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The Influence of Technical and Non-Technical Emergency Response Systems on Infrastructure Resilience

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Abstract

This study evaluates the impact of Emergency Response Systems (ERS) on infrastructure resilience in the Ashanti Region of Ghana using a quantitative research approach. A questionnaire survey was administered to 225 professionals, including facility managers, engineers, architects, building inspectors, and NADMO officials, yielding 159 valid responses. The data were analysed using descriptive statistics, such as means and standard deviations, and exploratory factor analysis and partial least squares structural equation modelling. The findings indicate that both technical and non-technical ERSs significantly affect infrastructure resilience, with nine technical and seven non-technical ERSs receiving high performance ratings. Economic factors, such as property damage, and socio-political issues, including low wages, were closely linked to ERS effectiveness. Key challenges identified included inadequate consideration of cultural factors, limited institutional capacity, and insufficient funding. These challenges were strongly influenced by technical ($\beta = 0.223$, $p < 0.05$) and non-technical ($\beta = 0.462$, $p < 0.05$) ERS elements. Consequently, these limitations affected economic ($\beta = 0.195$, $p < 0.05$) and socio-political ($\beta = 0.325$, $p < 0.05$) outcomes, highlighting the interdependence between ERS components and broader systemic resilience. In practice, the study emphasises the need for integrated ERS planning within broader institutional, legal, and socio- economic systems by government agencies and facility managers. It advocates for targeted technological investments, legal frameworks, community education, and long-term risk management strategies. This study presents a novel interdisciplinary framework that integrates engineering and policy perspectives. Its originality lies in the comprehensive assessment of both technical and non-technical ERS components, offering valuable insights for strengthening infrastructure resilience in developing contexts.

Keywords: Emergency response, Disaster, Facilities, Infrastructure resilience, Natural hazard.

1. Introduction

Emergency Response Systems (ERS) face growing challenges due to rising population levels and increasing natural and human-made hazards, which threaten lives, property, and community stability (Vinokurova *et al*., 2022; Zulu & Shi, 2023; Abudu *et al*., 2025a/b). Most infrastructure supports vital services such as transport, energy, and education (Sharma & Gardoni, 2018). Urbanisation increases population density in buildings, thereby raising vulnerability during emergencies (Matveev *et al*., 2021). Congested access points to facilities further exacerbate safety risks and delay emergency responders, underscoring the need for proactive disaster risk management (DRM) strategies (Khalid *et al*., 2021). Effective crowd control during evacuations is critical, as panic-induced behaviour can lead to severe injuries (Yazdi & Zarei, 2024; Adjei *et al*., 2025). Fires remain a major risk globally, with varying

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levels of regulatory effectiveness; incidents such as the Grenfell Tower fire in London expose critical weaknesses in emergency response mechanisms (Zualkernan *et al*., 2019). In Ghana, frequent fire outbreaks continue to cause loss of life and significant economic damage, reinforcing the urgency of strengthening all phases of DRM to improve public safety outcomes (Zulu & Shi, 2023).

Recent studies have examined nature-based solutions for improving emergency preparedness in Africa (Aghimien *et al*., 2024), the socio-economic impacts of veld fires (Adom *et al*., 2025), and climate resilience within smart city frameworks (Mallick, 2025). While these studies advance knowledge on risk mitigation and resilience, limited empirical attention has been given to how technical and non-technical ERS components jointly influence infrastructure resilience in sub-Saharan Africa, particularly from an integrated systems perspective. Moreover, existing studies often emphasise the importance of ERS without quantitatively disentangling the relative contributions of technological capacity, institutional arrangements, governance structures, and socio-cultural factors.

To address this gap, this study applies partial least squares structural equation modelling (PLS-SEM) to examine the complex relationships between technical and non-technical ERS elements and infrastructure resilience outcomes in the Ashanti Region of Ghana. The novelty of this study lies in its development of an integrated analytical framework that simultaneously evaluates technical systems and non-technical institutional and socio-cultural factors, thereby moving beyond confirmation of ERS relevance to reveal how and to what extent specific ERS components shape resilience performance.

Accordingly, the study is guided by the following research questions:

RQ1: What technical and non-technical ERS components significantly influence infrastructure resilience in Ghana?

RQ2: What challenges limit the effectiveness of emergency response systems in infrastructure resilience?

RQ3: How do technical and non-technical ERS elements interact to affect economic and socio-political resilience outcomes?

2. Literature Review

2.1. Overview of Emergency Response Systems

An Emergency Response System (ERS) is a coordinated framework for managing disasters and other emergencies by integrating technical, institutional, and human components (Wang *et al*., 2022). Its effectiveness is central to reducing fatalities, protecting assets, and enabling rapid recovery, thereby directly contributing to overall community and infrastructure resilience (Dwarakanath *et al*., 2021). Risk management is a core function of ERS and involves hazard identification, vulnerability assessment, exposure analysis, and strategic resource allocation to safeguard people and infrastructure (Perera *et al*., 2020). Exposure reflects the degree to which people and assets are at risk, while hazard characteristics and environmental conditions guide appropriate risk reduction measures.

Technological advancements have significantly enhanced ERS capabilities. Tools such as surveillance cameras, sensors, geographic information systems, and data analytics improve disaster detection, situational awareness, and early warning dissemination (Damaševičius *et al*., 2023). These technologies support rapid decision-making and coordinated response, particularly in complex urban and facility environments.

Beyond technology, data management and community involvement are widely recognised as critical enablers of effective ERS. Institutions, including governmental agencies, religious bodies, and civil society organisations, play key roles in collecting and analysing disaster-related data to inform preparedness and response strategies (Sutton *et al*., 2024). Forecasting tools utilise environmental data to predict hazard events, while social media and digital platforms enable rapid dissemination of alerts and public information (Sibiya, 2022). Public briefings, drills, and training programmes help translate warnings into actionable responses, and religious and social groups often support awareness creation and emergency training at the community level (Sutton *et al*., 2024).

Preparedness for emergencies within facilities requires collaboration among local communities, professional stakeholders, and communication experts to translate national disaster risk reduction (DRR) policies into context-specific actions (Perera *et al*., 2020). Investments in early warning systems, resilient infrastructure, and grassroots initiatives are therefore essential. Education and awareness programmes further enhance resilience by strengthening social networks and collective response capacity (Cvetković *et al*., 2021).

Assessing ERS capacity typically involves evaluating technical, organisational, and human resource dimensions, including the availability of tools such as GPS, drones, and thermal cameras (Damaševičius *et al*., 2023; Cvetković *et al*., 2021). However, empirical studies show that early warning systems often fail to trigger timely action due to weak institutional coordination or insufficient training (Perera *et al*., 2020), and overreliance on technology without adequate human capacity can create communication gaps (Kalogiannidis *et al*., 2022). Effective disaster response, therefore, requires coordinated action among government institutions, emergency services, and the public (Gilmore & DuRant, 2021).

