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Anti-unmanned aerial vehicle detection system for airports: aviation and national security perspective

John Shivute Anghuwo[1] · Peter Imanuel[1] · Sam Shimakeleni Nangolo[1]

Abstract

Unmanned Aerial Vehicles gained significant popularity in the last decade as demonstrated by their wide usage in various fields. From around the year 2001, the usage of unmanned aerial vehicles' technology was mainly confined to law enforcement agencies such as the military, police, and customs. In the contemporary, terrorists have also been observed to be using unmanned aerial vehicles to attack aviation facilities. The current paper examines the levels of vulnerability of the Namibian airports to possible intrusion and attack from unmanned aerial vehicles, a situation that could pose a serious threat to aviation and national security. Adopting a qualitative research approach, the study made use of a questionnaire and semi-structured interview guide to collect primary data from the participants. Microsoft Excel was used to analyse the data. The study establishes that Namibian airports are prone to attacks from unmanned aerial vehicles as there are no anti-unmanned aerial vehicle detection systems installed at all airports in the country. Thus, there is clear evidence that the Namibia Civil Aviation Authority and the Namibian Airport Company's regulations and policies on aviation safety and security did not prioritise the installation of anti-unmanned aerial vehicle detection systems at all airports in Namibia. The paper suggests that, in order to enhance aviation safety and security, a joint civil/military Information Technology Unit, responsible for spoofing, detection, and the monitoring of illicit unmanned aerial vehicle operations should be set up and operations activated at all airports and other public infrastructures in Namibia.

Keywords UAVs · Airports' vulnerability · Anti-unmanned aerial vehicle detection system · UAV attack · Aviation safety and security · National security

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Introduction

Unmanned Aerial Vehicles (UAVs) have significantly gained increased popularity in the last decade as demonstrated by their adoption and utilisation in varied fields of service provision. The range of usage for UAVs spans from agriculture (crop farming and monitoring), medical delivery services, airfield inspections to more sophisticated combat application (Lin et al. 2022; Pathak, 2020.; & Straub 2014). Despite the endless benefits that UAVs have provided to the end-users, UAV technology has also been observed to be posing a serious security threat within the aviation security (AVSEC) sector, as well as to national security in general. In this regard, for example, terrorists and individuals with bad intensions have begun using UAV technology in conducting malicious activities, which have been observed to have resulted in numerous disruptions of airport operations and activities globally. These malicious activities vary from physical attacks, in which unmanned aerial vehicles have been used to carry out attacks on airports' physical infrastructures (PI), which led to the disruptions in operations at airports including cyberattacks on airports' Artificial Intelligence (AI) and surveillance systems where UAV technology has been used in this regard. Cases of intentional midair collision between UAVs and manned aircraft have also been reported in different parts of the globe (Fox 2020).

Kotkova (2022) highlights that between 19 and 21 December 2018, several incidences of UAV intrusions or attacks on major airports in Europe were reported, which led to the closure of those facilities for several hours. It was further reported that one of such incidents happened at London's Gatwick Airport and this resulted in approximately 1000 flights being cancelled or delayed. Similar incident was also reported at Frankfurt Airport in Germany, where a UAV attack caused disruption in air traffic flow for two hours before the airport was finally reopened (Swinney and Woods 2022). The incident resulted in financial losses for the airport due to the grounding and diversion of flights. Over the years, airports' PI have suffered and survived frequent attacks from Improvised Explosive Devices (IEDs), chemical, biological and radiological (CBR) weapons, and light weapons. These events have raised serious concern regarding the safety of aviation facilities from terrorist attacks (Urban 2021). Airports' PI continue to be targeted by terrorists and criminal syndicates, with the chief goal of causing instabilities in the general operations of airports. Urban further submits that, as part of aviation and national security initiatives, individual states around the world have taken a serious stand and have implemented countermeasures at the airports to defend themselves against IEDs, CBRs and other related weapons. Ultimately, the protection of airports' PI is very crucial in the development of counterterrorism strategies at every airport, especially those that are designated as ports of entry/exit.

Apart from the threat posed by IEDs, CBRs and light weapons, the technological advancements have also brought along a new threat in the form of UAVs, especially when they are operated by terrorists or criminal syndicates to target airports' physical infrastructure (Schneider et al. 2021). Given the growing tension within the geopolitical sphere, and the war events globally, terrorists and criminal syndicates have made aviation their prime target and UAVs are being used as weapons for targeting civilian airports' PI (Fox 2021). We, thus here, examine the aviation security measures set up

at all airports in Namibia, specifically meant as anti-UAVs detection systems in order to determine the extent to which such facilities might be prone to UAV intrusions, as well as determine the extent to which this might impact aviation security and national security. The main objective of the study was to determine whether the Namibian airports, designated as ports of entry/exit, have established security measures capable of countering possible rogue UAV attacks. It was however, not the scope of this study to conduct an analysis of the different anti-UAV detection systems such as radar, acoustic, visual or radiofrequency sensors that are available on the market. The results of this study, presented here as recommendations to the Namibia Airports Company (NAC), exhort the NAC to prioritise the installation of suitable and efficient anti-UAV detection systems at airports in the country, especially those that are designated as ports of entry/exit.

This paper is organised in the following manner: Sect. 2 engages with the relevant extant literature on UAVs and their utilisation in different sectors, including and not limited to anti-UAV detection systems. Sect. 3 describes the methods used for data collection and analysis, while Sect. 4 presents the results and discussions of the findings. Finally, Sect. 5 provides the summary, conclusion and recommendations from the study.

