

Strategic Risk, Safety, and Emergency Preparedness Systems for Sustainable Infrastructure Development in Saudi Arabia

Muhammad Arslan Anwar Bhutta^{1*} 

¹DAR International Engineering and Consultancy: Riyadh, KSA, SA

*Corresponding Author

Muhammad Arslan Anwar Bhutta
DAR International Engineering and
Consultancy: Riyadh, KSA, SA

Article History

Received: 17.04.2026
Accepted: 13.06.2026
Published: 04.07.2026

Abstract: The infrastructure growth in Saudi Arabia takes place on a large scale, requiring more integration between strategic risk management, occupational safety, disaster preparedness and post-disaster recovery considerations. This study creates a conceptual architecture for sustainable infrastructure development that incorporates risk management, safety management, emergency response, community preparedness and information technologies as an integrated and adaptive process. Based on recent disaster management studies and the attached Springer framework, the paper adopts the rapid evidence review approach to analyze scholarly publications from 2020 to 2025 on disaster risk management, resilient infrastructure systems, healthcare emergency readiness, digitalization and the Saudi Vision 2030 agenda. The findings of the review indicate that sustainable infrastructure development is not possible without an appropriate institutional setting and real-time communication, along with skilled and knowledgeable responders, involvement of local communities and learning from past disasters. The study develops a theoretical architecture of Saudi infrastructure preparedness that encompasses hazard assessment, risk management during the design phase, safety management at project sites, emergency operations coordination, recovery planning and performance assessment. It contributes an evidence-informed framework that could be helpful for infrastructure clients, contractors, regulators and emergency organizations dealing with transportation systems, utility networks, energy facilities, healthcare facilities and giga projects.

Keywords: Strategic Risk, Safety Management, Emergency Preparedness, Sustainable Infrastructure, Saudi Arabia, Disaster Resilience, Vision 2030, Critical Infrastructure.

Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

1. INTRODUCTION

Saudi Arabia has been undertaking massive investments in transportation infrastructure, smart city developments, logistics hubs, hospitals, renewable energy facilities, mines, tourism areas and urban renewal projects. While such projects aim at creating a diversified national economy and improved quality of life according to the Vision 2030

plan, they increase vulnerability of supply chains, services and citizens in relation to infrastructure disruptions. This could mean disruptions by floods, extreme heat, sandstorms, industrial fires, cyber-physical events, crowd events or even construction accidents that disrupt operations and create a chain reaction extending into the community. Strategic infrastructure development, therefore, calls for both

Citation: Muhammad Arslan Anwar Bhutta (2026). Strategic Risk, Safety, and Emergency Preparedness Systems for Sustainable Infrastructure Development in Saudi Arabia; *Glob Acad J Econ Buss*, 8(4), 587-597.

safety and emergency preparedness perspectives rather than design-and-build considerations alone (Mani *et al.*, 2023; Al-Wathinani *et al.*, 2023).

The selected Springer paper on disaster management interoperability in Saudi Arabia provides an example for adopting the same approach because it takes a systems approach to emergency preparedness in relation to stakeholder interactions. Interoperability, international cooperation, standardization of procedures, readiness of the communities and advanced technologies are mentioned as crucial issues that should be taken into account for improving preparedness in Saudi Arabia (Mani *et al.*, 2023). Like any disaster management plan, infrastructure projects have their own stakeholders that should coordinate with each other in case of emergencies. Metro stations, desalination plants, hospitals, airport terminals and industrial complexes require protection by owners, contractors, regulatory bodies, medical services, civil defense, municipalities, suppliers and community organizations using interoperable procedures.

In the context of modern disaster management and infrastructure projects, emergency risks are often connected to multiple elements that require coordinated responses from different parties. For example, problems with drainage systems may turn into traffic interruptions; power outage affects operational capabilities of hospitals; digital disruptions cause delays in mobilizing the emergency services; and fires on construction sites have repercussions for adjacent areas. Therefore, this paper takes a strategic risk-based approach that covers all aspects from hazard identification to prevention, preparedness, responses and recovery. The term sustainable infrastructure implies good environmental performance and high resource utilization, but also operational reliability and quick recovery from emergencies (Poulin & Kane, 2021; Wen *et al.*, 2023).

2. Aim and Objectives of the Study

The objective of this review is to gain an analytical insight into the possible contribution of strategic risk, safety management and emergency preparedness systems in facilitating sustainable development of infrastructure projects in Saudi Arabia. As opposed to addressing safety as an isolated regulatory issue at the facility level and emergency planning as a standalone action plan, this research conceptualizes these factors as systemic capabilities, aimed at promoting resilience, creating public value and implementing the Vision 2030 program. The research aims to achieve the following tasks: first, to conduct a literature review on disaster risk reduction, infrastructure resilience, emergency preparedness and changing patterns of risks in Saudi

Arabia; second, to identify key components of a system that can facilitate safer and more resilient infrastructure projects; third, to summarize lessons learned from experience in achieving interoperability, utilizing new technologies, involving communities and coordinating institutions; fourth, to design a conceptual architecture of strategic risk and emergency preparedness system in Saudi infrastructure projects; and fifth, to suggest governance indicators to assess preparedness maturity. The guiding question for this research paper is as follows: how can strategic risk, safety management and emergency preparedness systems be incorporated in Saudi infrastructure projects to enhance sustainability? This question is relevant since there is a tendency to implement infrastructure projects within tight deadlines and complicated logistics, while emergency preparedness is often considered in relation to existing infrastructure facilities. With such approach, risk reduction will influence project design, procurement process, sequence of construction work, training of employees and other stages of implementation process.

