

## Lean Project Management using Unmanned Aerial Vehicles

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**Abstract:** Development of a lean and automated progress tracking system is one of the most challenging subjects in the construction industry. Since the current methods depend on individual and manual inspections of the site, they may have various problems. For instance, results include a natural bias since field personnel makes interpretations depending on their educational and expertise level. From the practical point of view, manual data collection and their comparison with construction drawings and schedules are inefficient as it takes too much time. With the recent advancement of Unmanned Aerial Vehicles (UAVs) into the market and inclusion of lean project management principles, project management studies are inclined towards the digital and lean approaches. Within this perspective, the objective of this study is to reveal the use of UAVs as a lean project management tool. This paper indicates merely that UAVs have the potential for such a purpose.

**Keywords:** automated progress tracking, construction monitoring lean construction, lean project management, unmanned aerial vehicles.

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### 1. INTRODUCTION

Lean production was introduced by Engineer Ohno when he was working in Toyota (Womack et al. 1990). Instead of dealing with the entire production system, he narrowed the focus on the productivity of the worker with a better meeting of customer needs. The main goal was to create a flow-based manufacturing system without any transitional inventories. After releasing Toyota Production System, lean principles had gained popularity and used in various industries. In the 1990s, the lean approach had implemented to project management of two complex buildings Sainsbury Wing of the National Gallery and New Glyndebourne Opera House. Although they were high-risk projects with strict budgets, avoiding duplication and providing effective communication among project members lowered risk to the client and increased performance and value (Gabriel 1997). In the 2000s, project phases were redefined considering lean principles. Ballard and Howell (2003) presented a new system called the Lean Project Delivery System (LPDS) which differs from traditional project management in terms of goals and phases. Concentration was associated directly with the production system instead of focusing on transactions and contracts. Rather than sequential designs of product and process stages, they were considered in a single design together. Those rules were applied to the precast concrete fabrication as a case study, and the results showed that LPDS is superior for the reducing the

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waiting and cycle time, inventories, defects and unexpected accidents. Considering these benefits, (Lapinski et al. 2006) performed project delivery methods to a sustainable building project.

The term “lean construction” have arisen to reduce waste and increase customer-focused value in the construction industry. Although lean manufacturing and lean construction differ from each other because of the physics of the industries, there are still common features to make the construction sector more productive (Salem et al. 2006).

The productivity of a construction highly depends on a well-maintained monitoring system. Any mistake done on the construction site should be detected in the early stage and solved by the field engineers. The continuous flow of construction can be provided only in this manner. It is difficult to monitor large-scale construction sites by field personnel because inspections of hard-to-reach areas are time-consuming and depend on the personnel’s point of view. At this point, Unmanned Aerial Vehicles (UAVs) or so-called drones provide easier and efficient inspections techniques (Ersoz et al. 2017). Advancement of computer vision techniques enabled to create 3D models of the construction site efficiently. Visualization of 3D as-built model helps to the better understanding of construction progress (Golparvar-Fard et al. 2015). Quality assessment can be performed remotely by making measurements on the digital model. Continuous monitoring of the construction site with drones enables to monitor and manage the construction site in a lean way. In this study, drone-based monitoring is discussed considering three lean principles: Visual management, transparency, and continuous improvement.

## 2. Relevant Lean Construction Principles

**Visual Management.** Visual management is one of the essential keys of lean production in which visual information is utilized to create a transparent view of the real scene (Tezel and Aziz 2017). With the help of drones, visual information of hard-to-reach regions can be collected easily and ordered daily photographs enables to follow changes on the site (Figure 1). Therefore, there is always a chance to control older status of stored information since all of them stored in a database.





**Figure 1:** Aerial photographs taken by drone

Significant improvements in the computer vision community enabled to create 3-dimensional point clouds from high-resolution images from the site using photogrammetry methods (Westoby et al. 2012). Frequently constructed as-built models give an opportunity to identify progress on the site from various angles (Ham et al. 2016). If the geometry of these 3D models is validated with GPS coordinates, centimeter-level accuracy measurements can be performed on this model such as length measurement, area, and volume (Figure 2). Thus, quality assessment is available in anytime and anywhere. Continuous visual data helps to track the progress of the construction and empowers to take precautions to maintain a continuous flow.



**Figure 2:** Measurements on the model

**Transparency.** Visual information helps to see the production with the first-person view instead of textual or spoken data that include bias. Visual data collected from the site show the status of the construction without any human interpretation. If aerial photographs and 3D as-built models are published on a web interface, field engineer, project manager and any other stakeholder of the project can access to the current status of the construction.

Monitoring site from a single model allows sharing information from the construction site to stakeholders in a transparent way. There is no human error and misunderstood explanation of the progress. Furthermore, since the field personnel is aware of remote monitoring of the site, they work on their task carefully. Therefore, the consciousness of being monitored increase quality and decrease amount of waste.

**Continuous Improvement.** In practice, most of the progress information is not digital, and they are stored on the hard copy files temporarily. There is no online environment that progress updates are stored in and shared with stakeholders. The sequence of the as-built models created from site photographs is a progress log of the construction (Figure 3). Thus, retrospective knowledge is always available and searchable.



**Figure 3: The sequence of 3D Models**

Each 3D model is constructed after a set of plans, sometimes plans work, and activity tasks are executed, but sometimes there could be delays because of the external reasons. For drone-based monitoring, there is an opportunity to take digital notes on the model regarding 3D models of the construction. If the reasons of delays are attached to the sequence of digital models, a lesson-learned database can be generated. Besides 3D visual information, the mistakes and solutions could be stored. This database supports continuous improvement (kaizen) and learning of a construction firm.

### 3. Conclusion

In this paper, we discussed drone-based construction monitoring and details of how it relates to lean production principles. Lean effects of the drone-usage are categorized into three groups. First, aerial photographs by their nature give a chance to understand and measure the progress of the construction visually. Second, one shared model gives an opportunity for better communication between stakeholders and transparent knowledge sharing. Finally, taking notes on the model makes possible to record experiences of the construction site which leads to continuous improvement. Drone-based construction monitoring enables stakeholders to understand the physics of the construction better and more transparent. Technological improvements and application of lean principles reveal the future of the construction site will not be monotonous and underdeveloped. Leaner and more productive construction methods are ahead of us.

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