Applications of Drone Technology with BIM to Increase Productivity

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This paper looks directly at BIM and Drone Technology in today's age and how their integrative capabilities with one another can result in a highly productive construction atmosphere. There is an abundance of research for the topic, but no real-life examples. Webcor will serve as this example via case study. The research methodology for the project will come from interviews and a questionnaire featuring a project manager, superintendent, licensed flyer, BIM engineer, and cost estimator. The variety of interviews, will showcase the effects drone technology and BIM have on different sectors of a business. Themes that come out of these interviews include, hardware, software, surveying, safety, and financial impact. These results prove that drone technology is a relatively new industry with great common applications. This paper focuses on major techniques companies can use to further integrate drones with BIM to increase productivity.

Keywords: Building Information Modeling (BIM), Unmanned Arial Vehicles (UAVs), drone technology, construction productivity, data collection

Introduction

The construction industry is behind other major industries in the technology race. Whether it's due to the dependence of pens, papers and spreadsheets for bids or the lack of infrastructure to go mobile, construction productivity has stayed constant for decades (Jones, 2019). With new technological advancements entering the construction world every day, the industry is finally headed in the right direction. And by integrating these innovative technologies with each other, construction will prosper. Some of these innovative technological advancements include unmanned aerial vehicles, virtual design and construction, and building information modeling.

Building information modeling (BIM) seems relatively straightforward but it does have some common misconceptions. BIM is not only a design tool, but a software that integrates that 3D modeling with data collection. The combination of the two processes provides the measure or standard for the building project—an analogy or smaller-scale representation of the final appearance and effect. It will continue to model this representation throughout the building's lifespan (Green, 2016). The model shows everyone involved in a project, what is happening at every aspect of construction. This visual information using a model benefits safety, estimation collaboration, and cost. Drones can serve a very important role modeling, which is why their surge in popularity has erupted.

Drones are also known as unmanned aerial vehicles (UAVs) and they've been around for a century (Desjardins, 2016). Their origins stem back to the U.S. military which has been a stimulant for the development of UAV technology. Over the years drones have gotten smaller, cheaper, more advanced and more common for commercial use. The number of Federal Aviation Administration (FAA) approved permits have skyrocketed over the last couple years and by 2025 drone technology could boost the US economy by 82 billion dollars (Desjardins, 2016).

Figure 1- Permits Approved by Federal Aviation Administration (Desjardins, 2016)

Importance of BIM Technology

Design and Development

During the preconstruction phase the potential work of a project is determined by all the decision makers and stakeholders. Using BIM as a single model for a project allows everyone involved in the design process (owners, architects, engineers, contractors, subcontractors and suppliers) to work collaboratively with one another (Vacanas, Themistocleous, and Agapiou, 2015). Team members can constantly monitor and modify their design areas throughout the preconstruction phase. This increases transparency between everyone involved in a project thus drastically improving the accuracy of the model, efficiency of cost feedback cycles and speed of decision-making processes (Vacanas, Themistocleous, and Agapiou, 2015). BIM coordinators issue out virtual mock ups and value analysis early on, so everyone involved makes the correct decision. Sometimes changes occur on the design, and BIM will update to accommodate. BIM models occur in real time, so everyone is working with up-to-date information constantly (Jones, 2019). With this coordination, members on the project can easily detect construction errors and come up with the best solutions for them. Having many eyes collaborating early on reduces the chance of errors to be made later in the construction process, and thus increases the overall performance of a project.

Construction

Construction is by far the longest and most unpredictable phase of a project. Even with a detailed plan and schedule challenges will occur. BIM will play a huge role in identifying and coming up with solutions for these problems. BIM's 3D information and data collection can be used to amplify virtual and augmented reality simulators to help aid construction. The use of virtual reality (VR) can give workers experience on everything from operating cranes and excavators to doing welding and masonry work (Jones, 2019). Augmented reality (AR) takes this to another step and augments possible hazards a worker can face on the jobsite, and trains them to workover it. The experience gained through these simulations are hazard free, and stem from BIM modeling. Worker safety is a top priority for every single construction company, and technology has made training for accidents much easier to prevent accidents and injuries (Jones, 2019).

