

American Journal of  
Environment Studies  
(AJES)



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## Influence of Anticipatory Action on Technological Multi-Hazards Management at International Airports in Kenya

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### Article history

Submitted 15.03.2026 Revised Version Received 13.04.2026 Accepted 01.05.2026

### Abstract

**Purpose:** Aviation is dynamic and multi-hazards continuously emerge, propelling sustainable development and emergency practitioners to increasingly recognize the need to anticipate and manage multiple, concurrent risks. This study aimed to determine the influence of anticipatory action on technological multi-hazards management at international airports in Kenya.

**Materials and Methods:** The evaluation research design was employed in this study. The study used a sample size of 285 airport workers selected through stratified random sampling approach at international airports in Kenya. Primary data were collected using questionnaires, Focus Group Discussions, observation checklists, and structured interview protocols. The study used descriptive and inferential statistics. The descriptive statistics involved measures of mean (average), standard deviation, frequency distributions and percentages. The inferential statistical procedure used in this study was t-test and Newman-Keuls multiple comparisons test using WINKS SDA Software.

**Findings:** The study found that structural anticipatory measures such as heat and smoke detectors, audio and visual flashing devices, emergency shut down system, emergency alerting system, avian radar and non-structural

anticipatory action such as the inspection programme for fire detections influence the management of technological multi-hazards. Conversely, the use of indigenous knowledge, a non-structural anticipatory action, did not exhibit a significant influence in the management of multiple compounding risks.

**Implications to Theory, Practice and Policy:** The study was informed by the “SHELL Model” which postulates that the person (liveware) represented at the centre of the model is the focus of interest, and has to appear in all the interaction (i.e., liveware-software, liveware-hardware, liveware-environment and liveware-liveware) (ICAO, (2015). This model is used to analyze human factors and system interactions. To airport operators, we recommend adoption of anticipatory measures to enhance management of technological multi-hazards at airports. For policymakers, we propose the formulation of a comprehensive policy framework that encourages the adoption of anticipatory technologies.

**Keyword:** (*Sustainability Forecast, Early Warning System, Technological Multi-Hazards, International Airports, Kenya*) *Q01: Sustainable Development*

## INTRODUCTION

Disaster Risk Reduction (DRR) is a vital constituent of the global efforts to manage the rising risk of hazards (UNISDR, 2015). Generally defined as the systematic assessment, identification, and mitigation of the effects of hazards (UNISDR, 2015). The DRR interventions commonly focus on long-term assistance to reduce vulnerability and exposure and increase preparedness to better manage hazards such as the technological related (ICAO, 2022b). However, an emerging but impactful form of action, positioned between DRR and traditional response, is anticipatory action: assistance provided in the often-limited time period between evidence-based early warnings and the occurrence of an extreme event (Costella *et al.*, 2017) (Figure 1).

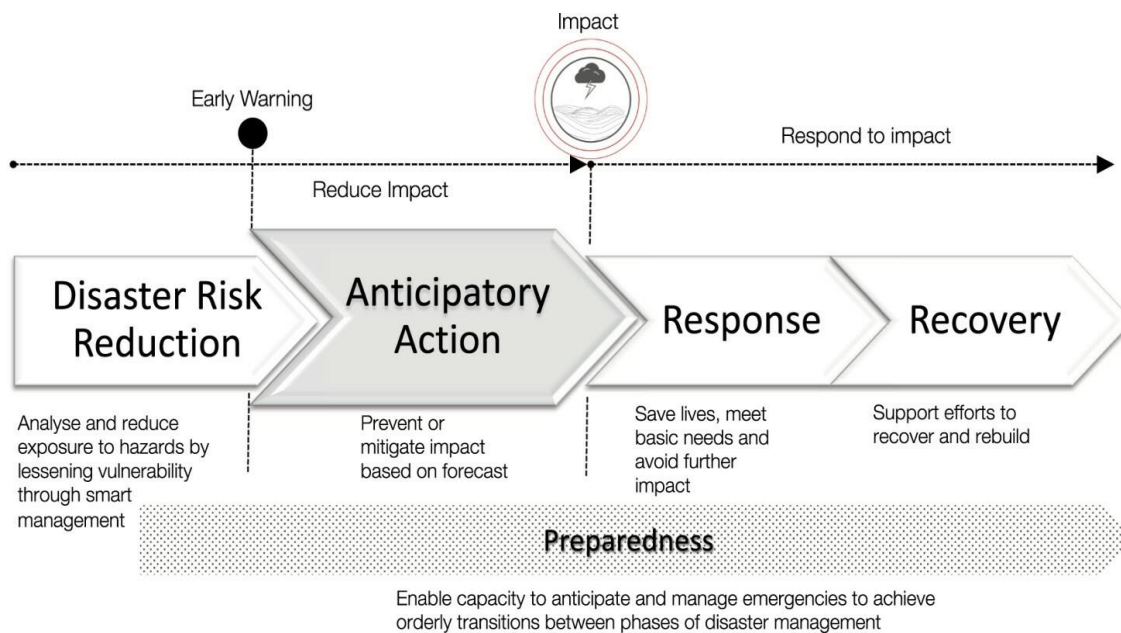


Figure 1: Anticipation in the Disaster Risk Management Continuum

Source: Tozier de la Poterie *et al.*, (2022)

Implementation of anticipatory actions varies between hazard types and their warning timelines (IFRC, 2021). Warnings refer to information about the monitored hazard, whose threshold has to be crossed according to predetermined observation protocols (Akerkar *et al.*, 2020). The objective of anticipatory action differs from traditional humanitarian action (IFRC, 2021). According to the International Federation of Red Cross and Red Crescent Societies (2021) anticipatory actions are designed to mitigate impacts preemptively to strengthen resilience, instead of responding to a manifested emergency (IFRC, 2021).

The objective of anticipatory action is to increase capacity for action in the face of an imminent hazard to thwart or reduce its negative impacts on vulnerable people and their livelihoods (Costella *et al.*, 2017). Various anticipatory action approaches are being implemented in many airports in

the world, for instance Zuluaga *et al.*, (2019) designed and implemented an early warning system for avoiding risks on military operations of Colombian air force. This system provided a better insight for air controllers and pilot, helping to maintain a situational awareness of the meteorological conditions that represent a danger to aviation, in favour of the efficiency and safety of air operations (Zuluaga *et al.*, 2019). Similarly, Shi *et al.*, (2013) analyzed the problems of current runway incursion systems and proposed an anticipatory runway incursion prevention system, which can predict and detect runway incursions, then give explicit instructions to pilots to avoid runway incursions/ collisions.

In airport terminal buildings, the alarm fire systems is critical anticipatory system in detecting fires at an early stage (Satyanarayana *et al.*, 2023). The importance of a fire alarm systems role for life safety, property protection and business continuity are evident (Cardemar, 2025). Heat and smoke detectors are the cornerstone of early fire detection, which can be installed in a number of locations, including an airport terminal buildings (Singh, 2022). In the new age of digital fire safety, Early Action technologies have arisen in the market that is now helping existing solutions (Cardemar, 2025). The Early Action system implemented in fire alarm systems can continuously read the collected data of smoke and heat levels from all the facility's sensors analyze what is happening in the system and automatically alert the person or persons who have the app (Cardemar, 2025).

