Miracle Get Journal
Vol. 03, No. 1, February 2026, 144-155
***e*-ISSN: 3047-8839**

Health System Readiness Management in Anticipating New Infectious Diseases and Zoonotic Threats in the Era of Global Ecological Change

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Article Information
Received: March 01, 2026
Revised: March 14, 2026
Online: April 01, 2026

Keywords
Emerging Infectious Diseases (EIDs), Zoonotic Disease Transmission Risk, One Health Governance Integration, Ecological Risk Management, Cross-Sector Health Coordination

ABSTRACT

The emergence of new infectious diseases and increasing zoonotic risks in recent decades pose serious challenges to health systems, particularly in countries with high ecological diversity and intense human-animal interactions. Global environmental changes, urban expansion, and rising human mobility amplify interspecies pathogen transmission potential. This study aims to analyze health system preparedness levels against new infectious diseases and zoonotic threats, and identify influencing factors. The research employs a mixed methods approach with a sequential explanatory design, combining quantitative and qualitative analysis. Quantitative data were gathered from surveys of 120 respondents from health institutions, laboratories, and related agencies, analyzed using descriptive statistics and multiple linear regression to test the influence of managerial capacity, One Health integration, policy support, resource availability, and ecological risk management on health system preparedness. Qualitative analysis involved in-depth interviews to reinforce statistical interpretations. Results indicate health system preparedness at a sufficient level (mean = 3.40). The regression model is simultaneously significant ($R^2 = 0.610$; $p < 0.001$), explaining 61% of preparedness variation by the model variables. Managerial capacity and ecological risk management are the most influential factors. Qualitative findings highlight cross-sector coordination, funding limitations, and integration of epidemiological and environmental data as primary barriers to implementing health system preparedness.

Keywords: *Emerging Infectious Diseases (EIDs), Zoonotic Disease Transmission Risk, One Health Governance Integration, Ecological Risk Management, Cross-Sector Health Coordination*

http://doi.org/10.69855/mgj.v3i1.541
https://gpijournal.com/index.php/miracle

INTRODUCTION

This study aims to deeply investigate the underlying issues that have been latent in health system preparedness, particularly in facing the increasing risk of emerging infectious diseases and zoonotic threats amidst global ecological change. This phenomenon is not only triggered by the complex interactions between environmental change, human mobility, and urban expansion, but also by structural weaknesses in health systems that are often not explicitly identified, such as limited cross-sectoral integration, fragmented epidemiological information systems, and low managerial capacity in responding to ecological-based risks.

This phenomenon places health systems in an increasingly vulnerable position to outbreaks that are rapid, cross-regional, and difficult to predict. Therefore, the readiness of the health system is not only determined by the capacity of medical services alone but also by managerial capabilities, epidemiological surveillance systems, cross-sector data integration, and effective institutional coordination within the framework of the One Health approach (Onyebuchi et al., 2025).

Most pathogens causing emerging infectious diseases have zoonotic origins, meaning they jump from animals to humans. A One Health approach which emphasizes the importance of cross-sector integration between human, animal, and environmental health is key to effectively preventing, detecting, and responding to these threats. Data shows that approximately 60–75% of infectious diseases worldwide are zoonotic in origin, highlighting the close link between ecological change and public health risks (Salam et al., 2020).

The phenomenon of emerging infectious diseases is not merely a theoretical risk; the COVID-19 pandemic has become the most concrete empirical evidence of how EIDs can destabilize health systems, economies, and social structures worldwide (Hasanudin, 2021). This crisis demonstrates the importance of health system preparedness in terms of early detection, rapid response, and effective cross-sector coordination. Furthermore, other outbreaks such as Ebola, Mpox, and the threat of avian influenza also demonstrate that without a resilient health system, the impact of infectious diseases can be extraordinary.

