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Comprehensive Review of Global Infectious Disease Preparedness Frameworks for Strengthening Health System Resilience

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Abstract- ***Global infectious disease threats continue to expose persistent weaknesses in national and international health systems, underscoring the urgent need for resilient preparedness frameworks. This comprehensive review examines major global infectious disease preparedness frameworks and evaluates their contributions to strengthening health system resilience across diverse settings. The review synthesizes evidence from international policy documents, peer-reviewed studies, and institutional reports addressing preparedness governance, surveillance systems, workforce capacity, laboratory infrastructure, emergency coordination, risk communication, financing, and equitable service delivery. Particular attention is given to the International Health Regulations, the Global Health Security Agenda, Joint External Evaluation processes, pandemic preparedness plans, and integrated One Health approaches. Findings indicate that effective preparedness frameworks share several core characteristics: strong governance and accountability mechanisms, interoperable surveillance and data systems, sustained investment in public health infrastructure, multisectoral coordination, community engagement, and adaptive response capacity. However, the review also identifies major implementation gaps, especially in low- and middle-income countries, where limited financing, weak institutions, fragmented data systems, and workforce shortages constrain preparedness outcomes. In addition, the unequal distribution of medical countermeasures, inconsistent political commitment, and insufficient integration of primary health care into emergency planning continue to undermine resilience. Lessons from recent outbreaks demonstrate that preparedness must extend beyond emergency response planning to include long-term system strengthening, local manufacturing capacity, digital health innovation, and context-specific policy adaptation. The review concludes that infectious disease preparedness frameworks are most effective when embedded within broader health system resilience strategies that promote flexibility, inclusiveness, and continuity of essential services during crises. Strengthening preparedness therefore requires coordinated global support, domestic policy commitment, and sustained investments that align health security with universal health coverage goals. By consolidating current knowledge, this review provides practical insights for policymakers, public health leaders, and researchers seeking to build more robust, equitable, and responsive health systems capable of withstanding future infectious disease threats. It further emphasizes the importance of simulation exercises, transparent information sharing, legal readiness, decentralized decision-making, and cross-border collaboration in improving preparedness performance. A resilience-oriented preparedness agenda can reduce morbidity, mortality, social disruption, and economic instability while enhancing trust in health institutions before, during, and after outbreaks. across contexts.***

Keywords: Infectious Disease Preparedness, Health System Resilience, Global Health Security, Pandemic Preparedness, One Health, Surveillance Systems, Emergency Response, Public Health Governance

I. INTRODUCTION

Infectious disease outbreaks remain one of the most persistent and complex threats to global health, social stability, and economic development. Over the past decades, the world has experienced repeated public health emergencies, including severe acute respiratory syndrome, H1N1 influenza, Ebola virus disease, Zika virus disease, coronavirus disease, mpox, and recurrent cholera and measles outbreaks. These events have shown that infectious diseases can spread rapidly across borders, overwhelm health services, disrupt livelihoods, and expose longstanding weaknesses in national and international response systems (Ike, et al., 2018, Kyere Yeboah & Enow, 2018). Globalization, urbanization, population displacement, climate variability, antimicrobial resistance, ecological

change, and increased human-animal interaction have further intensified the risk of emerging and re-emerging infectious diseases. As a result, preparedness for infectious disease threats has become a central priority in public health policy and health systems planning worldwide.

Preparedness frameworks are structured policy and operational instruments designed to guide countries and institutions in anticipating, detecting, preventing, responding to, and recovering from infectious disease threats. They provide the strategic foundations for organizing surveillance, laboratory systems, workforce readiness, emergency coordination, risk communication, logistics, financing, and multisectoral collaboration. Their importance lies in offering a coherent and standardized approach to managing uncertainty before crises escalate into large-scale emergencies (Filani, Nwokocha & Babatunde, 2019, Kyere Yeboah & Enow, 2019). Rather than relying on ad hoc responses, preparedness frameworks promote planned capacity development, clarify institutional roles, strengthen accountability, and support continuous improvement through assessment and monitoring. In the context of increasing epidemic threats, such frameworks are essential for ensuring that health systems can act early, respond effectively, and maintain essential services under pressure.

The connection between infectious disease preparedness and health system resilience is especially significant. Health system resilience refers to the capacity of health institutions, workers, and supporting structures to absorb shocks, adapt to changing conditions, and continue delivering core services during and after crises. Preparedness strengthens resilience by building core capacities that reduce vulnerability and improve system flexibility. Effective surveillance, trained personnel, integrated governance, strong supply chains, and adaptive financing mechanisms not only support outbreak control but also enhance the broader ability of health systems to withstand disruption. Thus, preparedness should not be viewed as a narrow emergency function, but as a key component of resilient health system development (Filani, Nwokocha & Babatunde, 2019).

Reviewing global infectious disease preparedness frameworks is important because multiple frameworks now shape how countries assess risks, build capacities, and coordinate responses. These include international legal instruments, technical guidance platforms, evaluation mechanisms, and multisectoral strategies developed by global institutions and partnerships. Although these frameworks share similar objectives, they differ in structure, emphasis, implementation requirements, and practical effectiveness across settings. A critical review is therefore necessary to identify their common pillars, strengths, limitations, and areas of overlap, while also clarifying how they contribute to stronger and more resilient health systems. Such a review is particularly relevant for understanding why preparedness outcomes remain uneven across countries despite the presence of established global guidance (Ike, et al., 2018, Kyere Yeboah & Enow, 2018).

This review aims to comprehensively examine major global infectious disease preparedness frameworks and analyze their relevance for strengthening health system resilience. It focuses on key components such as governance, surveillance, laboratory readiness, workforce development, emergency coordination, financing, community engagement, and multisectoral integration. The review also considers implementation challenges, contextual differences across health systems, and lessons from recent outbreaks. By synthesizing these dimensions, it seeks to provide a clearer understanding of how preparedness frameworks can be aligned with long-term health system strengthening efforts and used to improve resilience in the face of future infectious disease threats (Filani, Nwokocha & Babatunde, 2019, Kyere Yeboah & Enow, 2019).

2.1. Methodology

An integrative comprehensive review method was adopted for this study because the body of literature supplied for the topic contains a mixture of conceptual papers, policy-oriented studies, systems frameworks, empirical analyses, and multidisciplinary publications rather than a narrowly uniform set of primary studies. This method was considered the most suitable because the aim of the study is not to estimate a single pooled effect size, but to critically examine how major infectious disease preparedness frameworks contribute to strengthening health system resilience

across different contexts. An integrative review allows the inclusion and synthesis of varied forms of evidence, including conceptual contributions, framework papers, public health systems literature, and resilience-oriented analyses. This was especially important for the present topic because preparedness frameworks are multidimensional and cut across governance, surveillance, laboratory systems, health workforce capacity, financing, emergency response, and cross-sector coordination. The method therefore provided the flexibility needed to review diverse but relevant evidence while maintaining analytical rigor and thematic coherence.

The review was guided by a structured evidence synthesis process designed to ensure transparency, consistency, and relevance. The user-provided reference list served as the primary source pool for the review. However, because the supplied references included studies from multiple fields such as engineering, finance, architecture, digital systems, energy, and public health, the review first involved a relevance-based sorting of the literature. The purpose of this step was to identify those studies with direct or transferable relevance to infectious disease preparedness frameworks, public health system strengthening, disaster risk management, resilience, governance, emergency planning, surveillance systems, and institutional response capacity. In particular, papers such as Bloland et al. on global health system strengthening, Khan et al. on public health emergency preparedness and resilience, and Olu on resilient health systems and disaster risk management were treated as core anchor references because they directly aligned with the conceptual focus of the study. Other references that did not address infectious disease preparedness directly but offered transferable insights into governance, risk management, systems integration, resilience thinking, policy design, or infrastructure coordination were considered as supporting conceptual literature where relevant to the review objectives.

The review question was framed broadly to explore how global infectious disease preparedness frameworks are conceptualized, what their major components are, how they are implemented, and in what ways they contribute to health system resilience. In line with this objective, the literature selection was not restricted to one type of study design. Conceptual papers, reviews, framework articles, policy discussions, and empirical public health studies were all considered eligible if they contributed meaningfully to understanding preparedness systems, resilience capacities, and implementation lessons. This broad inclusion logic is one of the strengths of an integrative review, particularly for a topic where key insights often come not only from quantitative outcomes but from institutional analysis, systems thinking, and policy interpretation. At the same time, studies were not included automatically merely because they appeared in the source list. A purposive relevance screen was applied to ensure that only materials contributing to the topic of infectious disease preparedness and health system resilience were synthesized in the main analysis.

The relevance screening process involved reading titles first, followed by abstracts or introductory sections where available, in order to determine whether each source addressed one or more of the central concerns of the review. Studies were retained when they focused on infectious disease preparedness, health system strengthening, public health emergency readiness, resilience frameworks, surveillance and laboratory systems, emergency response structures, policy coordination, governance, community-based interventions, or cross-sector collaboration in health-related settings. Studies were excluded from the substantive synthesis when they focused exclusively on unrelated technical domains such as cloud computing, enterprise finance, telecommunications pricing, construction materials, housing design, or general infrastructure issues without a clear conceptual bridge to preparedness or health system resilience. This screening process was necessary because the supplied literature set was heterogeneous, and the methodological integrity of the review depended on separating directly relevant evidence from peripheral or non-applicable material. Where a source lay outside infectious disease preparedness but offered a systems-based concept such as resilience, risk governance, or integrated planning, it was used cautiously and only where it clearly strengthened the theoretical framing of the review.