Literature review

Applications of unmanned aerial vehicles

To sustain airports' safety and functionality, airport owners and operators are required to conduct inspections of runways, taxiways, and the rest of the airport's maneuvering areas several times a day to ensure that these areas are free of Foreign Objects and Debris/Damages (FODs). Throughout the years, this practice has been successfully conducted through the utilisation of different techniques and methods of airfield inspections. For the most part, humans (personnel) and machines have been utilised to conduct these tasks (Klisauskaite 2023). Traditionally, runway inspection is normally conducted using Airport Monitoring Vehicle (AMV), which is driven on the runway or taxiways at a very high speed in order to check for the possible presence of FODs (Tomic et al. 2020). As explicated by Congress et al. (2023), the traditional method of inspection was observed to be faster compare to other inspection methods as it requires only sampled units to be inspected at any given time. However, in some cases, the AMVs, as part of traditional method, can miss out potential FODs that can threaten the safety of aircrafts during take-off, landing, and the taxing process.

With contemporary trends and developments in new technology, UAV technology has emerged as a critical tool in operations in various fields including, but not limited to, runway and airport physical infrastructure inspection. Despite such developments, there is a challenge as it takes a bit of time to process the collected data, using UAVs for infrastructural inspections. The major strength of this technology is that it offers a comprehensive digital footprint and an immersive visualisation experience of the whole airports' PI, which can be reviewed from time to time using pictures, videos, and narrations (Congress et al., 2023). As such, it comes as no surprise that airport

operators around the world have adopted UAVs for runway inspections as a preferred method that saves time, costs, and provides an increase in the footprint being inspected. The preference for this technology has largely been because UAVs are equipped with different sensors such as visible, infrared, multi-spectral, and hyperspectral cameras, and light detection and ranging (LIDAR) that can be used to inspect a large area within a relatively short period of time, providing the operators with ample time to review the collected data timeously. The adoption of UAVs to perform runway inspections, has significantly reduced instances of runway interferences by AMVs, as well as witnessed a reduction in air traffic flow disruption between take-off, landing and taxing processes (Congress et al., 2023).

UAV technology has also been adopted for use in a wide range of different industries such as within the agricultural sector, where it is being utilised in various contexts ranging from crop irrigation and soil moisture monitoring, livestock management, fertilisation, and weed management among other tasks. This smart technology has been quite beneficial to the 21st century's farmers because it has literally turned the traditional methods of farming into precision farming, a practice that reduces costs while at the same time increases the productivity of the farmers (Boursianis et al. 2022). Furthermore, both communal and commercial farmers have been observed to have increased their agricultural productivity through adopting smart farming technologies such as the use UAV technology, and in the process, have contributed positively to global food security. The technology has become so handy that individual farmers are able to monitor the condition of their crops remotely, and are able to execute processes such as irrigation, administering pesticides and fertilisers, while at the same time reducing costs, saving time, and reducing the hazards effects of coming into physical contact with these products (Devi et al. 2020). Outside of farming, UAV technology has also found its way into medical services within which UAVs are being used to deliver medicines, healthcare, and health-related services to remote areas that are inaccessible by the normal means of transportation. UAVs within the medical field have been used to perform tasks such as the diagnosis and treatment of different medical cases in remote areas, as well as for the surveillance; and monitoring of disaster sites with possible biological contamination (Rosser et al. 2018).

With the global increase in challenges related to climate, the UAV technology has also been used in areas of disaster risk management, especially for flood and drought related assessments in countries that are heavily impacted by climate change. As such, UAVs have become very useful to sectors entrusted with disaster risk management because of their capacity to provide objective and relevant information through the mapping of the affected areas, rapidly and effectively collecting data that allows for a quick assessment of the impacted areas to be made (Restas 2018). Sectors such as forestry and nature conservations have also incorporated the use of UAV technology as part of their mitigation strategies or methods for combating poaching activities in several countries in Southern Africa. The integration of UAVs as part of anti-poaching strategies has evinced positive results, as poaching activities have significantly dropped in countries where UAV technology has been implemented (Penny et al. 2019).

Unmanned aerial vehicles technology as a threat to AVSEC and national security

The preceding sections explored the manners in which UAV technology has been adopted in different fields and sectors with positive ramification. The current sections explored the various manners in which UAV technology can pose a potential threat to AVSEC and national security.

Contemporary instabilities within global geopolitics and the expansion of terrorist affiliated organisations worldwide, has left aviation industry vulnerable to constant threats of unlawful acts directed towards the airports' PI by individuals and terrorist organisations. This is because the aviation industry has in many ways been the primary target for terrorists and individual groups with criminal intentions, and who believe that the aviation sector provides a visible and profound platform to send out their message, whose primary objective is to instill fear amongst the general public and force them to lose trust in the aviation industry as a key means of transport (Baker, n.d.). One example of such incidents is the terrorist attack on the World Trade Center in New York, USA in September 2001. In this instance, terrorists hijacked airplanes and used them as weapons to kill thousands of civilians and, in the process, reduced the twin towers to rumble (Gaibulloev and Sandler 2019). Around the year 2001, UAV technology had largely been confined to law enforcement agencies such as the military, police, and customs services. However, with the emergence of new and innovative technologies, especially in the area of Artificial Intelligence, UAV technology has become readily available to the layman. This has, however, generated serious concerns for aviation safety and security. The availability of UAVs and their access and utilization by the public has witnessed increased number of UAV intrusion incidents being reported at airports around the world (Schneider et al. 2021).

