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Review

Driving Sustainable Disaster Risk Reduction: A Rapid Review of the Policies and Strategies in Saudi Arabia

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Abstract: This article presents a comprehensive rapid review of the current disaster risk reduction (DRR) efforts in Saudi Arabia, a country exposed to a variety of hazards such as extreme heat, droughts, floods, dust, and sandstorms, along with threats from terrorism and violence. Employing a rapid review approach, our aim was to provide timely insights into DRR strategies, with an emphasis on the unique geographical and socio-political context of Saudi Arabia. This study serves as a valuable reference for similar hazard-prone regions worldwide. Our review encompasses Saudi Arabia's progress in key areas, such as improving building codes and infrastructure, developing early warning systems, raising public awareness, and strengthening emergency response capabilities. While Saudi Arabia has made commendable strides in implementing international best practices for DRR, our review also identified specific areas where further development and enhancement are needed. These include the need for more sophisticated early warning systems, expanded public awareness campaigns, and continual enhancements in emergency response capabilities. This review offers key insights into the challenges and opportunities within Saudi Arabia's DRR efforts, highlighting the steps that Saudi Arabia has taken towards resilience. Drawing from specific examples of past disasters, our findings shed light on practical considerations for improving disaster risk management, with the potential to inform policy, enhance public awareness, and contribute to building a safer and more resilient future in Saudi Arabia.

Keywords: disaster risk reduction; building infrastructure; early warning systems; public awareness; emergency response capabilities; community-based disaster preparedness

Citation: Al-Wathinani, A.M.; Barten, D.G.; Borowska-Stefańska, M.; Gołda, P.; AlDulijan, N.A.; Alhallaf, M.A.; Samarkandi, L.O.; Almuhaidly, A.S.; Goniewicz, M.; Samarkandi, W.O.; et al. Driving Sustainable Disaster Risk Reduction: A Rapid Review of the Policies and Strategies in Saudi Arabia. *Sustainability* **2023**, *15*, 10976. https://doi.org/10.3390/su151410976

Academic Editor: Nita Yodo

Received: 15 June 2023
Revised: 8 July 2023
Accepted: 11 July 2023
Published: 13 July 2023

1. Introduction

Saudi Arabia, given its unique geographic placement and arid climate, is inherently susceptible to a diverse array of natural and anthropogenic hazards. These pose considerable risks to its populace and infrastructure. These include, but are not limited to, extreme

heat events, prolonged drought conditions, flash floods, and severe dust and sandstorms, alongside non-environmental threats such as terrorism and violence [1,2].

The country has a history of experiencing disasters associated with these hazards, resulting in substantial human and economic losses. Furthermore, with climate change progressing, there is a potential for the frequency and intensity of some of these disaster events to increase. Particularly, issues related to extreme heat and water scarcity are expected to be exacerbated, emphasizing the growing need for robust DRR strategies in Saudi Arabia.

According to the World Risk Report, Saudi Arabia is classified as a country with a medium risk level, owing to its exposure to various hazards and the vulnerabilities inherent to its societal structures and systems [3]. These vulnerabilities can include factors such as the density of its population centers, the reliance on critical infrastructure, and the societal capacity to effectively respond to and recover from disaster events. Additionally, the Global Terrorism Index, a measure of the impact of terrorism on countries worldwide, ranks Saudi Arabia within the top fifty, indicating the presence of substantial risks and impacts related to violence and terrorism [4]. The reality of these risks emphasizes the critical need for effective Disaster Risk Reduction (DRR) strategies in the country.

DRR is an integral part of a country's sustainable development strategy. By systematically identifying, assessing, and reducing the risks of disasters, DRR can help to protect lives and assets, and sustain development progress. In the face of rising global disaster trends, DRR has become increasingly significant for countries worldwide, Saudi Arabia being no exception.

As a country with unique geographical and climatic conditions, Saudi Arabia is exposed to a range of natural and man-made hazards. Over the years, the country has taken determined steps to strengthen its DRR capabilities. Aligning with international best practices, Saudi Arabia has embarked on a comprehensive and multi-faceted approach to mitigate disaster risks. This includes strengthening its building codes and infrastructure to withstand potential hazards, establishing early warning systems for timely alerts, investing in public awareness campaigns to ensure preparedness, and reinforcing emergency response capabilities for effective disaster management [1,2,5].

Given the crucial role of DRR in safeguarding Saudi Arabia's sustainable development, this study focuses on reviewing the country's current DRR efforts. By understanding the strengths and areas for improvement in the existing measures, this study aims to provide valuable insights for further strengthening the DRR strategies in Saudi Arabia, and in other countries with similar risk profiles.

However, despite the progress made, there is a continued need for rigorous reviews of and improvements to the DRR strategies in Saudi Arabia to ensure their effectiveness in and responsiveness to the changing risk landscape. With the aim of shedding light on the current state of DRR in Saudi Arabia, this study provides a systematic literature review to identify the areas of strength and potential gaps in the existing DRR strategies.

The insights generated through this review are intended to serve as a valuable resource for policymakers, practitioners, and other stakeholders working in the field of DRR in Saudi Arabia and beyond. They highlight the importance of continued investment in DRR, suggesting pathways for further development and alignment with international best practices [3,4].

The global commitment to strengthening DRR is exemplified by the Sendai Framework for Disaster Risk Reduction 2015–2030. This voluntary, non-binding agreement emphasizes the primary role of the state in reducing disaster risks, but also highlights the shared responsibility among other stakeholders, including local government, the private sector, and others [6]. As such, it provides a guiding principle for nations such as Saudi Arabia in their ongoing DRR efforts.

By providing a comprehensive overview of the current state of DRR in Saudi Arabia, this study contributes to the ongoing discourse and action in the field of DRR, emphasizing

the importance of proactive and comprehensive approaches in reducing disaster risks, protecting lives and property, and building a safer and more resilient future for all [1,2,7,8].