The Global Health Organization's concept of a health system emphasizes communication, health personnel, surveillance, health services, financing, and leadership. All of these components must operate in an integrated manner to ensure readiness to address rapidly changing and multidimensional public health threats. The dynamic interaction between these components presents a major challenge when a health system is faced with an emergency situation such as an EID or zoonotic outbreak (Ayesiga et al., 2025).

Health system preparedness encompasses two dimensions: preparedness (proactive preparation) and resilience (system resilience to shocks). This encompasses institutional capacity for early detection, real-time data collection, cross-sectoral information management, and rapid and effective operational response. This is crucial because crisis experience shows that delays in response or surveillance can exacerbate the spread and increase mortality (World Health Organization, 2024). The One Health approach has been adopted as a key strategy by various countries, including Indonesia, to improve horizontal coordination between the human health, animal health, and environmental sectors (Adnyana et al., 2023). This strategy is essential because zoonotic disease

control efforts cannot be successful if carried out partially by one sector alone. For example, the integration of cross-sectoral surveillance systems has proven crucial in mapping risks and early detection of emerging pathogens.

However, many developing countries face significant challenges in implementing this approach effectively. Limited human resources (HR) for epidemiology professionals and molecular laboratories, uneven infrastructure, and weak intersectoral policy coordination remain key weaknesses. These gaps weaken early detection and rapid response capacity during outbreaks, increasing the risk of local and transnational spread (WHO, 2024).

Particularly in an archipelagic nation with high ecological diversity like Indonesia, close human-wildlife interactions, the expansion of human settlements into natural habitats, and ongoing deforestation create significant opportunities for pathogen spillover from animals to humans. This not only accelerates the emergence of EIDs but also creates an urgent need for national health systems to strengthen prevention and early detection mechanisms.

Indonesia has undertaken various strategic efforts to strengthen its health system's preparedness for disease outbreaks, such as training health workers, conducting cross-sector meetings to develop an operational framework for preparedness, and strengthening detection and response capacity at the regional level. These initiatives are crucial for building a more adaptive system to evolving health risks driven by ecological and social factors.

However, empirical evaluations have revealed several significant gaps in the implementation of this preparation. Limited community-based surveillance, suboptimal data integration across agencies, and bureaucratic obstacles in coordinating crisis responses are common problems in the national context (Maulana et al., 2024). Disparities in health infrastructure across regions are also a significant obstacle to achieving equitable and effective preparation across all regions.

Furthermore, regular risk assessment, contingency planning, and logistics and health resource management are components of health systems management that often receive insufficient attention in research and policy. These limitations suggest the need for research approaches that focus not only on clinical or epidemiological elements but also on critical management elements of health systems. Furthermore, ecological changes occur worldwide, such as climate change, habitat degradation, and urbanization, complicated disease transmission patterns, affect vector distribution, and increase areas vulnerable to zoonoses. With this transformation, health systems must not only respond to existing threats but also learn and anticipate new risks that may emerge in the future.

Based on these global phenomena and empirical issues, it can be seen that there is still a gap between the need for an adaptive health system and the reality of its implementation on the ground. Therefore, research that integrates a health systems perspective, a One Health approach, and risk management based on global ecological change is crucial for formulating a more holistic and effective preparedness model particularly in the context of a developing country like Indonesia.

Although numerous studies have addressed health system preparedness for infectious diseases, most research focuses on epidemiological or policy aspects, without integrating managerial dimensions, cross-sectoral governance, and ecological risks into a comprehensive analytical

framework. Furthermore, empirical approaches combining quantitative and qualitative analyses in developing country contexts remain relatively limited, leaving a gap in understanding the dynamics of health system preparedness holistically.

Against this backdrop, this research aims to explore and analyze the level of preparedness, managerial factors, and adaptive management models for health system preparedness in response to emerging infectious disease and zoonotic threats. The findings are expected to provide theoretical and practical contributions to the development of national health policies that are more resilient and responsive to the dynamics of global health threats.

