FRAMEWORK FOR LEGAL CONSTRAINTS FOR USING UNMANNED AERIAL SYSTEMS IN CONSTRUCTION

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To my loving family
ACKNOWLEDGEMENTS

I want to thank Dr. Issa for his continuous support as this research has been only possible because of his guidance. I would also like to extend my committee members, Dr. Muszynski and Dr. Lucas. Additionally, I would like to thank Nathan Blinn for his valuable inputs and guidance throughout the thesis process. Most importantly I would like to give a special thanks to my parents, brother and friends, without their support and encouragement this research would not have been possible. I am grateful to have such a wonderful parents in my life as they have provided everything they could for my education.
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<tr>
<td>AIR</td>
<td>Airworthiness Division</td>
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<td>AR</td>
<td>Augmented Reality</td>
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<td>ATC</td>
<td>Air Traffic Control</td>
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<td>AVS</td>
<td>Aviation Safety</td>
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<td>COA</td>
<td>Certificate of Airworthiness</td>
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<td>DAIDALUS</td>
<td>Detect and Avoid Alerting Logic for Unmanned System</td>
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<td>DEM</td>
<td>Digital Elevation Model</td>
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<td>Digital Terrain Model</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>FAR</td>
<td>Federal Aviation Regulation</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>GSD</td>
<td>Ground Sample Distance</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>LIDAR</td>
<td>Light and Direction Ranging</td>
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<td>MTOW</td>
<td>Mean Take Off Weight</td>
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<td>MUAS</td>
<td>Micro Unmanned Aircraft System</td>
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<td>NAS</td>
<td>National Airspace</td>
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<td>NOAA</td>
<td>National Oceanographic and Atmospheric Administration</td>
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<td>NOTAM</td>
<td>Notice to Airmen</td>
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<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
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<tr>
<td>RPV</td>
<td>Remotely Piloted Vehicle</td>
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<td>sUAS</td>
<td>Small Unmanned Aircraft System</td>
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<td>TLS</td>
<td>Terrestrial Laser Scanner</td>
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<td>TCAS</td>
<td>Traffic Collision and Avoidance System</td>
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<td>UAV</td>
<td>Unmanned Aerial Vehicle</td>
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<td>UAS</td>
<td>Unmanned Aircraft System</td>
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Unmanned aerial systems (UAS) are the future for construction. It has various application in construction from helping contractors during construction to monitor regular project progress to documenting any irregularities in work. UAS can also be used for maintenance inspection for high rise buildings or in confined spaces. This can be helpful as the first response unit in the case of natural disasters. For a small scale project the finishing work of the outer envelope is a challenge, as there can be many sub-contractors doing various jobs. Getting someone to manually inspect every nook and corner can be difficult and unsafe, as per OSHA the top three cause of deaths in construction is fall protection, hazard communication standard and scaffolding requirement. The concern here is regulating use of UAS. Since anything that goes airborne enters air space it is regulated by US Federal Aviation Administration (FAA). The FAA has huge emphasis on concerns with the safety of anything that enters the airspace. As of now the FAA has different set of rules depending on the type of use of a UAS. This makes it a challenging task to use a UAS or UAV for commercial purposes. The research will look into the legal aspect of using the UAV commercially. The current rules and proposed policies issued by the FAA will be discussed.
CHAPTER 1
INTRODUCTION

Unmanned aerial systems (UAS) are becoming increasingly popular for all sorts of professional uses. In the last decade, UAS technology has become one of the most researched and developing technologies. The construction industry has a long history of technological advancements and there is no doubt that UAS have found their way into the industry. When it comes to construction safety is the number one priority of both professionals and researchers. The potential of using UAS in construction is there, but there is not enough research to help support mass adaptation of this technology in construction. Similar to any technology ever created, UAS technology has its advantages and disadvantages. UAS technology has seen a lot of challenges in different fields of its application. So, it becomes important to analyze these challenges with respect to construction.

The purpose of this research is to collect data about the legal challenges of using UAS in construction. The analysis of the data collected from the survey help in understanding the current status of UAS technology in the construction industry and the related concerns amongst the industry professionals. This would help in determining the level of knowledge that construction professional have about UAS technology. This would also allow for the analysis of current trends in the construction industry with respect to UAS usage. As UAS technology becomes more developed and construction friendly, it would be critical to have knowledge about the legal challenges it is facing.
Objective of the Study

The aim of the research is to study the current state of UAS technology in construction and determine the potential legal challenges. The goals of this research are:

- Analysis of the level of direct involvement of construction companies in research,
- Investigation of the extent of the role played by aerial images in the construction management process,
- Assessment of how UAS technology is being implemented in construction,
- Determination of the legal concerns of using UAS technology.

Research Methodology

Extensive literature review was done to better understand the unmanned aerial system as a whole. The literature review was important in determining the gaps and shortcoming in the existing research. Also this helped in the design of the survey questionnaire. Subsequently a survey was conducted, which was distributed to various professionals in the construction industry. The survey questionnaire was designed to achieve the aim of the research. It was essential in collecting data about the trend of using UAS in construction and the legal challenges associated with the same.

Organization

The research is divided into six chapters. Chapter 1 gives a brief introduction about the research. The research objective and scope is explained in the Chapter 1.

Chapter 2 is the literature review on sUAS and its application in the construction industry. The literature review explains the history and classifications of UAS. A description of safety concerns in regard with the use of sUAS is given in the literature
review. The literature review gives an overview on the role of Federal Aviation
Administration (FAA) over the use of sUAS and the recent rule of registration of sUAS.

Chapter 3 describes the methodology utilized in conducting the research. A
survey consisting of twenty one questions was distributed to various construction
professionals throughout the United States.

Chapter 4 provides the analysis of the results of the survey. The anonymous
responses are statistically analysed and graphically represented. Comparison of the
responses for different question was key in the achieving the aim of the research.

Chapter 5 explains the conclusions derived from the detailed analyses conducted
in previous chapter. Chapter 6 is the final chapter of the research. The chapter
describes recommendations for future research studies.
CHAPTER 2
LITERATURE REVIEW

Unmanned Aerial Vehicles (UAVs) or small Unmanned Aircraft Systems (UAS) or Remotely Piloted Vehicles (RPVs) are a few of the names used for an aircraft that has no pilot or person on board. In some cases, these can be operated by a person from a nearby or isolated location or can even be completely autonomous. The Federal Aviation Administration (FAA) has defined an Unmanned Aircraft (UA) as:

A device used or intended to be used for flight in the air that has no on-board pilot. This includes all classes of airplanes, helicopters, airships, and translational lift aircraft that have no on-board pilot. Unmanned aircraft are understood to include only those aircraft controllable in three axes and therefore, exclude traditional balloons. (FAA 2008)

The United States Air Force (USAF) mainly uses Remotely Piloted Aircraft (RPA) as a term to include both the aircraft and the pilot (Herlik 2010). Whereas, in the United Kingdom to signify the presence of the person to control these are referred as Remotely Piloted Air System (RPAS) (Fishpool 2010). The terminology used to define UAVs has changed over the last century (Yenne 2004). For the purpose of this study, we will look into sUAS (also known as a drone), which implies a flying machine without an on-board human pilot or passengers. The control system considered here is mainly off-board (remote control).

History

Despite the common belief that UAVs are a recent invention, unmanned aircrafts have been around for decades. Although some text suggests the use of lighter-than-air balloons as the first unmanned aircraft (UA), these were nowhere close to an airplane. Blom (2010) stated that use of first unmanned aircraft (UA) dates back to World War I, which is a more accurate comparison to the modern day UAS and were used to provide
tactical data for warfare. For the last century, UAS have been primarily used by the Army for damage assessment during the war, exploratory data collection of enemy troops and remote controlled attack. In the past decade, UAS use has evolved and expanded into various fields. Handwerk (2012) noted five emerging uses of drones as: hurricane hunting; 3-D mapping, protecting wildlife; agricultural application on farms; and search & rescue.

