DRONE-ASSISTED INFRASTRUCTURE MONITORING FOR ROAD AND BRIDGE PLANNING OF BINALBAGAN-BAGACAY BRIDGE IN HINIGARAN, NEGROS OCCIDENTAL

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ABSTRACT

The growing demand for accurate and efficient infrastructure assessment has accelerated the adoption of drone-assisted surveying in transportation planning. This study evaluated the application of drone-assisted LiDAR technology in assessing the proposed Binalbagan–Bagacay Bridge in Hinigaran, Negros Occidental. Specifically, it assessed the bridge's physical condition and surrounding land-use characteristics, identified infrastructure vulnerabilities and spatial constraints, and developed planning recommendations using drone-derived geospatial data. A qualitative case study approach was employed through interviews and focus group discussions with geodetic and civil engineers involved in the survey. Spatial data were acquired using a DJI M350 LiDAR drone and processed using DJI Terra, CloudCompare, and AutoCAD Civil 3D. Results showed that the bridge's deteriorated steel truss members have significantly reduced its structural serviceability, while the surrounding terrain, riverbanks, and connecting roadway remain suitable for bridge replacement. The study also identified limitations of drone-assisted LiDAR in assessing submerged riverbeds and concealed structural components, indicating the need for complementary engineering investigations. Overall, the findings demonstrate that drone-assisted LiDAR provides accurate and timely geospatial information that supports evidence-based infrastructure assessment, planning, and decision-making for the development of safe, resilient, and sustainable road and bridge projects.

Keywords: Drone-assisted LiDAR; UAV; Bridge Assessment; Infrastructure Planning; Geospatial Analysis; Road and Bridge Planning.

INTRODUCTION

Roads and bridges play a vital role in economic and community development by connecting production and consumption areas, improving mobility, and providing better access to essential services (Napalang & Regidor, 2015). Transportation infrastructure plays a significant role in economic growth by improving accessibility, enhancing connectivity, and linking remote areas to essential services and economic opportunities (Zhang & Cheng, 2023).

However, effective project monitoring requires reliable and innovative tools to improve accuracy and efficiency. Traditional methods are often time-consuming and prone to errors, while modern digital technologies enable real-time monitoring and support better infrastructure planning (Umar et al., 2024). Traditional surveying methods are often time-consuming and labor-intensive, especially in complex terrains. Unmanned Aerial Vehicle (UAV) helps improve accuracy and efficiency in infrastructure planning (Sestras et. al., 2025). Drone

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technology, also known as Unmanned Aerial Vehicle (UAV) technology, has emerged as a powerful tool for infrastructure monitoring and planning. Initially developed for military applications such as surveillance and remote operations, drones have rapidly expanded into civilian and commercial sectors, proving highly valuable for remote tasks while minimizing risks to human operators (Hodgkinson and Johnston, 2018).

Drones provide high-resolution aerial imagery and accurate site assessments, enabling faster topographic surveys than traditional methods (Mohd et. al., 2025) Consequently, UAVs are increasingly utilized in infrastructure assessment because they maximize data collection efficiency, reduce operational costs, enhance personnel safety, and support comprehensive evaluations through advanced sensors (Zaman et al., 2025). This visual efficiency is especially critical for aging infrastructure. As bridges age, structural monitoring becomes crucial for public safety. Drones improve bridge inspections by offering safer, faster, and more cost-effective assessments, with the future potential for full automation through computer vision and the Internet of Drones (IoD) (Panigati et al., 2025).

This study aims to assess the application of drone-assisted infrastructure monitoring in generating spatial information to support road and bridge planning for the Binalbagan–Bagacay Bridge in Hinigaran, Negros Occidental. Specifically, it sought to: (a) assess the current physical condition and surrounding land-use characteristics of the Binalbagan–Bagacay Bridge and its connecting road network using drone-generated aerial imagery; (b) identify infrastructure vulnerabilities and spatial constraints affecting the road and bridge corridor through drone-based geospatial analysis; and (c) develop planning recommendations for road and bridge improvement using drone-derived spatial data to support sustainable and evidence-based infrastructure planning.

