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NATURAL DISASTERS AND THEIR IMPACT ON CRITICAL INFRASTRUCTURE IN THE UNITED ARAB EMIRATES

Abstract

Climate change is one of the main challenges facing the population around the world. The consequences of these changes have been manifested for decades in various ways, creating disasters that threaten the lives of an increasing number of people. This paper analyses the consequences of the floods that hit the United Arab Emirates on April 16, 2024. After any natural disaster, this flood also calls into question the approach, preparedness and response to this challenge, questioning the success of managing critical infrastructure. This is an important question given that in the last two decades the United Arab Emirates has encountered several floods of a more serious scale. In line with the further development of the consequences of climate change and in response to the challenges

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they bring with them when it comes to the United Arab Emirates, the authors also propose specific guidelines for the relevant institutions as a way of improving critical infrastructure. A significant area would be to focus on the latest technology in creating superior public-private partnerships that would become modern, national-integrated emergency management systems. The authors used the Risk Management Theory, suggesting ways in which preventive responses can be made. The authors also used content analysis, as well as the observation method.

Keywords: United Arab Emirates, natural disaster, critical infrastructure, flood, climate change

INTRODUCTION

The United Arab Emirates (UAE) was established in 1971, and seven emirates comprise the UAE. Those are Abu Dhabi, Ajman, Dubai, Fujairah, Ras Al Khaimah, Sharjah, and Ras Al Khaimah. It is located in the Arabian Peninsula, which is a tropical desert that has very hot summers and warm winters, and rain is very scanty; where research has shown that fog and dust usually contribute to the deterioration of visibility in the summer months (Aldababseh and Temimi 2017). However, it is also a country that is very close to the Zagros Fault, which is not as safe from natural hazards as one might think.

This paper will discuss the flooding that happened on 16 April 2024, the settings of the critical infrastructures that are in the UAE, and how the event has taught the government, citizens, and their residents how systems and processes could be improved through the effectiveness of Critical Infrastructure Management during natural disasters (Al Ruwaithi 2019). Critical infrastructure refers to the essential assets and systems that are truly critical for the country's economy, safety and public health, and these can be meant as simple as communications systems, water supplies or even transportation networks. However, a country's critical infrastructure has always been vulnerable to cyberattacks, terrorism, or even natural disasters such as earthquakes, hurricanes or flooding, and many developed countries have made sure that they implemented measures to prevent and mitigate all the risks mentioned (Hemme 2015).

Countries worldwide are prone to crises and challenges that will affect the government, the well-being of their people, and their

development. Negative connotations or impacts are presented by natural disasters, diseases and wars that can make the effect challenging and complex (Al Ruwaithi 2019). With global warming and climate change, natural disasters are more prone, increasing the threat to the country's people and communities. Countries and governments must examine preventive processes and measures (Wen et al. 2023). Some natural disasters may be avoided before occurring, such as moving a community to a higher land if they know a tsunami is approaching, and impacts from a natural disaster or emergency can be dramatically reduced through readiness; however, there are still some that are difficult to predict and avoid and usually, the only way to move forward is mintage through the damages, implement recovery efforts so that the people and the country can return to normalcy (Dhanhani, Duncan, and Chester 2010).

The United Arab Emirates seems to be a country that has experienced natural hazards over the years. They suffered an Al Qurayah Flood in 1995, the Masafi earthquake in 2002, the Al Tawaian Landslide in 2005 and the Sharm Flash Flood in 2009 (Fujairah 2008). The United Arab Emirates has been dealing with natural disasters promptly. However, 16 April 2024 was record-breaking as the country witnessed a record-breaking rainfall in 24 hours, surpassing the meteorological data since records began in 1949 (Al Ruwaithi 2019). Dubai was hit the hardest as they received a year's worth of rain within 12 hours; this affected and caused significant disruptions to daily lives. The weather had left the whole country in widespread flooding, cancellations of flights and impassable roads due to high water levels. The Mohammed Bin Zayed University of Artificial Intelligence decided to investigate with a satellite where they studied specific areas in Dubai and the impact that was caused by the rainfall. It was found that there was a significant rise in water levels, disrupting social activities and majorly affecting the roads, as well as critical infrastructure hospitals and schools (Mohamed Bin Zayed University of Artificial Intelligence n.d.). This also led to Dubai Airports temporarily rerouting inbound and outbound flights.

