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REMOTELY PILOTED AIRCRAFT SYSTEM AND ARTIFICIAL INTELLIGENCE INTEGRATION FOR CUSTOMS AND EXCISE SURVEILLANCE

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Abstract
To enhance surveillance capability in coastal and land border areas, the Directorate General of Customs and Excise (DGCE) has recently acquired locally-manufactured Remotely Piloted Aircraft Systems (RPAS). However, factors like the large area of interest to cover, limited personnel and assets, and post-flight data analysis hindered the optimization of the RPAS. On the other hand, the Ministry of Finance (MoF) in general has initiated Artificial Intelligence (AI) usage in strategic scenario planning through the establishment of the MoF AI Community of Practices (CoP) in early 2025. The early stage of adoption of both technologies within MoF and DGCE presents an opportunity for integration and future development. Various journals and industry practices have shown that the integration of AI into RPAS operations—including for surveillance operations—is highly feasible.

This research aims to examine how RPAS operation for DGCE surveillance missions could be further enhanced by the integration of AI. This research employs a mixed-method approach, combining internal surveys from RPAS pilots, practical insights from external sources, and a literature review on how RPAS and AI integration in surveillance missions. The findings highlight the stages of RPAS operation with possible AI integration—preparation, in-flight, and post-flight data analysis—, technological readiness of AI suitable for each stage, and challenges for the implementation. These results suggest that practical AI integration into existing RPAS could transform underutilized surveillance assets into powerful enforcement tools.

Keywords: *Remotely Piloted Aircraft Systems, Artificial Intelligence, Customs and Excise Surveillance, Mission Planning, Real-Time Object Detection, Post-Flight Data Analysis*

Abstrak
Untuk meningkatkan kemampuan pengawasan di area pesisir dan perbatasan darat, Direktorat Jenderal Bea dan Cukai (DJBC) baru-baru ini mengakuisisi Sistem Pesawat Udara Tanpa Awak (SPUTA) buatan lokal. Meski demikian, beberapa faktor seperti luasnya area pengawasan, keterbatasan personel dan aset, dan analisis pasca penerbangan menjadi hambatan dalam optimalisasi penggunaan SPUTA. Di sisi lain, Kementerian Keuangan telah menginisiasi penggunaan Akal Imitasi (AI) untuk perencanaan skenario strategis melalui pembentukan Komunitas Praktisi AI di Kementerian Keuangan di awal tahun 2025. Implementasi awal atas kedua teknologi ini di Kementerian Keuangan dan DJBC memberikan peluang untuk integrasi dan pengembangan ke depan. Beragam jurnal dan praktik dalam industri telah menunjukkan bahwa integrasi AI dalam pengoperasian SPUTA—termasuk untuk misi pengawasan—merupakan hal yang amat dimungkinkan untuk terjadi.

Riset ini bertujuan untuk membahas bagaimana pengoperasian SPUTA untuk misi pengawasan DJBC dapat ditingkatkan dengan integrasi AI. Riset ini menggunakan metode campuran, mengombinasikan survei internal dari pilot SPUTA DJBC, masukan dari sumber eksternal, dan kajian literatur mengenai integrasi SPUTA dan AI pada misi pengawasan. Riset ini mendapati tahapan-tahapan pengoperasian SPUTA yang memungkinkan untuk diintegrasikan dengan AI—persiapan, saat terbang, dan analisis setelah penerbangan—, kesiapan teknologi untuk tiap tahapan, dan tantangan implementasi. Riset ini menyimpulkan bahwa integrasi AI dalam pengoperasian SPUTA dapat mengubah aset yang kurang termanfaatkan menjadi komponen pengawasan yang berdaya guna.

Kata Kunci: *Sistem Pesawat Udara Tanpa Awak, Akal Imitasi, Pengawasan Kepabeanan dan Cukai, Perencanaan Misi, Pendeteksian Objek, Analisis Data Pasca-Penerbangan*

INTRODUCTION

Other than serving as one of Indonesia's revenue collectors and facilitators of trade and industry, DGCE also holds an important role as a community protector—safeguarding the public from illegal and dangerous goods entering Indonesia, as well as preventing the illicit outflow of natural resources that could deplete national stock and harm the environment. To fulfil this mandate, DGCE monitors the flow of goods through seaports, airports, and land borders. However, the unique geography of Indonesia presents significant challenges. With more than 80.000 km of coastline, over 13.000 islands, approximately 6 million km^2 of sea area, and more than 3.000 km of land borders, conducting surveillance through conventional means poses substantial difficulties.