Despite growing awareness, urban planning and social housing sectors continue to face resource and capacity gaps that undermine emergency preparedness (Travassos *et al*., 2021). Disaster risk management (DRM) increasingly relies on cross-sector collaboration, encompassing risk assessment, mitigation, preparedness, response, and financing mechanisms (Bello *et al*., 2021). While integrating DRM into national development policies improves coordination, Flood Early Warning Systems (FEWS) still face challenges related to community engagement and local ownership (Perera *et al*., 2020). Social media has emerged as a valuable tool for rapid crisis communication and can be effectively applied in facility-based emergency management (Dwarakanath *et al*., 2021).

Cities increasingly embed climate adaptation and resilience objectives into development plans to align with DRR and DRM priorities (Anguelovski *et al*., 2014). The World Meteorological Organisation's impact-based forecasting approach further strengthens hazard management by linking forecasts to potential consequences (Merz *et al*., 2020). In facility management, smart technologies support hazard detection, early warnings, and data-driven emergency decision-making. However, non-technical aspects of ERS, such as collaboration, communication, governance, and community participation, remain persistent challenges, particularly in developing-country contexts (Perera *et al*., 2020; Myeong *et al*., 2020).

2.2. Emergency Response Systems and Their Influence on Infrastructure and Facility Resilience

In this study, infrastructure resilience refers to the ability of interconnected physical systems such as buildings, transport networks, utilities, and essential services to withstand, absorb, recover from, and adapt to disruptive events.

Facility resilience, by contrast, focuses more narrowly on the performance and recovery of individual buildings or complexes within the broader infrastructure system. While conceptually distinct, both are interdependent, and effective ERS plays a critical role in enhancing resilience at both levels.

Globally, disasters impose substantial human and economic costs. Between 2001 and 2018, floods accounted for more than half of water-related disasters, causing approximately 94,000 deaths and USD 504 billion in losses worldwide (Perera *et al*., 2020).

Integrating early warning systems with impact-based forecasting has been shown to enhance emergency response effectiveness through improved data-driven insights (Merz *et al*., 2020). Economic conditions strongly influence disaster frequency, severity, and recovery capacity, with disasters causing significant loss of life and financial resources (Bello *et al*., 2021).

From 2010 to 2019, natural disasters resulted in average annual losses exceeding USD 187 billion and displaced approximately 24 million people per year. While high- income countries have reduced disaster impacts through robust ERS and institutional capacity, low- and middle-income countries such as Ghana continue to face significant DRM challenges (Mensah-Bonsu, 2022). Vulnerable populations often experience disproportionate impacts due to insecure housing, limited access to services, and weak recovery mechanisms, further undermining infrastructure and facility resilience.

The socio-economic impacts of disasters are commonly assessed using context-specific indicators such as hazard frequency, exposure levels, and population density (Merz *et al*., 2020). The 2010 Pakistan floods, for example, severely damaged homes, infrastructure, healthcare facilities, and schools, exposing weaknesses in institutional coordination and long-term recovery planning (Deen, 2015). Despite extensive relief efforts, resilience outcomes remained limited, highlighting the importance of effective ERS beyond immediate response.

Disaster risks continue to threaten community sustainability by disrupting economic activities, social systems, and development trajectories (Tanesab, 2020). Internal migration from rural to urban areas further exacerbates exposure and increases pressure on public facilities and infrastructure, particularly in rapidly urbanising regions (Mensah-Bonsu, 2022).

Figure 1 illustrates the conceptual structure of ERS and its associated challenges and impacts, providing a basis for examining the interrelationships tested in this study.

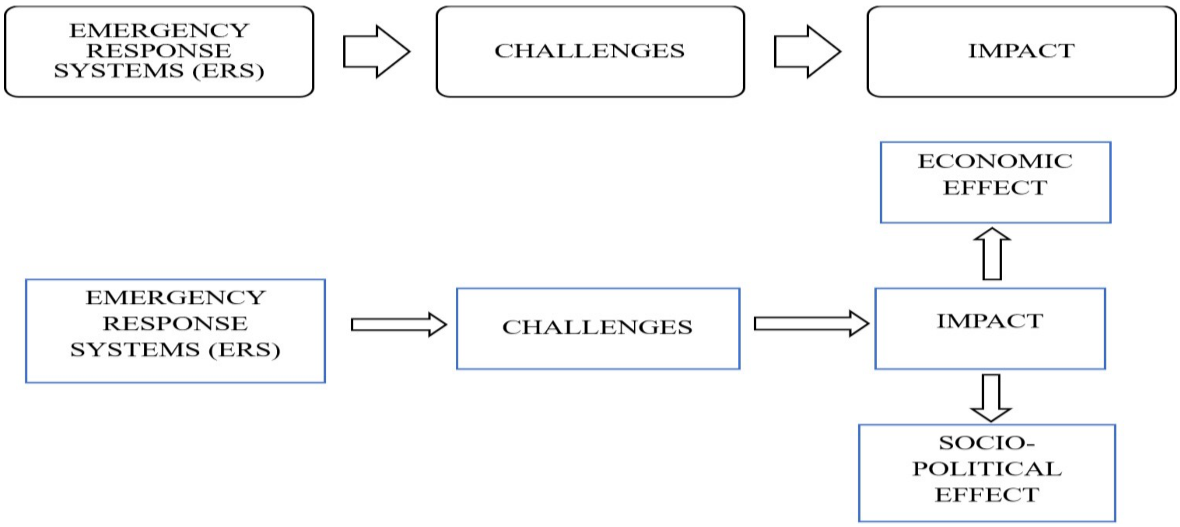

Figure 1: Conceptualised Emergency Response System
Source: Abudu *et al.* (2025b)

2.3. Research Model and Hypotheses

The reviewed literature highlights a consistent theme: infrastructure and facility resilience are shaped by the interaction between technical ERS components (e.g., monitoring, communication, data systems) and non-technical components (e.g., governance, institutional capacity, community engagement, and policy enforcement). However, many existing studies examine these elements in isolation or focus primarily on confirming the importance of ERS rather than empirically analysing their interrelationships.

This gap directly informs the development of the study's structural equation modelling (SEM) framework. Drawing on the reviewed evidence, the study hypothesises that:

1. Technical ERS components significantly influence emergency response challenges.
2. Non-technical ERS components exert a more substantial and more systemic influence on these challenges;
3. Emergency response challenges, in turn, significantly affect economic and socio-political resilience outcomes.

By explicitly modelling these relationships using PLS-SEM, the study advances the literature by quantifying the pathways through which ERS components affect infrastructure resilience, particularly in sub-Saharan Africa.

