

Emergency Preparedness and Disaster Response Capacity in Health Systems: Training Frameworks, Incident Monitoring, and Frontline Readiness

Sylvia Stella Favour Peteranaba^{1*}, Olakunle Saheed Soyege², Helen Ekwi Osinem³,
Florence Eribenne⁴

¹Independent Researcher

²Mamelodi Regional Hospital, Internal Medicine Department, Mamelodi, Pretoria, Gauteng, South Africa

³Jos University Teaching Hospital (JUTH), Nursing Services Department, Jos, Nigeria

⁴Bay Cove Human Services, Boston, MA, USA

ABSTRACT

This review examines how health systems develop and sustain emergency preparedness and disaster response capacity through institutional readiness, workforce training, incident monitoring, resource mobilisation, and frontline resilience. It synthesises evidence from international and context-specific literature published up to 2020, with attention to preparedness models, governance arrangements, surge capacity, competency-based training, simulation exercises, surveillance, real-time incident management, and persistent system inequalities. The review finds that effective preparedness depends on the integration of clear command structures, reliable financing, resilient infrastructure, interoperable information systems, trained personnel, and adaptable operational procedures. Competency-based education and simulation were consistently associated with improved role clarity, practical confidence, decision-making, and team coordination, while early warning systems were most effective when surveillance, laboratory confirmation, communication, and response mechanisms functioned as a connected cycle. The evidence also shows that resource scarcity, workforce maldistribution, fragmented governance, weak infrastructure, and uneven access to technology continue to constrain response effectiveness, especially in resource-limited settings. Frontline readiness was strengthened where occupational safety, psychosocial support, communication, and organisational flexibility were embedded within preparedness systems. The review concludes that emergency readiness should be institutionalised as a continuous health-system function rather than activated episodically during crises. It recommends protected preparedness financing, routine multi-agency drills, scalable competency frameworks, interoperable surveillance platforms, resilient energy and communication systems, equitable workforce deployment, and stronger implementation research. Future preparedness strategies should also integrate locally adaptable protocols with national standards and systematically translate lessons from exercises and real emergencies into measurable improvements in policy, training, infrastructure, and frontline response capacity across all levels of care. Equity must remain central to preparedness investment and recovery planning.

Keywords: Emergency preparedness; Disaster response; Health systems; Frontline readiness; Incident monitoring; Workforce training

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INTRODUCTION

Evolving Health Emergencies and System Vulnerabilities

Health emergencies have become multidimensional, combining infectious disease outbreaks, climate-related disasters, conflict, displacement, infrastructure disruption, and sudden surges in service demand. These events expose interdependencies across surveillance, laboratories, supply chains, referral

networks, financing, workforce availability, communication, and governance. A health system may appear functional under routine conditions yet become fragile when pressures occur simultaneously. Analysis of shocks ranging from Ebola and climatic disasters to financial crises and migration emergencies shows that resilience depends on how systems anticipate disruption, absorb stress, adapt operations, and preserve essential services as conditions evolve (Hanefeld et al., 2018).

The West African Ebola epidemic illustrated how rapidly an outbreak can transform underlying weaknesses into system-wide failure. Limited workforce density, inadequate infection control, weak surveillance, poor public trust, and constrained service capacity intensified transmission while reducing access to routine care. Resilience requires maintaining core functions, reorganising resources, and learning during disruption. Experience from Ebola-affected health systems showed that preparedness must be embedded in service delivery rather than treated as a temporary emergency function activated only after a threat becomes visible (Kruk et al., 2015).

Vulnerability is evident when emergencies originate outside infectious disease. Natural hazards can damage facilities, interrupt electricity and water, isolate communities, disrupt transport, exhaust supplies, and produce abrupt casualty loads. A scoping review identified recurring resilience requirements across outbreaks and natural hazards, including emergency planning, adaptable service delivery, communication, workforce capacity, continuity arrangements, recovery planning, and quality improvement. Their overlap indicates that preparedness should be organised around transferable system functions rather than disease-specific plans that may prove inadequate when hazards interact or cascade (Nuzzo et al., 2019).

Conflict settings reveal a dimension of health-system fragility because insecurity can increase population need while reducing resources available to meet it. Evidence from Yobe State, Nigeria, during the Boko Haram insurgency documented disrupted access, population movement, transport constraints, workforce losses, and interruptions to technical support. Yet staff commitment, community cohesion, flexible deployment, and decentralised arrangements helped preserve service delivery. This demonstrates that frontline readiness depends not only on emergency plans but also on local adaptive capacity and the ability to sustain operations under prolonged instability (Ager et al., 2015).

Health-system resilience should be understood as a dynamic property of complex institutions rather than an ability to “bounce back.” Evidence from Kenya and South Africa supports approaches that recognise adaptation, relationships, emergence, and problem-solving within health systems. This perspective matters because rigid command structures can become ineffective when frontline conditions change faster than central protocols. Preparedness frameworks must therefore combine authority with operational flexibility, allowing facilities and personnel to adjust workflows, redistribute resources, and respond to locally observed risks without undermining coordination or accountability (Barasa et al., 2017).

COVID-19 exposed the difference between nominal capacity and operational readiness. An analysis of International Health Regulations reporting from 182 countries found variation in capacities to prevent, detect, and respond to

public-health threats, with weaknesses in enabling functions and readiness across many settings. Formal plans, policies, and technical capabilities are insufficient unless they can be converted into deployable staff, functioning surveillance, laboratory access, logistics, risk communication, and coordinated decision-making at the point of crisis (Kandel et al., 2020).

The pandemic experience of Hong Kong, Singapore, and Japan showed that strong health systems remained vulnerable to sustained transmission and prolonged pressure. Their responses depended on adaptable surveillance, contact tracing, public-health staffing, infection-control measures, and the capacity to reorganise services as knowledge changed. Preparedness therefore requires continuous monitoring and iterative adjustment rather than static documents; frontline systems must detect changing risk patterns and translate intelligence rapidly into operational action while maintaining service continuity and public confidence (Legido-Quigley et al., 2020).