The procurement of locally-manufactured RPAS presents an opportunity for DGCE to enhance its surveillance capability, providing aerial support at a relatively low cost. Nevertheless, the implementation remains in its infancy and is hindered by several obstacles, such as limited assets and personnel, the vastness of the surveillance area, geographical complexity, and unpredictable weather. On the other hand, the Ministry of Finance (MoF)—DGCE's parent organization—has begun adopting Artificial Intelligence (AI) for strategic scenario planning through the establishment of a Ministry-wide Community of Practice in early 2025. The institutional adoption of AI offers a potential upgrade for DGCE's RPAS operation.

Studies and international practices have shown that AI can be integrated into RPAS operations across multiple stages—preparation, in-flight navigation, target tracking, anomaly detection, post-flight assessment, and data analysis. These approaches could directly respond to the challenges faced by DGCE's RPAS team. This research examines how AI integration into RPAS operations could improve surveillance effectiveness, using data gathered from an internal survey of DGCE drone operators, insights from academics and researchers, perspectives from industry practitioners, and international literature.

While the adoption of both technologies is still at an early stage, this research argues that integrating AI into RPAS operation could modernize DGCE's surveillance functions—not only in alignment with the World Customs Organization (WCO)'s Smart Customs Project but also in support of DGCE's vision to be the world's leading customs and excise administration. To achieve this vision, DGCE must harness innovation and technological advancements—such as RPAS and AI—to modernize customs operations and enhance operational efficiency without hindering the flow of legitimate trade. This research also explores the impact of technology and innovation on customs functions and addresses challenges in technology adoption and integration. Another key aspect of DGCE's RPAS operation is fostering local innovation and entrepreneurship through collaboration with domestic start-ups that serve as RPAS providers and potentially, in the future, AI-based solutions.

LITERATURE REVIEW

With the help of AI, the user of RPAS can use data from devices connected to the drone to collect and use data about the surroundings, automatically handle its navigation, detect possible threats, and identify anomalies, among other functions. All those applications can make RPAS operations more precise, rapid, and effective (Pal, et al, 2024). Cosar (2023) noted that RPAS operation benefited from AI capabilities to perform processes demanding cognitive functions, such as image perception, autonomous navigation and positioning, and other dynamic environmental variables. Moreover, the United Nations Interregional Crime and Justice Research Institute (UNICRI) and Interpol's Innovation Centre acknowledge that many countries are exploring the application of AI and robotics (including surveillance RPAS) in the context of law enforcement, with some countries having explored further than others. Since the concept is relatively new, expertise gaps exist, and there is a need for greater international coordination on this issue. In law enforcement, especially border security, which is relevant to DGCE's function, AI-powered RPAS offers real-time monitoring of borders to detect unauthorized crossings and potential smuggling (Chickwendu & Emeka, 2025).

AI implementation in RPAS operations could be found across each stage of its operation. Mission planning, as an important part of RPAS operation, faces several key challenges, such as the need to handle a large amount of information that is needed for real-time decision making (Huttner and Friedrich, 2023). Jie, et al (2017) proposed the inclusion of advanced technology like Virtual Reality (VR) and AI to address this specific problem. Aibin, et al (2021) argued that AI is a potential mitigation to reduce human error, which could contribute up to 70% of the cause of RPAS accidents. They further categorized the automation level on RPAS operation into path planning, collision avoidance, take-off and landing, and Simultaneous Localization and Mapping.

