5th African International Conference on Industrial Engineering and Operations Management, Johannesburg/Pretoria, South Africa, April 23 - 25, 2024
Publisher: IEOM Society International, USA
Published: April 23, 2024 DOI: 10.46254/AF05.20240033

Enhancing Post-disaster Relief Management Through Aerial Edge Computing: A Systematic Literature Review

Manduth Ramchander
Associate Professor
Department of Operations and Quality Management
Faculty of Management Sciences
Durban University of Technology
Durban, South Africa
Manduthr@dut.ac.za

Manikam Michael Nadar
Lecturer
Department of Operations and Quality Management
Faculty of Management Sciences
Durban University of Technology
Durban, South Africa
ManikamN@dut.ac.za

Abstract

Natural disasters have become more frequent in recent times, making post-disaster relief management a global concern. The resultant inaccessibility to large areas and damage to communication infrastructure hinders the optimized prioritization of relief measures. While unmanned aerial vehicles (UAVs) have played a limited role in disaster management operations, leveraging aerial edge computing (AEC) in disaster relief management supply chains has the potential to significantly enhance the efficiency and effectiveness of relief efforts. AEC combines the versatility of aerial platforms with real-time data processing and analysis, thus enabling quick data-driven actions. While academic interest in this field of AEC is noteworthy with an increase in the number of annual academic publications, such innovations tend to remain in the halls of academia, at a distance from the on-the-ground post-disaster decision-makers and practitioners. Thus, this study aimed to conduct a systematic literature review of the topic to bring to the fore current understandings, challenges, and possibilities for AEC adoption. The PRISMA methodology was used to execute the systematic literature review and thematic analysis was used to extract the dominant themes. The themes that were extracted include rapid needs assessment, logistics optimization, dynamic resource allocation, network establishment, and personnel and asset tracking. The themes around challenges revolve around platform stability, safety and security, regulatory compliance, and interoperability. Despite the challenges, positive sentiments resonate with the view that together with regulations, best practices are likely to overcome challenges.

Keywords
Aerial, Edge, Computing, Disaster, Supply.

1. Introduction
An increased spectrum of disasters, comprising both natural phenomena like storms, earthquakes, and floods, as well as human-originated crises has resulted in increasing calls for assistance in affected areas and the urgent nature, uncertainty, and complexity of these disasters underscore a need for innovative solutions (Cao, Xu, Aziz and Kamaruzzaman 2023). The significant challenge in disaster management arises from the disparity between heightened susceptibility to disasters, ineffective crisis response, and inadequate crisis resilience (Aboualola,

Abualsaud, Khattab, Zorba, and Hassanein 2023). The occurrence of multiple disaster threats calls for the adoption of a holistic disaster management approach that entails a strategic emphasis on actions and the use of emerging technologies (Vermiglio, Noto, Bolivar, and Zarone 2021).

Zhang, Luo, Jiang, and Zhang (2023) attest that although Mobile Edge Computing (MEC) is a promising technology, the service capability is limited by the constrained wireless coverage of the base station. Consequently, MEC faces limitations in providing services to terminals in remote areas or during natural disasters where the Internet of Things (IoT) infrastructure is lacking. Thus, to improve MEC performance, AEC has introduced utilizing unmanned aircraft vehicles (UAVs) to assist in edge computing (Zhang, Luo, Jiang, and Zhang 2023). Artificial Intelligence (AI) powered drones with onboard intelligence are becoming a game changer for many disaster management applications, including search and rescue, prompt infrastructure inspection, and remote sensing (Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti 2023). The implementation of onboard AI processing in UAVs, aided by the technological advancements in edge devices and their support of technologically advanced Graphics Processing Units (GPUs), enables the automated inspection process with real-time identification of target objects at high accuracy, showcasing the potential of processing complex deep learning models in real-time (Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti 2023). This study aimed to conduct a systematic literature review of the current understandings, challenges, and adoption of aerial edge computing in disaster relief management.