Italy's COVID-19 experience demonstrated how severe demand shocks can expose structural weaknesses even within established health systems. Rapid increases in hospitalisation and critical-care requirements placed pressure on personnel, beds, equipment, and regional coordination, while pre-existing organisational and resource constraints complicated response capacity. Such experience reinforces the need to examine vulnerability before emergencies occur, particularly at the interfaces between workforce readiness, surge capacity, incident monitoring, infrastructure, and governance. Effective preparedness depends on identifying where routine weaknesses could become emergency bottlenecks and strengthening those points before escalating demand overwhelms frontline services (Armocida et al., 2020).

Preparedness Capacity and Response Effectiveness

Preparedness capacity determines whether health systems can translate plans, personnel, infrastructure, and information into action during emergencies. It extends beyond protocols to include command structures, surveillance, logistics, communication, workforce competence, and continuity mechanisms. Hospital preparedness literature shows that readiness encompasses interconnected structural and process dimensions, indicating that effective response requires measurable capabilities that are routinely tested and embedded within institutional management rather than activated only after disruption occurs (Verheul & Dückers, 2020).

Nigeria demonstrates how strengthened surveillance, laboratory networks, emergency operations, and incident-management arrangements can improve response performance. However, recurrent outbreaks have also revealed constraints involving subnational coordination, financing, diagnostic capability, workforce availability, and risk communication. These weaknesses show that national preparedness gains must translate into operational capacity across states and

local systems, because uneven readiness can delay detection, resource mobilisation, containment, and continuity of essential services during fast-moving emergencies (Olumade et al., 2020).

Facility-level evidence from western Ethiopia similarly illustrates the consequences of limited preparedness. Hospitals demonstrated weak overall disaster readiness, particularly in response and recovery planning, showing that awareness of hazards does not necessarily produce functional response capacity. Effective preparedness therefore requires administrators to convert risk recognition into executable plans, trained teams, assigned responsibilities, dependable supplies, and procedures capable of preserving clinical operations when demand rises abruptly, or routine systems are disrupted (Woyessa et al., 2020).

Preparedness assessment must also recognise interdependence among hospital capabilities. Evidence from Turkish hospitals indicates that personnel, infrastructure, equipment, communication, transportation, and organisational flexibility collectively influence disaster readiness. Failure in one domain can restrict strong components: additional beds provide limited surge value without trained staff, while competent teams cannot function effectively without communications, supplies, transport, or reliable infrastructure. Readiness metrics should therefore evaluate coordinated capability rather than isolated assets or nominal resource inventories (Ortiz-Barrios et al., 2020).

Cross-country experience during COVID-19 further demonstrated that health-security capacity does not automatically ensure emergency performance. Differences in testing, case identification, treatment priorities, containment measures, and resource deployment generated contrasting response patterns across health systems. Preparedness should consequently be judged by its ability to support rapid detection, evidence-informed decisions, scalable services, and adaptive resource allocation under operational pressure, linking health-system strengthening with health-security functions to sustain frontline performance during routine and emergency demands (Wang et al., 2020).

Review Scope, Objectives, and Significance

This review examines emergency preparedness and disaster response capacity as interconnected health-system functions, with particular attention to workforce training, incident monitoring, frontline readiness, and the institutional conditions that shape effective response. Its scope encompasses preparedness across hospitals, public health agencies, emergency operations structures, and other service-delivery settings exposed to infectious disease outbreaks, natural hazards, technological failures, conflict-related disruptions, and complex emergencies. Rather than treating preparedness as a static planning exercise, the review considers it a dynamic capacity that depends on coordinated governance, operational flexibility, reliable information, competent personnel, resilient

infrastructure, and the ability to sustain essential services under pressure.

The review has three principal objectives. First, it evaluates the frameworks used to develop and assess preparedness capacity, including competency-based training, simulation, drills, and organisational readiness mechanisms. Second, it examines incident monitoring and operational response processes, focusing on surveillance, early warning, communication, situational awareness, resource mobilisation, and real-time decision-making. Third, it analyses the determinants of frontline readiness, including staff competence, safety, confidence, role clarity, interprofessional coordination, and resilience during rapidly changing emergencies.

The significance of this review lies in integrating these dimensions into a coherent health-systems perspective. By identifying how training, monitoring, governance, infrastructure, and frontline performance interact, it provides a basis for recognising preparedness gaps, strengthening institutional capacity, and informing future policy, investment, and research priorities. The review therefore supports a more comprehensive understanding of readiness as an operational capability that must be continuously developed, tested, evaluated, and adapted to emerging risks across diverse health systems and resource-constrained operational environments.

HEALTH-SYSTEM PREPAREDNESS AND RESPONSE CAPACITY

Preparedness Models and Institutional Readiness

Preparedness models provide the architecture through which health systems convert hazard awareness into organized capability. Their value lies in defining what must exist before an emergency, how readiness should be measured, and which functions must remain dependable under pressure. Early preparedness scholarship emphasized that plans or equipment alone are inadequate proxies for readiness because capability depends on coordinated performance, accountability, and assessment. Institutional preparedness is therefore best treated as a measurable, improved capacity rather than a binary state achieved through possession of a disaster plan (Nelson, Lurie & Wasserman, 2007).

Contemporary frameworks conceptualize preparedness as a complex adaptive system in which governance, leadership, partnerships, workforce capacity, information management, communication, learning, and community relationships interact. This perspective matters because failures rarely remain confined to one department. Laboratory delays can impede surveillance, weak communication can undermine triage, and unclear authority can slow resource deployment. Preparedness models should therefore map interdependencies and establish mechanisms enabling institutions to anticipate uncertainty, coordinate across organizational boundaries, and adapt functions without losing accountability during changing emergencies (Khan et al., 2018).

