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A Literature Review on Automated Construction Progress Verification Based on BIM and UAV Vision

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Abstract. Construction progress verification is a core task in engineering management, but traditional manual inspection is inefficient, lagging, and subjective, and carries safety risks. This paper, through a method of literature review, explores how the integration of Building Information Modeling (BIM) and unmanned aerial vehicle (UAV) vision can automate construction progress verification. Based on 24 listed studies, the review organizes the field around three fundamental problems: how site data are acquired, how data are converted and aligned with BIM, and how progress is automatically identified. It finds that point-cloud registration identifies components with accuracy above 95% in a bridge case, a deep-learning study obtains mAP@0.5 of 0.989, and a wind-solar-storage project reports about 400% higher acquisition efficiency with early-warning response within one hour. The paper concludes that the technology has moved from manual assistance to automated monitoring, yet the transition from progress monitoring to compliance-based verification remains unresolved, and future work should move toward digital twin closure, multi-modal fusion, and edge intelligence.

Keywords: BIM, UAV vision, construction progress, automated verification

1. Introduction

Construction progress management directly determines project duration, cost, and quality. In practice, progress verification still relies mainly on manual site inspection and report statistics, and four problems stand out. Walking a large project can take days, so coverage is slow and incomplete. Reports often lag the site by several days, so deviations are found late. Two-dimensional drawings do not map cleanly onto a three-dimensional site, which breeds disputes between owner and contractor. And some areas—high-altitude work, deep foundations, and rough terrain—are hard for inspectors to reach at all, which makes the inspection itself a safety risk. These pain points have driven the search for automated verification tools.

BIM provides an as-designed reference model for progress checking, while UAVs can efficiently collect site images and point clouds; the two technologies complement each other. In a review of visual monitoring of civil infrastructure via camera-equipped UAVs, Ham et al. identify two processing paths, with and without BIM priors [1]. Bhattacharjee et al. build an integrated system that fuses UAV photogrammetry with 4D BIM and quantifies delay in days [2]. Álvares and Costa survey UAV-based visual progress monitoring and find that point clouds and BIM are the most

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frequently discussed subjects [3]. Later reviews add computer-vision methods [4] and automated inspection pipelines [5], which together show that BIM-UAV integration has become a recognized research direction. At the same time, a distinction is emerging between progress monitoring, which detects deviation, and progress verification, which checks the actual state against contract milestones and specifications. Most existing studies focus on the former; the latter remains largely unexplored, as Bhattacharjee et al. note [2] and Samsami's review confirms [5].

This review traces the technical chain of BIM-UAV progress verification and assesses it in terms of accuracy, timeliness, and safety. It groups the literature around three recurring questions, with the aim of offering a structured reference for later research and practice.

2. Theoretical foundation: BIM-UAV integration and data processing

BIM-UAV integration can be understood as a three-layer chain. At the front end is data acquisition: UAVs equipped with visible-light cameras capture site images for photogrammetric reconstruction [1, 2], while LiDAR payloads directly generate three-dimensional point clouds [6]. Next comes data fusion. The UAV-derived model is aligned with the BIM design model through coordinate registration so that the as-built and as-designed states can be compared in the same reference system [2, 6]. The final layer is progress analysis, where two technical routes dominate: point-cloud geometric comparison and AI vision recognition [4, 5]. This three-layer view appears in several recent reviews. Jacob-Loyola et al. present a complete workflow from UAV photogrammetry to 4D BIM comparison [7], and Samsami groups automated inspection and progress monitoring tools into data acquisition, processing, and analysis layers [5]. It is also consistent with Klapa and Mitka's stage-dependent comparison of sensor utility [6].

A first question is how raw site information becomes data that can be compared with BIM. On the acquisition side, the sensor choice determines the capability boundary. Visible-light cameras support photogrammetric reconstruction and are cheap and flexible [1, 8], and LiDAR provides dense and accurate point clouds but costs more [6]. Klapa and Mitka compare LiDAR and multi-lens camera payloads for BIM-based building assessment and find that sensor utility differs by construction stage and by the required level of geometry versus texture [6]. A scientometric study by Videras Rodríguez et al. on UAV use in architecture and urbanism lists battery life, GPS interference, and weather among the main constraints on UAV operation [8].