There were news reports from all over the world mentioning that the cause of the rainfall was extreme cloud seeding, but this was caused by climate change, where low pressure at the surface created conditions for a thunderstorm that powerful. Global rising temperatures have led to extreme weather conditions, including intensive rainfall (Dhanhani, Duncan, and Chester 2010). Rainfall has become heavier as they can now hold more moisture in the atmosphere, although this was misled to

cloudseeding. The United Arab Emirates has set up a supreme national council under the name of NCEMA, National Emergency Crisis and Disaster Management Authority where they classify the decree into the following subsections with a disaster causing extensive damage and would need the cooperation of the government and communities coming together to achieve recovery and this might even include the assistance from other international countries (United Arab Emirates: The Supreme Council for National Security: National Emergency Crisis and Disaster Management Authority [NCEMA] n.d.).

The following subsection is preparedness, where the government would preempt situations and have resources, plans and manpower ready for the response to any emergencies or crises that were to occur. This stage would include training and developing plans and processes. Prevention and protection as the following subsection; this is to remove the cause of the disaster and reduce the probability of it, which involves several actions proposing important legislation and undertaking any preventative measure (Dhanhani, Duncan, and Chester 2010). The response is a procedure taken due to a crisis or disaster, mitigating its effects and offering aid (Hemme 2015). The following subsection is recovery, where actions and procedures were taken after an emergency or crisis aiming and rebuilding the affected places and infrastructure and attempting to return lives to normalcy (Wen et al. 2023). The last and final subsection is the risk, and that would mean calculating the probability of events or situations happening as a result of negligence or filling the gaps that might lead to any occurrence of crisis or emergencies, making sure that there is as little as injuries, death or loss of properties (Wyss and Al-Homoud 2004).

CRITICAL INFRASTRUCTURE IN THE UAE

Modern societies rely on organizational and physical infrastructure that facilitates the flow of information, goods, and services. This shall not only be restricted to roads and bridges but also encompass water supply systems, electricity grids, and communication networks crucial for business and daily life. In this great categorization of infrastructure, there is a subgroup known as critical infrastructure (Miles 2011). Those resources or systems are so essential that their loss or destruction would have a debilitating impact on the ability of a nation to defend itself, maintain economic stability, or otherwise perform societal functions.

For this reason, the current research will go a long way in explaining interdependence regarding infrastructure, the possible risks from natural hazards, and the vulnerabilities of hosting critical infrastructure within the UAE. It defines infrastructure and its role in maintaining social order, economic stability, and national security. It stresses how significant the CI is in fast development in the UAE. Later, we identify the basic infrastructure hazards associated with the most common natural disasters afflicting the UAE (Grandi 2021).

Additionally, we go over CI vulnerabilities associated with those natural disasters, demonstrating how even the most resilient systems can malfunction in extreme circumstances and providing guidance on how the UAE will best safeguard its vital infrastructure assets in the face of growing environmental danger. Linking the three domains will allow deeper detail toward the future with the UAE's opportunities and challenges in infrastructure preservation within a growing, increasingly unsure environment full of challenges.

CONTEMPORARY ENVIRONMENTAL AND CLIMATE CHALLENGES

Every nation is vulnerable to crises and difficulties impacting its development, government, and citizens' well-being. Natural disasters, illnesses, and wars might have unfavourable implications or effects that can be difficult and complicated to deal with (Al Ruwaithi 2019). Natural disasters are now discovered to be increasingly common due to climate change and global warming, which has increased the hazard to the nation's citizens and communities (Wen et al. 2023).