After the relevance screening, the retained sources were organized into an analytical review matrix. This

matrix was used to extract and compare key information from each selected study in a structured way. The extracted fields included author and year, publication type, setting or context, principal theme, methodological orientation, preparedness or resilience concept addressed, and the specific contribution made to understanding infectious disease preparedness frameworks. Additional fields captured whether the study contributed mainly to governance and policy, surveillance and information systems, workforce readiness, financing and logistics, community participation, One Health or multisector collaboration, or resilience theory and system adaptation. This extraction process was designed to move the review beyond simple description and toward a comparative understanding of how different studies contributed to the major domains of preparedness. The matrix also helped identify recurrent concepts, overlapping framework elements, implementation barriers, and transferable lessons across settings.

The synthesis process was framework-based and thematic. Rather than aggregating numerical outcomes, the review analyzed how the literature converged around major components of infectious disease preparedness and health system resilience. The included studies were grouped into thematic domains that reflected the structure of the review itself. These domains included conceptual foundations of preparedness and resilience, major global preparedness frameworks, governance and policy coordination, surveillance and laboratory systems, workforce readiness and resource mobilization, and implementation challenges across diverse health system settings. Within each domain, the literature was read comparatively to identify areas of agreement, divergence, and complementarity. The purpose of this method was to build a coherent account of the architecture of preparedness frameworks while also showing how these frameworks operate within broader health system realities. Through this approach, the review was able to connect high-level preparedness models with practical system functions such as leadership, information flow, staffing, financing, and service continuity.

A critical interpretive element was incorporated into the methodology because the review did not seek only to summarize existing frameworks but also to examine their strengths, limitations, and practical implications. This critical dimension involved assessing whether the identified frameworks were sufficiently integrated, context-sensitive, and adaptable to different health system environments. It also involved comparing how various sources conceptualized resilience, whether preparedness was treated narrowly as emergency response or more broadly as long-term system strengthening, and how far the literature addressed issues such as inequity, sustainability, implementation gaps, and institutional learning. In this way, the methodology moved beyond a catalog of frameworks and toward an analytical review of how preparedness knowledge is constructed and applied. This was particularly relevant for identifying why countries may adopt similar preparedness principles yet achieve different outcomes based on financing, infrastructure, governance quality, and social context.

Because the literature base included a combination of conceptual and applied studies, formal statistical meta-analysis was not appropriate. The sources differed widely in publication type, focus, scope, and methodological orientation, making quantitative pooling neither feasible nor meaningful for the study objective. Instead, narrative synthesis was used to integrate evidence into a coherent scholarly account. Narrative synthesis was suitable because it allowed the review to examine relationships across ideas, identify thematic continuities, and explain how different components of preparedness frameworks relate to health system resilience. This method also made it possible to preserve contextual nuance, which is essential in preparedness studies where implementation conditions vary greatly across countries and institutions. Through narrative integration, the study connected framework components to broader questions of resilience, such as absorptive capacity, adaptation, service continuity, and system learning.

To improve trustworthiness, the methodology emphasized conceptual relevance, internal consistency, and analytical triangulation across the retained studies. Sources were not treated as equally informative; greater interpretive weight was given to papers with direct relevance to public health preparedness, resilience, and health system strengthening. Foundational and conceptually strong

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studies were used to anchor the analysis, while supporting literature was used to extend or contextualize particular arguments. The review also maintained alignment between the selected evidence and the chapter structure, ensuring that each section of the study drew from literature most relevant to the issue under discussion. This helped reduce conceptual drift and strengthened the overall coherence of the review.

Overall, the methodology adopted for this study was appropriate for a comprehensive review of global infectious disease preparedness frameworks because it balanced breadth with relevance, allowed the use of mixed forms of evidence, and supported a critical thematic synthesis of preparedness and resilience literature. By applying an integrative review design, purposive relevance screening, structured data extraction, framework-based analysis, and narrative synthesis, the study was able to generate a logically organized and analytically grounded account of how preparedness frameworks contribute to stronger health systems. This methodology also provided a sound basis for identifying implementation gaps, comparing major preparedness domains, and developing conclusions about the role of integrated frameworks in strengthening health system resilience in the face of infectious disease threats.

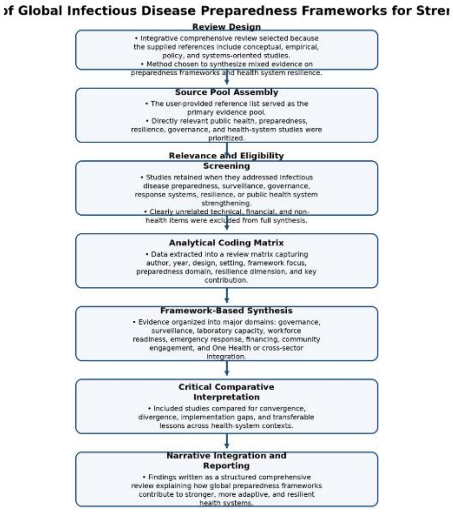

Figure 1: Flowchart of the study methodology

2.2. Conceptual Foundations of Infectious Disease Preparedness and Health System Resilience

Infectious disease preparedness refers to the deliberate development of policies, systems, capacities, and coordinated actions that enable health institutions and societies to anticipate, detect, prevent, respond to, and recover from infectious disease threats in a timely and effective manner. It is not limited to emergency response after an outbreak has already begun; rather, it includes the continuous strengthening of surveillance systems, laboratory networks, workforce competencies, legal frameworks, risk communication channels, emergency logistics, and governance arrangements before a crisis occurs (Ayanbode, et al., 2019, Bamgboye, et al., 2019, Ogbole, et al., 2019). Preparedness therefore represents a forward-looking public health function grounded in planning, risk assessment, simulation, resource mobilization, and institutional coordination. Its central purpose is to reduce the likelihood that infectious hazards escalate into widespread health emergencies and to minimize mortality, morbidity, social disruption, and economic loss when outbreaks do occur. In this sense, preparedness is both a technical and governance-oriented concept, because it requires scientific capability as well as clear leadership, accountability, and cross-sector collaboration.

Health system resilience, by contrast, refers to the capacity of a health system to absorb shocks, respond effectively to disruption, maintain core functions during a crisis, and reorganize itself based on lessons learned so that it becomes stronger and more adaptive over time. A resilient health system does not merely survive a public health emergency; it continues to provide essential services, protects vulnerable populations, supports its workforce, and adjusts its operations in ways that reduce future risk (Aransi, et al., 2019, Bankole, et al., 2019, Okeke, Ugwu-Oju & Nwankwo, 2019). The concept emerged from growing recognition that health systems are repeatedly exposed to pressures arising not only from epidemics, but also from conflict, economic instability, climate-related disasters, and demographic change. Within the context of infectious disease threats, resilience highlights the importance of flexibility, redundancy, coordination, and institutional learning. It shifts attention away from narrow event-based responses toward the broader

capacity of health structures to function under stress without collapsing or abandoning routine care. Figure 2 shows resilience framework for public health emergency preparedness presented by Khan, et al., 2018.

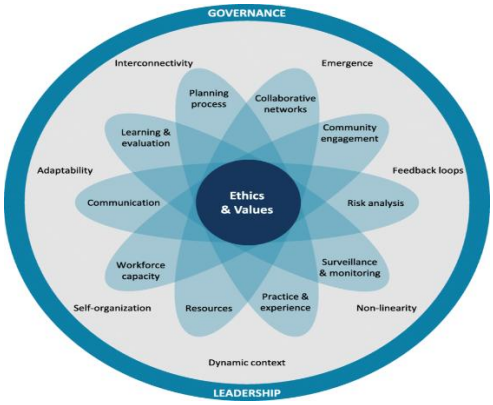

Figure 2: Resilience Framework for Public Health Emergency Preparedness (Khan, et al., 2018).

The conceptual relationship between preparedness and resilience is close and mutually reinforcing. Preparedness contributes to resilience by building the capacities that allow a health system to act early and effectively when faced with infectious threats. Resilience, in turn, determines whether preparedness measures are sufficiently embedded in the health system to remain functional under real-world pressure. A country may have preparedness plans on paper, but without resilient institutions, reliable financing, trained personnel, and public trust, those plans may fail when tested by a large outbreak (Uzondu & Ofoedu, 2014). Likewise, resilience without preparedness may leave a system adaptive in general terms but insufficiently equipped for the speed and complexity of epidemic events. The most effective approach therefore views preparedness as a foundational component of resilience and resilience as the broader system quality that sustains preparedness across time and crisis conditions.

Several core dimensions define resilience in health systems. The first is absorptive capacity, which refers to the ability of the system to withstand shocks while preserving essential structures and functions. During an outbreak, this includes maintaining hospital operations, ensuring the availability of medicines and protective equipment, and continuing critical services such as maternal care, immunization, and chronic disease treatment. The second is adaptive capacity, meaning the ability to modify strategies, reallocate resources, revise protocols, and innovate in response to changing conditions (Efobi, Akinleye & Fasawe, 2017, Ekechi, 2019, Ugwu-Oju, Okeke & Nwankwo, 2018). This may involve expanding telemedicine, decentralizing treatment delivery, retraining staff, or adjusting surveillance methods as an epidemic evolves. The third is transformative capacity, which goes beyond short-term adjustment and refers to the ability of the health system to undertake deeper structural reforms based on crisis experience. Examples include redesigning supply chains, investing in local manufacturing, reforming public health law, strengthening primary care, or integrating digital tools into routine service delivery. Together, these dimensions reflect the idea that resilience is not a single trait but a combination of resistance, flexibility, and long-term system improvement (Michael & Ogunsola, 2019, Seyi-Lande, Arowogbadamu & Oziri, 2019, Umoren, et al., 2019).