2. Materials and Methods

This rapid review was conducted following a structured approach, designed to offer a comprehensive yet time-efficient overview of the disaster risk reduction efforts in Saudi Arabia [9,10]. Despite its expedited nature, the review upheld rigorous standards of data collection and analysis to ensure the validity of its findings.

2.1. Search Strategy

A systematic electronic literature search was conducted using three online databases: PubMed, Scopus, and the Web of Science. The search was limited to papers published from 2010 to 2023 to ensure the relevance and timeliness of the information. The search strategy involved the use of keywords and MeSH terms related to "disaster risk reduction", "hazards", "resilience", "preparedness", and "Saudi Arabia." Boolean operators (AND, OR) were used to combine these terms for a comprehensive search. The search strings were tailored for each database to maximize the retrieval of the relevant literature.

2.2. Inclusion and Exclusion Criteria

Articles were included in the review if they were written in English and published in peer-reviewed journals. Both original empirical research and literature reviews focusing on DRR in Saudi Arabia were considered. The selected articles had to contribute to understanding the implementation, challenges, or outcomes of DRR strategies in Saudi Arabia. Excluded were conference proceedings, editorials, meeting notes, news articles, and abstracts. Articles not primarily focused on DRR in Saudi Arabia or not providing substantial data or insights on the subject were also omitted.

2.3. Study Selection

The initial search results from each database were merged, and duplicates were removed. Two independent reviewers then screened the titles and abstracts against the inclusion and exclusion criteria. Disagreements could occur in instances where the relevance or focus of the article was unclear, and these were resolved through discussion or consultation with a third reviewer. Full texts of potentially relevant articles were subsequently obtained. The same reviewers independently assessed these full texts for their eligibility. Decisions on inclusion were based on consensus, with further discussions being held if differences of opinion arose. Additionally, our review did not include the reference searching of the included studies, which is a commonly employed practice to enhance the comprehensiveness of literature reviews. While our data collection strategy was thorough, it is possible that relevant studies may have been missed due to this limitation.

2.4. Characteristics of Included Studies

The studies selected for this review employed a range of methodologies, which is reflective of the multifaceted nature of disaster risk reduction (DRR) research. While we did not include commentaries, we did review studies that utilized both qualitative and quantitative methods, including interviews and surveys, respectively. Additionally, we considered literature reviews that offered comprehensive insights into the current state and challenges of DRR in Saudi Arabia. This diversity of methodological approaches allowed us to derive a well-rounded understanding of the subject from multiple perspectives. However, we recognize that the distribution and type of methodologies employed in the included studies may have influenced the findings of this review. Future reviews could potentially expand the scope to include a wider variety of study types in order to capture even more diverse insights into DRR strategies in Saudi Arabia.

2.5. Data Extraction and Analysis

The data from the included studies were systematically extracted, using a standardized form. The extracted data comprised study aims, methods, key findings, and implications for DRR practice in Saudi Arabia. The data were then subjected to a qualitative content analysis. Key themes were identified, and patterns within these themes were noted. The content analysis was undertaken in an iterative manner, allowing for the themes to be refined as new insights emerged.

2.6. Quality Assessment

An adapted version of the Critical Appraisal Skills Programme (CASP) (Oxford, UK) tool was employed to evaluate the quality of the included studies [9]. The tool was used to scrutinize the validity of the studies' methodology, the reliability of their findings, and the relevance of their contribution to DRR practices in Saudi Arabia. The quality assessment was considered when interpreting the findings and was also used as a criterion for including studies in the review.

2.7. Data Synthesis

After extraction, the data were synthesized to give an overview of the body of evidence. A narrative synthesis was conducted, which involved grouping the studies based on similarities in their themes, and then summarizing and comparing the results within each group.

2.8. Interpreting Findings

The findings were interpreted in light of the quality assessment, the characteristics of the included studies, and the context of DRR in Saudi Arabia. Where possible, the implications of the findings for policy, practice, and future research were discussed.

2.9. Handling Disagreements

Throughout the review process, potential areas of disagreement between the two reviewers included the relevance of the articles to the research question, the quality of the studies, and the interpretation of the study findings. In instances of disagreement, discussions were held to reach a consensus. These discussions offered a platform for each reviewer to express their viewpoint and present their case, thereby ensuring a comprehensive evaluation of the studies. If a consensus could not be reached, a third senior reviewer was consulted. The decision of the senior reviewer was considered to be final, acting as a mechanism to maintain the objectivity and rigor of the review process (Figure 1).