1.1 Objectives

The research objectives of the study were to:Establish the current role of unmanned aerial vehicles in disaster relief management;
Understand the challenges associated with unmanned aerial vehicles and the role of aerial edge computing in disaster relief management.

2. Literature Review

According to the 2020 Global Assessment Report on Disaster Risk Reduction, the average number of medium and large-scale disasters recorded annually, between 2001 and 2020, was between 350 and 500 (Cao, Xu, Aziz, and Kamaruzzaman 2023). Natural disasters pose a significant threat, that results in physical damage to infrastructure and hinders the safety of people. It is essential to assess the magnitude of damage sustained by buildings and structures in the aftermath of the disaster to improve the survival rates of affected individuals (Cao, Xu, Aziz, and Kamaruzzaman 2023). In emergency scenarios like disaster relief and service recovery, the deployment of terrestrial infrastructures becomes economically impractical and challenging. This is attributed to the high operational costs and the intricate, unpredictable nature of the environments involved (Li, Fei and Zhang 2019). In the event of a disaster, emergency responders must gain a quick assessment of the unfolding disaster, understand what has transpired and identify the areas where assistance and resources are needed. Hence, during emergency situations, where a quick and immediate response is typically crucial, issues related to connection and information transit time can pose significant risks (Aboualola, Abualsaud, Khattab, Zorba and Hassanein 2023).

Emerging technologies now play a crucial and supportive role throughout the various phases of disaster management, enabling proactive responses to anticipate and address potential issues. The implementation of emerging technology, such as big data and predictive analytics, offers beneficial support to overcome the limitations in disaster management relief operations (Vermiglio, Noto, Bolivar and Zarone 2021). Big data, the IoT, machine learning, artificial intelligence, remote sensing, cloud computing, social media communication, and blockchain play an increasing role (Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti 2023). These technologies are integral in both responding to and proactively mitigating the emergence of problems in disaster scenarios (Vermiglio, Noto, Bolivar, and Zarone 2021).

UAVs are gaining attention within the smart industry, especially in smart cities where they can traverse urban areas to fulfill various tasks. These tasks include observation, data acquisition, mapping buildings, managing disasters, and engaging in agriculture, all facilitated by onboard sensors (Kim and Hong 2019). The current practice for search-and-rescue using UAVs is to manually explore a region with human observers to find missing people (Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti 2023). Banik, Hossain, Govindan, Nur, and Babski-Reeves (2021) allude that UAVs are preferred due to their speed and maneuverability, particularly in areas with limited road infrastructure or heavy traffic and these attributes make drones highly advantageous for delivering crucial medical supplies swiftly during post-disaster situations, ultimately contributing to a quicker response time in saving human lives.

The use of AI will help to automate the rescue/recovery process as the UAV will execute specialized person detection functions on board and automatically report their location in real time. It is also possible to use a swarm of drones to perform search-and-rescue missions in parallel, speeding up the search process and increasing the probability of finding and saving people.

UAVs represent advancing technology that has experienced significant development in recent years and considering that these vehicles can be operated remotely or autonomously, eliminates the requirement for human personnel to be close (Kamat, Shanker, and Barve 2020). Specialized drones can be assigned to specific tasks, that include establishing temporary communication structures, generating real-time maps of affected regions, and identifying hot spots where rescue teams are most likely to locate victims, aimed at enhancing disaster response efforts (Kamat, Shanker, and Barve 2020). Kim and Hong (2019) posit that mobile UAVs provide the benefits of being equipped with cameras, sensors, computing resources, and communication devices. The integration of communication technology with UAV capabilities enables swift responses in disaster areas, leveraging the UAV's multifunctional features for effective and rapid interventions. The widespread utilization of UAVs in commercial applications is constrained primarily by the absence of onboard edge AI, necessitating manual data observation and offline processing subsequent to data collection (Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti 2023).