METHODOLOGY

Study Area

The study was conducted at the Binalbagan–Bagacay Bridge, located in the Province of Negros Occidental, Philippines, and situated along the boundary of the Municipalities of Hinigaran and Isabela (Latitude: 10°13'51.33"N; Longitude: 122°57'10.70"E). The bridge serves as a significant transportation link within the area and has historically been utilized for the transport of agricultural products, particularly sugarcane. However, due to its deteriorated condition, the bridge has become impassable, necessitating assessment and planning for its rehabilitation or replacement.

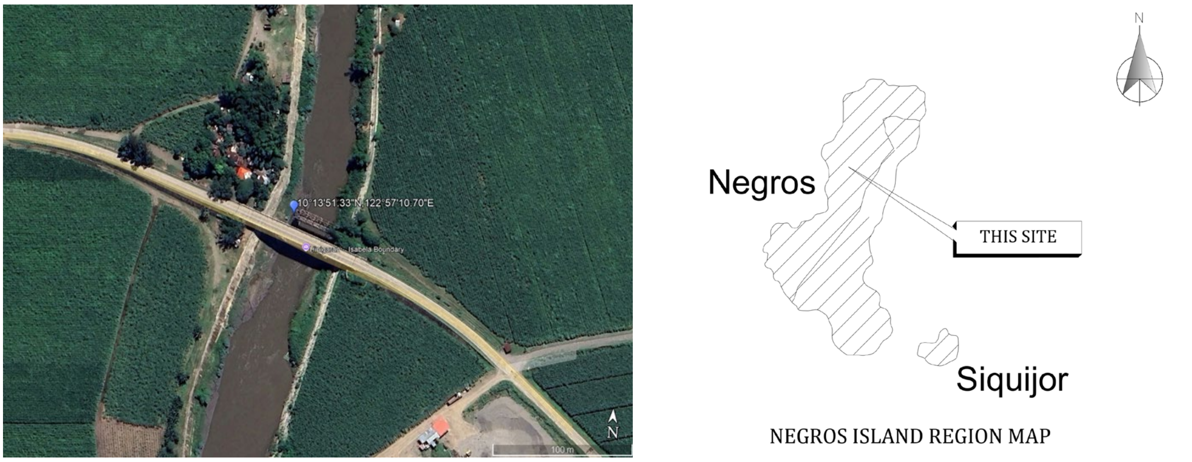

Figure 1. Site Location

Research Design

A qualitative research design through the interview from Geodetic and Civil Engineers who conducted the LIDAR Drone survey and post-processed the raw LIDAR data followed by a focus group discussion was applied in the study. This design has the capacity to gather input from the site engineers on their assessment towards the condition of the Binalbagan-Bagacay Bridge and its existing structures.

Source of Data

The study made use of primary data based on the interview and focus group discussion conducted with the Site Engineers assigned for the proposed road and bridge during the conduct of the LIDAR drone survey highlighting the evident observations on the physical structures of Binalbagan-Bagacay Bridge. The Site location was checked through Google Earth to foresee the existing structures available, trees, terrain slope, and other notable features that will be helpful in the creation of the site development plan. As checked, the dilapidated Binalbagan-Bagacay Bridge was once used as passage of trucks conveying sugar canes to transloading stations. As time went by, it became impassable.

A flight route was created through the drone controller, ensuring the road approach (100 meters for both lane directions) and bridge are covered. As per standard survey procedure, the river needs to be scanned approximately 200 meters going upstream and downstream from the bridge centerline. For safety, the site was also assessed for existing transmission lines, electrical posts, lamp posts, wires and other tall infrastructures that may cause drone crashes, once the drone flight commences.