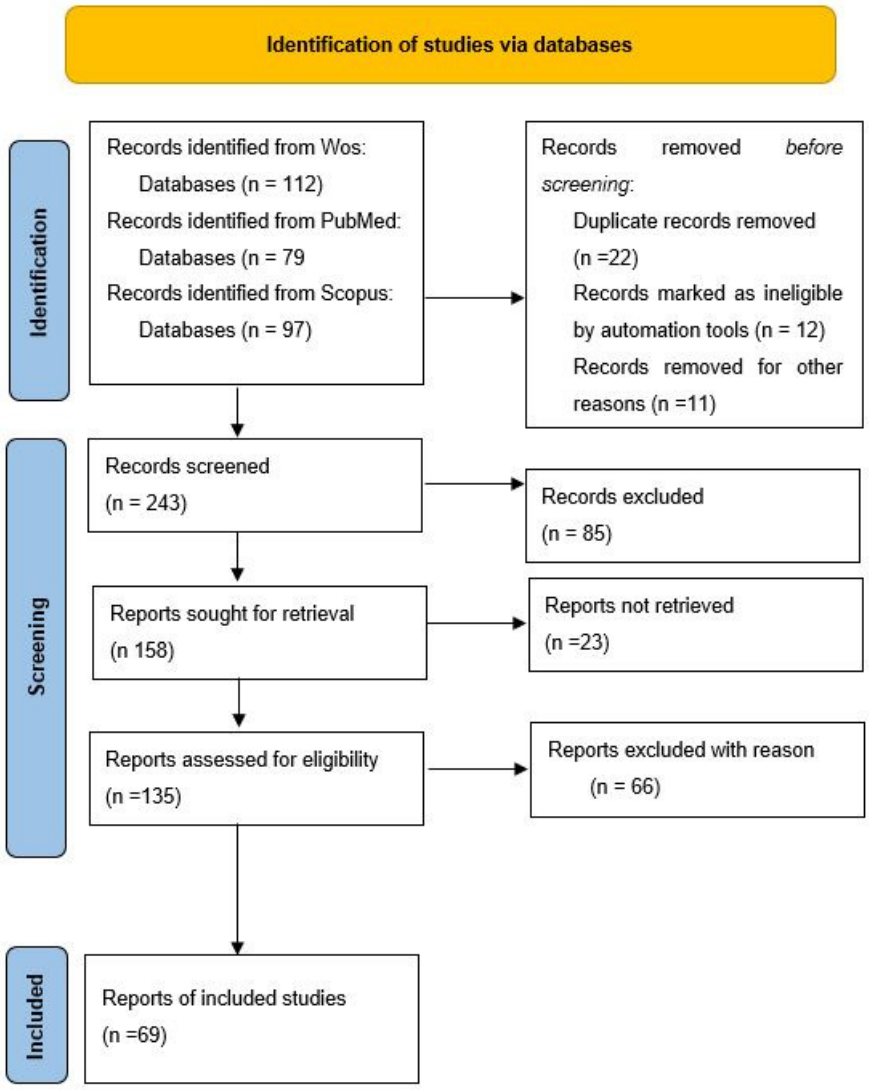

Figure 1. Flow diagram of literature selection process [10].

3. Results

A total of 69 studies were reviewed and assessed qualitatively, revealing valuable insights about the state of DRR in Saudi Arabia. Through the meticulous application of a content analysis, key domains emerged that centered on the disaster risk reduction efforts in the country. The subsequent sections provide a more detailed discussion of these domains, presenting a comprehensive picture of the strides made in each area and the potential gaps that need to be addressed.

3.1. Improving Building Codes and Infrastructure

Critical to the discourse on disaster risk reduction is the consideration of sturdy and resilient buildings and infrastructure, as underlined in the existing literature [10–12]. Structures constructed to withstand varying intensities of disasters considerably minimize the human and economic costs that disasters often entail [13]. Recognizing this, Saudi Arabia has been making considerable strides in modifying its building codes and standards to incorporate hazard-resistant engineering and construction practices [14].

Given the relatively minor, but not insignificant, seismic activity that Saudi Arabia has experienced [15], the authorities have prioritized focusing on seismic-resistant design and construction techniques [16]. While Saudi Arabia is not located in a seismic hotspot, the proactive measures taken to fortify its buildings against potential seismic activities

signify the country's holistic and preemptive approach to disaster resilience. It signals the understanding that a diverse set of hazards could potentially strike, hence the necessity for structures to be prepared to withstand a wide range of adverse events [16].

Moreover, the literature also highlights the potential for retrofitting and modernizing existing structures as a viable path towards enhancing community resilience [17]. Through appropriate interventions, older buildings can be transformed to better withstand disasters. Essential upgrades to electrical and plumbing systems and routine maintenance activities not only contribute to the longevity of these structures, but also bolster their safety profiles. Such efforts play a vital role in reducing disaster risk and ensuring safer living and working environments for residents [17–19]

Saudi Arabia's government has made evident its commitment to improving the country's infrastructure resilience. This is evidenced by several initiatives aimed at enhancing the strength and durability of its built structures [20]. Recent modifications to building codes reflect a deliberate move towards embedding resilience into construction practices [21]. Simultaneously, the authorities are placing increasing emphasis on retrofitting and upgrading existing buildings. Efforts are being directed towards enhancing the resilience of critical infrastructure such as hospitals, schools, and emergency response centers, which form the bedrock of any community, particularly in times of crisis. Ensuring their robustness and preparedness is, therefore, of paramount importance for an effective disaster response strategy [5,22].

Continuing with the focus on resilient infrastructure, the government of Saudi Arabia has demonstrated a firm commitment towards adopting green building codes [23]. These codes incorporate a broad spectrum of considerations beyond mere structural resilience. They promote environmental sustainability through strategies such as optimizing energy efficiency, enhancing water efficiency, using environmentally friendly materials, and minimizing waste [24]. By balancing development with environmental conservation, Saudi Arabia has integrated sustainable development goals within its DRR strategies, thereby embodying a holistic approach towards building resilience. This incorporation of green building codes is a significant stride towards the nation's commitment to environmental stewardship while ensuring disaster resilience [23,25].

One of the important initiatives in this direction is the implementation of the Saudi Building Code (SBC), which includes specifications for disaster resilience, as well as environmental sustainability [25,26]. The SBC is based on international standards and is adapted to the specific needs and conditions of Saudi Arabia. The code covers a wide range of factors, including structural design, fire safety, energy efficiency, and access for persons with disabilities. The implementation of the SBC is expected to significantly enhance the resilience of Saudi Arabia's built environment to various hazards [26].

Another noteworthy development in the realm of DRR is the emphasis on the resilience of urban infrastructure. As urban areas continue to grow, they are becoming increasingly exposed to various hazards. To mitigate these risks, Saudi Arabia is focusing on the development of resilient urban infrastructure [12]. This includes the planning and construction of resilient urban transport systems, water and wastewater systems, and energy infrastructure.

The evolving building codes and the emphasis on resilient and sustainable infrastructure provide insights into Saudi Arabia's comprehensive DRR strategy. The country's commitment to continual updates and improvements in these codes and standards reflects an adaptive approach to risk mitigation. However, it is important to remember that building and infrastructure resilience is just one piece of the complex DRR puzzle. Saudi Arabia's progress in this area needs to be matched by advancements in other aspects of DRR, such as early warning systems, public awareness, and emergency response mechanisms.

3.2. Developing Early Warning Systems

Early warning systems (EWS) are a critical element of DRR strategies, facilitating timely and accurate alerts about impending hazards, which consequently aid in effective

preparation and response. The vitality of EWSs in reducing the effects of disasters has been highlighted in numerous studies [27–29]. An effective EWS integrates a range of technologies and methodologies, drawing on data from seismic-monitoring networks, meteorological systems, hydrological forecasts, and satellite imagery to predict and track potential hazards.