Aircraft refuelling is a complex and delicate process that requires meticulous attention to detail to prevent the fuel leak and spill technological multi-hazard (Arc Refuellers, 2025). The early actions that can mitigate this occurrence is the emergency shutdown (ESD) system (Nolan, 2011). Fuel spillage or leaks can be very detrimental to the ecosystem (Idris *et al.*, 2013; Peterson *et al.*, 2003; Harwell & Gentile, 2006). An emergency shutdown (ESD) is an anticipatory system that rapidly ceases the operation of a process and isolates it from incoming and outgoing connections or flows to reduce the likelihood of a multi-hazard event from occurring, continuing or escalating (Nolan, 2011). According to Arc Refuellers, (2025) it is necessary to have a system that immediately shuts down to eliminate fuel flow in an emergency. Airports that do not have the capability to immediately provide an emergency shutdown should be considered as high risk (Nolan, 2011).

Further, collisions between birds and aircraft pose a serious risk to aviation (Metz *et al.*, 2020). On 7 September 1908, while piloting the Wright Flyer, Orville Wright had what is believed to be the first collision between an aircraft and a bird, what is now known as a bird strike (ICAO, 2012). Less than four years later, on 3 April 1912, at Long Beach, California, Calbraith Perry Rodgers, the first man to fly an aeroplane across the United States, became the first person to die as the result of a bird strike (ICAO, 2012). The annual damages from bird collisions with aircraft have been estimated at \$400 million in the United States and up to \$1.2 billion in commercial aviation worldwide (El-Sayed, 2019). Besides their potential to cause severe damage and accidents, they also pose a threat to aviation safety and a major cost to the airline industry (Metz *et al.*, 2020). The anticipatory measure used to reduce the risk of bird–aircraft collisions and increase human safety is the avian radar systems (Phillips *et al.*, 2018).

It is important therefore to put in place structural and non-structural anticipatory measures to manage these multi-hazard events involving fires and aircraft accidents at the airports (Sumathi *et al.*, 2018). The importance of multi-hazard management was first pronounced when this concept was introduced in the United Nations' Agenda 21 for Sustainable Development, held in Rio de Janeiro, Brazil, in 1992 under the title of "complete multi-hazard research" (United Nations, 1992). Succeeding international frameworks, including the Johannesburg Plan (UN, 2002), the Hyogo Framework for Action (2005) (UNISDR, 2007), and the Sendai Framework for Disaster Risk Reduction (2015-2030) (UNDRR, 2026), have further underlined the importance of these strategies. The Sendai Framework, for instance, highlights the necessity for multi-hazard approaches, defining them as "the selection of multiple-hazards, including the specific contexts in which hazardous events cascade or occur simultaneously or cumulatively, with consideration for their potential interconnected effects" (UNDRR, 2026). The international civil aviation organization (ICAO) provide key considerations and practices for implementing effective preparedness and response measures to these multi-hazards, in line with the Sendai Framework for Disaster Risk Reduction and consistently with the ICAO Standards and Recommended Practices (ICAO, 2022).

Globally research shows that, Asia tops as the continent with the highest number of technological multi-hazard events, recording 2,251 technological hazards, which resulted in 75, 072 deaths and affected 986, 282 people between 2000-2019 (EM-DAT, 2020). According to the Centre for Research on the Epidemiology of Disasters, Africa is listed second continent after Asia with the highest number of technological multi-hazard events, recording 1,690 technological hazards within the same period, resulting in 54, 755 deaths and affecting 419, 256 people (EM-DAT, 2020).

In Kenya, some of the technological multi-hazards that have occurred at international airports include the terminal building fire which occurred at Jomo Kenyatta International Airport in 2013 (Amboka, 2015). Similarly, on 17<sup>th</sup> of April, 2023, an aircraft accident, involving Singapore airline, which occurred at Jomo Kenyatta International Airport compounded and ended up causing cancelation of many domestic and international flights including economic losses (Goin, 2023). These figures illustrate the reality of compounding hazards and the critical need for risk managers and other actors to plan for and respond to multiple-hazards concurrently (Tozier de la Poterie *et al.*, 2022). It also reveals a need to better understand how risk managers can quickly axis between multiple-hazards and the successes and challenges that lie therein (Tozier de la Poterie *et al.*, 2022).

Many technological-related multi-hazards are projected to increase in frequency and intensity as airport development progresses, leading to a heightened likelihood of simultaneous disasters and compound events (Sumathi *et al.*, 2018). In light of this, a growing body of literature has called for multi-hazard research (Zscheischler *et al.*, 2018; Raymond *et al.*, 2020), recognizing that analysis and prediction of compound events are still emergent. Prior studies in Kenya have focused primarily on one hazard at a time and not on the reality of multiple-hazards and risks that interact with each other and other societal forces, as evidenced by the works of Ochieng (2015) and Otieno *et al.*, (2024). Comprehending the adaptations that take place when a single hazard scenario

becomes multi-hazard, and the structural and non-structural anticipatory actions that address these, are important areas in disaster risk reduction (Tozier de la Poterie *et al.*, 2022).

While an emerging body of academic and practitioner literature has called for immediate and long-term plans to address natural multi-hazards (Phillips *et al.*, 2020; Janzwood, 2020; Tozier de la Poterie *et al.*, 2022), little research has examined the influence of anticipatory action in the management of technological multi-hazards. This study evaluated the influence of anticipatory action in managing technological multi-hazards at international airports in Kenya.

### **Research Gaps**

Despite the growing body of literature on anticipatory action, existing studies have largely focused on its application in the context of natural multi-hazards. There is limited empirical research probing how anticipatory action frameworks can be adapted and applied to technological multi-hazard environments, particularly in critical facilities such as the airports. This creates a knowledge gap regarding the transferability and effectiveness of anticipatory action models from natural multi-hazard contexts to man-made multi-hazard backgrounds. This study addresses this gap by evaluating the applicability of anticipatory action approaches within Kenyan international airports, thereby contributing to a broader understanding of how anticipatory action can be operationalized in managing technological multi-hazards in a dynamic aviation industry.

## **MATERIAL AND METHODS**

### **Study Design**

This study utilized evaluation research design, to evaluate the influence of anticipatory action on management of technological multi-hazards at international airports in Kenya.

### **Study Location**

The international airports that this study targeted were; Jomo Kenyatta international airport (JKIA) and Moi international airport (MIA) in Kenya. The locations of these airports are as follows: JKIA is bounded by latitude 1° 20' 1.4'' South and longitude 36° 55' 37.6'' East and MIA are at latitude 4° 02' 05'' South and longitude 39° 35' 44'' East. Figure 2 shows the study area.