The United Arab Emirates is well known for its quick expansion and urbanisation. This vast desert was transformed into a global economic centre quickly. No success factor can make a nation like the UAE more susceptible to natural calamities. Seismic and volcanic activity, while uncommon and rare, are beyond the UAE's purview (Alteneiji, Ahmed, and Saboor 2020). Nevertheless, the nation is vulnerable to other unique natural hazards, such as heat waves, sandstorms, floods, and—more and more—the effects of climate change, which could jeopardise vital infrastructure and, in turn, jeopardise not only the nation's population's safety and security but also its economic stability and international standing.

Natural disasters have affected the UAE throughout the years. They have experienced several natural disasters, including the 1995 Al Qurayah Flood, the 2002 Masafi Earthquake, the 2005 Al Tawaian Landslide, and the 2009 Sharm Flash Flood (Fujairah 2008). The United Arab Emirates has demonstrated its ability to respond swiftly to natural calamities. However, on April 16, 2024, the nation experienced unprecedented rainfall daily, exceeding all meteorological data recorded since 1949 (Al Ruwaithi 2019). The other significant result of climate change in the UAE is related to the temperature rise. Though the temperatures in this country are very hot and usually beyond 40°C, peaking in summer, some climate projection models forecast that at this century's end, the average temperature in this region should increase by 2 to 4°C. It also has several significant infrastructure implications in the context of energy demand. A valid assumption would be that the hotter it gets, the more air conditioning and other cooling equipment must be used. This can put an inordinate strain on the nation's electrical grids (Krishnamurthy et al. 2016).

The remaining repercussions include sea level rise, to which coastal towns like Dubai, Abu Dhabi, and Sharjah are particularly vulnerable. These estimates by the Intergovernmental Panel on Climate Change consider that, contingent upon the amount of greenhouse gas emissions in the future, the global sea level could rise as much as one meter at the end of the century (Hegde 2010). Even a moderate rise in sea level would have huge impacts on coastal infrastructure, from costly developments such as Dubai's Palm Jumeirah to any form of infrastructure installation. For example, rising sea levels may exacerbate the high rate of coastal erosion, flooding, and saltwater intrusion into freshwater aquifers, impacting ecologies and structural components (Al-Mutairi et al. 2021). These increased coastal protection measures, such as seawalls and other costly urban design techniques that make communities resilient enough to prevent damage to valuable assets, are unquestionably necessary.

UAE's MANAGEMENT STRATEGIES FOR CRITICAL INFRASTRUCTURE IN NATURAL DISASTERS

Climate change is one of the chief concerns of the twenty-first century (See Stanković i Topalović 2022). During this period, it is evident within the arid regions of the Middle East. The United Arab Emirates belongs to nations highly prone to the different vagaries of climate

change. These have manifested in increased temperatures, rising sea levels, and extremities in weather, such as floods and droughts. It severely damages the infrastructure of the major coastal cities, such as Dubai and Abu Dhabi. This area is home to most of the nation's population and generates a significant portion of its economic activity. The UAE's authorities have not lagged behind their counterparts in creating plans for climate adaptation aimed at reducing the effects of these changes on their infrastructure (Beecham 2020). This is evidenced by how general infrastructure exposure of the UAE to the impacts brought about by climate change is highly vulnerable. It has included some of the most critical heat, flood dangers, and rise in sea level. Several adaptive measures against these risks have been addressed by the UAE, which has included critical infrastructure protection in pursuit of long-term resiliency.

Sea level rise is one threat that is quite obvious. By 2100, it is predicted that sea levels in the Arabian Gulf would have risen by up to 0.5 meters, which would have the potential to inundate low-lying coastal communities and disrupt several vital infrastructures, including airports, water desalination facilities, ports, and opulent beachfront residences (United Nations Environment Programme [UNEP] 2022). In this regard, the UAE has initiated the implementation of coastal defence systems, also forcing the recently built infrastructure to consider the consequences of sea level rise. The UAE defends its coastlines to safeguard vital infrastructure for its economy and populace.

