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Structural Vulnerabilities by Design: An Institutional Analysis of Zhengzhou's Multi-Level Warning and Risk Communication System Prior to the 2021 Urban Flood of China

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Abstract: *The design of multi-level warning and risk communication systems is a critical but analytically underexplored dimension of urban flood governance. Using a qualitative institutional document analysis design, this study reconstructs how Zhengzhou's warning and risk communication system was formally structured to function across eight governance levels (L1–L8) prior to the extreme rainfall event of July 2021. Drawing on the Emergency Response Law, national meteorological regulations, and the Zhengzhou Municipal Urban Flood Control Emergency Plan, the study identifies four structural tensions embedded in the institutional design. First, the "Tiao-Kuai" divide between warning issuance and emergency response activation as institutionally separate systems. Second, the gap between framework-level contingency plans and the operational precision required by extreme events. Third, long vertical transmission chains combined with insufficient horizontal coordination mechanisms. Fourth, the absence of institutionalized public feedback loops from the receiving end of the communication chain. These tensions did not individually determine system failure, but together constituted specific institutional pressure points that shaped the conditions under which governance capacity would be tested under extreme climate stress. These findings contribute to understanding how institutional design in hierarchical governance systems can embed structural vulnerabilities that remain latent until activated by extreme events, offering direct implications for flood governance reform in Chinese cities and rapidly urbanizing contexts across the Asia-Pacific region facing intensifying climate risks.*

Keywords: *Institutional Design; Early Warning Systems; Risk Communication; Structural Tensions; Urban Flood Governance; Zhengzhou of China*

Introduction

Urban flooding has become one of the most consequential climate risks for rapidly urbanizing cities worldwide. Asia remains the most disaster-prone region for weather and water-related hazards, with precipitation extremes projected to intensify across East Asia under continued climate change (IPCC, 2021; WMO, 2024). China faces particularly acute exposure. Repeated severe flooding in major cities has revealed persistent limitations in both drainage infrastructure and emergency governance (Zeng et al., 2023). Despite the launch of the Sponge City Initiative in 2015, Zhengzhou, as a designated national pilot city since 2016, still experienced on 20 July 2021 over 600 mm of rainfall within 24 hours, the most intense rainstorm in its recorded meteorological history, resulting in 398 deaths and direct economic losses approaching 100 billion yuan (State Council Investigation Group,

2022). The scale of disaster impacts cannot be explained by meteorological intensity alone. The *State Council Investigation Report* explicitly attributes the amplification of losses to inadequate risk preparedness, insufficient preventive organization, and improper emergency response. These are governance failures rooted in the institutional architecture of the warning and risk communication system itself.

Existing research on urban flood governance in China has developed along two streams. The first focuses on infrastructure performance and technical warning systems, documenting drainage capacity limitations, sponge city design constraints, and early warning technology gaps under extreme conditions (Fu et al., 2023; Chen & Kong, 2022). The second examines institutional and governance dimensions, identifying fragmented departmental responsibilities, vertical information flow biases, and coordination failures as recurring structural problems in China's emergency management system (Wang et al., 2025; He, 2024; Liu & Christensen, 2022). However, both streams tend to analyze governance failures after they have occurred. Less attention has been paid to the prior question: how the institutional design of warning and risk communication systems may itself embed structural vulnerabilities, the pressure points that remain latent under normal conditions but are activated under extreme climate stress. No study has systematically reconstructed the formal institutional design of a Chinese urban flood warning system at the level of individual governance nodes, nor identified the structural tensions built into that design prior to a major disaster event.

This study addresses that gap. It analyzes Zhengzhou's multi-level warning and risk communication system as a case of institutional design under pressure, examining how the system was formally structured to function and where its design contained the seeds of potential failure. The research objectives of this study are threefold. First, to reconstruct the formal institutional design of Zhengzhou's warning and risk communication system across eight governance levels prior to July 2021. Second, to identify and analyze the structural tensions embedded in that design. Third, to explain how these tensions constitute institutional preconditions for governance failure under extreme climate stress, with implications for flood governance reform in Chinese cities and comparable rapidly urbanizing contexts across the Asia-Pacific region.