3. REVIEW METHODOLOGY

The research presented in this paper can be referred to as a rapid narrative review with systematic evidence synthesis. The methodology employed follows the rapid evidence assessment approach presented in the Springer rapid review model, where literature is assessed, analyzed, organized, and synthesized to establish trends and issues in Saudi disaster management (Mani *et al.*, 2023). It is a reasonable method to employ in this case as the topic under investigation pertains to complicated spheres such as infrastructure risks and emergency preparedness. Specifically, it includes several types of evidence, namely, disaster research, safety science, preparedness for public health crises, smart cities, and crisis management as well as resilience engineering (Sun *et al.*, 2020; Khorram-Manesh *et al.*, 2021).

For the purposes of this study, the articles published in the peer-reviewed literature, relating to Saudi Arabia, the Gulf countries, and other international frameworks, have been selected. Their publication date ranges from 2020 to 2025. The key concepts are strategic risk management, emergency preparedness, disaster risk reduction, critical infrastructure resilience, safety management system, interoperable command, digital twins, artificial intelligence, IoT, community resilience, and Vision 2030. The selected papers have discussed one of the four themes: risk governance, safety prevention, emergency response coordination and recovery/continuity. Those publications that were irrelevant to the topic of infrastructure or emergency preparedness and had no relation to sustainability

and risks were excluded from further analysis.

Qualitative thematic synthesis was used as the method of analyzing data. At the first step of this process, the following themes came out of the data analysis: interoperability difficulties, emergency communication systems, workforce preparedness, community preparedness, technology use, governance accountability, and resilience. Next, they were categorized according to the lifecycle of

infrastructure and disasters as follows: planning, design, construction, operations, emergencies and response, and recovery. Finally, these themes were translated into a framework suitable for Saudi Arabia. This kind of review does not make any estimations concerning effects sizes or meta-analysis. The resulting paper will generate a framework for sustainable development.

Table 1: Rapid review design and inclusion logic

Review stage	Purpose	Inclusion focus	Output
Search strategy	Identify recent evidence	2020-2025 literature on Saudi DRR, safety, infrastructure and technology	Source pool
Screening	Remove weak or irrelevant records	Strategic risk, safety, emergency preparedness or resilience relevance	Focused corpus
Thematic synthesis	Group recurring findings	Interoperability, technology, community, governance and recovery themes	Conceptual categories
Framework design	Translate evidence into practice	Saudi infrastructure lifecycle from planning to operation	Preparedness architecture

4. Literature Review and Thematic Synthesis

The first theme is interoperability. Disaster and emergency management research demonstrates repeatedly that fragmented procedures, incompatible communication systems, and blurred roles reduce response effectiveness. In the case of Saudi Arabia, interoperability is recognized as one of the main problems as the emergency response will involve numerous public and private entities working within health, transport, civil defense, municipality and industry (Mani *et al.*, 2023). Interoperability should not be designed during an incident in regard to infrastructure development projects. Rather, it should be planned beforehand through incident command systems, information exchange, joint drills, asset mapping and escalation protocols before commissioning the assets. The second theme is resilience. Resilience is often considered to be about robust infrastructure only; however, the concept means that assets can withstand and absorb impacts and recover from incidents without major damage. Thus, critical infrastructure projects should identify their vulnerabilities in terms of electricity, water, communications, transport access, labor resources, digital solutions and supplies from outside the facility. A transport hub may have excellent structural stability but operational vulnerability because of limited power redundancy, lack of emergency access roads or poor crowd control procedures. Similarly, a hospital can be physically resilient but have vulnerabilities related to oxygen availability, generator capacity, temporary staff or record-keeping (Poulin & Kane, 2021; Goniewicz *et al.*, 2021). The third theme is safety management during construction and operation of assets. Construction projects in Saudi Arabia imply conducting lifting operations, excavations, tunnelling, electrical works, working in confined spaces, hot work, road diversion,

and high-place operations. Safety management during such activities is a matter of more than just personal protection equipment and toolbox talks. In addition to hazard assessments, the strategy involves design review for safety, prequalification of contractors, permit to work system, leading indicators, supervision qualifications, near miss reporting, auditing and corrective action management. Such a system helps reduce accidents and prepare for managing emergencies under stress (Aruru *et al.*, 2021; Al Ali *et al.*, 2022). The fourth theme is community preparedness. Infrastructure assets serve communities but can potentially disrupt them. Thus, projects involving flood channels, railroads, roads, hospitals, airports, industrial areas, and energy sources need community-level preparedness initiatives. Such initiatives may include messages to the public, evacuation plans, shelter plans, inclusive messaging for marginalized individuals, and platforms to receive feedback. In Saudi Arabia, community involvement is especially necessary due to the potential overlap between disaster scenarios and events involving religious mass gatherings, dense urban districts, desert travel routes, and urbanization challenges (Al-Wathinani, Alakeel, *et al.*, 2021; Al Kurdi, 2021). The fifth theme is technology. Digital technologies such as artificial intelligence, IoT, GIS, drones, satellite imagery, digital twinning and analytics based on big data can help detect hazards, increase situational awareness, monitor assets, plan recovery actions and coordinate efforts. However, technologies themselves do not generate resilience if there are no data governance processes, cybersecurity, user education, standardization of solutions, and interoperability of systems. The best use of technologies for managing emergencies is through integrating them into decision-making processes: stopping activities,

evacuating people, mobilizing resources, prioritizing asset restoration and coordinating with impacted

parties (Sun *et al.*, 2020; Golpira *et al.*, 2021; Gupta & Quamara, 2020).

