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Disclaimer:

This Health Technology Assessment has been developed from analysis, interpretation and synthesis of scientific research and/or technology assessment conducted by other organizations. It also incorporates, where available, Malaysian data, and information provided by experts to the Ministry of Health Malaysia. While effort has been made to do so, this document may not fully reflect all scientific research available. Additionally, other relevant scientific findings may have been reported since completion of the review.

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Background

Dengue fever remains a major public health concern globally and in Malaysia. The global burden of disease has increased over the past two decades, particularly in tropical and subtropical regions. In Malaysia, dengue is endemic in both urban and suburban areas, with recurrent outbreaks which present challenges for effective vector control. Entomological investigations have identified *Aedes albopictus* as the predominant vector in outbreak localities, with multiple indices exceeding risk thresholds, indicating active transmission and an increased risk of dengue outbreak.

Current dengue surveillance in Malaysia relies largely on manual, ground-based inspections, which are labour-intensive, time consuming, and constrained by workforce capacity and accessibility, particularly in high-density or hard-to-reach areas. These approaches are largely reactive, limiting early risk identification and the timely implementation of targeted interventions.

To address these limitations, Unmanned Aircraft Systems (UAS) have been explored as a potential tool to enhance dengue surveillance activities. This Health Technology Assessment was conducted at the request of the Head of the Vector Borne Disease Sector, Disease Control Division, Ministry of Health, to evaluate the potential role of UAS in supporting dengue surveillance, including assessment of effectiveness, safety, regulatory, and ethical implications prior to potential integration into the national vector control programme.

Technical Features

Unmanned Aircraft Systems comprise an Unmanned Aerial Vehicle (UAV) integrated with a Ground Control Station (GCS). For dengue surveillance, multirotor drones are commonly used due to their stability, manoeuvrability and ability to operate in confined urban environments. When equipped with optical sensors, these platforms can capture high-resolution imagery of areas that are difficult to access through conventional inspections, such as rooftops, backyards, and drainage systems.

Captured imagery is analysed using software with integrated artificial intelligence (AI) algorithms to identify environmental features associated with mosquito breeding risk. Outputs are typically translated into spatial risk maps to support targeted vector control activities.

In the Malaysian context, conventional ground-based dengue surveillance is labour-intensive. Each premise inspection typically requiring 20-25 minutes for indoor and outdoor assessment, as well as enforcement activities. A team of eight personnel can cover approximately 36 premises within three hours. This baseline highlights the operational constraints of current methods and emphasises the potential values of integrating UAS to improve coverage and efficiency.

There are two main requirements for conducting drone operations: obtaining the necessary permits or approvals, and having a certified remote pilot. In Malaysia, the deployment of UAS is regulated by the Civil Aviation Authority of Malaysia (CAAM). Operators must obtain the required permits and approvals from CAAM, as well as other relevant

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authorities such as the Standard and Industrial Research Institute of Malaysia (SIRIM), the Malaysian Communications and Multimedia Commission (MCMC), the Department of Survey and Mapping Malaysia (JUPEM) and the Malaysia Office of the Chief Government Security Officer (CGSO). For operations in Sabah and Sarawak, additional approvals from the Sabah Lands and Surveys Department (*Jabatan Tanah dan Ukur Sabah*) and the Land and Survey Department Sarawak (*Jabatan Tanah dan Survei Sarawak*) are required before any operations can be conducted. Remote pilots must be trained and certified through approved training organisations to ensure compliance with aviation safety requirements.

The selection of suitable UAS platforms must consider operational parameters such as flight endurance, payload capacity, sensor capability, environmental tolerance, regulatory classification, and maintenance requirements to ensure safe, effective, and sustainable use of drones in dengue surveillance operations.

Policy Question

Should Unmanned Aircraft Systems be implemented to enhance dengue surveillance in Malaysia, in addition to conventional methods?