2.4. Theories underpinning the study

Resilient ERS frameworks are grounded in systems theory and resilience theory, both of which emphasise interconnectedness, feedback mechanisms, and adaptive capacity (Bonaretti & Piccoli, 2018; Chen *et al*., 2017). Systems theory provides a holistic perspective for understanding interactions among technological, institutional, and social subsystems. In contrast, resilience theory focuses on a system's ability to absorb shocks, recover, and adapt to changing conditions. Together, these theories offer a robust foundation for analysing complex emergency response environments that rely on both technical and non-technical ERS components (Son *et al*., 2020).

3. Research Methodology

This study adopted a quantitative research approach to develop a framework for modernising emergency response infrastructure in Ghana. Data were collected through structured questionnaires administered to 225 professionals, including facility managers, engineers, architects, building inspectors, and officials from the National Disaster Management Organisation (NADMO), across 43 districts in the Ashanti Region. The target population comprised 516 professionals involved in facility planning and disaster response. A sample size of 225 respondents was determined using Yamane's formula. Purposive and convenience sampling techniques were employed to access respondents with relevant professional expertise who were easily accessible.

Data was collected using a structured questionnaire designed on a 5-point Likert scale. Responses were cleaned, coded, and normalised using Min–Max scaling prior to analysis. Descriptive statistics, such as means and standard deviations, and an Exploratory Factor Analysis (EFA) were conducted using the Statistical Package for the Social Sciences (SPSS) version 30. EFA was performed using Principal Component Analysis (PCA) with Varimax rotation to identify underlying factor structures. The suitability of the data for factor analysis was assessed using the Kaiser–Meyer–Olkin (KMO) measure (≥ 0.6) and Bartlett's test of sphericity ($p < 0.05$). Factors with eigenvalues ≥ 1 and factor loadings ≥ 0.5 were retained. Internal consistency reliability was assessed using Cronbach's Alpha coefficients, with values ≥ 0.7 considered acceptable.

Following the descriptive analysis, Min–Max normalisation was applied to rank indicators by their relative importance. Indicators with a normalisation value (NV) ≥ 0.60 were classified as key indicators. This threshold enabled the model to focus on the most salient and consistently rated indicators while maintaining construct content validity, as further supported by prior factor analysis and expert review. Structural Equation Modelling (SEM) was conducted using a variance-based Partial Least Squares approach implemented in SmartPLS 4 (Ringle *et al*., 2024). This method was selected due to its suitability for exploratory research, complex models, and non-normal data distributions. Model reliability, validity, and predictive relevance were assessed using established PLS-SEM criteria.

Content validity was ensured through expert review of the questionnaire, while construct validity was established through factor analysis. The inclusion of respondents from diverse professional backgrounds enhanced the analytical robustness of the findings. Ethical standards were strictly observed, with participation being voluntary and anonymous to ensure confidentiality. The study adhered to Institutional Review Board requirements and received ethical approval under clearance number IREC 287/24.

4. Findings and Discussion

The analysis followed three stages: descriptive analysis, normalisation, and PLS-SEM. Descriptive analysis summarised indicator ratings, while normalisation identified key variables.

4.1. Descriptive Statistics and Normalisation of the Constructs' Indicators

This section summarises descriptive statistics in Tables 1-3 for the emergency response system, response challenges, and their economic and socio-political impacts. Mean scores, standard deviations, and normalised values were used to rank indicators, with those scoring ≥ 0.60 considered key contributors.

The study identified nine (9) TERS indicators in Table 1 (See Appendix 1) with high ratings (NV: 1.00–0.649; mean: 4.30–4.12), and low standard deviations (<1.00), indicating consistent responses. The key indicators included disaster monitoring, communication networks, traffic and crime surveillance, risk analysis, and data management. Seven NTERS were also highly rated (NV: 1.00–0.608; mean: 4.18–3.91) with strong consistency. Key areas included policy enforcement, capacity building, risk reduction planning, loss assessment, rescue communication, social inclusion, and investment in risk reduction.

4.2. Discussion on the Technical Emergency Response System and Its Impact on Infrastructure Resilience

The key technical emergency response system (TERS) variables were ranked using mean effectiveness, standard deviation, normalised value (NV), and importance, reflecting the relative contribution of essential technologies to effective emergency management and infrastructure resilience. Disaster Monitoring emerged as the most critical construct (Mean = 4.30; NV = 1.000), underscoring its foundational role in detecting hazards and initiating timely response actions. This finding aligns with Bello *et al*. (2021), who emphasised that real-time disaster monitoring systems enhance early warning capabilities, reduce response delays, and significantly minimise damage to critical infrastructure. Practically, facility managers and government agencies should prioritise investments in sensor-based monitoring, satellite surveillance, and integrated alert systems to strengthen preparedness and response capacities.

Communication and Networking of Disaster ranked second (Mean = 4.27; NV = 0.947), reinforcing the importance of seamless information flow among emergency responders, institutions, and affected populations. This result corroborates the findings of Damaševiˇcius *et al*. (2023), who demonstrated that interoperable communication platforms improve coordination and reduce fragmentation during emergencies. From an implementation perspective, this highlights the need for unified communication protocols, resilient digital networks, and redundancy measures to ensure uninterrupted information exchange during crises.

Traffic Monitoring (Mean = 4.27; NV = 0.936) was also identified as a critical determinant of infrastructure resilience. Consistent with Myeong *et al*. (2020), the results show that smart traffic management systems enhance situational awareness, facilitate efficient evacuations, and ensure unobstructed access for emergency vehicles. Actionably, integrating traffic monitoring technologies into urban transport systems can improve evacuation planning and reduce congestion-related delays during emergencies.

Recognising and Analysing Disaster Risk (Mean = 4.24; NV = 0.894) highlights the growing relevance of predictive analytics and modelling tools in proactive risk management. This supports the assertions of Damaševiˇcius *et al*. (2023) that data-driven risk analysis strengthens preparedness by enabling scenario planning and targeted mitigation strategies.

Infrastructure planners can apply these tools to identify vulnerabilities and prioritise reinforcement measures before disasters occur.

Monitoring of Street Security (Mean = 4.23; NV = 0.872) and Crime Watch Monitoring Systems, including CCTV and drones (Mean = 4.21; NV = 0.819), further demonstrate the convergence of public safety and disaster response technologies. These findings align with Myeong *et al*. (2020), who noted that surveillance systems improve real-time decision-making and maintain order during crises. In practice, integrating security monitoring into ERS can support crowd management, protect emergency assets, and reduce secondary risks such as looting or vandalism.

Data Management and Analysis of Disaster (Mean = 4.19; NV = 0.787) reinforces the role of structured data systems in supporting evidence-based decision-making. As noted by Damaševiˇcius *et al*. (2023), effective data management enhances coordination, learning, and continuous improvement of emergency response strategies. Agencies should therefore establish centralised disaster data platforms to support timely analysis and institutional learning.

