MARI

MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

Vol. 7 No. 2 (2026) 203-209
https://publisher.uthm.edu.my/periodicals/index.php/mari

Case Study: Road Safety Inspection Along Federal Route FT23 in Bandar Tangkak Using Unmanned Aerial Vehicle

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DOI: https://doi.org/10.30880/mari.2026.07.02.026

Article Info

Received: 1 March 2026
Accepted: 1 May 2026
Available online: 30 June 2026

Keywords

Road Safety, UAV, MeTRA, Vulnerable Road Users, Federal Route FT23, Inspection

Abstract

Road safety remains a critical concern, particularly for vulnerable road users (VRUs) such as pedestrians and motorcyclists. This study examines road safety along Federal Route FT23 in Bandar Tangkak using Unmanned Aerial Vehicle (UAV) technology in accordance with MeTRA framework and Stage 5 Audit standards. UAVs offer a modern alternative to traditional inspection methods, providing detailed evaluations of road infrastructure and user behavior. UAVs improve inspections by providing safer access to hard-to-reach areas, reducing the need for scaffolding or lane closures. They capture high-resolution images and real-time data quickly and accurately, allowing for faster, cost-effective and detailed assessments. This enhances safety, efficiency and decision-making in industries like construction, infrastructure and disaster response. This study aims to improve interventions such as exclusive motorcycle lanes, maintained sidewalks, improved pedestrian crossings and continuous monitoring using UAVs.

1. Introduction

Road safety is a serious problem in Malaysia, especially in areas with heavy use by vulnerable road users (VRUs) like pedestrians, cyclists, and motorcyclists. Despite efforts by the government and agencies, VRUs still account for a high number of traffic accidents, many of which lead to serious injury or death [1], [2].Traditional road inspections are often limited covering too little area, taking too much time and sometimes risky for inspectors especially on busy stretches or hard-to-reach roads. Because of these problems, new and safer methods are needed.

In recent years, drones (Unmanned Aerial Vehicles, UAVs) have provided a practical and safer alternative. They give aerial views with high resolution images, helping inspectors find problems quickly and safely [3], [4]. When the drone imaging was paired with a structured safety assessment system like MeTRA (Malaysian Road Assessment Programme), the inspections become more accurate, standardized, and easier to manage. This project focuses on using UAVs to inspect road safety along Federal Route FT23 in the Tangkak Central Business District (CBD) in Johor. Bandar Tangkak has been chosen for study location because the Tangkak District Council (MDT) has received several national-level recognitions. Some of the awards received are National Sustainable City Award 2023. MDT successfully retained this award for the second consecutive year, demonstrating its commitment to sustainable urban development. Besides they also received a Special Sustainable City Award Johor 2023. This recognition was awarded in conjunction with the World Town Planning Day 2023 celebration at the Johor state level, as an appreciation for MDT's outstanding achievements in maintaining urban

sustainability. These recognitions reflect MDT's continuous efforts to ensure balanced development in physical, social, and environmental aspects for the well-being of the local community.

The scope of this project is limited to the stretch of FT23 within the Tangkak CBD with emphasis on features affecting pedestrian and motorcycle safety. These features include road geometry, pedestrian walkways, intersections, U-turns, traffic signage, and visibility of road markings. The inspection did not include structural integrity assessments or evaluations of underground infrastructure, as the primary focus was on observable safety elements relevant to road users. Using drones in this way can help avoid placing human inspectors in dangerous spots, covering larger areas, and reaching places that are hard to access. MeTRA provides a clear list of things to check and compare against national standards. This also shows how local authorities may use UAVs as a regular tool for road checks in the future. The main goal of this project is to examine the road safety conditions along FT23 using drones (UAV) following MeTRA guidelines. The project looks at the facilities for pedestrians and motorcyclists, finds problems like missing signs, unsafe road shapes and faded markings, and gives useful suggestions to make the road safer for everyone.