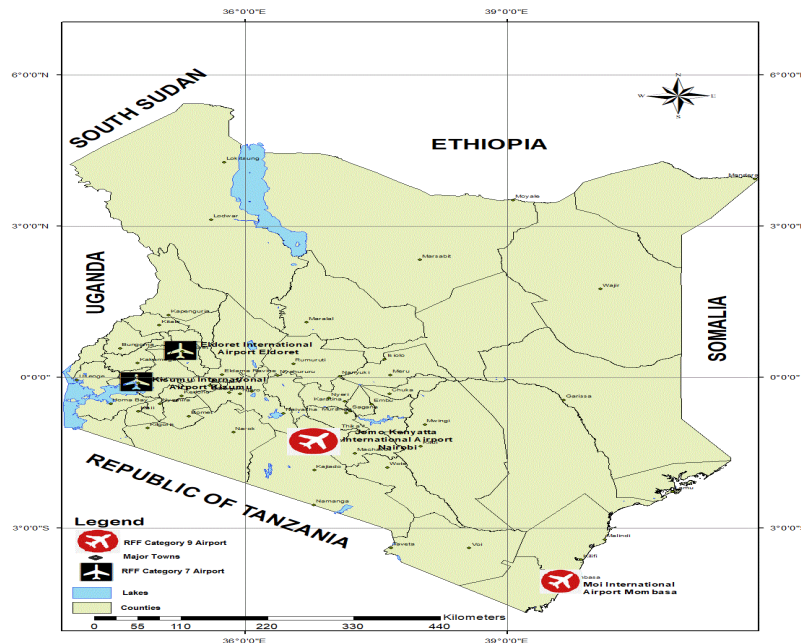


Figure 2: Map of the Study Area Showing the Geographical Location of International Airports

Source: Author (2025)

## Population

The main unit of observation was the employees at Jomo Kenyatta International Airport (JKIA) and Moi International Airport (MIA) in Kenya. Based on the population size of 1,115, the sample size of 285 was extracted from the Krejcie & Morgan (1970) Table.

## Sample and sampling techniques

Sampling involved choosing a representative subset of a larger population to investigate specific characteristics of the entire group. Based on the population size of 1,115, the sample size of 285 was extracted from the Krejcie & Morgan (1970) Table. Quota sampling was used to sample Focus Group Discussion participants, which comprised of 10 participants. The researcher conducted two groups of Focus Group Discussion (FGD) in each airport, one for those staff working at the landside and another for those working at the airside. The sampling methodology for the key informant interview protocol was purposive. In-depth interviews were conducted in person with the officials. Appointments for these key informants was scheduled for the qualitative follow up sample when collecting quantitative data on instruments.

## Data Collection

Data were collected using structured questionnaire administered to different airport employees. Field observation was accompanied by photographic registration to substantiate the information collected. Key Informant Interview Protocol tool and Focus Group Discussions guide were also used to collect data. Both quantitative and qualitative techniques were used to process, analyze and present the data. The qualitative data generated from interview and observation guide were

reported in narrative form along with quantitative presentation and were used to reinforce the quantitative data. Thematic and narration analysis techniques was used to analyze data from Focus Group Discussions and key informants.

### Statistical Analysis

The quantitative data generated from questionnaire was analyzed using both descriptive, and inferential statistics. Descriptive statistics enable users to present and see the data in a more meaningful way, allowing simpler interpretation of the data. Tools such as tables, and figures are examples of tools that were used for summarizing data. Descriptive statistics include measures of central tendency such as mean (average), median and mode, as well as measures of variability such as frequency distributions, variance and standard deviation (SD). According to Gay *et al.*, (2011) the most commonly used method of reporting descriptive survey is by developing frequency distributions, calculating percentages and tabulating them appropriately.

The inferential statistical procedure that was used in this study was t-test, a special case of the analysis of variance (ANOVA) and Newman-Keuls multiple comparisons test using WINKS SDA Software. The t-test was used to determine significant difference between two sample means while the Newman-Keuls multiple comparisons test was used to determine significant difference between more than two sample means.

## FINDINGS

### Structural Anticipatory Action

#### Structural Anticipatory Action for Airport Terminal Building Fire

As shown in Table 2 below, 76% (172) of the respondents at JKIA and 74% (44) in MIA, agreed that heat and smoke detectors have a positive influence in the management of airport terminal building fire. A t-test was performed to ascertain the influence of heat and smoke detectors in the management of airport terminal building fire. The t-test at both JKIA and MIA was statistically significant ( $p < 0.05$ ).

**Table 2: Influence of Structural Anticipatory Action on Airport Terminal Building Fire**

Structural Anticipatory Action	Response	JKIA		MIA	
		Frequency	Percentage	Frequency	Percentage
Heat and Smoke Detectors	Agree	172	76	44	74
	Disagree	9	4	4	7
	Not sure	45	20	11	19
Audio and Visual Flashing Devices	Agree	158	70		76
	Disagree	18	8		5
	Not sure	50	22		19

The key informants at JKIA and observation checklist showed that the airport terminal building is installed with heat and smoke detectors except for T1D terminals, M-Station and cargo. Similarly, the key informants at MIA and observation checklist corroborate the findings that the airport terminal building had not been installed with heat and smoke detectors.

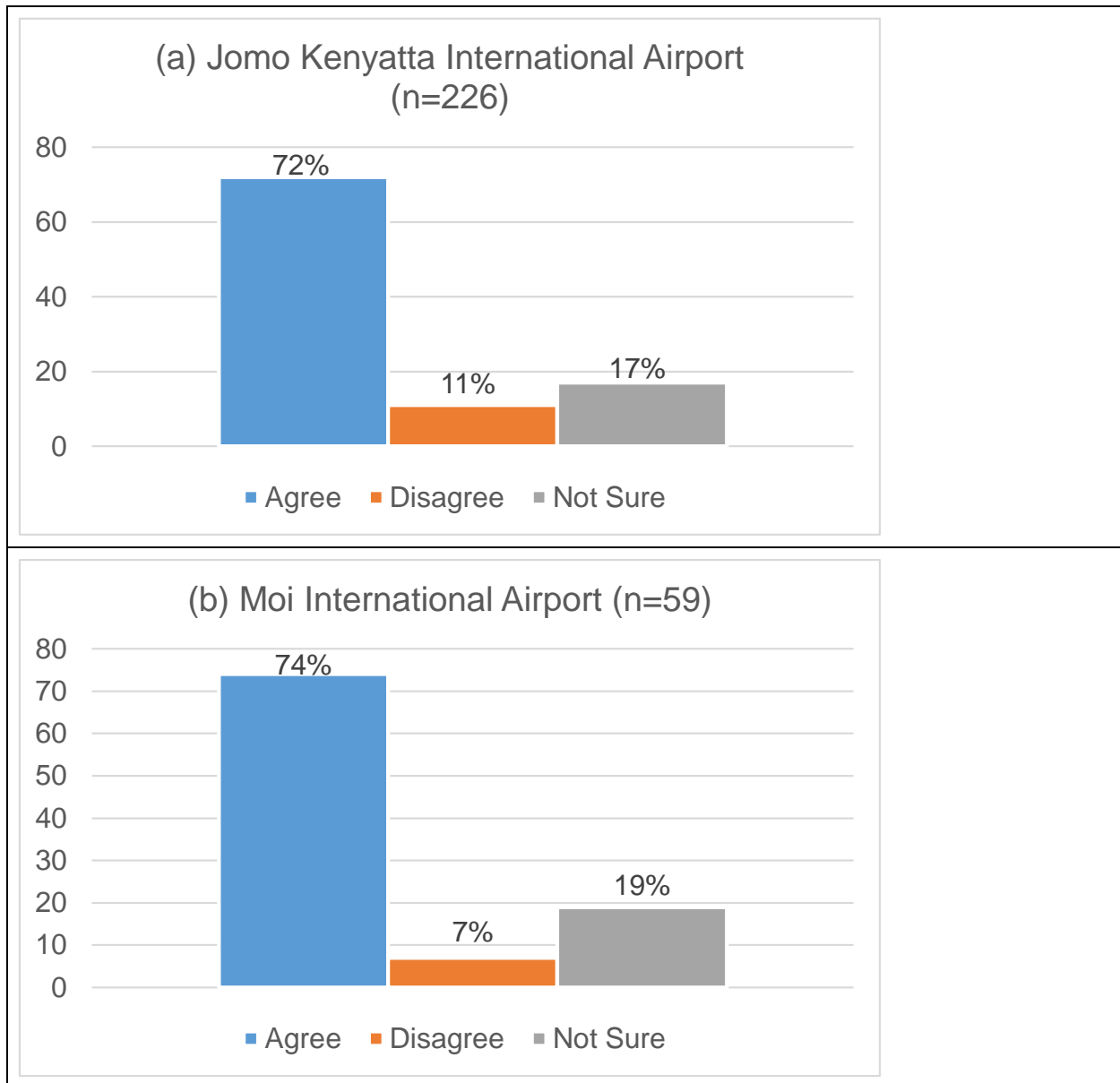
According to Satyanarayana *et al.*, (2023) fire and smoke warning system provide an early opportunity to detect the flame and put it out before it spreads out of control and pose a hazard to human life. The findings underscore the importance of promoting anticipatory action like heat and smoke detectors as they are the cornerstone of early fire detection and offer critical time to protect lives and property (Singh, 2022; Cardemar, 2025). Efforts should also address the barriers to adopting these early fire detection practices to fully realize their potential in enhancing safety at airport terminal buildings.