The utilisation of aerial platforms, including unmanned aerial vehicles (UAVs), has emerged as a promising solution for delivering reliable and cost-effective wireless communication services to ground wireless devices. Specifically, UAVs can serve as flying base stations to expand coverage and enhance capacity in terrestrial cellular networks (Mozaffari, Saad, Bennis and Debbah 2017). Edge servers typically deploy at the periphery of base stations, with their service capabilities limited by the constrained wireless coverage of the base station. Consequently, MEC faces challenges in delivering services to terminals situated in remote areas or during natural disasters, where IoT infrastructure is deficient. To improve MEC performance, aerial edge computing is introduced, leveraging UAVs to assist in edge computing, enabling cost-effective service provision for terminals (Zhang, Luo, Jiang, and Zhang 2023).

3 . Methods

This study adopted a systematic literature review (SLR) approach using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The SLR approach encompasses the synthesis of results from various qualitative, quantitative, and mixed methods research studies, contributing to the evidence base for both research and practice (Hesse-Biber and Johnson 2015). A systematic literature review attempts to answer a specific research question (Kraus, Breier and Dasí-Rodríguez 2020), and in the context of this study, the research question is: *What are the understandings, challenges, and possibilities for the adoption of Aerial Edge Computing?*

The words that were deemed critical to identify the research articles that related to the research objective and question were strung together using specific Boolean operators. Boolean operators, such as “AND”, “OR”, and “NOT” are used in search queries to combine keywords in order to narrow down or broaden search results (Hollier 2020). Table 1 reflects the search strategy used in this SLR.

Table 1. Search strategy

“Aerial Edge Computing” OR “AEC”
AND
“Adoption” OR “Implementation” OR “Application”
AND
“Understanding” OR “Challenges” OR “Possibilities”

Source: Researchers” own construction

EBSCOhost, Scopus and Emerald Insight databases were searched for relevant articles. The inclusion criteria were Year of publication (2018-2023); Language (English); Article type (Journal full text).

4. Data Collection

Figure 1 depicts the identification, screening, and inclusion phases of the SLR. Ninety-one records were identified in the three databases.

A total of 78 were left for screening after the removal of 13 duplicates. A further 16 were excluded due to there being no full texts and another 18 were removed due to a lack of relevance after reading the abstract. Upon reading the full texts, another 31 were removed due to lack of relevance. Thirteen articles were considered for thematic analysis. In the typical application of thematic analysis to systematic reviews of qualitative research, the goal is to locate themes that apply across the results of the various studies. NVivo software Version 12 was used to identify emergent themes.