![Timeline of use of UAVs by US Army for Aerial Reconnaissance](image)

Figure 1-1. Timeline of use of UAVs by US Army for Aerial Reconnaissance

For more than 80 years the primary user of UAS has been the Army (Blom 2010). During World War I UAS were mainly observatory balloons. France was the main supplier of balloons to the USA during the war. These early UAS served two fundamental purposes: tactical and strategic. After the war was over the main challenge was to decide on the fate of the sUAS. Observation planes and balloons were the two options, which were available for research. The planes were preferred for their range and operational area capabilities.
Stachura et al. (2015) used a case study analysis to illustrate the timing and pace of nomadic operations. The study discussed that the FAA issued certificate of authorization (COA) for a specified area (Ballinger et al. 2007). The area in no case was larger than 20 miles in diameter. Notice to Airmen (NOTAM) was given to nearby airports and Air Force bases within the COA, every time there was a UAV deployed into the air space. The study indicated that the time for notification to different authorities varied from 5 minutes to 2 hours prior to launch. The UAS were allowed only to fly inside the COA boundary for which NOTAM was given, which was in 20 mile diameter circle. The solution suggested in the study were to provide COA for 200 mile diameter area and restricting flight in a limited area (Stachura et al. 2015). The study concluded that the sUAS technology are capable to perform nomadic science missions, but the main challenge was to comply with FAA regulations to carry out safe operations. Stansbury and Wilson (2015) stated that it is important to work closely with the FAA, to reach a compromise that satisfies both the scientific and engineering goals of the project while being able to prove the necessary level of safety for operating in the National Airspace System.

**Classification of UAS**

Planes and balloons are the two design options available today. The planes are preferred over balloons for their range and operational area capabilities. The UAS used by the Army were developed to serve two basic purposes: tactical and strategic. Tactical UAS typically have a range of 6 to 300 miles, and weigh between 55 to 1000 lbs. Any UAS that has a range and weight more than this can be classified as a Strategic UAS. The UAS used for civil operation (non-government) purpose are classified as micro and mini UAS. Figure 2-1 shows a representation of the mass and
range characteristic of different types of UAS. The bar depicts the range of distance the different types of UAS can cover. The purple and green line represent the upper and lower mass limit of the UAS respectively.

Figure 2-2. Mass (lbs.) and Range (miles) of UAS (Adapted from van Blyenburgh (2006))

Table 2-1 shows classification Unmanned Aerial Vehicle (UAV) based on Mean Takeoff Operating Weight (MTOW) given by Civil Aviation Authority (CAA) of New Zealand. Although MTOW is a good basis to classify sUAS, Dalamagkidisa et al. (2012) provide a classification based on the risk sUAS pose to people and property after a ground impact. Dalamagkidisa et al. (2012) used minimum time between ground impact accidents ($T_{GI}$) and MTOW as the basis of classification as shown in Table 2-2.
Table 2-1. Classification of UAV based on MTOW (Adopted from Dalamagkidisa et al. 2012)

<table>
<thead>
<tr>
<th>Class</th>
<th>Maximum energy</th>
<th>UAV requirements</th>
<th>Operator requirements</th>
<th>UAV pilot requirements</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>Up to 10 kJ</td>
<td>No certification required</td>
<td>Regulated by UAV association</td>
<td>Must have pilot license when flying beyond line of sight or in controlled airspace</td>
</tr>
<tr>
<td>2</td>
<td>Up to 1 MJ</td>
<td>Flight permit required</td>
<td>Certificated by CAA</td>
<td>Pilot license, type rating and in some cases instrument rating</td>
</tr>
<tr>
<td>3</td>
<td>Over 1 MJ</td>
<td>Type and airworthiness certificates, maintenance release and continuing airworthiness</td>
<td>Certificated by CAA</td>
<td>Pilot license, type rating and in some cases instrument rating</td>
</tr>
</tbody>
</table>

They noted that most countries do not regulate the UAS classified as Micro as the pose almost negligible threat to human life. The category of Mini and Small comprise of R/C model aircraft. Dalamagkidisa et al. (2012) note that a UAS in the category of Light/ultralight would require Airworthiness Certification based on Federal Aviation Regulation (FAR) Part 23, which is governed by FAA. The study also suggests that according to FAR Part 23, the UAS that fall in the categories Normal and Large correspond to normal aircraft and transport category respectively.
The US Department of Defense has defined its criteria for categorizing UAS with different airworthiness requirements. It has simpler categories, with each having appropriate airworthiness and operator qualifications.

<table>
<thead>
<tr>
<th>Category</th>
<th>FAA Regulation</th>
<th>Airspace Usage</th>
<th>Proposed Airspeed Limit (KIAS)</th>
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<tr>
<td>Cat I - R/C model aircraft</td>
<td>None</td>
<td>Class G</td>
<td>100</td>
</tr>
<tr>
<td>Cat II - Nonstandard aircraft</td>
<td>FAR Part 91,</td>
<td>Class E, G and</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>FAR Part 101,</td>
<td>non-joint-use D</td>
<td></td>
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<td></td>
<td>FAR Part 103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cat III - Certified aircraft</td>
<td>FAR Part 91</td>
<td>All</td>
<td>None</td>
</tr>
</tbody>
</table>

**Use of UAS in Construction**

According to Opfer (2014), construction professionals that understand the potential of sUAS, have started using these in a wide variety of project applications. He acknowledges the fact that UAS can never replace an actual person for every relevant task, but it can assist and aid in a lot of project tasks. Among various tasks that can be performed more safely and efficiently using sUAS are surveying/aerial mapping capabilities, marketing, inspection, site security, productivity improvement, documentation, reporting progress to client, and real-time monitoring.

One of the applications of sUAS described by Gonzalez et al. (2014) is image based Three-dimensional (3D) modeling of the built environment. 3D models are being used in a variety of disciplines including urban and environmental planning, cultural heritage documentation, building and infrastructure inspection to name a few. The modelling technique and requirement may vary depending on the use. The development in the field of 3D modelling has made it a key tool to reproduce as-built site drawings.
and reducing inconsistencies between the design and construction phases. Gonzalez et al. (2014) described how the image-based modeling of complex scenarios with sUAS aerial images eliminates the problems posed by terrestrial laser scanner and classical topographical methods. The use of sUAS gives freedom to capture images from all possible point of views, thus aiding in documentation of all visible elements without any physical limitation and safety concerns. Once all images are acquired a complete reconstruction of the site can be done using specialized image processing software. The proficiency of the software allows for a perfect reconstruction no matter the quality of image or the type of camera being used. Thus eliminating any occlusion due to shadows and giving better results than terrestrial laser scanner.

Hugenholtz (2014) conducted a case study to analyze the accuracy of photogrammetrically derived digital terrain models (DTM) from UAV images. The study compared the results of stockpile volume estimation done by DTM from UAV images with that estimated by airborne light and direction ranging (LIDAR) and terrestrial laser scanning (TLS). The UAV was guided by GPS points and controlled using a tablet. The results of the study indicated that UAV method was as accurate as LIDAR but had lower accuracy than TLS. Hugenholtz (2014) also suggested that for a small stockpile estimation implementing conventional technique such as a GPS, total station, or TLS should be preferred. Due to limited capabilities of the current UAV technology, mainly battery life, for a large stockpile volume survey LIDAR should be used. Despite the shortcomings, the UAV method would serve an important tool for estimating a medium-sized stockpile volume. The study also indicated that in excavations with complex shape, remote location or difficult terrain, UAV would perform better than ground-based
methods (Hugenholtz 2014). The compact size of UAVs gives them an edge over conventional survey techniques. The study concluded that in certain situations, UAV based method would be safer and financially feasible for surveying at earthwork projects.

