A Case Study on the Use of Drones on Heavy Civil Construction Projects

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Even though the construction industry is known for being behind the curve in adopting new technologies for change, construction professionals are constantly striving for ways to save money and improve efficiency. The emergence of drone technology in recent years has sparked new interest among these professionals for those exact reasons. These flying machines offer numerous benefits to construction companies such as bypassing traditional surveying methods, using photogrammetry to create 3D models used for estimating quantities, improving team communication, ensuring worker safety, increasing owner satisfaction, among other benefits. In this case study, personal interviews will be conducted on a single construction company in order to evaluate these potential benefits. After analyzing these interviews, drones indeed offer actionable information in the form of computer generated cut and fill quantities, effective jobsite monitoring, improved team transparency and awareness, increased owner awareness and satisfaction, cost savings in the form of legal dispute avoidance, and improved planning capabilities reflected by a more accurate schedule.

Keywords: Drones, UAV, Heavy Civil Construction, Project Management, Time Savings

Introduction

The construction industry has always been known for its reluctance to change. However, graduating students from universities all over the world do not hold the same attitude. New, younger minds are entering construction and striving for ways to bring the industry up to date. This technologically inclined generation has been pushing new programs to eliminate reliance on traditional methods and streamline the construction process to save money and improve efficiency. The newest trend in this era of change is the emerging drone technology being adopted by many other industries.

Over the last 10 years, drone technology has developed to increase battery life for longer flight times, carry heavier payloads to hold more sensors, and create an easier system for the pilots to control. These improvements have made drone technology appealing enough to enter the skeptical world of construction. Software programs have been designed to accompany these advances in order to process the information from the drone to give construction companies actionable information that can be accessed by the whole project team through smart phones and tablets. This information being available to everyone in the company allows for the avoidance of costly problems before they happen.

General Background

The United States military began to invest in drone technology in 1984, following effective applications by other nations (Ford, 2018). This investment led to the successful development and deployment of the well-known MQ-1 Predator drone in 1995. Originally, drones in the military served the primary roles of intelligence gathering, surveillance, identifying targets and reconnaissance. Additionally in 2002, Predator drones expanded their capabilities by becoming equipped with laser guided missiles for precision air strikes (BBC).

The first drone that was widely available for the average consumer was the Parrot AR Drone in 2010. This drone was composed of nylon and carbon fiber parts in order to have a lightweight structure and measured 22 inches across. This drone was controlled through WiFi connection by utilizing Parrot's AR.Freeflight application (Dormehl, 2018). This drone utilized quadcopter technology, utilizing four propellers that allowed it to be stationary in the air.

Emerging Markets

The first commercial drone permit was issued by the Federal Aviation Administration (FAA) in 2006 (Ford, 2018). There was a low demand for permits as the FAA only issued an average of two permits per year for the next 10 years. This changed in 2016 when the FAA issued more than 3000 permits to commercial users (Desjardins, 2016). In addition to increased permit interest, the drone market was expanding. According to IFI Claims' global patent database, the amount of granted patents, utility patents, and patent applications has been increasing exponentially, as seen in Figure 1. This is indicative of the rapidly expanding drone market that companies are heavily investing in.

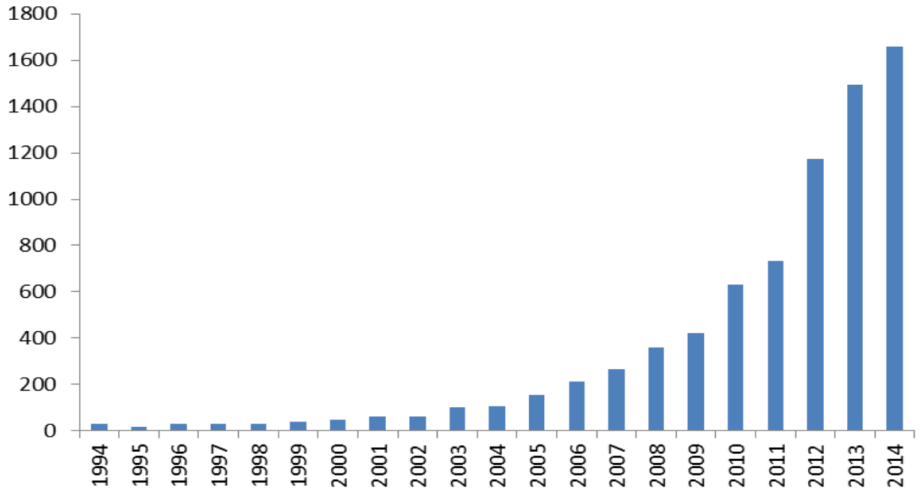

Figure 1 – Patent applications, granted patents, and utility patents for drone technology (Carrasoca and Encorsa, 2014)