Risk Assessment of Disaster (Mean = 4.17; NV = 0.755) and Risk Identification (Mean = 4.12; NV = 0.649), although ranked lower, remain integral to resilience planning. These findings are consistent with Mensah-Bonsu (2022) and Perera *et al*. (2020), who highlighted that systematic risk identification and assessment underpin prevention and preparedness strategies. Practically, embedding routine risk assessments into infrastructure lifecycle planning can enhance adaptive capacity and long-term resilience.

4.3. Discussion on Non-Technical Emergency Response System Constructs and Their Impact on Infrastructure Resilience

While TERSs are critical for immediate response, the findings confirm that non-technical emergency response systems (NTERSs) play a decisive role in shaping long-term infrastructure resilience by addressing governance, institutional capacity, and social dimensions of disaster risk management (DRM). Enforcement and Translation of Disaster Risk Policies ranked highest among NTERS constructs (Mean = 4.18; NV = 1.000), underscoring the importance of translating policy frameworks into actionable, enforceable measures. This result supports Perera *et al*. (2020), who argued that weak policy implementation undermines resilience outcomes despite well-articulated DRR strategies. Actionably, strengthening enforcement mechanisms, monitoring compliance, and clarifying institutional roles can bridge the gap between policy intent and on-ground practice.

Capacity Building in DRR and DRM across Institutions, Organisations, and Communities (Mean = 4.03; NV = 0.792) underscores the importance of human capital development in resilience-building. This finding aligns with Cvetkovi'c *et al*. (2021), who emphasised that training, education, and institutional readiness enhance decentralised and sustainable emergency response systems. Practically, continuous professional development programmes and community-based training initiatives can improve preparedness at multiple governance levels.

DRR Plans and Platforms for Cities or Communities (Mean = 4.03; NV = 0.784) highlight the need for localised, context-specific resilience strategies. Consistent with Damaševiˇcius *et al*. (2023), the results suggest that tailored DRR platforms improve urban planning, hazard mapping, and resource allocation. Policymakers and planners can leverage these platforms to integrate local risk profiles into broader development and infrastructure planning processes.

Assessment of Damage and Losses for Resilient Rebuilding (Mean = 3.98; NV = 0.712) highlights the significance of post-disaster evaluation in supporting effective recovery. This finding supports Sutton *et al*. (2024) and Mensah-Bonsu (2022), who noted that accurate damage assessments enable the integration of resilience principles into reconstruction efforts. Practically, adopting standardised assessment frameworks can improve transparency and guide investment towards “build-back-better” outcomes.

Communication and Networking Between Rescue Teams and Victims (Mean = 3.97; NV = 0.704) addresses the human and relational dimensions of emergency response. In line with Damaševiˇcius *et al*. (2023), the results indicate that effective communication enhances trust, situational awareness, and operational efficiency. Implementing inclusive communication channels, including multilingual and accessible platforms, can improve engagement with affected populations.

Gender and Social Inclusiveness in DRR Management (Mean = 3.95; NV = 0.672) reflects the growing recognition that resilience depends on equitable participation. This finding is consistent with Perera *et al*. (2020) and Sutton *et al*. (2024), who stressed that excluding vulnerable groups weakens overall resilience. In practice, mainstreaming gender and social inclusion into DRR policies and programmes can ensure that diverse needs are addressed in both the planning and response phases.

Although investing in DRR for Resilience at the national and Local Levels ranked lowest (Mean = 3.91; NV = 0.608), it remains fundamental to sustainable resilience outcomes. As noted by Bello *et al*. (2021), long-term investment in infrastructure, education, early warning systems, and risk mitigation provides the foundation for effective ERS performance.

Governments should therefore prioritise sustained financing mechanisms to support both technical and non-technical resilience-building initiatives.

4.4. Descriptive Statistics of Emergency Response Impact

Economic impact indicators showed strong perceived effects of the emergency response system, with mean scores from 4.27 to 4.15 (Table 2). Three indicators, loss of properties (4.27; SD=0.818), loss of life (4.26; SD=0.743), and global economic losses (4.24; SD=0.787), met the normalisation threshold (≥0.60). Socio-political indicators also scored high (4.19 to 3.94) with consistent responses, and four low wages, increased vulnerability, lack of social amenities, and rising unemployment, met the threshold.

Table 2: Descriptive Statistics of Emergency Response Impact

Code	Emergency Response Impact	Mean	Std. Dev.	NV	Rank
Economic Impact					
EIE3	Loss of properties	4.27	0.818	1.000**	1
EIE2	Loss of lives	4.26	0.743	0.909**	2
EIE1	Global economic losses	4.24	0.787	0.727**	3
EIE4	Inadequate residential infrastructure	4.19	0.851	0.318	4
EIE5	Inadequate health care facilities	4.15	0.815	0.000	5
Socio-Political Impact					
SIE6	Low salaries and wages	4.19	0.831	1.000**	1
SIE3	Increase in vulnerability	4.18	0.799	0.955**	2
SIE2	Lack of social amenities	4.17	0.797	0.932**	3
SIE4	Increase in unemployment rate	4.13	0.787	0.773**	4
SIR5	Low productivity	3.97	0.893	0.114	5
SIE1	Population density and urbanisation	3.94	0.973	0.000	6

Source: Fieldwork, 2025

** Normalisation value greater than 0.60

4.5. Discussion on the Economic Impact of Emergency Response Systems and their Influence on Infrastructure Resilience

Economic impacts constitute a critical dimension of Emergency Response Systems (ERS), as they directly influence infrastructure resilience, recovery capacity, and long-term development outcomes. This study assessed loss of properties, loss of life, and global economic losses using mean scores, standard deviations, normalised values (NV), and rankings, highlighting the severity of disaster-related economic disruptions and the importance of effective ERS interventions.

Loss of Properties emerged as the most significant economic impact (Mean = 4.27; NV = 1.000), reflecting widespread recognition of the extensive material and infrastructural damage caused by disasters. This finding is consistent with Bello *et al.* (2021) and Abudu *et al.* (2025a), who reported that damage to buildings, utilities, transport networks, and essential services generates cascading economic effects, including business interruptions and increased reconstruction costs. From a practical standpoint, this result underscores the need for ERS to be integrated with risk-sensitive land-use planning, enforcement of resilient building standards, and proactive maintenance of critical infrastructure to minimise property losses during emergencies.

Loss of Life followed closely (Mean = 4.26; NV = 0.909), emphasising the profound human and economic consequences of inadequate disaster preparedness. Although often categorised as a social impact, the loss of human capital significantly affects labour productivity, household income, and the trajectories of national economic recovery. This result aligns with the findings of Bello *et al.* (2021), Mensah-Bonsu (2022), and Abudu *et al.* (2025b), who demonstrated that high mortality rates during disasters undermine workforce stability and slow post-disaster economic recovery.
Actionably, this highlights the importance of strengthening early warning systems, improving response times, and ensuring inclusive evacuation and sheltering strategies to protect lives and sustain economic resilience.