2. Project Method and Implementation

2.1 Site Location

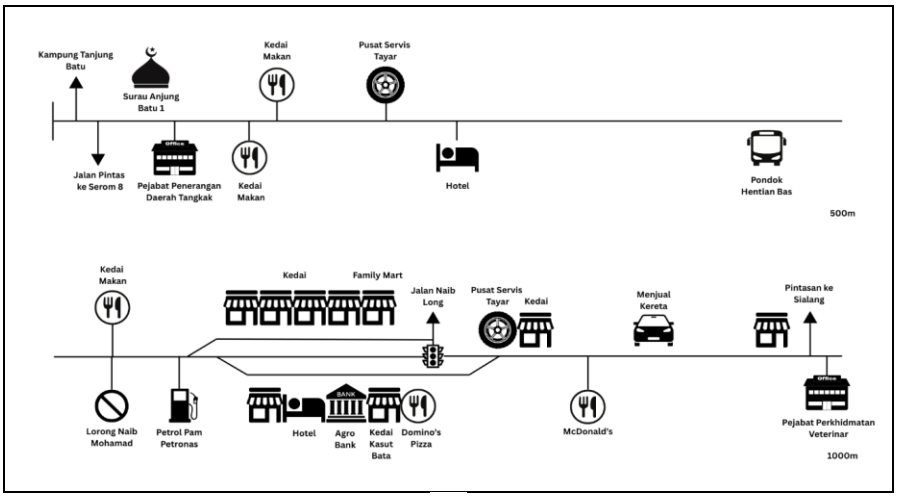
The selected site for this road safety inspection is a section of Federal Route FT23, focusing specifically on the area within the Tangkak Central Business District (CBD) in the state of Johor. FT23 is a federal road that connects several towns and plays a key role in linking local communities and supporting the daily movement of people and goods. The Tangkak CBD was selected due to its high traffic volume and frequent use by vulnerable road users such as pedestrians and motorcyclists. The area includes commercial shops, schools, government buildings, and residential access points, making it an important zone for safety monitoring.

This location features a mix of straight and curved road sections, several intersections and shared-use infrastructure, as in Fig. 1. These characteristics make it suitable for evaluation using MeTRA guidelines. The combination of urban surroundings, traffic congestion and active pedestrian movement allows for a practical assessment of road safety issues under real conditions.

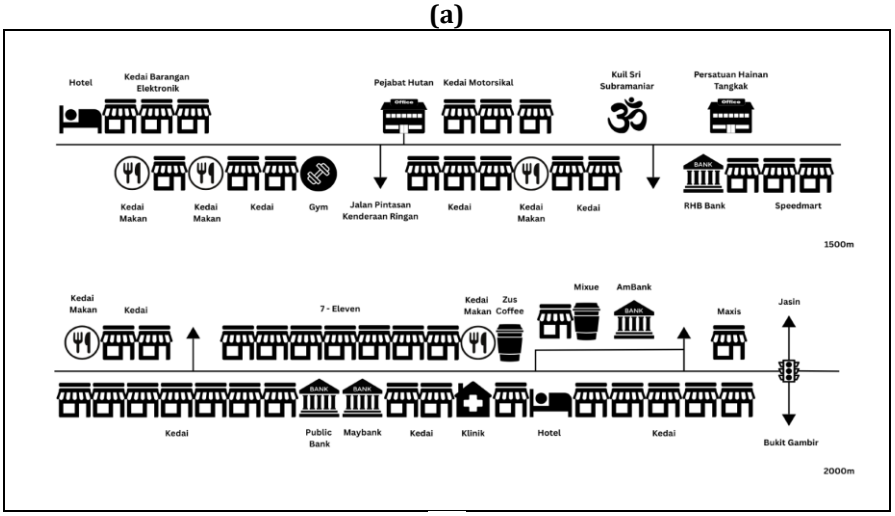
Fig. 1 *Study Area Location*

Fig. 2 illustrates a 2 km strip map prepared for the audit inspection. The strip map provides a clear linear visualization of the road layout in a continuous sequence from the start point to the end point, allowing critical locations to be easily identified and monitored during the audit.

