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Enhancing Disaster Management by leveraging Smart Cities Technologies

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Abstract— As urbanization intensifies worldwide, the frequency and severity of natural and man-made disasters pose significant challenges to the resilience of cities. In response, the concept of smart cities has emerged, leveraging advanced technologies to enhance various aspects of urban life, including disaster management. This research explores the potential contribution of smart cities technologies to enhancing disaster management strategies and processes. By analyzing existing literature, case studies, the study investigates the application of technologies such as Internet of Things (IoT), artificial intelligence (AI), data analytics, and GIS and Digital Twin in disaster preparedness, response, recovery, and mitigation efforts. Furthermore, it proposes the integration of these technologies into an end-to-end technology stack to build resilient and adaptive cities. This research aims to provide valuable insights into the role of smart cities technologies in improving disaster management practices, fostering greater resilience

Keywords—Disaster Management; Smart Cities; AI; Digital Twin

I. Introduction

Between 2000 and 2019, Natural Disasters have led to 1.23 million deaths affecting four billion people globally. And despite global efforts to increase disaster prediction and preparedness, the number of recognized disasters in the Middle East and North Africa (MENA) region has tripled since the 1980s. [1]

Over the past 30 years, disasters have affected more than 40 million people in the Middle East and North Africa (MNA) Region and have cost their economies about US$20 billion. During the last 5 years alone, more than 120 disasters have caused an average of US$1 billion per year in damages and losses. [2]

The most frequent disasters in the region are floods, earthquakes, storms, and droughts. Over the period of (1981–2011), floods have been the most recurrent disasters recorded in EM-DAT, with at least 300 events (53 percent of the total number of disasters). [3]

If we take a closer look into north Africa countries, Morocco would rank among the Arab world's most prone to natural disasters, with a high risk of droughts, earthquakes, intense heat waves, floods, tsunamis, and wildfires. An estimated USD 790 million is lost each year because of natural disasters, with floods accounting for the majority of damages due to extended rainy seasons.

There was a dire need to have integrated smart systems which can timely forecast, respond and recover from disasters.

Smart cities technologies have a great potential to improve disaster management by revolutionizing early warning systems and response processes. Cities can detect and monitor potential disasters with unprecedented accuracy and timeliness through the integration of smart sensors, Internet of Things (IoT) devices, and advanced data analytics,. These technologies enable real-time data collection and analysis, allowing authorities to foresee threats and issue timely warnings to residents. Additionally, smart communication infrastructure facilitates swift dissemination of critical information, enabling residents to take necessary precautions and evacuate if needed. Moreover, smart cities technologies empower emergency responders with actionable insights, optimizing resource allocation and coordination during crises. Overall, the implementation of smart cities technologies is transforming disaster management practices, increasing resilience and resulting in life saving during difficult times

An effective Disaster Management plan must effectively handle all stages of disaster—preparedness, response and recovery.

In this paper we aim to examine the state of the literature pertaining to how different smart cities technologies could contribute to enhancing disaster management, and how could all those technologies function together in an end-to-end technology stack to increase the efficiency of disaster management, under the framework of disaster management cycle (preparedness, response, recovery, mitigation). We will explore different research papers and review case studies from different cities to reach an overview on to what extent those systems have succeeded in enhancing disaster management.

II. LITERATURE REVIEW

A systematic search on the topic was conducted in one electronic database: Scopus. The main objective was to identify and select research papers related to smart cities and disaster management research area.

Using the key words of smart AND cities AND disaster AND management to search within article title, key words and abstract, 612 documents were found.

It was observed that all articles that appeared in the search results were intended to address a specific technical challenge or a proposed approach regarding a specific technology used in disaster management. There are no research papers that has addressed an end-to-end technology stack in the same context of disaster management, And since the purpose of our study was more intended to be as a holistic literature review without deep diving into a particular technology or technical issue, we have filtered search results to look into the above words in the article titles only, which resulted on 31 related articles.