European preparedness research demonstrates the importance of generic, all-hazards principles across diverse threats. Consensus work across European Union and European Economic Area countries identified governance, capacity building, surveillance, risk assessment, crisis management, post-event evaluation, and implementation of lessons learned as central preparedness domains. Institutional readiness requires a cyclical model in which planning is followed by capability development, testing, evaluation, and corrective action. Such models reduce dependence on hazard-specific assumptions and strengthen response when emergencies differ from anticipated scenarios (Belfroid et al., 2020; Shittu et al., 2020).

Hospital-level models require explicit links between structures, processes, and performance. A disaster risk-management evaluation model developed in Iran organized readiness around management and leadership, risk assessment, planning, prevention and mitigation, preparedness, response, recovery, and measurable results. Institutions may possess policies while lacking operational conditions for execution. Evaluating leadership commitment, financing, information systems, partnerships, and implementation alongside response functions provides a credible picture of preparedness and identifies weaknesses that managers can address before an emergency exposes them (Abbasabadi Arab et al., 2019).

Evidence from Japan shows why institutional designation does not automatically equate to operational readiness. Hospitals assigned to manage highly infectious diseases varied in guidance, facilities, human resources, and preparedness activities, demonstrating that formal responsibility requires practical capability. Readiness models should test whether isolation arrangements, staffing, occupational protections, protocols, and procedures can function under pressure. This distinction between nominal capacity and executable capability is fundamental where specialized facilities must absorb cases while protecting staff and sustaining routine services (Toyokawa, Hori & Kato, 2017).

Nigeria's experience during the 2014 Ebola threat illustrates how institutions can strengthen readiness through rapid organizational adaptation. A tertiary hospital established a response team, introduced staff training, commenced surveillance, created isolation capacity, improved waste-management arrangements, and procured protective equipment. The experience also revealed fear and misconceptions among health workers, indicating that physical preparedness alone cannot secure institutional readiness. Effective models must integrate workforce knowledge, risk communication, infection prevention, leadership, and response arrangements so that plans translate into coordinated frontline action (Ogoina et al., 2016).

In South Africa, assessment of public hospitals in the Western Cape demonstrated variation in disaster planning and highlighted the importance of standardized arrangements, regular updating, training, and exercises. Institutional readiness cannot depend exclusively on written plans because personnel

must understand command responsibilities and rehearse procedures before major incidents. Preparedness models should connect policy with implementation through assigned roles, multidisciplinary participation, interoperable communication, resource planning, and testing, enabling hospitals to identify weaknesses under controlled conditions rather than during emergencies (Stander, Wallis & Smith, 2011).

Operational assessment reveals gaps between mandated planning and frontline preparedness. Evaluation of Italian emergency departments found deficiencies in disaster knowledge and preparedness despite requirements for mass-casualty planning. Such findings underscore the need for institutional models that examine not only whether governance instruments exist but whether clinicians can execute them. Readiness should be demonstrated through competent staff, functional command systems, surge procedures, triage protocols, communication pathways, and periodic evaluation, with identified deficiencies feeding directly into training, planning revisions, and organizational quality improvement (Paganini et al., 2016).

Emergency Governance and Coordination Structures

Emergency governance is the institutional mechanism through which authority, information, resources, and accountability are organized during rapidly evolving health crises. Effective coordination requires more than a designated lead agency; it depends on clearly distributed responsibilities, interoperable reporting arrangements, trusted communication, and the capacity to align subnational, clinical, laboratory, humanitarian, and community actors around common operational priorities. Global reviews following the West African Ebola epidemic showed that weak international leadership, delayed escalation, fragmented mandates, and inadequate accountability can magnify containable outbreaks, making governance reform integral to preparedness rather than an administrative adjunct (Moon et al., 2015).

Nigeria's 2014 Ebola response illustrates the value of decisive governance linked to epidemiological intelligence. Rapid case identification, contact tracing, isolation, surveillance, and coordinated implementation of control measures helped interrupt transmission despite introduction into a densely connected urban environment. The experience demonstrates that response effectiveness depends on institutions converting technical evidence into authoritative decisions, synchronizing operational actors, and maintaining implementation discipline across the response network (Fasina et al., 2014).

Comparable lessons emerged in Liberia, where an Incident Management System replaced a cumbersome task-force arrangement and established clearer authority, accountability, technical working groups, and operational follow-up. Government leadership remained central while international agencies contributed expertise, logistics, laboratory capacity, and field support through coordinated structures. This arrangement strengthened unity of effort while allowing

tactical adaptation as transmission patterns and resource requirements changed (Nyenswah et al., 2016).

Sierra Leone further demonstrates that coordination structures must evolve when existing institutions cannot manage emergency scale. The transition from early task-force mechanisms to national and district Ebola response centres created stronger command relationships, improved operational oversight, and connected technical pillars with field implementation. Nevertheless, political tensions, organizational cultures, and competing institutional relationships initially impeded performance, underscoring that formal structures require functional collaboration and leadership to become effective (Ross, 2017; Enaifoghe, Dlamini & Agwuna, 2020).

Regional governance is equally important where infectious threats cross borders faster than administrative systems can respond. Southeast Asian experience shows that population mobility, ecological change, uneven national capacities, and differing institutional arrangements complicate collective disease control. Effective emergency governance therefore requires cross-border surveillance, information exchange, harmonized preparedness, and regional cooperation, ensuring that frontline actions are linked to coordination mechanisms capable of managing risks that exceed institutional or national jurisdictions (Coker et al., 2011).

Resource Mobilization and Surge Capacity

Resource mobilization and surge capacity determine whether health systems can expand services rapidly when emergencies produce demand beyond routine operational limits. Surge capacity is not simply the availability of additional beds; it reflects the coordinated expansion of personnel, supplies, physical space, clinical processes, and supporting systems. A widely used conceptual approach emphasizes staff, stuff, and structure, reinforcing that effective surge performance depends on balancing human resources, material assets, and care environments rather than increasing any single component (Kaji, Koenig & Bey, 2006).