In Saudi Arabia, the diversity of its potential natural hazards—including extreme heat, flash floods, dust and sand storms, and earthquakes—necessitates the development of a tailored EWS for each distinct risk [30,31]

To recognize the severity and potential devastation of floods, especially in urban areas, Saudi Arabia has established the "Jeddah Flood Forecast and Warning System" (JFFWS) [32]. This system employs cutting-edge technologies to forecast flash floods through real-time data collection and processing from hydrological and meteorological stations distributed in the catchment areas. The JFFWS has significantly improved the response time and preventive measures during the flood season in Jeddah city, demonstrating the importance of well-designed early warning systems [32].

In response to extreme heat events, which have been predicted to increase in frequency and intensity due to climate change, Saudi Arabia has implemented a Heat Health Warning System (HHWS). This system integrates meteorological forecasts with historical medical data, particularly hospital admissions due to heat-related illnesses, to predict dangerous heat conditions [33]. By correlating past incidences of heat-related health issues with specific weather conditions, the HHWS can trigger alerts when forecasts indicate that these thresholds may be exceeded. This provides healthcare systems and the public with ample time to prepare. It has not been specified whether the Saudi HHWS operates on a tiered or color-coded alert system, similar to those in other countries, and future studies might offer further insights into its intricacies.

To mitigate the risk of earthquakes, Saudi Arabia has a Seismic-Monitoring Network in place, operated by the Saudi Geological Survey (SGS) [34]. The SGS employs advanced seismic sensors distributed across the country, feeding real-time data to a central hub for processing and analysis. If a potential seismic event is detected, alerts are sent to the relevant authorities so they can prepare and respond effectively.

Aside from technological advancements, Saudi Arabia has emphasized enhancing the public's understanding of these early warning systems and their appropriate responses. This includes education campaigns through various media channels and community outreach programs [30].

As per Kelman and Glantz, the continuous advancement, adaptation, and integration of early warning systems are crucial for an effective DRR strategy [35]. The commitment demonstrated by Saudi Arabia towards its EWSs—through its technological initiatives, system integration, and public education—illustrates its dedication towards a resilient future, fortified against potential hazards and disasters.

3.3. Enhancing Public Awareness and Education

Public awareness and education form the backbone of effective DRR. Knowledge about potential hazards, their impacts, and necessary responses can significantly reduce the severity of disasters and foster a more resilient society.

In Saudi Arabia, there is an increasing recognition of the role that public education plays in disaster risk reduction. As a result, various measures have been adopted by government agencies and non-governmental organizations to enhance the public understanding of disaster-related risks.

One such initiative is the General Directorate of Civil Defense's (GDCD) educational campaigns aimed at increasing public awareness about these hazards. These campaigns employ various channels, including social media, radio, and television, to disseminate information about common hazards and appropriate responses [36]. These initiatives target a diverse audience, from school children to adults, and provide practical, actionable information that can be used in cases of emergencies.

Another initiative is the inclusion of disaster risk education in school curricula. The Saudi Ministry of Education, in collaboration with the United Nations International Strategy for Disaster Reduction (UNISDR), has integrated DRR into its school curriculum [37]. This is an important step, as it ensures that the future generation is equipped with the knowledge and skills necessary to deal with potential disasters [38].

Public awareness is also being fostered through community-based initiatives. For instance, the Saudi Red Crescent Authority regularly organizes workshops and seminars on disaster preparedness and responses at the community level [39]. Similarly, city municipalities run local campaigns to educate their residents about specific hazards, such as flash floods and sandstorms, particularly in regions that are more susceptible to these risks [40]

Another important development in Saudi Arabia's DRR efforts is the utilization of technology and digital platforms for public education. Recognizing the widespread use of digital technology in Saudi Arabia, authorities have leveraged this to disseminate information and engage the public in DRR efforts [41]. For example, the General Directorate of Civil Defense developed a mobile app that provides real-time updates on disaster risks, offers advice on preparedness measures, and enables citizens to report incidents [36]. By using technology to reach out to and engage with the public, Saudi Arabia is not only increasing awareness, but also facilitating the involvement of citizens in disaster risk management.

Community-based disaster risk reduction (CBDRR) initiatives also form a key part of Saudi Arabia's efforts to enhance public awareness and education. CBDRR initiatives aim to empower communities to understand, assess, and mitigate the risks they face, thereby enhancing their resilience to disasters [17,38,42,43]. For instance, in Jeddah, a community-based initiative was launched to address the recurrent flooding issue in the city. The initiative involved community participation in the design and implementation of flood risk reduction measures, along with community-based awareness campaigns. This not only helped in reducing the flood risk, but also increased the community's understanding and awareness of the issue [44].

Saudi Arabia has also invested in disaster risk education and research. Universities and research institutions across the country are contributing to the DRR field through research, education, and capacity-building programs. For example, the King Saud University offers a specialized program in disaster management and risk reduction, which focuses on equipping students with the knowledge and skills needed to deal with disaster risks [45].

The aforementioned initiatives demonstrate the width and depth of Saudi Arabia's efforts towards enhancing the public awareness of and education on disaster risks. However, it is important to continue these efforts and address the existing gaps. The public understanding of disaster risks should be comprehensive, covering a wide range of hazards and emphasizing the importance of proactive measures such as preparedness and mitigation. Furthermore, the initiatives should be tailored to the needs and characteristics of different target groups, ensuring that their messages are accessible and relevant to all. Lastly, it is important to evaluate and assess the effectiveness of these initiatives regularly, in order to inform future strategies and actions.

3.4. Strengthening Emergency Response Capabilities

Efficient and immediate emergency response is pivotal to minimizing the human, material, and financial losses following disasters. This involves not only the immediate actions taken post-disaster, but also the ongoing efforts to prepare, plan, and train for such scenarios.

