D.	20	0.0306	5
11	Structural engineering, Research	9 years	8	Research Fellow	Ph.D.	21	0.0322	5
12	Field command, Safety officer, Structural engineering, Search-and-rescue team member	10 years	8	Research Fellow	Ph.D.	22	0.0337	5
13	Structural engineering, Search-and-rescue team member	4 years	3	Associate Research Fellow	Ph.D.	17	0.0260	5
14	Structural engineering	3 years	3	Associate Research Fellow	Ph.D.	17	0.0260	5
15	Structural engineering, Breaching/shoring technical guidance, Search-and-rescue team member, Research	15 years	12	Research Fellow	Ph.D.	24	0.0368	5
16	Structural engineering, Equipment/logistics coordination, Research	6 years	4	Research Fellow	Ph.D.	20	0.0306	5
17	Field command, Search-and-rescue team member	7 years	7	Research Fellow	Ph.D.	21	0.0322	5
18	Safety officer, Structural-engineering coordination, Search-and-rescue team member, Equipment/logistics coordination, Research	8 years	6	Associate Research Fellow	Master's	18	0.0276	5
19	Field command, Search-and-rescue team member, Equipment/logistics coordination	11 years	8	Research Fellow	Ph.D.	22	0.0337	5
20	Safety officer, Search-and-rescue team member, Equipment/logistics coordination	5 years	3	Associate Research Fellow	Master's	17	0.0260	5
21	Field command, Search-and-rescue team member	7 years	6	Research Fellow	Ph.D.	20	0.0306	5
22	Not specified (professional category scored as "Other" = 1)	8 years	5	Associate Research Fellow	Ph.D.	15	0.0230	1
23	Field command, Search-and-rescue team member, Equipment/logistics coordination, Research	7 years	4	Research Fellow	Ph.D.	20	0.0306	5
24	Safety officer, Structural-engineering coordination, Search-and-rescue team member, Equipment/logistics coordination, Research	8 years	5	Associate Research Fellow	Ph.D.	19	0.0291	5
25	Field command, Safety officer, Structural-engineering coordination, Search-and-rescue team member, Equipment/logistics coordination, Research	8 years	6	Research Fellow	Ph.D.	20	0.0306	5

I D	Primary roles (multi-select)	Experience	Major earthquakes	Professional title	Education	Table 6 total	Weight	Professional-category score
26	Safety officer, Search-and-rescue team member, Equipment/logistics coordination	9 years	5	Associate Research Fellow	Ph.D.	19	0.0291	5
27	Structural-engineering coordination, Breaching/shoring operations, Search-and-rescue team member, Equipment/logistics coordination, Research	6 years	4	Associate Research Fellow	Master's	18	0.0276	5
28	Field command, Safety officer, Research	7 years	8	Professor	Ph.D.	21	0.0322	5
29	Safety officer, Research	5 years	6	Associate Professor	Ph.D.	19	0.0291	5
30	Research	8 years	7	Associate Research Fellow	Ph.D.	19	0.0291	4
31	Field command, Research	12 years	14	Research Fellow	Ph.D.	22	0.0337	4
32	Safety officer, Research	5 years	6	Research Fellow	Ph.D.	20	0.0306	5
33	Field command, Research	11 years	8	Research Fellow	Ph.D.	21	0.0322	4

Note: Forty questionnaires were distributed, 37 were returned, and 33 were valid. Respondents could select multiple roles. Professional-category scores are listed separately according to Table 6 in the main text. The total score was 653, and each weight equals the individual total divided by 653. Nineteen experts had qualifications or experience in international rescue missions.

S7.2. Criterion-level review across three dimensions (Review Module C; retention rule: median ≥ 4 , IQR ≤ 1 , and $\geq 75\%$ ratings of 4–5)

Table S7-2. Three-dimensional review statistics for the 19 criteria

Criterion	Median safety relevance	IQR	Ratings 4–5	Median generalizability	Median observability	Decision
C1	5	0	100%	5	4	Retain
C2	5	0	100%	5	4	Retain
C3	4	0	100%	5	3	Retain
C4	5	0	100%	5	4	Retain
C5	5	0	100%	5	4	Retain
C6	5	0	100%	5	4	Retain
C7	5	0	100%	5	5	Retain
C8	5	0	100%	4	4	Retain
C9	5	0	100%	5	4	Retain
C10	5	0	100%	4	4	Retain
C11	4	1	100%	4	3	Retain
C12	4	1	100%	4	4	Retain
C13	5	0	100%	5	3	Retain
C14	5	0	100%	5	5	Retain
C15	5	0	100%	5	4	Retain
C16	4	0	100%	4	4	Retain
C17	5	0	100%	5	4	Retain
C18	5	0	100%	4	4	Retain
C19	5	0	100%	5	4	Retain

Agreement for safety relevance was Kendall's $W = 0.515$ ($\chi^2 = 305.9$, $df = 18$, $p < 0.001$). All 19 criteria received ratings of 4–5 from 100% of respondents; the resulting ceiling effect and possible acquiescence bias should be considered.