METHODS

This research uses a mixed methods approach with a sequential explanatory design, which combines quantitative and qualitative approaches. The qualitative approach was conducted to gain an in-depth understanding of the dynamics of policy implementation, institutional barriers, and cross-sector interactions in health system preparedness. Qualitative data were collected through in-depth interviews with 15 key informants purposively selected based on their strategic roles in the epidemiological surveillance system and outbreak management.

Qualitative data analysis was conducted using a thematic analysis approach which includes the following stages: (1) data transcription, (2) open coding to identify units of meaning, (3) axial coding to group codes into categories, and (4) selective coding to build main themes that represent the research phenomena.

To ensure data validity and credibility, source triangulation and member checking techniques were used, while dependability was maintained through an audit trail of the data analysis process. This approach enabled the integration of qualitative results with quantitative findings in a complementary manner within a sequential explanatory design framework.

In the quantitative component, the research population includes stakeholders directly involved in the epidemiological surveillance system and outbreak preparedness management. The sample was determined using purposive sampling techniques, considering the institutional roles of the respondents within the health system. Quantitative data were collected through structured questionnaires using a five-point Likert scale to measure health system readiness indicators, including surveillance capacity, laboratory readiness, resource availability, policy support, One Health approach integration, and managerial capacity.

The research instrument was tested through the Pearson correlation validity test and the Cronbach's Alpha reliability test to ensure the internal consistency of each research construct. Quantitative data analysis was conducted using statistical software through several stages, namely descriptive analysis to describe the characteristics of the data and the level of readiness of the health system, classical assumption tests including normality, multicollinearity, and heteroscedasticity, as well as multiple linear regression analysis to examine the influence of independent variables on the dependent variable. Model significance tests were conducted using the F-test, while the influence of each independent variable was analyzed using the t-test at a significance level of $\alpha = 0.05$. The magnitude of the model's contribution is explained through the coefficient of determination (R^2).

The qualitative component was conducted through in-depth interviews with key informants from health institutions and related agencies. Qualitative analysis was conducted using a thematic analysis approach, aimed at identifying patterns of interpretation regarding policy implementation constraints, cross-sector coordination, and institutional dynamics that affect the preparedness of the health system.

RESULTS

1. Characteristics of Respondents and Units of Analysis

This study involved 120 respondents from key institutions in the infectious disease and zoonotic preparedness system, consisting of health services (30.0%), referral hospitals (25.8%), public health laboratories (20.0%), and cross-sectoral agencies (animal husbandry and the environment) (24.2%). The majority of respondents had >10 years of work experience (62.5%) and held managerial or program coordinator positions (54.2%), making them methodologically representative for evaluating system capacity.

2. Test the Validity and Reliability of the Instrument

Table 1. Results of the Validity and Reliability Test of the Health System Readiness Instrument

Variables	Number of Items	r-count (range)	r-table (α=0.05)	Cronbach's Alpha
Surveillance Capacity	6	0.54–0.81	0.361	0.87
Laboratory Readiness	5	0.49–0.78	0.361	0.84
Health Human Resources	5	0.52–0.76	0.361	0.82
Information Systems	4	0.57–0.80	0.361	0.85
Governance & Coordination	6	0.60–0.83	0.361	0.89
One Health Integration	5	0.58–0.79	0.361	0.86

All items had a calculated r value > r table (0.361), thus declared valid. Cronbach's Alpha values for all variables were >0.80, indicating excellent internal consistency. The instrument is suitable for further analysis.

3. Multiple Linear Regression Analysis

Dependent variable: Health System Readiness Level Independent variables: Managerial Capacity, One Health Integration, Policy Support, Resource Availability, Ecological Risk Management

Table 2. Results of Multiple Linear Regression Analysis

Independent Variables	β (Standardized)	t	Sig. (p)
Managerial Capacity	0.412	5.89	0,000
One Health Integration	0.276	3.74	0.001
Policy Support	0.221	2.98	0.004

Resource Availability	0.193	2.45	0.016
Ecological Risk Management	0.305	4.12	0,000

$R = 0.781$

$R^2 = 0.610$

$F = 35.27$

$p(F) = 0.000$

Significant at $\alpha < 0.05$

The results of the regression analysis showed that all independent variables had a positive and significant influence on health system preparedness ($p < 0.05$). The β coefficient value indicates the strength of each variable's contribution, with managerial capacity having the greatest influence ($\beta = 0.412$), meaning that a one-unit increase in managerial capacity significantly increases system preparedness compared to other variables.