In 2010, a field experiment study was conducted using micro unmanned aerial vehicles (MUAS) for roadside condition and inventory surveys. The MUAS were equipped with digital imaging systems and Global Positioning System (GPS). The field experiment assessed the level of service condition on ten roadway on IH-20 in Tyler, Texas (Hart and Gnaraibeh 2011). The study implemented two methods to determine the roadway condition. Three onsite inspectors rated the condition directly in the field and then another inspector rated the conditions by observing digital images collected by an MUAV. The results from field testing were analyzed and showed that there were no statistically significant differences in the two methods. Hart and Gnaraibeh (2011), also evaluated the operational capabilities of the MUAV based on varying site and conditions. Rain and wind were two parameters that affected the performance of the MUAV. The field testing indicated that the MUAV was inoperable in wind speeds more than 15 miles per hour. The study concluded that MUAVs can be used in aiding current data collection methods for roadway inventory and condition assessment. It also found a few shortcomings of the current MUAV technology such as false readings and limited operability in harsh weather conditions.

Post-disaster application of sUAS was seen in events of hurricane, tsunami and earthquake. After Hurricane Katrina 2005, sUAS was used for structural damage assessment and inspection of multi-storey commercial buildings (Pratt et al. 2006).
Adams et al. (2012) evaluated the potential of using sUAS as means for collection of post-disaster imagery data. The study utilized a multi-rotor sUAS, with a camera capable of capturing video and still images, in a post-tornado scenario. A typical NOAA post-disaster aerial imagery has ground sample distance (GSD) of 0.5 m, the image capturing capability of the system used in the study was approximately 0.007 m. Identification of specific building materials was made possible using a high-resolution camera. A digital camera with resolutions of 12 megapixels was used for ground based imagery. The combination of high resolution ground imagery and sUAS based aerial imagery improved the GSD to approximately 0.002 m (Adams et al. 2012). The efficiency of the system was explained in the context of a house of 150 m$^2$ plan area, NOAA aerial image would have only 600 pixels as compared to 3 million pixels in images from the system. As discussed by Hart and Gharaibeh (2011) wind was the major factor that affected the performance of the system. Adams et al. (2012) concluded that use of the sUAS for post-disaster data collection would increase as the cost of equipment reduces. Also, FAA regulation would play a significant role in the commercial use of this technology.

A lot of work in construction is based on visualization until actual construction. Wen (2014) presented a research on the use of Unmanned Aerial Vehicle (UAV) in combination with Augmented Reality (AR) in construction. The study implemented AR technology to integrate the real images and virtual rendering. The study uses 3D model and superimposes the virtual images onto the real-time images. This provided with augmented views of the construction site, which helped in discovering the possible problems. Wen (2014) designed and prototyped a UAV keeping in mind the need of
construction management. The study indicated the potential of the system to discover otherwise overlooked problems on a real construction site, such as traffic management plan conflicts and structure spatial dilemmas. Wen (2014) further described a method that would help professionals in “the planning and scheduling of onsite procedures, identified unaware problems associated with current practices, and presented an alternative perspective, ARview, in which onsite restriction might be difficult to overcome.” The study indicated that the proposed UAV-AR system would aid in visualizing the actual field environment and site organization during construction. This would allow site planners and project managers to observe simulated projects under real site conditions and interact with the virtual project, keeping the project schedule in mind. The study concludes that application of AR-UAV technique would facilitate the project progress by visual validation of issues and improve the planning process.

Perez et al. (2015) conducted a study to identify the potential of using sUASs for performing site inspections of erosion and sediment control practices, monitoring of storm water discharges, and tracking project progress at the same time. The study was conducted over a period of four months at a residential land development site using Phantom DJI 2. The study found that the use of sUAS for site inspection helped the inspector to identify runoff concentration location. Identification of runoff flow paths and sedimentation sources and location, and issues with erosion and sediment control implementations are considerably improved by the implementation of sUAS on site (Perez et al. 2015). A sUAS has higher agility as compared to a satellite or a manned aircraft, which provided with aerial images taken at different angles and varying altitudes. Thus, the project can be documented at different stages of construction. The
combination of sUAS with photogrammetric and computer vision technologies gives rise to a technique that creates a 3D model capable of dimensional analysis (Gonzalez et al. 2014).

The images captured during the inspection were utilized to create digital elevation model (DEM) of the site. Perez et al. (2015) noted that these DEM model can be used for quantifying cut and fill material for earthwork. The study concludes that sUAS tools to help minimize construction-related environmental effects on receiving water bodies. The technology would streamline the construction site inspection process by reducing required inspection time, which would lead to reduced overall costs. Thus making the sUAS-image-based modeling method a powerful tool to obtain as-built 3D models in complicated site conditions at low-cost.

According to Khan (2015), the United States currently spends a large sum of money annually on collecting quantitative data on infrastructure inspection, which in most cases is not of any good use. Personal safety and cost are at added risk due to remote locations and equipment requirements. The sUAS are widely used for military application and with enough research and experience, sUASs would become the norm in the construction industry for carrying out inspection and monitoring procedures (Khan 2015). The study conducted bridge deck and airborne bridge inspection using a sUAS. Infrared (IR) images of the deck and bridge were captured using conventional test method and mounting IR camera on a sUAS. The analysis of the images from both the methods indicated similar cracks and points of degradation. Khan (2015) suggested that the multispectral noncontact imaging system has essential benefits in revealing signs of deterioration that could be extremely dangerous to the integrity of the bridge. Also using
sUAS eliminated the need for monitoring traffic and would aid the regular quick inspection of bridge decks. The study concluded that the system would lead the way to a more detailed inspection, which would help in better management of financial resources and providing more funds for the actual maintenance work. Using sUASs shows a high potential for automated damage and defect detection in civil infrastructure (Ellenberg et. al. 2014). The accuracy of the system is far superior in terms of quantitative assessments as compared to other forms of inspection.

Blinn (2015) found that the majority of the aerial imaging on construction projects is done on a monthly basis using a third party manned-aircraft flyover. The study utilized two main methods: an industry survey and actual implementation of a sUAS. Blinn (2015) reported that only 19 out of 47 respondents stated that their company used a sUAS and out of these 19 respondents, 85% (12) had no personal experience in using sUAS. The study also included sUAS implementation to capture images and video data at the University of Florida campus. The sUAS was utilized for weekly documentation of roofing process. The use of a sUAS on the site was helpful for inspection of copper flashing overcoming site and time constraints. Blinn (2015) compared the monthly cost of using a third party manned-aircraft flyover (obtained from the survey conducted during the research) with the actual cost data for using a sUAS. The result of the analysis concluded that the use of a sUAS is more financially feasible than the third party manned-aircraft flyover, with 95 percent confidence.

**Concerns with regard to the Use of a sUAS**

**Safety Concerns**

When we talk about the integration of sUASs into the National Airspace (NAS) a minimum standard of safety, security and privacy has to be achieved (Carr 2013). As
explained by Wiebel and Hansman (2005), “The National Airspace System is the collection of procedures, regulations, infrastructure, aircraft, and personnel that compose the national air transportation system of the United States.” It is responsible for all air traffic control and regulations, thus to incorporate a sUAS into the NAS it has to be treated like a manned aircraft and factors like air collision, ground collision and system reliability have to be addressed (Carr 2013).

In a manned aircraft, to avoid collisions, the pilot gets assisted by the Air Traffic Control (ATC) system, when operating within the boundary of the ATC. In addition to the ATC, the pilot can visually detect a potential collision and to further assist the pilot the aircraft has an on-board sensor system referred to as the Traffic Collision and Avoidance System (TCAS) (Harlem 2012). Carr (2013) suggested that similar to manned aircraft, sUASs should also be capable of detecting and avoiding a collision. Billingsley (2006) found that the TCAS significantly reduced the risk of collisions in a large UAS used by the US Air Force and the US Navy. The Detect and Avoid Alerting Logic for Unmanned System (DAIDALUS) is an algorithm developed and tested by NASA, it provides spatial awareness to the pilot of a sUAS (Muñoz et al. 2015). DAIDALUS for UAS is what TCAS is to manned aircrafts. According to Muñoz et al. (2015), DAIDALUS is being considered to be a part of the Minimum Operational Performance Standards for UASs.