The Saudi Arabian government has been proactively working to augment its emergency response capabilities. One key aspect of this has been the creation and continuous updating of its comprehensive emergency response plans. The GDCD, in conjunction with other governmental and non-governmental entities, develops these plans, which are designed to ensure that every aspect of disaster response is covered, from search and rescue to emergency medical care and disaster recovery [36].

There has been a considerable emphasis on personnel training to ensure swift and effective responses to disasters. GDCD personnel, as well as those from other emergency services, regularly participate in drills and exercises simulating different disaster scenarios, thus honing their skills and improving the coordination among different agencies [36,46].

Another critical aspect of strengthening these emergency response capabilities is the provision and maintenance of the appropriate equipment and infrastructure. To this end, Saudi Arabia has made significant investments in its emergency services. For instance, advanced search and rescue equipment, firefighting vehicles, and other necessary tools have been procured and are regularly updated. Moreover, the Saudi government has initiated upgrades to its crucial infrastructure, including hospitals and emergency response centers, to amplify their disaster readiness and response capabilities [47]. This has entailed strengthening the structural resilience of the buildings against hazards, scaling up their capacities for dealing with disaster-induced surges, and integrating sophisticated communication and data systems for more streamlined coordination during emergencies. Combined, all these measures ensure that these facilities can continue to serve their communities effectively, even under adverse conditions.

Delving deeper into the strengthening of its emergency response capabilities, Saudi Arabia has also been making strides in harnessing the power of modern technology to enhance its emergency response. The use of Geographic Information System (GIS) technologies and Remote Sensing (RS) has greatly enhanced the country's disaster response mechanisms. These technologies facilitate efficient resource allocation and management during emergencies and aid in the rapid assessment of disaster impacts [30,48,49].

Collaboration, both national and international, is another crucial aspect of Saudi Arabia's approach to enhancing its emergency response capabilities. The government has partnered with different national stakeholders, such as the Saudi Red Crescent Authority and the Saudi Geological Survey, to maximize the efficiency of its disaster response [34,39]. On an international level, collaborations with entities such as the United Nations Office for Disaster Risk Reduction (UNDRR) and the World Health Organization (WHO) help with building capacity, sharing best practices, and ensuring compliance with international standards [50,51].

Importantly, Saudi Arabia has started focusing on community-based emergency response strategies. The government has initiated training programs to equip community members with basic emergency response skills, such as first aid, search and rescue, and firefighting. This not only helps in the immediate aftermath of a disaster, when professional help may not be immediately available, but also fosters a sense of community resilience and empowerment [52].

Public–private partnerships (PPPs) are also being explored as a means to enhancing these emergency response capabilities. Through PPPs, the government can tap into the resources, technology, and expertise of the private sector, thereby augmenting its own capabilities. PPPs also promote the innovation of disaster response, as private entities often bring fresh perspectives and novel solutions [53,54].

Despite the strides made in strengthening emergency response capabilities, there is always room for improvement. Building on these initiatives, future efforts should focus on enhancing inter-agency coordination, adopting the latest technologies, continuously training personnel, and promoting community participation in emergency responses. Moreover, performance evaluation and learning from past experiences should be integral parts of these efforts, ensuring continuous improvement and readiness for future emergencies.

3.5. Fostering Community-Based Disaster Preparedness

Community-based disaster preparedness in Saudi Arabia is not just about preparing for disasters, but also about empowering communities to become active participants in disaster risk reduction. Several initiatives aimed at bolstering the role of communities in DRR have been launched. For instance, community drills and simulations involving

various disaster scenarios have been conducted, giving residents hands-on experience with disaster response and preparing them for actual emergencies [5,17].

Various organizations are actively engaging communities in the identification and mitigation of local disaster risks. By encouraging active participation, these initiatives allow communities to gain a deeper understanding of the risks they face and the measures they can take to reduce these risks. This also fosters a sense of ownership over local DRR strategies, making them more likely to be sustained in the long term [55].

To reach a wider audience and ensure the effective communication of disaster-related information, authorities are increasingly leveraging digital platforms. Social media, for example, is being used to disseminate emergency alerts, share safety tips, and raise awareness about different types of disasters [56].

The Saudi government has also been working to integrate DRR into religious and cultural practices, recognizing that these can play a critical role in shaping people's attitudes and behaviors towards disaster risks. For example, sermons in mosques often include messages about disaster preparedness and safety, and cultural festivals are used as platforms to promote DRR activities [57].

In terms of community-based disaster preparedness, Saudi Arabia is making strides in the incorporation of local knowledge and practices into DRR strategies. This approach capitalizes on the existing resources, skills, and resilience mechanisms within communities and tailors strategies to the specific local context [58]. Recognizing the wisdom of local populations, traditional coping mechanisms, and indigenous knowledge of the environment can add valuable dimensions to DRR efforts.

Recognizing the importance of community involvement in disaster management, the Saudi Arabian government has also focused on building the capacity of local institutions and organizations. Support is given to local disaster management committees, providing them with the necessary resources, training, and authority to manage and reduce disaster risks at the community level [11,58]. This support is not just about financial resources, but also includes technical guidance, training, policy support, and networking opportunities.

There are, however, several challenges associated with fostering community-based disaster preparedness. First, there is the issue of ensuring consistent community participation and commitment, especially in areas with high levels of transiency or social fragmentation [59]. Second, there is the challenge of ensuring that local DRR initiatives align with the national strategies and plans. This requires effective communication and coordination between various levels of government and local communities, as well as flexibility in adapting national strategies to local contexts. Lastly, there is the challenge of measuring the impact and effectiveness of these community-based DRR initiatives [60]. While it is clear that these initiatives have the potential to significantly enhance community resilience, further research is needed to quantify their impact and identify best practices.