Increased flooding risks are some of the most visible signs of climate change in the United Arab Emirates. These days, the country has gone through flash flooding in several parts, including Fujairah and Sharjah. Besides buildings, this also causes colossal losses in roads and bridges, bringing daily life and other economic activities to a grinding halt (Khaleej Times 2024). For instance, the torrential rains of 2024 flooded a great area and thus exhibited that this region is too unpredictable about its weather patterns. The UAE has hugely invested in various management systems related to flood and stormwater control policies, thus reducing the chances of disaster. These cities are implementing underground drainage systems, and dams with reservoirs are also being constructed to enhance the potential of water retention to avoid further destruction due to flooding (Danhani, Duncan, and Chester, 2010).

UAE MANAGEMENT STRATEGIES FOR CRITICAL INFRASTRUCTURE

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One of the most decisive factors in this respect has been the relationship between the public and private sectors. In this case, the UAE developed Public-Private Partnerships to build and secure critical infrastructure. In such a way, the private sector had the opportunity to

explore means through which it could invest in mega projects, mainly within the energy, water treatment, and transport industries (Al-Saadi and Abdou 2016). While these partnerships made the region's transport system one of the most extensive, especially in advanced incorporations of modern technologies, the same system has also emerged as one of the most efficient, for instance, the partnership which introduced the Dubai Metro. This will also contribute to infrastructural resilience in general in the UAE against different levels of physical and cyber threats. Substantial numbers focus on resilience against natural catastrophes, building rules, and regulations especially targeting designing new projects in coastal cities such as Dubai and Abu Dhabi. This would put the necessary perspective into place about critical energy-related infrastructure projects, desalination plants, and oil refineries reliant on this area concerning disrupted operations due to natural calamities (United Nations Office for Disaster Risk Reduction [UNDRR] n.d).

Therefore, the UAE's intention to deal with critical infrastructure encompasses an ensemble that includes collaboration, technology development, and an attitude towards risk management. With the ever-increasing incorporation of smart city technologies into its economic blueprint, robust models of public-private partnership, and an enshrined structure as magnificent as NCIPP, the UAE has saved first rank in the region concerning security and resilience in infrastructures (Okem et al. 2024). Therefore, these tactics will play a significant role in ensuring its vital infrastructure is strong and supportive enough to achieve its goals of being a major global economic centre while seeking more expansion (Chandra, Sharma, and Liaqat 2019).

Resilience, adaptation and challenges of critical infrastructure

The United Arab Emirates has invested highly in infrastructures resilient against extreme weather conditions, such as flash flooding. In contrast, for example, to the critical levee collapse in the United States during Hurricane Katrina. Adequate Government Coordination. There was effective coordination by the UAE government during the disaster response. These resulted in good mobilization of resources and, at the same time, a rapid rebuilding of damaged infrastructure. On the other hand, the reaction by the US federal government to Hurricane Katrina was wholly criticized as it was prolonged and uncoordinated (Yereseme,

Surendra, and Kuntoji 2022). During the recent crisis caused by heavy rains due to climate change, the UAE took an exceptional approach in dealing with the situation to minimize the damage caused to His Highness Sheikh Mohammed bin Rashid, ordered that all the duties and needs assigned to stricken families be catered for, to contain the crisis, as well as their transfer to safe shelters in coordination with government agencies and specialized teams (Evans 2024).

In the case of UAE, one might observe how the government is working for continuity regarding working remotely within different educational and governmental institutions for more thickness and build-up in infrastructure. In addition, some flights have been suspended from providing their service according to the given order so as not to have any casualties among the population, keeping life and safety among its people. It involves neither human safety in priorities taken and courses taken by the state nor states that these are under equal protection (Evans 2024).

THE ROLE OF THE FEDERAL GOVERNMENT AND PRIVATE INSTITUTIONS

We must consider that all government agencies and private institutions participate in crises that harm their interests. The priorities and responsibilities of the government and governmental organizations are to protect national security and their interests in crises, which are reflected in protecting national security by implementing laws and legislation and implementing the constitution within its legitimate limits, in addition to preparing and putting in place appropriate measures and responding to various crises (World Health Organization [WHO] 2019). His Highness Sheikh Mohammed bin Zayed called for a comprehensive review of climate preparedness and supporting those affected. In addition, His Highness Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum, Crown Prince of Dubai and Chairman of the Dubai Executive Council, directed management companies and developers to provide alternative housing and basic and necessary needs promptly. Moreover, to ensure that the Department of Lands and Properties works to rebuild damaged homes to restore them to their normal condition (WAM 2024).