The Drone Base GNSS RTK was set-up on a stable structure/bench mark that will serve as a control point for all the surveying activities on this location. The DJI M350 LiDAR Drone was placed on a level surface and opened up the propellers. The payload camera was attached at the bottom part of the drone and made sure all the pre-cautionary locks are secured for safety purposes.

Once the Drone Base and LIDAR drone are now all set-up, the controller opened the flight route previously created. The start button was pressed to hover the drone to its launch height. Once hovered, it will go to its flight elevation which is the maintained scanning height of the drone (not more than 120 m as regulated by the Civil Aviation Authority of the Philippines or CAAP). It will automatically scan the river and ground terrain and monitor the drone from time to time to guarantee that the drone is still on sight. The Drone scanning time will be depending on the area being scanned and the flight elevation. It took about 9 mins to complete the LiDAR scanning of the site. Once done, the Drone returns safely to its home point.

Raw LiDAR data was post-processed using DJI Terra, CloudCompare and AutoCAD Civil 3D. The topography including the contours, river profile and cross sections and road profile and cross-section will play a vital role in the decision-making of the site engineers for the proposed Binalbagan-Bagacay Bridge. The Site Engineers reviewed the River and Road Profile and Cross-sections and began the preparation of the bridge and road design. The length of the bridge will depend on the elevation of both top banks and where the bridge abutment will be placed. The number of piers will be determined to ensure the bridge strength. The road approach in both directions will be prepared once the bridge design is finalized considering the existing road carriageway and shoulder.

Scope and Limitation

The study limits the assessment and monitoring of Binalbagan-Bagacay Bridge in support of the proposed bridge and road. Data will be based on the on-site inspection of the site engineers and the post-processed LIDAR data through DJI Terra, CloudCompare and AutoCAD Civil 3D.

RESULTS AND DISCUSSION

A. Physical Condition and Land-Use Characteristics of the Binalbagan–Bagacay Bridge and its Connecting Road Network

The drone-assisted LiDAR survey provided high-resolution spatial data that enabled a comprehensive assessment of the physical condition of the Binalbagan–Bagacay Bridge and its surrounding land-use characteristics. The survey revealed that the Binalbagan River has an average width of approximately 80 meters with an elevation difference of about 8 meters between the riverbank and the water surface. The surrounding area is predominantly composed of flat agricultural land planted with sugarcane, indicating favorable terrain for future bridge replacement and road improvement due to minimal topographic constraints. The existing bridge deck remains physically intact despite years of abandonment and vegetation overgrowth; however, the steel truss members exhibited severe corrosion, missing bolts, and deteriorated connections, indicating reduced structural integrity and limited serviceability. In contrast, the bridge piers remained stable, while the existing flood-control structures effectively minimized riverbank erosion and protected the bridge foundations. These findings demonstrate the capability of drone-assisted surveys to generate accurate geospatial information for infrastructure assessment, supporting more efficient engineering evaluation and land-use planning compared with conventional field methods (Colomina & Molina, 2014; Nex & Remondino, 2014).

The connecting roadway was found to be generally in good condition, consisting of a well-maintained two-lane carriageway with elevated approaches, guardrails, and no significant pavement defects observed during the survey. The presence of a functional road network suggests that future infrastructure investments can primarily focus on bridge replacement rather than complete corridor reconstruction, thereby reducing development costs while maximizing existing public assets. Furthermore, the observed deterioration of the steel superstructure, coupled with the stability of the bridge foundations and surrounding terrain, indicates that the site remains physically suitable for a replacement bridge. This finding highlights the value of drone-derived spatial data in supporting evidence-based infrastructure planning by enabling planners to simultaneously evaluate structural conditions, terrain characteristics, and land-use patterns for more informed and sustainable decision-making (Eisenbeiss, 2009; Melchers & Li, 2009).