During flight, AI could be used to assist in the take-off and landing process, flight path optimization, obstacle and collision avoidance, object recognition and tracking, and anomaly detection (Biju, 2025). A complicated process, such as the landing process on a moving ship, could be assisted, using AI to evaluate various variables (Polvara, 2018). Deng, et al (2024) argued that the traditional RPAS flight anomaly detection fails to integrate data from various sensors, generalizing error prediction results in false positives, and uses an irrelevant data set model to process data from heterogeneous sensors. All these shortcomings hamper the accurate assessment of RPAS status. Deng, et al proposed to increase RPAS flight safety using an anomaly detection model based on sensor information fusion and a hybrid multimodal neural network (IF-HMNN). Using the Multi-source Heterogeneous UAV Sensor Information Alignment algorithm (MHSIA) could realize data fusion from multiple sensors, increase focus on key classes, and be trained to different domain features. AI could assist in object and anomaly detection based on two distinct operational principles: off-board processing, which relies on a communication medium to transfer and process data from the RPAS into an external computer system operating the AI, and on-board processing, which relies on built-in hardware and software (Cosar, 2023). Yazid, et al (2021) focused on the on-board-processing aspect of RPAS and AI integration, using Mobile Edge Computing to address latency issues in off-board processing. Ramachandran and Sangaiah (2021) classify object detection methods from RPAS operation into traditional image processing methods and deep learning methods, with their own characteristics that suit better in some scenarios, but are less effective in others. Ionescu, et al (2017) proposed a framework for abnormal event detection in video without the need for training sequences based on an unmasking technique to distinguish between two consecutive video sequences while removing the most discriminant features at each step.

After each mission, operators should analyse the video captured by the surveillance RPAS. Depending on the mission duration, video analysis could be a lengthy and demanding process. Liu, et al (2023) proposed an innovative approach to detect anomalous occurrences in video data without being supervised by operators by leveraging scene comprehensions to encompass object manifestations, their interrelation within the spatio-temporal domain, and the categorization of the scenes.

METHODS

This exploratory research adopts a mixed-method approach, combining internal surveys, semi-structured interviews with academics, researchers, and industry practitioners, and literature reviews to identify the potential of AI integration across various stages of RPAS operations. This approach allows triangulation between internal operator experience, insight from industry practitioners, and academic findings.

From internal perspectives, data from 8 respondents from various units operating RPAS were collected via an online questionnaire. The focus of internal perspective is to identify operational challenges and their view on AI potential. From external perspectives, a purposive sampling method was used to gather insights from researchers (from the National Research and Innovation Agency, State University of Yogyakarta, Gajah Mada University, and Bandung Institute of Technology) and RPAS industry experts (AMX UAS, Beehive Drone, BETA UAS, Big & W UAS, and Keppler Drone as RPAS manufacturers; Drone Edutec as RPAS Training Center; Geosurvey Indonesia as RPAS operator, and Nodeflux and Holovision as AI Solution providers). The focus of external perspectives is to identify real-world usage of AI in RPAS operation, the technological aspect of integration, and limitations and feasibility for implementation.

Participation in the survey and interviews was voluntary, and respondents' identities and affiliations are anonymized to protect confidentiality. Data from both internal and external perspectives were organized, analyzed, and structured thematically using NVivo to identify operational challenges and AI integration opportunities across RPAS operation stages, with literature findings used to triangulate and strengthen the findings. The literature review focused on peer-reviewed papers and reports between 2018 and 2025, emphasizing AI application across RPAS operational stages: pre-flight/mission planning, in-flight navigation, object and anomaly detection, and post-flight data analysis.

RESULTS AND DISCUSSION

This section will be divided into three sub-sections. The first sub-section is focused on the internal perspective to identify challenges faced during real operations and their perspective on potential AI usage. The second sub-section is focused on external insights to gain real-world implementation of AI in the RPAS industry by experienced practitioners. The last sub-section is focused on aspects needed to be taken into consideration in the integration of AI into RPAS operations. Each sub-section is supported by relevant literature to strengthen the argument.

Internal Experience

The internal surveys were conducted on the officers in charge of the RPAS operation in DGCE located in Aceh, Western Borneo Regional Office, and Headquarters. The performance matrix of the RPAS system is shown below:

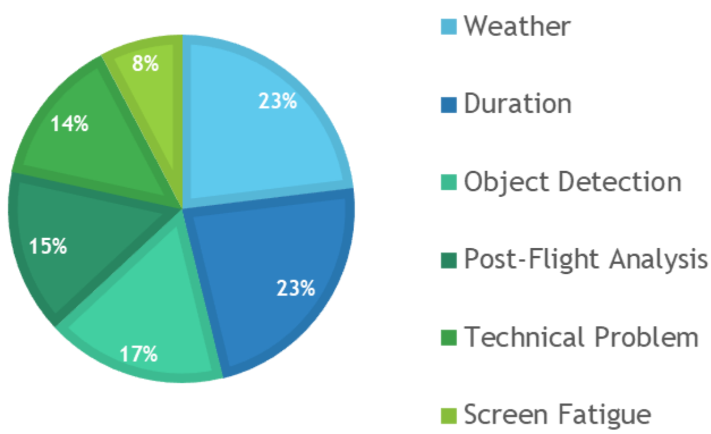
Table 1: Omnibe Drone Performance Parameter