Incidents of UAV intrusion and attacks have not been limited to airports' PI only, but such threats have also been observed to extend to other sectors of the General Aviation (GA) flight operations such as: humanitarian aid flights, flight training, agriculture, recreational flights, environmental conservation, business flights, bush flying, and experimental aircrafts. Despite the existence of the aviation regulations governing the operation of UAVs in controlled airspaces, airports are still lagging behind with regards to the development and implementation of safety and security measures that are specifically designed to deal with UAV intrusions and attacks at airport facilities. In the past, criminals and terrorists carried out attacks on airports' PI using UAVs of different kinds and sizes, and that were weaponized with IEDs and CBR. Nowadays, the report of any UAV intrusion within the vicinities of airports and in particular the airports' PI, can result in flight disruptions and this often leads to the closure of airports, closure as airport authorities would be unable to immediately establish whether such UAVs are weaponised or not (Pyrgies 2019).

The impact of UAVs on AVSEC is directly proportional to concerns surrounding national security in many countries worldwide. Ultimately, in order for these countries to ensure the safety and security of their people, extensive analyses of the threats posed by UAVs have been conducted. Based on the recommendations of such studies, tactical countermeasures have been developed in order to militate against such forms of threats. Such tactical countermeasures are developed as part of the national security strategic objectives for such nations. However, with the availability

of internet access to the layman, amateur developers continue to develop UAVs that are still posing serious threats to both AVSEC and national security (Adnan and Khamis 2022). Hence, the misuse of UAV technology by terrorists and individuals with bad intentions has resulted in the infringement of national security measures in many countries globally, especially countries that do not have laws and regulations related to UAV operations in force.

Airports' anti-unmanned aerial vehicle detection systems

Globally, airports' PI have fallen victim to UAVs attacks by criminals and terrorists alike who make use of UAVs of different kinds and sizes to carry out such attacks. These attacks by means of UAVs have, in many cases, resulted in serious disruptions in flight operations at airports, which has ultimately resulted in huge financial losses by airports (Kotkova 2022). Such attacks have been mostly successful, largely because most of the attacked airports did not have anti-unmanned aerial vehicle detection systems and related sensors installed. On the other hand, it is very challenging to detect small commercial UAVs due to their small radar cross-section. This makes it nearly impossible for the radar systems, and other sensors to pick up any electromagnetic reflectivity from such smaller gadgets, even in cases where airports are actually equipped with radar system (Systems, n.d.). This situation, however, prevails within a context in which anti-unmanned aerial vehicle detecting systems and other related sensors are readily available on the market, and could be easily adopted to service the security needs of individual airports. These systems include, but are not limited to: Radio Detection And Ranging (RADAR); Radio Frequency (RF); Acoustic; Laser Detection And Ranging (LiDAR/LADAR); Imagery (electrooptical), and Thermal and so on (Swinney and Woods 2022). The systems identified here are not limited in use to airports only, but they have also been effectively used elsewhere, for example, some of them are being used by state intelligence agencies and Very Important Person(s) (VIP) protection units, for the protection of Heads of States and other dignitaries. However, if the anti-unmanned aerial vehicle detecting systems are not properly set up, they can be compromised, as demonstrated by the case of the alleged failed assassination attempt on the Venezuela's president Nicolás Maduro in 2018, in which a weaponised UAV was used (Escribà-Folch 2024).

Apart from the failed assassination attempt indicated above, Swinney (2022) also identifies 11 other cases of UAV intrusions between 2018 and 2021 at different airports in Europe, where most of these instances were recorded as disruptive. If the UAV market continues to grow exponentially as it is currently doing, and without proper regulatory control, UAVs will surely continue to pose a serious threat, especially at airports and within general aviation. Perhaps it is this reality that many countries around the world have awakened to, and are thus are trying to promulgate and enforce more stringent legal and regulatory frameworks on the operation of UAVs at airports and within the general aviation sector, This is in order to ensure that mandatory safety protocols that are in place will minimise the disruptions of operations at airports. This can be achieved through the upgrading of anti-unmanned aerial vehicle detection systems for airports and the general aviation sector (Pascarella et al. 2023).

Methods used for data collection and analysis

The study employed a qualitative research approach to collect the primary data from the respondents at five (5) major airports in Namibia. A questionnaire and semi-structured interviews were the research instruments. The Microsoft Excel programme was used to analyse the collected data. Secondary data was collected through the analysis of journal articles, research reports, and other comparable materials, as well as credible websites which contained information that was relevant to the current research. The researchers went on further to evaluate the Namibian Aviation Act No 16 of 2016 and specifically, the sections that explicate the regulatory policies on operation UAVs in the country.

Results and discussion

The first question posed to interviewees during the interview sessions was: *Is there an anti-unmanned aerial vehicle detecting system and/or mitigation measures in place or the capacity for detecting UAV intrusions at major airports in Namibia?* The majority of the responses provided by respondents intimated that there were no anti-unmanned aerial vehicle detection systems, mitigation measures nor the capacity in place for detecting UAV intrusions at all of the five (5) major airports in the country. They further indicated that AUVs were a new technology on the market, and that they however, have not seen any reinforcement drives for such systems from the Namibian regulatory perspective. The respondents also pointed out that they were aware of the dangers that the UAV technology posed to aviation safety and security. Be that as it may they further appreciated that UAVs technology has both positives and negatives. On the one hand UAVs threaten aviation safety while on the other, the technology can be a very useful security measure as demonstrated by how they are currently being used elsewhere for runway, taxiways, and other airports' PI inspection. The respondents indicated that Namibia does not seem to pose a real threat to any other state, and perhaps that is the reason why security is a bit lax as evinced by the fact that there are no anti-unmanned aerial vehicle detection systems and related sensors installed at major Namibian airports.