Global Economic Losses (Mean = 4.24; NV = 0.727), although ranked third, remain highly significant. These losses reflect disruptions to global supply chains, reduced foreign direct investment, inflationary pressures, and GDP contractions, particularly in disaster-prone developing economies. This finding corroborates earlier studies by Bello *et al.* (2021), Mensah-Bonsu (2022), and Abudu *et al.* (2025a), which emphasised that recurrent disasters amplify macroeconomic instability. The result suggests that national governments should prioritise investment in robust ERS and regional cooperation mechanisms to reduce the spillover effects of disasters on global and regional economies.

4.6. Discussion on the Socio-Political Impact of Emergency Response Systems (ERS) and Their Influence on Infrastructure Resilience

Socio-political factors play a decisive role in shaping ERS effectiveness and infrastructure resilience by influencing vulnerability, response capacity, and recovery outcomes. This study evaluated key socio-political variables using mean scores, standard deviations, normalised values (NV), and rankings, revealing how underlying social and political conditions mediate ERS performance.

Low Salaries and Wages ranked highest (Mean = 4.19; NV = 1.000), indicating their critical influence on individual, institutional, and community resilience. Inadequate income limits households' ability to invest in preparedness measures, recover from losses, or adopt adaptive strategies. It also constrains institutions' capacity to attract, motivate, and retain skilled emergency response personnel. This finding aligns with Abudu *et al*. (2025a/b), who highlighted the link between income insecurity and reduced disaster coping capacity. From an implementation perspective, improving remuneration structures and social protection schemes can enhance both workforce stability and community resilience.

Increase in Vulnerability (Mean = 4.18; NV = 0.955) highlights the compounding effects of socio-economic inequality, poor housing conditions, and limited access to education and healthcare. Consistent with Merz *et al.* (2020), Bello *et al*. (2021), and Abudu *et al*. (2025c), the results show that vulnerable populations disproportionately suffer from infrastructure failures and experience slower recovery. Actionably, this underscores the importance of targeted ERS interventions, such as risk-informed social protection programmes and community-based preparedness initiatives, to reduce differential vulnerability.

Lack of Social Amenities (Mean = 4.17; NV = 0.932), including healthcare facilities, clean water supply, transportation systems, and educational infrastructure, significantly undermines community resilience. This finding supports Merz *et al*. (2020) and Bello *et al*. (2021), who noted that inadequate access to basic services increases dependency on external assistance during disasters and prolongs recovery periods. In practice, strengthening social infrastructure and integrating essential services into emergency planning can improve response effectiveness and resilience.

The increase in the Unemployment Rate (Mean = 4.13; NV = 0.773) represents both a driver and a consequence of weak infrastructure resilience. Disasters frequently disrupt livelihoods, displace workers, and damage economic assets, leading to job losses. Persistent unemployment further reduces households' ability to invest in preparedness or adaptation measures. This finding aligns with Merz *et al*. (2020), Bello *et al*. (2021), and Abudu *et al*. (2025a). Actionably, post-disaster recovery programmes that prioritise job creation, skills development, and livelihood restoration can strengthen socio-economic resilience and support sustainable infrastructure recovery.

4.7. Descriptive Statistics of Emergency Response Challenges

The challenges associated with the emergency response system revealed nine indicators with high normalisation values (≥ 0.60). From the results, the mean scores of these indicators (Table 3) ranged from 4.22 to 3.98, with relatively low standard deviations, indicating high consistency in ratings.

Table 3: Descriptive Statistics of Emergency Response Challenges

Code	Emergency Response Challenges	Mean	Std. Dev.	NV	Rank
CHG14	Inadequate consideration of social, cultural, and religious norms and practices in emergency response infrastructure.	4.22	0.788	1.000**	1
CHG11	Lack of knowledge or capacity	4.17	0.831	0.922**	2
CHG8	Inadequate institution/organisation	4.12	0.880	0.835**	3
CHG13	Lack of capacity building	4.10	0.898	0.809**	4
CHG1	Rapid urbanisation and population growth	4.06	0.946	0.748**	5
CHG10	Lack of human resources	4.06	0.916	0.748**	6
CHG2	Limited resources and funding	4.01	1.028	0.661**	7
CHG7	Ineffective building by-laws	3.99	1.170	0.643**	8
CHG9	Policy/legal issues	3.98	0.912	0.626**	9
CHG12	Lack of community engagement	3.95	0.886	0.574	10
CHG3	Vulnerability to natural disasters	3.94	1.079	0.557	11
CHG6	Political influence	3.91	1.137	0.504	12
CHG5	Inadequate infrastructure	3.79	1.083	0.322	13
CHG4	Lack of technology	3.58	1.157	0.000	14

Source: Fieldwork, 2025

** Normalisation value greater than 0.60

4.8. *Discussion on Emergency Response Challenges and Their Implications for Infrastructure Resilience*

Identifying the constraints on Emergency Response Systems (ERS) is essential to strengthening infrastructure resilience and improving disaster response effectiveness. As presented in Table 3, the study categorised these challenges into institutional, socio-cultural, and structural dimensions. It ranked them using mean scores, standard deviations, normalised values (NV), and levels of significance. The findings reveal that non-technical and governance-related barriers exert a substantial influence on ERS performance, reinforcing the need for systemic, context-sensitive interventions.

Inadequate consideration of social, cultural, and religious norms emerged as the most critical challenge (Mean = 4.22), indicating a significant disconnect between emergency planning frameworks and local community contexts. This finding aligns with Abudu *et al*. (2025a) and Wamsler *et al*. (2020), who argued that emergency interventions that overlook cultural and religious practices often face resistance, low compliance, and reduced effectiveness. In practice, incorporating culturally sensitive engagement strategies, such as involving traditional leaders, faith-based organisations, and community influencers, can improve trust, participation, and cooperation during emergency preparedness and response efforts.

Lack of knowledge or capacity (Mean = 4.17) highlights deficiencies in human capital and technical expertise that limit preparedness and response capabilities. Consistent with Abudu *et al*. (2025b) and Wamsler *et al*. (2020), this result underscores how insufficient skills and awareness contribute to delayed response and ineffective coordination. Actionable implications include investing in continuous professional training for emergency personnel and community education programmes to enhance disaster literacy and preparedness at the grassroots level.

Inadequate institutions (Mean = 4.12) reflect systemic weaknesses in governance structures, inter-agency coordination, and accountability mechanisms. This finding supports earlier work by Abudu *et al*. (2025b) and Wamsler *et al*. (2020), which identified institutional fragmentation as a significant obstacle to effective disaster risk management. Strengthening institutional frameworks through more explicit mandates, improved coordination platforms, and performance monitoring systems can enhance ERS efficiency and infrastructure resilience.