An R^2 value of 0.610 indicates that 61% of the variation in health system preparedness can be explained by the model, while the remaining 39% is influenced by factors outside the model. An F value of 35.27 with a significance of $p < 0.001$ indicates that the model simultaneously has strong predictive ability.

4. Gap Analysis against IHR Core Capacity Standards

Referring to the core capacity standards of the World Health Organization through the International Health Regulations (IHR 2005) framework:

Table 3. Core Capacity Gap Analysis

IHR Components	Standard (%)	Achievement (%)	Gap (%)
Surveillance	100	78	22
Laboratory	100	70	30
Emergency Response	100	74	26
Cross-Sector Coordination	100	76	24
Risk Management	100	68	32

The gap analysis results show that all core capacity components remain below the ideal standard (100%). The largest gaps are in risk management (32%) and laboratory capacity (30%), indicating that the health system still tends to be reactive rather than preventive.

The 68% achievement rate in risk management indicates limitations in integrating data-based risk analysis and ecological indicators, while the 70% achievement rate in laboratories reflects limitations in diagnostic capacity and facility distribution. These gaps have implications for delays in early detection and epidemiological response.

Table 4. of Qualitative Analysis Results of Health System Readiness

No	Main Theme	Category/Subtheme	Description of Findings
1	Weaknesses of Cross-Sector Governance	Fragmentation of inter-agency coordination	Coordination between the health, environment and livestock sectors is

			still partial and has not been operationally integrated.
		Unclear coordination mechanisms	The absence of integrated SOPs in handling cross-sectoral zoonoses
2	Limitations of Information System Integration	Data is not integrated	Epidemiological, veterinary and environmental information systems run separately
		Delay in data reporting	The reporting process is still manual/semi-digital, thus slowing down early detection.
3	Resource Capacity Limitations	Lack of skilled manpower	Limited number of epidemiologists and laboratory analysts
		Unequal distribution of human resources	Professional workforce is concentrated in certain areas
4	Policy Support	Disharmony between central and regional policies	Policies are not yet synchronized between levels of government
		Policy implementation is not optimal	The policy is normative and not yet operational
5	Health System Financing	Budget constraints	The budget for surveillance and preparedness is still limited.
		Dependence on incidental programs	Funding is more reactive when an outbreak occurs
6	One Health Implementation	Implementation is not yet integrated	The One Health approach has not been implemented systematically
		Lack of cross-sector collaboration	Collaboration is still ad hoc, not systemic

The results of the thematic analysis show that the preparedness of the health system in dealing with emerging and zoonotic infectious diseases is influenced by interrelated structural and operational factors, especially in the aspects of governance, system integration, and resource capacity.

The theme of weak cross-sectoral governance emerged as the most dominant issue, with 80% of informants highlighting fragmented coordination between institutions. This figure indicates that despite a normative collaborative framework, implementation at the operational level still faces serious obstacles, particularly related to role clarity, coordination mechanisms, and standard operating procedures. This situation has implications for the low effectiveness of integrated responses to zoonotic threats.

Regarding the issue of limited information system integration, 73% of informants indicated that surveillance systems are not yet integrated across sectors. This reflects the existence of data silos between institutions, leading to delays in early detection and epidemiological risk analysis.

Furthermore, 60% of informants highlighted slow data reporting due to limited digitalization, further weakening the system's capacity to respond to threats in real time.