The second question of the survey was: *Do you believe that there is a need to amend airports' Standards Operational Procedures (SOPs) regarding the operations of illicit UAVs in Namibia?* Fig. 1 provides the percentage distribution of the results/ responses to the question.

As demonstrated in Fig. 1, 44% of the respondents agreed that it was imperative to amend SOPs at airports, and their sentiments are also supported by 22% of the respondents who strongly agreed with the propositions made in the question. However, 25% and 8.5% of the respondents disagree and strongly disagree with this proposition, respectively, and this represent a difference of opinion. Those who agreed to the proposition constitute the large percentage distribution summation of 66%. They indicated that there is need for the amendment of the existing safety and security policies at airports, specifically the considerations for incorporating anti-unmanned aerial vehicle detection and mitigation measures and systems in the airports' standard
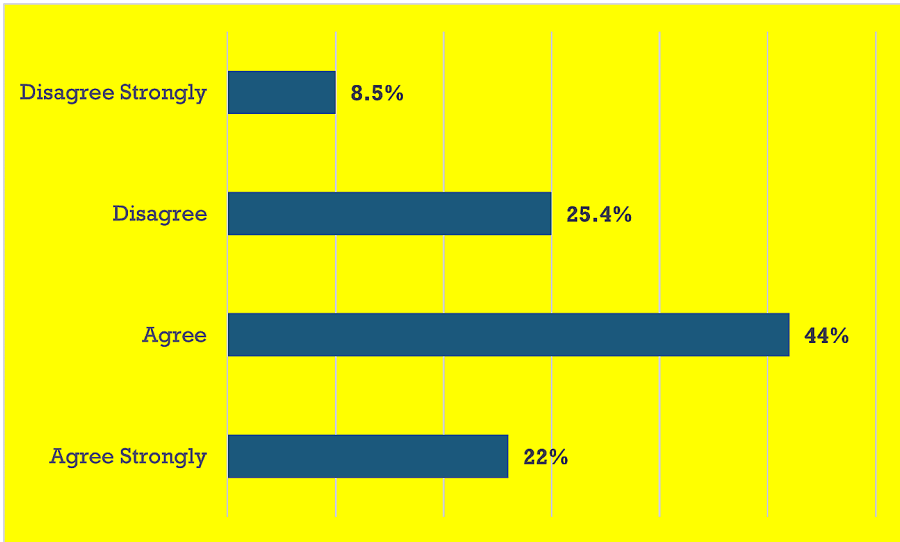
Fig. 1 Amendment of airports Standard Operation Procedures (Source: Authors' Own work)
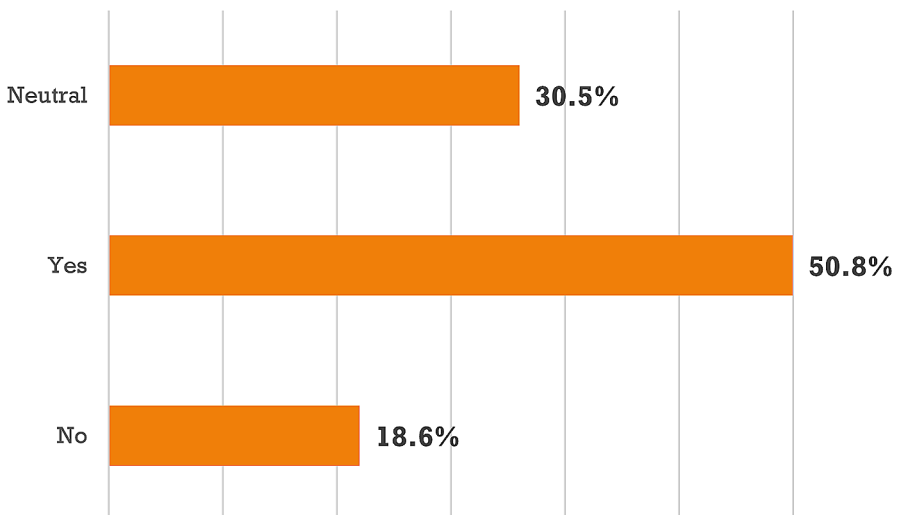
Fig. 2 Vulnerability of airports from UAV attacks (Source: Authors' Own work)

operational procedures, and as part of the national civil aviation regulations in order to enhance aviation safety and security as well as bolster national security.

The third question of the survey was: *Do you believe that airports in Namibia are vulnerable to attacks from terrorist groups or individuals using available UAVs' technology?* A percentage distribution of the responses to the question is provided in Fig. 2 .