At the system level, surge capacity also requires mechanisms for reallocating resources across facilities, activating reserve personnel, adjusting standards of care, and sustaining essential services while emergency demand escalates. Review evidence shows that surge planning remains conceptually inconsistent across health systems, with variation in definitions, measurement approaches, and assumptions about how additional capacity becomes operational. This variability makes pre-event assessment, scenario modelling, and defined thresholds for escalation essential components of preparedness (Watson, Rudge & Coker, 2013).

Evidence from Tanzania illustrates the resource constraints confronting hospitals in lower-resource settings. Regional hospitals reported shortages across healthcare cadres, limited stockpiling arrangements, incomplete disaster plans, and uneven access to intensive care and contingency infrastructure. Although many facilities identified alternative care areas, no

hospital possessed all assessed surge-capacity components, demonstrating that physical expansion must be matched by personnel, supplies, communication, and logistical preparedness (Koka et al., 2018).

Resource readiness also depends on inventory management and supply-chain resilience. In China, assessment across hospitals in four regions identified variation in emergency stockpile evaluation, supply-system assessment, surveillance capability, training, and preparedness. These findings indicate that mobilization should be pre-arranged through procurement pathways, transport mechanisms, reserve inventories, and interfacility agreements so that additional resources can be deployed before shortages compromise frontline response (Li, Huang & Zhang, 2008).

Reliable infrastructure is equally fundamental because expanded clinical activity cannot be sustained without dependable energy. Nigerian evidence on decentralized solar integration demonstrates how alternative power systems can reduce dependence on unstable grid supply and strengthen operational continuity. Within health-emergency preparedness, comparable diversification of energy sources can support laboratories, communications, cold chains, oxygen systems, and clinical services during disruptions. Resource-mobilization frameworks should therefore incorporate resilient power alongside staffing, supplies, space, transport, and financing when planning for surge operations (Sunday & Omoegun, 2018).

WORKFORCE TRAINING AND FRONTLINE READINESS

Competency-Based Emergency Training Frameworks

Competency-based emergency training translates preparedness expectations into workforce performance. Unlike content-heavy courses that equate attendance with readiness, competency frameworks specify what personnel should know, demonstrate, and apply under pressure. Early work on disaster education identified cross-cutting competencies encompassing recognition of critical events, incident management, safety, institutional plans, communication, command structures, and role-specific skills. This approach establishes measurable learning outcomes and permits training to be differentiated by responsibility while preserving common standards across multidisciplinary teams (Hsu et al., 2006).

All-hazards training strengthens this logic by defining capabilities relevant across infectious outbreaks, mass-casualty incidents, infrastructure failures, and other emergencies. Standardized competencies for acute-care physicians, nurses, and emergency medical services personnel emphasize personal preparedness, communication, situational awareness, ethical practice, incident management, safety, and clinical response. Their value lies in separating universal competencies from profession-specific tasks, reducing curricular fragmentation and enabling interprofessional teams to operate from a shared

conceptual and operational vocabulary during changing events (Schultz et al., 2012).

Competency frameworks must also reflect risk, health-system structure, and workforce realities. In Africa, a process involving public-health institutions identified 14 core competencies and 45 sub-competencies grouped around disaster-risk management, operational effectiveness, leadership, preparedness and risk reduction, emergency response, and recovery. The proposed basic, intermediate, and advanced training levels recognize that frontline workers, managers, and specialist responders require different depths of capability. This tiered architecture is important where workforce shortages make training every professional to the same technical level impractical (Olu et al., 2018).

Nigeria illustrates why competency development must be linked to practical workforce roles. The University of Benin Teaching Hospital EMT-paramedic programme responded to deficiencies in organized prehospital trauma and emergency care by developing a dedicated cadre with emergency training. Its emergence demonstrates that readiness depends not merely on general awareness but on institutional investment in personnel whose competencies match time-critical functions. Sustainable frameworks therefore require professional recognition, recurrent education, supportive supervision, and integration of trained personnel into wider referral and emergency-response systems (Iribhogbe, 2011).

At the organizational level, competency development can be strengthened through talent-management systems. Capability-building models for distributed operations emphasize identifying required skills, developing personnel, and aligning learning with operational responsibilities across dispersed units. Applied to emergency preparedness, this principle supports competency mapping by facility, role, hazard exposure, and escalation responsibility, while encouraging training pathways that address identified deficits rather than uniform instruction irrespective of need. Such alignment can improve workforce deployment, succession planning, and organizational learning across distributed services (Falemi, Akhigbe & Akin-Oluyomi, 2020).

European experience further demonstrates the importance of linking competencies to health-system capabilities. The European Centre for Disease Prevention and Control model defined competency, knowledge, and skill statements for professionals involved in public-health emergency preparedness. By connecting individual learning requirements with preparedness functions, the framework provides a basis for curriculum design, workforce assessment, and standardization across jurisdictions. This systems orientation helps ensure that training contributes to surveillance, risk assessment, coordination, communication, and response rather than remaining detached from capabilities institutions must deliver during emergencies (Stoto et al., 2018).

Training design also requires educational methods capable of moving learners from declarative knowledge to applied

judgment. In China, a disaster-nursing course developed around International Council of Nurses competencies combined structured learning with assessment and produced improvements in participants' self-rated disaster competencies. The experience illustrates the importance of aligning curriculum content, learning activities, and evaluation with predefined competencies. Repeated assessment can identify whether learners merely understand emergency concepts or can demonstrate the decision-making, teamwork, communication, and role execution expected during frontline response (Chan et al., 2010).

