DOI:10.5937/IIZS26244S

# PROJECT MANAGEMENT APPROACH TO DRONE TECHNOLOGY IMPLEMENTATION IN CIVIL ENGINEERING

*Research paper*

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**Abstract:** The increasing application of unmanned aerial vehicles (UAVs) in civil engineering provides new opportunities not only for data collection and site monitoring but also for supporting project management activities. This paper examines the implementation of drone technology in civil engineering from a project management perspective. Based on practical applications of UAVs in construction-related activities, the study analyses their potential contribution to project planning, monitoring and control, documentation, and decision-making. Particular attention is given to the integration of drone-based activities into the project workflow and to the identification of technical, operational, environmental, and organizational risks that may influence their successful implementation. The proposed approach demonstrates how drone technology can support more systematic project monitoring while providing timely visual information on project progress and site conditions. The results indicate that the effective integration of UAV technology requires not only appropriate technical solutions but also structured planning, risk management, and coordination with the overall project management process.
**Key words:** project management, unmanned aerial vehicles, civil engineering, project monitoring, risk management

## INTRODUCTION

Unmanned aerial vehicles (UAVs) have evolved from primarily recreational devices into versatile technological tools with applications in numerous engineering fields. In civil engineering and construction, UAVs can support activities such as site observation, visual documentation, progress monitoring, inspection, and the collection of spatial information (Ahmed et al., 2022; Albeaino et al., 2019; Mohsan et al., 2022; Rachmawati & Kim, 2022). Their ability to acquire information rapidly from locations that may be difficult, time-consuming, or costly to access using conventional methods makes them particularly suitable for construction-related applications (Shakhatreh et al., 2019; Halder & Afsari, 2023).

The practical applicability of drone technology in civil engineering has already been demonstrated in different stages of the building life cycle, ranging from the observation of potential construction sites and documentation of construction activities to periodic inspections and long-term monitoring (Sabo et al., 2017). Previous practical experience has also shown that repeated aerial imaging can provide useful information about changes in the built environment over time and can therefore contribute to systematic project documentation and subsequent analysis (Sabo et al., 2017).

However, the implementation of UAV technology in construction projects should not be considered exclusively as a technical task. Drone-based activities have to be planned and coordinated with other project activities, while the required equipment, personnel, time, data processing, operational limitations, and potential risks need to be considered (Rachmawati & Kim, 2022; Molina et al., 2023). Consequently, the effective use of UAVs can also be examined from a project management perspective.

The aim of this paper is to analyse the implementation of drone technology in civil engineering within a project management framework. Based on previously demonstrated practical applications, the study focuses on the integration of UAV-supported activities into project planning, monitoring and control, documentation, and decision-making processes. Particular attention is given to the identification of relevant project resources, implementation activities, expected outputs, and technical, operational, environmental, and organizational risks. In this way, the study extends the technological perspective of UAV application by

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examining how drone-supported activities can be systematically incorporated into the management of civil engineering projects.

## PROJECT MANAGEMENT FRAMEWORK FOR DRONE IMPLEMENTATION

The implementation of drone technology in civil engineering can be considered as a set of interconnected project activities rather than as an isolated technical operation. The use of UAVs requires the definition of objectives, selection of appropriate equipment and data acquisition methods, allocation of human and technical resources, scheduling of flight and processing activities, and coordination with the overall construction project (Otto et al., 2018; Rachmawati & Kim, 2022; Molina et al., 2023). These elements make a structured project management approach particularly relevant.

The planning phase should begin with the definition of the purpose of UAV deployment and the expected project outputs. Depending on the project, drone-supported activities may include preliminary site observation, documentation of existing conditions, monitoring of construction progress, inspection of structures, or periodic recording of changes in the built environment (Albeaino et al., 2019; Halder & Afsari, 2023). Clearly defined objectives are necessary because they influence flight planning, required image quality, frequency of data acquisition, equipment selection, data processing requirements, and the allocation of project resources.

From a project management perspective, UAV implementation can be structured into five main groups of activities: planning and preparation, data acquisition, data processing, analysis and evaluation, and reporting and documentation. Planning and preparation include defining the area of interest, determining the required outputs, selecting the equipment, preparing the flight activities, and identifying operational constraints. Data acquisition covers the execution of the planned flights and collection of visual or spatial information. The collected data are subsequently processed and transformed into information suitable for engineering analysis. The results can then be evaluated and incorporated into project reports, progress documentation, or decision-making processes.