Objective:

- i. To assess the effectiveness of UAS in dengue surveillance.
- ii. To assess the safety aspects, including public safety and privacy concerns, of operating UAS.
- iii. To assess the organisational aspects, regulatory challenges, ethical, and societal implications of operating UAS.
- iv. To assess the cost-effectiveness of implementing UAS in the dengue surveillance.

Results:

Part A: Systematic Review of Literature

A total of 1,504 records were identified from electronic databases, with 19 additional records identified from other sources. Systematic screening using predefined inclusion and exclusion criteria resulted in the inclusion of 17 primary studies published between 2015 and 2024. Most studies were feasibility in design, followed by observational and cross-sectional studies. The studies were conducted across eight countries, predominantly in urban settings, highlighting the adaptability of UAS for dengue surveillance in various environments.

Effectiveness

The available evidence suggests that UAS, particularly when integrated with AI, can enhance dengue vector surveillance by improving the identification of potential mosquito breeding sites, especially in areas that are difficult to access through conventional ground-based inspections.

Unmanned Aircraft Systems integrated with AI-based image analysis demonstrated high accuracy (generally exceeding 90%) in detecting water-holding containers and environmental features associated with mosquito breeding risk. Across studies, AI-enabled detection consistently achieved high performance levels in identifying potential

breeding sites in urban environments, with improved image quality reported under optimised flight conditions.

Unmanned Aircraft Systems also supported spatial classification and risk mapping of breeding habitats by incorporating environmental indicators such as vegetation and container density. These outputs enabled the identification of high-risk zones at household or community levels, facilitating more targeted vector control planning.

When compared with conventional surveillance methods, UAS detected fewer total containers overall, with one container for every 2.8 containers detected by ground-based surveillance. However, UAS were more effective in identifying breeding sites located in hard-to-reach areas, including rooftops, enclosed compounds, and backyards. Evidence indicates that UAS function best as a complementary tool, with ground inspections remaining necessary for the detection of indoor or small shaded containers. Consistent spatial concordance was reported between breeding sites identified using UAS and those detected through traditional entomological surveys.

In terms of coverage and operational efficiency, UAS enabled surveillance of substantially larger areas within shorter timeframes, covering approximately 60-100 houses within 2-4 hours, compared with manual inspections. UAS-based surveys reduced inspection time and manpower requirements and minimised occupational risks to field staff, particularly in hazardous or elevated locations. In contrast, conventional ground surveys required two inspectors approximately 20-30 minutes per house, with coverage of around 12-14 houses per day.

Safety

No major incidents or technical failures were reported across the studies reviewed. However, operational challenges such as signal interference near large water bodies or telecommunications towers, as well as flight navigation issues in urban areas with physical obstacles, were noted. These findings highlighted the need for trained personnel, operational planning, and strict adherence to aviation safety regulations.

Economic implication

Economic analysis was limited, with no cost-effectiveness studies available. Reported acquisition costs varied by platform, with lower-cost quadcopters and higher-cost hexacopters, excluding associated expenses such as imaging software, maintenance, regulatory approvals, and remote pilot training.

Organisational

Currently, there is no retrievable evidence on the procedural timelines or learning curves associated with the use of UAS in public health settings. The successful adoption of UAS will require inter-agency coordination, certified pilot training, integration of drone data into existing surveillance systems such as eDengueV2, and dedicated infrastructure for data management.

The development of a Concept of Operations (CONOPS) may be useful to provide structured guidance on the use of UAS for dengue surveillance. Such a framework could help clarify operational procedures, roles and responsibilities, safety considerations, data

handling, and regulatory compliance to support effective implementation.

Social, ethical and legal

High community acceptance was reported in studies conducted in Malaysia and Mexico, especially in rural areas where residents expressed willingness to participate in training. Nevertheless, concerns about privacy and surveillance were linked to reduced acceptance, demonstrating the need for transparent communication, ethical safeguards, and ongoing community engagement.