The theme of limited resource capacity indicates that 60% of informants identified a shortage of epidemiologists and laboratory analysts as a major obstacle. Not only is the number of professionals affected, but the uneven distribution of professionals (47%) also widens the capacity gap between regions. This directly impacts the quality of epidemiological investigations and the speed of response to outbreaks.

Regarding policy support, more than half of the respondents (53%) assessed that there was disharmony between central and regional policies. This indicates that existing policies are not fully adaptive to local needs. Furthermore, the still normative nature of policy implementation (47%) indicates a gap between planning and implementation on the ground.

The theme of health system financing revealed that budget constraints are a significant obstacle, with 47% of informants highlighting the minimal allocation of funds for surveillance and preparedness activities. The reactive financing pattern (40%) suggests that the system is not fully oriented towards prevention, but rather focuses on post-outbreak response.

Finally, regarding the implementation of One Health, 67% of informants stated that this approach has not been implemented in an integrated manner. Although conceptually adopted, its implementation still faces obstacles in the form of minimal cross-sector collaboration (60%) and the absence of a sustainable coordination system. This indicates that the integration between human, animal, and environmental health remains partial.

Overall, these qualitative findings reinforce the quantitative results, demonstrating that health system preparedness is not solely determined by technical factors, but is also heavily influenced by the quality of governance, system integration, and institutional capacity. The interplay between these factors creates a complex preparedness framework that requires a holistic approach based on cross-sectoral integration and strengthened health system management.

DISCUSSION

1. Health System Readiness Level

These quantitative findings are reinforced by qualitative analysis results showing that most informants assess that cross-sector coordination and surveillance capacity have structurally developed, but still face challenges in the aspects of epidemiological information system integration and the sustainability of preparedness program financing. Informants also emphasized that the reporting systems for human health, animal health, and environmental indicators still operate separately, so the early detection and epidemiological risk analysis processes are not yet fully based on integrated data. Thus, although institutional and regulatory frameworks are in place, the preparedness of the health system still faces challenges in terms of data interoperability and resource support.

Theoretically, these findings align with the health system building blocks framework developed by the World Health Organization, which emphasizes that the effectiveness of the health system depends on the balance between six main components: leadership and governance,

financing, health workforce, information systems, service delivery, and access to technology and laboratories. The imbalance between these components has the potential to reduce the adaptive capacity of the health system in facing epidemiological shocks. In the perspective of health system resilience, preparedness is not only determined by the existence of formal policies but also by the system's ability to absorb, adapt, and transform itself when facing a health crisis.

These findings are consistent with a global study evaluating the preparedness capacity of health systems against infectious disease outbreaks in 186 countries during the period 2018–2022, which showed that although there was an increase in capacity across various domains of preparedness, significant gaps still existed, particularly in financing, resource coordination, and early disease detection systems (Eze et al., 2024). Thus, the integration of quantitative and qualitative results indicates that the health system's preparedness in the context of this study tends to have a fairly strong regulatory foundation, but is not yet fully supported by adequate financing infrastructure and information systems.

This study demonstrates the uniqueness of integrating managerial, ecological, and cross-sectoral governance dimensions into a single empirical model of health system preparedness. Unlike previous studies that tended to isolate these factors, this study demonstrates that managerial capacity plays a central role as a bridge between policy, resources, and technical implementation on the ground.

In addition, the integration of the One Health approach with quantitative analysis provides a novel contribution in explaining how interactions between human, animal, and environmental health systems significantly influence preparedness for emerging diseases.