Other important dimensions of resilience include governance, information flow, workforce stability, community trust, and equity. Good governance ensures that decision-making is timely, transparent, coordinated, and evidence-based. Information flow supports situational awareness through surveillance, data integration, and communication across different levels of the health system. Workforce stability depends on adequate staffing, training, protection, and psychosocial support, especially during prolonged emergencies. Community trust influences whether populations comply with public health measures, seek care early, and accept interventions such as testing and vaccination (Anthony, et al., 2019, Bankole, et al., 2019, Okeke, Ugwu-Oju & Nwankwo, 2019). Equity is equally central because health systems cannot be considered resilient if they preserve services only for privileged groups while marginalized populations face disproportionate harm. A resilience-oriented framework therefore emphasizes inclusive planning and the ability to meet the needs of diverse communities under crisis conditions.

Preparedness, response, recovery, and adaptation should be understood as interconnected phases within a continuous cycle rather than as isolated stages.

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Preparedness lays the groundwork by establishing the capacities, relationships, plans, and resources needed before an outbreak occurs. Response begins once a threat emerges and involves activating emergency mechanisms, investigating cases, containing transmission, treating affected populations, and communicating risks to the public. Recovery follows the acute phase and focuses on restoring disrupted services, addressing secondary health impacts, rebuilding institutional stability, and evaluating the effectiveness of actions taken (Anichukwueze, Osuji & Oguntegbe, 2019, Dako, et al., 2019, Ugwu-Oju, Okeke & Nwankwo, 2018). Adaptation then uses lessons from recovery and response to improve future preparedness, refine governance arrangements, strengthen infrastructure, and reduce recurring vulnerabilities. This cyclical relationship shows that outbreak management is not a temporary function detached from routine health system development; instead, every epidemic reveals weaknesses that should inform future reform. When this cycle is broken, health systems repeat the same failures across successive outbreaks. Figure 3 shows public health framework for health systems strengthening presented by Bloland, et al., 2012.

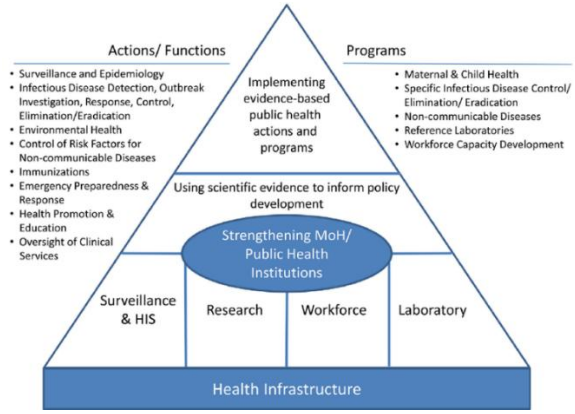

Figure 3: Public health framework for health systems strengthening (Bloland, et al., 2012).

The importance of prevention within this cycle cannot be overstated. Prevention reduces the burden placed on emergency response systems by identifying and addressing risks before they generate widespread transmission. In infectious disease preparedness, prevention includes immunization, infection prevention and control, vector control, health education, border health measures, antimicrobial stewardship, community surveillance, and One Health collaboration that addresses the links between human, animal, and environmental health. Preventive measures are cost-effective and strategically valuable because they reduce exposure, interrupt transmission pathways, and lower the scale of crisis response required (Uzondu & Ofoedu, 2011, Yeboah & Enow, 2018). They also create a more stable foundation for resilience, since a system that invests in prevention is less likely to become overwhelmed during shocks.

Readiness is another critical concept and refers to the operational state of being able to act immediately when a threat appears. Whereas preparedness can be seen as the broader long-term process of building capacity, readiness reflects whether that capacity is currently functional, accessible, and deployable. A country may have trained personnel, diagnostic tools, and emergency plans, but if supplies are expired, reporting channels are delayed, funding is inaccessible, or coordination roles are unclear, real readiness is weak. Readiness therefore depends on regular drills, stockpile maintenance, clear command structures, interoperable systems, and continuous review. It is the practical expression of preparedness and a key determinant of response speed and effectiveness (Onovo, Gado & Atobatele, 2012, Patrick, et al., 2019, Ugwu-Oju, Okeke & Nwankwo, 2018).

Continuity of care is equally fundamental to both preparedness and resilience. Infectious disease emergencies often disrupt routine health services, leading to indirect deaths and long-term health setbacks unrelated to the outbreak itself. During epidemics, patients may lose access to maternal services, immunization, HIV treatment, tuberculosis care, mental health support, and management of non-communicable diseases. A resilient and prepared health system must therefore protect essential care pathways even while responding to new threats. Continuity of care preserves public trust, reduces secondary harm, and prevents health crises from multiplying across populations. It also reflects the maturity of the health system, because the ability to manage both emergency and routine needs simultaneously is one of the clearest markers of resilience (Erigha, et al., 2019, Filani, Fasawe & Umoren, 2019, Ugwu-Oju, Okeke & Nwankwo,

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2018). Figure 4 shows the health system building blocks as a conceptual framework for public health disaster risk management presented by Olu, 2017.

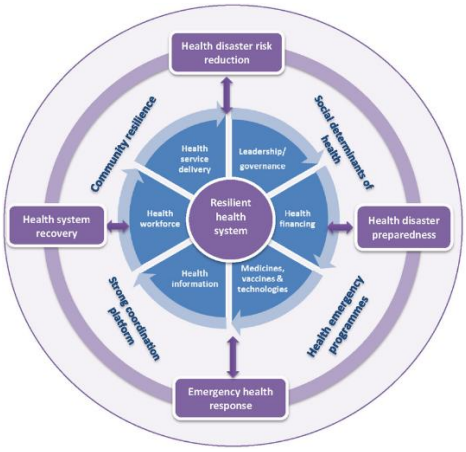

Figure 4: The health system building blocks as a conceptual framework for public health disaster risk management (Olu, 2017).

Taken together, the conceptual foundations of infectious disease preparedness and health system resilience show that neither concept can be treated as narrow emergency terminology. Preparedness is a strategic, continuous investment in the capacities required to confront infectious threats, while resilience is the broader ability of the health system to absorb, adapt, transform, and continue serving populations under stress. Their integration is essential for effective outbreak management, sustained service delivery, and long-term health security (Yetunde, Onyelucheya & Dako, 2018). A review of global preparedness frameworks must therefore pay close attention to how these concepts are defined, operationalized, and linked in practice, because strong preparedness without resilience is fragile, and resilience without preparedness is incomplete.

2.3. Major Global Infectious Disease Preparedness Frameworks and Their Core Components

Major global infectious disease preparedness frameworks have evolved in response to repeated epidemics, pandemics, and transboundary health emergencies that revealed the limits of fragmented national responses. These frameworks provide the legal, institutional, and operational foundations through which countries and international bodies seek to prevent, detect, and respond to infectious disease threats. They are designed not only to improve emergency management, but also to strengthen routine public health capacity, governance, coordination, and resilience across health systems (Aye and Tawose, 2015). Although they differ in scope, authority, and implementation mechanisms, the major frameworks collectively shape contemporary global health security architecture and influence how preparedness is assessed, financed, and operationalized.

One of the most important frameworks is the International Health Regulations, commonly recognized as the central legally binding instrument for global health emergency preparedness and response. The International Health Regulations were developed to help countries prevent the international spread of disease while avoiding unnecessary interference with travel and trade. Their modern relevance lies in requiring States Parties to build core capacities in surveillance, reporting, verification, response, risk communication, laboratory systems, and coordination at points of entry. The framework emphasizes timely notification of events that may constitute a public health emergency of international concern and establishes obligations for information sharing between countries and the World Health Organization (Aye and Tawose, 2016, Lawal & Oduleye, 2018). In practical terms, the International Health Regulations provide a rules-based structure for collective vigilance and accountability. Their strength lies in setting universal expectations for preparedness and creating a shared language for outbreak reporting and response. However, implementation has varied widely across countries, often reflecting differences in financial resources, political commitment, technical capacity, and institutional maturity. Even so, the framework remains foundational because it links national preparedness to global responsibility and makes infectious disease control a matter of international cooperation rather than solely domestic concern.

Closely related to the regulatory approach of the International Health Regulations is the Global Health Security Agenda, which introduced a more action-oriented and partnership-driven model for improving preparedness capacity. The Global Health Security

Agenda was established to accelerate progress toward a world safe from infectious disease threats by promoting practical collaboration among governments, international organizations, civil society, and technical partners (Lawal & Oduleye, 2018, Okonkwo, Ogunwole & Okeke, 2018). Its strategic focus is on strengthening countries' ability to prevent avoidable epidemics, detect threats early, and respond rapidly and effectively. Unlike purely legal frameworks, the Global Health Security Agenda places strong emphasis on targeted capacity-building, measurable action packages, and multisector engagement. Its agenda has highlighted issues such as biosafety, biosecurity, immunization, real-time surveillance, laboratory systems, workforce development, emergency operations, and linking public health with security and development priorities. One of its distinguishing features is that it encourages operational improvements through partnerships and technical cooperation rather than relying primarily on legal obligation. This has made it especially influential in supporting low- and middle-income countries that require external financing, expertise, and institutional support to strengthen preparedness systems. At the same time, critiques of the agenda often note that its security-oriented framing can sometimes overshadow broader health system goals or equity concerns. Nevertheless, its contribution has been significant in translating abstract preparedness principles into actionable areas for reform.

The Joint External Evaluation emerged as an important assessment tool for measuring country-level preparedness capacities in a structured and transparent way. Developed to support implementation of the International Health Regulations and aligned with the priorities of the Global Health Security Agenda, the Joint External Evaluation provides a voluntary, collaborative process through which countries assess their strengths and weaknesses across multiple technical areas. These usually include surveillance, laboratory capacity, workforce development, emergency response operations, antimicrobial resistance, zoonotic disease control, food safety, biosafety, risk communication, and points of entry (Anioke & Atima, 2019, Badmus & Olamide, 2019). The value of the Joint External Evaluation lies in its ability to offer a standardized framework for benchmarking preparedness performance and identifying priority gaps that may not be visible through internal self-assessment alone. By involving both national experts and external reviewers, the process encourages objectivity, dialogue, and accountability. It also helps countries generate evidence that can inform strategic planning, donor engagement, and resource mobilization. Importantly, the Joint External Evaluation is not merely a scorecard; it is a diagnostic mechanism that can guide policy reform and investment decisions. However, its effectiveness depends heavily on whether countries translate findings into sustained action. In some settings, evaluation results have not been followed by adequate financing or implementation support, limiting their practical value. Even so, the tool remains highly relevant because preparedness cannot be strengthened effectively without credible assessment of existing capacity.