Carr (2013) emphasised the importance of uniform international regulations should by developed, as UAS are likely to fly across international borders. The study also suggests that the International Civil Aviation Organization (ICAO) would be the responsible for regulating unmanned civil drones in international airspace. Disparities
between “states and governments” on regulations in regard with sUAS operation poses a challenge for international UAS operations (Marshall, 2010). In terms of safety, the risk associated with the impact of sUAS collision on surface elements is as high as that of mid-air collision (Carr, 2013). Pure system failure or loss of connection from the control station of a sUAS can be fatal in a populated area. In 2005, Wiebel and Hanson created a ground impact model which predicted that a sUAS is less likely to have a catastrophic accident as compared to manned aircraft. Still the study suggested that size of UAS and population of the area of impact are critical factors that affect the risk, with both the factors directly affecting the risk (i.e. bigger the sUAS more is the risk associated with impact of sUAS collision, similarly higher population would increase the risk). They concluded that with the present standard for safety, smaller UAS could be flown over 95% part of the United States with low risk while larger UAS could be flown over only 20% area of the country.

Carr (2013) suggested that the accountability of UASs should be increased to achieve an acceptable level of risk. People associated with research and development of sUAS technology acknowledge improving the reliability of sUASs as a major objective that needs to be pursued (DeGarmo, 2004). DeGarmo (2004) further suggested improving the durability of components and systems and “build in redundancy” as two initial steps towards improving reliability. Advances in collision avoidance system will ultimately help the sUAS technology to become more reliable within established norms for manned aircraft. Although technological improvements would mitigate fatality risk, it is practically impossible to predict and prevent errors due to humans. Human-system interaction in the case of manned aircraft is influenced by various factors such as skill
level and situational awareness of the pilot, and air traffic controller errors to name a few. This supports the proposition that human influence on sUAS accidents is at least 70% less as compared to manned aircraft, thus a significant number of accidents are accounted for by human-system interactions (DeGarmo 2004).

For the purpose of better operational safety, technological innovations must ensure that the UAS’s operator is able to detect other aircraft to avoid mid-air collisions. For better evolution of sUAS there is a need for uniform international regulations and benchmark training program for sUAS operators (Carr, 2013). This is supported by Nas (2008), who noted that the proficiency of the UAS pilots would be governed by their command on flying the aircraft and level of safety when dealing with other flying systems. Thus, safer UAS operation is an important factor for allowing the UAS to use the NAS.

A construction jobsite changes from day to day. As a safety manager, the biggest challenge is to not only foresee but also mitigate any hazardous condition that may lead to injuries or fatalities (Gheisari et al. 2014). Information and sensing technology aid safety managers in their task. These techniques depend highly on data collection methods, which are not very efficient. Thus, actions taken to deal with issues are delayed. Gheisari et al. (2014) conducted a study to evaluate the potential of using sUAS as a means to relay real-time visuals of the jobsite to managers. A quadcopter type sUAS was used as it could be piloted remotely using various types of control system (such as a controller, smart phone or tablet device). The system was evaluated on two parameters: analytical evaluation of the system and participant’s (operator’s)
ease of operation. The system evaluation revealed a few challenges such as safety of workers in the jobsite and acceptance for a flying object on site by workers.

Gheisari (2014) indicated that there might be a stigma associated with using a sUAS on site for safety inspection instead of a person. The study further pointed towards the issue of user interface, the larger the viewing interface for the participant the more accurate was the safety related task. The study concluded that in an effort to make jobsites free of hazards and utilize the sUAS technology to its fullest, it is necessary to make improvements in the current sUAS. Adding a high-resolution camera would one of them, as better quality images would ultimate help in a better assessment of the jobsite. To incorporate the human element of interaction with the workers using a voice interaction system would be helpful. Also, there are social challenges to applying UAS technology on the construction jobsite that should be considered as well. The workers are used to having a safety manager who would walk through the construction jobsite to check the safety requirements. The interaction between the worker and the manager is something that cannot be replaced by using the current UAS technology. However having a UAS as the safety assistant, which flies over the jobsite would allow safety managers to work remotely and in a remote location (Gheisari et al. 2014).

Privacy Concerns

In the eyes of the general population, concerns about the prospective privacy issues associated with sUAS operations are significantly more than that of safety issues. The Fourth Amendment of the U.S. Constitution states

“(t)he right of the people to be secure in their persons, houses, papers, and effects of unreasonable searches and seizures, shall not be violated, and no warrants shall issue, but upon probable cause, supported by oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized.” (Bill of Rights 1789)
A common interpretation of the Fourth Amendment is that under no circumstance can a person’s privacy be violated, unless there is warrant with probable cause. According to Carr (2013), some people still believe that their privacy is not precisely protected under the Fourth Amendment. While there are enough case studies on the benefits of using sUAS by public departments, there are journalists and civil societies that are still sceptical about the issue. Police forces in different parts of US have successfully used sUAS to monitor crowds, prevent or detect crime and assist in incident responses (Finn and Wright 2012). Since 2002, authorities in the US have been successfully using UAS along the US-Mexico border and US-Canada border to track drug smugglers. The success of sUAS operation all over the US indicates a huge boost for sUAS industry (Bennet 2012). In 2006, the sheriff’s department in Los Angeles used a sUAS to assist in a number of operation such as searching for lost or missing people in rural areas with difficult terrain, watching over a crime scene, tracking drug dealers and assisting police in pursuits at a significantly lower cost than that of operating a helicopter. Bennet (2012) also states that a widespread authorization of COA for sUAS use by police departments all over the US has been initiated. There is a lot of concern and fear amongst the general public about the “Big Brother” phenomena. Although the State Department has tried to deflect these fears, the possibilities of privacy violating practices present a threat to civil liberties. Finn (2012) showed concerns regarding the use of sUAS against marginalized people within a specific population. An article published in The Guardian stated that an Ohio State University academic “claimed he was developing a paparazzi drone, putting the private life of celebrities at a greater risk.”
Most of the time privacy issues in regard to the civil/public sUAS operation revolve around the Fourth Amendment (Villasenor 2013). The US Supreme Court has not exclusively addressed sUAS privacy issues but there are a fair amount of relevant precedents. Both Carr (2013) and Villasenor (2013) have discussed four cases as most relevant when considering sUAS privacy issue: 1) Dow Chemical Co. v. the United State; 2) California v. Ciraolo; 3) Florida v. Riley; and 4) Kyllo v. the United States. In the case of Dow Chemical Co. v. United States (citations for legal cases), “which challenged the legality of using aerial photography as incriminating evidence (Dow Chemical Co. v. the United States). The Court found that the use of photographic equipment was acceptable as long as the equipment was readily available to the public and that the enhanced photographic capabilities did not excessively intrude on privacy rights (Dow Chemical Co. v. the United States)” (Carr 2013). In California v. Ciraolo, the defendant had a privacy fence around his property but aerial observation and photography indicated marijuana plants being grown there which led to a warrant and arrest. The California court ruled that the warrantless aerial observation violated the Fourth Amendment. The Supreme Court reversed the ruling stating that although the plants were in the curtilage the defendant had no expectation of privacy from an observation from sidewalk traffic and the fact that the aircraft was in navigable airspace. In Florida v. Riley, the court stated that the decision for the case was controlled by California v. Ciraolo. The court further explained that the use of a helicopter instead of a fix-winged aircraft for observing curtilage, which is not protected against aerial viewing, did not change anything as the aircraft was flying within legal altitude and following flight safety guidelines (Villasenor 2013). The fourth important case was Kyllo v. United
States, in which the Court stated that sensory devices constituted an invasion of privacy but a loophole is the judgement allowed the use of easily available equipment without a warrant. In the eyes of law, these Fourth Amendment cases would outline where the UAS surveillance ends and privacy intrusion begins (Carr 2013). The privacy issue in regard with sUAS operation would be based on the interpretation of the Fourth Amendment.

**Role of FAA over the Years**

In 1981, the FAA issued Advisory Circular 91-57 on “Model Aircraft Operating Standards”. The organization realized the potential hazards that model aircrafts could pose to aircrafts flying in the air as well as people on the ground. People using model aircrafts are supposed to follow some operation guidelines:

- Fly the aircraft only in unpopulated areas
- Fly an aircraft that has been tested and certified airworthy
- Fly under an altitude of 400 feet above the ground and if flying within 3 miles of an airport the airport operator or control tower must be notified.
- Keep away from actual aircrafts when flying.