Literature Review and Theoretical Framework

Early Warning Systems and Institutional Interfaces

Early warning system research has progressively moved beyond technical components toward end-to-end process analysis. Basher (2006) argues that effective warning systems require operational linkages among detection, issuance, dissemination, and response phases. A break at any interface substantially reduces the system's protective value. Sorensen (2000) similarly finds that warning failures tend to occur more frequently at the connections between components than within the components themselves. Baudoin et al. (2016) reinforce this point, emphasizing that the institutional processes and linkages connecting risk knowledge to emergency management action are as analytically important as the technical instruments of warning generation themselves. These insights shift

analytical attention from the performance of individual nodes to the design of the interfaces connecting them.

Risk communication research reinforces this perspective. Mileti and Sorensen (1990) identify that effective warnings must provide clear source, channel, consistency, and specific protective action guidance. The absence of any of these elements significantly reduces public willingness and capacity to respond. Lindell and Perry (2012) further demonstrate that after receiving a warning, individuals must sequentially complete information receipt, threat assessment, and feasibility judgement before taking protective action. Disruption at any stage can suppress or delay behavioral response. Together, these findings establish that warning effectiveness is not only a technical problem. It is a governance design problem.

In the Chinese context, Chen and Kong (2022) document persistent fragmentation in emergency management responsibilities following the Zhengzhou disaster. Wang et al. (2025) identify weak inter-agency information flows as a structural feature of the governance network. He (2024) specifically identifies the absence of effective two-way interaction mechanisms between government and the public as a design-level gap. Yu et al. (2022) provide a detailed hydrological reconstruction of the event, establishing the technical baseline against which governance responses can be assessed. Shi and Xie (2024) further demonstrate that institutional vulnerability, not meteorological intensity alone, was the primary determinant of loss scale in the Zhengzhou case. These studies collectively point to institutional design as a critical explanatory layer. Yet none has systematically reconstructed the formal design prior to a disaster event to locate where structural tensions are built in.

Adaptive Governance as a Theoretical Lens

This study draws on adaptive governance as its primary theoretical lens. Adaptive governance refers to governance arrangements that enable systems to adjust, learn, and reorganize in the face of uncertainty and change (Folke et al., 2005). It emphasizes multi-level coordination across governance levels (Dietz et al., 2003), institutional flexibility, and mechanisms for feedback and learning as conditions for effective governance performance under dynamic and uncertain conditions.

This study applies the adaptive governance framework specifically to the analysis of institutional design, examining whether the formal architecture of Zhengzhou's warning system was designed to support coordination, interface coupling, operational specificity, and feedback — the preconditions for adaptive governance capacity under extreme conditions. This focus on design rather than performance distinguishes this study from companion analyses that assess actual governance behavior during the event itself. The analytical question here is not whether governance actors performed adaptively, but whether the institutional architecture they operated within was designed in a way that made adaptive performance possible.

Pahl-Wostl (2009) argues that adaptive capacity in governance systems depends critically on multi-level learning processes and on the quality of institutional interfaces connecting different levels of the system. Smit and Wandel (2006) identify that adaptive

capacity is shaped by the determinants built into governance systems prior to a crisis, rather than being improvised in real time. Chaffin et al. (2014) synthesize a decade of adaptive governance scholarship, confirming that the quality of institutional design, particularly the mechanisms enabling coordination and learning across levels, is a consistent predictor of governance system performance under uncertainty. Engle (2011) further argues that adaptive capacity must be assessed at the level of specific institutional arrangements, not only at the aggregate system level, supporting the node-level analytical approach adopted in this study. Tierney (2012) further argues that the scale of disaster impacts is determined not only by hazard intensity but by the institutional arrangements that shape the response. These perspectives together establish that institutional design is not merely a precondition for governance performance. It is itself a legitimate and necessary object of analysis.

The structural tensions identified in this study are assessed against these theoretical expectations. Where the formal institutional design fails to provide adequate coordination mechanisms, clear interface coupling, sufficient operational specificity, or effective feedback loops, it falls short of the design conditions that adaptive governance theory identifies as necessary for system performance under extreme climate stress.