Regulatory compliance emerged as a key consideration. In Malaysia, UAS operations are governed by the CAAM under the Civil Aviation (Amendment) Act 2017, Civil Aviation Regulations 2016 and Civil Aviation Directive CAD 6011 (Part V). Operators are required to obtain authorisation to fly or Special UAS Project (SUP) approval and coordinate with agencies such as SIRIM, MCMC, JUPEM, and the CGSO to address mapping, security, and communication requirements.

Part B: Local Economic Evaluation

The estimated initial investment required for a single drone-based surveillance per locality was significantly higher compared to ground-based surveillance. The estimated annual cost for a locality with 3-monthly routine surveillance similarly showed that drone-based operations incur a substantial higher costs compared with ground-based methods. Cost breakdowns for individual components (e.g., UAS platform, sensors, data processing software) were included in the analysis but are not publicly disclosed due to sensitivity of commercial pricing. Further information is available from the author upon request.

Conclusion:

Part A: Systematic Review of Literature

Based on the available evidence, UAS integrated with AI models such as YOLO, CNN, and SVM offer substantial potential to enhance dengue surveillance. They are feasible for detecting outdoor water-holding containers and environmental cues linked to mosquito breeding risk. Unmanned aircraft systems can complement existing surveillance frameworks by improving coverage, timeliness, and access to hard-to-reach rooftop and outdoor areas, supporting a proactive and data-driven approach to vector control. However, practical limitations remain. Legal and organisational, and cost considerations, must be addressed before routine use. Structured pilot studies, stakeholder engagement, and capacity building are essential to support sustainable implementation in Malaysia.

Part B: Economic Evaluation

Based on the analysis, drone surveillance requires a higher initial investment and can incur substantial annual costs. Traditional ground surveillance has lower initial and annual costs but is less efficient in terms of time and personnel, potentially delaying responses and requiring more manpower. The high initial investment or cost of using drone for routine surveillance suggests strategic deployment for selected settings or specific scenarios.

Recommendation

Based on the review, Unmanned Aircraft Systems may be used as a **complementary tool in dengue vector surveillance**, particularly in selected high-risk or hard-to-reach areas. Their implementation should be supported through targeted pilot projects, adherence to regulatory requirements, community engagement, and further evaluation of cost-effectiveness and integration into existing surveillance systems.

Methods

Part A: Systematic Review of Literature

Literature search was developed by the main author and Information Specialist who searched for published articles pertaining to Unmanned Aircraft Systems for dengue surveillance. The following electronic databases were searched through the Ovid interface: Ovid MEDLINE(R) ALL 1946 to January 24, 2025, EBM Reviews - Health Technology Assessment (4th Quarter 2016), EBM Reviews - Cochrane Database of Systematic Review (2005 to January 28, 2025), EBM Reviews - Cochrane Central Register of Controlled Trials (up to December 2024), and EBM Reviews - NHS Economic Evaluation Database (1st Quarter 2016). Parallel searches were run in PubMed, EMBASE, and the International Network of Agencies for Health Technology Assessment (INAHTA) database. General web searches, including Google, were also performed to retrieve grey literature and supplementary information from organisational or government websites. No restrictions were applied in terms of publication year or language. The final search was conducted on 28 January 2025.

Part B: Economic Evaluation

A comparative cost analysis was performed to evaluate two strategies for dengue surveillance, namely drone-based surveillance (integrated drone-ground surveillance) compared to traditional ground surveillance. Costs were measured in Malaysian Ringgit (MYR). The analysis took the perspective of the Ministry of Health. The costs were categorised into the capital costs and annual operating costs. The annual cost of the drone was calculated using the unit of production method, considering a 5 year lifetime, flight hours over 5 years, and its salvage value. The rest of capital items were annualised using a straight-line depreciation method, considering the useful life of 3 years. The analysis acknowledges limitations in data availability and the fact that some cost data was estimated.