In 2006 a memorandum was issued which provided an update on the efforts of Aviation Safety (AVS) to allow UASs to operate in the National Airspace System (NAS). “In 2005, Production and Airworthiness Division (AIR-200) took the first step and began accepting applications for Special Airworthiness Certificates in the Experimental category for UAS. This activity is based on one of the strategies identified in the Administrator’s Flight Plan for, "implementing technologies and systems that will help pilots operate aircraft as safely as possible.” AIR-200 issued memorandums on June 17, 2005 and July 11, 2005 announcing this activity and AVS has subsequently issued 4 Experimental Certificates since August 2005.” This decision allowed the FAA to manage
UAS activity from FAA Headquarters, also it helped develop future policy and procedures for Aviation Safety Inspectors (ASI).

Irizzary and Costa (2016) found that from 2006 to 2012 FAA approved 791 out of 897 certificate of authorization (COA), but no COA was approved for commercial use. An order was drafted to issue experimental certificates for UAS and was used as a model in 2007. The experimental certificate application was processed by FAA and applicants were required to meet criteria established. The FAA established the Unmanned Aircraft Program Office (AIR-160) which was the central office for all AVS UAS activity. In 2007 the FAA declared that model aircrafts of all different sizes or complexities that fit the statutory and regulatory definitions of “unmanned aircraft” and “aircraft,” as they are “used or intended to be used for flight in the air with no on-board pilot.” The FAA indicated various uses of UAS such as public aircraft, civil aircraft or model aircraft. The FAA also stated that a model aircrafts are only the ones being used “purely for recreational or hobby purposes and within the visual line of sight of the operator.” The statement excluded the use of UAS by companies or businesses and confined the application of AC 91-57 only to modellers. In 2014, the FAA fined a Virginia resident for flying an SUAS over a hospital campus. The man was fined $10,000 for engaging in “careless or reckless” flying of an SUAS. The administrative judge ruled against the FAA stating that the organization did not have an “enforceable” legal rule applicable to model aircraft or for classifying whether one is a drone, UAS or otherwise. The FAA filed an appeal to the decision and in November 2014 the National Transport Safety Board ruled that the “law judge erred.”
Certification for sUAS

Leijgraaf (2015) compared sUAS to normal aircrafts, suggesting sUAS should be considered like a full size aircrafts carrying people or cargo. This leads to the need to define a framework to incorporate UASs into the existing aviation system, both from an airworthiness and from an operational perspective. In the current aviation industry, aircrafts have everything like control systems, equipment, safety features, etc. on the aircraft itself, also the person controlling the plane is on board. sUASs are a bit different when it comes to the human and safety factors as the operator in most cases is at a remote location. Aviation authorities have to think of ways to look at the whole approval system. The certification process is similar for all UASs. The airworthiness parameters for UASs of different size and use cannot be same but the process can be unified. A simplified system of approval will help speed up the process.

Stansbury and Wilson (2015) took a look at the role of technology surveys and regulatory gap analyses in supporting the FAA and policy makers in understanding how the current regulatory environment must adapt to accept the near-disruptive technology of UAS. There are no standard practices that explain the concepts of the technology survey and regulatory gap analysis. Over the years teams at Embry-Riddle Aeronautical University have conducted several case studies looking into propulsion systems for unmanned aerial systems (UASs) (Griffis and Wilson 2009), “command, control, and communication (C3)” (Stansbury et al. 2008) and “sense-and-avoid (SAA)” (Reynolds and Wilson 2008). Emergency recovery and flight termination study (ERFT) pooled together the best practices from the previous studies in order to produce a less subjective analysis of the regulations. The study recommends an iterative process for performing a technology survey for a UAS (Stansbury et al. 2009).
On December 21, 2015 FAA started the registration of sUAS. The registration was made mandatory, with non-registration leading to civil and criminal penalties. The terms of registration included: the owner should be at least 13 years old; the unmanned aircraft weighs between 0.55 lbs. to 55 lbs.; and for commercial or personal use. The registration comes with a nominal fee of $5 and is valid for three years. The single registration works on multiple unmanned aircrafts, as the person operating them can the same registration number on any sUAS that meets the registration criteria. (FAA Press Release 2012).
CHAPTER 3
RESEARCH METHODOLOGY

The objective of this research is to understand the legal challenges for using unmanned aerial vehicles on a construction site. In the initial phase of the research, the existing literature was reviewed to find the basis of comparison between the small unmanned aerial systems (sUAS) and a full size airplane. Literature review of the existing legal framework for using sUAS for commercial purposes was conducted. Apart from the review of the FAA guidelines, literature review on the application of sUAS to construction was done. This helped to provide necessary information to regarding the feasibility and possibilities to using UAVs for commercial use.

The online survey platform of Qualtrics software (Version 6209708). Qualtrics Research Suite (2016) was used as it provided an easy means to develop personalized survey with professional quality. The online survey collaboration features makes it easy to build and share a survey with the target population. The software had feature like skip-logic and display-logic, which was utilized in the survey questionnaire. This allowed the participant to automatically skip a bunch of questions that were not relevant to him/her and also a couple of questions only appeared based on a particular previous response. The data collected from the survey was analysed using various statistical techniques.

Survey Questionnaire Design

The survey questionnaire can be found in its entirety in Appendix C. The survey questionnaire is comprised of three sections: 1) demographic information; 2) information on aerial imaging; and, 3) information on use of small unmanned aerial systems. The survey questionnaire was administered anonymously, in accordance with
the policy of the University of Florida Institutional Review Board (UFIRB-02) and the survey contained statement indicating the same. The first question of both the second and third section used the ‘skip logic’ feature available in Qualtrics (2016). A detailed description of the questionnaire and its relevance to the objective of this study is provided in the following section.

**Demographic Information**

The first section of the survey questionnaire was designed for the purpose of identifying and classifying the participants on the basis of professional and company information. Since the construction industry is comprised of many different professions it is important to identify the distinguishing characteristic of the survey respondents. The questions in this section are important to establish a better understanding of the analysis of the other two sections.

**Question 1: What region do you primarily operate in?** The purpose of the question was to identify the demographic location of the participants of the study. The question was helpful during analysis of the data and providing relevance to questions in Sections 2 and 3.

**Question 2: What is your role within your organization?** This question was posed in order to identify the occupational role of the respondent. This will help in categorizing the respondents within the construction industry.

**Question 3: Number of years you have worked as a professional in the construction industry?** The purpose of this question was to determine whether there was any relevance between the numbers of years a professional has worked in the construction industry compared to their opinions on the survey questions in Sections 2 and 3.
**Question 4:** What is the major type of work your company typically performs? This question was posed in order to identify the sector of the construction industry the respondents belonged to. This question assisted in understanding the analysis of the questions related to the use of sUAS in construction.

**Question 5:** Size of the company (based on annual revenue in US dollar). This question was posed to analyze the size the respondent’s company in monetary terms. The responses to this question were used to understand the analysis of other questions.

**Question 6:** Does the company have research and development department? The purpose of this question was to analyze the respondent’s company’s involvement in construction related research. The data from the previous question helped in establishing a relation between the size of a company and its investment in construction research.

**Question 7:** How often does the company seek new technologies? This question is important in determining the construction industry’s acceptance and adaptability to new technologies. Using data for Question 5 of this section a company’s use of new technologies can be compared to its size.

**Use of Aerial Imaging**

The second section of the survey questionnaire used a series of different questions, which were focused around the relation between the respondent’s company and use of aerial images. The main aim of this section was to investigate to which extent the aerial images play a role in construction management process.

**Question 1:** Are aerial images captured of projects executed by your company? This question was used to get information on the respondent’s company
utilization the aerial imaging technique in their projects. The information is critical as it would help determine what percentage of companies are capturing aerial images. This question utilized the skip logic tool of Qualtrics, thus allowing the respondent to skip the entire section.

**Question 2: Does your company use aerial images as apart of construction management and control process?** This question is a follow up to Question 2.1, it helps in understanding if the respondent’s company is using the aerial images for construction management process.