According to a report by Goldman Sachs, the drone industry will reach a $100 billion market opportunity by the year 2020. Additionally, the report forecasts that the construction industry will account for just over $11 billion of that market. To complement this rapid growth, the U.S. economy could experience an increase in 100,000 jobs in the drone sector by the year 2025 (Desjardins, 2016).

Drone Technology

The quadcopter distinguishes itself by being the optimal choice of the construction industry (DeYoung, 2018, p.8). The quadcopter's domination is due to its pricing, simplicity, maneuverability, and flight times around 30 minutes (DeYoung, 2018, p. 9). One may ask, how does a drone stay stable in the air when differing atmospheric conditions are present? The answer to this lies in the technology contained in the drone's onboard flight controller. The flight controller is comprised of multiple sensors, the most important of those being the inertial measurement unit (IMU). The IMU first receives information from the drone's gyroscope, which detects forces acting against the drone that cause it to rotate or move off of its axes. This information is then transmitted to the IMU, which instantly changes the rate of the propellers in order to keep it stationary (Corrigan, 2019).

Since the introduction of the Parrot AR Drone in 2010, new technologies have developed to be paired with these vehicles to increase their capabilities. Some of these technologies include, GPS navigation units, high definition

cameras, passive/active radio-frequency identification readers, infrared/heat sensors, night vision, RADAR systems, ultrasound devices, laser scanners, and biological/chemical sensors (DeYoung, 2018, p. 13).

Applications in Construction

The argument for applying drone technology to construction projects is increasing year by year. The new systems that have been designed to accompany drones on their flights have been the main contributing factor. These technologies allow construction companies to use the data collected from their drones to perform processes and improve aspects of construction management related to:

- Estimating
- Surveying
- Site monitoring
- Quality assurance
- Safety
- Team communication

The drone's capability to accurately survey areas of land is an essential benefit of utilizing drones in construction. Estimating, specifically relating to calculations of earthwork volumes, is often done by an engineering-surveyor and takes a significant amount of time to complete. By utilizing drones with laser scanners combined with standard topographic survey, 3D models of large areas can be created in a computer programs to identify what earthwork volumes are present on the jobsite (Zaychenko, Smirnova, Borremans, 2018, p. 5). This data can be compared to past mappings and plan data to identify what earthwork has been moved and the remaining earthwork to be completed, as represented in Figure 2. Because the drone flights take millions of points of data per flight, the data is much more accurate than that of a traditional human calculation and allows for the project manager to have a much better understanding of the status of construction.