The study as shown in Table 2 revealed that 70% (158) of the respondents at JKIA and 76% (45) in MIA concurred that the audio and visual flashing devices is vital and that it is key in the management of fire incidents occurring in the airport terminal building. A single sample t-test was performed to ascertain the influence of the audio and visual flashing devices on management of airport terminal building fire. The single sample t-test at both JKIA and MIA was statistically significant ( $p < 0.05$ ).

The key informant protocol during the study revealed that the connection of audio and visual flashing devices to the audio and visual flashing devices at the airport terminal building of both JKIA and MIA was lacking. The lack of audio and visual flashing devices at these airports suggests systemic challenges, such as inadequate infrastructure, or limited financial resources. This disparity limits the capacity for improved anticipatory action and exacerbates vulnerabilities among persons with hearing loss. Addressing these barriers is pivotal in ensuring safety of individuals with hearing impairments by providing critical anticipatory alerts like flashing lights.

### **Structural Anticipatory Action for Airport Fuel Leak and Spills**

As illustrated in Fig. 3, 78% (176) of the respondents at JKIA and 75% (44) in MIA indicated that the emergency shutdown (ESD) system has been useful in minimizing the consequences of potential fuel leak and spill hazards. A t-test was performed to ascertain the influence of the emergency shutdown (ESD) system on fuel leak and spill hazards. The t-test at both JKIA and MIA was statistically significant ( $p < 0.05$ ).



*Figure 3: Influence of Emergency Shut Down (ESD) System on Fuel Leak and Spills*

The key informant protocol conducted at both JKIA and MIA revealed that the Emergency Shut Down (ESD) system has been provided at the aircraft refuelling areas of these airports to minimize the consequences of potential fuel leak and spill multi-hazards by rapidly shutting down the process to prevent escalation and protect personnel, facilities, and the environment. The observation checklist corroborated the findings with the below Photograph 1 showing the fuel emergency shut down (ESD) system at JKIA bay number 10.



*Photograph 1: Emergency Shut Down (ESD) at JKIA Bay No. 10*

### Structural Anticipatory Action for Aircraft Accident

The study established how the crash alarm alerting system provided for rescue and firefighting personnel at the fire station influences management of aircraft accident. Table 3 shows the findings.

**Table 3: Influence of Structural Anticipatory Action on Aircraft Accident**

Structural Anticipatory Action	Response	JKIA		MIA	
		Frequency	Percentage	Frequency	Percentage
Influence of Crash Alarm Alerting System	Agree	163	72	47	80
	Disagree	9	4	5	8
	Not sure	54	24	7	12
Influence of Communication System	Agree	176	78	47	80
	Disagree	9	4	2	3
	Not sure	41	18	10	17
Influence of Avian Radar	Agree	167	74	47	80
	Disagree	14	6	5	8
	Not sure	45	20	7	12

From Table 3 above, 72% (163) of the respondents at JKIA and 80% (47) in MIA agreed that the crash alarm alerting system have a positive influence in the management of aircraft accident. The t-test performed to ascertain the influence of the emergency shutdown (ESD) system on management of fuel leak and spill hazards at both JKIA and MIA was statistically significant ( $p < 0.05$ ).

The key informant revealed that the crash alarm system has been a useful anticipatory alert, enabling firefighters to be alerted to incidents that occur on or near the airport. The observation checklist corroborated this findings whereby the crash alarm was tested during the study visit at both JKIA and MIA. Nowell & Steelman (2014) asserts that during a disaster situation the responders need to communicate and coordinate effectively in order to successfully manage the chaotic state.

The respondents were further queried whether the communication system linking fire station with the control tower and the rescue and firefighting vehicles influence management of aircraft accident. Table 3 shows that 78% (176) of respondents at JKIA and 80% (47) in MIA indicated that the communication system influenced management of aircraft accident. According to the key informant the communication system linking the fire station with the control tower, has been useful in enhancing safety and efficient emergency response. This is in agreement with Almansoori (2018), who asserts that airports have a well-defined emergency communication plans, which maintain coordination between different teams that operate during emergency operations (Almansoori, 2018). These allows a proper channelling of information between different response teams and helps in proper management of a disaster (Rapan *et al.*, 2017). According to Rapan *et al.*, (2017) the use of information technology (IT) systems significantly increase dispersion of necessary information for fast disaster response.

The respondents were further asked whether the Avian radar influence management of aircraft and bird strikes and the results in Table 3 shows 74% (167) of the respondents at JKIA and 80% (47) in MIA, concurring that the avian radar had a positive influence in the management of aircraft and bird strikes. The t-test performed to ascertain the influence of the avian radar on management of aircraft and bird strikes at both JKIA and MIA was statistically significant ( $p < 0.05$ ).

The key informant protocol conducted at both JKIA and MIA revealed that the Avian radar was in JKIA while MIA did not have the radar. The observation checklist corroborated the findings with the below Photograph 2 showing the avian radar installed at station November at JKIA. Part (A) of the photo shows the avian radar antenna system with one dish antenna, which is used to detect and track birds within the vicinity of JKIA. On the other hand, part (B) of the photo shows how the captured information is displayed at the operating system called Accipiter NM1-24D.