There is agreement amongst 50.8% of respondents who believe that Namibia's airports are prone to cyber-attacks from terrorists and individuals with bad intentions, especially in the contemporary environment within which UAV technology can be used to cause disruptions in operations at airports. 30.5% of the respondents were neutral in their response to the question, while 18.6% did not agree with the propositions of the question. Based on the results above, the study believes that airports in Namibia are not equipped with multispectral UAV detection systems such as: radio frequency detection sensors, visual sensors, acoustic sensors, and radar detection sensors as part of safety and security countermeasures to curtail or thwart rogue UAV operations. The findings are in line with the observations made by Yasmine et al. (2023) who submit that, due to the dramatic increase in the production and operation of UAVs, the strengthening and securing of aerial security specifically around airports' physical infrastructures (PI) has become an urgent and mandatory task for airport owners and operators. The study further submits that there exists a huge gap in Artificial Intelligence (AI) and Cybersecurity subsystems which can be manipulated by terrorists and individual groups through the usage of malicious UAVs to attack airports' PI. This trend increases the vulnerability to attack for any airport without anti-UAV detection systems as part of its security mitigation measures against rouge UAVs (Yasmine et al. 2023). Thus, given the literature and the findings of this paper, it is clear that the absence of anti-UAV detection systems for airports is not a challenge confined to Namibia alone, but rather, it is a global security concern.

The following statement was presented to the respondents: *I do believe there is a need for the Namibia Civil Aviation Authority (NCAA) and Namibia Airport Company (NAC) to strictly enforce anti-unmanned aerial vehicle safety and security measures at all airports in the country.* The responses to the statement are presented in the form of percentage distribution in Fig. 3.

A cumulative total of 93% of respondents made up of agreed (49%) and strongly agreed (44%) recognise the need for the relevant aviation authorities to enforce anti-unmanned aerial vehicle safety measures at all airports in Namibian, while only 7% of the respondents were not sure if there was such a need. This evidence provides clear indications that Namibia's airports are lagging behind with regards to the implementation of anti-unmanned aerial vehicle detection systems and mitigation measures, raising questions regarding aviation safety and national security. Thus, the Namibian Airports Company could make considerations for the installation of the Yolov7 anti-UAV detecting system at its airports, and in the manners proposed by (Yasmine et al. 2023). This is because, reviews indicate that this type of system is capable of identifying, detecting and distinguishing UAVs from none-UAV objects, including the localisation of "encountered aerial targets" which, as a result, would "enhance airspace and airport security" (Yasmine et al. 2023; p.13). It is also critical here to observe that while several studies have been conducted on anti-UAV systems for airports, only a few have proposed and identified anti-UAVs systems with the ability to identify and distinguish UAVs from non-UAV objects - which forms a critical concept for airport safety and security.

The fourth question of the survey was: *Do you believe the absence of anti-unmanned aerial vehicles' operational safety and security measures at Namibia's airports increase the likelihood for individuals and terrorist groups to attack air-*
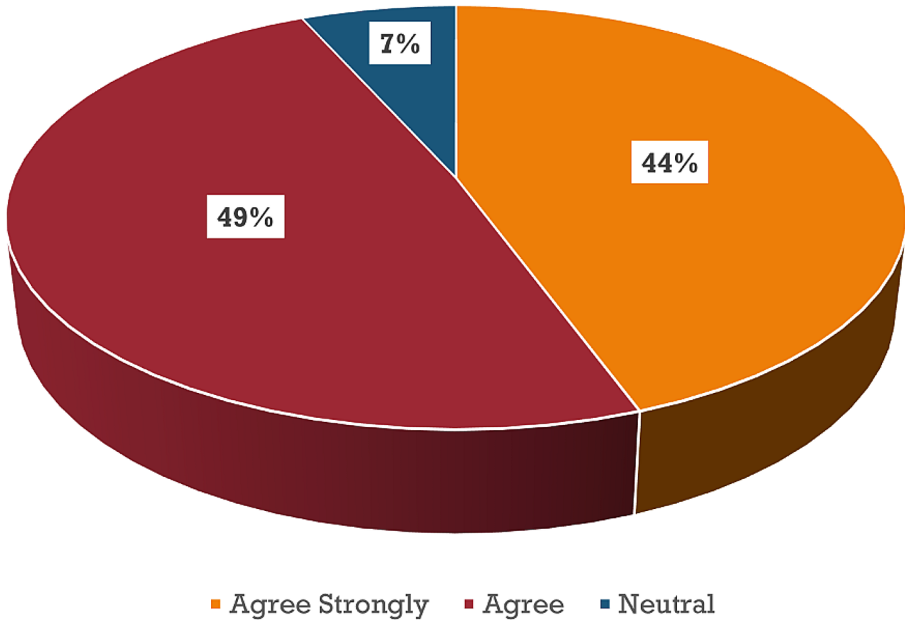
Fig. 3 Enforcement of anti-unmanned aerial vehicle safety and security measures at airports (Source: Authors' Own work)
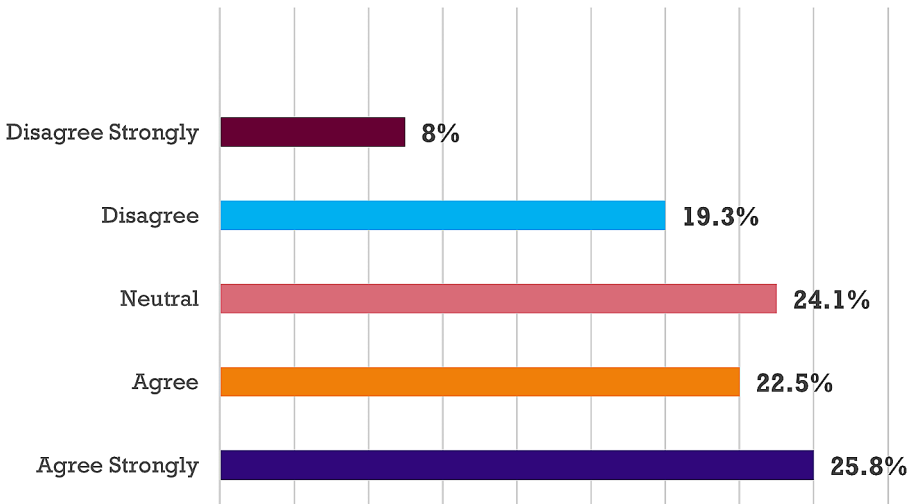
Fig. 4 The likelihood of airport attacks by weaponized UAVs (Source: Authors' Own work)

ports' PI with weaponised UAVs? Fig. 4 presents a percentage distribution of the responses to the question.