The UAE faced the crisis with outstanding professionalism due to the extensive damage to the country's infrastructure. Roads, vehicles, buildings, public facilities and housing units were also affected, and required resources to restore, repair and recover from the damage

(GuyCarpenter n.d.). However, in light of the development of the UAE's infrastructure in communication between governments and private institutions, it urged, as a private company, the Surplus provide humanitarian aid to families affected by the heavy rains more than 3,000 people to meet their basic needs through direct communication. Awareness among people and helping each other on the streets. It is known that people's cohesion in crises increases away from the clash of cultures (Abdulla 2024).

The UAE government lessened the damage of the 2024 floods quickly and efficiently. After that, the police did not waste any time dispatching rescue services to succour the bedraggled citizens, thus enabling the evacuation of people besides clearing blockades from the roads. The government had also erected temporary shelters for the displaced families besides promptly restoring electricity and water supplies to the affected areas (WAM 2024). It had been able to respond relatively quickly because it had already set up disaster management plans, invested sizable amounts in resilience hardening, and upgraded the catchments-most significantly in the stormwater management systems and the flood barriers (See Cvetković and Radović 2022) because the alert and communication mechanisms of the government had kept the casualty number low along with the infrastructure damage contained (Eyimoga et al. 2024). This realisation furthered the work that needed to be done to improve urban drainage systems and stormwater management, given the unpredictable nature of the climate.

These rains led to traffic disruptions, which led to the closure of schools and businesses. Thanks to the efforts of the UAE government, preventive measures and the strength of the UAE's infrastructure, work from home was activated for students and employees to ensure business continuity (The United Arab Emirates' Government portal n.d.). It is the general scheme and principles of the government, institutions, organizations, and persons for managing their difficulties and critical situations to reduce casualties, return their lives to normal, and receive complete recovery as soon as possible (Goodman Lantern n.d.). From this standpoint, the UAE has developed a proactive plan to deal with various crises to overcome their consequences so that life can return to normal within 24 hours. It is also considered an exceptional challenge and a unique experience, yet it overcame these challenges with minimal damage compared to other countries (JBA Risk Management n.d.). During the crisis, people and residents joined forces to provide humanitarian aid to those affected. In addition, restaurants in the country volunteered

by giving free meals to those affected by the storm (WAM 2024). The UAE takes into account that a proactive strategy is of utmost importance to mitigate the damage caused by floods, and it also includes various economic, tourism and technology sectors, in addition to investing in infrastructure to enhance the management of natural disasters and future risks resulting from them (Safi 2024).

The government of the UAE never ran away from standing for its people when there was a time of great need. The best example is the compensatory project it undertook after the flood of 2024 within the country's borders. That is to say, it freed up cash for the families whose houses or business places were either damaged or destroyed by the flood, directly converting into an emergency shelter, food and medical supplies were provided. In that way, the compensation delivery project's effectiveness in mitigating the long-term economic impact was reduced.

CONCLUSION

The UAE should be committed to continuously building more infrastructures related to climate change in areas most vulnerable to sea-level rise. A design to enhance coastline resilience shall be pursued with nature-based solutions that could restore mangroves as a robust barrier against erosion and flooding along these beaches. The authors suggest the following: a) Establish Tighter Guidelines for Critical Infrastructure Design (consequently, natural disasters became more violent and unpredictable; hence, the UAE Government would revisit the rules and standards related to the design of infrastructure projects to ensure that every new undertaking comprises disaster resiliency in its design. The transport networks, water supply networks, and electricity grids will be made lousy weather-resistant with no disruption); b) enhancing Public Awareness and Community Preparedness (apart from these technical and governmental initiatives, much has to be done by the UAE in terms of creating public awareness campaigns that highlight citizens' preparedness against these catastrophes. The more prepared people and communities are, the more resilient and better equipped they are in the case of disasters); c) More investments in intelligent infrastructure (in the case where UAE places innovative city agendas, it would be an assurance that in the event of a natural disaster, all the key infrastructures would be managed well. In situations where governments increase investments in emerging technologies such as blockchain, big