Those papers have been categorized according to the main technology being addressed as an enabler for effective disaster management. The below table indicates a summary of the outcome

Technology Research Area in Disaster Management	Research paper Count	References
Digital Twin	4	[4]; [5]; [6]; [7]
IOT	5	[8]; [9]; [10]; [11]; [12]
Artificial Intelligence, Machine Learning, Data Analytics, Big Data, Web Semantics	6	[13]; [14]; [15]; [16]; [17]; [18]
Deep Learning	3	[19]; [20]; [21]
UAV	2	[22]; [23]
GIS & BIM	2	[24]; [25]
Traffic Management & Intelligent Traffic Systems	3	[26]; [27]; [28]
Social media & Crowd Sourcing;	3	[29]; [30]; [31]
Networks and Connectivity.	2	[32]; [33]

Note that there was one research paper addressing citizen awareness in case of disasters without any analysis of any specific technology, hence it was excluded from the above table.

III. THE ROLE OF SMART CITIES TECHNOLOGIES IN DISASTER MANAGEMENT

Smart cities technologies encompass a diverse range of innovations aimed at enhancing urban living through connectivity, sustainability, and efficiency. These technologies leverage digital infrastructure, Internet of Things (IoT) devices and platforms, BIM, GIS addition to digital twin technologies, data analytics to support the four phases of disaster management (mitigation, preparedness, response, recovery)

Data exchange and data-driven approach contribute to Preparedness, Response, Recovery, and Mitigation [34]

Examples include smart sensors for monitoring weather conditions and traffic flow, IoT-enabled infrastructure for efficient energy usage, real-time data analytics platforms for forecast and resource allocation, and integrated.

IV. HOW SMART CITIES TECHNOLOGIES CAN ENHANCE DISASTER MANAGEMENT

a) Connected Early warning Systems.

EWS framework described as “People centered Early Warning System” (UN ISDR (United Nations International Strategy for Disaster Risk Reduction), 2006; Basher, 2006).

It considers EWS to comprise of four interrelated elements or components: (a) Risk knowledge, (b) Monitoring and warning services, (c) Dissemination and communication, and (d) Response capability. Its goal is to enable people and communities who are at risk of harm to take appropriate action at the appropriate time to reduce losses. (UN ISDR (United Nations International Strategy for Disaster Risk Reduction), 2006).

Connected Early Warning Systems (EWS) can leverage IOT sensors and platforms as follows [35] :

1. Event Detection: Real-time monitoring of a variety of environmental parameters, such as temperature, rainfall, seismic activity, and other pertinent data, in order to spot any anomalies or significant changes.
2. Threshold Value Monitoring: Setting predefined threshold values for each monitored parameter. These thresholds serve as limits beyond which the data is considered abnormal or indicative of a potential disaster. For instance, if rain fall exceeds a certain level or if seismic activity on the Richter scale reaches a specific magnitude, the threshold is crossed.
3. Disaster Detection: When EWS perceives a possible disaster scenario when it finds that one or more of the tracked parameters have exceeded their corresponding threshold values. For example, if the amount of rainfall surpasses a certain level, it might indicate a higher chance of flooding.
4. Alert Generation: Upon recognizing a disaster or threshold crossing, the EWS immediately generates an alert message. This message is composed to provide essential information about the detected event or parameter exceeding the threshold. ↳

5. Notification Sending: The alert message is then sent via SMS to the governing body or relevant authorities responsible for disaster management and response. This SMS serves as a rapid notification mechanism to inform the authorities of the unfolding situation.

6. Registered User Alerts: In addition to notifying the governing body, The EWS may also send SMS alerts to registered users or individuals residing in the affected area. This broader alert system ensures that not only the authorities, but also residents are informed about the potential disaster and can take necessary precautions.

7. Disaster Preparedness: EWS proactive approach aids in disaster preparedness. By providing early warning and alerts, it enables timely response and action, potentially saving lives and minimizing damage.

Case Study for Early Warning System; Kerala City; India [36]

The Indian state of Kerala is affected by a series of disasters caused by rainfall events. The flooding and landslides, which resulted from the rainfall in 2018, resulted in approximately 500 casualties, 19,000 homes destroyed, temporary displacement of 1.1 million persons, and 5.5 million people affected. The World Bank estimated a total economic loss of 3.4 billion USD and the UN system estimated 3.7 billion USD in recovery costs.