S7.3. Direct 100-point weights for dimensions and criteria (Review Module D)

Table S7-3. Direct 100-point weights for the four dimensions

Dimension	Unweighted mean $\pm$ SD	Expert-weighted mean	Median
Personnel B1	22.9 $\pm$ 2.7	22.7	22
Equipment B2	17.2 $\pm$ 1.5	17.2	17
Environment B3	34.1 $\pm$ 2.7	34.2	34
Management and operation control B4	25.9 $\pm$ 3.3	25.9	26

Note: Each expert allocated a total of 100 points across the four dimensions. Differences between the sum of the reported means or medians and 100 are due only to rounding; the expert-weighted means sum to 100.0.

S7.4. Three-state judgments of stage condition (“deteriorate/no change/improve”) (Review Module E; general scenario, standard 1-h window, n=33; directional description only)

Table S7-4. Three-state judgments of stage condition (“deteriorate/no change/improve”)

Stage	Variable	Deteriorate / % (mean $\pm$ SD)	Improve / % (mean)	Exploratory λ / h ⁻¹	Exploratory μ / h ⁻¹
S1 Shoring/bracing	X29	14.9 $\pm$ 2	40.5	0.217	0.591
S1 Shoring/bracing	X31	18.4 $\pm$ 4	34.3	0.262	0.487
S1 Shoring/bracing	X11	40.8 $\pm$ 4	10.4	0.572	0.147
S1 Shoring/bracing	X21	17.8 $\pm$ 4	15.0	0.215	0.181
S2 Slab breaching	X29	35.9 $\pm$ 3	14.7	0.501	0.204
S2 Slab breaching	X31	30.6 $\pm$ 3	15.1	0.408	0.202
S2 Slab breaching	X11	51.9 $\pm$ 4	5.9	0.775	0.088
S2 Slab breaching	X21	23.9 $\pm$ 2	13.7	0.300	0.172
S3 Debris removal	X29	31.1 $\pm$ 3	14.7	0.415	0.196
S3 Debris removal	X31	33.6 $\pm$ 3	15.6	0.463	0.214
S3 Debris removal	X11	47.6 $\pm$ 4	5.9	0.681	0.084
S3 Debris removal	X21	19.1 $\pm$ 3	14.0	0.231	0.170
S4 Casualty transport	X29	19.7 $\pm$ 2	14.9	0.242	0.183
S4 Casualty transport	X31	23.8 $\pm$ 3	15.6	0.303	0.198
S4 Casualty transport	X11	42.8 $\pm$ 5	5.9	0.586	0.081
S4 Casualty transport	X21	13.9 $\pm$ 3	14.0	0.164	0.164

The table reports the mean proportions of “deteriorate” and “improve” judgments from the same baseline; the “no change” proportion is the remainder in each row. In the CTMC, d and r are conditioned on different initial states and therefore cannot be identified directly from these three-state proportions. The exploratory λ and μ values shown here were obtained by applying the Section 2.3.3 back-calculation to the 1-h proportions as if they were d(1 h) and r(1 h), solely for directional comparison. They differ from the calibrated rates in Table S4-2 by two to three orders of magnitude because the two instruments use different reference windows and conditioning bases. These results are descriptive only and are not used to recalibrate the parameters in S4.3.

S7.5. Three-point estimates of 30-min local/progressive collapse probability for standardized scenarios (Review Module F; medians, n=33)

Table S7-5. Three-point estimates of 30-min local/progressive collapse probability for eight standardized scenarios (Review Module F; medians, n=33)

ID	Scenario summary	Median L / %	Median M / %	Median U / %
V1	Tilted RC frame; shoring completed; monitoring stable; low-disturbance entry	1	4	10
V2	Persistent friction sounds and slight visible deformation during breaching	20	40	64
V3	Sounds accompanied by displacement increasing continuously for 10 min during breaching; work not stopped	51	75	95
V4	Perceptible aftershock during removal; coupled component movement; debris falling from passage	63	86	99
V5	Shallow burial; manual removal of small components; no aftershock	0.5	2	6
V6	Cutting a cantilevered component; uncertain lifting point; secondary restraint installed	15	35	62
V7	Continuous >4 h operation in a hot confined space; structural monitoring normal	2	9	23
V8	Combustible gas near warning threshold; spark-generating work planned; insufficient ventilation	18	43	74

Review Module F targets local or progressive collapse within 30 min, whereas NSRI is a broader unsafe-state score; the two are not numerically equivalent. Table S7-5 is used only to compare scenario rankings and to provide standardized scenarios for future calibration.