Beyond these major instruments, pandemic preparedness plans and broader emergency frameworks play a central role in translating international guidance into operational readiness. Pandemic preparedness plans are typically developed at national or regional levels to define how governments will organize surveillance, command structures, case management, logistics, communication, border control, and continuity of essential services during a large-scale infectious disease event. These plans often include scenario-based protocols, stockpiling arrangements, surge staffing models, triage guidelines, and legal provisions for emergency action. Emergency frameworks extend this planning function by outlining broader principles for incident management, interagency coordination, rapid financing, and recovery (Olude & Badmus, 2015, Kolndadacha, et al., 2013). Their importance lies in shifting preparedness from general capacity-building to event-specific operationalization. A country may possess good surveillance and laboratory systems, but without a clear pandemic plan, those assets may not be mobilized efficiently when a fast-moving crisis emerges. The recent experience of major outbreaks has demonstrated that effective preparedness requires not only technical capability, but also predefined arrangements for leadership, communication, decentralization, and public engagement. Well-designed pandemic plans also support resilience by protecting continuity of care,

ensuring essential supply chains, and reducing confusion during emergency escalation. However, plans that remain outdated, overly centralized, or detached from frontline realities tend to fail under pressure. Thus, the quality of preparedness depends not only on the existence of plans, but also on regular revision, testing, and adaptation.

The One Health approach has become increasingly central to global infectious disease preparedness because many emerging infectious threats arise at the intersection of human, animal, and environmental health. This approach recognizes that disease emergence cannot be understood or controlled through a purely biomedical or human health lens. Zoonotic spillover, antimicrobial resistance, foodborne illness, and environmental disruption all demonstrate the need for coordinated action across sectors. Within preparedness frameworks, One Health promotes collaboration among public health agencies, veterinary services, environmental institutions, agriculture ministries, wildlife authorities, and research bodies. Its value lies in encouraging upstream prevention, integrated surveillance, shared data systems, and coordinated response to complex biological threats (Okonkwo, Ogunwole & Okeke, 2018, Olamide & Badmus, 2018). For example, monitoring animal reservoirs, regulating antimicrobial use in agriculture, and addressing ecological drivers of disease can significantly improve prevention and early detection. One Health also strengthens resilience by expanding the institutional base of preparedness beyond hospitals and ministries of health alone. In practice, however, cross-sector integration remains challenging due to fragmented governance, unequal resource allocation, professional silos, and inconsistent legal mandates. Despite these obstacles, One Health has become an essential conceptual and operational pillar in modern preparedness frameworks because it reflects the real-world complexity of infectious disease risk.

Across these major frameworks, several common pillars can be identified. The first is governance and coordination, which includes legal authority, leadership structures, accountability mechanisms, and intersectoral collaboration. Without strong governance, even technically sound frameworks cannot function effectively. The second is surveillance and early warning, since preparedness depends on the ability to detect unusual events rapidly and communicate them accurately. The third is laboratory capacity, which enables confirmation of cases, tracking of transmission patterns, and evidence-based decision-making (Lawal & Oduleye, 2019). The fourth is workforce development, including training, surge capacity, occupational protection, and deployment systems for public health and clinical personnel. The fifth is emergency response capability, which covers incident management, logistics, rapid mobilization, and operational command. The sixth is risk communication and community engagement, reflecting the need for trust, transparency, and public cooperation during crises. The seventh is financing and resource mobilization, since preparedness requires sustained investment rather than short-term crisis spending. The eighth is continuity of essential health services, which links preparedness directly to health system resilience by ensuring that routine care is not abandoned during emergencies.

Taken together, these frameworks demonstrate that global infectious disease preparedness is not built around a single instrument, but through an interconnected architecture of law, assessment, planning, partnership, and cross-sector collaboration. The International Health Regulations provide the legal backbone, the Global Health Security Agenda advances practical action, the Joint External Evaluation measures capacity, pandemic plans operationalize readiness, and the One Health approach broadens the scope of preparedness to reflect shared biological and environmental realities (Agbabiaka, et al., 2019, Olamide & Badmus, 2019). Their common pillars reinforce the idea that preparedness is most effective when embedded in strong, adaptive, and equitable health systems. A comprehensive review of these frameworks is therefore necessary not only to understand their individual contributions, but also to evaluate how they collectively shape the resilience of health systems confronting present and future infectious disease threats.

2.4. Governance, Policy Coordination, and Multisectoral Collaboration in Preparedness Systems

Governance, policy coordination, and multisectoral collaboration are central to the effectiveness of

infectious disease preparedness systems because outbreaks do not unfold only as biomedical events; they also test institutions, laws, leadership, communication systems, and social trust. Even where technical tools such as surveillance platforms, laboratories, and emergency stockpiles are available, preparedness can still fail if governance arrangements are weak, fragmented, or politically unsupported (Lawal & Oduleye, 2019). Infectious disease threats demand decisions that are rapid, coordinated, legitimate, and evidence-informed, and these qualities depend on the broader governance environment within which preparedness systems are embedded. For this reason, strong preparedness cannot be separated from strong public institutions. Governance determines who leads, who decides, who coordinates, who is accountable, and how resources are mobilized before and during health emergencies. It is therefore one of the most decisive factors in whether preparedness frameworks translate from policy documents into effective action that strengthens health system resilience.

National leadership and political commitment play a foundational role in shaping preparedness performance. Political leaders influence whether infectious disease preparedness is treated as a short-term technical concern or as a strategic national priority linked to health security, economic stability, and public welfare. When national leadership is committed, preparedness receives visibility, funding, legislative support, and inter-ministerial attention. Political commitment also affects the speed with which decisions are made during crises, including activation of emergency operations, allocation of budgetary resources, enforcement of public health measures, and communication with the public. In many settings, the difference between effective containment and widespread system failure has depended less on the availability of guidance and more on whether leaders acted decisively, transparently, and in alignment with scientific advice. Leadership also influences public trust (Badmus, 2019, Okonkwo, et al., 2019). Citizens are more likely to comply with risk communication, testing protocols, isolation measures, and vaccination campaigns when leaders communicate consistently and demonstrate competence. In contrast, weak political commitment often leads to delayed response, policy inconsistency, underinvestment in preparedness capacities, and the politicization of outbreak management. Sustainable preparedness therefore requires leadership that extends beyond emergency declarations and invests in long-term system strengthening even during periods of apparent epidemiological calm.

Policy development and legal preparedness are equally important because infectious disease response depends on a clear and enforceable policy environment. Preparedness systems require laws, regulations, and policy instruments that define institutional roles, enable data sharing, authorize emergency powers, regulate movement and quarantine where necessary, protect rights, and ensure continuity of essential services. Legal preparedness also provides the basis for public health surveillance, reporting obligations, procurement mechanisms, workforce mobilization, and cross-border coordination. Without a well-developed legal framework, response efforts may become ad hoc, contested, or delayed by institutional uncertainty (Anioke & Atima, 2018, Badmus & Olamide, 2018). Policy development must therefore address both routine preparedness and emergency response, linking public health legislation with broader frameworks related to civil protection, border health, occupational safety, digital governance, and biosecurity. Effective policy systems are not only comprehensive but also flexible enough to adapt to different infectious threats and changing scientific knowledge. They should clarify lines of authority while preserving legal safeguards against abuse. This balance is especially important because emergency powers can generate tension between public health protection and civil liberties. A robust preparedness system must therefore combine legal clarity with proportionality, transparency, and human rights considerations. Policies that are too rigid may fail to accommodate rapidly evolving crises, while policies that are vague or outdated may produce confusion and weak implementation. Legal preparedness is thus not a peripheral matter; it is one of the structural conditions that determines whether preparedness can function effectively in practice.

Institutional coordination across ministries and agencies is another defining feature of strong preparedness systems. Infectious disease threats affect multiple sectors simultaneously, including health,

finance, education, transport, agriculture, immigration, defense, environment, labor, and local government. Preparedness therefore depends on more than the capacity of ministries of health alone. Institutional coordination is needed to ensure aligned decision-making, shared situational awareness, interoperable systems, and timely action across the public sector. Coordination mechanisms may include national preparedness committees, interagency task forces, emergency operations centers, technical working groups, and local response networks. These structures help reduce duplication, clarify responsibilities, and enable rapid escalation of action when threats emerge (Agbabiaka, et al., 2019, Olamide & Badmus, 2019). Their effectiveness depends on clearly defined mandates, reliable communication channels, and regular joint planning before crises occur. Fragmentation between agencies is one of the most persistent barriers to preparedness because siloed institutions often operate with different priorities, data systems, and reporting lines. For example, surveillance data may not flow efficiently between health authorities and border control agencies, or animal health institutions may not be fully integrated into human disease monitoring. Institutional coordination is therefore not merely administrative; it is a strategic function that strengthens preparedness by ensuring that the health system is supported by the full machinery of government. It also contributes to resilience because coordinated systems are better able to absorb shocks, reallocate resources, and maintain continuity of services during emergencies.