Research Method

Research Design

This study employs a qualitative institutional document analysis design. Zhengzhou is treated as a critical case for examining how institutional design embeds structural vulnerabilities in multi-level warning and risk communication systems (Yin, 2018). Document analysis as a primary research method is well-established in qualitative governance research (Bowen, 2009). It is particularly suited to institutional design analysis, where the formal texts are both the object of study and the primary source of evidence. Flyvbjerg (2006) further argues that single critical cases can generate disproportionate analytical value precisely because they are selected to test a system under conditions where it should perform well, making failure especially revealing. The case is analytically significant for two reasons. First, Zhengzhou was a designated national Sponge City Initiative pilot city with formally coherent emergency governance arrangements, representing a context in which the warning system should have been well-designed. Second, the availability of authoritative primary institutional texts makes the formal design of the system recoverable in precise documentary detail.

Data Sources and Selection

The analysis focuses on the institutional design of Zhengzhou's warning and risk communication system as it stood prior to the extreme rainfall event of July 2021. The primary analytical period spans 2007 to July 2021, beginning with the promulgation of the *Emergency Response Law* and the *Measures for the Issuance and Dissemination of Meteorological Disaster Warning Signals* — the foundational legal documents governing the warning system, and closing at the moment the July 2021 event began. A significant structural inflection point within this period is the 2018 establishment of the Ministry of Emergency Management,

which reshaped the governance architecture operative during the event. Documentary sources were selected according to two criteria: direct relevance to the institutional arrangements governing warning issuance and emergency response, and coverage of the pre-event institutional design period.

Primary sources include the *Emergency Response Law* (2007; 2024 revision), the *Measures for the Issuance and Dissemination of Meteorological Disaster Warning Signals* (CMA, 2007), the *Zhengzhou Municipal Urban Flood Control Emergency Plan* (2019), and the *Henan Provincial Flood Control Emergency Plan* (2022). Sources excluded from primary analysis include documents addressing infrastructure construction or environmental engineering without bearing on the warning and risk communication process chain. The *State Council Investigation Report* (State Council Investigation Group, 2022) is drawn upon selectively and solely to identify where the formal design was characterized as structurally insufficient. It is not used to analyze event-level governance performance. Secondary sources comprising peer-reviewed academic literature were used for theoretical framing and cross-validation only.

Analytical Instrument

The analysis follows the eight-level governance structure embedded in Zhengzhou's formal institutional design, from national and provincial authorities (L1) through to the general public (L8), as specified in the *Emergency Response Law* and the *Zhengzhou Municipal Urban Flood Control Emergency Plan*. Each level is examined against four design dimensions. Coordination design asks whether the institutional architecture establishes clear mechanisms for information sharing and task distribution across governance levels and departments. Interface design asks whether the linkage between the meteorological warning system and the emergency response activation system is structured to function reliably under time pressure. Specificity design asks whether contingency plans provide sufficient operational detail to guide concrete action when conditions exceed anticipated scenarios. Feedback design asks whether the institutional architecture contains mechanisms to verify that warning information has reached and influenced its intended recipients.

Where the institutional texts reveal a gap between what the design requires and what the design actually provides the conditions to achieve, the pattern is coded as a structural tension. Structural tensions are distinguished from implementation failures. They are features of the design itself, not of how actors performed within it.

Trustworthiness

This study relies exclusively on publicly available government documents and published academic sources and does not involve human subjects; formal ethics committee approval was therefore not required. Credibility was established through source triangulation: each analytical claim is anchored to at least one primary institutional text and cross-validated against independent secondary sources drawn from peer-reviewed literature. Dependability is supported by the consistent application of the four design dimensions across all eight governance levels. Confirmability is maintained by grounding

all claims in specific, citable documentary evidence. The primary limitation is the study's reliance on formal institutional texts, which capture design intent but cannot fully reveal the informal norms, organizational cultures, and political dynamics that also shape how systems function in practice.