LFEWS (Local Flood Early Warning System), which is a watershed-based system managed by local government units and affected communities, has been established to minimize losses for flood disasters.
LFEWS has an integrated system of communication. Its Operation Center works 24/7 to monitor real-time data and issues the official appropriate alert signals to the communities [37]

The primary monitoring system of Kerala is that established by India Meteorological Department. This includes 21 Automated Weather Stations, 5 Automated Rain Gauges, 68 Manual Rain Gauges and 2 Doppler Radarsi.

Rainfall, Temperature, Wind and Lightning are the phenomena that State Emergency Operations Centre (SEOC) closely monitors daily. and issues the official appropriate alert signals to the communities.

The best data for predicting a flood is measuring the water level of the river. The second-best way is predicting a flood from rainfall data. LFEWS uses both and the system operates 24 hours a day. The variability of rainfall and river water levels are processed and converted.
into warning signals to inform courses of action in the form of warning signals.

b) Command and Control Centers

City command control centers act as a focal point for monitor and control of city digital systems. It relies on real-time data acquisition subsystem of supervision data for the rapid collection and transmission of field information by different sensing elements. a call center, which is a window to contact the internal and external departments and the publicii. Its main work is to accept the city management problems from the city management supervisor, the public, the higher authorities, and the leaders, and then audit the problems, record the location of the problems, and pass them to the city management command center after filing the case. Therefore, the main function of the acceptance subsystem of the supervision center is to provide problem acceptance, registration and filing for the agent staff of the call center.

Case Study for Command-and-Control Center; Rio De Janeiro City; Brazil [38]

Since 2010, The city of Rio De Janeiro has Initiated the creation of their city command and control center, The initiative leading to the creation of the Operations Center was triggered by a destructive summer storm in Rio. In the middle of night, City has started to receive warnings about landslides and floods in favelas and cars and trucks trapped by the floodwater. Due to absence of coordination and quick response between several city authorities, over sixty persons lost their lives.

As reported in the media, the incident triggered Paes to meet with IBM to develop a solution to “knock down silos among departments and combine their data to help the whole enterprise” This led to a partnership with IBM in the Smarter Cities project, with investments of over US$10 million.

Although the center primarily deals with traffic and weather monitoring (Sete Rios, the local public traffic organization, has the most representatives inside the Operations Center), its main purpose is the rapid coordination of a variety of agencies in response to potential crisis situations.

As a result, the center features a crisis room with a direct connection to the mayor's official house and the civil defense headquarters, as well as a press room where media representatives provide information and alerts This demonstrates how the Operations Center has been designed with particular consideration for the public relations aspect. It is an example of "embedded journalism."

c) Data Analytics & Artificial Intelligence

Due to the availability of tremendous amount of data collected by devices in a smart city, many Data Analytics and machine learning approaches could be applied on that data to get useful insights. and based on the collected information from that data, the future steps taken by individuals or authorities in specific conditions could be predicted. Deep learning is also a machine learning approach that could be used to train the models using historic or real-time data and then those trained models could be used to predict the expected values.

Using large datasets, it is possible to analyze past disaster data and develop future scenarios for the possibilities of disasters and the damage caused by them. Big data contribute to the science of decision-making by developing a technology that can read common patterns of user behaviors and predict future steps [39]. Existing data serve as the criteria for core judgments, and an AI learning algorithm narrows the choices for decision-making and provides feedback that is very similar to human judgment. For an optimal response to complex disasters, a large amount of data should be analyzed and used; hence, AI can be used to understand large-scale social phenomena [40]. By big data analysis and simulation, the selection of the required actual data can be achieved using the judgment of AI based on the existing empirical data.

AI applications in Disaster Management [41]

In the disaster mitigation phase, decision makers need to identify hazards and risks, predict possible impact, assess vulnerability, and develop mitigation strategies, in order to create stronger, safer, and more resilient communities. AI methods have been widely applied to support disaster mitigation management in the four areas. In particular, supervised models and unsupervised models have been extensively used.

AI techniques have been applied to estimate possible impacts and assess vulnerability. For instance, possible structural damage under natural hazard(s) can be predicted by using fragility curves, which were traditionally built from statistical analyses of historical and simulation data and now can be estimated from the application of AI methods. Infrastructure service disruptions due to hazards can be predicted based on historical data using generalized regression models.