An important advantage of this structured approach is the possibility of integrating drone-based information into project monitoring and control. Repeated data acquisition can provide a visual record of project development and facilitate comparisons between different stages of construction (Rachmawati & Kim, 2022; Molina et al., 2023). Such information can support the identification of deviations, documentation of completed activities, evaluation of site conditions, and communication among project participants. The original practical application demonstrated that repeated aerial images can reveal changes in construction and urban development over time, illustrating the value of systematic visual documentation (Sabo et al., 2017).

For effective implementation, UAV activities should therefore be coordinated with the schedule and information requirements of the overall project. Drone deployment should take place when the collected information can contribute to project decisions rather than simply generate additional visual material. This requires coordination between technical personnel responsible for UAV operation and project participants responsible for planning, supervision, documentation, and decision-making.

***Table 1.*** *Project management framework for UAV implementation in civil engineering*

| Project stage | Main activities | Required resources | Expected output |
|---|---|---|---|
| Planning and preparation | Define objectives, area, flight plan and requirements | Project team, UAV operator, equipment, project documentation | UAV implementation plan |
| Data acquisition | Execute flights and collect data | UAV, sensors, operator | Images and spatial data |
| Data processing | Organize and process collected data | Software, computing resources, personnel | Processed project information |
| Analysis and | Compare and interpret | Engineering and project | Information for |

| Project stage | Main activities | Required resources | Expected output |
|---|---|---|---|
| evaluation | results | expertise | monitoring and decisions |
| Reporting and documentation | Integrate results into project documentation | Project management and reporting tools | Progress records and project reports |

## CASE STUDY AND METHODOLOGY

The case study is based on previously investigated practical applications of UAV technology in civil engineering (Sabo et al., 2017). The original application focused on the use of drones for building modelling, construction-site supervision, periodic inspection, and the documentation of changes in the built environment. In the present study, these technical activities are reconsidered from a project management perspective in order to identify how they can be planned, coordinated, monitored, and integrated into the overall project workflow.

The original contribution of the present study therefore lies not in introducing new UAV measurements, but in systematically reanalysing the previously reported technical case from a project management perspective. The activities and operational constraints described in Sabo et al. (2017) are reclassified in terms of project activities, resources, dependencies, risks, monitoring requirements, and decision-support information, providing the basis for the project management and risk management frameworks proposed in this study.

The methodology consists of three main steps. First, the UAV-supported activities identified in the practical application are classified according to their role within a civil engineering project. Second, the technical requirements and operational constraints associated with these activities are analysed as project resources, dependencies, and potential sources of risk. Finally, the information generated through UAV operations is evaluated according to its potential contribution to project monitoring, documentation, and decision-making.

For building modelling and site documentation, UAV operation requires several preparatory activities. The flight path has to be defined according to the area or structure to be recorded, while flight altitude, camera orientation, image resolution, and the required degree of image overlap have to be determined in advance. Accurate spatial positioning can be supported by GNSS data or, where necessary, by Ground Control Points (GCPs). The previous practical implementation showed that control points must be clearly identifiable in aerial images and accurately measured before data acquisition (Sabo et al., 2017).

The execution phase includes establishing communication between the UAV, flight controller, and control workstation, uploading and verifying the planned flight route, identifying possible emergency landing locations, and continuously supervising the UAV during automatic flight. Battery capacity represents an additional operational constraint. In the investigated application, the available flight duration was approximately 10–15 minutes, meaning that larger tasks could require several take-off, landing, and charging cycles (Sabo et al., 2017). These constraints directly influence activity scheduling and therefore need to be considered during project planning.

Data processing constitutes another important part of the workflow. For accurate modelling, images were acquired with substantial overlap—approximately 80% in the flight direction and 70% in the cross-flight direction (Sabo et al., 2017). This produces a large number of images that have to be stored and processed, making data processing one of the more time-consuming stages of the UAV-supported activity. From a project management perspective, processing capacity, storage requirements, and personnel time should therefore be included in resource and schedule planning rather than treating the flight itself as the complete UAV task.

The case also demonstrates the potential of UAVs for repeated construction monitoring. Drone-supported observation can be performed before construction begins, during foundation, structural, masonry, scaffolding and roofing activities, and later during periodic inspection or demolition (Sabo et al., 2017). Depending on project requirements, flights may be performed occasionally at significant project milestones or repeatedly at predefined

intervals. The resulting visual records can subsequently be organized and compared to identify changes over time.