The lack of capacity building (Mean = 4.10) further underscores the need for sustained investment in education, training, and organisational development. As noted by Abudu *et al*. (2025a) and Wamsler *et al*. (2020), capacity-building initiatives are critical for developing adaptive skills and enabling local actors to respond effectively to evolving risks. Practically, embedding capacity-building programmes within national and local DRM strategies can support long-term resilience outcomes.

Rapid urbanisation and population growth (Mean = 4.06) place increasing pressure on existing infrastructure and emergency services, thereby amplifying disaster risks. This finding is consistent with Wamsler *et al*. (2020) and Abudu *et al*. (2025b), who highlighted the need for risk-sensitive urban development to manage growing exposure. Integrating ERS considerations into urban planning, zoning regulations, and infrastructure expansion can help mitigate the adverse effects of rapid urban growth.

Insufficient human resources (Mean = 4.06) further constrain emergency response effectiveness by limiting operational capacity during crises. In line with Kalogiannidis *et al*. (2022) and Abudu *et al*. (2025c), the results indicate that staffing shortages increase response times and reduce service coverage. Addressing this challenge requires strategic workforce planning, improved recruitment and retention policies, and incentives for emergency response professionals.

Limited resources and funding (Mean = 4.01) represent a persistent barrier, particularly in low- and middle-income countries. This finding corroborates Abudu *et al*. (2025a) and Kalogiannidis *et al*. (2022), who emphasised that inadequate financing restricts technological upgrades, training, and infrastructure maintenance. Actionably, diversifying funding sources, strengthening public–private partnerships, and prioritising disaster risk reduction investments can improve ERS sustainability.

Ineffective building by-laws (Mean = 3.99) highlight regulatory shortcomings that increase infrastructure vulnerability. Consistent with Abudu *et al*. (2025a), Abdul and Yu (2020), and Wamsler *et al*. (2020), outdated or weakly enforced building codes expose communities to higher risks. Regularly updating building regulations and enforcing compliance can significantly enhance structural resilience and reduce disaster-related losses.

Finally, policy and legal issues (Mean = 3.98) reveal gaps in legislative clarity, enforcement, and political commitment. This finding aligns with Abudu *et al*. (2025a/b), who noted that weak legal frameworks undermine coordinated emergency response. Strengthening legal instruments, clarifying institutional responsibilities, and ensuring sustained political support are therefore essential for effective ERS implementation and resilient infrastructure development.

4.9. *Partial Least Squares Structural Equation Modelling*

PLS-SEM was used to estimate relationships between latent variables using a reflective approach. The analysis included evaluations of the measurement and structural models. The reflective measurement model was assessed by evaluating indicator loadings per SEM guidelines (Hair *et al*., 2016). All items were treated as reflective indicators. Reliability was confirmed via Cronbach's alpha and composite reliability (Hair *et al*., 2019), and indicator reliability was assessed via factor loadings.

Convergent validity was confirmed by AVEs above 0.50 (Fornell & Larcker, 1981). Discriminant validity was assessed via the HTMT ratio and the Fornell-Larcker criterion (Henseler *et al*, 2015), confirming conceptual and empirical distinctiveness. Results appear in Figure 2 and Tables 4 and 5.

4.10. *Reliability and Convergent Validity of the Model*

Table 4 (See Appendix 1) confirms the model's reliability and validity. Factor loadings (0.716–0.928) showed strong indicator-construct associations. Path coefficients and indicator weights reinforced these links. Bootstrapping (5,000 samples) produced t-values above 1.96 at the 5% level, confirming high and significant loadings and supporting item reliability. Internal consistency was confirmed with composite reliability (0.821–0.930) and Cronbach's alpha (0.889–0.944), exceeding the 0.70 threshold. AVE values (0.612–0.770) surpassed the 0.50 benchmark, indicating strong convergent validity and that constructs explained over half the variance in their indicators (Hair *et al*., 2016).

4.11. *Discriminant Validity Statistics*

Discriminant validity was confirmed using the HTMT and Fornell-Larcker criteria. HTMT values were all below the 0.85 threshold (max = 0.480), indicating strong validity (Voorhees *et al*., 2016; Hair *et al*., 2019). Similarly, Fornell-Larcker results showed all AVE square roots exceeded inter-construct correlations, further supporting discriminant validity (Table 5).

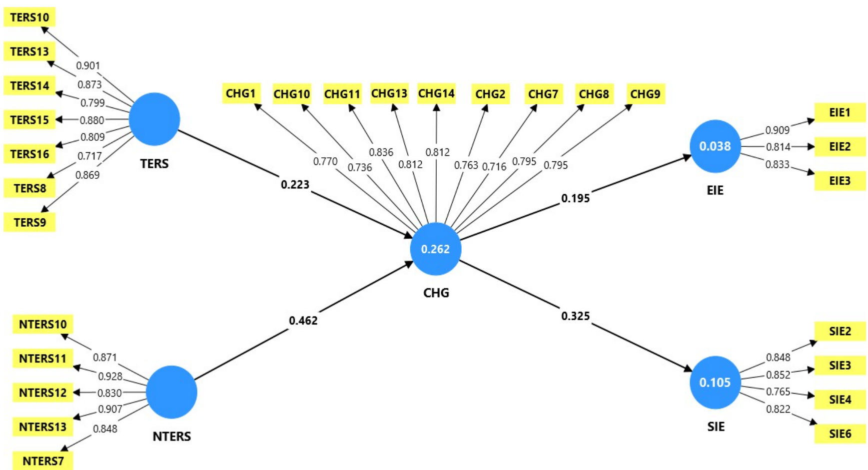

Figure 2: Measurement Model Diagram
Source: Fieldwork, 2025

Table 5: Discriminant Validity Statistics

	CHG	EIE	NTERS	SIE	TERS
Heterotrait-Monotrait (HTMT) Ratio	-				
CHG					
EIE	0.203				
NTERS	0.480	0.240			
SIE	0.365	0.393	0.244		
TERS	0.216	0.084	0.067	0.192	-
Fornell-Larcker criterion	-				
CHG	**0.782**				
EIE	0.195	**0.853**			
NTERS	0.460	0.216	**0.878**		
SIE	0.325	0.352	0.225	**0.822**	
TERS	0.220	-0.011	-0.006	0.164	**0.837**

Source: Fieldwork, 2025

4.12. *Path Analysis and Predictive Relevance*

The structural model was assessed after confirming measurement model adequacy. Key evaluation criteria included R^2, Q^2, path coefficients, and statistical significance. The R^2 values for challenges (0.262), economic impact (0.038), and socio-political impact (0.105) indicate varying levels of explained variance. Q^2 values revealed small predictive relevance for economic and socio-political impacts and moderate relevance for challenges.