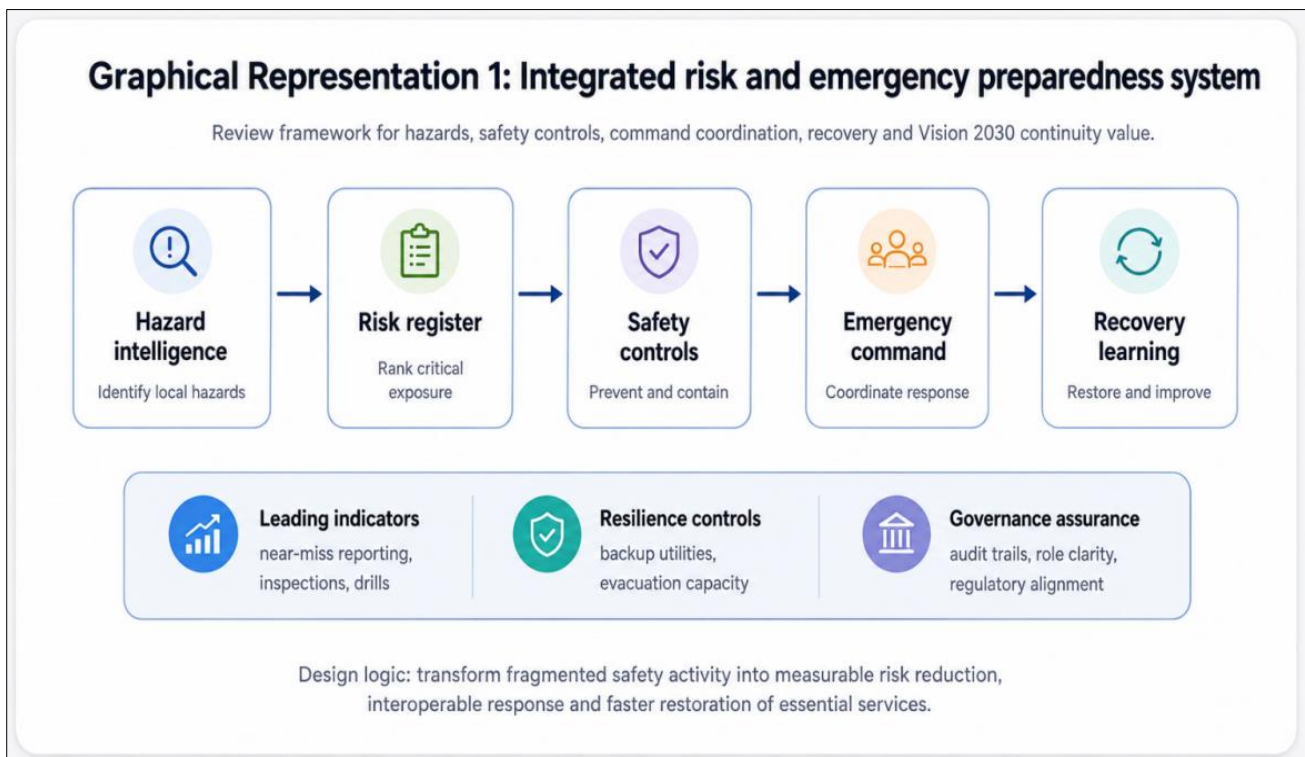


Figure 1: Integrated risk and emergency preparedness architecture for Saudi infrastructure

5. Strategic Risk and Safety Framework for Saudi Infrastructure

Hazard intelligence should be the initial layer of any infrastructure preparedness framework in Saudi Arabia. Hazard intelligence involves the combination of incident history, climate predictions, land use, population density, industry, cyber threat levels, and operations dependencies. Such an approach should inform a strategic risk register that prioritizes hazards according to their likelihood, consequence, velocity, detectability, and cascading impact. In real life, a risk of flooding may occur rarely but be impactful; a risk of heat stress may be seasonal and predictable; or a risk of failure of the cyber-physical control system may be unlikely but severe for utility infrastructure. Such a risk register should not become a static spreadsheet. Instead, it should be constantly updated in case design criteria, construction techniques, contractor, surrounding land use, and operational assumption change. Prevention is the second layer of infrastructure preparedness. The implementation of safety considerations during design typically becomes more cost-effective than the implementation of similar measures during operations. Prevention during design refers to the inclusion of such measures as drainage, fire compartmentation, minimum distances required for evacuation, emergency access, power, water, and air supply, sensor placements, protection barriers, maintenance, and failure-resistant

materials. For major giga-projects and rapidly developing areas, such considerations as crowd management, heat waves, sand deposits, flash-flood corridors, and emergency shelters must be considered. The creation of an infrastructure design review committee will help prevent future architectural versus resilience conflicts. Construction is the third layer in the proposed infrastructure preparedness framework. The majority of projects in Saudi Arabia typically involve numerous subcontractors and a workforce from different countries. Therefore, construction safety governance requires a common risk language across the entire supply chain. Construction plans for contractors must align with emergency plans of the owner. Site inductions must cover not only the identification of hazards, but also alarms, mobilization, escalation, and reporting procedures. Weekly monitoring of leading indicators, such as high-risk permits, late inspections, closed safety observations, drill participation rate, certified equipment, and fatigue reports, may serve as early warning signals. Emergency preparedness is the fourth component of any preparedness strategy. As soon as the infrastructure becomes operational, the emergency plans must be tested in realistic scenarios. Tabletop exercises are suitable for the preparation and alignment of leadership, while drills expose limitations, such as blocked access, no coverage on radio, long muster time, vague evacuation signs, or

inadequate first aid stations. Such exercises must include credible multi-threat scenarios, such as the occurrence of a sandstorm resulting in multiple accidents along a road; a flash flood affecting a transportation corridor; fire at a utility room; cyber security issue affecting building systems; or a mass-casualty event at a public place. Lessons must be turned into corrective action items. The last layer of the proposed framework involves recovery and continuity. Emergency preparedness cannot ignore the recovery process. An infrastructure organization should define maximum acceptable downtime and

priorities of its assets. Alternative service routes, spare parts, mutual aid agreements, insurance, and communication strategies should be developed. Additionally, a recovery process should take into account social considerations, such as the necessity of interaction with schools, hospitals, logistics companies, and other business entities. Recovery planning in line with sustainable principles should focus on quick service restoration, clear communication, vulnerability protection, and continuous learning.