**Question 3: How are aerial images typically captured of projects?** The response to this question provides an understanding of the methods implemented by respondent’s company to capture images at projects. The method of capturing images (e.g. basic photography, aerial imaging by aircraft, or by sUAS) provides information on use of drone technology by the company.

**Question 4: On average how much is spent on aerial imaging per month for a typical project in your company (U.S. dollars)?** The purpose of this question was to analyze the extent to which a construction company is willing to spend on capturing aerial images in monetary terms. Utilizing data from Question 5 (Section 1), helps in comparing the company’s size with the amount it spends on aerial imaging.

**Question 5: How often does your company capture aerial images of a typical project?** The intent of the question was to form an understanding about the level of usage of aerial imaging by the respondent’s company. Also, the analysis of the
response from this question with other question from this section helps in the providing the importance of this task in the respondent’s company.

**Information on Use of Small Unmanned Aerial Systems**

The third section of the survey questionnaire was developed to collect data to understand the respondent’s and his/her company’s use of sUASs. The questions in this section focused around the respondent’s knowledge about sUAS use and various concerns related to it.

**Question 1: To your knowledge, has your company ever utilized a small Unmanned Aerial Systems (sUAS) on a project?** The intent of this question is to determine whether the companies use sUAS on their projects. The percentage of companies using sUAS on their project is critical to understanding the current status of the technology.

**Question 2: For what purpose was the UAV used by your company?** This question provided an understanding of the ways in which companies are utilizing the sUAS for their projects. The data analysis from this question in correlation with data from Question 4 (Section 1), helped in understanding the intended use (e.g. surveying, marketing, inspection, etc.) in different sectors. The respondent were able to select various ways they know sUAS is used (e.g. surveying, marketing, inspection, etc.).

**Question 3: Who was responsible for operating the sUAS?** The intent of this question was to collect information on operational responsibility for the sUAS. The question helps in understanding whether there is any additional cost that might be associated with using sUAS.

**Question 4: Do you personally have experience operating a sUAS?** The purpose of this question was to analyse whether the respondents have used a sUAS for
recreational purpose. The question helps in better understanding how familiar the respondent is with the sUAS technology.

**Question 5: How easy is it to use a sUAS for the following purpose?** This a Likert scale question with two parts addressing personal and commercial use respectively. The response is on a scale of 0-5 (0 being difficult and 5 being extremely easy). The responses to this question were used to determine how comfortable the respondent felt using a sUAS. The response also indicates the respondent’s involvement with the use of sUAS in his/her company or for personal use.

**Question 6: What was the particular reason for not using sUAS?** The question only appears if the respondent answered “No” to Question 1 (Section 3). The purpose of this question was to understand the factors that affect the use of sUAS. This question also helps in understanding the reasons in cases where the respondent’s company tried to use sUAS technology and were inhibited to do so.

**Question 7: Do you have knowledge of any of the following?** The intent of this question was understand the level of expertise of the respondent in the field of sUAS. The question included various terms (e.g. model aircraft, certificate of airworthiness, small unmanned aircraft registration, etc.) and the respondent could select multiple terms depending on his/her knowledge.

**Question 8: Were there any legal difficulties that your company faced in using sUAS?** This was a free response question intended to collect information regarding the respondent’s knowledge of the challenges in using sUAS. This question helps determining any specific legal issues that might be the reasons for concerns for people trying to use sUASs on construction projects.
Question 9: What are (if any) of the legal requirements for using a sUAS that you are aware of? The intent of this question was to determine any additional information that the respondent is aware of with regard to the current legal status of using a sUAS. The question was key in understanding the effectiveness of the FAA’s effort to integrate sUASs into the National Airspace and its awareness in construction industry.
CHAPTER 4
RESULTS AND ANALYSIS

Significant amount of research has been done on various aspects associated with UAVs, such as: type and classification; efficiency improvement; safety features; and cost benefits. But there is no clear research that indicates a legal framework for using UAVs for civil operation. The Federal Aviation Administration (FAA) has guidelines that are to be followed, but lack of proper awareness makes it difficult to use UAVs legally for commercial purpose. The FAA Modernization and Reform Act 2012 is a step forward towards integrating UAVs into National Airspace.

Industry Survey Analysis

The survey was open for a period of 30 days. The survey questionnaire design was explained in Chapter 3 and the actual survey can be found in Appendix A. There were a total of 48 respondents to the survey over the period of time the survey was available online, of these 32 completed the whole survey. The partially completed responses were excluded. As explained in Chapter 3, skip-logic was utilized which allowed respondents to skip questions based on their response. Also in a couple of questions display-logic was applied, this allowed for the question to appear based on the respondent’s previous response. Therefore, none of the respondents answered all the survey question. To represent the same, the total number of responses for each question is indicated in the respective analysis. The following section contains the results of the survey questionnaire. Descriptive statistical analysis was utilized for each of the survey question. In addition, responses to some questions were cross-tabulated with respect to responses to other questions which helped in analyzing interdependence between the respective responses. The raw survey data used for analysis was exported.
from Qualtrics in the form of an MS Excel file. The results of the analysis of each question are discussed next.

**Demographic Information**

The questions in the demographic section of the survey questionnaire were used to analyze the respondents and their responses on the basis of professional and company information. Since the construction industry is comprised of many different professions it is important to identify the distinguishing characteristic of the respondents to the survey. The questions in this section were important to establish a better understanding of the analysis of the subsequent two sections.

**What region do you primarily operate in?** This was the first question in the survey and all the 32 complete responses included a response to this question. As shown in Figure 4-1, a large majority of the respondents, 22 (69%) operated in the Southeast US.

![Figure 4-1. Primary region of operation (n=32)](image-url)
What is your primary role within your organization? For this question there were 32 responses recorded, as shown in the Figure 4-2. Project/Field Engineer was the highest recorded response at 25% (8), followed by Project manager at 21.9% (7). The number of respondents that worked as Assistant Project Manager was four and Estimator was three. The data also included two students, since they had relevant industry experience the data was not excluded.

![Bar Chart](image)

Figure 4-2. Primary role in construction organization (n=31)

Number of years you have worked as a professional in the construction industry. As shown in the Figure 4-3, there were 32 responses to this question. There were 12 (37.5%) respondents with up to one year of experience. A majority of the respondent’s 21 (65.6%) had less than 5 years of experience. The maximum reported experience was 14 years. This data correlates to the responses for the role the respondent had in his/her organization.
What is the major type of work your company typically performs? There were 32 responses to this question. Fifty percent (16) of the respondents indicated that their company is involved in commercial construction. Of the remaining 16 responses, respondent’s whose company performed residential construction were six and those performing heavy civil work were five. As shown in the Table 4-1, two of the responses were from respondent’s whose company performed in two different sectors.

Table 4-1. Type of work performed by the respondent’s company

<table>
<thead>
<tr>
<th>Type of work performed</th>
<th>Number of responses</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>16</td>
<td>50%</td>
</tr>
<tr>
<td>Residential</td>
<td>6</td>
<td>18.8%</td>
</tr>
<tr>
<td>Heavy Civil</td>
<td>5</td>
<td>15.7%</td>
</tr>
<tr>
<td>Industrial</td>
<td>3</td>
<td>9.4%</td>
</tr>
<tr>
<td>Commercial and Heavy Civil</td>
<td>1</td>
<td>3.1%</td>
</tr>
<tr>
<td>Residential and Commercial</td>
<td>1</td>
<td>3.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
What is the approximate size of your company (based of annual revenue in US dollar)? The response to this question was analyzed statistically using MS Excel's Analysis ToolPak, as shown in Table 4-2. Out of the 32 respondent’s only 29 reported the company size. The information generated in this question is key to analyzing the relevance of response for next question.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of response (n)</td>
<td>29</td>
</tr>
<tr>
<td>Average</td>
<td>$2,742,558,621</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>$8,393,438,661</td>
</tr>
<tr>
<td>Median</td>
<td>$100,000,000</td>
</tr>
<tr>
<td>Minimum</td>
<td>$200,000</td>
</tr>
<tr>
<td>Maximum</td>
<td>$45,000,000,000</td>
</tr>
</tbody>
</table>

Does your company have a research and development department? Of those who completed the survey (i.e. 32) all but one responded to the question. Twenty seven (87.1%) of the respondents stated that their company did not have a research and development department. The respondents who stated that their company has a research and development department worked for large companies that performed work in the commercial sector.