Photograph 2: Avian Radar at Station November, JKIA

The Newman-Keuls multiple comparisons test was used to test whether there were significant differences between the sets of means derived from the structural anticipatory action for technological multi-hazard management category samples for Jomo Kenyatta International Airport (JKIA) and Moi International Airport (MIA) as shown in Table 4. According to the Newman-Keuls multiple comparisons test, the means of structural anticipatory action involving heat and smoke detectors, audio and visual flashing devices, emergency shut down system, crash alarm alerting system, discrete communication system, avian radar at both JKIA and MIA influenced management of technological multi-hazards ( $p < 0.05$ ).

**Table 4: Influence of Structural Anticipatory Action on Technological Multi-Hazards**

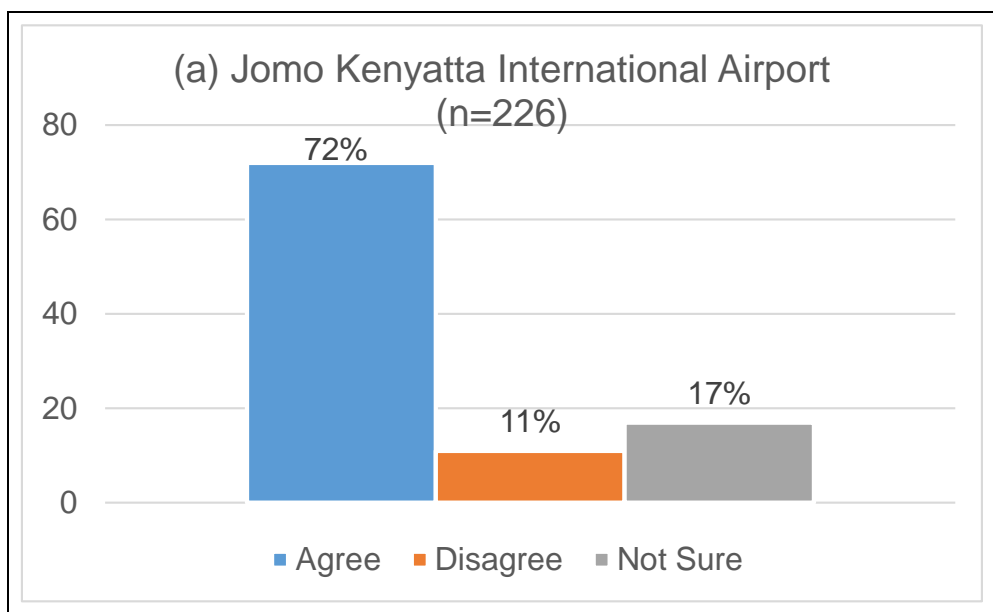
Structural Anticipatory Action	JKIA	MIA
	Average Mean $\pm$ Standard Deviation	Average Mean $\pm$ Standard Deviation
Heat and smoke detectors	0.7611 $\pm$ 0.4274 <sup>a</sup>	0.7458 $\pm$ 0.4392 <sup>r</sup>
Audio and visual flashing devices	0.6991 $\pm$ 0.4597 <sup>a</sup>	0.7627 $\pm$ 0.429 <sup>r</sup>
Emergency shut down system	0.7788 $\pm$ 0.416 <sup>a</sup>	0.7458 $\pm$ 0.4392 <sup>r</sup>
Emergency alerting system	0.7212 $\pm$ 0.4494 <sup>a</sup>	0.7966 $\pm$ 0.406 <sup>r</sup>
Discrete communication system	0.7788 $\pm$ 0.416 <sup>a</sup>	0.7966 $\pm$ 0.406 <sup>r</sup>
Avian radar	0.7389 $\pm$ 0.4402 <sup>a</sup>	0.7966 $\pm$ 0.406 <sup>r</sup>

Means  $\pm$  SD followed by same letter are not significantly different at 95% confidence level.

**Non-Structural Anticipatory Action**

### Non-Structural Anticipatory Action for Airport Terminal Building Fire

The study established how the maintenance of fire detection appliances influences technological multi-hazards management. Figure 4 below, shows that 72% (163) of the respondents at JKIA and 74% (44) in MIA, indicated that the maintenance of fire detection appliances had influence in the management of airport terminal building fire. A t-test performed to ascertain the influence of fire detection appliances maintenance on management of airport terminal building fire for both JKIA and MIA were found to be statistically significant ( $p < 0.05$ ).



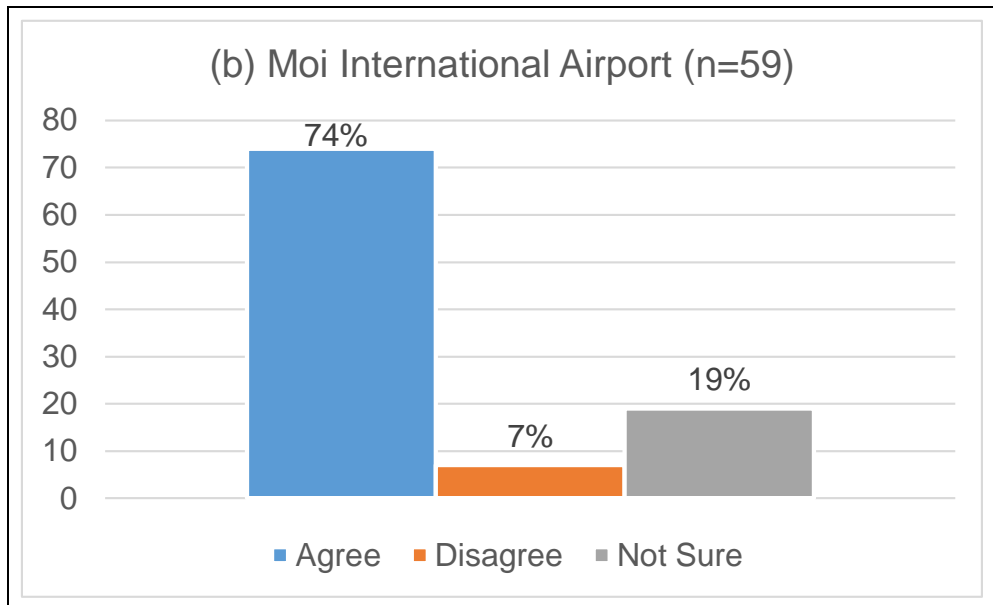


Figure 4: Influence of Maintenance of Fire Detection Appliances on Airport Terminal Building Fire

The key informant protocol conducted at both JKIA and MIA revealed that the fire detection appliances at JKIA are maintained regularly and inspected at least once every twelve months by a competent person. However, the study established that the fire detection appliances have not been installed in MIA, which was also corroborated by the observation checklist.

#### Non-Structural Anticipatory Action for Fuel Leak and Spills

The study established how the basic airside safety training influences management of fuel leak and spills. Table 5 below shows the findings.