Table 2: Infrastructure preparedness indicators across the project lifecycle

Lifecycle phase	Core risk question	Preparedness control	Leading indicator	Responsible actors
Planning	What hazards can affect the asset and surrounding community?	Multi-hazard risk screening and stakeholder mapping	Risk register reviewed before approval	Owner, regulator, municipality
Design	How can failures be prevented or contained?	Design-for-safety, redundancy and emergency access review	Critical design actions closed	Design consultant, safety team, operator
Construction	Are high-risk works controlled daily?	Permit-to-work, supervisor competence and site emergency drills	Overdue permits and corrective actions	Main contractor, subcontractors
Operation	Can the organization detect and respond quickly?	Incident command, alert protocols and interoperable communications	Communication test success rate	Operator, Civil Defense, EMS
Recovery	How fast can essential service be restored?	Continuity plans, spare parts and mutual-aid agreements	Maximum tolerable downtime achieved	Owner, operator, suppliers

6. Role of Digital Technologies and Data Governance

Also, digital technologies will enable the improvement of emergency preparedness in terms of infrastructural facilities in Saudi Arabia. As has been mentioned previously, sensors may be regarded as instruments that are needed to assess such factors as water level, air quality, vibrations, thermal impact, equipment evaluation, and crowd counting. Technologies related to Geographical Information Systems will assist in the unification of hazard maps, infrastructural facilities, evacuation pathways, hospitals, fire departments, as well as locations where vulnerable population groups are located. Furthermore, drones will help to visualize disaster scenarios associated with flooding, fires, and similar events in cases where physical inspection is impossible. Artificial intelligence may be used for predicting, scenario analysis, allocation, anomaly detection, and predictive maintenance (Hassounah *et al.*, 2020; Sun *et al.*, 2020; Al-Wathinani *et al.*, 2023). Nevertheless, considering the process of digitalization of infrastructural facilities, it is vital to address the problem of regulation. The framework of digital transformation offered by Springer not only

focuses on opportunities but also highlights such risks as privacy, security, interoperability, and lack of standardization (Mani *et al.*, 2023). In particular, they will become evident when discussing the process of digital transformation of infrastructural facilities. In such a way, it becomes clear that if a sensor produces some data but cannot communicate with the incident management dashboard, the former one will become useless. The malfunctioning of the latter system reduces its effectiveness. Inaccuracies will lead to misleading digital twins. Notifications will fail to work if they are not tested beforehand. In conclusion, the major elements to be included in the data governance strategy must include ownership policies, data validation procedures, cybersecurity measures, access regulations, data retention procedures, data integration, and escalation policy. It may also consist of defining thresholds in cases where data relating to floods make it necessary for the responsibility teams to act as well as developing backup options for communicating in cases where roads are inaccessible. Data accessibility is crucial. Nevertheless, it is crucial to avoid generating too many dashboards due to information overload. Visualization will prove helpful in this situation.