Omnibe Drone Parameter

Components		
Battery	Motor	Dimension
2 x 27,000 mAH	4+1 unit	2,7m wingspan
Flight Duration (minutes)		140
Wind Resistance (m/s)		12
Sensor Capability (SIYI ZT30)		
RGB Camera	Thermal Cam	Other
4K (3840x2160), 30x optical zoom	640x512	2048 x 1080 wide lens, 1200m Laser Rangefinder

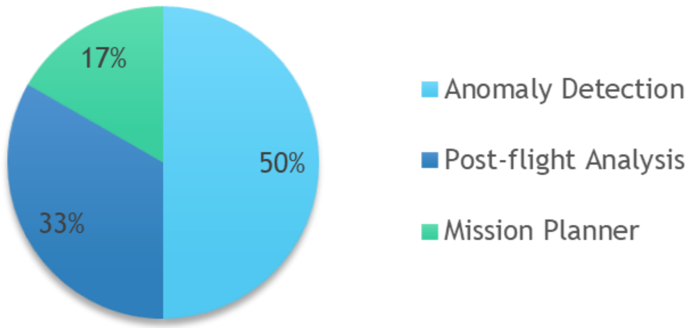
From the survey, it can be concluded that weather conditions and mission duration are the most significant challenges in RPAS operation, weighted 23.08% each. Weather conditions often force operators to delay, or even abort the planned mission. Even when the mission could be executed, unexpected weather could negatively impact the drone's performance, reducing its endurance. While the drone itself is rated for 140 minutes of flight duration, real flight duration depends on several factors such as payload weight, wind speed and direction, and cloud existence, hampering already-limited duration. Object detection followed with 16,92%, especially during night missions, solely dependent on the thermal camera, given the infantile nature of the team. Post-flight analysis followed with 15,38%, technical issues with 13,85%, and lastly, operator workload, which was considered as the least significant challenge with 7,69% significancy.

Figure 1 Challenge in RPAS operation according to the internal survey



Internal sources consider automated anomaly detection stages as the most important area to be improved with AI, with 50% weighted average significance, compared to post-flight report (33,3%) and flight planning (16,67%). These findings are consistent with Huttner and Friedrich (2023), Du, et al (2018), and Ramachandran and Sangaiah (2021), which emphasize the importance of object detection of the sensor systems, with the RPAS only serving as the carrier of the sensor itself.

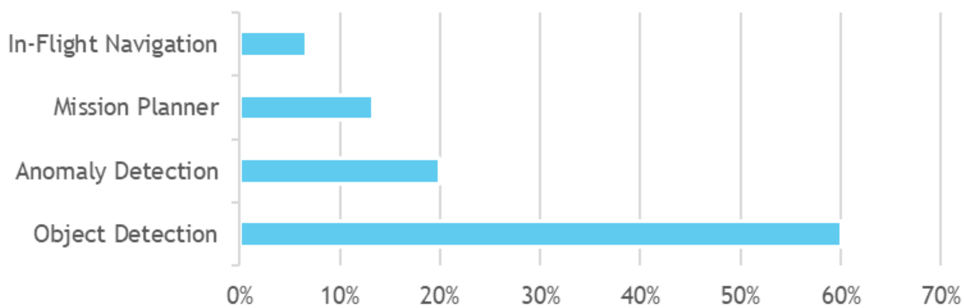
Figure 2 Potential AI improvement according to the internal survey



External Insight

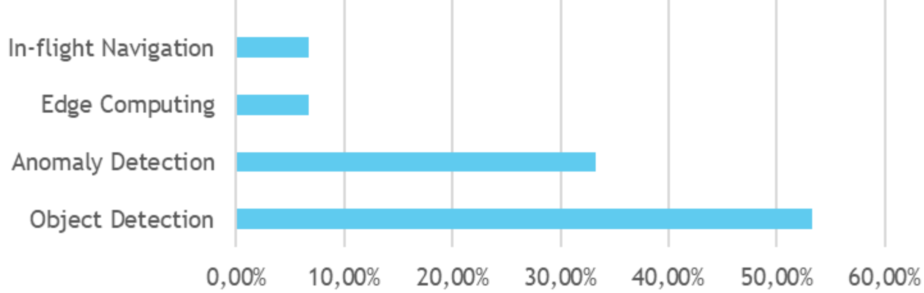
An external survey was conducted on industry experts, such as manufacturers, pilots, academics, and researchers. Compared to the respondents of the internal survey, external experts have more extensive experience in RPAS operation, clocking 3-7 years of experience. highlighted object detection (60% significance) as the most important aspect of RPAS operation, followed with automated anomaly detection (20%), mission planning (13,33%), and in-flight navigation (6,67%).