Table 5: Influence of Basic Airside Safety Training on Management of Fuel Spills

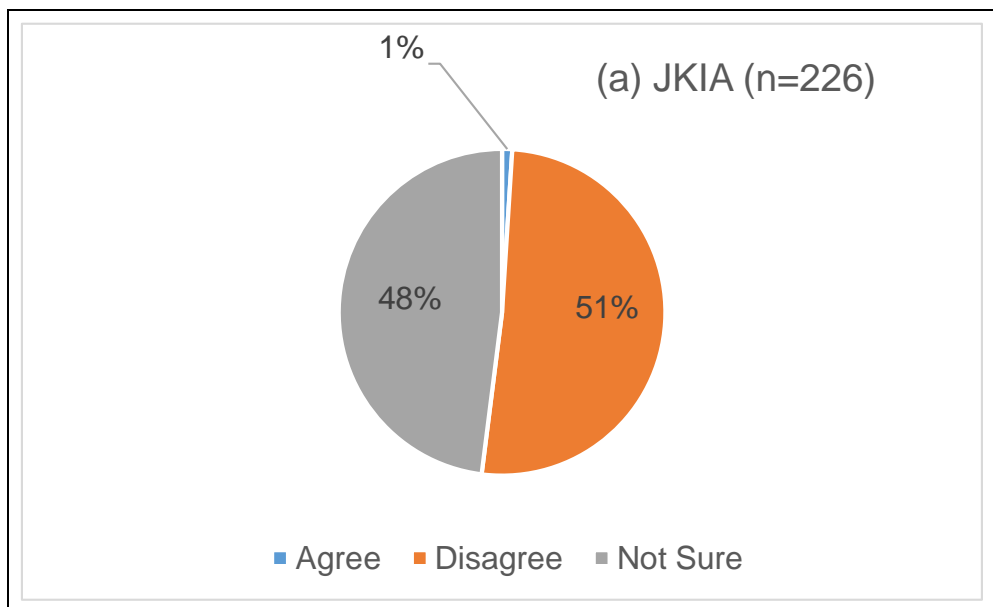
Name of the International Airport	Response	Frequency	Percentage
Jomo Kenyatta International Airport	Agree	167	74
	Disagree	23	10
	Not sure	36	16
Moi International Airport	Agree	45	77
	Disagree	10	17
	Not sure	4	6

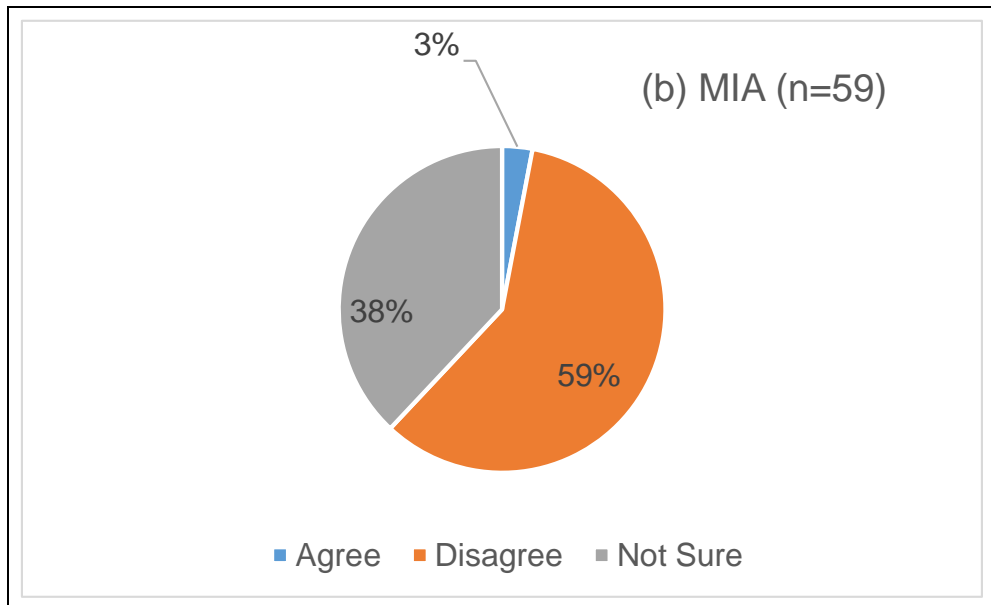
As illustrated in Table 5 above, 74% (167) of the respondents at JKIA and 77% (45) in MIA concurred that the basic airside safety training had a positive influence in the management of fuel leak and spills. A t-test performed to ascertain the influence of basic airside safety training on management of fuel leak and spills at both JKIA and MIA were found to be statistically significant ( $p < 0.05$ ).

The key informant protocol conducted at both JKIA and MIA revealed that the basic airside safety training involved learning about the airport environment, airside safety, rules, aircraft danger zones, fire prevention measures and in the event of a fuel leak and spills, the training taught on the procedures to follow such as the emergency shutdown (ESD) system procedures.

### Non-Structural Anticipatory Action for Aircraft Accidents

The study established how the indigenous knowledge influence management of aircraft and bird strikes. Figure 5 shows the findings of JKIA and MIA respectively.





*Figure 5: Influence of Indigenous Knowledge on Aircraft Accident*

From Figure 5 above, 51% (115) of the respondents at JKIA and 59% (35) in MIA disagreed that the indigenous knowledge influence management of aircraft and bird strikes. On the other hand 48% (108) of the respondents at JKIA and 38% (22) in MIA were not sure. A t-test performed to ascertain the influence of indigenous knowledge on management of aircraft and bird strikes at both JKIA and MIA was not statistically significant ( $p > 0.05$ ).

The key informant protocol conducted at both JKIA and MIA revealed that the indigenous knowledge help predict the seasonal movements, breeding habits, and foraging patterns of different species, allowing for proactive measures to minimize. According the primary data obtained from the key informant protocol, indigenous communities around the airports in Kenya have not been well sensitized, although they are very crucial in terms of acting as eyes and ears on the ground. According to the key informants the indigenous communities can provide valuable information about wildlife sightings, changes in behaviour, and potential hazards, allowing for early intervention and prevention of incidents. The study established that engaging indigenous communities foster a sense of ownership and responsibility for wildlife management, leading to a more sustainable and effective solutions.

The study established that Indigenous knowledge can contribute to bird strike management through traditional ecological knowledge about local bird behavior, habitat use, alongside community involvement in habitat management and monitoring, complementing formal management plans. Research conducted by Musonda *et al.*, (2024) found that lack of staff knowledge at Zambian airports was identified as one major concern necessary to effectively identify and deter wildlife hazards. According to Musonda *et al.*, (2024) knowledge gap can lead to a reactive approach to bird strikes, rather than a proactive one focused on prevention. Indigenous knowledge can complement modern knowledge through utilizing traditional conservation

practices to mitigate risks by managing land use around airports in collaboration with local communities.

The Newman-Keuls multiple comparisons test was used to test whether there were significant differences between the sets of means derived from the non-structural anticipatory action for managing technological hazard category samples as shown in Table 6. According to the Newman-Keuls multiple comparisons test, the means of non-structural anticipatory action involving fire detection maintenance and inspection programme and basic airside safety training at both JKIA and MIA influenced management of technological multi-hazards ( $p < 0.05$ ). Similarly, monitoring birds and wildlife using indigenous knowledge at both JKIA and MIA had no significant influence on the management of technological multi-hazards ( $p > 0.05$ ).