International partnerships and global cooperation are indispensable in preparedness systems because infectious diseases do not respect national borders. No country can fully secure itself against emerging or re-emerging pathogens in isolation, especially in an era of rapid travel, trade interdependence, migration, and ecological change. Global cooperation supports preparedness through shared surveillance, technical guidance, research collaboration, financing, mutual assistance, and coordinated response to transboundary threats. International institutions, regional bodies, donor agencies, academic networks, and humanitarian organizations all contribute to this cooperative architecture (Lawal & Oduleye, 2019). Partnerships are particularly important for countries with limited resources, where domestic preparedness efforts may depend on external technical assistance, laboratory support, workforce training, or emergency funding. International cooperation also promotes standardization by encouraging countries to align with common norms, reporting expectations, and assessment tools. In this way, global partnerships can strengthen both national systems and collective security. At the same time, preparedness frameworks must be sensitive to inequalities within global cooperation. Some countries face structural disadvantages in accessing medical countermeasures, financing, and technological innovation, while external support can sometimes be fragmented or donor-driven rather than nationally owned. Effective international collaboration therefore requires reciprocity, trust, fair resource distribution, and respect for local context. Preparedness is strongest when global cooperation complements national leadership rather than substituting for it. The goal is not dependency, but solidarity and shared capacity-building in a world where local outbreaks can rapidly become global crises.

Community participation and stakeholder engagement are increasingly recognized as essential elements of governance in preparedness systems. Infectious disease control cannot succeed through top-down directives alone because public behavior, social norms, local knowledge, and trust strongly influence whether interventions are accepted and sustained. Communities are not passive recipients of preparedness policy; they are active participants in prevention, early detection, response, and recovery. Their involvement can improve the design and implementation of surveillance, contact tracing, health education, vaccination campaigns, and continuity of care strategies (Badmus, 2019, Okonkwo, et al., 2019). Stakeholder engagement also broadens preparedness beyond government institutions to include civil society organizations, religious bodies, professional associations, the private sector, traditional leaders, media actors, patient groups, and academic institutions. These actors often provide social legitimacy, communication channels, logistical support, and contextual understanding that formal systems alone may lack. Meaningful participation is especially important in marginalized or high-risk populations, where historical exclusion,

discrimination, or medical mistrust may undermine response efforts. Governance that values community engagement is more likely to produce culturally appropriate communication, reduce resistance to interventions, and identify practical barriers that central authorities might overlook. Moreover, community participation contributes to resilience because it strengthens local ownership, social cohesion, and adaptive capacity. Preparedness systems that ignore local voices may appear technically sound but remain socially fragile. In contrast, systems that embed stakeholder engagement into planning and implementation are better positioned to respond effectively under pressure and sustain public cooperation over time.

Accountability and monitoring mechanisms are critical because preparedness systems require continuous oversight, learning, and improvement. Governance is not effective simply because institutions and policies exist; it is effective when performance is tracked, gaps are identified, and responsibilities are enforced. Accountability mechanisms help ensure that preparedness commitments translate into real capacities rather than symbolic compliance. These mechanisms may include national assessments, simulation exercises, after-action reviews, public reporting, independent audits, legislative oversight, and performance indicators linked to strategic plans (Anioke & Atima, 2018, Badmus & Olamide, 2018). Monitoring enables governments and partners to evaluate whether surveillance is functioning, stockpiles are maintained, workforce training is adequate, legal frameworks are current, and emergency coordination systems are operational. It also helps reveal inequalities within preparedness, such as geographic disparities in laboratory access or weaknesses in service continuity for vulnerable groups. Importantly, accountability is not only upward, toward international institutions or national executives; it is also downward, toward citizens who depend on the health system for protection. Transparent monitoring can build trust by showing that preparedness is being taken seriously and that failures are acknowledged and addressed. Without accountability, preparedness systems risk becoming reactive, fragmented, and underfunded. Repeated outbreaks have shown that many failures are not due to lack of knowledge, but to weak follow-through, poor coordination, and inadequate institutional memory. Monitoring and accountability therefore create the feedback loops through which preparedness becomes dynamic rather than static.

Taken together, governance, policy coordination, and multisectoral collaboration form the institutional backbone of infectious disease preparedness systems. National leadership sets priorities and mobilizes commitment; legal and policy frameworks authorize action and clarify responsibilities; interagency coordination links the full apparatus of government; international cooperation strengthens collective security; community engagement builds trust and local ownership; and accountability mechanisms ensure that preparedness remains active, measurable, and continuously improved. These dimensions are deeply interconnected, and weakness in one often undermines the others (Anioke & Atima, 2019, Badmus & Olamide, 2019). A technically advanced preparedness framework cannot deliver results if governance is fragmented, laws are outdated, communities are excluded, or monitoring is weak. Conversely, strong governance can amplify the impact of limited resources by improving coordination, legitimacy, and strategic focus. For health system resilience, this matters profoundly. Preparedness is not only about having plans and tools, but about building institutions capable of leading, learning, coordinating, and adapting in the face of infectious disease threats. A comprehensive review of global preparedness frameworks must therefore pay close attention to governance architecture, because resilient health systems are ultimately shaped as much by institutional quality and collaborative capacity as by technical public health assets.

2.5. Surveillance, Laboratory Capacity, and Digital Health Infrastructure for Early Detection and Response

Surveillance, laboratory capacity, and digital health infrastructure are among the most critical components of infectious disease preparedness because they determine whether threats are detected early, understood accurately, and managed effectively before they escalate into widespread emergencies. In the context of global infectious disease preparedness frameworks, these components form the operational

core of early detection and response. They enable health systems to move from passive reaction to active anticipation by identifying unusual health events, confirming diagnoses, tracking transmission patterns, and communicating timely information to decision-makers and the public (Adamah, et al., 2016, Lawal & Oduleye, 2018). Their importance has been repeatedly demonstrated during outbreaks of influenza, Ebola, Zika, COVID-19, cholera, mpox, and other infectious diseases, where delays in detection, weak diagnostic capacity, fragmented reporting systems, or poor communication often contributed to avoidable spread and increased mortality. A resilient health system depends not only on having these technical functions in place, but on ensuring that they are integrated, adaptive, equitable, and capable of functioning under pressure.

Disease surveillance systems and reporting structures are the foundation of infectious disease intelligence. Surveillance refers to the continuous, systematic collection, analysis, interpretation, and dissemination of health-related data for the purpose of informing public health action. In preparedness systems, surveillance is not limited to counting cases after an outbreak is evident; it is intended to detect signals of unusual patterns early enough to trigger investigation and containment. Effective surveillance systems monitor disease trends, identify clusters, capture geographic spread, and provide evidence that supports decision-making at local, national, and global levels (Adeojo and Osinibi, 2016). Reporting structures are equally important because surveillance data only become useful when they move efficiently through the health system. Clear reporting channels ensure that frontline facilities, laboratories, community health workers, and local authorities can transmit information upward in a timely and standardized manner, while national authorities can return guidance and feedback downward. Strong reporting systems depend on case definitions, notification protocols, legal requirements, trained personnel, and mechanisms for rapid escalation when thresholds are reached. Weaknesses in reporting, such as delayed notification, inconsistent formats, underreporting, or poor coordination between levels of government, can severely compromise response efforts. Preparedness frameworks therefore emphasize surveillance not only as a technical activity, but as an institutional function requiring standardization, accountability, and continuous improvement.

Early warning systems and outbreak intelligence expand the role of surveillance by focusing on the rapid detection of signals that may indicate emerging or re-emerging threats. While routine surveillance often tracks known diseases through established indicators, early warning systems are designed to identify anomalies, unusual syndromes, or sudden increases in cases that may represent an outbreak in its early stage. These systems may include event-based surveillance, syndromic surveillance, community-based reporting, media monitoring, environmental monitoring, and the analysis of informal data sources (Agbosu & Ekpedo, 2018). Outbreak intelligence refers to the ability to gather, validate, interpret, and act on information from multiple channels in order to identify risks before they become fully visible through conventional surveillance alone. This function is especially important for pathogens with epidemic or pandemic potential, where the speed of response can determine whether an outbreak remains localized or spreads widely. In resilient preparedness systems, early warning is supported by clear thresholds for action, analytic capacity, multisector input, and communication links between surveillance units, emergency operations centers, and leadership structures. It also depends on local sensitivity, since community-level observations are often the first indication that a new threat is emerging. Delays in translating early signals into response have been a recurring weakness in many outbreaks, highlighting that early warning systems are only as effective as the governance, trust, and operational readiness that support them.

Laboratory preparedness and diagnostic capacity are indispensable for confirming cases, identifying pathogens, guiding case management, and supporting surveillance accuracy. While clinical suspicion can suggest the presence of an infectious disease threat, laboratory confirmation provides the evidence needed for reliable diagnosis, outbreak characterization, and epidemiological control. Preparedness therefore requires laboratory systems that are accessible, technically competent, quality-assured, and linked to public health decision-making. Diagnostic capacity includes the availability of equipment, reagents,

biosafety measures, trained personnel, specimen collection protocols, transport networks, and testing algorithms that can function under routine conditions and surge situations (Aye and Tawose, 2015, Lawal & Oduleye, 2018). During an outbreak, laboratories play multiple roles: confirming initial cases, differentiating among pathogens with similar symptoms, monitoring variants or strains, supporting contact tracing, and informing treatment or infection prevention strategies. Laboratory preparedness also includes referral systems that connect peripheral facilities with regional or national reference laboratories, ensuring that complex testing can be performed when local capacity is limited. A resilient health system requires diagnostic networks that are geographically distributed, scalable, and protected from supply chain disruption. Many health emergencies have exposed the consequences of underdeveloped laboratory systems, including delayed confirmation, diagnostic backlogs, weak specimen logistics, and dependence on external laboratories. Preparedness frameworks therefore place strong emphasis on laboratory strengthening as both a health security function and a broader investment in routine health system capacity.