Figure 3 Potential AI improvement according to the external survey



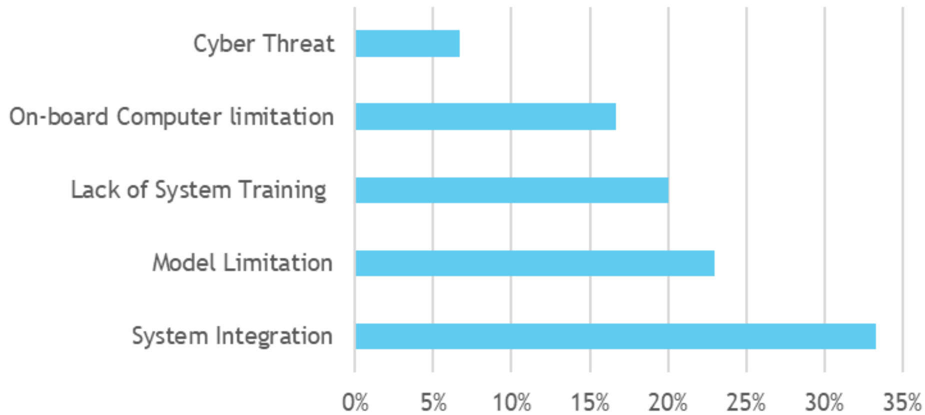
It is also worth noting that the external respondents considered object detection subsystem as the most feasible aspect of AI for RPAS integration with 53,33% weighted average value, compared to automated anomaly detection (33,33%), edge computing, and in-flight navigation (both 6,67%).

Figure 4 AI improvement feasibility according to the external survey



These findings are in line with Pal et al (2024), Liu et al (2023), and Du et al (2018), which emphasized various object detection systems available in the market, as well as the availability of object detection datasets, especially in maritime environments.

Figure 5 Challenge in AI integration according to external survey



Contrary to the internal surveys' result, external respondents considered system integration as the most significant challenge with 33% weighted average value, compared to model limitation (23%), the lack of a dataset for system training (20%), on-board computer limitation (16,67%), and cyber threat (6,67%). The result, however, might reflect how technical expertise of those already involved in RPAS and AI industry, compared to the internal respondents which only recently begun to implement RPAS technology in surveillance operations.

Aspects to Consider

This subsection is based on semi-structured interviews with external experts, whose experience in RPAS operation (60% of which has >7 years of experience) and AI knowledge (50% already familiar) are superior to those of internal respondents (66,67% has 1-3 years of experience and are mostly unfamiliar with AI integration into RPAS operation). External experts agreed on legal aspects such as regulatory framework, privacy preservation, data safety, clear responsibility sharing, and public monitoring. The finding is in line with Tian et al (2019), which stressed the authentication framework for privacy preserving in RPAS surveillance operations.

Technical aspects such as integration with existing systems to create a continuous ecosystem, on-board computing and edge AI, and dataset availability are also being considered by multiple sources, citing that the lack of a compatible dataset often leads to the mismatch of training data with real-world scenarios, which in turn generates false positives, hindering effective AI implementation into RPAS operations. The problems are also mentioned by Du et al (2018), Deng et al (2024), and Aibin et al (2021).