On the transformation side, point-cloud formats such as PLY, LAS, and E57, and the software chains that produce them, become the bridge between UAV output and BIM. Keyvanfar and Shafaghat review UAV three-dimensional reconstruction modeling and note that output formats affect downstream compatibility [9]. Mihić et al. analyze the uses and barriers of 3D scan data in construction management and find that technical limitations and the industry's limited readiness hinder its wide adoption [10]. In practice, Bhattacharjee et al. use DroneDeploy to generate point clouds, ReCap for registration and Navisworks with a C# algorithm for comparison, with their point-cloud RMSE reaching 0.038m [2]. Chinese studies report similar efforts. Feng, D. M., et al. register UAV point clouds with a bridge BIM using ICP and nearest-neighbor segmentation; the registration RMSE is 0.13m, and component recognition accuracy exceeds 95% [11]. Hu et al. propose an improved ICP alignment for building progress using UAV LiDAR, keeping the false positive rate below 15% and the scanning accuracy around ±2cm [12]. In many reported cases, data acquisition and transformation have reached a level sufficient to support automated comparison, though implementation barriers remain [10].

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3. Progress identification: two complementary technical routes

Once the data are aligned, the next question is how to judge progress from aligned data. Two routes appear most often.

One route is point-cloud geometric comparison. The BIM model is converted into a reference point cloud, registered with the actual point cloud, and completed components are identified through segmentation and change detection. Feng, D. M., et al. apply this route to a Yellow River bridge; component recognition stays above 95%, with a registration RMSE of 0.13 m [11]. Hu et al. align building progress with an improved ICP, keeping the false positive rate below 15% [12]. Guo et al. go further, coupling a Siamese CNN with M3C2 change detection for roads, and bringing construction completion estimates down to the centimeter level [13]. This route is strong in geometry and suits bridges and buildings, where component shapes are clear, but it depends on complete point clouds and is sensitive to dynamic occlusion [11].

The other route is AI vision recognition. Instead of geometric comparison, object detection algorithms directly recognize construction machines, component states, and construction phases from UAV images. Feng, H. Y., et al. upgrade YOLOv5 with SIFT features and DeepSORT tracking to identify four construction states of hydraulic pier grooves; mAP@0.5 reaches 0.989 [14]. Liu et al. pair object detection with SIFT feature matching and monocular motion parallax to track river regulation revetment progress; their mean error is 1.026 m [15]. In a systematic review, Rehman et al. describe data acquisition, information extraction, progress estimation, and visualization as the standard pipeline, while most techniques still require human intervention and the sub-processes lack connectivity [4]. This route is flexible and suits procedure-driven projects such as roads and water conservancy, but it requires large labeled datasets.

These two routes are complementary rather than substitutable: point clouds provide geometric accuracy, and AI provides semantic understanding. Several frameworks already combine them. Bhattacharjee et al.'s integrated system is a representative case [2], and recent reviews by Rehman et al. [4. and Samsami [5] point in the same direction.

4. Application in different engineering scenarios

4.1. Linear projects

Roads, railways, and levees share a long, narrow layout, so full-line coverage and earthwork volume are the main concerns. Studies here tend to combine point-cloud measurement with AI change detection. Vick and Brilakis, in their review of linear transportation progress monitoring, note that 4D BIM is commonly used to automate the comparison between as-planned and as-built data [16]. Guo et al. achieve automated road construction progress monitoring at the centimeter level [13], and Xu et al. apply UAV surveying to dynamic earthwork accounting in levee projects [17]. For railways, Zhang et al. build an intelligent management system that integrates autonomous inspection and progress analysis [18]. Rail transit projects have also begun to use UAV-BIM integration for site management [19].

