From BIM to UAVs: A Systematic Review of Digital Solutions for Productivity Challenges in Construction

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1. Background

There is a productivity issue facing the construction industry (CI). It is worth noting that the civil engineering construction sector devotes limited investments to assessing and improving task quality and productivity onsite. Inefficient management of engineering resources in construction might directly affect productivity [1]. Aspects such as time and cost overruns, quality and associated management of constructed facilities using innovative tools, and labor productivity are some issues faced by the global construction industry. [2]. In recent years, digitization has offered the Architecture, Engineering, Construction, and Operations (AECO) sector the opportunity to improve performance and accuracy, thus reducing costs, modernizing the industry, and increasing productivity.

Productivity is the output that results from a given number of inputs. Construction productivity increased by only 1% annually over the past 20 years. In contrast, the productivity of the economy and manufacturing sectors increased by 2.7% and 3.6%, respectively, for 27 years, according to an analysis of 41 different countries [3].

Productivity measurement should not be regarded as a one-time activity solely for reporting purposes. It is a continuous process essential for obtaining representative indicators that enable more accurate project monitoring. It is also important to note that isolated productivity values lack practical meaning and should only be interpreted when related to a reference scale or comparative baseline. A crew-level model of construction labor productivity serves as a critical foundation for understanding productivity and identifying the most effective improvement strategies to implement.

Onsite project monitoring typically involves gathering data at the project level through direct observations, surveys, and interviews to evaluate progress at the execution stage. While these methods are complementary, each is designed to assess specific aspects of construction production. Additionally, construction companies' approaches to implementing these processes can vary significantly [4].

Onsite observations and methods based on surveys or interviews are employed to assess construction production at the functional level [5-6]. These approaches indicate how effectively workers and equipment are utilized. By analyzing the tasks performed by craft workers and linking them to productivity performance metrics, monitoring at the operational level identifies critical factors contributing to performance variations that arise during operations.

In recent years, automation and digitalization have provided this sector with tools to achieve greater efficiency and precision, lowering costs and advancing production processes. Recently, A significant area of research in the construction industry has concentrated on developing information and sensing systems for automated productivity data collection onsite. This research can be categorized into two main domains: (1) automated tracking of project progress to evaluate construction production [7-8] and (2) automated tracking of resource utilization to assess construction production [9-10].

Recognizing the increasing interest and investment in digital technologies for productivity assessment, this study provides a systematic review of the use and application of digital tools in the AECO sector. It explores their connection to productivity, highlighting associated benefits, significance, and tangible outcomes. This review is structured to address eight key objectives. Specifically, it poses eight critical questions to identify available and commonly used tools, evaluate the methods employed, and examine their benefits and significance in improving productivity. The following questions will be addressed.

2. Materials and Methods

2.1. Type of Study

A systematic review approach was used to determine which technologies are available globally and where their application has proven successful in the construction industry. In contrast to a traditional literature review, a systematic review follows a set procedure to find, analyze, evaluate, and summarize the most significant study findings from the publications that are most relevant to the review subject [11]. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement [12] was followed in this systematic review. According to relevant methodology [13].

2.2. Review Questions

This review is structured to address eight key objectives. Specifically, it poses eight critical questions to identify available and commonly used tools, evaluate the methods employed, and examine their benefits and significance in improving productivity. The following questions will be addressed.

- Mapping the technologies in use
    - Q1. Which are the main technologies used to measure/manage construction productivity on site?
    - Q2. How can these technologies increase the productivity of direct labor?
- Analysis of the impact of specific technologies
    - Q3. What is the relative importance of point cloud technologies, and how has this importance varied over time?
    - Q5. What is the importance, and how do video and images enhance labor productivity?
    - Q7. What is the importance, and how do sensors enhance labor productivity?
- Supporting and integrative technologies
    - Q4. What digital tools help in training on-site activities?
    - Q6. Is BIM necessary to support an automatic productivity control solution on-site? And what are the benefits?
- Empirical grounding
    - Q8. Do the articles present empirical results from real-world case studies?

2.3. Eligibility Criteria

During the initial search phase, 431 records were identified across multiple databases. After removing 146 duplicates, 285 articles remained for screening. Applying predefined exclusion criteria, 247 articles were excluded—202 due to document type (e.g., book chapters, editorials, conference proceedings, and surveys), five due to language (only English-language publications were considered), and 40 for lack of relevance to the research topic.

Documents not written in English were excluded, using a linguistic criterion. Geographic location was not considered as an exclusion factor. Finally, the titles and abstracts of all documents were

reviewed to ensure alignment with the study's theme. This process resulted in a final selection of 28 documents.

2.4. Sources of Information and Search Strategy

All searches were conducted in the Scopus and Web of Science (WOS) multidisciplinary scientific databases during the first week of October 2024. After carefully considering pertinent and alternative terms frequently employed to depict technologies used in the construction sector, significant schemas were selected and incorporated into the initial search. The query phrases((Surveying OR "Point Cloud" OR "Computer vision" OR "Laser Scan*" OR photogrammetry OR lidar OR uav) AND ("Labor productivity" OR "Progress Monitoring" OR quantity OR "Construction automation" OR "Productivity Monitoring") AND (construction OR building) AND (bim OR "Building Information Model*")) were employed to search all databases' article titles, abstracts, and keyword fields. After that, the search was carried out using the snowballing technique, and the reference lists of the papers that had initially been retrieved were reviewed until no more pertinent material could be located.

2.5. Process of Studies Selection

The identified studies will be imported to Mendley to remove duplicate documents. No chronological exclusion criteria were applied to ensure both recent and foundational publications were included. Studies without duplicate documents will then be evaluated and selected based on eligibility criteria.

This screening resulted in 38 full-text articles assessed for eligibility. Of these, 33 were excluded for not meeting the core inclusion criteria, particularly regarding direct focus on on-site productivity and the application of digital technologies. Only 5 articles were retained at this stage. Although this number may seem limited, it reflects the strict methodological rigor adopted in this review to ensure relevance and quality.

A snowballing strategy was employed to strengthen the dataset, reviewing the reference lists of the initially included studies. This process led to identifying 23 relevant articles and expanded the final sample to 28 high-quality studies. The integration of snowballing is a recognized and effective method in systematic reviews, especially when addressing emerging or multidisciplinary topics with sparse direct literature. Figure 1 outlines this process following the PRISMA-P framework [14].

2.6. Process of Data Extraction from selected studies

The data ofselectedstudieswillberigorouslyanalyzedandcollectedbytwoindependentand blinded reviewers, by filling out a characterization table in Microsoft Word software, which contains:

- Characteristics of study: identification (citation), study design, the country in which the study was developed, follow-up period, and digital tools;
- Main outcomes: on-site productivity and the application of digital technologies.

2.7. Data Synthesis

The study aimed to address research questions about assessing productivity in construction tasks using digital technologies.

This study comprehensively synthesizes how digital technologies transform construction productivity management. By categorizing technologies and methodologies, the review establishes a clear connection between innovative tools and their practical applications, such as progress tracking, real-time data collection, and predictive modeling. Identifying recurring themes, including the critical role of BIM in productivity enhancement and the increasing importance of image-based monitoring, enriches the understanding of digital innovation in construction

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