## RISK MANAGEMENT AND PROJECT CONTROL

The integration of UAV technology into civil engineering projects introduces several risks that can affect project schedule, cost, quality, safety, and the availability of information required for decision-making. Consequently, risk identification and response planning should form an integral part of UAV implementation rather than being addressed only when operational problems occur (Mohsan et al., 2023; Telli et al., 2023).

Technical risks are primarily associated with UAV equipment, communication systems, positioning accuracy, sensors, batteries, and data processing. Loss of communication, insufficient battery capacity, inaccurate positioning, or equipment failure can interrupt data acquisition and require the repetition of planned activities (Mohsan et al., 2022; Mohsan et al., 2023). The practical application showed that automatic flights require continuous supervision and predefined emergency landing locations, while limited battery capacity may necessitate several take-off, landing, and charging cycles (Sabo et al., 2017). These factors can directly influence the duration and sequencing of project activities.

Operational and environmental risks are particularly important in construction environments. Flight paths that were initially considered safe may become unsuitable as construction progresses because the position and height of site objects change. Newly constructed floors, cranes, scaffolding, and other temporary structures can therefore require modifications to previously defined flight routes (Sabo et al., 2017). Weather conditions may also influence whether planned UAV activities can be performed at the required time (Shakhatreh et al., 2019; Mohsan et al., 2023). Delayed data acquisition can consequently reduce the value of UAV information when it is needed for a specific project milestone or management decision.

Data-related risks should also be considered. High image overlap improves the availability of information for modelling but simultaneously increases the amount of data that must be transferred, stored, and processed. The analysed application demonstrated that these requirements can result in substantial data volumes and additional processing demands (Sabo et al., 2017). Insufficient processing capacity or inadequate data management may therefore create delays between data acquisition and the availability of useful project information.

From the project management perspective, these risks can be addressed through preventive planning, continuous monitoring, and predefined response measures. Table 2 summarizes the principal risk categories identified through the analysis of UAV-supported civil engineering activities.

***Table 2.*** *Risk management framework for UAV-supported project activities*

| Risk category | Example of risk | Possible project impact | Proposed response |
|---|---|---|---|
| Technical | UAV or communication failure | Interrupted activity, repeated flight, delay | Pre-flight checks, backup procedures |
| Energy | Insufficient battery capacity | Additional flight cycles, schedule delay | Battery planning and reserve batteries |
| Positioning | Inaccurate GNSS/GCP data | Reduced data quality, repeated measurement | Verification of positioning data and control points |
| Site conditions | New structures, cranes or scaffolding | Unsafe or unsuitable flight path | Flight-route review before each operation |
| Environmental | Unsuitable weather conditions | Postponed data acquisition | Flexible scheduling and weather assessment |
| Data management | Large volume of images | Processing and reporting delay | Adequate storage and processing capacity |
| Safety | Collision or emergency landing | Equipment damage, safety incident | Emergency landing plan and continuous supervision |

| Risk category | Example of risk | Possible project impact | Proposed response |
|---|---|---|---|
| Organizational | Poor coordination with project activities | Data collected at an inappropriate time | Integration of UAV activities into the project schedule |

Project control should focus not only on whether a UAV flight has been successfully completed, but also on whether the required information has been obtained at the appropriate time and quality. This distinction is important because the flight itself represents only one activity in a broader workflow that includes preparation, data acquisition, processing, analysis, and reporting. Effective control therefore requires monitoring the entire UAV-supported process and its relationship with relevant construction milestones.
Repeated UAV operations can also contribute directly to project control. Depending on the purpose of monitoring, flights can be scheduled after important construction stages or performed at regular intervals. Systematic comparison of the resulting visual information enables changes to be identified over time and provides documented evidence of project progress (Albeaino et al., 2019; Rachmawati & Kim, 2022). In this way, UAV technology functions not only as a data acquisition tool but also as a potential information source for project monitoring and management decisions.