The results suggest that, the absence of anti-unmanned aerial vehicle detection measures and systems at Namibian airports, potentially increase the likelihood of

weaponised UAV attacks by terrorists and individuals with the intention to cause disruption in traffic flow and/or destructions to the airports' PI. This is clearly demonstrated by the fact that 25.8% and 22.5% of respondents agreed or strongly agreed, respectively, with the propositions of the question. On the other hand, a cumulative total of 27.3% of the respondents disagreed with this observation, whilst 24.1% of respondents preferred to be neutral in their responses. From the above results, there is abundant evidence that the Namibian national security agencies are not at par with agencies in other nations with regards to the development and implementation of effective anti-unmanned aerial vehicle detection and mitigation technologies at airports. The respondents also pointed out that there is an urgent need for Namibia as a country to invest in anti-unmanned aerial vehicles' detection systems and other related sensors. These sentiments are in tandem with observations by Haugstvedt and Jacobsen (2020) who opine that UAVs are an imminent threat to the security of societies, especially given the instabilities characteristic of the contemporary geopolitical sphere, as well as the rise in global conflict zones, exemplified by the operations of terrorists groups such the Islamic State of Iraq and Syria (ISIS) or individuals with bad intentions who are more likely to make use of weaponised UAVs to attack soft targets such as airports' PI.

The fifth question of the survey was: *Do you believe there is a need for the establishment of joint civil/military Information Technology (IT) units responsible for spoofing, detection, and monitoring of illicit UAVs' operations at all airport facilities in Namibia?* A percentage distribution of the responses to the question is presented in Fig. 5.

A combination of 93.4% constituted of 52.1% who agreed and 41.3% who strongly agreed and believe that there is an urgent need to establish a joint civil/military IT unit responsible for spoofing, detection, and monitoring of illicit UAV operations at all airport facilities in Namibia. The remaining 6.5% of respondents were neutral in
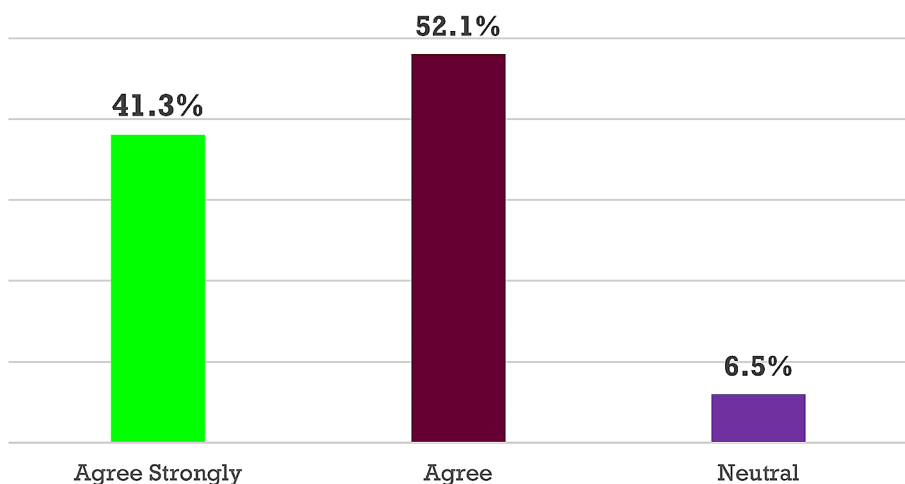

Fig. 5 Establishment of civil/military joint IT unit (Source: Authors' Own work)

their responses to the question. Similar to these findings, are observations made by Cox et al. (2022) who submit arguments for the need for civil-military cooperation towards the safety and security for PI. It is evident in their findings that there is an urgent need for military and civic societies, including academic institutions, to collaborate towards the search for solutions to vulnerable PI, among which airports' PI are also included. The study further calls for the creation of sophisticated disaster preparedness models as mitigation measures to curtail the vulnerability of PI against terrorist attacks using UAVs. Without perseverance to protect states' PI, such infrastructures becomes vulnerable to various threats that range from, but are not limited to: "terrorist attacks, hybrid attacks, asymmetrical warfare, and CBR strikes" (Cox et al., 2022, p.34). The cooperation between civic society and the military is not a new trend as these sectors often coalesce in areas of "counterterrorism, cybersecurity, natural disasters, biohazards, technological hazards, energy, supply-chain challenges, and research and development in hypersonic and other emerging technologies" (Cox et al., 2022, p. 26).

As all of these are global challenges, it is crucial for Namibia be innovative and take the initiative to work towards the creation of civil-military Information Technology (IT) units to mitigate the vulnerability of airports' critical infrastructures, in order to ensure aviation and national security.