A challenge is the lack of agreement on terminology, professional levels, and competency domains across disaster and humanitarian education. Systematic review evidence found substantial variation in how competencies were defined and organized, despite recurring emphasis on healthcare roles and responsibility-based learning. Competency-based frameworks should therefore combine standardization with contextual flexibility: common capabilities can establish minimum expectations, while local hazards, resources, professional scopes, and institutional arrangements determine how those capabilities are taught and assessed. This balance enables portable preparedness standards without disconnecting education from operational realities that ultimately determine frontline readiness (Ripoll Gallardo et al., 2015).

Simulation, Drills, and Practical Preparedness

Simulation and drills convert emergency plans into observable performance by placing personnel, systems, and interagency relationships under pressure. Their value lies in revealing whether procedures that appear coherent on paper remain workable when information is incomplete, demand escalates, and responsibilities overlap. Tabletop exercises with public health agencies have shown that realistic scenarios can expose weaknesses in surveillance, epidemiological investigation, communication, command, and surge arrangements while strengthening relationships among participants (Dausey, Buehler & Lurie, 2007).

Full-scale exercises provide a more demanding test because they require institutions to coordinate people, equipment, information, and decision-making rapidly. Nigeria's 2018 yellow-fever simulation in Lagos involved health facilities, laboratories, points of entry, and emergency operations centres, allowing preparedness to be examined across response layers. The exercise demonstrated the importance of testing notification, coordination, laboratory pathways, risk communication, and recovery processes before an actual outbreak places those functions under operational strain (Okunromade et al., 2019).

Simulation is important at the hospital level, where clinical competence must interact with organizational systems. A multimodality programme for hospital nurses in South Korea combined triage, incident command, surge capacity, life-saving procedures, crisis management, and problem-solving exercises.

Participants demonstrated improved disaster-response competencies, illustrating that simulation can move training beyond theoretical familiarity toward applied judgement, teamwork, and technical performance when educational objectives are matched to realistic emergency tasks (Noh et al., 2020).

Exercises can also test institutional preparedness without the expense and disruption of a full-scale drill. Before the 2010 FIFA World Cup, nine hospitals in the Western Cape, South Africa participated in a long-distance, scenario-based tabletop exercise assessing safety, communication, supplies, incident management, and surge capacity. The process identified stronger and weaker preparedness domains, demonstrating how simulation can provide actionable evidence for corrective planning before high-risk events (Valesky et al., 2011).

Practical preparedness also benefits from progressive training that links planning with execution. Canadian emergency medicine residents participated in a multiphase programme combining web-based planning, redesign of an institutional disaster plan, a multidisciplinary exercise involving simulated casualties, and joint debriefing. This sequencing allowed learners to connect conceptual planning with operational consequences, highlighting the educational value of exercises that culminate in reflection and feedback rather than treating successful scenario completion as the sole indicator of readiness (Alexander, Bandiera & Mazurik, 2005).

Simulation technology can broaden practical preparedness without eliminating the need for disciplined assessment. Italian research comparing virtual reality with live mass-casualty simulation found that both approaches could assess triage accuracy, lifesaving interventions, and improvement after instruction. This supports using technology to supplement resource-intensive drills, provided scenarios preserve operational realism and measurable objectives. Digital simulation is therefore most useful when embedded within broader exercise programmes that include feedback, repeated assessment, and opportunities to transfer acquired skills into coordinated frontline practice with confidence (Ingrassia et al., 2015).

Frontline Confidence, Safety, and Resilience

Frontline confidence is essential for emergency readiness because personnel must act under uncertainty, exposure risk, workload escalation, and changing protocols. Confidence strengthens when workers understand hazards, know assigned roles, trust procedures, and believe protective resources will be available. Nigerian evidence from a tertiary hospital during the Ebola threat showed high awareness but gaps in preparedness and infection-control practice, demonstrating that knowledge alone does not guarantee assured frontline performance (Olowookere et al., 2015).

Safety is important because willingness to respond is shaped by perceived risks to workers and their families. Survey evidence from emergency healthcare providers found that willingness varied across disaster scenarios, while lack of confidence and uncertainty about personal and family safety were deterrents. Preparedness programmes should therefore integrate protective equipment, occupational-health procedures, exposure management, family-support arrangements, and risk communication, so personnel are not expected to rely on professional obligation without credible institutional protection (Sultan et al., 2020).

The psychosocial burden of prolonged emergencies can erode readiness even when competence remains. During the Ebola epidemic in Sierra Leone, health workers reported fear, stigma, increased workload, resource shortages, and concerns about infection, yet relied on peer relationships, teamwork, training, protective practices, and commitment to patients as coping resources. Frontline resilience therefore emerges from social and organisational conditions that enable staff to function despite sustained adversity, rather than from individual toughness alone (Raven, Wurie & Witter, 2018).

COVID-19 further demonstrated that frontline safety includes psychological as well as physical protection. Healthcare workers in Wuhan experienced symptoms of stress, anxiety, and depression, with frontline exposure creating emotional demands. Emergency preparedness should provide rest opportunities, rotations, confidential counselling, and supportive supervision. These mechanisms can preserve decision quality and prevent cumulative strain from becoming an operational vulnerability during extended responses

Table 1: Illustrative simulation-to-readiness framework

<i>Exercise modality</i>	<i>Primary preparedness function</i>	<i>Capability tested</i>	<i>Practical readiness value</i>
Tabletop exercise	Strategic decision-making	Command, communication, coordination	Identifies procedural and governance gaps
Functional drill	Operational process testing	Surveillance, notification, logistics	Tests workflows without full deployment
Full-scale exercise	System-wide response	Multi-agency coordination and surge	Reveals real-time operational weaknesses
Clinical simulation	Frontline skill development	Triage, treatment, teamwork	Strengthens applied clinical competence
Virtual simulation	Repeatable skills assessment	Triage and decision accuracy	Enables scalable, lower-burden practice
Debriefing cycle	Organisational learning	Reflection and corrective action	Converts exercise findings into improvement

requiring management of uncertainty and high-consequence decisions (Du et al., 2020).