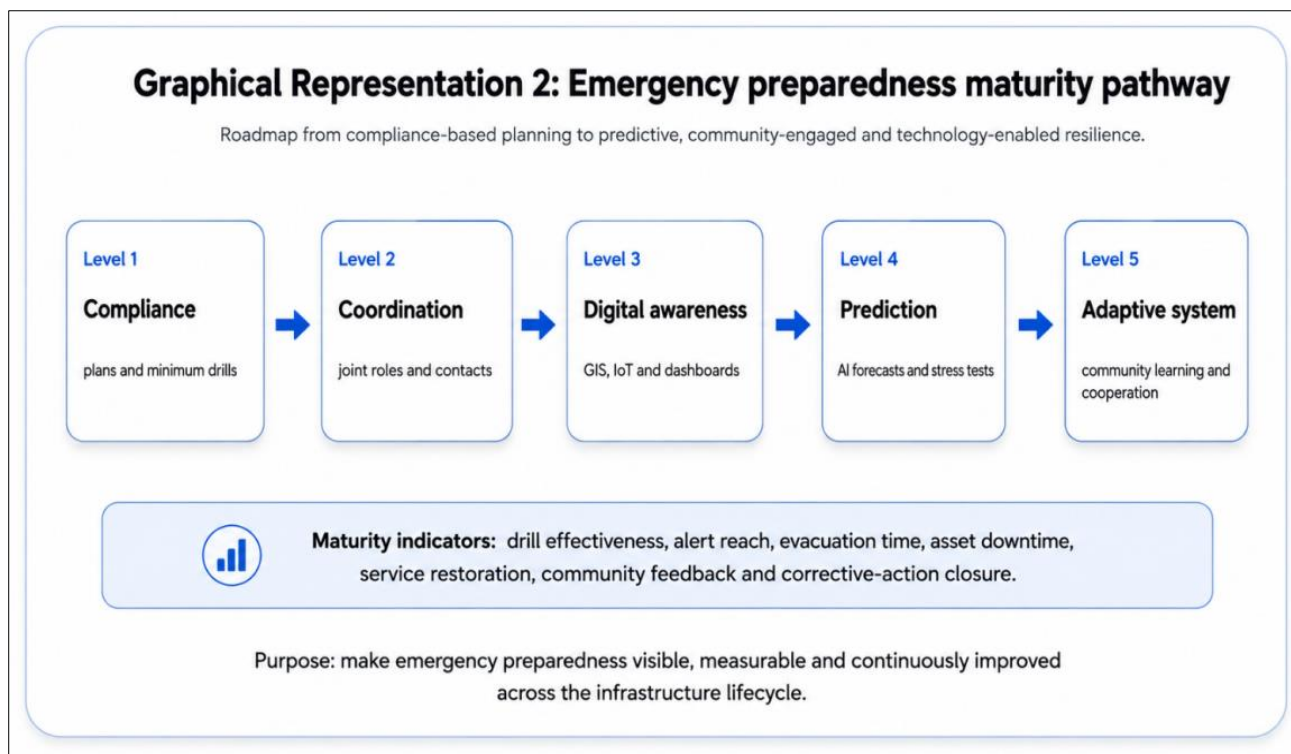


Figure 2: Emergency preparedness maturity pathway for sustainable infrastructure

7. DISCUSSION: ALIGNING PREPAREDNESS WITH VISION 2030 DELIVERY

Saudi Arabia's infrastructure pipeline is closely connected to national transformation goals. Tourism, logistics, mining, renewable energy, healthcare, entertainment and smart-city programs all depend on safe and reliable infrastructure. A serious disruption can delay investment, reduce public confidence, create reputational damage and increase lifecycle costs. Strategic risk and emergency preparedness therefore support economic diversification as well as public safety. They protect the continuity of services required for a modern, attractive and resilient economy (Vision 2030, 2025; Wen *et al.*, 2023).

One implication is that emergency preparedness should be integrated into project governance gates. Feasibility studies should include multi-hazard screening. Design approvals should include resilience and emergency access reviews. Procurement should evaluate contractor safety capability and business-continuity arrangements. Construction progress meetings should review leading safety indicators and emergency readiness. Commissioning should require drill evidence, asset information handover and emergency-service familiarization. Operation should include periodic reassessment as demand, technology and surrounding urban conditions change. This gate-based approach makes preparedness a normal part of project delivery rather than an afterthought.

Another implication is that leadership culture matters. A strong safety culture is visible when managers respond to weak signals, reward reporting, allocate resources for prevention and participate in exercises. Conversely, a compliance-only culture may produce attractive documents but weak practice. Emergency preparedness should be led by senior decision-makers because many resilience choices involve trade-offs between cost, time, operational flexibility and public protection. Boards and executive committees should therefore review risk exposure, critical corrective actions, drill performance and recovery capability as part of infrastructure governance.

A further implication concerns workforce capability. Saudi infrastructure development requires engineers, safety professionals, emergency planners, digital specialists, healthcare responders, security teams and operations managers who can work together. Training should move beyond isolated awareness sessions. Joint simulations, scenario-based learning, cross-agency exercises and after-action reviews build shared mental models. Workforce development should also include contractors and subcontractors, because emergency performance is only as strong as the least-prepared actor in the chain. Preparedness maturity depends on repeated practice, not one-time training.

Finally, the framework supports sustainability by reducing waste, downtime and social harm. Prevention reduces the material and

financial losses associated with accidents. Preparedness reduces confusion and duplication during response. Recovery planning shortens service interruption and limits economic damage. Community engagement builds trust and improves compliance with warnings. Digital tools provide earlier detection and smarter resource allocation when they are well governed. Together, these elements convert emergency preparedness from a cost center into a value-protection system for Saudi infrastructure development.

8. RECOMMENDATIONS

Moreover, the portfolio of investments in infrastructure in Saudi Arabia includes tourism, logistics, mining, sources of renewable energy, medical institutions, entertainment, and smart cities – projects aimed at nation-building and transformation. Therefore, any potential problem may hinder the inflow of investments, erode confidence in the sector, compromise reputation and inflate life cycle costs. In this way, strategic risk management and preparedness contribute to the economic diversification and public safety due to protection of services continuity in a dynamic economy (Vision 2030, 2025; Wen *et al.*, 2023). It means that, first, emergency preparedness must be made part of gates of project governance. For instance, feasibility studies could include multi-hazard risk screening; design approvals could incorporate assessment of resilience and emergency access; procurement could take into account the contractor safety capabilities and continuity of its business processes; progress in construction could be examined through leading safety indicators and preparation for emergencies; commissioning could involve drill demonstration, transferring of asset information to emergency services, and cooperation; and operations could imply periodical risk review based on demand changes, innovation development and new urban settings. Second, the implication is associated with leadership culture as a driver of success of emergency preparedness efforts. The fact is that effective safety culture can be observed in proactive behavior of managers regarding even low-risk events, reward system, resources dedicated to prevention, and participation in drills. Compliance-focused leaders would result in an attractive set of documentation but would do nothing about effective safety and emergency readiness efforts. In other words, emergency preparedness decisions imply trade-offs for senior management that should be examined in infrastructure governance. Third, the importance of taking workforce capability into consideration should be acknowledged. In order to achieve successful implementation, engineering, safety, emergency planning, digital, medical response, security, and operational professionals capable of working in an interdisciplinary

environment are needed. Consequently, training programs are to be created involving not only individual courses but joint simulations, scenario-based training, cross-sector exercises and after-action analysis in order to develop a common mental model. Moreover, since emergencies can affect both general contractors and subcontractors, it implies similar preparedness efforts for both categories. The framework is supportive of sustainability of the project as well. First, there is no disruption and therefore less loss of physical assets and costs for replacement. Second, being prepared for emergency situations decreases redundancies and coordination problems in the process of recovery. Third, having a recovery plan decreases time of services interruption and thus negative impact on economics. Fourth, community involvement increases trust in authorities and compliance with warnings provided. Fifth, digital technologies help intervene in time and save resources. In other words, emergency preparedness becomes a value-protection system.