BIMs 3D capabilities may be highlighted by clash detection and coordination, but it's not just limited to three dimensions. By synchronizing the fourth dimension of time to 3D models, it is possible to simulate the construction process at any point in time (Vacanas, Themistocleous, and Agapiou, 2015). This insight is incredibly useful when monitoring the schedule of a project. Problems and their occurrence can be visualized well ahead of time and change orders can be made early to conserve the schedule of the project. The longer a change is made the more likely the project is delayed, and dollars are wasted. To help speed up the construction process, BIM technology enhances the coordination between designs and contractors (Vacanas, Themistocleous, and Agapiou, 2015). With all the information up- to-date, both workers can quickly make decisions regarding cost effective methods of construction and efficiently allocated resources.

Importance of Drone Technology

Data Collecting

UAVs have the ability to create dense highly detailed 3D models of anything in sight. But in order to ensure that these renderings are accurate, good data collection methods are essential. Drones are either laser-based with LiDAR, a remote sensing method that uses light in the form of lasers or visual with a camera (Dupont, Chua, Tashrif, and Abbot, 2017). LiDAR specializes on quick surveying while the visual aid of drones uses photogrammetry to converts two-dimensional images to three-dimensional models (Tatum, 2017). Photogrammetry is integrated with LiDAR highly accurate surveys to produce incredibly detailed 3D models. Though the hardware acquires the information, the software is what makes the difference in applications (Desjardins, 2016). A specific database is needed to process and store all the information taken through drone data collection. Here the data should be available to everyone involved in the project and used as a cross reference to future projects.

Aerial Photography

Record keeping plays a huge role in project management and is tedious aspect of the job. The abundance of reports, resource records, work progress, and daily site records could get overwhelming, which is why it's important to minimize the amount of work needed. UAVs offer a high-resolution imagery analysis by determining object characteristics from improved stereo-photographs (Vacanas, Themistocleous, and Agapiou, 2015). Measurements can be pulled out of these images instantly, thus drastically decreasing the amount of time record keeping could take. As seen in Figure 2 below, the most popular use for UAVs are progress photos, followed by promotional videos, visual inspections, and site management.

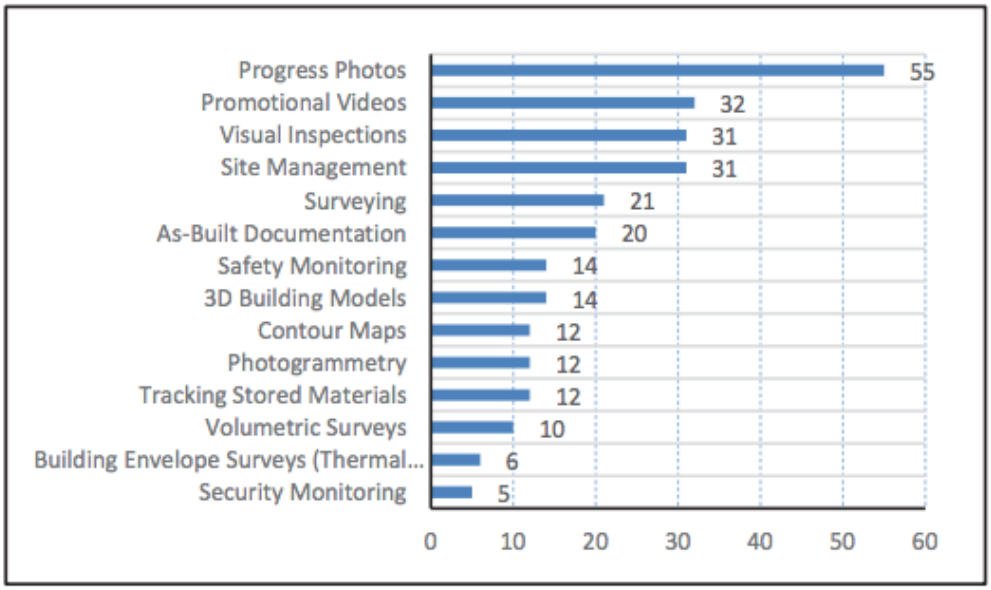

Figure 2- UAV Uses in Construction (Tatum, 2017)

Residential and commercial real estate, depend on drone marketing imagery. Many firms are shifting over to drones and a high-quality camera to capture stunning photos and videos of property instead of hiring a crane or helicopter (Danielak, 2018). Not only is this method cheaper upfront, but it is also more convenient and quicker. The drone can get to spots and capture shots from almost impossible angles resulting in endless creative possibilities.