Resilience should also be treated as an organisational capability. Evidence across healthcare settings characterises resilient performance as the capacity to anticipate, monitor, respond, learn, and adapt when actual conditions differ from expected procedures. Team relationships, communication, training, and learning from adaptations strengthen this capacity. Frontline staff therefore require systems permitting flexibility within safety boundaries, because rigid adherence to plans may become counterproductive when resources, patient volumes, or hazards change unexpectedly (Ifaifel et al., 2020).

The physical work environment influences safe and sustained frontline functioning. Engineering evidence on thermodynamic efficiency and environmental-control strategies demonstrates the importance of maintaining controllable indoor conditions through reliable system operation. In emergency healthcare settings, attention to ventilation, temperature control, utilities, and environmental stability can support staff endurance and service continuity when facilities operate beyond routine capacity. Frontline readiness is strengthened when confidence, occupational protection, psychosocial support, adaptive teamwork, and resilient physical infrastructure function as preparedness assets (Sunday et al., 2019).

INCIDENT MONITORING AND OPERATIONAL RESPONSE

Surveillance and Early Warning Systems

Surveillance and early warning systems constitute the information backbone of emergency preparedness because they convert dispersed observations into signals that trigger verification, risk assessment, and timely response. Effective systems combine indicator-based surveillance with event-based approaches capturing unusual occurrences before formal diagnoses accumulate. Evidence from low- and middle-income countries shows that event-based surveillance can complement routine reporting by detecting signals from communities and health facilities, although effectiveness depends on clear event definitions, verification, feedback, and integration with response structures (Kuehne et al., 2019).

At the frontline level, surveillance performance depends on health workers' ability to recognize priority conditions, apply case definitions, complete reporting tools, and understand escalation pathways. In Oyo State, Nigeria, health workers recognized the importance of reporting epidemic-prone diseases, but knowledge of several Integrated Disease Surveillance and Response forms remained limited. Such gaps can weaken sensitivity and timeliness because an early warning architecture is only as reliable as personnel who generate, classify, and transmit signals (Jinadu et al., 2018).

Institutional weaknesses interrupt progression from detection to action. In northern Ghana, surveillance officers

reported improvements in mobile-phone reporting, yet inadequate laboratory capacity, irregular feedback, weak supervision, and limited technical guidance constrained surveillance functions. Early warning therefore requires more than data collection; laboratories, supervision, communication channels, logistics, and feedback loops must operate as an integrated chain that confirms signals and supports prompt intervention (Adokiya et al., 2015).

Emergency settings require surveillance systems that can be deployed rapidly despite disrupted infrastructure and displaced populations. During the Rohingya crisis in Bangladesh, the World Health Organization's Early Warning, Alert and Response System used web-based and mobile technologies to collect and analyse information on epidemic-prone conditions across refugee settlements. Its operation illustrates how standardized syndromic reporting, alert thresholds, and rapid information transfer can sustain situational awareness where conventional surveillance structures are incomplete or under pressure (Karo et al., 2018).

Digital technologies can strengthen timeliness by supporting near-real-time acquisition, processing, visualization, and transmission of health information. Experience across developing settings indicates that technological platforms require appropriate software, trained personnel, professional networks, sustainable financing, and reliable data-processing arrangements. Electronic surveillance should therefore augment rather than replace epidemiological judgement, with automated alerts embedded within governance structures capable of validating anomalies, prioritizing threats, and initiating proportionate response (Chretien & Lewis, 2008).

Automated pattern-recognition principles also demonstrate the value of computational assistance in identifying abnormalities within complex datasets. Nigerian biomedical engineering research using template matching for mammographic feature detection illustrates how algorithms can identify predefined patterns within large information environments. Applied cautiously to public-health surveillance, the underlying principle supports automated screening of data streams for deviations requiring human verification, while reinforcing that detection algorithms must be validated for sensitivity, specificity, context, and operational usefulness before informing emergency decisions (Ejofodomi et al., 2014).

Real-Time Incident Management and Communication

Real-time incident management depends on a command architecture capable of converting changing information into coordinated decisions. During health emergencies, leaders must maintain situational awareness, define priorities, allocate responsibilities, and update actions as evidence evolves. Systematic review evidence on hospital incident command systems identifies clear command structures, staff training, communication, coordination, and organizational support

Table 2: Illustrative Surveillance-to-Response Architecture

<i>Surveillance component</i>	<i>Primary signal source</i>	<i>Early-warning function</i>	<i>Preparedness value</i>
Indicator-based surveillance	Routine facility reports	Detects threshold changes	Tracks established priority conditions
Event-based surveillance	Community and informal signals	Identifies unusual events	Extends detection beyond routine reporting
Syndromic surveillance	Symptoms and clinical presentations	Detects emerging patterns	Provides warning before confirmation
Laboratory surveillance	Diagnostic and genomic results	Confirms suspected threats	Improves specificity of alerts
Digital surveillance	Electronic and online data	Accelerates signal recognition	Strengthens near-real-time awareness
Alert verification	Epidemiological investigation	Validates detected signals	Prevents unnecessary escalation
Response linkage	Incident-management structures	Converts alerts into action	Reduces detection-to-response delays

as determinants of effectiveness, indicating that command arrangements should be rehearsed rather than merely documented (Bahrami et al., 2020).

Communication is equally important because delayed, fragmented, or inconsistent information can undermine otherwise sound decisions. Crisis and Emergency Risk Communication provides a model in which communication changes across pre-crisis, initial event, maintenance, resolution, and evaluation phases. The model emphasizes accurate, credible, and empathetic messaging while recognizing that information needs change as uncertainty develops. Integrating these principles into incident management helps align internal instructions, public messaging, and behavioral guidance with the evolving operational picture (Reynolds & Seeger, 2005).