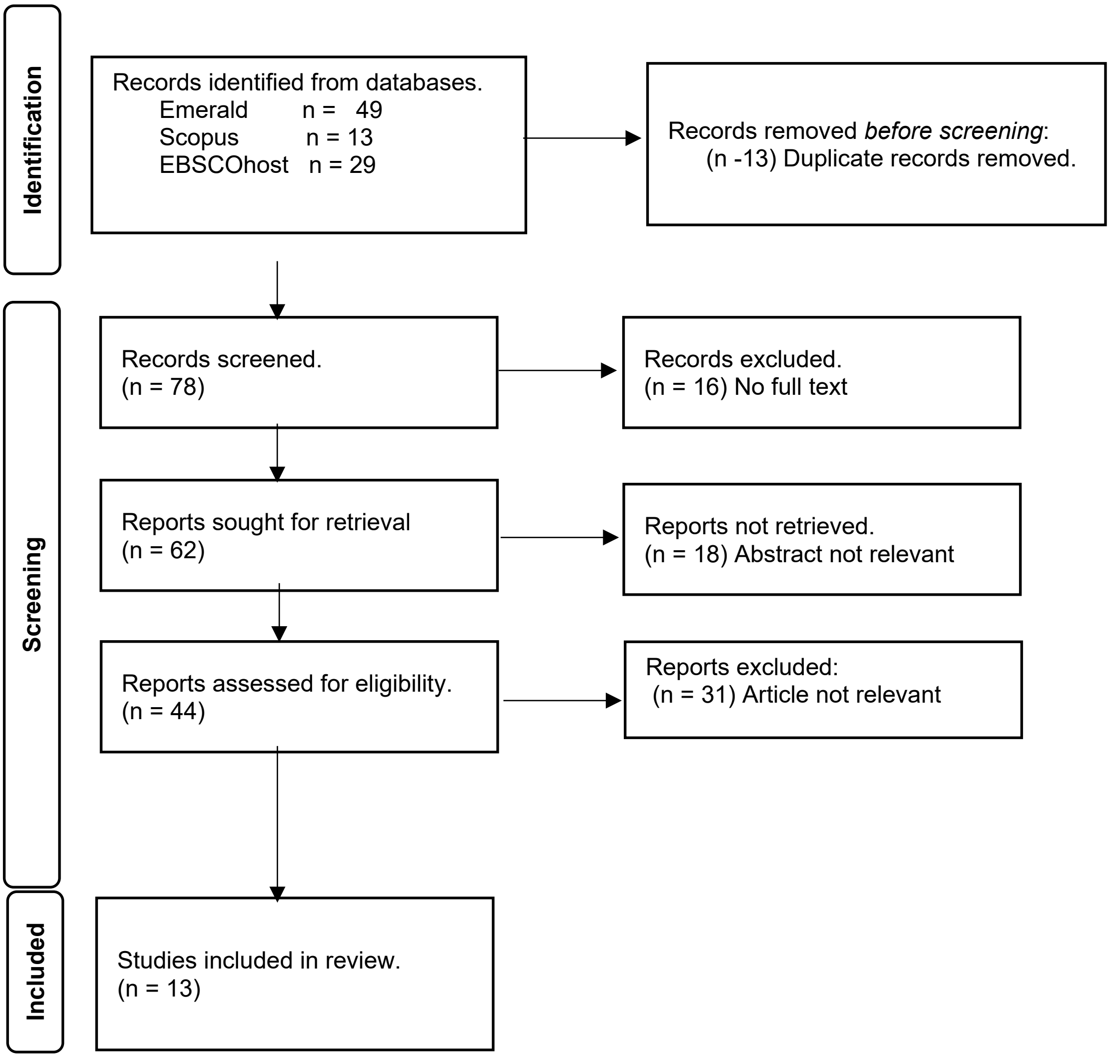

Figure 1. PRISMA flow chart
Source: Adapted from Page et al. (2021)

5. Results and Discussion

The cloud diagram presented in Figure 2 is a visual representation of text data, displaying words in varying sizes based on their frequency, thus providing an intuitive overview of prominent terms, with larger font sizes indicating more frequent usage. This visual tool is valuable for pinpointing key themes and areas by highlighting the prominence of specific words in each text or dataset.

Figure 2. Word cloud
Source: NVivo software version 12 construct

The results sections of qualitative studies are frequently organized around themes as a way of aggregating and comparing the findings from the separate studies. Figure 3 illustrates the key themes of the systematic literature review.