The sixth question of the survey was: *Are there regulations or policies in place on anti-unmanned aerial vehicle detection systems and mitigation measures in Namibia?* A percentage distribution of the responses to the question is depicted in Fig. 6.

As observed from the results in Fig. 6, 60% of respondents indicated that there are no regulations or policies in place for regulating anti-unmanned aerial vehicle detection and mitigation measures in Namibia. However, 15% believes that there are such regulations or policies in place while 25% indicated that they were not sure. From the
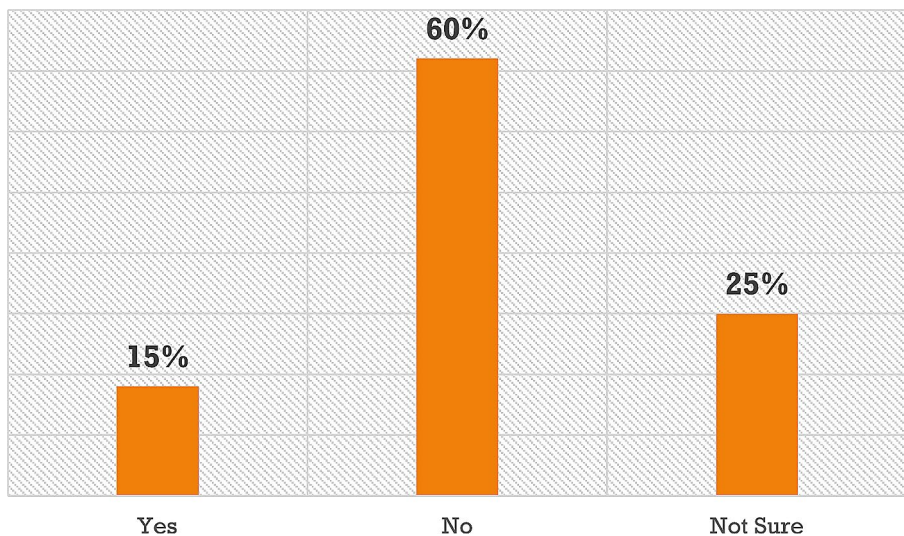
Fig. 6 Policy on anti-unmanned aerial vehicle detection and mitigation measures (Source: Authors' Own work)

evidence presented, there is a clear indication that 60% of the respondents are aware that such policies are not in place, believing that they would have come across such regulations or policies during the duration of their employment with the company, if such existed. The absence of such regulations is believable because the majority of respondents who partook in the study have been employed by NAC for between16 to 20 years as per the results presentation in Fig. 7. This group of respondents would have vast of experience with regards to the existence, or lack thereof, of policies and regulations as they have been employed by NAC for substantially longer periods compared to the rest of respondents whose employment history with the organisation range between 11 and 15 years (17.5%), 6–10 years (24.1%) and 0–5 years (8.8%). According to the Namibia Civil Aviation Act 2016 (2023), the regulations on the general prohibition of UAV operations within the prohibited and restricted airspace are clearly stipulated. However, there are no specific regulations and policies on anti-UAV detection systems, as part of the mitigation measures towards curtailing threats to aviation and national security (*Namibia* Civil Aviation Act 2016, 202*3*). The absence of such regulations and policies may entice terrorists and individuals with bad intentions to attack airports' PI using weaponised UAVs.

The following statement was presented to respondents: *Given the shift in geopolitical sphere, there is a need to extend the security screening parameters beyond the airport terminal area which would require that vehicles and personnel be screened before they enter the airports' facilities.* Figure 8 shows a percentage distribution of the reactions to the statement.

The results indicate that 45% of respondents the strongly agree that there is a need for the establishment of security screening checkpoints beyond the airports' terminal areas. This was backed up by 25% of the respondents who agree with the statement, while 13% of the respondents were neutral in their responses to the statement, and 17% of respondents disagreed with the concept.
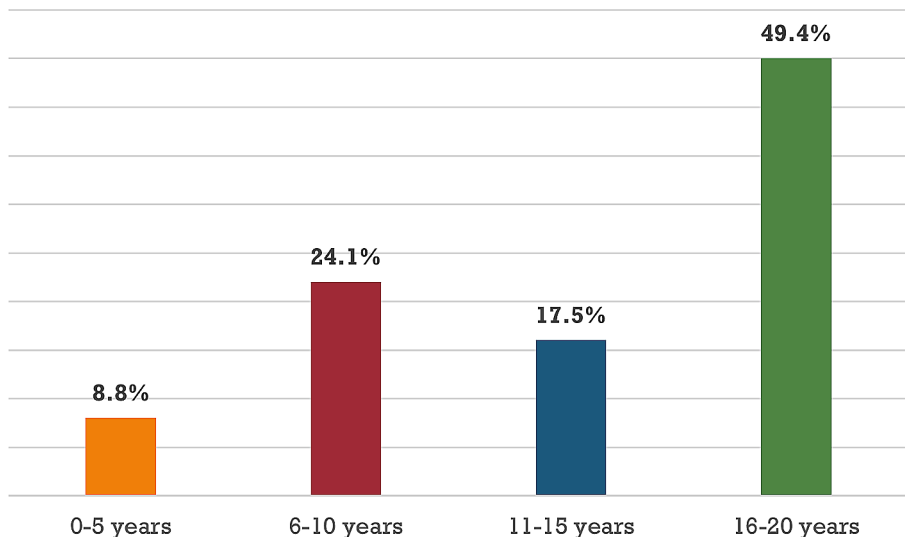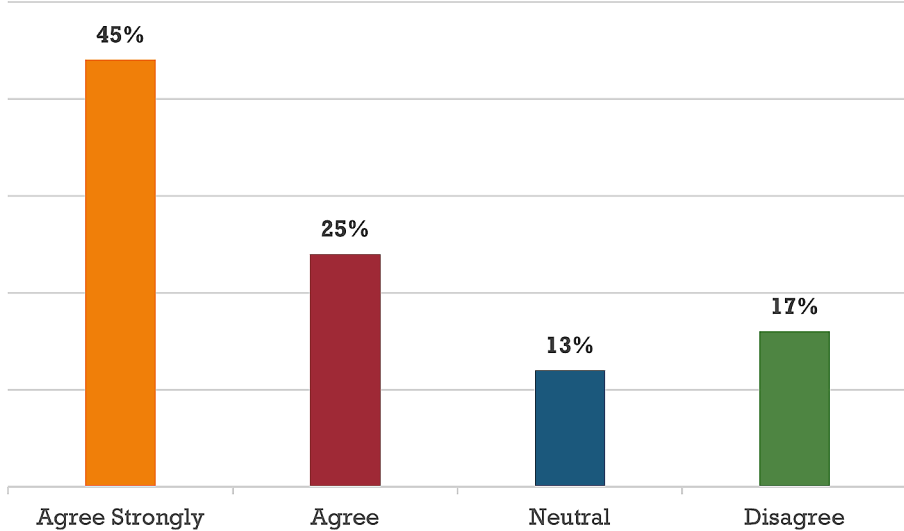