Data integration, interoperability, and real-time information sharing are essential because surveillance and laboratory systems cannot operate effectively in isolation. Preparedness depends not only on collecting data, but on connecting information across institutions, sectors, and levels of the health system in ways that support rapid understanding and coordinated action. Data integration refers to the ability to combine information from multiple sources, such as health facilities, laboratories, pharmacies, border points, veterinary systems, and community networks, into a coherent picture of disease activity. Interoperability means that different digital platforms, databases, and reporting systems can communicate with one another through compatible standards, formats, and protocols (Adeniji, et al., 2019, Lawal & Oduleye, 2019, Olamide & Badmus, 2019). Without interoperability, health systems often suffer from duplication, incomplete visibility, delayed aggregation, and inconsistent analysis. Real-time information sharing is particularly important during fast-moving outbreaks because delayed or fragmented data can lead to missed opportunities for containment, inefficient resource allocation, and poor communication to the public. Effective preparedness systems therefore invest in integrated dashboards, automated notification tools, standardized coding systems, and governance arrangements that support secure and timely data exchange. At the same time, real-time sharing must be balanced with data protection, confidentiality, and appropriate legal safeguards. Information systems that are rapid but unreliable can mislead decision-makers, while systems that are accurate but too slow can render data operationally useless. The goal is to build a data environment where information is timely, trusted, and actionable.

The role of digital health tools and innovation has become increasingly prominent in preparedness systems because digital technologies can expand speed, reach, efficiency, and adaptability across surveillance and response functions. Digital health tools include electronic reporting platforms, mobile health applications, digital dashboards, telemedicine systems, geographic information systems, artificial intelligence-supported analytics, electronic laboratory information systems, and cloud-based data platforms. These tools support preparedness by enabling faster case reporting, automated analysis, visualization of transmission trends, remote monitoring of patients, digital contact tracing, logistics management, and workforce communication (Agbosu, Ekpedo & Adeyoyin, 2019). Innovation in digital health can also improve access in remote or underserved settings by reducing geographic barriers and creating new pathways for community engagement and data submission. During outbreaks, digital tools may help track hotspots, support decision-making through predictive models, optimize supply chains, and maintain continuity of care when movement is restricted. However, the value of digital health innovation depends on context. Technologies that are poorly integrated, inequitable, difficult to use, or unsupported by infrastructure may increase fragmentation rather than improve preparedness. Challenges such as unstable electricity, weak internet connectivity, limited digital literacy, inadequate maintenance, and cybersecurity risks can undermine effectiveness, especially in resource-constrained settings. For this reason, resilient preparedness frameworks treat digital innovation not as a substitute for system strengthening, but as an enabler that must

be aligned with workforce capacity, governance, and service delivery needs.

Risk communication and public information systems are vital because early detection and response are not only technical processes; they also require timely, credible, and understandable communication with the public and relevant stakeholders. Risk communication involves the exchange of information, advice, and guidance between authorities and communities during public health threats so that people can make informed decisions to protect themselves and others. Public information systems support this function by organizing how messages are developed, approved, disseminated, and updated across channels such as radio, television, digital media, community networks, and health facilities (Adeniji, 2019, Lawal & Oduleye, 2019, Shittu, et al., 2019). Effective communication is central to preparedness because even the best surveillance and laboratory systems cannot contain outbreaks if populations do not understand the risk, trust the guidance, or know how to act. Public compliance with testing, treatment, quarantine, vaccination, hygiene measures, and care-seeking behavior depends heavily on communication quality. During outbreaks, misinformation, rumors, fear, and stigma can spread as rapidly as disease, making communication a core response capability rather than a supplementary activity. Preparedness frameworks therefore emphasize communication planning, spokesperson training, media engagement, social listening, and adaptation of messages to different cultural and linguistic contexts. Strong public information systems are transparent, consistent, and responsive to uncertainty. They acknowledge what is known, what is not yet known, and what actions are recommended. They also create feedback loops through which authorities can understand community concerns and adjust interventions accordingly. In resilient systems, communication is integrated into surveillance and response, ensuring that technical information is translated into socially meaningful action.

Taken together, surveillance, laboratory capacity, and digital health infrastructure form a tightly connected ecosystem that underpins early detection and effective response to infectious disease threats. Surveillance generates the signals, early warning systems interpret emerging risks, laboratories confirm and characterize threats, integrated data systems connect information across institutions, digital tools enhance speed and coordination, and communication systems translate evidence into public action. Each of these elements is essential on its own, but preparedness is strongest when they function as an integrated whole supported by clear governance, sustainable investment, skilled personnel, and equity-oriented design (Anioke & Atima, 2018, Badmus & Olamide, 2018). Their collective importance extends beyond outbreak control because they also strengthen routine health system performance, improve service continuity, and contribute to long-term resilience. A comprehensive review of global infectious disease preparedness frameworks must therefore recognize these components not merely as technical assets, but as foundational capacities through which health systems become more responsive, adaptive, and capable of protecting populations against current and future infectious disease threats.

2.6. Health Workforce Readiness, Resource Mobilization, and Emergency Response Capacity

Health workforce readiness, resource mobilization, and emergency response capacity are central pillars of infectious disease preparedness because even the most sophisticated policies and surveillance systems cannot protect populations if there are not enough trained people, essential supplies, operational resources, and organized response structures to act quickly during a health emergency. Preparedness frameworks across the world consistently emphasize that resilient health systems depend on their ability to translate plans into action under conditions of uncertainty, urgency, and pressure (Aye and Tawose, 2016, Olamide & Badmus, 2018). This translation is made possible through a capable workforce, reliable access to medicines and equipment, responsive logistics systems, sustainable financing, coordinated emergency teams, and strong protections for those working on the front lines. These elements are deeply interconnected. A trained workforce cannot function effectively without supplies, medicines cannot reach affected communities without resilient logistics, and emergency response systems cannot be sustained without financing and protection mechanisms. Together, they determine whether a health system can

contain outbreaks, maintain essential services, and recover with strengthened capacity.

Public health workforce training and surge capacity form the human foundation of infectious disease preparedness. Preparedness depends not only on the number of health workers in a system, but also on the quality, relevance, and adaptability of their training. Public health professionals, clinicians, epidemiologists, laboratory scientists, community health workers, environmental officers, logisticians, and emergency coordinators all play critical roles in outbreak detection and control. Workforce readiness requires that these actors possess competencies in surveillance, case investigation, infection prevention and control, laboratory procedures, contact tracing, risk communication, data management, emergency coordination, and community engagement (Adeniji, et al., 2019, Lawal & Oduleye, 2019, Olamide & Badmus, 2019). Training must therefore extend beyond routine professional education and include regular in-service learning, simulation exercises, scenario planning, and multidisciplinary drills that prepare personnel for outbreak conditions. Surge capacity is equally important because infectious disease emergencies often create sudden increases in workload that exceed routine staffing levels. A resilient preparedness system must be able to mobilize additional personnel rapidly, redeploy staff across facilities, activate reserve pools, and collaborate with volunteers or retired professionals where appropriate. This requires pre-established staffing plans, legal and administrative flexibility, credentialing systems, and psychosocial support arrangements. Weak workforce readiness has been one of the most visible constraints in many outbreaks, where exhausted staff, insufficient training, and poor deployment mechanisms undermined response effectiveness. Preparedness frameworks therefore treat workforce development not as a one-time activity, but as a continuous investment in human capability and institutional memory.

The availability of essential medicines, vaccines, and equipment is another indispensable component of preparedness because response capacity depends on timely access to the materials required for prevention, diagnosis, treatment, and protection. During infectious disease emergencies, health systems need reliable supplies of antimicrobial agents where indicated, rehydration products, supportive therapies, vaccines, diagnostic kits, oxygen, personal protective equipment, disinfectants, and clinical consumables. The availability of these commodities can determine whether outbreaks are contained early or allowed to escalate due to treatment delays, inadequate infection control, or loss of public confidence (Agbosu, Ekpedo & Adeyoyin, 2019). Vaccines are especially significant in preparedness because they serve as both preventive and outbreak control tools. A resilient system must be able to forecast needs, maintain appropriate stock levels, prioritize distribution based on risk, and scale up procurement during emergencies. Equipment availability is equally critical, including cold chain infrastructure, ventilators where relevant, specimen transport materials, screening tools, and communication devices for responders. Shortages in any of these areas can weaken clinical care, disrupt laboratory services, and increase transmission risk among health workers and communities. The challenge is not only ensuring stock existence, but also ensuring quality, geographic accessibility, and equitable distribution. Preparedness frameworks increasingly recognize that stockpiles and procurement strategies must be linked to broader national manufacturing capacity, supplier diversification, and regional cooperation so that countries are less vulnerable to global shortages during pandemics or cross-border emergencies.

Emergency logistics and supply chain resilience are closely linked to resource availability because supplies are only useful if they can be moved rapidly, safely, and efficiently to where they are needed. Infectious disease emergencies place extraordinary demands on supply chains, often requiring sudden increases in procurement, transport, warehousing, cold storage, inventory tracking, and last-mile delivery. Supply chain resilience refers to the ability of logistics systems to continue functioning despite disruptions such as border closures, transportation delays, panic buying, global market shortages, insecurity, or infrastructure breakdown. Preparedness therefore requires logistics systems that are flexible, diversified, data-informed, and capable of rapid reconfiguration (Adeniji, 2019, Lawal & Oduleye, 2019, Shittu, et al., 2019). This includes pre-positioned stockpiles, emergency transport arrangements, vendor

agreements, route mapping, warehouse management systems, and contingency plans for high-demand scenarios. Effective logistics are especially important in decentralized health systems and remote areas, where outbreaks may occur far from central stores or urban hospitals. In such contexts, delays in transporting diagnostics, protective equipment, or medicines can have severe consequences for both containment and continuity of care. Supply chain resilience also depends on information visibility. Decision-makers need accurate, real-time knowledge of what supplies exist, where they are located, how quickly they are being used, and when replenishment is needed. Without this visibility, shortages may be recognized too late, while some areas receive duplicate supplies and others remain underserved. Global infectious disease preparedness frameworks increasingly highlight logistics as a strategic function rather than a back-office concern, because resilient response capacity cannot exist without reliable systems for moving critical resources under crisis conditions.