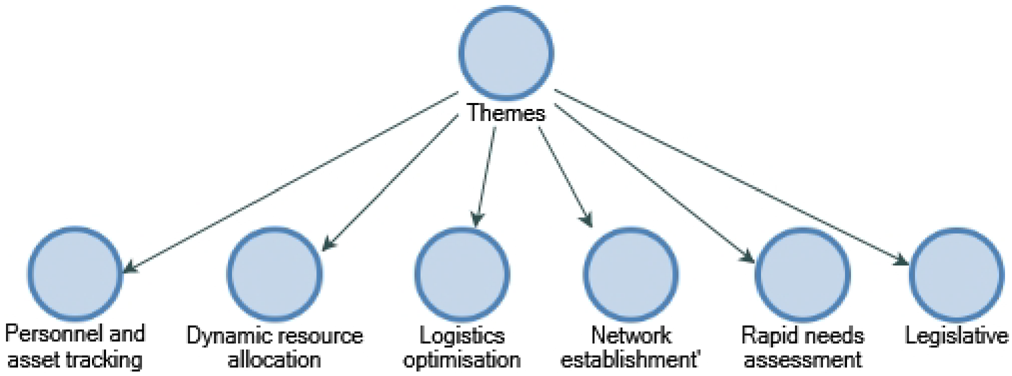

Figure 3. Key themes of the SLR
Source: NVivo software version 12 construct

The themes that were extracted include rapid needs assessment, logistics optimization, dynamic resource allocation, network establishment, personnel and asset tracking, and legislation. Each theme is further explained in Table 1.

Table 2. Themes extracted

Theme	Explanation	Authors
Rapid needs assessment	The micro-level internal structure of individual buildings can be efficiently replicated, and the overall landscape and layout of an entire area can be displayed on a macroscopic scale by simulation. The integration of Building Information Modelling (BIM) and Geographic Information System (GIS) capabilities can make substantial contributions to post-disaster recovery.	Cao, Xu, Aziz and Kamaruzzaman (2023).
	Infrared sensors or deep penetration radars, drones can play a crucial role in locating individuals trapped amidst the wreckage of destroyed infrastructure.	Kamat, Shanker, and Barve (2020).
	AEC and UAVs allow rescue teams to run activities that are not accessible to humans during disasters, offering crucial quick response time.	Zhang, Luo, Jiang, and Zhang (2023).

	Disaster management teams can use the latest edge technologies to predict, detect, manage, and respond to possible disaster risks in real-time.	Aboualola, Abualsaud, Khattab, Zorba and Hassanein (2023).
Logistics optimisation	AEC offers swift and flexible deployment in disaster areas, potentially replacing terrestrial infrastructures to deliver low-latency services for the terminals of disaster victims.	Zhang, Luo, Jiang, and Zhang (2023).
	Planning routes and automated pathfinding are crucial integrated capabilities.	Cao, Xu, Aziz and Kamaruzzaman (2023).
Dynamic resource allocation	The energy cost of onboard batteries in the context of collaborative aerial edge computing involving multiple UAVs is minimised. The energy consumption is initially modelled based on the flying attitudes of quadrotor UAVs. The collaborative strategy design employs Monte Carlo Tree Search to enable independent operations of individual UAVs while fostering cooperation.	Xu, Ota, and Dong (2023).
	Energy-efficient mobility, ensures that the movement of the UAVs is carefully controlled by considering the energy consumption associated with every manoeuvre. The other category of energy-efficient operation is energy-efficient communication, which aims to satisfy the communication requirement with the minimum energy expenditure on communication-related functions, such as communication circuits, signal transmission, etc.	Zeng, Zhang and Lim (2016).
	The study explored the efficient utilisation of flight-time-constrained UAVs functioning as flying base stations to deliver wireless services to ground users. It introduces a novel framework designed to optimize the performance of UAV-based wireless systems. This optimisation is focused on enhancing the average number of bits (data service) transmitted to users and the hover duration of the UAVs, which corresponds to their flight time.	Mozaffari, Saad, Bennis and Debbah (2017).
	Compared to the communications with fixed infrastructure, UAVs have salient attributes, such as flexible deployment, strong line-of-sight connection links, and additional design degrees of freedom with controlled mobility.	Li, Fei and Zhang (2019).
Network establishment	The research suggests a new way to use drones and a communication system called LoRaWAN for disaster management,a three-tier network model with different parts like User Tier, UAV-mounted edge nodes, and LoRa concentrator and central server. The study also creates plans to manage tasks and waiting lists, time and energy use, signal strength, and the amount of information that can be sent. The results of the study indicated that the research ideas can provide efficient and long-distance services for disaster management using drones.	Xu, Ota, and Dong (2020).
	The increasing number of IoT mobile devices necessitates a robust communication system with high capacity and broadband connectivity. Flying UAVs have become a focus of research to meet these demands. This survey offers insights into UAV communications within 5G/B5G wireless networks. Three key contributions are highlighted: envisioning a space–air–ground integrated network for B5G communication systems, discussing design challenges to understand this novel architecture, and providing an overview of recent research on UAV communications integrating 5G techniques. The research concludes by identifying open research issues for future exploration. This timely exploration aims to serve as a valuable starting point for integrating IoT applications into 5G/B5G.	Li, Fei and Zhang (2019).
Legislative	To maximise the effectiveness of drone systems, more stringent government regulations are essential to establish laws that facilitate the seamless operation of UAVs without persistent delays arising from private property concerns. Until comprehensive regulations addressing these issues are formulated, the integration of drone usage will remain unattainable.	Kamat, Shanker and Barve (2020); Banik, Hossain, Govindan, Nur and Babski-Reeves (2021).