Fig. 7 Period of employment with Namibian Airport Company (Source: Authors' Own work)

Fig. 8 Establishment of security screening checkpoints beyond airports' terminals areas (Source: Authors' Own work)

During the interview sessions the respondents revealed that some countries elsewhere have already implemented security screening checkpoints stationed a few kilometers before national airports terminal areas to curb any possible threats posed by UAVs, IEDs, CBR and light weapons that can be brought in by vehicles. The literature further reveals that the shift in geopolitics, especially given the wars in different parts of the world, there is a bigger threat for the possible proliferation of weaponised UAVs, light weapons, IEDs and CBR that can be used to attack civil aviation facilities in the near future (Yasmine et al. 2023). Such weapons may end up in the hands of terrorists and individuals who may use them to destroy airports' PI, and this poses a serious threat to AVSEC and national security in general.

Conclusion

On the basis of the findings presented and discussed above, the study concludes that the Namibia Civil Aviation Authority and the Namibian Airport Company's regulations and policies on aviation safety and security are currently not focused on the installation and implementation of anti-unmanned aerial vehicle detection systems and other related sensors at the Namibian airports. It was further established by the study that Namibia's airports are currently vulnerable and thus, prone to UAV attacks if systems and countermeasures suggested herein are not installed at all major airports in the country. In view of the above, the authors believe that it would be appropriate for the NCAA and NAC to adopt and implement effective and practical solutions that can minimise and eliminate the vulnerability of airports to malicious UAV activities, and which can potentially damage the airports' infrastructure and pose a security risk to both commercial and general aviation. Despite the existence of the aviation policy

that deals with the operation of UAVs in Namibia, a lot more emphasis is needed on working towards the acquisition and implementation of relevant anti-unmanned aerial vehicle detection and mitigation systems at all major airports in the country. Airport owners and operators need to continuously improve airports' SOPs by focusing more on the risks posed by IEDs, CBR, light weapons and UAV attacks. To enhance aviation and national security, there is need to establish a joint civil/military IT unit responsible for spoofing, detection, and monitoring of illicit UAV operations at all airport facilities and other public infrastructures in Namibia. This is because with the everchanging dynamics within the geopolitical sphere, a clear understanding of various threats is key to the successful response to IEDs, CBR and UAV attacks. The study believes that the possibility of terrorist attacks on the Namibian airports using UAVs' technology is highly likely, if mitigation measures are not implemented. Such a threat poses significant challenges for aviation and national security.

In conclusion, and in view of the discussions above, there is need for the NAC to review policies and regulations on operations within vehicle parking areas at all the Namibian airports, because such parking areas are situated too close to the airports' terminal buildings. In some cases, the distance between the vehicles parking areas and the airport terminal building is less than 20 m. The set up is in contradiction with Annex 17 to the Chicago Convention which recommends a minimum distance of 30 m as the "appropriate distance of exclusion zone separating the curbside from the public access road to airport terminal buildings, in an effort to mitigate the effects of vehicle-borne IEDs (VBIEDs)" (*Aviation Security Manual (Doc 8973 - Restricted)*, 2022). As a result, this can have catastrophic outcomes in case of any possible explosion from IEDs/VBIEDS and other related weapons that could have been brought in by vehicles and parked within the airport's vehicles parking areas. Therefore, to further enhance safety and security at Namibian airports, there a is need for the Namibian Police Force, and other security clusters entrusted with aviation safety and security, to setup secondary security screening checkpoints a few kilometers outside of the airport facilities. The checkpoints would be used for the screening of IEDs, CBR, UAVs and light weapons on both passengers and vehicles, specifically those who would be enroute to airports' terminal areas and other airport situated facilities.

Namibian Airports Company. However, data are available from the corresponding author upon reasonable request.

Declarations

Conflicts of interests: The authors declared that there were no potential conflicts of interests with respect to the research, authorship, and publication of this paper.

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