8. Implementation Roadmap and Measurement Model

Implementation should commence with establishing governance baseline for each infrastructure owner. An infrastructure owner needs to determine what assets require protection, which parties to contact in the case of emergencies, what responsibilities it has, what information and communication flows need to be established, and services continuity issues. Such baseline serves as a single point of reference in the case where several projects are conducted by multiple parties, under different contractual and technical frameworks. Otherwise, even the best technically sound projects might experience delay once a crisis hits, because of undefined decision-making rights. The next stage would be the development of realistic scenarios that suit Saudi Arabia infrastructure conditions. Scenarios can range from such events as extreme temperatures affecting construction crews, sudden flash flood affecting urban drainage canals, sandstorms affecting transport links, substation fires, accidents with cranes, utility disruptions at healthcare facilities, hazardous substance releases in the industrial areas, computer network disruption of building management systems, and pressure crowds at the large-scale events. Each scenario should clearly identify triggers and warnings, required resources, communication flows, and recovery priorities. The third step should be capability mapping. Organizations should identify whether current capabilities match what is required to respond to potential crises. Capabilities can relate to such factors as the availability of incident commander with qualifications, rescue equipment, first-aid kits, emergency fleet, backup power source, emergency water supplies, access routes, emergency shelter,

spare parts, communication equipment, and specialists. Deficiencies in organizational capabilities should be prioritized according to their impact and addressed through purchases, training, agreements with other organizations, or design changes. Capability mapping is extremely helpful during the construction phase when the site conditions constantly change. Next, organizations can design exercises that increasingly integrate the processes of responding to emergencies. The simplest type of exercise is a table-top one, focusing on decision-making and communication processes of the leadership. A functional exercise should concentrate on the effectiveness of the control room operation, emergency chain of command, or dashboard usage. The final form of exercises should consist of the full-scale drills evaluating the ability to evacuate personnel, deal with injuries, cooperate with firefighting agencies, and maintain site access. Post-action review should always search for root causes and not lay blames on people. The fifth stage is associated with measuring the preparedness maturity. There are three categories of indicators that can help measure the success. Compliance indicators can confirm the presence of such elements as plans, inspections, and trainings. Capability indicators can verify the readiness of resources and personnel to perform necessary activities in the realistic conditions. Outcome indicators measure the duration of evacuation, reach of the alerts, service restoration, injury severity, downtime, and stakeholders' satisfaction. Finally, learning indicators can track the completion of corrective measures identified during exercises. The last stage is the integration into the sustainability report. Sustainability reports usually contain data regarding such aspects of infrastructure facility's operation as energy consumption, carbon emissions, water management, and use of raw materials. It can be useful to incorporate such indicators in those reports as resiliency investment, downtime of critical services, performance of exercises, protection of construction workers from heat stress, participation of the community in preparedness planning, and lessons learned from incidents. Thus, sustainability reporting can show how important safety and resiliency are for overall sustainability.

Lastly, reviewing the events that took place and adapting the preparedness plan to evolving conditions of Saudi Arabia infrastructure should be conducted on a regular basis. When new neighbourhoods emerge, traffic volumes change, climatic conditions change, digital networks evolve, or new contractors enter the market, a preparedness plan must change too. Any design revisions, incidents, annual exercises, regulatory change, and operational transitions should be subject to reviewing. Roadmap

for Saudi Infrastructure is a process, not a one-time compliance activity.

9. Policy and Practice Implications

Policy Implications It would be reasonable to assume that the need for a set of guidelines on infrastructure preparedness at the national level includes a description of minimal requirements in terms of risk register, emergency access, command structure, drill cycle, alert system, recovery plan, and data management. Nevertheless, this set of guidelines will not contradict any existing regulatory documents in particular sectors but rather serve as the basis for interconnectivity among roads, ports, utilities, hospitals, industrial zones, and other elements of smart cities during emergencies. In case of public clients, it means that preparedness must become part of tender evaluation and contract compliance process. In this respect, tender submission must show the client company's previous experience in dealing with emergencies, staffing and capability in terms of safety, capability to report on incidents digitally, business continuity plans, and engagement in joint exercise. For designers, safety evaluation has to take into account aspects such as maintenance, operation in emergencies, appearance, capacity, and cost. In the case of contractors, preparedness will be included in the day-to-day project management via staff inductions, multilingual alarm systems, control of heat stress levels, evacuation plans, medical preparedness, and digital reporting on potentially risky processes. Operators have to give priority to the maintenance of asset records' accuracy, backup systems' testing, data integrity assurance, and service restoration coordination with vendor partners. Emergency agencies must collaborate closely with project managers both during the design and commissioning phases to avoid any response uncertainties as they get acquainted with the access points, hazards storage, utilities disconnection procedures, and communication channels beforehand. Community members will gain confidence about warning risks to avoid dangerous actions. Thus, strategic risk management cannot become a bureaucratic process but serve as the coordination tool bringing technical designs, safety behavior, emergency response, and sustainable public value together. **Portfolio Thinking and Budgeting from Lifecycle Perspective** As a tool for decision-makers at the program level, the framework calls for taking into consideration portfolio thinking when addressing risks associated with implementation stage. Even if individual projects appear well-designed, their impact on each other within infrastructure network during implementation poses serious risks. Using portfolio dashboards, stakeholders can identify the moments when construction activities will create a cumulative effect in terms of simultaneous road closings,