4.2. Point-type projects

Bridges and buildings are compact structures where component-level identification matters most. Point-cloud registration, often paired with segmentation or difference comparison, is commonly used. Feng, D. M., et al. apply UAV point-cloud registration to a bridge BIM model and achieve

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component recognition above 95%, with a registration RMSE of 0.13 m [11]. For buildings, Luo et al. use BIM-UAV difference comparison in construction supervision [20], and Gao et al. visualize building progress with UAV three-dimensional real-scene models [21].

4.3. Regional projects

Water conservancy and new energy projects cover large, dispersed areas, so regional coordination and early warning are the main focus. Zhuang et al. generate dam earthwork volume intelligently in a pumped-storage project using BIM and UAV data [22]. Liu et al. apply BIM-UAV intelligent control to a 300 MW wind-solar-storage project [23]. Their system improves acquisition efficiency by about 400% and shortens early-warning response to within one hour; it also raises schedule control accuracy by 30%, completing the project 15 days ahead of plan and saving more than 2 million RMB [23].

So the pattern is clear: linear projects track full-line progress and earthwork, point-type projects identify individual components, and regional projects coordinate across a wide area. Open and linear sites see the widest use of UAV monitoring, because sparse obstacles and open terrain make data acquisition easier; Vick and Brilakis observe this for linear transport [16], and Liu et al. report a similar advantage in a wind-solar-storage project where open terrain helps acquisition [23].

5. Discussion: accuracy, timeliness, safety, and remaining gaps

Three dimensions help judge the current state: accuracy, timeliness, and safety. For accuracy, point-cloud comparison identifies components with accuracy above 95% in a bridge case, with a registration RMSE of about 0.13m [11]; another study reports mAP@0.5 of 0.989 for four construction states [14]. Timeliness figures come mainly from one wind-solar-storage project, where UAV acquisition is about 400% more efficient than manual work, site data are synchronized with BIM within 24 hours, and early warnings are issued within one hour through three alert levels [23]. On safety, UAVs replace personnel in high-risk areas, and integrated progress-safety inspection is emerging. Lu uses UAVs and AI for bridge progress-safety inspection and optimizes patrol routes with the Dijkstra algorithm [24]. Liu et al.'s platform focuses on progress control with multi-level early warning [23].

However, some gaps still remain. Dynamic occlusion by machines and materials still degrades point-cloud quality and visual recognition, especially under bridges and in dense sites [11]. AI-based recognition still requires human intervention in several steps, and the sub-processes are not yet fully connected [4]. More importantly, most studies stop at detecting deviation rather than checking compliance against contract milestones and specifications, which is precisely what compliance-based verification requires. UAV, LiDAR, IoT, and BIM data are also not yet deeply fused. Progress prediction is rarely addressed either: current systems usually answer what the progress is, not what it will be. The field appears to have reached automated monitoring, but not yet automated verification.

6. Conclusion

This study aimed to investigate how BIM and UAV vision can be integrated for automated construction progress verification, and the evidence suggests that the technical chain of data acquisition, data transformation, progress identification, and scenario application has been largely established. The analysis shows that point-cloud registration and AI vision recognition are complementary routes. In the reviewed cases, linear and open projects appear to be the most suitable

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application scenarios, and accuracy, timeliness, and safety all improved substantially over manual inspection. This supports the potential of BIM-UAV integration to reduce reliance on manual progress checking in suitable cases.

This research contributes by organizing a fragmented literature around fundamental problems and by evaluating the field along accuracy, timeliness, and safety, giving newcomers a structured map of the field. For construction management, this study has practical value: it helps engineers choose monitoring routes that fit the project type.

This study is limited by two things: the Chinese literature was mainly collected from domestic databases, and the quantitative indicators are not fully comparable across studies; both may affect the generalizability of the findings. Future studies could focus on standardized benchmarks for progress verification, compliance-based comparison against specifications, and edge intelligence for minute-level real-time verification. Overall, this review maps the current state of BIM-UAV integration and argues for moving from progress monitoring toward automated progress verification.

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