In the preparedness phase, decision-makers should send out early warnings and alert the public after identifying the disaster that is about to come, utilize emergency training systems and tools and prepare for evacuations if needed. Most AI methods have been applied to all the previous steps with very limited applications to utilizing emergency training systems

d) Geographical Information Systems (GIS)

The Disaster Management of a city consists of planning for disasters, training for response and designing contingencies for recovery. The involvement of GIS tools to design and plan above procedures effectively could help manage the resources effectively. Geographic Information Systems (GIS) have proven to be invaluable tools for data collection and analysis. These systems allow for the visualization, mapping and spatial analysis of data related to disaster events. By incorporating IoT technologies into GIS, disaster management practitioners can gain access to real-time data that can aid in decision-making processes. GIS complements IoT by providing a spatial context to the collected data. This way allows for the visualization and analysis of the data on a map, which assist in the identification of high-risk areas, planning evacuation routes and allocating resources effectively [42]

Many trending technologies like IoT could help better management of disaster in case of smart cities. Combining these technologies could cater to the needs of a greater number of communities in smart cities.

e) Digital Twin

Digital Twin is a digital replica of a real-world asset or operation and differs from traditional Computer-Aided Design (CAD) and is based on massive, cumulative, real-world, real-time data measurements in multiple dimensions [4]

The extent of research on Smart Cities Digital Twin (SCDT) in the context of disaster management has exponentially increased over the past few years to unlock the full potential of adopting SCDT for more resilient disaster risk management systems.

SCDT can improve all four phases of disaster management [43]. In the mitigation phase SCDT can be used to evaluate alternative policies and plans to reduce loss of life and property and can thereby guide community leaders in disaster management investment decisions. In the preparation phase SCDT can be used to collect and analyze near-real-time data about community and disaster event conditions as the basis for proactive actions such as evacuations. In the response phase SCDT can be used to report damage and threats to lives and well-being and thereby improve first responder deployment. In the recovery phase SCDT can be used to identify rebuilding bottlenecks and effective and efficient means to build back better and to guide resource allocation strategies.

As an example, The Digital Twin City of Atlanta [44] an ongoing project, is a virtual reality (VR)-based platform mainly built on the Unity cross-platform game engine. This interactive and data-driven platform containing a fully modeled City of Atlanta in three dimensions brings together the entire City of Atlanta in virtual space to facilitate discovery of interactions and interoperability of its human-infrastructure systems during emergencies.

V. Proposed End-to-End Technology Stack for Disaster Management

Emergency managers think of disasters as recurring events with four phases: Mitigation, Preparedness, Response, and Recovery. the below is a proposed End-to-End technology stack which is compatible with the four phases of disaster management.

a) Preparedness

Proper preparation for disasters would utilize an early warning system that uses a wireless sensor network to monitor various environmental parameters in real time and transfer these data to an IOT platform to allow emergency response teams to identify any anomalies upfront and predict any hazardous events.

GIS systems would be used to visualize the real-time data on Maps and identify high risk areas.

Digital Systems connected to the command control center would transmit data feeds to monitor city infrastructure and traffic to ensure quick response to any issues within day-to-day operation.

b) Response

Early warning System would detect that monitored parameters have crossed their respective threshold values. It would interpret this event as a disaster and start alert generation to all respective emergency response teams.

The command control center will be a focal point of data acquisition analysis for all data points including CCTV Cameras, Fleet Management, or UAV. It will also host all decision makers from different organizational emergency response teams (civil defense, traffic, ambulance authorities) to facilitate proper coordination between different entities and joint decision making.

Developing maps of the impact area(s) using GIS is essential for situation awareness, supporting efficient disaster response efforts. Event maps and damage information that are generated from different AI methods can provide vital information for planning search and rescue operations, staging and deploying resources, and understanding short-term housing needs

Alert Generation would target to notify citizens so that they can start emergency evacuation procedures previously announced. It will also aim to instruct response teams to mobilize to the risk area and roll out their emergency response plans.