Result and Discussion

The Eight-Level Governance Structure: Institutional Design Baseline

Zhengzhou's warning and risk communication system was formally structured across eight governance levels. This eight-level structure is not an analytical construct imposed on the case. It reflects the formal distribution of responsibilities embedded in the *Emergency Response Law* and the *Zhengzhou Municipal Urban Flood Control Emergency Plan* (Zhengzhou Municipal People's Government, 2019). Each level was assigned specific institutional obligations for generating, receiving, transmitting, and acting upon warning signals. The intended information flow moved downward from L1 to L8, and upward from L8 to L1 through disaster reporting channels. As shown in Table 1, each level carries distinct institutional obligations within the warning and risk communication chain.

Table 1 Eight-Level Governance Structure of Zhengzhou's Warning and Risk Communication System

Governance Level	Representative Actors	Core Institutional Responsibilities
L1 — National and provincial authorities	China Meteorological Administration; Henan Provincial Meteorological Bureau; Henan Provincial Flood Control and Drought Relief Headquarters	Issue national and provincial technical forecasts and directives; set overarching policy constraints; mobilize cross-jurisdictional resources
L2 — Municipal command and coordination	Zhengzhou Municipal Party Committee and Government; Zhengzhou Flood Control and Drought Relief Headquarters; Zhengzhou Emergency Management Bureau	Activate emergency response; issue city-wide directives; coordinate all municipal departments; maintain situational awareness of city-wide disaster conditions
L3 — Municipal functional departments	Zhengzhou Meteorological Bureau; Water Resources Bureau; Urban Management Bureau; Transport Bureau; Urban-Rural Construction Bureau	Provide specialised monitoring data; issue departmental warnings and directives; supervise critical infrastructure and construction risk nodes; coordinate with L6 operational units
L4— District and county governments	Jinshui District; Erqi District; Gongyi City; Xingyang City; Zhengdong New District	Activate district-level responses; organize evacuation; supervise townships; submit disaster information upward

Governance Level	Representative Actors	Core Institutional Responsibilities
L5 — Township and subdistrict governments	Mihe Town; Heluo Town; Cuimiao Town; Jicheng Road Subdistrict; Baisha Town	Execute population transfer; implement emergency plans; report field conditions upward; mobilise community resources
L6 — Critical operational units and infrastructure operators	Zhengzhou Metro Group; Urban Tunnel Management and Maintenance Centre; Guojiazui Reservoir management; construction site operators	Implement site-level emergency plans; conduct safety inspections; close or restrict access to high-risk facilities; communicate risks to adjacent communities
L7 — Media and telecommunication networks	Zhengzhou Publicity Department; broadcast and television; three major telecom operators; new media channels	Disseminate warning signals and defense guidelines; broadcast administrative directives (e.g., suspension of work, school closures); conduct public education on flood avoidance
L8 — General public	Residents; enterprises; schools; users of metro, tunnels, and other public facilities	Receive and act upon warnings and administrative directives; execute self-protection and evacuation; report local conditions upward through community channels

Source: *Emergency Response Law of the People's Republic of China* (2007); *Measures for the Issuance and Dissemination of Meteorological Disaster Warning Signals* (CMA, 2007); *Zhengzhou Municipal Urban Flood Control Emergency Plan* (2019). Compiled by the author based on primary institutional texts.

The following four subsections identify where this design contained structural tensions, assessed against the four design dimensions established in the theoretical framework.

Structural Tension One: The "Tiao-Kuai" Divide

The most consequential structural tension in the design lies at the interface between the meteorological warning system and the emergency response activation system. These two systems operate through fundamentally different institutional logics. The meteorological warning system follows a vertical professional hierarchy, known in Chinese governance as Tiao, running from the China Meteorological Administration through provincial and municipal meteorological bureaus. The emergency response activation system operates through the territorial administrative hierarchy of local government, known as Kuai, centered on the municipal Party committee and government. The 2018 establishment of the Ministry of Emergency Management consolidated emergency management functions under a single institutional umbrella. However, it did not eliminate this structural separation. The meteorological warning system retained its independent technical hierarchy, while emergency response activation remained within the territorial administrative system.