	The implementation of encryption and authentication protocols as security measures is required to protect the system from unauthorised access and potential data breaches (Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti 2023: 2).	Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti (2023).
Personnel and Asset tracking	The utilisation of unmanned aerial vehicles, in disaster management has become progressively advantageous as these contribute to expediting the collection of data related to targeted assets and finding missing people by capturing aerial images.	Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti (2023).

Source: Authors own construction

Table 3 illustrates the challenges postulated in various research studies.

Table 3. AEC challenges

Theme	**Challenges**	**Citations**
System	Several factors, such as the device employed, the detection model, input video resolution, utilisation of cloud connectivity, and the presence of a tracker or local storage of output videos, can influence the inference speed of an AI system for object detection.	Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti (2023).
	A notable drawback remains their limited battery endurance, posing a significant challenge to their practical use.	Banik, Hossain, Govindan, Nur and Babski-Reeves (2021: 474) and Zhang, Luo, Jiang, and Zhang (2023).
	There are several drawbacks of UAVs such as instability, limited charging efficiencyand dependence on related infrastructure. Also, the high cruising speed of UAVs implies elevated aerodynamic resistance, leading to increased energy consumption.	Zhang, Luo, Jiang, and Zhang (2023).
Data security	Drone communications are vulnerable to cyber-attacks. This underscores the importance of safeguarding the transmitted data between the UAV and the cloud. Attackers can gain control over UAVs by infiltrating the control center network. Additionally, as higher security protection may lead to increased energy consumption, it becomes crucial to explore the balance between energy consumption and security performance.	Koubaa, Ammar, Abdelkader, Alhabashi and Ghouti (2023: 2) and Zhang, Luo, Jiang, and Zhang (2023).
Personnel	Data processing and verification requires specialised skills to verify data reliability and quality.	Vermiglio, Noto, Bolivar and Zarone (2021).
Network	Satellite navigation techniques have recently seen rapid development. The path planning of UAVs is heavily dependent on navigation, making it a crucial aspect of AEC. Therefore, the evolution of Global Navigation Satellite System (GNSS) technology significantly influences the application of AEC. However, the increasing complexity of electromagnetic scenarios introduces challenges for UAVs, particularly in dealing with GNSS interference.	Zhang, Luo, Jiang, and Zhang (2023).

Source: Researcher's own construct

6. Discussion

Aboualola, Abualsaud, Khattab, Zorba and Hassanein (2023), assert that disasters are intense and frequently deviate substantially from past experiences, demanding unique and urgent responses. Therefore, it is crucial to take note of the significance of disaster impact information, as slow or inadequate information flow can impede disaster response operations.