Community-based disaster preparedness is a fundamental aspect of DRR in Saudi Arabia. The nation has made significant strides in this area, but further development remains to be achieved. Future endeavors should prioritize enhancing community participation, including the equal participation of men and women. The strengthening of local institutions and the alignment of local initiatives with national DRR strategies are crucial. Moreover, it is imperative that gender considerations are incorporated into these strategies, ensuring that women, as well as men, are equipped with the necessary skills and resources to manage disasters. Furthermore, continuous research and evaluation are required to gauge the effectiveness of these community-based DRR initiatives, inform the development of best practices, and ensure a truly inclusive and equitable approach to disaster risk reduction.

3.6. Enchanting Critical Infrastructure

The enhancement of critical infrastructure for disaster risk reduction in Saudi Arabia is a dynamic process, requiring consistent updates and iterations to match the evolving nature of disaster risks. Critical infrastructure facilities, such as hospitals, power plants,

communication networks, and emergency services, provide the essential services during emergencies and can significantly influence the outcomes of disaster scenarios.

Saudi Arabian health facilities, such as hospitals and clinics, are increasingly prioritizing disaster preparedness [61]. This includes bolstering their capacity to handle a surge in patients during disasters, safeguarding essential medical supplies, and establishing clear emergency protocols. Disaster preparedness training programs have also been integrated into the professional development of healthcare workers, ensuring that they are equipped with the necessary skills and knowledge to effectively respond to emergencies [62].

The Saudi Electric Company (SEC), a critical player in the country's power sector, has likewise invested in strengthening its emergency preparedness and response [63]. This includes the enhancement of its physical infrastructure to withstand various hazards, establishing redundancy in its power supply systems to ensure continuity in the event of failures, and utilizing advanced technologies to monitor, predict, and swiftly address potential disruptions [47,64].

In the digital age, communication networks have become a vital part of this critical infrastructure, facilitating real-time information exchange and coordination during emergencies. The Communications and Information Technology Commission (CITC) has put regulations into place to ensure the continuity and resilience of these networks during disasters. This includes requirements for service providers to have comprehensive disaster recovery and business continuity plans [65].

To orchestrate these diverse efforts towards enhancing critical infrastructure's resilience, the Critical Infrastructure Networks of Buildings and Communities was established. The center serves as a hub for strategic planning, setting standards, and fostering collaboration among the key stakeholders involved in critical infrastructure protection [12].

While these efforts underscore the commitment of Saudi Arabia to enhancing the resilience of its critical infrastructure, it is vital to maintain a proactive approach in this rapidly evolving domain. The emerging threat of cyber-attacks, for instance, highlights the need for a multifaceted approach to critical infrastructure protection that goes beyond physical enhancements to include cybersecurity measures [66]. Additionally, as infrastructure systems become more interconnected, the risk of cascading failures increases, necessitating the development of strategies that consider this interconnectivity and aim for systemic resilience.

Furthermore, as we move into an era where climate change and technology advancements continuously shape our risk landscape, the importance of sustainable and smart solutions cannot be overstated. Integrating renewable energy sources, enhancing grid flexibility, and incorporating smart technologies can significantly increase the resilience of the power sector [67]. Similar innovative approaches can be extended to other sectors, creating a more resilient, sustainable, and inclusive critical infrastructure system.

Recognizing this, Saudi Arabian entities are investing in research and development initiatives and collaborating with international partners to harness the power of technology and innovation. Community-based disaster preparedness constitutes an integral part of DRR in Saudi Arabia. The country has been making impressive strides in encouraging local communities to play a more active role in disaster preparedness and management. This is embodied in projects such as NEOM, a planned cross-border city in northwestern Saudi Arabia [68]. The concept of NEOM—a blend of the Greek word 'neo', meaning 'new', and the Arabic term 'Mostaqbal', meaning 'future'—represents a revolutionary leap in sustainable and resilient urban living [69]. Designed from scratch, NEOM is envisaged to integrate advanced technologies and innovative urban planning methods to create an environment that is not only futuristic and sustainable, but also capable of effectively mitigating, responding to, and recovering from potential disasters. While such projects are indeed commendable, there still remains scope for further enhancing the community involvement in DRR initiatives, strengthening local institutional capacities, and better aligning local strategies with the national DRR goals [70]. The regular monitoring and

evaluation of these initiatives would also contribute to their ongoing improvement and the development of evidence-based best practices.

Another key aspect that needs more attention is the involvement of local communities in critical infrastructure resilience efforts. Community members can provide valuable insights about local hazards and vulnerabilities, and their participation can lead to more tailored and effective strategies [71]. Public awareness campaigns and capacity-building activities focusing on critical infrastructure protection can help in empowering communities and enhancing their role in these efforts.

The private sector has a crucial role in enhancing critical infrastructure resilience. As the owners and operators of a significant portion of the country's critical infrastructure, private entities need to be more actively involved in these resilience efforts. Public–private partnerships, regulations, incentives, and guidance can be used to encourage and facilitate their participation.

Enhancing critical infrastructure resilience is not a one-off task, but an ongoing process. This involves regular risk assessments, performance monitoring, learning from past incidents, and continuous improvement. It also involves staying abreast with the latest scientific knowledge, best practices, and technological advancements.

To sum up, Saudi Arabia's efforts towards enhancing its critical infrastructure resilience are multi-faceted, involving a range of strategies and stakeholders. While significant progress has been made, there are areas that need further attention and improvement. By adopting a proactive, inclusive, and dynamic approach, Saudi Arabia can further strengthen its critical infrastructure resilience, thereby reducing disaster risks and promoting sustainable development.

4. Discussion

As this review demonstrates, Saudi Arabia's progress in the realm of Disaster Risk Reduction is significant. This journey has been characterized by a distinct alignment of local strategies with international best practices, reflecting the proactive approach that the country has taken to managing diverse hazards [72].

Of notable mention is Saudi Arabia's emphasis on enforcing building codes and fortifying its infrastructure. This approach resonates with Japan's disaster management practices, where the enforcement of the Japanese Building Standard Law has played a pivotal role in creating earthquake-resistant structures [13,73]. Saudi Arabia, located along the tectonic boundary between the Arabian and Eurasian plates, has embraced a similar commitment to seismic safety in its construction practices, despite not being traditionally recognized as a seismic hotspot [15,51,74].