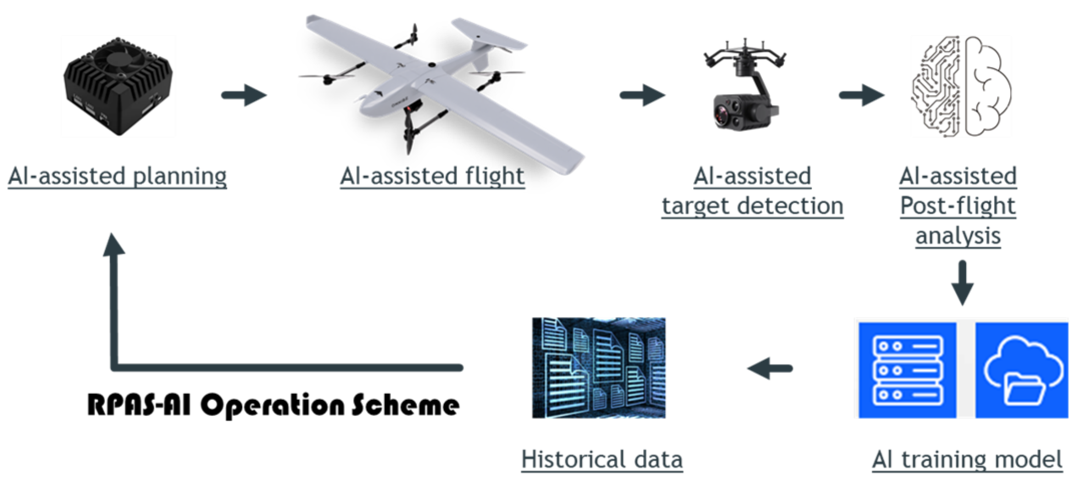
Last but not least, the RPAS system as the carrier of the sensor is considered an equally important factor. The ability to operate under Indonesia's unique climate, the vastness of the area (which in turn, should be countered by RPAS flight endurance and telemetry range), and collision avoidance given the intensity of air traffic in certain areas, are among the aspects mentioned by the respondents. Human factor, as another component in AI-RPAS operation, is also mentioned. In the end, RPAS and AI are tools to help human operator achieve their designated goals. Whether to map a certain swath of land, monitor the flow of vehicles, or conduct wildlife monitoring, the decision-making process should not be left to the system. Man in the loop must be a consideration, given ethical constraints and the limited capability of the existing system, especially in Indonesia, which is still in the early phase of AI-RPAS integration in general. Respondents also noted that cooperation between government, researchers, and industry (triple-helix concept) is one of the keys to success, with each component holding important value to the chain. Coordination between government agencies and the regulator could help pave the way into legal aspects, while researchers and industry could focus on technical aspects of AI integration into RPAS operations.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The integration of AI into RPAS operations has the potential to aid DGCE in conducting surveillance along the land border and coastal areas. AI could aid RPAS operation across various stages—pre-flight, in-flight, and post-flight. Mission planning, path optimization, collision avoidance, object detection and tracking, anomaly detection, and video analysis are among the uses of AI that could leverage RPAS operational effectiveness.

Figure 6 RPAS operation scheme with AI integration



However, challenges such as the lack of a dataset, the vastness of the surveillance area, system integration, and legal aspects remain to be solved by operators. DGCE as an early adopter of RPAS in its surveillance mission, could gain leverage by adopting AI into the system. Risk mitigation could be done by coordination with the relevant government agency for legal considerations, and researchers and industry for technical aspects.

Recommendations

This research is limited by the small number of internal respondents in the population, given the infancy of the RPAS implementation. As RPAS implementation widens over time, further research could be done to validate or update the findings in this research. Given the heavier emphasis on technical aspects of AI on external experts' input, more external experts from AI-related solution providers could also be interviewed for further research.

The untapped potential of AI integration into RPAS operations in DGCE's surveillance mission should be approached with caution. Challenges like legal aspects should be mitigated by coordination and cooperation with the Ministry of Transportation as the regulating body of RPAS operation in general, the Ministry of Communication and Digitalization as the regulating body in regard to network, communication, and AI system, and various other government agencies using RPAS in their operation. Technical aspects such as dataset availability, system integration, and hardware should be a chance for local providers, that has strong understanding of how Indonesia's unique environment (both geographically and demographically), could result in a specially-tailored AI system to be integrated into DGCE's RPAS operation. By doing this, not only could DGCE gain leverage in its RPAS operation, thus improving its fulfilment of community protector duties, but also could foster innovation and entrepreneurship with local businesses and innovation hubs. This action could bring another domino effect, such as more revenue generated to local businesses, which in turn could increase the state's revenue, creating more jobs, and avoiding brain drain by supporting high-technology businesses operated by local talent.

REFERENCES

Aibin, Michal., Aldiab, Motasem., Bhavsar, Ruchi., Lodhra, Jasleen., Reyes, Mino., Rezaeian, Fifi., Saczuk, Eric., Taer, Mahsa., Taer, Maryam (2021). *Survey of RPAS Autonomous Control Systems Using Artificial Intelligence*. IEEE.