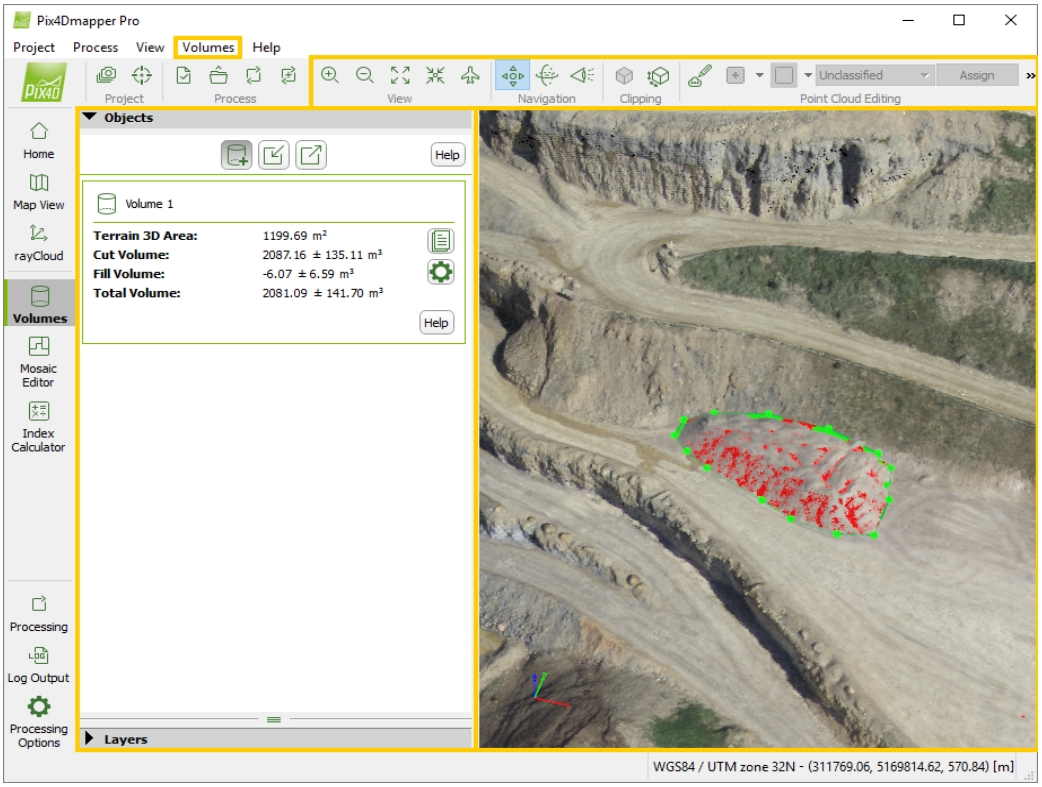

Figure 2 – Screenshot of cut and fill volumes from Pix4D software

It is not a secret that construction is a dangerous occupation, especially for field workers. According to OSHA, construction has been ranked as the most dangerous industry in the last decade (DeYoung, 2018, p. 24). Some of these accidents may be attributed to the fast nature of construction and the quickly changing conditions on every jobsite. Drone monitoring is able to provide real time site conditions that can help prevent serious injuries or the loss of life. A publication by Pricewaterhouse Coopers and Agoria titled "A drone's eye view," states that the average construction site monitored by drones reduced its life-threatening accidents by up to 91%. This reduction in serious incidences has been attributed to increased site awareness in addition to utilizing drones to inspect areas that are hard to reach or otherwise dangerous for human workers to access.

Drones combined with infrared thermography sensors have been able to increase the quality assurance of a builder's product to the client. This technology allows drones to scan a building and create a 3D image of a building envelope to evaluate its energy efficiency and identify defects that may be present (DeYoung, 2018, p. 27). These defects would most likely go unnoticed without the implementation of this technology.

In regards to team communication and transparency, visual management (VM) is gaining traction as a popular idea within lean construction. This is where the project team and its employees can address different aspects of site operations with a software glance of its live data from drones. This type of transparency can lead to, "…simplification and coherence in decision making and production control, increased work coordination, easier identification of problems and deviation, stimulation of contacts among work units and broadened employee engagement and autonomy (Tezel and Aziz, 2017, p. 222)." The utilization of drones on these projects is the key player in the VM process as represented in Figure 3.