The design consequence is critical. Under the *Emergency Response Law*, the issuance of

a red warning signal by a meteorological station is a technical act. The activation of a government emergency response is a separate administrative act. Between these two acts lies a built-in institutional decision interval that requires independent governmental judgement. The *Zhengzhou Municipal Urban Flood Control Emergency Plan* formalizes a conversion pathway from meteorological warning level to urban flood warning level to emergency response level, but this pathway depends on the municipal command system making a deliberate and timely decision at each conversion step. No automatic coupling mechanism exists.

This design feature aligns with what Sorensen (2000) identifies as a systemic pattern: warning system failures tend to occur at the connections between components rather than within them. Basher (2006) similarly argues that end-to-end warning systems require effective institutional linkage among detection, issuance, and response phases. The "Tiao-Kuai" divide is precisely such a connection point. Under normal conditions, the decision interval is manageable. Under the time pressure of a rapidly escalating extreme event, it becomes a critical institutional friction point. The design is internally consistent. What it lacks is a coupling mechanism robust enough to function when speed of conversion matters most. Ansell and Gash (2008) demonstrate that effective cross-boundary governance requires clear institutional arrangements for shared authority and information exchange to be established before a crisis, rather than negotiated under time pressure. The "Tiao-Kuai" divide is a failure of precisely this pre-design.

Structural Tension Two: Framework-Level Plans and Operational Precision

The second structural tension lies in the character of the contingency planning framework. The *Zhengzhou Municipal Urban Flood Control Emergency Plan* provides a coherent overall framework. It establishes the command structure, assigns member unit responsibilities, defines warning and response levels, and specifies information reporting intervals. What it does not provide is operational detail at the level of specific scenarios. The plan does not specify precise trigger conditions for individual departments, inter-departmental information exchange protocols, or concrete action sequences for conditions that exceed anticipated scenarios.

As shown in Table 2, each warning level carries legally specified defense requirements. The classification system is formally precise at the level of threshold definition. However, the plan does not provide the operational mechanism through which these requirements are converted into coordinated action across departments and levels under time pressure.

Table 2 Classification of Rainstorm Warning Levels, Precipitation Thresholds, and Statutory Defense Requirements

Warning Level	Signal Color	Precipitation Threshold	Statutory Defense Requirements
Level I	Red	3-hour rainfall ≥ 100 mm and continuing	Suspend meetings, classes, and business operations (except special industries); evacuate personnel to safe areas.
Level II	Orange	3-hour rainfall ≥ 50 mm and continuing	Suspend outdoor operations; relevant departments enter emergency positions and

			maintain standby status.
Level III	Yellow	6-hour rainfall ≥ 50 mm	Check drainage systems in urban areas, farmland, and fishponds; prepare for drainage operations.
Level IV	Blue	12-hour rainfall ≥ 50 mm	Monitor the latest warning information; schools and kindergartens take appropriate measures to ensure safety.

Information Source: *Measures for the Issuance and Dissemination of Meteorological Disaster Warning Signals* (CMA Order No. 16, 2007); *Zhengzhou Municipal Urban Flood Control Emergency Plan* (2019).

This characteristic is not unique to Zhengzhou. The *State Council Investigation Report* explicitly observes that contingency plans in China's urban flood governance system tend toward framework coverage at the expense of operational specificity, and notes that some plans treat the occurrence of serious harm as an activation condition rather than prescribing proactive pre-event action (State Council Investigation Group, 2022). Related research similarly notes that local plans in China's emergency management system tend toward isomorphism and uniformity across levels, providing limited guidance for specific actions in extreme conditions (Chen & Kong, 2022).

The design implication is that the conversion of institutional framework into coordinated action depends heavily on the judgement and initiative of individual commanders and department heads. When conditions fall within familiar scenarios, this conversion can rely on prior experience. When an extreme event exceeds the scenarios the plan anticipated, the gap between framework-level provisions and the operational precision actually required becomes a visible institutional constraint. Comfort et al. (2010) identify this dynamic as a consistent feature of governance systems that fail under extreme conditions: the absence of pre-built operational protocols forces improvisation precisely when improvisation is least reliable. Birkland (2009) identifies a related pattern: contingency plans are often designed to demonstrate institutional readiness rather than to provide operationally precise guidance. The *Zhengzhou Municipal Urban Flood Control Emergency Plan* exhibits characteristics consistent with this pattern. Specificity design, in this case, was sacrificed for framework generality.