B. Infrastructure Vulnerabilities and Spatial Constraints

The drone-based assessment identified several infrastructure vulnerabilities and spatial constraints that are important for future road and bridge planning. Dense vegetation in portions of the study area occasionally obstructed the detection of the ground surface, while LiDAR was unable to capture riverbed elevations beneath the water surface, making supplementary hydrographic sounding and field investigations necessary for accurate hydraulic and foundation design. In addition, aerial imagery could only evaluate visible portions of the bridge and could not fully assess concealed structural components such as foundations, footings, and underside members. Survey operations were likewise influenced by weather conditions, and the processing of large datasets required additional time and technical expertise. These findings are consistent with previous studies indicating that unmanned aerial vehicle (UAV) surveys, although highly effective for surface mapping and visual inspection, should be integrated with conventional engineering investigations to achieve a complete structural assessment (Colomina & Molina, 2014; Nex & Remondino, 2014).

Despite these limitations, the drone survey substantially improved the efficiency and quality of the site assessment by generating accurate topographic information, river profiles, and spatial datasets within a relatively short period. The resulting imagery and geospatial outputs enabled the identification of critical site conditions, including deteriorated bridge components, riverbank characteristics, and potential design constraints, without the need for extensive and time-consuming ground surveys. Such capabilities enhance evidence-based decision-making by allowing planners and engineers to evaluate infrastructure conditions, prioritize interventions, and develop more resilient transportation projects. As noted by Eisenbeiss (2009) and Rakha and Gorodetsky (2018), drone technology serves as a valuable support tool for infrastructure monitoring and planning because it provides rapid, cost-effective, and reliable spatial information while reducing operational risks associated with traditional inspection methods.

C. Planning Recommendations

Based on the drone-derived spatial data, the proposed Binalbagan–Bagacay Bridge should be designed using the generated topographic profiles and river cross-sections to ensure structural stability, adequate hydraulic clearance, and resilience against flooding. The findings also support the widening of the existing roadway to provide a safer and more efficient transition between the proposed bridge and the connecting road network. To enhance road safety and operational efficiency, the project should incorporate appropriate traffic signs, pavement markings, guardrails, and other traffic control devices consistent with national road design standards. Furthermore, potential right-of-way issues should be addressed during the early stages of project planning through continuous consultation with affected landowners and local stakeholders, as participatory planning helps minimize implementation delays, strengthen community acceptance, and promote socially sustainable infrastructure development (Rodrigue, 2020; Litman, 2023).

The study further recommends the integration of drone-assisted LiDAR surveys throughout the detailed engineering design, construction, and post-construction phases of the project. Continuous drone monitoring can provide updated spatial information, facilitate progress tracking, detect construction deviations, and support periodic infrastructure inspections, thereby improving project management and long-term asset maintenance. The use of drone technology also enhances evidence-based decision-making by providing timely, accurate, and cost-effective geospatial data that support sustainable infrastructure planning and more resilient transportation systems. These recommendations reinforce the growing recognition of unmanned aerial systems as valuable decision-support tools for modern infrastructure development and monitoring (Colomina & Molina, 2014; Eisenbeiss, 2009; Nex & Remondino, 2014).

CONCLUSION

The study demonstrated the effectiveness of drone-assisted LiDAR surveying in assessing the existing condition of the Binalbagan–Bagacay Bridge and supporting infrastructure planning. The findings revealed that while the bridge deck and piers remain intact, the deteriorated steel truss members indicate the need for bridge replacement. The surrounding area, characterized by stable riverbanks, existing flood control structures, and a well-maintained road network, remains suitable for future development.

Although drone-assisted surveys have limitations in capturing riverbed elevations and concealed structural components, they provide accurate and reliable spatial information that supports evidence-based decision-making. Overall, drone-assisted LiDAR technology serves as a valuable tool for planning safe, resilient, and sustainable road and bridge infrastructure projects.

The study further highlights the importance of integrating drone-derived data with conventional engineering investigations to achieve a more comprehensive assessment of infrastructure conditions. Through the efficient generation of topographic and spatial information, drone technology can support project planning, design, monitoring, and decision-making, ultimately contributing to the successful implementation of future road and bridge development projects.

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