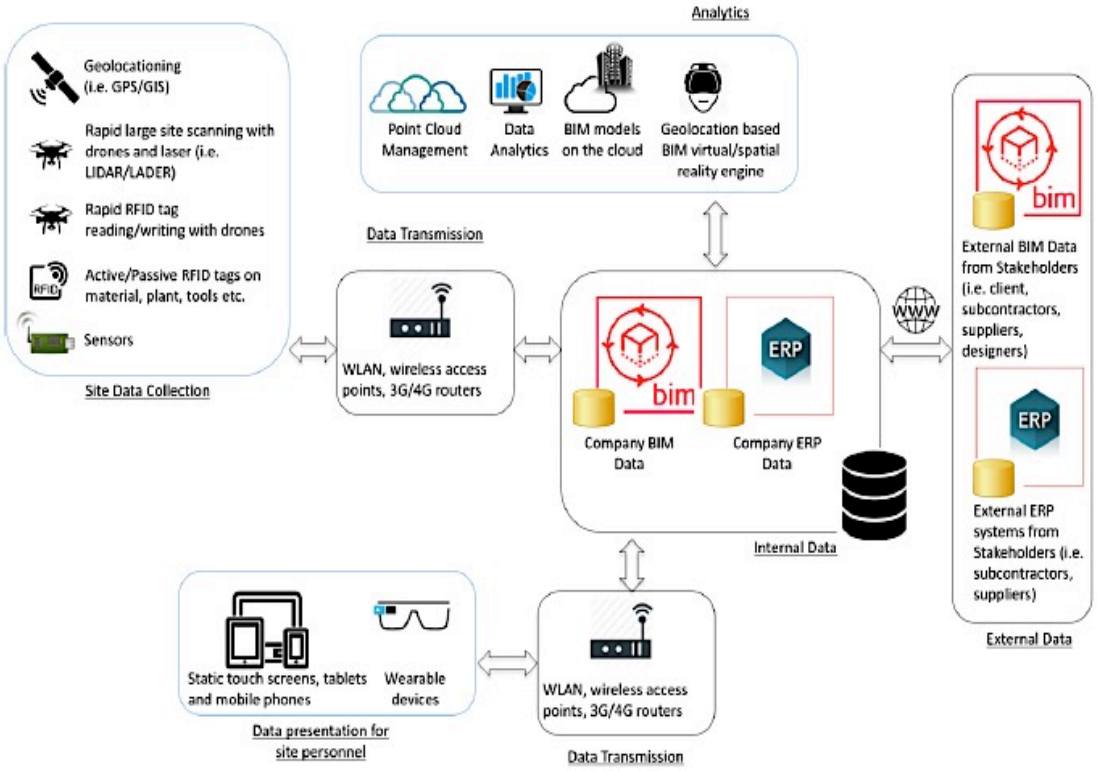

Figure 3 – A flowchart representation of the visual management process (Tezel and Aziz, 2017, p. 237)

Methodology

The methodology chosen for this case study is qualitative in nature. Exploratory research has been implemented due to the fact that the subject requires opinions, views and perceptions from various industry professionals to determine the effectiveness of implementing drones on multiple construction projects. By utilizing this approach to data

collection, various benefits and challenges of applying this emerging technology may be properly evaluated and analyzed. The information presented in this section is collected by conducting multiple interviews of employees that are heavily involved in drone operations at a single construction company. The main focus during these interviews is to identify the aspects of drone implementation in regards to surveying, schedule, team communication, owner satisfaction, and cost savings.

By utilizing this methodology, the aims of this case study are to:

- Provide a better understanding of the process a company must experience to fully apply drone technology to its projects
- Analyze the benefits and challenges of using drones on jobsites for a specific company
- Offer a real life narrative of drone usage as a guide for other companies who are considering adopting this technology into their organizations
- Demonstrate how drones can have a positive impact on the overall flow of a construction project

Case Study

For this case study, the subject company is Ghilotti Bros., Inc. (GBI). GBI is a general contractor based out of San Rafael, California that has been operating for over 100 years all over the Bay Area. They are a multi-million dollar company and one of the largest employers of construction personnel in Northern California. GBI takes on large earthwork, concrete, underground, and heavy highway projects, among others. In addition the expansive nature of the work they do, they also maintain numerous yards for stockpiles of materials. This type of work and company operation makes GBI a great candidate for the implementation of drones into their daily activities.

Discussion

The information contained in the following paragraph has been collected from interviews with GBI's Chief Pilot/UAV Operations Coordinator and 3D Modeling and Digital Designer, Hasan Sume, and Project Manager, Mario Ghilotti. Discussed below are the benefits and challenges GBI experiences with using drones on their projects.

Benefits of Drone Implementation

A significant benefit of drone usage on jobsites occurs before the start of construction. GBI is able to upload plans into their program and overlay it with images taken by their drone. By doing this, they are able assess the current conditions of a job site and see where parts of construction are going to take place. For example, by comparing certain plan sheets to PDF images, they are able to see where certain construction operations, such as underground work, will take place. Additionally, they can use this method to plan traffic control operations and SWPPP. Traditionally, some companies may choose to use images from Google Earth to plan these types of activities. The problem with this is that these images may be months or years old and therefore not reflective of current site conditions.