The versatility of UAVs and AEC, in their structure, design, and functionality has generated substantial interest, that fosters technological growth in the field of post-disaster management. Utilizing UAV-aided wireless communication presents a promising solution in scenarios where devices lack infrastructure coverage, particularly in situations involving severe shadowing by urban or mountainous terrain, or when natural disasters cause damage to existing communication infrastructure (Zeng, Zhang and Lim 2016).

The researcher summarises the following key findings of the systematic literature review:

i. *Theme 1- Rapid needs assessment:* Efficient disaster management is reliant upon the ability to promptly respond to emergencies, with the aim to mitigate the extent of the impact on human lives and infrastructure. This encompasses the quick deployment of resources by implementing well-coordinated disaster management strategies. Prompt action ensures that emergency response teams and authorities can work towards minimising casualties, injuries, and the overall disruption caused by disasters.

ii. *Theme 2 - Logistics optimisation*: The objective of optimising logistics in disaster management is to enhance the streamlining of the overall response, to ensure that critical resources are allocated promptly, thus minimising the impact on human lives and communities affected by disasters.

iii. *Theme 3 - Dynamic resource allocation*: Through the integration of real-time information, adopting flexibility, and fostering collaboration, disaster emergency responders can optimise the use of resources to address the most pressing needs, ultimately enhancing the effectiveness of the disaster response. The energy efficiency of UAVs reduces unnecessary energy consumption, allowing for wider area accessibility.

iv. *Theme 4 - Network establishment:* The establishment of networks for disaster management involves creating interconnected systems that facilitate communication, collaboration, and information sharing that enhances the overall efficiency of disaster response, leading to a more effective and coordinated effort to mitigate the impact.

v. *Theme 5 – Legislative support*: A legal framework that encompasses a range of legal issues, including authority, funding, coordination, community engagement, and risk reduction strategies, is essential for successful disaster management. The objective of such legislative framework is to enhance the resilience of communities and minimise the impact of disasters.

vi. *Theme 6 – Personnel and asset tracking*: By employing aerial edge computing technology to monitor and manage assets, disaster emergency responders can enhance their ability to respond rapidly, make informed decisions, and improve the overall outcomes during and after a disaster.

Despite the promising advantages of AEC, such as Line of Sight (LoS), flexibility, and low deployment costs, it faces various challenges that include energy limitations, security concerns, mobility issues, and interference from the GNSS (Zhang, Luo, Jiang, and Zhang 2023).

7. Conclusion

Global disasters claim millions of lives annually, and while the occurrence of natural disasters is unavoidable, effective disaster management can substantially reduce the number of fatalities and injuries in the consequences of such disasters. The period between sustaining an injury during a disaster and receiving medical intervention plays a crucial role in determining the outcome of disaster rescue operations. Prompt and timely post-disaster decisions and emergency relief efforts are essential for effectiveness, and this necessitates that decisions are quick and timely. The use of emerging technology, such as edge computing, can assist with the reduction of fatalities and injuries by providing information for speedy decision-making.

Key References

Aboualola, M., Abualsaud, K., Khattab, T., Zorba. N. and Hassanein, H. S., Edge technologies for disaster management: a survey of social media and artificial intelligence integration, *IEEE Access*. 11: 73782-73802, 2023.

Banik, D., Hossain, N. U.I., Govindan, K., Nur, F. and Babski-Reeves, K., A decision support model for selecting unmanned aerial vehicle for medical supplies: context of COVID-19 pandemic. *The International Journal of Logistics Management*. 34 (2): 473-496, 2021.

Cao, Y., Xu, C., Aziz, N. M. and Kamaruzzaman. S.N., BIM–GIS Integrated utilization in urban disaster management: contributions, challenges, and future directions. *Remote Sensing*. 15: 1-26, 2023.

Global Assessment Report on Disaster Risk Reduction 2023,

Hesse-Biber, S. and Johnson, R.B., The Oxford handbook of multimethod and mixed methods research inquiry. Oxford: Oxford University Press, 2015.