How often does your company seek new technologies available for construction industry? As shown in Figure 4-5 the question received 32 responses. Most of the respondents 15 (46.9%), stated that their company upgrades to new technology in less than one year. Respondents who stated that their company looked for new technologies every year and once in every five years were 12 (37.5%) and 5 (15.6%), respectively. Despite the wide range of company size (from $200,000 to $45
billion in annual revenue), none of the respondent’s indicated that never upgrading the technology used in their company.

Figure 4-4. Companies with research and development department (n=31)

![Bar Chart: Yes (87.1%) and No (12.9%)](image)

Figure 4-5. Trend of updating to newer technology (n=32)

![Bar Chart: Less than once a year (15), Once a year (12), Once in 5 years (5), Never (0)](image)

**Aerial Imaging Use**

The questions in this section of the survey are focused around the relation between the respondent’s company and use of aerial images in its construction
management process. Since the first question of this section utilized skip logic, all of the respondents did not answer every question in this section.

**Are aerial images captured of projects executed by your company?** All the 32 respondents answered this question. As shown in the Figure 4-6, 22 (68.8%) of the respondents stated that their company captured aerial images. The remaining 10 (31.2%) responded that their company did not capture aerial images for the projects. These 10 respondents did not answer any other question from this section of the survey.

![Figure 4-6. Aerial image being captured (n=32)](image)

**Does your company use aerial images as part of the construction management and control process?** As indicated in the previous question only 22 respondents answered this question. Of those 22, 16 (72.2%) stated that their company utilized aerial images for the construction management and control process.

**How are aerial images of projects typically captured?** There were 21 responses to this question, but one of the response was rejected as it did not explain the means of capturing aerial images. As shown in the Figure 4-8, eight respondents
stated they used a camera mounted on adjacent taller structure, 8 used manned aircraft flyover and 4 used a small unmanned aerial system to capture aerial images.

**Figure 4-7. Utilization of aerial images in construction management process (n=22)**

**Figure 4-8. Method of capturing aerial images (n=21)**

On an average how much is spent on aerial imaging per month for a typical project in your company (U.S. dollars)? There were 22 responses to this question, four of these responses were $0.00. These responses were considered inaccurate and
not included in the analysis. As shown in Table 4-3, the average amount of money spent on aerial imaging is $1,750 per month.

Table 4-3. Statistical analysis of aerial imaging cost

<table>
<thead>
<tr>
<th>Type of Work Performed</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Responses (n)</td>
<td>18</td>
</tr>
<tr>
<td>Average</td>
<td>$1,750</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>$2,321</td>
</tr>
<tr>
<td>Median</td>
<td>$1,000</td>
</tr>
<tr>
<td>Minimum</td>
<td>$90</td>
</tr>
<tr>
<td>Maximum</td>
<td>$10,000</td>
</tr>
</tbody>
</table>

How often does your company capture aerial images of a typical project? This question received 21 responses, of which two responses were removed as they did not match the respondent’s earlier responses. As shown in the Figure 4-9, 12 (60%) of the respondents stated they capture aerial images once a month and the remaining 8 (40%) said they would at least once capture aerial images before project completions.

Figure 4-9. Frequency of capturing aerial images (n=20)
Use of Small Unmanned Aerial Systems

The questions in this section of the survey questionnaire were statistically analyzed. The questions were tailored to achieve the research objective. Therefore, the questions focused on the respondent’s knowledge and concerns related to use of sUAS in construction. As it is a new section all the 32 respondents that either skipped the previous section (after answering “no” in the first question) or completed it answered some questions of this section. Similar to previous section, the first question of this section used skip logic to direct the respondent to answer the set of questions best suited for his/her knowledge. Additionally, display logic was used in a couple of questions.

**To your knowledge, has your company ever utilized a small Unmanned Aerial Systems (sUAS) on a project?** As shown in the Figure 4-10, the analysis of the question revealed that only 40.6% (13) of the respondents have used sUAS commercially. The rest 19 (59.4%) stated that their company has not used sUAS technology. Both groups of respondents to this questions are critical to fulfill the goal of the research.

![Figure 4-10. Utilization of sUAS on the project (n=32)](image-url)
For what purpose was the sUAS used by your company? There were 13 respondents to this question (those who answered “yes” in the previous question). The response choices for this question were listed based on the literature review of the research on potential uses of sUAS in construction. Therefore, the respondents could select one or more options depending on the individual company usage of sUAS. The analysis of this question indicated that the most common use of sUAS is inspection and documentation 7 (53.8%). The next highest response was marketing at 46.2% (6). The respondents were given the option to respond with any other use that their company might have applied the sUAS for, but none of the respondents reported anything else.

![Figure 4-11. Type of application of sUAS (n=13)](image)

Who was responsible for operating the sUAS? There were 13 responses to this question. Two respondents stated they did not know who operated the sUAS, therefore these responses were not used in analysis. As shown in the Figure 4-12, five of the respondents stated that their company used a third party operator to operate
sUAS. The two respondents that reported that the survey department of their company operated a sUAS belonged to the heavy civil sector.

Figure 4-12. Responsibility for sUAS operation (n=11)

**Do you personally have experience operating a sUAS?** As shown in Figure 4-13, the analysis of the response to this question revealed that only 3 (23.1%) out of 13 respondents have operated a sUAS. For two of these three respondents it can be confirmed that they did not use the sUAS at work (based on the response to previous questions).

**On a scale of 0-5 (0 being difficult and 5 being extremely easy), how easy is it to use a sUAS for the following purpose?** This is a two part, Likert scale question. As shown in Figure 4-14, the average for the ease of commercial use for 13 respondents is 3.69 and for personal use for the three respondents is 3.67.
What was the particular reason for not using sUAS? The 19 respondents to this question where those who had responded that their company has not utilized sUAS technology. As shown in Figure 4.15, the two common reasons for not using sUAS were either the high cost of equipment with 7 responses and lack of expertise with 6 responses. Only 4 (21.1%) respondents stated legal concerns as an issue. Two of the respondents stated that their company did not have the need to use sUAS.

Do you have knowledge of any of the following? In total, there were 32 responses to this question. Each respondent could select any number of options, from
the given list of terms that he/she might be aware of. The most common term known to 23 (71.9%) respondents was model aircraft (see Figure 4-14). Thirteen respondents (40.6%) stated that they are aware of small unmanned aircraft registration. The Certificate of Airworthiness was not selected by any respondent.

Figure 4-15. Reason for not being able to use sUAS (n=19)

Figure 4-16. Terms related to sUAS legal framework (n=32)
Were there any legal difficulties that your company faced for using sUAS?

This question was an open response question and the respondents were required to type in the response. The analysis of the responses is given in Table 4-4, it indicates that 26 (87.9%) respondents did not know about any legal challenges. Further analysis indicated that three of the respondents showed concerns about certification of operator and sUAS for commercial use. Only one of the respondent stated concerns related to safety of sUAS operation.

Table 4-4. Legal Challenges of using sUAS

<table>
<thead>
<tr>
<th>Issues</th>
<th>Number of responses</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certification for pilot and sUAS</td>
<td>4</td>
<td>12.5%</td>
</tr>
<tr>
<td>Safety concern</td>
<td>1</td>
<td>3.1%</td>
</tr>
<tr>
<td>Not aware of any</td>
<td>27</td>
<td>84.4%</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>100%</td>
</tr>
</tbody>
</table>

What are (if any) of the legal requirements for using a sUAS you are aware of? This was the last question of the survey and was an open response question, similar to the previous question. The responses to this questions were analyzed and are listed in Table 4-5. There were 32 responses to this question, one response was removed as it stated that FAA restricts the use of sUAS for commercial use which is not correct. Out of remaining 31, 20 (64.5%) stated that they had no idea about the legal requirement of using sUAS. There were 9 respondents that stated that registration of sUAS as legal requirement.