Multidisciplinary Applied Research and Innovation Vol. 7 No. 2 (2026) p. 203-209



(a)



(b)

Fig. 2 *Strip map of (a) the first kilometre inspected; (b) the second kilometre inspected*

2.2 UAV Setup and Planning

Before carrying out the inspection, proper planning was done to ensure smooth and safe UAV operation. The team first checked weather forecasts to avoid strong winds and rain, which could affect drone stability. Flight altitudes were selected to provide a clear view of road elements while staying away from obstacles like trees and electric poles. Each drone was checked for battery level, GPS signal and general condition before each flight.

The DJI Phantom 3 Advanced features a 12MP camera capable of recording up to 2.7K video with a 3-axis gimbal for stable footage. It has a maximum flight time of 23 minutes, a control range of up to 5 km, and typically operates at altitudes up to 120 meters above ground level. Equipped with GPS and GLONASS, it provides reliable positioning and HD live video transmission.

The UAVs were manually controlled to fly over targeted areas, capturing images and videos of key locations such as intersections, road markings and pedestrian zones. No automated software was use; all data was reviewed manually after each session. Safety procedures were followed as guided by the Civil Aviation Authority of Malaysia (CAAM), and the flight plan was arranged based on the road layout and visibility on site.

2.3 Road Safety Inspection Elements

The inspection focused on elements listed in the MeTRA guidelines, which are important for the safety of road users. These include vertical and horizontal road alignment, such as the straightness or curvature of the road and any sudden elevation changes. The cross-section of the road was also checked, including the width of lanes, road shoulders, and space available for motorcyclists and pedestrians. Junctions and U-turns were observed to see if they were clear and safe for turning. Pedestrian infrastructure such as sidewalks, crossings, and ramps was inspected for accessibility and condition. Finally, all traffic signs and road markings were checked to ensure they were clearly visible and followed standards [5].

2.4 Data Collection

The data collection was done manually using a DJI Phantom 3 Advance UAV, which was flown at a low altitude along a planned path to take aerial photos of the FT23 road in the Tangkak Central Business District (CBD). Important areas such as walkways, intersections, zebra crossings, and traffic signs were captured clearly in the photos. No special mapping software or automation tools were used during the process.

After the photos were collected, they were reviewed manually by comparing them with the checklist provided in the MeTRA guidelines [6]. This helped the team identify common road safety issues, especially those affecting vulnerable road users (VRUs), such as missing signs, worn road markings, and poor pedestrian infrastructure. Although some road inspections use software or automated flight modes, this manual method allowed for more control and focus on specific areas. Similar approaches have been used in other studies where manually flown UAVs helped collect detailed road data effectively [7].

2.5 Types of Data Collected

During the drone flights, two main types of data were collected. First, clear aerial photos were taken to show road features like walkways, zebra crossings, road signs, and the shape of the road. These pictures helped the team see and understand the conditions of the road area. Second, the team also noted obstacles such as bushes, blocked paths, and things that might get in the way of pedestrians or motorcyclists. This helped in finding problems that could make the road unsafe or hard to use, especially for vulnerable road users (VRUs).

3. Results and Discussion

3.1 Findings from UAV Inspection

Traditional inspection methods can be time consuming, limited by ground visibility and potentially hazardous. UAVs equipped with advanced imaging systems allow for efficient and comprehensive assessments of road environments [8]. Based on visual data and aerial imagery analysis, several locations were identified as requiring further attention. These areas have been recognized as suitable for upgrades to enhance the overall safety and comfort of road users.

Fig. 3 illustrates the starting point of the study. The UAV image was used to model the road surface structure from different viewing angles, enabling faster and more detailed analysis. Several issues were identified from the UAV observations. The absence of footpaths along the road forces pedestrians to walk on the roadway, particularly near commercial areas. Furthermore, some road markings were faded or improperly located, reducing their visibility to road users.

Fig. 3 *Aerial View of FT23 Segment*

4. Discussion

A total of 30 different elements were identified in this study, resulting in 76 inspections. The most observed issues were surface wear and cracking (8 inspections), damaged curbs (6 inspections), and obstructed tactile paths (6 inspections) as shown in Fig. 4. Although these problems occur frequently, they do not present an immediate high risk. Nevertheless, proper maintenance and corrective actions are required to prevent further deterioration and potential safety hazards.