Decision makers from respective authorities will track first responders' actions via command control center screens displaying CCTV footage or UAV images of damaged areas or bottlenecks in the evacuation routes. Instant communication with first responders will enable quick guidance and actions during critical situations.

c) Recovery

AI methods have been applied to disaster recovery management, by assessing the disaster induced impact in detail, developing recovery plans, tracking the recovery process, and estimating loss and repair costs.

AI methods can help eliminate the human efforts needed when assessing physical damage, based on aerial images, social media imagery data, and sensor measurement data.

Digital Twin can be used to create simulations of the disasters scenario and the performance of emergency response teams, in order to enhance the emergency r

d) Mitigation

AI methods have been widely applied to support disaster mitigation management. It can be applied to estimate possible impacts and assess vulnerability. Infrastructure service disruptions due to hazards can be predicted based on historical data. Digital Twin and Big Data analytics can enable conducting simulated scenarios of for the disasters to support the same purpose

Based on the impact and vulnerability analyses, decision makers can gain better situation awareness with more confidence and develop effective mitigation strategies such as retrofitting vulnerable structures, elevating electric substations and using underground cables , and developing effective disaster-related policies, In this process, AI techniques can support developing and comparing mitigation strategies.

VI. Conclusion

This paper has provided a clear overview on how smart cities technologies significantly enhance disaster management processes, demonstrating their efficiency in mitigating risks, optimizing response strategies, and safeguarding communities. By leveraging advanced data analytics, IoT sensors, and interconnected systems, smart cities empower authorities with real-time insights, swift decision-making capabilities, and proactive measures to effectively address and mitigate the impacts of disasters. As we continue to integrate and innovate these technologies, the potential for smart cities to revolutionize disaster management and enhance resilience becomes increasingly evident, offering promising pathways towards safer and more sustainable urban environments.

Recommendations for future research

Literature review has indicated that there is a shortage in research papers that use quantitative analysis to benchmark the impact of disaster management technologies in mitigation of disasters. The case studies mentioned above did not provide any quantitative measure on so this should be a topic for future research area to emphasize the importance of smart technologies in disaster management, and open the door for further improvements by developing quantitative measures for this impact.

On a similar yet different note, the implementation of smart cities technologies is not a straightforward activity. It includes various technical challenges and learned lessons. There are an absence of research work on implementation challenges for smart cities technologies in the context of disaster management. This would be an important area of research to cater for the proper planning and implementation mandated by cities. It would also reflect on the time and cost of implementation which is of significant importance for cities during budget planning for such a kind of projects.

REFERENCES

VII. REFERENCES

[1] "CRED—Human cost of disasters. An overview of the last 20 years 2000-2019.," UNDRR.

[2] "Atlas of Natural Hazards in the Arab Region".

[3] W. B. Group, "Natural Disasters in the Middle East and North Africa,A Regional Overview".

[4] M. Ariyachandra and G. Wedawatta, "Digital Twin Smart Cities for Disaster Risk Management: A Review of Evolving Concepts," *Sustainability (Switzerland),* vol. 15, no. 15, 2023.

[5] H. C.-T., L. S. and J. C., "Digital Twin for Disaster Management in Smart City," 2024.

[6] F. D.N. and W. C.M., "Smart Cities with Digital Twin Systems for Disaster Management," 2020.

[7] G. K., "User Intervention in Disaster Management Systems for Resilient Smart Cities," 2023.

[8] P. S., P. S.H., P. L.W., P. S., L. S., L. T., L. S.H., J. H., K. S.M., C. H. and P. S., "Design and implementation of a Smart IoT based building and town disaster management system in Smart City Infrastructure," 2018.

[9] in *Disaster management in smart cities using IoT and big data*, 2021.

[10] H. M.F., T. R., R. A., K. A., A. I. and A. A., "Designing a Smart Building Fire Disaster Management System for Smart Cities," 2023.

[11] S. P., H. S. and K. S., "Design of disaster management system using IoT based interconnected network with smart city monitoring," 2016.

[12] Nurwatik and H. J.H., "A framework: Implementation of smart city concept towards evacuation route mapping in disaster management system".

[13] G. S.P., F. J.C. and M. A., "Data-Driven Disaster Management in a Smart City," 2022.