Structural Tension Three: Long Vertical Chains and Weak Horizontal Coordination

The third structural tension concerns the structural combination of a long vertical transmission chain and insufficient horizontal coordination mechanisms. Warning information in the formal design must travel from the China Meteorological Administration through the Henan Provincial Meteorological Bureau to the Zhengzhou Meteorological Bureau, and then downward through the municipal command system to districts, townships, and grassroots units level by level. This is a chain of at least five transmission steps before a warning signal reaches the operational level.

The *Emergency Response Law* requires the interconnection of information systems

across departments and levels, and mandates inter-departmental information exchange (Standing Committee of the National People's Congress, 2007). These provisions express the aspiration that information should reach all relevant actors. They do not prescribe the specific mechanisms through which that aspiration is achieved. The *Zhengzhou Municipal Urban Flood Control Emergency Plan* establishes a multi-department consultation mechanism and lists member units. But it does not provide explicit institutional guarantees for routine inter-departmental information-sharing channels or cross-departmental coordination procedures.

The result is a design that is structurally strong on vertical transmission but structurally weak on horizontal integration. Information is designed to flow up and down the hierarchy. It is not designed to flow laterally across departments with equivalent efficiency. Kapucu (2006) demonstrates that effective cross-agency coordination requires communication relationships and shared procedures to have been established before a disaster occurs. Wang et al. (2025) identify this pattern empirically in the Zhengzhou governance network, finding that inter-agency information flows were structurally weak. The design, in concentrating authority and communication pathways along vertical lines, embedded the conditions for horizontal coordination failure before any event occurred. Duit and Galaz (2008) argue that governance systems operating in complex and uncertain environments require horizontal coordination mechanisms that are structurally embedded, not contingent on crisis-induced improvisation. The Zhengzhou design's vertical concentration of authority directly contradicts this requirement.

Structural Tension Four: The Absence of Public Feedback Loops

The fourth structural tension is the one-directional character of the public communication design. The institutional framework contains detailed provisions on warning dissemination. The *Measures for the Issuance and Dissemination of Meteorological Disaster Warning Signals* require broadcast and telecommunications media to promptly disseminate warning signals (CMA, 2007). The *National Emergency Response Plan for Public Emergencies* specifies dissemination forms including broadcast, television, and telecommunications networks. Warning signals are designed to contain four components: name, icon, standard, and defense guidelines.

What the institutional framework does not contain is any provision for verifying whether these warnings have been received and acted upon by the public. The *Emergency Response Law* establishes an information reporter system for upward reporting of emergency conditions, but this system functions to report the state of the disaster to higher levels, not to assess the quality of public reception of warning signals (Standing Committee of the National People's Congress, 2007). The *Zhengzhou Municipal General Emergency Response Plan* references feedback, but restricts its scope to the internal administrative system, requiring relevant units to report receipt of warning information back to the issuing unit. This is an arrangement for internal command chain operation, not a mechanism for monitoring public response.

He (2024) explicitly identifies the limited channels for information interaction between

government and the public as a design-level gap, noting the absence of a functioning two-way interaction mechanism. Chen and Kong (2022) argue that the one-directional character of information flow is a significant contributing factor to the disconnect between warning issuance and actual public response. Fischhoff (1995) argues that effective risk communication is fundamentally interactive: without mechanisms for feedback and verification, communicators cannot assess whether messages have been understood or acted upon. Mileti and Sorensen (1990) establish that effective warning communication requires feedback mechanisms to confirm message receipt and comprehension. Lindell and Perry (2012) further demonstrate that without feedback, the command system cannot assess whether the public has moved through the sequential stages required for protective action. The Zhengzhou design contains no institutional mechanism to close this loop. Information was designed to flow toward the public. No return path was institutionalized.