Autonomy

UAVs are to be able to perform without human intervention, called autonomy. The three stages of autonomy get more complex and depend on its predecessor. The first is sensory-motor autonomy which only uses high-level commands such as following GPS, followed by reactive autonomy which allows drones to handle obstacles, and lastly reactive, and lastly cognitive autonomy which resolves conflicts and learns from them (Dupont, Chua, Tashrif, and Abbot, 2017).

This autonomous feature can add constant surveillance of a jobsite without affecting the schedule of a project. It also increases the safety on site due to the constant safety inspections the drone can assistant on (Irizarry, Gheisari, and Walker, 2012). Another safety monitoring tool drones can have are security alarm systems. A UAV can be resting at a charging station and when an alarm goes off, it can deploy and capture a video of what's happening (Tatum, 2017). This tool can be incredibly useful, in case no one is on site during an accident. The video can be streamed and with the quality of the footage, objects can be easily identified. As seen in Figure 3 below, drones can move autonomously using predetermined paths and coordinates.

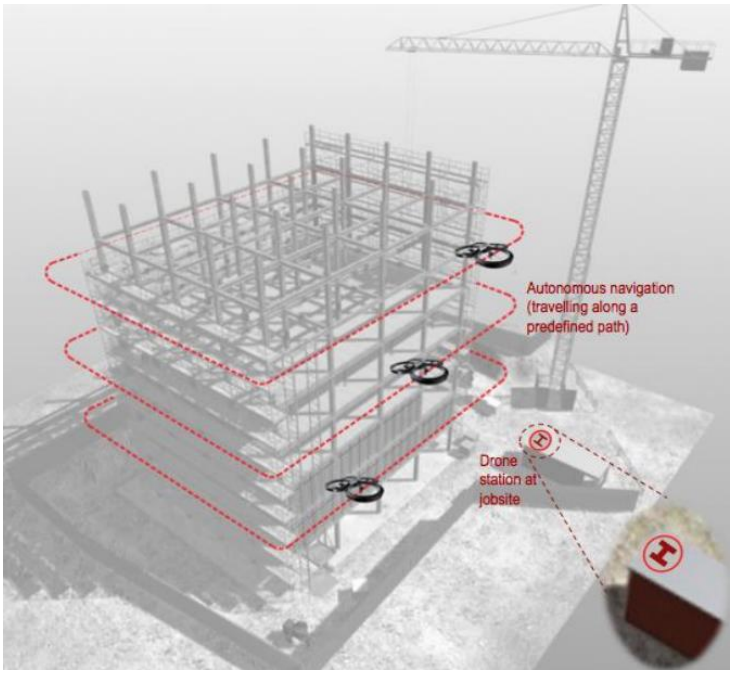

Figure 3- Autonomous Navigation of Drones (Irizarry, Gheisari, and Walker, 2012)

Methodology

The objective of this case study are as follows:

- To show the effects of drone technology during pre-construction
- To showcase real applications of drone technology on the field
- To highlight the effects UAVs, have on different job positions
- To report the limitations drone technology faces
- Uncover myths related to drone technology
- Discover possible future uses of UAVs in construction

The methodology chosen for my project was all qualitative. The data collection technique used to get all my information, were unstructured interviews. All five interviewees have different positions for Webcor, which influenced the questions being asked to them. Because this topic is fairly new, qualitative information from multiple diverse sources can lead to a more impactful case study. The interviewees consisted of a project manager, superintendent, BIM engineer, estimator, and licensed flyer. The interviews were informal and taken after my literature review was completed. This gave me the knowledge to ask proper questions that will benefit my hypothesis. Once the interviews were completed I sent out questionnaires to the interviewees stating, "Where do you see a future use in UAVs for construction?" This questionnaire was relayed to their peers and I was able to get 17 responses.

Data Analysis and Discussion

Applications

The overall theme, that come out in every interview is that drone technology is very beneficial during pre-construction and construction. Senior project manager Matthew Faith, stated that even though UAVs don't necessarily affect the schedule significantly, they play an important role in visualization for weekly meetings with owners. Owners don't always have the best understanding of construction processes, thus limiting effective communication throughout a project. The use of drone imagery and 3D modeling serves as a solution to confusion

an owner can face. Superintendent Gentry Mehringer stated that drones are either used daily for snapshots, weekly, or monthly depending on the project. This is all situational depending on the scope of work needed to be done. For example, rough grades and excavation require drones nonstop to profile and survey the site. Estimator Pat Vayaphat stated that this saves time in the field and gives the project team an accurate record of site conditions. This is due to the integration between data collection and modeling. BIM engineer Jocelyn Mezofenyi expressed that Webcor depends heavily on Revit and Navisworks to stream and collaborate models. Changes that the drone captures, automatically updates BIM modeling at real-time, laying out information instantly to all workers. This results in increased productivity throughout the project by increasing awareness on a project as well as limiting the amount of errors made. To put this in perspective for an actual project, interviewees were asked where drone technology was necessary, and all the answers were the same. The UC Merced 2020 expansion depended on drone technology due to its size and openness of the site.