[14] D. Wessel, J. Holtz and F. Konig, "Practice Report "smart Disaster Management" - Combining Smart City Data and Citizen Participation to Increase Disaster Resilience," *i-com,* vol. 20, no. 2, p. 177–193, 2021.

[15] I. O., K. V., S. N. and D. C., "RES-Q: Toward Semantic Interoperability for Risk and Disaster Management in Smart Cities," 2022.

[16] K. M., K. M.R., L. C.K. and Z. B., "Analysis of Multi-Dimensional Road Accident Data for Disaster Management in Smart Cities," 2022.

[17] J. D., T. V.T., T. D.Q., P. M. and P. S., "Conceptual framework of an intelligent decision support system for smart city disaster management," 2020.

[18] A. J.-K., K. B., K. B. and H. E.-H., "Virtual Scenarios of Earthquake Early Warning to Disaster Management in Smart Cities Based on Auxiliary Classifier Generative Adversarial Networks," 2023.

[19] K. T. and T. A., "Deep learning and stereo vision based detection of post-earthquake fire geolocation for smart cities within the scope of disaster management: İstanbul case," 2023.

[20] A. M., M. R., A. A. and K. I., "A smart disaster management system for future cities using deep learning, gpus, and in-memory computing," 2020.

[21] E. L.B., M. B.M., M. A.L. and F. J.C., "Disaster management in smart cities," 2021.

[22] A. W., H. N.B. and A. L., "An Unmanned Aerial Vehicle (UAV) System for Disaster and Crisis Management in Smart Cities," 2023.

[23] Q. Z., Z. M.H., M. S.K.R., L. K.N. and T. V.W.Y., "Optimizing UAV Path for Disaster Management in Smart Cities Using Metaheuristic Algorithms," 2022.

[24] D. S., Z. C. and K. D., "Integrating BIM and GIS for Disaster Management in Smart Cities: Key Benefits and Challenges," 2023.

[25] A. A., S. R. S. and R. P.J., "A Spatial Disaster Management Framework for Smart Cities—A Case

Study of Amaravati City—Flood Management," 2019.

[26] H. D., M. H., Z. M., S. R.W., F. M., A. D. and R. R., "A research framework of disaster traffic management to Smart City," 2017.

[27] A. Z., A. O., A. M.B., A. S. and M. R., "A smart disaster management system for future cities," 2014.

[28] A. M., M. R., A. A. and A. A., "Disaster management in smart cities by forecasting traffic plan using deep learning and GPUs," 2018.

[29] K. S., A. A., H. M.M. and A. M., "Social Media-Based Intelligence for Disaster Response and Management in Smart Cities".

[30] C. S., B. A., T. N. and P. M., "Dynamic Notifications in Smart Cities for Disaster Management".

[31] A. E. and B. N., "Buildings and crowds: Forming smart cities for more effective disaster management," 2011.

[32] T. A.I., D. Z. and Z. Y., "3DMAT: data dissemination for disaster management using available technology in a smart city," 2021.

[33] H. R., H. R. and I. T., "Smart City Technology for Disaster Management: Demonstrating the Use of Bluetooth Low Energy (BLE) Beacons for Emergency Alert Dissemination," 2022.

[34] L. B. Elvas, B. M. Mataloto, A. L. Martins and J. C. Ferreira, "Disaster management in smart cities," *Smart Cities,* vol. 4, no. 2, p. 819–839, 2021.

[35] S. A. J. J. A. P. D. M. K. K. a. S. S. 19. S. Rajendran, "Leveraging the Internet of Things (IOT) for Disaster Management: Enhancing Resilince, Early Warning System in a Globally Connected World," *9th International Conference on Smart Structures and Systems (ICSSS), CHENNAI, India,* 2023.

[36] "Weather – Kerala State Disaster Management Authority," [Online].

[37] "Early Warning System Plan".

[38] B. Paschoal and K. Wegrich, "Urban governance innovations in Rio de Janeiro: The political management of digital innovations," *Journal of Urban Affairs,* vol. 41, no. 1, p. 117–134, 2019.