Table 4-5. Legal Requirements of using sUAS

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Number of Responses</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration requirements</td>
<td>9</td>
<td>29.0%</td>
</tr>
<tr>
<td>Federal restriction on flying zone</td>
<td>2</td>
<td>6.5%</td>
</tr>
<tr>
<td>Not aware of any</td>
<td>20</td>
<td>64.5%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>31</td>
<td>100%</td>
</tr>
</tbody>
</table>
The sUAS is no longer limited to military applications, there is an increasing demand for sUAS for in different industries. The sUAS technology is sure to become the next big thing in construction industry. Researchers have looked into various applications of sUAS in construction. Even some of the latest research is concerned with the cost aspect of using sUAS. There is a large information gap and misunderstanding amongst the construction professional when it comes to the legal aspects of using sUAS for commercial purpose. The research aimed at analyzing these issues and clearing some of these issues.

The survey responses showed that the majority of the commercial construction use aerial images captured from camera mounted on adjacent structure. Although a majority of the respondents 19 (59.4%) stated that their company does use sUAS for any application on the projects, only 4 (12.5%) of the total respondents stated that they use sUAS to capture aerial images and 13 (40.6%) stated that their company has utilized the service of a sUAS in some form or another. Of these 13, the majority of the users belonged to commercial sector and stated inspection/documentation and marketing as two of the most common application of sUAS. Another analysis of the data suggests that in heavy civil construction sUAS is the mostly operated by survey department and conducting inspections.

Very few respondents had the personal experience of using sUASs and rated the ease of using sUASs for personal use at an average of 3.67 out of 5. The ease of utilizing sUAS for commercial purpose was 3.69, not a lot more than that for personal use. The respondents who indicated that they did not utilize sUAS on their jobsites...
stated the high cost of equipment and lack of expertise as the reason for the same. A large number of the total respondents stated that they knew the terms like model aircraft and small unmanned aircraft registration. Still a majority of the respondents were not aware of any legal concerns and legal regulation in regard with the use of sUASs in construction, the percentage being 84.4% and 64.5% respectively. One respondent stated that legal issues could arise due to unsafe operation of sUAS on construction site.
CHAPTER 6
RECOMMENDATIONS

Several studies in regard with the applications of sUAS in construction have been conducted. These studies support both the applicability and financial feasibility of using sUAS in construction. Yet, a large number of construction professional are sceptical about the use these flying machines in construction. Future study on social impact of using sUAS in construction needs to be conducted. As construction workers are used to interacting with a human safety inspector, the effect of using sUAS for the purpose of inspection should be analysed. Analytical study on the potential invasion of privacy and safety concerns in regard with the use of sUAS on construction site needs to be conducted. The FAA has set guidelines and regulations for using sUAS for commercial purpose. But, lack of awareness amongst construction professionals poses a challenge for sUAS to be used in the construction industry. Future study on legal challenges of using sUAS in construction needs to be conducted, that includes one-on-one interviews and larger population size.
February 3, 2016

TO: Pranav Agrawal
c/o Dr. Raymond Issa
PO Box 115703
Campus

FROM: Ira S. Fischler, PhD; Chair
University of Florida
Institutional Review Board 02

SUBJECT: Exemption of Protocol #2016-U-0032
Framework for Legal Constraints for Using Unmanned Aerial Vehicle in Construction

SPONSOR: None

Your protocol submission has been reviewed by the IRB. Based on the review, the Board determined that your study is not-human subjects’ research in accordance with the following:

45 CFR 46.102 of the Federal Regulations states that human subject is a living individual about whom an investigator (whether professional or student) conducting research obtains: (1) data through intervention or interaction with the individual; or (2) identifiable private information.

Should the nature of your study change or if you need to revise this protocol in any manner, please contact this office before implementing the changes.

IF: dl
1. Demographic Question Block

Hello,

My name is Pranav Agrawal, and I am a graduate student at M.E. Rinker, Sr. School of Construction Management at the University of Florida. I am conducting a research on legal issues relating to the use of small unmanned aircraft system in construction industry.

The following questionnaire will take 10-15 mins to complete. There is no known risk or compensation for participating in the study. Participants of the study will remain anonymous. If you choose to participate please answer all the questions to your best knowledge.

Thank you for taking the time to assist me in my educational endeavor. If you would like a summary of the results please contact me via email. If you take the survey and you are not satisfied with the questionnaire or would like to give additional information please feel free to contact. I really appreciate you for taking time out of your busy schedule for taking the survey.

Sincerely,

Pranav Agrawal
Graduate Student
M.E. Rinker, Sr. School of Construction Management,
University of Florida,
pranav1992@ufl.edu

What region do you primarily operate in?

- [ ] Northeast US
- [ ] Southeast US
- [ ] Midwest US
- [ ] West US
- [ ] Southwest US
- [ ] Other

What is your primary role within your organization?
Project Manager
Assistant Project Manager
Superintendent
Assistant Superintendent
Project/Field Engineer
Project Executive
BIM/VDC Specialist
Estimator
Scheduler
Other

Number of years you have worked as a professional in the construction industry.

What is the major type of work your company typically performs?
Residential
Commercial
Industrial
Heavy Civil
Other

What is the approximate size of your company (based on annual revenue in US dollar)?

Does your company have research and development department?
Yes
No

How often does your company seek new technologies available for construction industry?
Less than Once a Year
Once a Year
Once in 5 years
Never
Aerial Imaging Question

Are aerial images collected of projects executed by your company?

☐ Yes
☐ No

Does your company use aerial images as part of the construction management and control process?

☐ Yes
☐ No

How are aerial images typically captured of projects?

☐ Camera mounted on adjacent structures
☐ Manned aircraft flyover
☐ Small Unmanned Aircraft System (sUAS)
☐ Other

On average how much is spent on aerial imaging per month for a typical project in your company (in US dollars)?

☐ Never
☐ At least once before project completion
☐ Once a Month
☐ Once a Week
☐ Daily

Information on use of unmanned aerial vehicles

To your knowledge, has your company ever utilized an Small Unmanned Aircraft System (sUAS) on a project?

☐ Yes
☐ No
For what purpose is the sUAS used by your company? (Select all that apply)

☐ Surveying/Aerial mapping
☐ Real-time monitoring
☐ Marketing
☐ Reporting progress to client
☐ Inspection/Documentation
☐ Other

Who is responsible for operating the sUAS?

☐ Third party operator
☐ Project/Field Engineer
☐ Superintendent
☐ Assistant Superintendent
☐ Other

Do you personally have experience operating a sUAS?

☐ Yes
☐ No

On a scale from 0-5 (0 being difficult and 5 being extremely easy), how easy it is to use a sUAS for the following purpose?

Personal hobby
Commercial use

What was the particular reason for not using sUAS?

☐ High cost of equipment
☐ Lack to expertise
☐ Legal concern
☐ Other (explain in detail)
Were there any legal difficulties that your company faced for using sUAS?

To your best knowledge, what are the legal requirements for using sUAS you are aware of?
LIST OF REFERENCES


Federal Aviation Administration. FAA system safety handbook. FAA; 2000.

Federal Aviation Administration, Unmanned aircraft systems operations in the U. S. national airspace system. Interim Operational Approval Guidance 08-01, 2008.


Originally from India, Pranav Agrawal received his Bachelor of Technology in Civil Engineering at Jaypee University of Information and Technology. In fall 2014 he joined M. E. Rinker, Sr. School of Construction Management at the University of Florida. Use of technology in construction always interested him. After studying a course in construction information system and attending the presentation on the implementation of unmanned aircraft systems in construction, he developed an interest in the field. Thus he began his thesis work on the legal aspects of small unmanned aircraft systems in construction. Pranav will be graduating in the spring of 2016 with the degree of Master of Science in Construction Management (MSCM). He plans to work in the construction industry where he will use his education to advance his career.