hazardous transportation route, big camps of workers, increased electricity consumption, and exposure to unfavorable weather conditions. Moreover, portfolio thinking can also help promote lifecycle budgeting in safety matters. Money invested in installation of sensor devices, drills, backup systems, and improvement of resilience will result in savings in future. Finally, national-level aggregated data anonymized for incident reports and joint exercises will prove valuable for other industries. This approach leads to safer infrastructure ecosystem, in which every project can contribute knowledge for future ones. Insurance Companies, Banks, and Strategic Investors The information obtained through evidence-based approach can prove helpful for such stakeholders as insurance companies, banks, and strategic investors to assess the risk level of particular projects. Projects with continuity plans, personnel with appropriate skills, and reliable recovery programs involve less operational risk than those fulfilling minimum documentation requirements. Therefore, it will bring greater incentives to engage in better risk management and improved governance. Faculty members and professional associations can play a role in this process by developing specific educational materials tailored for Saudi Arabia in regards to infrastructure emergencies, human factors, data resilience, and crisis leadership. As a consequence, it will lead to better infrastructure ecosystem required for the implementation of Vision 2030 strategy.

10. Limitations and Future Research

There are several limitations to this rapid-review paper. While it summarizes current research and puts forward a conceptual framework, it fails to test its findings with surveys, interviews, and incident data analysis. At the moment, there is not enough Saudi-specific research on infrastructure emergency preparedness available, most of it comes from disaster management, healthcare preparedness, and global resilience management studies. Even though the findings are relevant for Saudi Arabia, further empirical research needs to explore the functioning of preparedness management systems within individual infrastructure sectors. Further research in this field should be focused on analysing the maturity of preparedness management systems in transportation, utilities, healthcare services, oil/gas industry, mining, tourism, and large-scale construction projects. Empirical studies can analyze different approaches to governance that can speed up response times and recovery. There is potential for quantitative research on how leading safety indicators, drills' performance, and incident results correlate. Research can also assess how artificial intelligence, Internet of Things, and geographic information systems improve situational awareness of emergencies in Saudi Arabia.

11. CONCLUSION

Risk management, safety, and emergency preparedness are key components of sustainable infrastructure development in the Kingdom of Saudi Arabia. The Kingdom's plans for infrastructure must be not only advanced and efficient but also safe, interoperable, resilient, and able to recover. In reviewing the key elements of an effective infrastructure emergency preparedness system, the current paper finds that such a system requires several related capacities, including hazard intelligence, design phase prevention measures, safety and emergency planning during construction, digital situational awareness tools, community engagement, recovery planning, and continuous learning. The proposed theoretical framework is consistent with the key ideas found in recent disaster management literature in Saudi Arabia in that it emphasizes interoperability, standardized processes, international collaboration, new technology, and community readiness. However, it also incorporates all these ideas in an infrastructure perspective, as most critical risk decisions must be made even before an emergency takes place. The main recommendation from this analysis is to embed risk and safety management systems in the governance of infrastructure projects. This will ensure that accidents are prevented, communities protected, disruption minimized, and the value of Saudi Arabia's development investments secured. Given the strategic importance of reliable physical systems that will allow Saudi Arabia to diversify its economy and improve people's lives, resilience should be seen as a strategic investment in the nation's future.

REFERENCES

- Ahern, S., & Loh, E. (2021). Leadership during the COVID-19 pandemic: Building and sustaining trust in times of uncertainty. *BMJ Leader*, 5(4), 266-269.
- Al Ali, Y. T., Al Qahtani, A. A., Assiri, H. Y., Alyahya, A. M., Al Alkharsh, F. S., Assiri, A. Y., Alghamdi, M. S., & Saeed, A. Q. (2022). Effectiveness of technology on organizational development and services in the Saudi health sector. *Journal of Pharmaceutical Negative Results*, 13(9), 2144-2155.
- Al Kurdi, O. F. (2021). A critical comparative review of emergency and disaster management in the Arab world. *Journal of Business and Socio-Economic Development*, 1(1), 24-46.
- Al-Wathinani, A. M., Alakeel, A., Alani, A. H., Alharbi, M., Almutairi, A., Alonaizi, T., Alhazmi, R. A., & Alghadeer, S. M. (2021). Flood emergency preparedness among healthcare providers in Saudi Arabia. *International Journal of Environmental Research and Public Health*, 18(3), 1329.