Integrated Assessment: Institutional Preconditions for Governance Failure

The four structural tensions do not operate independently. They constitute a system of mutually reinforcing institutional pressure points. The "Tiao-Kuai" divide means that warning signals do not automatically trigger administrative responses. The specificity gap means that even when responses are triggered, the institutional framework provides insufficient operational guidance for coordinated action. The horizontal coordination deficit means that departments cannot efficiently share information and align their responses. The absence of public feedback loops means that the command system cannot verify whether warnings have reached and influenced the public. Together, these four tensions define a governance architecture that is formally coherent but operationally fragile and structurally vulnerable.

This integrated finding directly addresses the three research objectives of this study. The formal institutional design has been reconstructed across eight governance levels (refer to Table 1). The structural tensions embedded in that design have been identified and analyzed, each assessed against the four design dimensions derived from the adaptive governance and early warning system literature. Their significance as institutional preconditions for governance failure under extreme climate stress has been explained through the adaptive governance framework.

The broader implication is theoretical as well as practical. Tierney (2012) argues that disaster outcomes are governance outcomes. This study demonstrates that governance outcomes are in part design outcomes. The structural vulnerabilities that shaped the Zhengzhou disaster were not introduced by the event. They were present in the institutional architecture before the event began. Pahl-Wostl (2009) argues that adaptive capacity depends on the quality of institutional interfaces built into governance systems prior to a crisis. Smit and Wandel (2006) identify that adaptive capacity is shaped by the determinants built into governance systems before a crisis rather than being improvised in real time. The Zhengzhou case illustrates precisely what happens when those interfaces are weak and those determinants are absent.

For urban flood governance in China and comparable rapidly urbanizing contexts

across the Asia-Pacific region, the implication is direct. Infrastructure investment and meteorological monitoring capacity are necessary but insufficient. The institutional architecture connecting warning signals to protective action must itself be designed with the same rigor as the technical systems it is meant to activate. Liu and Zhu (2021) trace the evolution of China's emergency management system, showing that the structural tensions identified in this study reflect broader features of China's hierarchical emergency governance architecture as it developed through successive reform cycles. This finding suggests that the design vulnerabilities documented here are not idiosyncratic to Zhengzhou but are likely to recur across comparable Chinese cities without targeted reform of the governance architecture itself. Where that architecture contains the structural tensions identified in this study, the governance system will underperform its technical capabilities under extreme conditions, regardless of the sophistication of the monitoring infrastructure above it.

International experience offers instructive contrast at the level of institutional design. In the United States, the Emergency Management Assistance Compact provides pre-negotiated cross-jurisdictional coordination agreements that eliminate the need for real-time institutional improvisation during disasters (Kapucu, 2006). In collaborative governance systems examined by Ansell and Gash (2008), clear boundary-spanning mechanisms are established before a crisis rather than activated under time pressure. Both models directly address the interface and coordination design weaknesses identified in the Zhengzhou case. The comparison suggests that the structural tensions documented in this study are not inherent features of multi-level governance systems. They are features of a particular institutional design, one that can be reformed through targeted redesign of the interfaces and coordination mechanisms that the current architecture leaves underdeveloped.

Conclusion

This study has reconstructed the formal institutional design of Zhengzhou's multi-level warning and risk communication system across eight governance levels, identified four structural tensions embedded in that design, and explained how those tensions constitute institutional preconditions for governance failure under extreme climate stress. The contribution of this study lies in demonstrating that institutional design is itself a legitimate object of analysis in disaster governance research, not merely a background condition. By applying an adaptive governance framework specifically to the pre-event institutional architecture, the study shows that structural vulnerabilities can be identified through documentary analysis before a disaster occurs, offering a replicable analytical approach for governance audits in comparable multi-level administrative contexts. For practitioners and policymakers, the central implication is clear: the four structural tensions identified — the Tiao-Kuai interface gap, the specificity deficit, the horizontal coordination weakness, and the absence of public feedback loops — are design problems. These design problems require design solutions, not merely demands for better performance within a structurally inadequate system. Future research should extend this institutional analysis

through comparative case study across other Chinese cities and Asia-Pacific urban contexts to determine which structural tensions are specific to Zhengzhou's governance architecture and which reflect systemic features of hierarchical emergency governance systems more broadly. Interview-based fieldwork with governance actors at the design and planning level would further illuminate the political and organizational conditions that produced these tensions and the constraints that make them difficult to reform.

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