## RESULTS AND DISCUSSION

The analysis indicates that the effective implementation of UAV technology in civil engineering depends on the integration of technical activities with project management processes. Although data acquisition is the most visible part of drone operation, the complete workflow includes planning, preparation, flight execution, data processing, analysis, reporting, and the subsequent use of the collected information (Rachmawati & Kim, 2022; Molina et al., 2023). Considering these activities as an integrated process makes it possible to identify their resource requirements, dependencies, and potential influence on project performance (Boje et al., 2020; Rasheed et al., 2020).
One of the main benefits of UAV-supported monitoring is the possibility of collecting visual information at predefined project stages. The practical application demonstrated the use of UAVs before construction, during different construction phases, during periodic inspections of completed structures, and during demolition and subsequent site observation (Sabo et al., 2017). From a project management perspective, this allows UAV activities to be associated with project milestones and control points rather than being performed as independent technical operations.
The frequency of data acquisition represents an important management decision. More frequent monitoring can provide more detailed information about project development, but it also increases flight time, data volume, processing requirements, and resource consumption. Therefore, the frequency of UAV operations should be determined according to the information needs of the project and the expected value of the collected data.
The results of the risk analysis further demonstrate that UAV implementation involves dependencies between technical and managerial factors. Technical and operational constraints identified in the analysed application can affect the schedule, resource requirements, and availability of project information. These dependencies illustrate why UAV deployment should be incorporated into resource and schedule planning rather than treated as an isolated technical activity.
Another relevant result concerns the role of UAV-generated information in project control. The comparison of images recorded at different times can reveal changes in structures, construction activities, and the surrounding built environment. In the original application, images of the same residential area recorded at different times demonstrated substantial urban development and road construction changes, illustrating the documentation potential of repeated aerial observation (Sabo et al., 2017). Within a project management framework, the same principle can be applied over shorter intervals to document progress and provide visual information for project evaluation.

For example, if UAV images acquired at a predefined project milestone indicate that the observed construction progress differs from the planned state, this information can support a project decision to review the schedule, investigate the cause of the deviation, and, where necessary, adjust subsequent activities or resource allocation. In this way, UAV-generated information becomes an input to project monitoring and control rather than serving only as visual documentation.

However, the use of UAVs should not be interpreted as a replacement for conventional project supervision or engineering assessment. The value of drone technology lies primarily in providing an additional source of timely and systematically collected information. Its effectiveness depends on whether the information is acquired at the appropriate project stage, processed within an acceptable time, and communicated to the participants responsible for project decisions (Albeaino et al., 2019; Halder & Afsari, 2023).

Based on the analysis, the proposed framework establishes a direct relationship between UAV activities and four project management functions: planning, resource management, monitoring and control, and risk management. The contribution of UAV technology is therefore not limited to improving data acquisition. When properly integrated into the project workflow, it can support a more structured documentation process and provide additional information for monitoring project progress and site conditions.

## CONCLUSION

The application of UAV technology in civil engineering provides opportunities that extend beyond aerial data acquisition and visual documentation. This study examined drone implementation from a project management perspective by integrating UAV-supported activities into a structured framework covering planning and preparation, data acquisition, data processing, analysis and evaluation, and reporting and documentation.

The analysis showed that effective UAV implementation requires coordination between technical operations and the overall project workflow. Flight planning, equipment and personnel requirements, battery limitations, positioning accuracy, changing site conditions, data processing demands, and the timing of monitoring activities can all influence the successful completion of UAV-supported tasks. Consequently, these factors should be considered during project planning, resource allocation, scheduling, risk management, and project control.

The proposed risk management framework identified technical, energy-related, positioning, environmental, safety, data-management, and organizational risks that may affect UAV-supported activities. Preventive planning, verification of flight conditions and routes, adequate resource allocation, continuous supervision, and coordination with construction activities can contribute to reducing their potential impact on the project.

The results also indicate that repeated UAV-based observation can provide useful visual information for project monitoring and documentation. When data acquisition is coordinated with relevant construction stages and project milestones, the collected information can support progress assessment, documentation of site conditions, and project decision-making. However, UAV technology should be regarded as a complementary project information source rather than a substitute for engineering supervision and professional assessment.

The proposed approach demonstrates that the benefits of UAV technology depend not only on the capabilities of the technology itself but also on how effectively drone-supported activities are integrated into project management processes. The study is based on a project management reinterpretation of previously investigated practical UAV applications and does not provide new quantitative measurements of project performance. Future research could extend the framework through its application to specific construction projects and evaluate its effects on project duration, costs, information availability, and decision-making efficiency.

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