- Al-Wathinani, A. M., Hertelendy, A. J., Mobrad, A. M., Alhazmi, R., Althunayyan, S., Molloy, M. S., & Goniewicz, K. (2021). Emergency medical providers' knowledge regarding disasters during mass gatherings in Saudi Arabia. *Sustainability*, 13(6), 3342.
- Al-Wathinani, A. M., Barten, D. G., Borowska-Stefanska, M., Golda, P., AlDulijan, N. A., Alhallaf, M. A., Samarkandi, L. O., Almuhaidly, A. S., Goniewicz, M., Samarkandi, W. O., & Goniewicz, K. (2023). Driving sustainable disaster risk reduction: A rapid review of the policies and strategies in Saudi Arabia. *Sustainability*, 15(14), 10976.
- Al-Wathinani, A. M., Alhallaf, M. A., Borowska-Stefanska, M., Wisniewski, S., Sultan, M. A. S., Samman, O. Y., Alobaid, A. M., Althunayyan, S. M., & Goniewicz, K. (2023). Drone applications for streamlining disaster management and prehospital care in Saudi Arabia. *Healthcare*, 11(11), 1575.
- Aladsani, H. K. (2022). University instructors' stories about promoting student engagement during COVID-19 emergency remote teaching in Saudi Arabia. *Journal of Research on Technology in Education*, 54(S1), S165-S181.
- Algahtani, F. D., Hassan, S. U., Alsaif, B., & Zrieq, R. (2021). Assessment of quality of life during COVID-19 pandemic in the Kingdom of Saudi Arabia. *International Journal of Environmental Research and Public Health*, 18(3), 847.
- Alrubaiq, A., & Alharbi, T. (2021). Developing a cybersecurity framework for e-government project in the Kingdom of Saudi Arabia. *Journal of Cybersecurity and Privacy*, 1(2), 302-318.
- Alzahrani, F. R., & Al-Moteri, M. (2022). The influence of Saudi national COVID-19 preparedness programs on triage decision-making skills of healthcare practitioners. *Infection and Drug Resistance*, 15, 925-932.
- Aruru, M., Truong, H. A., & Clark, S. (2021). Pharmacy emergency preparedness and response: A framework for expanding roles during COVID-19 and beyond. *Research in Social and Administrative Pharmacy*, 17(1), 1967-1977.
- Aziri, R., & Miralam, M. S. (2021). The impact of crisis and disasters risk management in COVID-19 times: Insights from Saudi Arabia. *Ethics, Medicine and Public Health*, 18, 100705.
- Berreman, J. M., & Guest, L. T. (2022). Effective pandemic response: Lessons from Kauai. *Health Security*, 20(6), 510-519.
- Borowska-Stefanska, M., Balazovicova, L., Goniewicz, K., Kowalski, M., Kurzyk, P., Masny, M., Wisniewski, S., Zoncova, M., & Khorram-Manesh, A. (2022). Emergency management of self-evacuation from flood hazard areas in Poland. *Transportation Research Procedia*, 107, 103307.
- Burkle, F. M., Khorram-Manesh, A., & Goniewicz, K. (2023). COVID-19 and beyond: The pivotal role of health literacy in pandemic preparedness. *Prehospital and Disaster Medicine*, 38(3), 285-286.
- Djafri, L., & Gafour, Y. (2022). Machine learning algorithms for big data mining processing: A review. In *Artificial Intelligence and Its Applications* (pp. 43-55). Springer.
- Golpira, H., Khan, S. A., & Safaeipour, S. (2021). A review of logistics Internet-of-Things: Current trends and scope for future research. *Journal of Industrial Information Integration*, 22, 100194.
- Goniewicz, K., & Goniewicz, M. (2020). Disaster preparedness and professional competence among healthcare providers: Pilot study results. *Sustainability*, 12(12), 4931.
- Goniewicz, K., Carlstrom, E., Hertelendy, A. J., Burkle, F. M., Goniewicz, M., Lasota, D., Richmond, J. G., & Khorram-Manesh, A. (2021). Integrated healthcare and the dilemma of public health emergencies. *Sustainability*, 13(8), 4517.
- Goniewicz, K., Goniewicz, M., Wloszczak-Szubzda, A., Burkle, F. M., Hertelendy, A. J., Al-Wathinani, A., Molloy, M. S., & Khorram-Manesh, A. (2021). Pre-training gap analyses and competencies for mass casualty incidents and disaster training. *BMC Public Health*, 21, 114.
- Gupta, B. B., & Quamara, M. (2020). An overview of Internet of Things: Architectural aspects, challenges and protocols. *Concurrency and Computation: Practice and Experience*, 32(21), e4946.
- Hassounah, M., Raheel, H., & Alhefzi, M. (2020). Digital response during the COVID-19 pandemic in Saudi Arabia. *Journal of Medical Internet Research*, 22(9), e19338.
- Janssen, M., & van der Voort, H. (2020). Agile and adaptive governance in crisis response: Lessons from the COVID-19 pandemic. *International Journal of Information Management*, 55, 102180.
- Khorram-Manesh, A., Dulebenets, M. A., & Goniewicz, K. (2021). Implementing public health strategies: The need for educational initiatives. *International Journal of Environmental Research and Public Health*, 18(11), 5888.
- Mani, Z. A., Sultan, M. A. S., Plummer, V., & Goniewicz, K. (2023). Navigating interoperability in disaster management: Insights of current trends and challenges in Saudi Arabia. *International Journal of Disaster Risk Science*, 14, 873-885.
- Poulin, C., & Kane, M. B. (2021). Infrastructure resilience curves: Performance measures and summary metrics. *Reliability Engineering & System Safety*, 216, 107926.

- Sultan, M. A. S., Khorram-Manesh, A., Sorensen, J. L., Berlin, J., & Carlstrom, E. (2023). Disaster collaborative exercises for healthcare teamwork in a Saudi context. *International Journal of Disaster Risk Science*, 14(2), 183-193.
- Sun, W., Bocchini, P., & Davison, B. D. (2020). Applications of artificial intelligence for disaster management. *Natural Hazards*, 103(3), 2631-2689.
- Wen, J., Wan, C., Ye, Q., Yan, J., & Li, W. (2023). Disaster risk reduction, climate change adaptation and their linkages with sustainable development over the past 30 years. *International Journal of Disaster Risk Science*, 14(1), 1-13.