Path analysis (Table 6) shows that all structural relationships are positive. Higher scores on the technical and non-technical emergency response system constructs indicate stronger ERS capacity. In comparison, higher scores on the challenges construct reflect greater recognition and reporting of response constraints. Consequently, the positive paths from TERS → CHG ($\beta = 0.223$; $p < 0.05$) and NTERS → CHG ($\beta = 0.462$; $p < 0.05$) suggest that contexts with more developed ERS capacities are more likely to identify and articulate operational, institutional, and governance-related challenges, potentially due to higher organisational awareness and diagnostic capability.

While the relationships are statistically significant, the low R^2 values for economic and socio-political impacts indicate limited explanatory power. These results should therefore be interpreted as indicative rather than strongly predictive, highlighting the likelihood that additional contextual factors such as governance quality, macroeconomic conditions, and broader development dynamics also shape these outcomes.

Table 6: Path Analysis and Predictive Relevance

	Path Coefficient	Sample Coefficient	Std. Dev.	t-value	P values	Confidence Interval		f-square
						2.5%	97.5%	
CHG -> EIE	0.195	0.212	0.072	2.708	0.007	-0.073	0.312	0.039
CHG -> SIE	0.325	0.333	0.068	4.762	0.000	0.177	0.443	0.118
NTERS -> CHG	0.462	0.463	0.059	7.882	0.000	0.335	0.565	0.289
TERS -> CHG	0.223	0.231	0.065	3.446	0.001	0.109	0.331	0.067

Source: Fieldwork, 2025

4.13. *Discussion of the emergency response system and its relationships*

The results demonstrate that technical emergency response system (ERS) components, such as disaster monitoring, communication networks, and traffic surveillance, have a statistically significant influence on the magnitude of challenges encountered during emergencies. The positive and significant path coefficient ($\beta = 0.223$; $t = 3.446$; $p < 0.05$) indicates that deficiencies in the development, integration, and maintenance of technical ERS components are associated with increased operational challenges, including delayed response times, ineffective information exchange, and inefficient resource allocation. This finding is consistent with Abudu *et al*. (2025a), who reported that inadequate technological infrastructure constrains situational awareness and coordination during disaster events. From a practical perspective, the result underscores the need for sustained investment in interoperable technologies, regular system maintenance, and redundancy planning to reduce technical bottlenecks and enhance response effectiveness.

More notably, the non-technical ERS dimension, which encompasses policy enforcement, institutional capacity, governance structures, and community engagement, exerts an even stronger influence on emergency response challenges. The path coefficient of 0.462, together with a t-value of 7.882 and a p-value < 0.05, indicates a robust, highly significant relationship. This suggests that weaknesses in governance arrangements, institutional coordination, and stakeholder engagement substantially intensify the challenges faced during emergency response operations. This finding aligns with Abudu *et al*. (2025b), who emphasised that deficiencies in governance and institutional capacity undermine the effectiveness of emergency responses regardless of the availability of advanced technologies. The results suggest that policymakers and emergency managers should prioritise strengthening institutional frameworks, enforcing disaster risk reduction policies, and expanding community-based capacity-building programmes to complement technical system investments.

The analysis further reveals that emergency response challenges have a significant downstream effect on economic outcomes during and after disaster events. With a path coefficient of 0.195 ($t = 2.708$; $p < 0.05$), the findings confirm that ineffective emergency response systems contribute to heightened economic losses, including property damage, business disruption, and increased recovery expenditures. This result supports the findings of Abudu *et al*. (2025c) and Bello *et al*. (2021), who demonstrated that delayed or poorly coordinated emergency responses exacerbate economic vulnerability and prolong recovery processes. Practically, strengthening both technical and non-technical ERS components can serve as a proactive economic risk mitigation strategy by reducing direct losses and limiting indirect economic impacts.

Beyond economic consequences, the study also establishes a significant relationship between emergency response challenges and socio-political outcomes. The observed path coefficient of 0.325 ($t = 4.762$; $p < 0.05$) indicates that persistent emergency response challenges exacerbate socio-political stresses, including unemployment, inequitable access to services, and declining public confidence in institutions. This finding is consistent with Abudu *et al.* (2025b) and Bello *et al.* (2021), who highlighted that ineffective disaster management erodes social cohesion and weakens trust in governance systems. From an implementation standpoint, this underscores the importance of inclusive, transparent, and community-sensitive emergency planning processes that actively engage stakeholders and promote institutional accountability.

The findings reinforce the interdependent nature of technical and non-technical emergency response system components and their collective influence on economic and socio-political resilience. Achieving sustainable infrastructure resilience, therefore, requires an integrated ERS approach that balances technological innovation with strong governance arrangements, institutional capacity, and meaningful community participation.

Unlike the authors' previous review-based studies (Abudu *et al*., 2025a–c), which synthesised conceptual and qualitative insights, this study provides empirical evidence on the relative influence of technical and non-technical ERS components using PLS-SEM. The findings empirically confirm earlier qualitative assertions regarding the centrality of governance and institutional capacity, while also revealing the limited explanatory power of ERS variables for economic and socio-political outcomes, thereby identifying critical gaps for future quantitative research.

5. Conclusions

This study examined the influence of technical and non-technical emergency response systems (TERS and NTERS) on infrastructure resilience, providing empirical evidence on how their interaction shapes resilience outcomes across technical, institutional, economic, and socio-political dimensions.

Key empirical contributions of the study can be summarised as follows:

- Among technical ERS domains, early warning and disaster monitoring systems, communication networks, and real-time data analytics emerged as the most critical contributors to infrastructure resilience, particularly in enhancing response speed, coordination, and adaptive capacity.
- Non-technical ERS domains, notably governance capacity, institutional coordination, community engagement, and inclusive planning, demonstrated a strong enabling effect, amplifying the performance and Sustainability of technical systems.
- The findings indicate that while TERS have a more immediate and measurable impact on operational resilience, NTERS exert a significant complementary influence, particularly on long-term recovery, adaptability, and equitable outcomes.
- The combined implementation of TERS and NTERS yields greater resilience gains than isolated investments, reinforcing the need for integrated emergency response strategies.

Despite these contributions, the study is subject to several methodological limitations that constrain the generalisability of the findings. The findings are limited by the use of non-probability sampling and a single regional focus. In addition, the low R^2 values indicate that the model explains only a limited proportion of infrastructure resilience, suggesting that other factors beyond those examined in this study may also play a role. Significantly, this study advances the existing literature by empirically demonstrating that infrastructure resilience is not solely a function of technological sophistication but also depends on institutional effectiveness, economic preparedness, and socio-political inclusiveness. By integrating economic risk considerations into ERS design, decision-makers can reduce long-term recovery costs, safeguard livelihoods, and sustain economic continuity. Similarly, addressing socio-political dimensions such as equity, access to resources, and participatory governance strengthens the legitimacy and effectiveness of emergency response systems.