data analytics, and artificial intelligence, the development and recovery response times and predictability of catastrophes could be facilitated); d) Regional cooperation and information sharing: it is highly relevant that the UAE develops closer ties with other GCC members apart from other international organizations dealing with issues related to disaster planning and response. This will ensure more of a regional approach, culminating in better disaster management- particularly for hazards that transcend a country's borders and often affect several countries at one time.

This is a projection of what study into the risks that natural disasters pose to the critical infrastructures in the UAE and elsewhere in the world may have if there is a prediction of increased vulnerability for both developed and developing countries. The United Arab Emirates has made significant progress in safeguarding its infrastructure from the aftermath of natural calamities. Furthermore, the UAE's adoption of a strong risk management framework and innovative city programs have expanded its capability for monitoring, quickly responding to, and recovering from such calamities. The same is well evidenced by the test of infrastructure preparedness about the 2024 Flood in Fujairah. Quicker response and recovery are how UAE lives by the same, showcasing successful technocrats of disaster management.

Other violent natural disasters such as flooding, storms, and even wildfires may prove to be more likely due to all the processes of climate change that enhance the frequency and violence of natural disasters. This has created a difficult task for the world's vital infrastructure, particularly where systems are either ageing or inadequately maintained and built to withstand more frequent calamities. The critical infrastructure sectors of electricity, transportation, water, and communication networks are especially susceptible. The devastating effects of natural catastrophes on life safety, economic security, and recovery are compounded by cascading failures within any one of these.

Countries throughout the globe are realising that interconnected infrastructure systems need to be developed with resilience. That is where a strategic UAE approach to investment can make much difference. The prime area would focus on the latest technology in creating superior public-private partnerships. Most important would be the modern, nationwide integrated emergency management systems, which would go long towards that. While UAE has up till now focused on flood management and excessive heat, similar mechanisms for multi-geographically bordered natural disaster risks can be taken up.

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ПРИРОДНЕ КАТАСТРОФЕ И ЊИХОВ УТИЦАЈ НА КРИТИЧНУ ИНФРАСТРУКТУРУ У УЈЕДИЊЕНИМ АРАПСКИМ ЕМИРАТИМА

Резиме

Климатске промене представљају један од главних изазова са којим се суочава становништво широм света. Последице ових промена испољавају се већ деценијама на различите начине стварајући катастрофе које угрожавају животе све већег броја људи. Аутори у овом раду анализирају последице поплава које су погодиле Уједињене Арапске Емирате, 16. априла 2024. године. Као и после сваке природне непогоде, и ова поплава доводи у питање приступ, спремност и одговор на ову врсту изазова преиспитујући успешност у управљању критичном инфраструктуром. Ово је важно питање с обзиром на то да су се у последње две деценије Уједињени Арапски Емирати сусрели са неколико поплава озбиљнијих размера. У складу са даљим развојем последица климатских промена, а као одговор на изазове које оне са собом носе, када су Уједињени Арапски Емирати у питању, аутори предлажу и конкретне смернице ка надлежним институцијама као вид побољшања критичне инфраструктуре. Главна област би била фокусирање на најновију технологију у стварању супериорних јавно-приватних партнерстава који би постали модерни, национални

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интегрисани системи за управљање ванредним ситуацијама. Аутори су користили теорију управљања ризиком, сугеришући начине на које се могу предузети превентивни одговори. Аутори су користили и анализу садржаја, као и метод посматрања.

Кључне речи: Уједињени Арапски Емирати, природне катастрофе, критична инфраструктура, поплаве, климатске промене

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