Financing preparedness and sustainable investment are essential because workforce readiness, supplies, logistics, and emergency structures all depend on predictable resources. One of the most persistent weaknesses in global preparedness has been the tendency to invest heavily during crises and then allow capacities to erode once immediate danger declines. This cycle of panic and neglect leaves health systems vulnerable to repeated failure and undermines institutional memory. Sustainable preparedness requires financing models that support routine capacity-building, maintenance of stockpiles, workforce training, laboratory strengthening, digital infrastructure, and emergency reserve funds before an outbreak occurs (Anioke & Atima, 2018, Badmus & Olamide, 2018). It also requires mechanisms for rapidly releasing funds once a threat emerges so that delays in procurement, staffing, and operations do not undermine early response. Preparedness financing must therefore be both sustained and agile. Domestic investment is especially important because reliance on short-term donor funding can produce fragmentation, weak national ownership, and vulnerability when external priorities shift. At the same time, international financing remains important for low-resource settings that face structural constraints in building preparedness capacities. The broader challenge is ensuring that preparedness is recognized as a long-term public good rather than an optional expenditure. Investments in preparedness may appear costly in the short term, but they are generally far less expensive than the social, economic, and health costs of uncontrolled outbreaks. Financing also carries an equity dimension, because underfunded systems are more likely to experience service disruption, protect privileged populations first, and leave vulnerable groups exposed. Strong preparedness frameworks therefore emphasize strategic budgeting, reserve mechanisms, transparent financial governance, and integration of preparedness funding into broader health system strengthening agendas.

Rapid response teams and incident management systems translate preparedness from planning into coordinated field action. Rapid response teams are multidisciplinary groups trained to investigate alerts, verify cases, conduct risk assessment, initiate containment measures, and support local health authorities during the early stages of an outbreak. Their effectiveness depends on clear activation procedures, role definitions, logistical support, technical training, and access to transport and communication tools. These teams often include epidemiologists, clinicians, laboratory personnel, risk communicators, infection prevention specialists, and logisticians who can work together under emergency conditions. Incident management systems provide the organizational structure that enables such teams and other response actors to coordinate effectively. They define command hierarchies, reporting lines, operational sections, resource management procedures, and communication flows during emergencies (Aye and Tawose, 2016, Olamide & Badmus, 2018). This is crucial because outbreaks involve many moving parts, and disorganized response can lead to duplication, delays, misinformation, and inefficient use of resources. A well-functioning incident management system supports rapid decision-making, delegation of responsibilities, and integration of local, national, and sometimes international actors into a common operational framework. It also promotes accountability by clarifying who is responsible for surveillance, case management, logistics, risk communication, and stakeholder liaison at each stage

of the response. Preparedness frameworks consistently include rapid response teams and incident management systems because they provide the practical architecture for turning technical capacity into timely and organized intervention.

Protection of frontline health workers is one of the most important and ethically significant dimensions of preparedness because these workers bear a disproportionate share of exposure risk during infectious disease emergencies. Frontline staff include doctors, nurses, laboratory personnel, community health workers, cleaners, ambulance crews, burial teams, pharmacists, and others whose work places them in close contact with infected individuals, contaminated materials, or high-risk environments. Their protection is essential not only for moral reasons, but also for operational continuity. When health workers become infected, burned out, traumatized, or demoralized, the response capacity of the entire system declines. Preparedness therefore requires strong infection prevention and control measures, reliable access to personal protective equipment, training in safe clinical and laboratory practices, occupational health services, vaccination where available, mental health and psychosocial support, and fair compensation arrangements (Dako, et al., 2019, Nwafor, et al., 2019, Oguntegbe, Farounbi & Okafor, 2019). Protection also includes mechanisms to address stigma, violence, excessive workload, and legal insecurity that health workers may face during crises. In many outbreaks, frontline workers have continued to serve under conditions of fear, social pressure, and personal sacrifice, yet their needs are often addressed too late or inconsistently. A resilient preparedness system recognizes that protecting health workers is not an optional welfare measure but a strategic requirement for maintaining response capacity and public trust. It also recognizes that worker safety contributes to the quality of patient care, the integrity of surveillance, and the continuity of essential services across the health system.

Taken together, health workforce readiness, resource mobilization, and emergency response capacity reveal that preparedness is as much about operational strength as it is about policy or planning. A resilient health system must have trained personnel who can scale up under pressure, reliable access to medicines and vaccines, logistics systems that function in disruption, financing that supports both readiness and rapid action, coordinated response teams that can be deployed immediately, and protections that preserve the safety and morale of frontline workers. These elements do not function independently; they reinforce one another and collectively determine whether outbreaks are contained efficiently or allowed to overwhelm health services (Akinrinoye, et al., 2015, Aminu-Ibrahim, Ogbete & Ambali, 2019). A comprehensive review of global infectious disease preparedness frameworks must therefore pay close attention to these operational pillars, because health system resilience is ultimately tested not by what is written in plans, but by whether people, resources, and institutions can perform effectively when infectious disease threats become real.

2.7. Challenges, Gaps, and Lessons from Global Implementation Across Different Health System Contexts

Challenges, gaps, and lessons from the global implementation of infectious disease preparedness frameworks reveal that the existence of international guidance alone does not guarantee effective preparedness outcomes. While major frameworks have helped establish norms, assessment tools, and operational priorities, their implementation has been uneven across countries and regions because health systems differ widely in institutional capacity, financing, infrastructure, governance quality, and social context. As a result, preparedness performance has often reflected broader structural inequalities rather than the formal presence of preparedness plans or commitments (Oguntegbe, Farounbi & Okafor, 2019, Michael & Ogunsola, 2019, Oziri, Seyi-Lande & Arowogbadamu, 2019). Repeated outbreaks have shown that many countries remain vulnerable not because the world lacks frameworks, but because translating those frameworks into sustained action requires political will, resources, institutional coherence, and public trust. A critical examination of implementation challenges is therefore essential for understanding why preparedness gaps persist and how health systems can become more resilient over time.

One of the most persistent barriers to implementation is funding limitation and unequal resource

distribution. Preparedness requires continuous investment in surveillance, laboratories, workforce development, stockpiles, emergency operations, digital systems, and community engagement, yet many countries allocate insufficient resources to these areas until a crisis is already underway. Even where governments recognize the importance of preparedness, competing development priorities, fiscal constraints, debt burdens, and political short-termism often push preparedness lower on the policy agenda. This creates a recurring cycle in which emergency funding surges during outbreaks but declines sharply once the immediate threat subsides. Such instability weakens institutional continuity, erodes technical capacity, and undermines long-term planning. Unequal global resource distribution further compounds this problem (Aransi, et al., 2018, Farounbi, et al., 2018, Odejobi & Ahmed, 2018). Wealthier countries are generally better positioned to finance preparedness infrastructure, secure medical countermeasures, and retain trained personnel, while lower-income countries may depend heavily on external support that is often fragmented, project-based, or donor-driven. The result is a preparedness landscape marked by structural imbalance, where vulnerabilities are concentrated in settings that can least afford major outbreaks. Unequal resource allocation within countries also matters. Urban centers and politically visible regions often receive more investment than rural or marginalized communities, leaving large segments of the population poorly protected. These funding disparities demonstrate that preparedness is not simply a technical issue but a political and economic one, shaped by decisions about whose safety is prioritized and whose risk remains neglected.

Weak infrastructure in low- and middle-income countries remains another major challenge to effective implementation. Preparedness frameworks often assume the presence of basic institutional and service delivery foundations, including functioning laboratories, stable electricity, reliable transport systems, adequate health facilities, trained personnel, digital connectivity, and strong referral networks. In many low-resource settings, however, these prerequisites are incomplete or unevenly distributed. Laboratories may be scarce or concentrated in capital cities, specimen transport systems may be slow or unreliable, and health facilities may struggle with insufficient staffing, weak infection prevention infrastructure, or chronic shortages of essential supplies. Digital reporting systems may be hindered by poor internet access or weak maintenance capacity, while emergency operations may depend on ad hoc arrangements rather than institutionalized structures (Odejobi & Ahmed, 2018, Seyi-Lande, Arowogbadamu & Oziri, 2018). These infrastructural limitations make it difficult to operationalize preparedness frameworks as intended, even when national policies align with international guidance. They also reduce resilience because systems already under strain from routine service demands have limited capacity to absorb the added burden of infectious disease emergencies. Importantly, infrastructure weakness is not only physical but institutional. Fragile administrative systems, inconsistent procurement processes, and limited planning capacity can all undermine preparedness. In such contexts, outbreaks do not merely test emergency response; they expose deeper development deficits that constrain every stage of prevention, detection, and recovery. This means that global preparedness efforts must be grounded in realistic assessments of health system foundations rather than relying on uniform assumptions about implementation readiness.

Fragmentation of policies and systems is another recurring gap that weakens preparedness across different contexts. In many countries, infectious disease preparedness is distributed across multiple ministries, agencies, and programs without sufficient integration. Surveillance may be managed separately from laboratory services, emergency operations may function independently of primary care systems, and animal health monitoring may be disconnected from human health authorities despite the growing importance of zoonotic threats. Fragmentation can also occur between national and subnational levels, where local authorities may have implementation responsibilities but limited access to data, financing, or decision-making power (Ahmed & Odejobi, 2018, Nwafor, et al., 2018, Seyi-Lande, Arowogbadamu & Oziri, 2018). The consequence is often duplication of effort, poor communication, contradictory guidance, and delays in coordinated action during emergencies. Programmatic fragmentation is equally problematic when vertical disease initiatives operate in parallel

without contributing to broader system strengthening. For example, investments in a single disease area may improve selected capacities while leaving overall preparedness weak and uneven. Policy fragmentation can arise when preparedness strategies are not aligned with legislation, budget frameworks, workforce planning, or service delivery reforms. In such cases, countries may possess multiple plans and assessments but lack the coherence needed for real operational readiness. These patterns suggest that one of the major lessons from global implementation is that preparedness must be embedded within integrated health systems rather than treated as a separate technical domain. Fragmented preparedness is inherently fragile because outbreak response requires unified action across institutions and sectors.