From an estimating standpoint, their drones offer information that is accurate and reliable. GBI is able to set up a flight over a certain area within Trimble Propeller, which can all be handled on an iPad. Once they set the flight area, the drone can automatically scan the area without the need for a pilot to manually control it. During the flight, the drone takes millions of data points in order to accurately survey the area. This data is then uploaded into the computer software and can conduct cut and fill comparisons to find out quantities of work done or needing to be completed. Once this information is gathered, it becomes available for the entire company. This data can be shared with anyone who has access to the application. Workers in the field are able to receive this information via iPad and can take the necessary actions to make progress on construction. Additionally, management can use this information to track job progress and make adjustments to the schedule if needed.

Another benefit from using drones is the ability to use pictures from flights as legal records. If flights are conducted regularly, the pictures from can be used to answer questions about conditions on the job site on a particular date. For example, GBI experienced a situation where a civilian claimed to have tripped on something while crossing the street and decided to take legal action against them. GBI was able to use pictures from the day of the incident to identify what obstacles were actually present in the street and effectively defend themselves in that situation.

In regards to cost savings, GBI has been able to use drone data to benefit themselves monetarily. The first example of this lies in the Trimble Propeller system. With GBI's first drone program, DroneDeploy, grade checkers were needed to come to the job site to establish control points for the drone. These control points contained northing, easting and elevation data that was entered in manually in order to generate volumetric calculations used for cut and fill quantities. Propeller eliminates the need for grade checkers by offering portable GPS boxes that can be placed on the site to generate northing, easting and elevation data on its own. According to Ghilotti, the ability to eliminate grade checkers from this process saved a significant amount of time in generating control points for the drone in addition to not having to input the information manually. Another way that GBI has benefitted in cost savings was through disputes with their clients over work completed. For example, there was a disagreement with an owner over the amount of pavement that GBI had completed over a twelve-mile stretch of roadway. A drone flight was conducted and GBI was able to use the calculations from the drone to confirm the amount of pavement that was used. This resulted in the gain of tens of thousands of dollars from the owner.

Another significant benefit of drone usage is client satisfaction. GBI has been able to use aerial photos from their drone to keep their owners informed on the status of construction. According to Sume, owners are very receptive to these photos. On projects where drones are used, the owners come to expect these photos at weekly planning meetings.

Challenges of Drone Implementation

One of GBI's main challenges with implementing drones into their construction activities was the learning curve associated with figuring out the best way to use the drone software and what drone software was the best for them. The company first adopted DroneDeploy and it took them a while to figure out the most efficient way to use it. After they figured out the best way to use that software, they learned that Trimble Propeller may be a better option for them. This revelation took about a year of using DroneDeploy, their initial choice. However, now that they have started using Propeller, they are still figuring out the best way to use that program.

Another challenge associated with operating drones is acquiring the pilot's license. This is the Part 107 certification test that commercial operators are required to obtain from the FAA. Sume reflected that this was challenging because of all the rules and charts you must memorize and study in order to pass the test. However, once he acquired the license, it wasn't difficult for him to apply those rules in the field.

In regards to the capability of the drone, the main challenge was making sure that obstacles on the jobsite weren't impeding the machine's calculations. Sume talked about how foliage can make it more difficult to use the drone's surveying capabilities. If there objects such as trees and tall grass, the sensors on the drone will pick up the tops of these obstacles instead of the ground they rest on. However, he said that this was only a problem when there was a significant amount of foliage. If there were only a few trees or areas of tall grass, the drone is able to calculate around those and eliminate them.

Conclusions

The construction industry is experiencing a digital transformation that has been highlighted by the emergence of computer programs used to increase communication and expedite construction. The newest compliment to these programs is the emergence of drone technology. Even though there are improvements to be made in the capability of drone technology and the programs that accompany it, there are a significant amount of benefits that a companies can experience if they choose to bring on this new method of acquiring information.

GBI's introduction of drone technology into their construction operations has allowed them to revolutionize the way that they conduct every day operations. They have been able to eliminate excessive surveying operations during construction, increase the efficiency of their planning capabilities, more effectively track job progress, more accurately determine quantities, make monetary gains, settle disputes, improve team communication, and improve client awareness and satisfaction. As the technology and software improves, GBI will be able to further improve these aspects of construction and advance the company into the future.

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