Hollier, C. Research basics: using Boolean operators to build a search. Available: https://www.ifis.org/en/research-skills-blog/research-basics-boolean-operators, Accessed 28 December 2023.

Kamat, A., Shanker, S. and Barve, A., Assessing the factors affecting implementation of unmanned aerial vehicles in Indian humanitarian logistics: a g-DANP approach. *Journal of Modelling in Management*. 18 (2): 416-456, 2020.

Kim, K., and Hong, C. S., Optimal task-UAV-edge matching for computation offloading in UAV assisted mobile edge computing. *20th Asia-Pacific Network Operations and Management Symposium* (APNOMS), Matsue, Japan: 1-4, 2019.

Koubaa, A., Ammar, A., Abdelkader, M., Alhabashi, Y. and Ghouti, L., AERO: AI-enabled remote sensing observation with onboard edge computing in UAVs. *Remote Sensing.* 15: 1-36, 2023.

Kraus, Breier and Dasí-Rodríguez The art of crafting a systematic literature review in entrepreneurship research. *International entrepreneurship and management journal* 16:1023-1042, 2020

Li, B., Fei, Z. and Zhang, Y., UAV Communications for 5G and beyond: Recent advances and future trends. *IEEE Internet Of Things Journal*, 6(2): 2241-2263, 2019.

Mozaffari, M., Saad, W., Bennis, M. and Debbah, M., Wireless communication using unmanned aerial vehicles (UAVs): optimal transport theory for hover time optimization. *IEEE Transactions on Wireless Communications*, 16(12): 8052-8066, 2017.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C. and Mulrow, C.D. . The prisma 2020 statement: an updated guideline for reporting systematic reviews. *BMJ 2021*. 372(71), 2021.

Vermiglio, C., Noto, G., Bolivar, M. P. R., and Zarone, V., Disaster management and emerging technologies: a performance-based perspective. *Meditari Accountancy Research*. 30 (4): 1093-1117, 2021.

Xu, J., Ota, K. and Dong, M., Big Data on the Fly: UAV-mounted mobile edge computing for disaster management. *IEEE Transactions on Network Science and Engineering*, 7(4): 2620-2630, 2020.

Xu, J., Ota, K. and Dong, M., Aerial edge computing: flying attitude-aware collaboration for multi-UAV. *IEEE Transactions on Mobile Computing*, 22 (10): 5706-5717, 2023.

Zeng, Y., Zhang, R. and Lim, T. J., Wireless communications with unmanned aerial vehicles: opportunities and challenges. *IEEE Communications Magazine*: 1-7., 2016.

Zhang, Q., Luo, Y., Jiang, H. and Zhang, K., Aerial edge computing: A Survey. *IEEE Internet of Things Journal*, 10 (16): 14357-14374, 2023.

Biographies

Manduth Ramchander is an Associate Professor and the Head of Department of Operations and Quality Management at the Durban University of Technology. His qualifications include: BPaed(Sc), NDip (Engineering), Diploma in Management Sciences, MBA and D.Com. He has previously lectured at the University of Zululand and thereafter at the University of KwaZulu-Natal. He has published in the fields of Teaching and Learning, Entrepreneurship Education, Research Methodology, and Operations and Quality Management.

Manikam Michael Nadar is a lecturer at the Durban University of Technology, Department of Operations and Quality Management. His qualifications include: a Diploma and a Bachelor of Technology degree in Human Resource Management, a Master of Philosophy degree in Management Science with a specialization in Quality Management, and a Doctor of Philosophy degree in Management Science, also focusing on Quality Management. His expertise extends beyond the classroom, as he has published articles in the fields of Safety, Health, Environment, and Quality Management, and has presented research papers at prestigious conferences such as the 2021 Mbali Virtual International Conference hosted by the University of Zululand and the 2023 BRICS Research Virtual International Conference hosted by the University of Kota, India.