**Table 6: Influence of Non-Structural Anticipatory Action on Technological Multi-Hazards**

Non-Structural Anticipatory Action	JKIA	MIA
	Average Mean ±Standard Deviation	Average Mean ±Standard Deviation
Maintenance and inspection of Fire detections	0.7212±0.4494 <sup>a</sup>	0.7458±0.4392 <sup>r</sup>
Basic airside safety training	0.7389±0.4402 <sup>a</sup>	0.7627±0.4291 <sup>r</sup>
Monitoring of birds and wildlife using indigenous knowledge	0.2301±0.4218 <sup>b</sup>	0.339±0.477 <sup>s</sup>

*Means ± SD followed by same letter are not significantly different at 95% confidence level.*

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

The study revealed that the structural anticipatory measures such as heat and smoke detectors, audio and visual flashing devices, emergency shut down system, emergency alerting system, avian radar and non-structural anticipatory action such as the schedule maintenance and inspection programme for fire detections influence the management of technological multi-hazards. However, not all non-structural anticipatory action influence management of technological multi-hazards, for instance the use of indigenous knowledge to mitigate bird strikes did not significantly have an impact in the study area.

### Recommendations

The study recommends adoption of structural anticipatory measures such as heat and smoke detectors, audio and visual flashing devices, avian radar and a non-structural formulation of a comprehensive policy framework that encourages the adoption of anticipatory technologies to enhance management of man-made multi-hazards at airports in Kenya.

### **Acknowledgment**

We wish to express our sincere thanks to Kenya Airports Authority and National Commission for Science, Technology and Innovation (NACOSTI) for permitting us to carry out this research work in Jomo Kenyatta International Airport and Moi International Airport, Masinde Muliro university, Directorate of Postgraduate studies for providing the required facilities and working environment through School of Disaster Management and Humanitarian Assistance, for making the research a success.

### **Conflicts of Interest Declaration.**

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

## REFERENCES

- Akerkar, S., Ayers, J., Boswell, C., DeCoster, M., Jimerson, A., & Alegre, L. W. (2020). *Early Warning for Early Action: Toward More Behaviorally Informed Early Warning Systems. Resilience Evaluation, Analysis and Learning (REAL) Associate Award.* <https://preparecenter.org/wp-content/uploads/2023/01/EARLY-WARNING-FOR-EARLY-ACTION-Toward-More-Behaviorally-Informed-Early-Warning-Systems.pdf>
- Almansoori, M. K. (2018). Factors Impacting Crisis Preparedness At Airports. *The Journal of Organizational Management Studies*, 2018(2018), 1–7. <https://doi.org/10.5171/2018.824277>
- Amboka, A. T. M. (2015). *Factors affecting disaster preparedness at Moi International Airport, Mombasa County, Kenya.* [University of Nairobi]. [https://erepository.uonbi.ac.ke/bitstream/handle/11295/90506/Amboka\\_Factors affecting disaster preparedness at Moi International Airport% 2C Mombasa County% 2C Kenya.”.pdf?sequence=3&isAllowed=y](https://erepository.uonbi.ac.ke/bitstream/handle/11295/90506/Amboka_Factors%20affecting%20disaster%20preparedness%20at%20Moi%20International%20Airport%20Mombasa%20County%20Kenya.pdf?sequence=3&isAllowed=y)
- Arc Refuellers. (2025). *Importance of Emergency Fuel Shutoff in Aircraft Refueling.* <https://arc-refuellers.be/emergency-fuel-shutoff/#:~:text=Having an emergency fuel shutoff,from fuel leaks or spills.>
- Cardemar, M. (2025). *Early Action prevents unnecessary call.* Consilium Safety. <https://www.consiliumsafety.com/en/8587/>
- Costella, C., Jaime, C., Arrighi, J., Coughlan de Perez, E., Suarez, P., & Aalst, M. van. (2017). Glossary: Courting Catastrophe: Humanitarian Policy and Practice in a Changing Climate. *IDS Bulletin*, 48(4), 30–46. <https://doi.org/10.19088/1968-2017.158>
- El-Sayed, A. F. (2019). *Bird Strike in Aviation: Statistics, Analysis and Management.* John Wiley & Sons Ltd. <https://doi.org/10.1002/9781119529835>
- EM-DAT. (2020). *Technological Disasters Issue No. 60 Cred Crunch Newsletter.* EM-DAT. <https://www.emdat.be/publications/>
- Gay, L. R. G., Mills, P. W., & Airasian. (2012). *Education research: competencies for analysis and application* (10th ed.). Pearson Education, Inc. [https://yuli-elearning.com/pluginfile.php/4831/mod\\_resource/content/1/Gay-E Book Educational Research-2012.pdf](https://yuli-elearning.com/pluginfile.php/4831/mod_resource/content/1/Gay-E%20Book%20Educational%20Research-2012.pdf)
- Goin, J. (2023). *Kenya Airport Authority says it has restored normal flight operations.* Citizen TV. <https://youtu.be/hk4TyT80DBA>
- Harwell, M. A., & Gentile, J. H. (2006). Ecological Significance of Residual Exposures and Effects from the Exxon Valdez Oil Spill. *Integrated Environmental Assessment and Management*, 2(3), 204-246.
- Idris, J., Eyu, G. D., Ahman, Z., & Chukwuekezie, C. S. (2013). Oil Spills and Sustainable Cleanup Approach. *Australian Journal of Basic and Applied Sciences*, 7(14), 272–280.

- International Civil Aviation Organization. (2012). *Airport Service Manual Doc 9137-AN/898 Part 3 Wildlife Control and Reduction* (Fourth). 999 University Street, Montréal, Quebec, Canada H3C 5H7. [www.icao.int](http://www.icao.int).
- International Civil Aviation Organization. (2015). *Airport Services Manual Doc 9137-AN/898 Part 1 — Rescue and Firefighting*. Aviation Organization 999 University Street, Montréal, Quebec, Canada H3C 5H7. <http://ufuav.asn.au/wp/wp-content/uploads/2016/11/operations-manual.pdf>
- International Civil Aviation Organization. (2022). *Guidance Material on Airport Preparedness for Effective Humanitarian Assistance and Disaster Response*. <https://www.icao.int/HADRA/Documents/HADRA-Guidance-FINAL-May2022.pdf>
- International Federation of Red Cross and Red Crescent Societies. (2021). *Disaster Relief Emergency Fund: 2020 Annual Report*. <https://www.ifrc.org/sites/default/files/2021-06/IFRC-DREF2020-AnnualReportwithFinancial-3.pdf>
- Janzwood, S. (2020). *Evacuating communities affected by disasters during future COVID-19 waves. Pandemic Shock: Brief #4, Inter-Systemic Cascades*. Cascade Institute. <https://cascadeinstitute.org/wp-content/uploads/2020/08/%0AJanzwood-Brief-4-v2.0-Aug31.pdf>
- Krejcie, R. V, & Morgan, D. W. (1970). *Determining Sample Size for Research Activities*. Educational and Psychological Measurement. [https://home.kku.ac.th/sompong/guest\\_speaker/KrejcieandMorgan\\_article.pdf](https://home.kku.ac.th/sompong/guest_speaker/KrejcieandMorgan_article.pdf)
- Metz, I. C., Ellerbroek, J., Mühlhausen, T., Kügler, D., & Hoekstra, J. M. (2020). The bird strike challenge. *Aerospace*, 7(3), 1–20. <https://doi.org/10.3390/aerospace7030026>
- Musonda, K. E., Joe, K. C., Zingapeta, E., & Njovu, E. (2024). Bird Hazard Management At Zambian Airports: A Critical Analysis Of Current Practices And Future Directions. *IOSR Journal of Environmental Science Toxicology and Food Technology*, 18(11), 08–22. <https://doi.org/10.9790/2402-1811020822>
- Nolan, D. P. (2011). Emergency Shutdown. In *Handbook of Fire and Explosion Protection Engineering Principles* (pp. 119–126). <https://doi.org/doi:10.1016/b978-1-4377-7857-1.00011-2>
- Nowell, B., & Steelman, T. (2014). Communication under Fire: The Role of Embeddedness in the Emergence and Efficacy of Disaster Response Communication Networks. *Journal of Public Administration Research and Theory*, 25(3), 1–24. <https://doi.org/10.1093/jopart/muu021>
- Ochieng, D. (2015). *The Influence of Emergency Preparedness on Response Strategies*. (Issue February). <https://doi.org/10.13140/RG.2.2.36351.56485>
- Otieno, P., Mburu, C. M., Karanja, B., Otieno, P., & Karanja, B. (2024). Influence of Compliance with Fire Safety Standards and Regulations in Fire Safety Management