The implementation of advanced early warning systems has been a key element of Saudi Arabia's DRR strategy. This aspect reflects the path chosen by countries such as Japan and the United States, which have implemented comprehensive early warning systems in response to their prevalent hazards [75]. Japan's Meteorological Agency has developed a sophisticated earthquake early warning (EEW) system, providing critical lead time to its citizens in the face of seismic events [76]. The United States, on the other hand, has an effective hurricane early warning system managed by the National Hurricane Center, which helps with timely evacuation and preparedness measures when a hurricane is imminent [77]. Saudi Arabia, already having a functional system for meteorological hazards, can look to learn from these models and diversify its early warning systems to include a broader range of risks, thereby further strengthening its disaster preparedness and response capabilities.

Public awareness and education initiatives also underscore Saudi Arabia's comprehensive DRR efforts. These initiatives mirror the strategies seen in the United States, where the Federal Emergency Management Agency's (FEMA) Ready Campaign has had substantial success in improving the public preparedness for disasters [78]. Saudi Arabia has undertaken similar endeavors, with a focus on ensuring that all segments of society, from

school children to adults, are equipped with actionable information that can be used in emergencies [79].

Emergency response capabilities form another critical dimension of Saudi Arabia's DRR framework, aligning with countries such as Australia and the Netherlands. Australia's State Emergency Services (SES) rely heavily on trained volunteer teams who provide quick and effective responses to emergencies [56,80]. Meanwhile, the Netherlands has been pioneering in community-led emergency response programs, including citizen responder networks for cardiac arrest scenarios, where trained volunteers within the vicinity are alerted to provide immediate CPR until professional help arrives [81].

Saudi Arabia is making strides in a similar direction, with regular drills and training exercises for emergency service personnel becoming commonplace in order to enhance the nation's readiness for disaster scenarios [82–84]. Such community-based rapid response initiatives can significantly reduce the time until treatment in emergencies and can be extended to apply to a variety of disaster scenarios. Drawing lessons from these international practices can further bolster Saudi Arabia's emergency response capabilities.

Community-based disaster preparedness is another facet of Saudi Arabia's DRR strategy, an approach that parallels New Zealand's Community Resilience Strategy [85]. Recognizing the power of community engagement in building resilience, Saudi Arabia has undertaken a series of initiatives, including promoting community-based disaster response plans and providing resources for community-led resilience initiatives [86].

The framework of the Federal Emergency Management Agency (FEMA) illustrates four pivotal phases of emergency management: mitigation, preparedness, response, and recovery [87]. In our analysis of Saudi Arabia's progress in the domain of Disaster Risk Reduction (DRR), we found evidence of significant strides across these four phases. However, these efforts are particularly noticeable in the preparedness and response stages.

In the phase of mitigation, Saudi Arabia has focused on a range of strategies, including improving its building codes and fortifying its infrastructure. These initiatives aim to reduce or eliminate the risks posed by hazards and serve as a proactive approach to DRR [87].

Preparedness, the second phase, has been highlighted by the development of sophisticated early warning systems and public awareness initiatives. Such efforts aim to equip the population with the necessary knowledge and tools to respond effectively when disaster strikes [87].

In terms of response, Saudi Arabia has demonstrated a commitment to strengthening its emergency response capabilities. This has been exemplified by regular drills and training exercises for emergency services personnel, aimed at enhancing their readiness for various disaster scenarios [87].

Lastly, the recovery phase has been marked by fostering community-based disaster preparedness. Such a strategy helps to ensure a resilient recovery from any disaster and contributes to the building of a more resilient society for future events [87].

However, each phase has its own set of challenges that need to be addressed in order to improve Saudi Arabia's overall disaster resilience. Addressing these gaps is a vital step towards building a safer, more resilient future. By learning from international best practices and adapting these strategies to fit local conditions, Saudi Arabia can continue to make strides in DRR.

Moving forward, this community-based approach could be a game-changer in the Saudi Arabian context. The country's unique social and cultural fabric calls for DRR strategies that are deeply rooted in its communities. In Saudi Arabia, where family and community ties are strong, a bottom-up approach to disaster preparedness can capitalize on these bonds to foster a culture of resilience. This focus on community-level resilience not only aligns with global best practices, but also reflects the specific societal dynamics of Saudi Arabia, setting it apart from Western-centric models.

While Saudi Arabia's commitment to DRR is commendable, one area that requires ongoing attention is the protection and enhancement of its critical infrastructure. Critical

facilities such as hospitals, power plants, and communication networks play vital roles in maintaining societal functions and ensuring safety during disasters [88]. Lessons from the European Union's Programme for Critical Infrastructure Protection could provide valuable insights for Saudi Arabia, as the program offers a comprehensive approach to enhancing the resilience of critical infrastructure [89].

Saudi Arabia's Ministry of Health has made significant strides in improving the disaster preparedness in hospitals and health facilities [90]. This initiative is reminiscent of the efforts made by the United States' Healthcare Ready program, which strives to strengthen its healthcare supply chains through collaboration with public health and private sectors [91]. Emulating such collaborative approaches could help Saudi Arabia to further enhance the disaster readiness of its health sector [92–97].

The Saudi Electric Company, too, is committed to ensuring a continuous supply of electricity during emergencies [63]. This echoes the measures taken in countries such as Japan, which, after the Great East Japan Earthquake, has prioritized making its electricity supply system more robust and resilient [98]. The experience of Japan highlights the importance of contingency planning, technological investment, and the regular testing of readiness, providing valuable insights for Saudi Arabia's power sector.

Additionally, Saudi Arabia's emphasis on maintaining its communication networks during disasters closely aligns with initiatives seen in countries such as Australia. The Australian government's mobile black spot program, for example, has been instrumental in enhancing the mobile coverage in rural and remote areas, thereby improving emergency communications [99]. Saudi Arabia could take cues from such programs to further strengthen its communication infrastructure.