[39] M. Arslan, A. Roxin and C. Cruz, "A Review on Applications of Big Data for Disaster Management," *13th International Conference on Signal Image Technology & Internet Based Systems, Jaipur, India.*

[40] D. Jung, V. T. Tuan, D. Q. Tran, M. Park and S. Park, "Conceptual framework of an intelligent decision support system for smart city disaster management," *Applied Sciences (Switzerland),* vol. 10, no. 2, 2020.

[41] W. Sun, P. Bocchini and B. D. Davison, "Applications of artificial intelligence for disaster management," *In Nat Hazards 103 (3), pp. 2631–2689*, 2020.

[42] N. M. AbdelAziz, K. A. Eldrandaly, S. Al-Saeed, A. Gamal and M. Abdel-Basset, "Application of GIS and IoT Technology based MCDM for Disaster Risk Management: Methods and Case Study," *Decision Making: Applications in Management and Engineering,* vol. 7, no. 1, p. 1–36, 2023.

[43] D. N. Ford and C. M. Wolf, "Smart Cities with Digital Twin Systems for Disaster Management," *Journal of Management in Engineering,* vol. 36, no. 4, 2020.

[44] N. M. a. J. E. Taylor, "Smart city digital twins," *IEEE Symposium Series on Computational Intelligence (SSCI), Honolulu, HI, USA, 2017, pp. 1-5*, 2017.

[45] U. O. f. D. R. R. B. B. Centre for Research on the Epidemiology of Disasters CRED, "CRED, UNDRR, Human Cost of Natural Disasters - an Overview of the Last 20 Years 2000-2019," 2020.

[46] R. B. C. B. O. H. A. R. S. S. D. T. A. Z. A. Banerjee, "Natural Disasters in the Middle East and North Africa: A Regional Overview, Global Facility for Disaster Reduction and Recovery," *World Bank, Washington, D.C.*

[47] "https://sdma.kerala.gov.in/wp-content/uploads/2018/11/TVM-EWSP-2016.pdf," [Online].

[48] P. Z. T. W. T. L. a. Z. S. Y. Xiao, ""A Study of the Framework of Smart City Management System Construction," *2021 2nd International Conference on Artificial Intelligence and Computer Engineering* .

[49] unesco, "Atlas of Natural Hazards in the Arab Region," 2021.

[50] E. Mastroianni, J. Lancaster, B. Korkmann, A. Opdyke and W. Beitelmal, "Mitigating infrastructure disaster losses through asset management practices in the Middle East and North Africa region," *International Journal of Disaster Risk Reduction,* 2021.

[51] D. Dai, M. Bo, X. Ren and K. Dai, "Application and exploration of artificial intelligence technology in urban ecosystem-based disaster risk reduction: A scoping review," *Ecological Indicators,* vol. 158, p. 111565, 2024.

[52] Okonta and Donatus, "Smart Cities Software Application for Sustainability and Resilience".

[53] F. Özen and A. Souri, "Cloud-based disaster management architecture using hybrid machine learning approach in IoT," *Multimedia Tools and Applications,* 2024.

[54] C. Prakash, A. Barthwal and D. Acharya, "An IoT-based system for monitoring and forecasting flash floods in real-time," *Journal of Earth System Science,* vol. 132, no. 4, 2023.

[55] M. Subashini, R. Sudarmani, S. Gobika and R. Varshini, "Development of Smart Flood Monitoring and Early Warning System using

Weather Forecasting Data and Wireless Sensor Networks-A Review," IEEE, 2021, p. 132–135.

[56] World Bank Group, "Natural Disasters in the Middle East and North Africa".

[57] "Early Warning System Plan," 2016. [Online]. Available: https://sdma.kerala.gov.in/wp-content/uploads/2018/11/TVM-EWSP-2016.pdf.

[58] R. A., R. S. and L. J.L.M., "Disaster management in smart cities using IoT and big data," 2021.

[59] W. D., H. J. and K. F., "Practice Report "smart Disaster Management" - Combining Smart City Data and Citizen Participation to Increase Disaster Resilience," 2021.

[60] S. I.A., P. A.L., W. P.P.K. and A. G.B., "Assisting smart disaster management for smart city program, case study: Pringgokusuman village, Yogyakarta," 2021.

[61] A. M.R.M.F. and W. G., "Digital Twin Smart Cities for Disaster Risk Management: A Review of Evolving Concepts)," 2023.