- Performance at International Airports in Kenya. *American Journal of Environment Studies*, 7(5), 1–14.
- Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. L., Ballachey, B. E., & Irons, D. B. (2003). Long-Term Ecosystem Response to the Exxon Valdez Oil Spill. *Long-Term Ecosystem Response to the Exxon Valdez Oil Spill*, 302(5653), 2082-2086.
- Phillips, A. C., Majumdar, S., Washburn, B. E., Mayer, D., Swearingin, R. M., Herricks, E. E., Guerrant, T. L., Beckerman, S. F., & Pullins, C. K. (2018). Efficacy of avian radar systems for tracking birds on the airfield of a large international airport. *Wildlife Society Bulletin*, 42(3), 467–477.
- Phillips, C. A., Caldas, A., Cleetus, R., Dahl, K. A., Declet-Barreto, J., Licker, R., Merner, L. D., Ortiz-Partida, J. P., Phelan, A. L., Spanger-Siegfried, E., Talati, S., Trisos, C. H., & Carlson, C. J. (2020). Compound climate risks in the COVID-19 pandemic. *Nature Climate Change*, 10(7), 586–588. <https://doi.org/https://doi.org/10.1038/s41558-020-0804-2>
- Rapan, M., Štimac, I., & Steiner, S. (2017). *Implementation of IT systems for emergency management at the Zadar Airport*. [https://bib.irb.hr/datoteka/872168.Implementation\\_of\\_IT\\_Systems\\_for\\_Emergency\\_Management\\_at\\_the\\_Zadar\\_Airport.pdf](https://bib.irb.hr/datoteka/872168.Implementation_of_IT_Systems_for_Emergency_Management_at_the_Zadar_Airport.pdf)
- Raymond, C., Horton, R. M., Zscheischler, J., Martius, O., AghaKouchak, A., Balch, J., Bowen, S. G., Camargo, S. J., Hess, J., Kornhuber, K., Oppenheimer, M., Ruane, A. C., Wahl, T., & White, K. (2020). Understanding and managing connected extreme events. *Nature Climate Change*, 10(7), 611–621. <https://doi.org/https://doi.org/10.1038/s41558-020-0790-4>
- Satyanarayana, M., Sai Bhargav, N., Prasanna, P. L., Priyadarshini, M., & Maharshi, M. (2023). Fire Detection and Automatic Water Sprinkler System Using Iot. *International Journal of Creative Research Thoughts*, 11(4), e747–e750. [www.ijcrt.org](http://www.ijcrt.org)
- Shi, K., Goto, Y., Zhu, Z., & Cheng, J. (2013). Anticipatory Runway Incursion Prevention Systems. *IEICE Transactions on Information and Systems*, E-96-D(11), 2385–2396. <https://doi.org/https://doi.org/10.1587/transinf.E96.D.2385>
- Singh, R. P. (2022). A Brief Study on Alarm System of Fire. *International Journal of Innovative Research in Computer Science & Technology*, 10(2), 405–408. <https://doi.org/10.55524/ijircst>.
- Sumathi, N., V, K. K., & M, R. S. (2018). Analysis of Fire Accidents in Airports and Its Mitigation Measures. *International Journal of Latest Technology in Engineering, Management & Applied Science*, 7(4), 90–96. [https://www.researchgate.net/publication/324154220\\_Accidents\\_in\\_Airports\\_and\\_Prevention](https://www.researchgate.net/publication/324154220_Accidents_in_Airports_and_Prevention)

- Tozier de la Poterie, A., Clatworthy, Y., Easton-Calabria, E., Coughlan de Perez, E., Lux, S., & van Aalst, M. (2022). Managing multiple hazards: lessons from anticipatory humanitarian action for climate disasters during COVID-19. *Climate and Development*, 14(4), 374–388. <https://doi.org/10.1080/17565529.2021.1927659>
- United Nations. (1992). Agenda 21 - Sustainable Development Goals (SDGs). *United Nations Conference on Environment & Development Rio de Janeiro, Brazil, 3 to 14 June 1992 Agenda 21*. <https://sdgs.un.org/sites/default/files/publications/Agenda21.pdf>
- United Nations International Strategy for Disaster Reduction. (2007). Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. *World Conference on Disaster Reduction (A/CONF.206/6)*. [https://www.unisdr.org/files/1037\\_hyogoframeworkforactionenglish.pdf](https://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf)
- United Nations International Strategy for Disaster Reduction. (2015). Sendai Framework for Disaster Risk Reduction. *A/CONF.224/CRP.1*, 1–36. [https://www.preventionweb.net/files/43291\\_sendaiframeworkfordrren.pdf](https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf)
- United Nations Office for Disaster Risk Reduction. (2026). *Sendai Framework for Disaster Risk Reduction 2015-2030*. UNDRR Publications. <https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030>
- Zscheischler, J., Westra, S., van den Hurk, B. J., Seneviratne, S. I., Ward, P. J., Pitman, A., AghaKouchak, A., Bresch, D. N., Leonard, M., Wahl, T., & Zhang, X. (2018). Future climate risk from compound events. *Nature Climate Change*, 8(6), 469–477. <https://doi.org/https://doi.org/10.1038/s41558-018-0156-3>
- Zuluaga, J. A. F., Pabón, J. D. O., Bonilla, J. F. V., & Montoya, O. L. Q. (2019). Meteorological Risk Early Warning System for Air Operations. *International Symposium on Technology in Society (ISTAS) Proceedings*. <https://sci-hub.hlgczx.com/10.1109/istas48451.2019.8938012#gsc.tab=0>

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