Future research should build on these findings by employing probability-based sampling, multi-regional or cross-country comparisons, and longitudinal designs to capture resilience dynamics over time. Further work is also needed to develop robust metrics for operationalising socio-political and economic factors within ERS frameworks. From a policy and practice perspective, the results underscore the need for coordinated investments in both technical capabilities and governance structures to achieve resilient, adaptive, and inclusive infrastructure systems.

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Appendix 1

Table 1: Descriptive Statistics of Emergency Response System

Code	Technical Emergency Response System (TERS)	Mean	Std. Dev.	NV	Rank
TERS10	Disaster monitoring.	4.30	0.884	1.000**	1
TERS13	Communication and networking of disasters.	4.27	0.871	0.947**	2
TERS9	Traffic monitoring.	4.27	0.901	0.936**	3
TERS15	Recognising and analysing disaster risk.	4.24	0.978	0.894**	4
TERS8	Monitoring of street security.	4.23	0.891	0.872**	5
TERS11	Crime watch monitoring systems (eg, CCTV and drones).	4.21	0.895	0.819**	6
TERS14	Data management and analysis of disasters.	4.19	0.932	0.787**	7
TERS16	Risk assessment of disaster.	4.17	0.902	0.755**	8
TERS2	Risk identification.	4.12	0.892	0.649**	9
TERS1	Understanding disaster risk in its dimensions.	4.08	0.930	0.574	10
TERS7	Environmental conditions of risk.	4.06	0.964	0.543	11
TERS17	Community engagement in monitory disaster.	4.03	0.974	0.489	12
TERS23	Predicting trends of disaster occurrence for DRR management actions.	4.01	0.963	0.447	13
TERS3	Vulnerability of risk factor.	3.98	1.054	0.394	14
TERS6	Hazard characteristics of risk.	3.98	1.019	0.383	15
TERS19	Creation of a system for the prediction of disaster events.	3.97	0.971	0.372	16
TERS20	Data management and analysis of past and present disasters for DRR and DRM.	3.97	0.769	0.362	17
TERS22	Identifying problems associated with pre-disaster management measures.	3.94	0.830	0.319	18
TERS5	Exposure of risk.	3.92	1.000	0.277	19
TERS18	Religious institution involvement in monitoring disasters.	3.92	1.016	0.277	20
TERS4	Capacity of risk factor.	3.91	1.037	0.255	21
TERS21	Assessing the current situation of disaster occurrence for DRR and DRM.	3.83	0.896	0.096	22
TERS12	Provision of monitoring devices and sensors.	3.78	1.086	0.000	23
Non-Technical Emergency Response System (NTERS)					
NTERS10	Enforcement translation of disaster risk policies.	4.18	0.916	1.000**	1
NTERS13	Capacity building in DRR and DRM in various institutions, organisations, and communities.	4.03	1.246	0.792**	2
NTERS12	DRR plan and platforms for various cities or communities.	4.03	1.070	0.784**	3
NTERS21	Assessment of damage and losses for resilient rebuilding of DRR plan and strategies.	3.98	0.865	0.712**	4
NTERS17	Communication and networking between rescue teams and victims in disaster situations for effective, sound rescue.	3.97	0.960	0.704**	5
NTERS7	Gender and social inclusiveness in DRR and DRM.	3.95	1.004	0.672**	6
NTERS11	Investing in DRR for resilience at both national and local levels.	3.91	1.204	0.608**	7
NTERS15	Inclusive of religious and social institutions in DRR and DRM.	3.89	1.049	0.592	8
NTERS8	Institutional communication and awareness in DRR.	3.89	0.909	0.584	9
NTERS24	Resilient public investment for post-disaster.	3.89	0.957	0.584	10
NTERS9	Community participation in DRM.	3.88	1.159	0.576	11
NTERS3	Creation of a database for easy accessibility of risk information and ease of communication.	3.88	1.001	0.568	12
NTERS2	Institutions' and organisations' awareness of pre-disaster	3.87	0.963	0.560	13

	information for DRM.				
NTERS1	Social media broadcasting of disaster information for readiness and preparedness.	3.87	1.011	0.552	14
NTERS16	Rescue of lives and properties by emergency responders in the event of a disaster.	3.84	1.020	0.512	15
NTERS18	Provision of devices and sensors for speedy detection and rescue of victims in emergencies.	3.82	1.037	0.488	16
NTERS23	Multi-stakeholders' coordination for post-disaster recovery plans, policies, and implementation.	3.82	0.948	0.480	17
NTERS19	Setting an optimal search-and-rescue plan for DRR and DRM at the national and local levels.	3.77	1.103	0.416	18
NTERS6	Stakeholders' cooperation for DRM.	3.77	1.251	0.408	19
NTERS22	Planning for resilient reconstruction and rehabilitation for post-disaster recovery.	3.74	0.912	0.368	20
NTERS20	Creation of assessment measures for post-disaster event(s) for resilience measures.	3.72	1.095	0.336	21
NTERS14	Inclusive DRR in the educational curriculum.	3.71	1.227	0.320	22
NTERS26	Adaptation Measures of DRR and DRM.	3.59	1.082	0.152	23
NTERS25	Planning for a resilient recovery for post-disaster	3.57	1.104	0.120	24
NTERS5	Involvement of religious and social institutions in the pre-disaster stage for effective DRR.	3.54	1.032	0.088	25
NTERS4	Platformization of early warning systems in various cities, institutions, and communities.	3.48	1.126	0.000	26

Source: Fieldwork, 2025

** Normalisation value greater than 0.60.

Table 4: Reliability and Convergent Validity of the Model

	Loadings	t-value	CA	CR	AVE
TERS8	0.717	6.586	0.930	0.942	0.701
TERS9	0.869	11.441			
TERS10	0.901	11.725			
TERS13	0.873	11.086			
TERS14	0.799	7.902			
TERS15	0.880	11.377			
TERS16	0.809	10.672			
NTERS7	0.848	24.913	0.925	0.944	0.770
NTERS10	0.871	25.151			
NTERS11	0.928	87.395			
NTERS12	0.830	26.759			
NTERS13	0.907	64.548			
CHG1	0.770	17.542	0.921	0.934	0.612
CHG2	0.763	19.903			
CHG7	0.716	13.886			
CHG8	0.795	20.211			
CHG9	0.795	26.069			
CHG10	0.736	16.179			
CHG11	0.836	28.505			
CHG13	0.812	24.204			
CHG14	0.812	20.503			
EIE1	0.909	9.059	0.821	0.889	0.728
EIE2	0.814	6.443			
EIE3	0.833	6.874			
SIE2	0.848	20.790	0.840	0.893	0.676
SIE3	0.852	26.469			
SIE4	0.765	13.355			
SIE6	0.822	17.933			

Source: Fieldwork, 2025

CA: *Cronbach's alpha*
CR: *Composite reliability*
AVE: *Average variance extracted*