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Review

# Data acquisition technologies for construction progress tracking

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ABSTRACT

Falling behind schedule and having discrepancy between the as-built and designed baseline plans are unfavourable events that often occur in construction projects. Hence, real-time progress tracking and monitoring of construction components remains a vital part of project management and is critical to achieving project objectives. Yet manual approaches for progress tracking lack the required accuracy for integration with other construction interfaces. Conversely, automatic progress tracking can result in timely detection of potential time delays and construction discrepancies and directly supports project control decision-making. This paper examines different technologies of automated and electronic construction data collection. In particular, enhanced IT, geo-spatial, 3D imaging, and augmented reality technologies have recently achieved significant advances in this field. Each of these technologies is discussed herein in terms of its advantages and limitations. Comparisons of such technologies to identify various trends concerning their applicability in real-time data acquisition of construction projects are made, along with recommendations for their suitability in different projects. This should assist construction stakeholders in choosing appropriate tools to enhance time and cost effectiveness and achieve better control and more effective decisions during construction. It is also hoped that this review will stimulate further research on and development of these technologies.



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## 1. Introduction

On-time actions are necessary for a construction management system to flow forward and be operative and productive. The forward flow of actions requires a feedback signal to track the status of the system each time it is maintained and assessed [1]. Site information can provide feedback for various purposes, including progress measurement [1,2], equipment and material tracking [3,4], safety planning [5], and productivity tracking [6]. Construction site information has generally been organized into three main categories: finance, quality, and progress [7]. One example of necessary action in construction management systems is to mitigate defects and imperfections that could have time and cost consequences. Late detection of such defects is problematic and allows only minimal time to mitigate the associated detrimental cost and schedule implications [8,12]. According to Nahangi and Haas [13], about 10% of construction budgets associated with industrial projects are attributable to rework due to late detection of deficiencies in construction sites. Approximately 50% of the associated rework cost of defective components arise from human errors and 10% is attributable to material defects.

Early assessment of the as-built status during construction is also essential for effective and efficient corrective action planning. NYSOT [18] summarized the characteristics of efficient methods of progress and performance measurement as follows: measurable, reliable, consistent, understandable, verifiable, timely, and unaffected by external influences, cost-effective, useful, and suitable for effective decisions. Currently, there is a lack of systematic evaluation and monitoring in construction projects. Conventional progress tracking methods depend on extensive manual interaction, which is inaccurate, time-consuming, and labour-intensive even for small projects. Such an approach has been recognized as one of the major problems that cause project delays and cost overruns [14]. It also lack electronic data integration between different interfaces.

Progress monitoring activities are recently becoming more automated and integrated. Automated approaches have emerged as advantageous tools for quality management and as-built tracking purposes [9,16,17] and is also important in improving productivity, which is paramount in construction management systems [10]. However, the vision for the future of the construction industry is of a highly automated project management environment integrated across all phases of the project lifecycle. This integrated environment will enable all project partners and project functions to instantly connect their operations and systems. Interconnected, automated systems, processes, and equipment will reduce the time and cost of planning, design, and construction [4].

### 1.1. Challenges with construction progress tracking

Most of the research efforts in the field of project control still focus on the development of cost control models where the earned value concept has proven to be the most reliable tool for tracking and control of construction projects [11]. A critical part of project control is progress tracking or as-built sensing. Construction progress tracking, however, is not a simple task and is associated with many challenges because construction projects involve large amounts of information related to a variety of functions, such as scheduling, construction methods, cost management, resources, quality control, and change order management. In addition, information is provided by a number of different sources and is presented in a wide variety of forms. Furthermore, it may be difficult to track and record changes based on conscious decisions that are made during construction. It can even be more difficult to adequately track and record deviations that are more subtle not emanating from conscious decisions (e.g., deviations due to poor workmanship) [13].

### 1.2. Research on automated progress tracking

A number of advanced automated data collection technologies are used today for real-time on-site progress tracking. Substantial research on automated project progress tracking has aimed at automating the measurement of physical quantities in-place using spatial sensing technologies, for example for earth moving, structural erection, and masonry work. Information technology tools have been supported by a number of research studies to improve communication on construction sites and enable daily automated progress tracking of construction activities. Three-dimensional (3D) sensing technologies are being widely investigated by several researchers for providing real-time 3D as-built information and comparing with the design information embedded in building information models (BIM) [19]. Augmented Reality can be applied to address a plethora of problems throughout a construction project's lifecycle. It has been impacting the mobile communications industry by providing a radical shift in human–computer interaction and has been receiving increasing attention of researchers and practitioners alike. Adopting such a variety of automated progress tracking technologies can provide decision makers with timely progress details to follow the project progress more effectively, facilitating schedule updates and accurate schedule forensics, delay analysis, and planning of appropriate corrective actions.

## 2. Research objectives

The aim of this study is to explore the automated progress and performance measurement technologies that are currently in use by the construction industry. To achieve this goal, the following sub-objectives are outlined: (1) delineate recent research efforts in this field; (2) study the characteristics of the different automated data acquisition technologies; (3) determine the challenges associated with these technologies and their potential applications with particular focus on their capabilities and limitations; (4) survey related commercial software systems; (5) provide the construction industry with guidance to make more informed decisions to select suitable technologies for their specific projects; and (6) outline the technology gaps for future research.

## 3. Research methodology

The methodology adopted for the achievement of the above objectives is as follows: (1) collect a wide range of recent research on

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