Biju, Abin M., M, Sulfath P., M, Sheena K., (2025). *Drone Technology Using Machine Learning and Artificial Intelligence*. TechRxiv. doi: 10.36227/techrxiv.174438711.17012283/v1

Chikwendu, Okpala Charles., Emeka, Udu Chukwudi (2025). *Autonomous Drones and Artificial Intelligence: A New Era of Surveillance and Security Applications.* International Journal of Science, Engineering and Technology

Cosar, Mustafa (2023). *Artificial Intelligence Technologies and Applications used in Unmanned Aerial Vehicle Systems*. The Eurosia Proceedings of Science, Technology, Engineering and Mathematics.

Deng, Hongli., Lu,Yu., Yang, Tao., Liu, Ziyu., Chen, JiangChuan., (2024). *Unmanned Aerial Vehicles anomaly detection model based on sensor information fusion and hybrid multimodal neural network*. Engineering Applications of Artificial Intelligence Volume 132, June 2024, 107961, doi: 10.1016/j.engappai.2024.107961

Du, Dawei., Qi, Yuankai., Yu, Hongyang., Yang, Yifan., Duan, Kaiwen., Li, Guorong., Zhang, Weigang., Huang, Qingming., Tian, Qi. (2018). *The Unmanned Aerial Vehicle Benchmark: Object Detection and Tracking.* European Conference on Computer Vision.

Huttner, Jan-Paul., Friedrich, Max. (2023). *Current Challenges in Mission Planning Systems for UAVs: A Systematic Review*. 2023 Integrated Communication, Navigation and Surveillance Conference (ICNS), Herndon, VA, USA, 2023, pp. 1-7, doi: 10.1109/ICNS58246.2023.10124299.

Ionescu, R. T., Smeureanu, S., Alexe, B., and Popescu, M. (2017). *Unmasking the abnormal events in video*. 2017 IEEE International Conference on Computer Vision (ICCV) (Venice, Italy: IEEE). doi: 10.1109/ICCV.2017.315

Jie, Liang., Jian, Cao. and Lei, Wang. (2017). *Design of multi-mode UAV human-computer interaction system*. 2017 IEEE International Conference on Unmanned Systems (ICUS), Beijing, China, 2017, pp. 353-357, doi: 10.1109/ICUS.2017.8278368.

Liu, Gang., Shu, Lisheng., Yang, Yuhui., Jin, Chen (2023). *Unsupervised Video Anomaly Detection in UAVs: A New Approach Based on Learning and Inference*. Front. Sustain. Cities. doi: 10.3389/frsc.2023.1197434

Pal, Osim Kumar., Shovon, MD Sakib Hossain., Mridha, M.F., Shin, Jungfil. (2024). *In-depth review of AI-enabled unmanned aerial vehicles: trends, vision, and challenges*. Discover Artificial Intelligence.

Polvara, R. (2018). *Vision-based autonomous landing of a quadrotor on the perturbed deck of an unmanned surface vehicle*. Drones, 2(2), 15

Ramachandran, Anita., Sangaiah, Arun Kumar. (2021) *A review on object detection in unmanned aerial vehicle surveillance*. International Journal of Cognitive Computing in Engineering.

Roy, P., Asenjo, À., Trujillo, J., Cetin, E., & Barrado, C. (2022). *Enhancing Drones for Law Enforcement and Capacity Monitoring at Open Large Events*. Drones. doi: 10.3390/drones6110359

Tian, Y.; Yuan, J.; Song, H. (2019) *Efficient privacy-preserving authentication framework for edge-assisted Internet of Drones*. Journal of Information Security and Applications 48, 102354.

United Nations Interregional Crime and Justice Research Institute (UNICRI) & International Criminal Police Organization (INTERPOL). (2019). *Artificial intelligence and robotics for law enforcement*. UNICRI & INTERPOL. https://unicri.org/sites/default/files/2019-10/ARTIFICIAL_INTELLIGENCE_ROBOTICS_LAW%20ENFORCEMENT_WEB_0.pdf

Yazid, Yassine., Ez-Zazi, Imad., Guerrero-Gonzalez, Antonia., El-Oualkadi, Ahmed., Arioua, Mounir. (2021) *UAV-enabled Mobile Edge-Computing for IoT Based on AI: A Comprehensive Review.* Drones. Doi: 10.3390/drones5040148