Experience from Liberia demonstrates the value of locally responsive communication during outbreak management. Post-Ebola responses to meningococcal disease incorporated community engagement, radio messaging, interpersonal communication, rumor monitoring, and dialogue with local leaders. These practices strengthened trust and encouraged timely reporting of illness, showing that real-time communication must operate bidirectionally: authorities disseminate guidance while continuously receiving community perceptions, misinformation, and behavioral signals that can influence incident priorities (Sumo et al., 2019).

Within multi-agency disaster operations, information sharing becomes more difficult when teams use different terminology, technologies, objectives, and organizational assumptions. Evidence from a European disaster exercise found that shared frames of reference, common information structures, role clarity, and coordination supported information exchange across national and professional boundaries. Incident managers therefore require standardized reporting formats, interoperable communication channels, and disciplined briefing routines that reduce ambiguity while preserving speed for operational decisions (Waring, Humann & Dawson, 2019).

Technology can strengthen real-time management by enabling information capture, victim tracking, capacity assessment, event logging, and distributed access to data.

Research on out-of-hospital disaster response highlights the potential of information technology to improve coordination, while identifying human, technical, communications, and security constraints. Digital platforms should therefore support rather than replace command judgement, with redundancy built into communications so teams can continue operating if networks, devices, or systems fail (Arnold et al., 2004).

Operational communication also depends on resilient supporting infrastructure. Nigerian engineering research on hybrid solar installations demonstrates the importance of optimizing electrical load distribution where power resources are constrained. In health emergencies, the same systems principle supports prioritizing electricity for command centres, communications equipment, laboratories, data systems, refrigeration, and clinical functions. Real-time incident management is strengthened when information flows and physical infrastructure are jointly monitored, enabling leaders to identify constraints, rebalance resources, and sustain communication-intensive response functions during prolonged or infrastructure-disrupting emergencies (Sunday & Omoegun, 2019).

PREPAREDNESS GAPS AND FUTURE PRIORITIES

System Barriers and Capacity Inequalities

Health-system barriers become most visible during emergencies because shocks amplify weaknesses tolerated during routine service delivery. Capacity inequalities arise from uneven financing, infrastructure, workforce distribution, information systems, and managerial capability, producing differences in the ability of facilities and regions to absorb sudden demand effectively. In Nigeria, longstanding deficiencies in surveillance, medical intelligence, infrastructure, management, and coordination have limited system responsiveness, where public-health functions depend on fragmented institutional arrangements and weak information flows (Welcome, 2011).

Workforce inequality is central because emergency capacity depends not merely on where personnel are located, retained,

Table 3: Illustrative Real-Time Incident Management and Communication Framework

<i>Incident-management function</i>	<i>Real-time information required</i>	<i>Communication mechanism</i>	<i>Operational purpose</i>
Situation monitoring	Cases, hazards, capacity, resources	Dashboards and situation reports	Maintains shared situational awareness
Command activation	Incident severity and escalation triggers	Incident command briefings	Establishes authority and priorities
Resource coordination	Staff, beds, supplies, transport	Logistics and operations channels	Directs scarce resources dynamically
Clinical coordination	Patient volumes and acuity	Facility and referral communication	Balances demand across services
Public risk communication	Threat level and protective guidance	Media and community channels	Promotes informed protective behaviour
Rumour management	Misinformation and public concerns	Community feedback mechanisms	Protects trust and message credibility
Infrastructure monitoring	Power, connectivity, equipment status	Technical operations reporting	Sustains critical response functions
Feedback and adaptation	Outcomes and operational bottlenecks	Command-cycle review	Supports rapid corrective decisions

and supported. Rural Sierra Leone illustrates this problem: health workers reported living conditions, professional isolation, weak infrastructure, limited career opportunities, and family separation as factors discouraging rural retention. Such maldistribution means peripheral facilities may enter emergencies with fewer skilled personnel than urban centres, creating unequal surge capability, slower referral, and greater risk that underserved populations lose access when routine services are disrupted (Wurie, Samai & Witter, 2016).

These disparities are reinforced by labour-market imbalances. Projections indicate that health-worker shortages will be concentrated in lower-income settings, while higher-income countries may have greater capacity to attract professionals. This mismatch between population need, fiscal capacity, and labour demand can deepen inequities, leaving vulnerable systems with insufficient staffing for surveillance, emergency care, infection prevention, logistics, and recovery. Workforce planning must therefore address training, financing, retention, geographic distribution, and task allocation rather than focusing solely on graduate numbers (Liu et al., 2017).

Financing capacity determines whether preparedness plans can be converted into deployable resources. Evidence across 184 countries demonstrates marked differences in health expenditure, with low-income and lower-middle-income countries relying more heavily on out-of-pocket payments and development assistance while mobilising fewer prepaid resources. In emergencies, these gaps can restrict procurement, laboratory expansion, staffing, transport, communications, and continuity of services. Unequal fiscal space consequently becomes unequal response capacity where emergency expenditure competes with underfunded routine programmes (Global Burden of Disease Health Financing Collaborator Network, 2017).

Across Africa, health-system weaknesses reflect interacting deficiencies rather than isolated shortages. Multicountry evidence identifies inadequate human resources, insufficient

budgetary allocation, and weak leadership and management among prominent constraints, alongside problems involving infrastructure, medicines, information, and service delivery. Because these components are interdependent, investment in one domain may produce limited preparedness gains if complementary capabilities remain weak. Emergency strengthening therefore requires balanced development across governance, workforce, financing, logistics, technology, and service delivery, with attention to under-resourced districts and facilities (Oleribe et al., 2019).

Inequality also concerns quality, not simply availability. Health systems may expand coverage while leaving populations exposed to inaccurate diagnosis, delayed treatment, unsafe care, or weak referral pathways. Global evidence shows that poor-quality services account for preventable mortality in low- and middle-income countries and that access without competent care cannot deliver expected gains. During disasters, these deficits become operational vulnerabilities because facilities must manage greater clinical complexity under pressure, making dependable processes, competent teams, and effective referral systems fundamental to preparedness (Kruk et al., 2018).