Such initiatives hold significant potential for the future of disaster risk reduction in Saudi Arabia, especially considering the rapid digitalization and urbanization of the country. The integration of advanced technologies, such as artificial intelligence and the Internet of Things, could revolutionize the way that Saudi Arabia prepares for and responds to disasters. For instance, AI could be used for the predictive modeling of disaster scenarios, while the IoT could facilitate real-time data collection and communication during emergencies [100,101].

In our ongoing mission to deepen and broaden the scope of our research, we fully acknowledge the immense importance of adopting international advancement strategies. Recognizing that effective disaster management is a shared global responsibility, it becomes vital to absorb innovative practices and lessons from around the world. This commitment forms an integral part of our upcoming research initiatives and stands as a cornerstone of our future studies.

By integrating this global perspective, we significantly enhance our ability to shape and evaluate potential domestic policies within a broader international framework. This rich exchange of knowledge and experiences across borders helps us to refine our strategies, bolster our strengths, and identify areas for improvement [102].

Looking ahead, we are eager to embrace this amalgamation of domestic initiatives and international best practices. Doing so not only allows us to stay at the forefront of disaster risk reduction efforts, but also aligns us with the global momentum towards creating safer, more resilient societies. This approach reinforces our resolve to continue striving for enhanced disaster preparedness and response capabilities in Saudi Arabia

Furthermore, the lessons learned from the Saudi Arabian context provide a valuable point of comparison with the DRR practices in other regions. While many DRR strategies are universal in nature, the specifics of their implementation can vary greatly depending on the local conditions and contexts [103]. For example, the emphasis on community-based approaches in Saudi Arabia stands in contrast to the more top-down approaches often seen in Western countries. This distinction underscores the importance of tailoring these DRR strategies to fit the local context, a lesson that can be applied globally [104,105].

By looking towards the future and building on its current progress, Saudi Arabia is poised to become a leader in DRR, not only within the Middle East, but also on the global stage.

Ultimately, the pursuit of enhancing disaster risk reduction is a continuous journey. For Saudi Arabia, this path will continue to be shaped by a combination of learning from international best practices, adapting to local needs and contexts, and fostering a culture of innovation to navigate an ever-evolving risk landscape. With ongoing commitment, the nation will continue building towards a safer and more resilient future.

5. Limitations

Like all scholarly work, this review is not without its limitations. One key limitation of this review was the exclusion of grey literature, which could have provided additional valuable insights, particularly in the field of disaster risk reduction, where policy documents, reports, and other forms of grey literature often contain critical information. Furthermore, our review did not include the reference searching of the included studies, which could have potentially expanded our dataset and strengthened our review's comprehensiveness.

The primary constraint is the scope of the articles utilized in the analysis. The data collection was primarily from online databases, and it is plausible that significant works, particularly those not digitally archived, were inadvertently overlooked. This has the potential to skew the review towards more recent publications that were more readily available in digital format. It would be prudent in future research to ensure the inclusion of offline resources, hardcopy reports, and historical archives to deliver a more encompassing review.

The language barrier presents another significant limitation. As this review was conducted solely in English, the crucial literature published in other languages, most notably Arabic, may have been excluded. This exclusion likely impacted the breadth of perspectives considered, particularly local research conducted in Saudi Arabia, thereby affecting the overall generalizability of the findings.

The application of inclusion and exclusion criteria, while necessary for streamlining the data, could have been influenced by researcher biases, potentially leading to the inadvertent exclusion of significant findings. Furthermore, despite stringent criteria, there may have been variations in the quality and rigor of the included studies, which could have impacted the reliability and replicability of the findings. It would be beneficial to employ a double-blind approach in future reviews to minimize personal or professional biases.

Lastly, while a rapid review methodology enables a swift synthesis of the existing literature, it may lack the depth of a systematic review. Rapid reviews inherently involve some degree of simplification, and as a result, may overlook subtle nuances or complexities in the data.

Nonetheless, despite these limitations, this review offers valuable insights into Saudi Arabia's current DRR measures. It lays the groundwork for more exhaustive, multi-lingual research endeavors, and illuminates the path for strengthening the DRR strategies in the nation. Ultimately, the goal remains a safer, more resilient Saudi Arabia, and every piece of research brings us a step closer to that reality.

6. Conclusions

In conclusion, this review highlights Saudi Arabia's commendable progress in aligning its DRR strategies with international best practices. The key areas of success include the enforcement of stringent building codes, the development of advanced early warning systems, and the cultivation of broad public awareness and community-based preparedness. The country's strides in these areas underscore a significant commitment to fostering resilience in the face of diverse hazards.

However, the journey towards enhanced disaster resilience is ongoing. The future focus areas for Saudi Arabia include leveraging emerging technologies for more sophisticated warning systems, developing engaging public awareness initiatives, and continually refining its emergency response capabilities. Furthermore, there is considerable potential

for greater community involvement, facilitating grassroots resilience that can substantially contribute to its national DRR goals.

This review emphasizes the importance of continuous investment in resilience-building initiatives and the necessity of drawing from past experiences, current insights, and future aspirations. The process of disaster risk reduction is a journey—a journey Saudi Arabia is taking confidently and proactively. As Saudi Arabia continues this voyage, it can serve as a valuable model for other nations, demonstrating that a commitment to DRR is not just about safeguarding the present, but about investing in a safer, more resilient future.

Author Contributions: Conceptualization, A.M.A.-W.; methodology, A.M.A.-W.; validation, A.M.A.-W.; formal analysis, A.M.A.-W.; investigation, A.M.A.-W.; writing—original draft preparation, A.M.A.-W., D.G.B., M.B.-S., P.G., N.A.A., M.A.A., L.O.S., A.S.A., M.G., W.O.S. and K.G.; writing—review and editing, A.M.A.-W. and. K.G.; visualization, A.M.A.-W.; supervision, K.G.; project administration, A.M.A.-W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments: The authors would like to extend their appreciation to King Saud University for funding this work through the Researchers Supporting Project number (RSPD2023R649), King Saud University, Riyadh, Saud Arabia.

Conflicts of Interest: The authors declare no conflict of interest.

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