2. Determinants of Health System Readiness

These quantitative findings are reinforced by in-depth interview results that show the effectiveness of institutional coordination and the quality of health organization leadership play a crucial role in determining the speed of response to potential outbreaks. Informants emphasized that institutions with clear coordination structures and adaptive leadership tend to be more capable of integrating epidemiological data, conducting risk analysis, and formulating mitigation steps more quickly compared to institutions with fragmented governance. Thus, the results of this study indicate that the preparedness of the health system does not only depend on the availability of physical resources but also on the managerial capacity to manage the complexity of cross-sector health risks. Conceptually, the dominance of managerial factors reinforces the perspective of health system resilience, which emphasizes the importance of adaptive leadership and strategic governance in enhancing the health system's ability to face epidemiological crises. The International Health Regulations (IHR 2005) established framework by the World Health Organization also places governance and cross-sector coordination as core capacities in national preparedness. Furthermore, the One Health approach emphasizes the integration of the human, animal, and environmental health sectors as a key strategy in mitigating zoonotic risks amid global ecological changes.

The findings of this study align with research results that indicate managerial factors and the governance characteristics of healthcare facilities are significant determinants in enhancing the

health system's response capacity to pandemics in low- and middle-income countries (Hakim & Anamul Haque, 2025). Another study also found that governance dimensions, policy coordination, and risk management are key components determining the level of preparedness and resilience of the national health system (Fadi El-Jardali et al., 2025). Additionally, cross-sectoral integration within the One Health framework has proven to enhance the effectiveness of responses to biological and zoonotic threats, particularly through the strengthening of data coordination and integrated response mechanisms (Zhou et al., 2024). The synthesis of global research also shows that health systems with adaptive leadership and integrated risk management have more effective response performance to high-impact infectious disease threats (Saif-Ur-Rahman et al., 2025). The integration of quantitative and qualitative findings in this study shows that strengthening managerial capacity and cross-sector governance are strategic interventions in enhancing health system preparedness. This emphasises that the transformation of the health system should not only focus on improving physical infrastructure but also on strengthening organizational capacity to manage complex and multidimensional health risks.

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In addition, the integration of the One Health approach with quantitative analysis provides a novel contribution in explaining how interactions between human, animal, and environmental health systems significantly influence preparedness for emerging diseases.

3. Gap in Core Capacity against IHR Standards

These findings indicate that although the institutional structure for preparedness is in place, the operational capacity for early molecular detection, data-driven risk analysis, and epidemiological response still needs to be strengthened. In-depth interview results reinforce these findings by showing that the limitations in laboratory capacity are not only related to the availability of diagnostic facilities but also to the distribution of expert personnel, laboratory results reporting systems, and data connectivity between healthcare facilities and national surveillance agencies. The informants also emphasized that epidemiological risk analysis still does not fully integrate ecological change indicators such as environmental dynamics, land use changes, and human-animal interactions, which are important factors in the emergence of zoonoses.

In the perspective of the International Health Regulations (2005), laboratory capacity and risk management are fundamental components in supporting early detection systems and rapid responses to extraordinary public health events. The preparedness–resilience theory emphasizes that health systems with weaknesses in diagnostic capacity and risk assessment tend to be reactive and experience delays in epidemiological decision-making.

These findings are consistent with research showing that national surveillance and laboratory capacity are directly related to the quality of epidemiological data and the effectiveness

of pandemic response (Ledesma et al., 2024). Other multi-country studies have also found that healthcare facilities in various developing countries still face significant gaps in laboratory infrastructure, health information systems, and risk management mechanisms (Gomez-Perez et al., 2024). Therefore, the enhancement of core IHR capacities should be directed towards strengthening risk-based early detection systems and integrating epidemiological, veterinary, and environmental data within the One Health approach framework.

CONCLUSIONS

This study concludes that health system preparedness in facing emerging infectious diseases and zoonotic threats is the result of a complex interaction between managerial capacity, One Health integration, ecological risk management, policy support, and resource availability.

Empirical findings indicate that managerial capacity is the main determinant in improving system preparedness, while qualitative results confirm that the main challenges lie in weak cross-sector coordination, limited integration of information systems, and limited human resources and funding.

Thus, improving health system preparedness requires a transformational approach that focuses not only on technical aspects, but also on strengthening governance, integrating cross-sectoral policies, and developing an ecological risk-based surveillance system within the One Health framework.

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