Governance can either mitigate or reproduce capacity inequalities. Resilient systems require the ability to absorb disruption, adapt operations, and transform arrangements when existing structures no longer fit changing conditions. This depends on knowledge, uncertainty management, interdependence, and institutional legitimacy. Where authority, information, and resources are concentrated centrally, peripheral institutions may lack flexibility to resolve bottlenecks. Preparedness policy should therefore combine national standards with local authority, coordination mechanisms, and learning capacity to address context-specific constraints during emergencies (Blanchet et al., 2017).

Ebola outbreaks in sub-Saharan Africa show how poverty, fragile infrastructure, weak surveillance, limited laboratory

capability, inadequate budgets, and constrained treatment capacity can converge during high-consequence events. These barriers are compounded by geographic and social inequalities that delay diagnosis and reduce access to care. Strengthening preparedness requires directing resources toward vulnerable communities before crises, improving laboratories and early warning, reinforcing primary care, and ensuring emergency investments leave durable capacity. Without equity-oriented strengthening, disaster response risks reproducing existing disparities when population needs are greatest (Rugarabamu et al., 2020).

Policy, Innovation, and Research Priorities

Policy priorities for emergency preparedness should move health systems from episodic crisis reaction toward sustained, financed readiness. Nigeria's Joint External Evaluation and National Action Plan for Health Security illustrate the value of multisectoral assessment, costed planning, and accountability across surveillance, laboratories, workforce, emergency operations, immunisation, and risk communication. Future policy should protect preparedness budgets, establish targets, and link evaluation to implementation, financing, and corrective action (Ojo et al., 2020).

Policy effectiveness depends on how ministries generate, manage, update, and institutionalise guidance. South African experience shows fragmented policy processes can weaken implementation, whereas standardised procedures, documented responsibilities, and policy-information systems improve consistency and institutional memory. Emergency-preparedness governance should embed evidence review, revision cycles, stakeholder consultation, and implementation tracking within routine administration, allowing policies to change without sacrificing accountability, coherence, or continuity across levels (Lane et al., 2020).

Innovation priorities should concentrate on technologies that strengthen detection, communication, service continuity, and distributed decision-making. Digital health can support remote screening, surveillance, epidemiological analysis, information dissemination, and population engagement, but adoption requires interoperable data standards, cybersecurity, workforce capability, reliable connectivity, and safeguards for privacy and equity. Investment should favour platforms integrated with existing health-information architecture rather than short-lived emergency applications that fragment datasets or become unusable when external financing ends (Mahmood et al., 2020).

Preparedness innovation must address chronic underinvestment in countermeasure development for epidemic threats. The Coalition for Epidemic Preparedness Innovations demonstrates the importance of pooled financing, international partnerships, platform technologies, and coordinated research portfolios for vaccines against diseases lacking attractive commercial markets. Similar mechanisms should extend to diagnostics, therapeutics, protective technologies, and

manufacturing capacity, while ensuring research agendas reflect disease burdens and access requirements in resource-constrained settings rather than priorities defined mainly by wealthier markets (Brende et al., 2017).

Research priorities should be determined with practitioners who implement emergency programmes. Evidence from United States preparedness agencies indicates that research agendas become more useful when frontline and jurisdictional decision-makers identify knowledge gaps concerning communication, workforce, exercises, vulnerable populations, recovery, and programme effectiveness. Future studies should move beyond descriptive readiness assessments toward comparative implementation research, longitudinal evaluation, cost-effectiveness analysis, and validated performance indicators that establish which preparedness interventions work, for whom, under what conditions, and at sustainable cost (Siegfried et al., 2017).

Systems modelling should complement policy and research priorities by testing how innovations interact with infrastructure before deployment. Nigerian work modelling hydrogen integration within national energy systems illustrates the value of analysing compatibility, capacity, system balance, and integration requirements when introducing technologies. Applied to health emergency preparedness, comparable modelling can test resilient energy options, logistics networks, surge pathways, communications, and resource dependencies under different hazard scenarios, enabling policymakers to identify bottlenecks and evaluate investments before emergencies expose system weaknesses (Adeniji et al., 2019).

CONCLUSION

This review examined how health systems build and sustain emergency preparedness and disaster response capacity through institutional readiness, workforce training, incident monitoring, resource mobilisation, and frontline resilience. The evidence demonstrated that preparedness is not a static plan but an operational capability shaped by governance, financing, infrastructure, surveillance, communication, workforce competence, and the ability to adapt under pressure. Across diverse settings, systems performed more effectively when emergency structures were clearly defined, responsibilities were rehearsed, information moved rapidly, and resources could be redeployed without disrupting essential services.

The review also showed that competency-based training, simulation exercises, and structured drills are central to converting theoretical preparedness into reliable frontline performance. Practical exercises expose weaknesses in command, communication, triage, logistics, and interagency coordination before real events occur, while repeated assessment strengthens confidence and role clarity. Similarly, surveillance and early warning systems were found to be most effective when data collection, verification, laboratory support, digital tools, and incident-management pathways were integrated into a continuous decision cycle.

Persistent inequalities in workforce distribution, financing, infrastructure, and institutional capability nevertheless continue to weaken preparedness, particularly in resource-constrained environments.

The study therefore concludes that resilient emergency response depends on sustained investment in preparedness as a core health-system function rather than an episodic crisis activity. Health authorities should institutionalise competency-based education, routine multi-agency simulation, interoperable surveillance platforms, resilient power and communication systems, and transparent incident-command structures. Greater priority should also be given to equitable workforce deployment, protected preparedness financing, local manufacturing and supply resilience, and implementation research that evaluates preparedness interventions under realistic conditions. Such integration is essential for protecting populations during increasingly complex emergencies. Future policy should link national standards with locally adaptable response mechanisms, ensuring that lessons from exercises and emergencies are systematically translated into updated protocols, training priorities, infrastructure investment, and measurable readiness improvements across all levels of care.

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