The UC Merced project covers around 200 acres, with 14 buildings covering about 373,400 square feet (Webcor, 2018). Drone technology played a huge role so far in the project and continues to do so. Its visual aid and LiDAR have been essential in collecting data to create BIM models that include an accurate representation of site topography. Gentry Mehringer expressed that a picture/video is worth a 1000 words and having the ability to conveniently obtain those with UAVs can do wonders for the project.

Figure 4- UC Merced 2020 Expansion Project (Webcor, 2018)

Limitations

The Federal Aviation Administration (FAA) regulate all drone use in the US. To operate a UAV, one must either be a registered flyer or be under the supervision of one. Webcor has only one licensed flyer named Trevor Nadler and he revealed that registration is dependent on your drone use. Regardless of your intent, the FAA puts restrictions on all drone use. First off, UAVs can only be used between 30 minutes before sunrise to 30 minutes after sunset. This eliminates the use of drones at night which can burden construction projects that require night work. Another regulation is that drones can't fly more than 400 feet above ground or a structure. This limits the ability to use drones for designing skyscrapers, which are increasing in all urban cities nationally. Luckily waivers for these restrictions can be requested as long as safety precautions are provided.

Limitations are also dependent on your location, and since Webcor is stationed inside San Francisco navigation is a problem. The amount of buildings inside a dense city like San Francisco, make it difficult to navigate and obtain accurate visual aids. Gentry Mehringer voiced that these limitations are similar to that of interior work, because drones don't have access to every spot. This can all lead to less informative information which can affect the safety and efficiency of a worker.

Financial Impact

Because of how recently the drone industry entered construction, Webcor has not seen big financial impacts. Estimator Pat Vayaphat revealed that the drones their company use range from $1,500 - $10,000 but aren't considered in their budget since they rent them from a warehouse. In the next couple of decades, more information can be analyzed on drone technology and its BIM capabilities. However, it is apparent through the case study of Webcor that this industry is very promising and the sky's the limit for UAVs.

The Future of Drone Technology

To get the best out of drone technology, everyone needs to share their input on them. This questionnaire served as platform for Webcor employees to do so. There are many possible future functions for UAVs and they can be seen in the responses below.

- Promotional videos for company websites
- Resource delivery
- Product delivery
- Safety checks
- Fire Protection plan
- Thermal imagery of building
- Home inspections
- Waste removal
- Infrared sensors
- Power line surveillance

Findings and Conclusion

This research highlights the importance of drone technology, BIM, and their integration with one another. The construction industry is finally adapting to the technology learning curve that other businesses have always adapted to. Companies like Webcor are leaders in the field and push for innovation to shape the future of construction. Webcor is one of the biggest construction companies in all of San Francisco but are still learning to incorporate drone technology alongside BIM to benefit company productivity. This goes to show how new UAVs are in the construction world and how much room for growth there is. It may take years, or even decades to see quantitative improvements due to drones and BIM. Regardless, innovation is a key factor that must be focused on in order to take that next stop in The Technology Age.

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Appendix A - Interview Questions

Project Manager
How has drone technology affected the schedule of preconstruction?
How has drone technology helped resource allocation?
How has drone technology affected staff management?
How has drone technology affected budget management?
What project was drone technology essential in? How and why?

Superintendent
Who do you coordinate with before using Drone Technology? (such as city permitting)
What are limitations you see on the field from drone technology?
How often are drones used on the field?
What project was drone technology essential in? How and why?

Licensed Flyer
How do you become licensed?
What are the limitations when operating the vehicle?
What project was drone technology essential in? How and why?

BIM Engineer
How do you generate plan and diagrams from drone technology?
What software do you use?
How often do you go on site, when using drone technology plans?
What construction environments are most common for Drone technology?
What project was drone technology essential in? How and why?

Estimator
How much are drones and maintenance?
How have drones affected financial success?
How have drones been used to resolve cost discrepancies?
What documentation is needed for drone use?

Questionnaire
Where do you see a future use in UAVs for construction?