Multidisciplinary Applied Research and Innovation Vol. 7 No. 2 (2026) p. 203-209

(a) **(b)** **(c)**

Fig. 4 *Observed issues (a)Obstructed Tactile Path; (b)Surface Cracking; (c)Damaged Curb*

The most concerning issues are those that are less frequent but pose significant safety risks. Missing accessibility features and a lack of pedestrian paths (Fig. 5) were found in 1 or 2 inspections, and these are especially dangerous for pedestrians and cyclists, as they limit mobility and increase the risk of accidents. As a conclusion, while frequent issues like damaged curbs and walkways need repair, the most dangerous issues are the gaps in infrastructure that affect accessibility for vulnerable groups. Addressing these issues should be a priority to improve public safety.

Fig. 5 *Pedestrian Path*

There are a few exposed drainage systems near the pedestrian path that present a significant safety risk (Fig. 6). The open drainage and absence of proper barriers or covers could lead to pedestrians, cyclists or motorcyclists accidentally falling into the drain resulting in injuries. Additionally, the exposed drain and surrounding grass area may obstruct pedestrian movement particularly for those with limited mobility. The lack of visible warning signs or barriers increases the chances of accidents.

Fig. 6 *Exposed Drainage*

The metal guardrail ends without proper transition or extension (Fig. 7). There's no clear termination treatment like flared ends, energy-absorbing terminals or pedestrian deflection panels. The guardrail is placed close to the road edge but without a designated footpath behind it, meaning pedestrians may be forced to walk on the grass, which can be uneven or slippery.

Fig. 7 *No Proper Guardrails Extension*

5. Conclusion and Recommendations

In this project, the use of Unmanned Aerial Vehicles (UAVs) for road safety inspections was successfully demonstrated. UAV technology significantly enhanced the data collection process, providing high-resolution imagery and real-image footage, which helped identify potential hazards along Federal Route FT23. The integration of UAVs with traditional manual inspection methods resulted in improved efficiency, reduced risks for inspectors, and more accurate hazard mapping. The project confirmed that UAVs are a valuable tool for enhancing road safety inspections, streamlining the process while minimizing costs and maximizing safety. Moving forward, UAVs can play a key role in regular road safety assessments, helping to prioritize maintenance and ensure safer infrastructure for all road users.

UAVs have significantly improved inspection effectiveness compared to traditional methods. They enable faster data collection over large or hard-to-reach areas, reducing the time needed for inspections. UAVs also enhance safety by minimizing the need for workers to enter hazardous environments. Additionally, they provide high-resolution imagery and accurate data through advanced sensors, improving the precision of inspections. With lower manpower and equipment requirements, UAVs are more cost-efficient. They also offer better documentation through geo-referenced data and repeatable flight paths, making long-term monitoring and comparison more effective.

To improve the effectiveness of future UAV based inspections, it is recommended to upgrade the camera used during data collection. In this study, some images were blurry and had to be retaken, which delayed the process. Using a higher resolution camera such as a GoPro would help capture clearer images, reduce the need for repeated flights, and improve the overall efficiency of the inspection. It is also suggested to digitalise the MeTRA inspection process. Currently, the team relies on printed tables from the MeTRA Guidebook during fieldwork, which proved difficult to manage in windy outdoor conditions. Converting the guide into a mobile application or digital form would make it easier to access, fill in, and review inspection elements on site, resulting in a smoother and more practical workflow

Acknowledgement

The authors would like to thank the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design****: Dominick Andy Amry, Haikal Hadie, Azurah Ismail, Mohd Erwan Sanik;* ***data collection****: Dominick Andy Amry, Haikal Hadie, Azurah Ismail;* ***analysis and interpretation of results****: Dominick Andy Amry, Haikal Hadie, Azurah Ismail;* ***draft manuscript preparation****: Dominick Andy Amry, Haikal Hadie, Azurah Ismail, Mohd Erwan Sanik. All authors reviewed the results and approved the final version of the manuscript*

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