Inequities in access to health services and countermeasures represent another profound challenge in the global implementation of preparedness frameworks. Infectious disease emergencies do not affect all populations equally. People living in poverty, rural populations, displaced communities, informal workers, ethnic minorities, people with disabilities, and other marginalized groups often face greater exposure risk, delayed diagnosis, weaker access to treatment, and more severe social consequences during outbreaks. These inequities are not accidental; they reflect longstanding patterns of exclusion, underinvestment, discrimination, and geographic neglect within health systems (Akinrinoye, et al., 2019, Nwafor, et al., 2019, Sanusi, Bayeroju & Nwokediegwu, 2019). Preparedness frameworks may call for universal coverage and equitable response, but implementation frequently falls short when social and structural inequalities are not addressed directly. Access to vaccines, diagnostics, therapeutics, and protective equipment has been especially unequal during major global emergencies, with wealthier countries or privileged populations securing supplies earlier and in greater volume than others. This undermines both fairness and effectiveness, because outbreaks cannot be controlled sustainably when large groups remain unprotected. Inequity also affects trust. Communities that have historically experienced neglect or mistreatment may be less likely to engage with testing, isolation, treatment, or vaccination programs unless preparedness efforts are designed with inclusion and cultural sensitivity in mind. A resilient health system must therefore be judged not only by whether it responds, but by whom it reaches, how fairly it distributes protection, and whether it reduces rather than reproduces vulnerability during crises.

Lessons from recent epidemics and pandemics have been especially instructive in revealing both the strengths and weaknesses of global preparedness systems. Recent health emergencies have shown that early detection is indispensable, but early warning alone is insufficient if it is not followed by decisive leadership, rapid financing, operational coordination, and public communication. They have also demonstrated that health security cannot be separated from broader health system performance. Countries with stronger primary care networks, better workforce support, more integrated data systems, and higher public trust were often better able to maintain continuity of care while responding to emerging threats. Another lesson is that preparedness plans on paper are not enough. Systems that had not regularly tested, updated, or financed their plans struggled to convert formal preparedness into real readiness. The importance of local capacity has also become clear (Aransi, et al., 2019, Nwafor, et al., 2019, Oguntegbe, Farounbi & Okafor, 2019, Umoren, et al., 2019). Overreliance on global supply chains, external laboratories, or donor-driven technical assistance can create vulnerability when international demand surges or borders close. At the same time, recent outbreaks have reinforced the value of international cooperation, transparent information sharing, and scientific collaboration, particularly in relation to genomic surveillance, vaccine development, and technical guidance. Yet they have also exposed major weaknesses in global solidarity, especially regarding equitable access to countermeasures. Another critical lesson is that communication and trust are central to outbreak control (Ahmed, Odejobi & Oshoba, 2019, Nwafor, et al., 2019, Oziri, Seyi-Lande & Arowogbadamu, 2019). Misinformation, inconsistent messaging, and politicization can rapidly undermine technically sound response efforts. Finally, recent epidemics have highlighted that preparedness must address not only mortality from the pathogen itself, but also indirect effects on essential services, livelihoods, education, and mental health. This broadens the

meaning of preparedness and reinforces its connection to health system resilience.

Strategies for improving adaptability and long-term resilience must therefore move beyond narrow emergency planning and focus on sustained, system-oriented reform. One essential strategy is increasing domestic investment in preparedness as a routine budget priority rather than an episodic emergency expense. This should include protected funding for laboratories, surveillance, workforce training, supply chains, and emergency reserves. Another strategy is integrating preparedness into primary health care and broader service delivery systems so that outbreak capacities strengthen routine care rather than operate in isolation (Ahmed & Odejobi, 2018, Seyi-Lande, Arowogbadamu & Oziri, 2018). Strengthening local manufacturing, regional procurement networks, and diversified supply chains can reduce dependence on volatile external markets and improve timely access to critical countermeasures. Countries also need stronger institutional integration, with interoperable data systems, clear legal mandates, and established coordination mechanisms across ministries and levels of government. Adaptability depends heavily on learning, so simulation exercises, after-action reviews, and real-time performance monitoring should be institutionalized rather than conducted only after major crises. Community engagement must also be central. Resilient systems build trust before emergencies occur by involving local actors in planning, communication, and implementation. Equally important is an explicit commitment to equity. Preparedness strategies must identify vulnerable groups in advance, map service gaps, and design distribution systems that protect those most at risk (Bayeroju, Sanusi & Nwokediegwu, 2019, Filani, Fasawe & Umoren, 2019, Nwafor, et al., 2019). Finally, long-term resilience requires a mindset shift: preparedness should be understood as an ongoing capacity for anticipation, adaptation, and transformation rather than a fixed checklist of technical assets.

Taken together, the global implementation of infectious disease preparedness frameworks reveals a clear pattern. Frameworks are necessary, but they are not sufficient. Their effectiveness depends on whether countries and institutions can finance them, integrate them, adapt them to local realities, and apply them equitably across populations. Funding gaps, weak infrastructure, fragmented systems, and persistent inequalities have limited preparedness performance in many contexts, while recent epidemics have shown that resilience depends on more than emergency response alone (Nwafor, et al., 2018, Seyi-Lande, Arowogbadamu & Oziri, 2018). The most important lesson is that preparedness must be embedded within stronger, fairer, and more adaptive health systems. Global frameworks provide direction, but resilience is built through sustained investment, institutional learning, inclusive governance, and the practical ability to maintain protection and care under conditions of crisis.

2.8. Conclusion

In conclusion, this review has shown that global infectious disease preparedness frameworks play a critical role in shaping how countries and institutions anticipate, detect, respond to, and recover from infectious disease threats. Across the review, major findings consistently point to the importance of strong governance, coordinated policy systems, surveillance and laboratory capacity, digital health infrastructure, workforce readiness, emergency logistics, sustainable financing, community engagement, and accountability mechanisms. The analysis also demonstrates that preparedness is most effective when it is not treated as a narrow emergency function, but as a continuous process embedded within broader health system strengthening. While frameworks such as the International Health Regulations, the Global Health Security Agenda, Joint External Evaluation processes, pandemic preparedness plans, and the One Health approach provide valuable direction, their impact depends greatly on implementation capacity, political commitment, and the broader structural conditions within which health systems operate.

A major insight from the review is the significance of integrated preparedness frameworks in promoting coherence across multiple dimensions of health security. Infectious disease threats are complex and often cross institutional, sectoral, and national boundaries, making fragmented approaches insufficient. Integrated frameworks are important because they link legal obligations, technical

capacities, operational planning, cross-sector collaboration, and long-term resilience objectives into a more unified preparedness architecture. They encourage countries to move beyond isolated interventions and toward coordinated systems that can detect threats early, mobilize resources efficiently, maintain continuity of essential services, and adapt to evolving risks. This integration is particularly valuable in addressing the interconnected nature of human, animal, and environmental health, as well as the relationship between emergency preparedness and routine health system performance. In this way, preparedness frameworks are not only response tools, but strategic instruments for improving the overall strength and functionality of health systems.

The review also underscores the urgent need for resilient and adaptive health systems capable of withstanding the pressures created by infectious disease emergencies. Preparedness plans and technical guidelines alone are not enough if health systems lack the flexibility, institutional stability, and operational depth needed to function during crises. Resilience requires the capacity to absorb shocks, adapt to changing circumstances, continue delivering essential health services, and transform based on lessons learned. This means that countries must invest not only in outbreak-specific capacities, but also in the broader foundations of health system performance, including primary health care, workforce development, supply chains, financing systems, public trust, and equitable service delivery. Adaptive health systems are better positioned to respond to uncertainty, integrate innovation, and avoid repeating failures across successive outbreaks. Strengthening resilience is therefore central to the long-term effectiveness of all preparedness frameworks.

Important policy implications emerge from this review for governments, public institutions, and global health actors. First, preparedness should be institutionalized as a permanent policy priority supported by sustained domestic investment rather than episodic crisis funding. Second, governments should strengthen legal and governance frameworks to clarify authority, improve accountability, and support rapid action during emergencies while protecting rights and public trust. Third, institutions should prioritize integrated surveillance, laboratory readiness, interoperable digital systems, and community-centered communication strategies to improve early detection and response. Fourth, greater attention must be given to equity, ensuring that vulnerable and underserved populations are not excluded from preparedness planning, essential services, or access to countermeasures. Fifth, multisectoral and international collaboration should be strengthened to address transboundary threats, zoonotic risks, and uneven global capacity. These policy directions suggest that preparedness must be approached as both a technical and developmental priority with direct implications for national stability, public welfare, and global health security.

Looking ahead, the future of global preparedness will depend on whether countries and institutions can convert the lessons of past outbreaks into durable reform. Future preparedness efforts must be more adaptive, equitable, and prevention-oriented, with stronger local capacity, better cross-sector coordination, and greater investment in innovation, simulation, and institutional learning. There is also a need for more balanced global solidarity, particularly in the fair distribution of diagnostics, vaccines, therapeutics, and financial support during health emergencies. Ultimately, global preparedness should evolve toward a model that combines health security with health system resilience, recognizing that sustainable protection against infectious disease threats cannot be achieved through emergency response alone. It requires long-term commitment to building systems that are responsive, inclusive, and capable of protecting populations before, during, and after crises.

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