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Factors Influencing And Risk Associated With The Use Of Drones By Specialty Construction Companies In The United States Of America

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FACTORS INFLUENCING AND RISK ASSOCIATED WITH THE USE OF DRONES BY SPECIALTY CONSTRUCTION COMPANIES IN THE UNITED STATES OF AMERICA

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ABSTRACT

Unmanned Aerial Vehicles (drones) are being used by many industries through special use permits. Currently, the real estate industry leads in use of aerial vehicles for aerial views of property while agriculture follows at second being utilized to determine chemical and moisture content allowing the owners to treat the crops with the exact amount of chemical or water saving on cost of excessive treatment and possible crop loss. Drone use increased the visibility of real estate and also the profit margin of the agricultural business as well as the quality of the product being produced. Other industries are also using drones such as transmission line companies, oil companies and real estate companies. No complete legislation has been written to allow the use of drones in the FAA airspace for commercial use. Currently hobby use of below 400 feet and line of site including other restrictions are the only airspace allowed for the use of drones. It was mandated that the end of 2015, legislation will be written to allow drones for commercial use. This legislation was to address the safety factors of unmanned vehicles flying in the skies shared with manned vehicles such as passenger aircraft. This date has since past without a comprehensive legislation so section 333 of the FAA Modernization Reform Act allows an application for a case by case approval for commercial use.

The purpose of this study was to investigate the factors that are influencing the use of drones in the commercial building construction industry in the United States. In addition to the factors of proper legislation and safety, the legal and functional use of drones in construction will be addressed. This study was performed through research of existing bodies of influence such as the six test sites approved by the government to use and study drones to determine safety standards and help the government write legislation. This study also addresses universities that are studying and teaching as a curriculum, unmanned aerial vehicles. There was a survey sent to multiple construction companies and in the specialty trades to determine their knowledge and experience with UAV and possible uses that would benefit their business.

The conclusion of the investigation leads to the need of construction companies and factors that will influence their adoption of UAV in their business to help overcome the labor shortage and loss of intellectual assets.

PREFACE

The use of drones in the construction industry has only been adopted on a case by case basis because the Federal Aviation Administration (FAA) has not released a comprehensive law governing the use of drones for commercial use. Currently the use of drones is only governed under the law of hobby use. Once the FAA publishes the regulations, the commercial drone use will be legal to everyone that follow the regulations and drones use will increase over time. There is limited peer reviewed or academic articles written on drone use in the construction industry since the concept is new to the construction industry. There are many trades involved in a construction project and usually the research would be provided on one specific area of the construction industry; however, since there are very little publications documenting use of drones in the construction industry, the research shall include 400 specialty trades that have been listed in the 2014 edition of the Engineering News Record to obtain a sample population of how the construction industry views drone use in construction.

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INTRODUCTION

Background

The construction industry is a complex and broad industry that involves many types of specialty trades. To further complicate the industry, there is an exodus of workers which are depleting the industries intellectual assets and not enough people are entering the industry to fill the voids. The baby boomers are retiring at a rate of one every 12 seconds through the year 2032 that will cause a void of over 20 million workers (Reeves, 2005). Companies wanting to overcome the work force shortage must use technology and innovation to help fill some of these voids. The use of drones can help fill these voids by programming them to do human task.

There are differing opinions on the use of drones; however, based on the increased news coverage and articles about drones, within the next few years, drones will become a tool of the construction industry and not a futuristic ideology. Currently several efforts are underway to supplement human construction actives through both process innovation and technology improvements. This paper addresses the possibilities and uses of drones that will fill these voids as well as identify risk factors associated with the use of drones.

Description

Drones have been manufactured in many shapes, sizes and styles. Each of the drone styles has taken on a different name to categorize and identify the multiple characteristics of each drone. This paper will limit the research of these drones to micro drones (see Figure 1);

Figure 1. Micro Drone
(Microdrone.com)

helocraft (rotor craft helicopter type) and the spider drone (see Figure 2). These devices are equipped with high resolution cameras, clamping arms for picking up objects and spooling devices to help carry and shed a payload. Drone technology is continually being developed for different needs and uses including the adaption of sensors that can learn and distinguish between images or make their own maneuver decision based on the images they see (Rosenblum, 2012).

Figure 2. Spider Drones
(Parrot.com)

Statement of the Problem

The problem of this study was to determine the significance of the human, technological and risk factors influencing the use of drones by United States based specialty construction companies.

Statement of Purpose

The purpose for this study was two-fold:

1. To help construction companies understand the potential uses of Unmanned Aerial Vehicles (UAV) and the pending laws that will open the market for their use.

2. To help construction companies understand the risks associated in the use of drones.

Statement of Need

Labor performed in construction is the one of the highest risk associated with a project as it relates to profitability. The lack of a qualified work force and a diminishing work force due to baby boomers exiting the industry and fewer people entering the work force will result in a shortage of workers. These two factors can be addressed by adapting the use of drones to take the

place of some of the activities performed by human beings and perform the work faster and less expensive. Using technology with labor
exponentially increases labor performance as identified by Adam Smith in the Wealth of Nations (Rogers, 1983).

Questions of the Study

In order to provide an answer to the problem statement provided in this research, this study attempted to answering following questions;

Research Question #1: What are the risks associated with the use of drones on commercial construction projects in the United States?

Research Question #2: How widespread is the current use of drones in the construction industry?

Research Question #3: What are the factors that influence the use of drones by commercial specialty construction companies in the United States?

Research Question #4: Is there a difference in the respondents' perception of risk in the use of drones based on their position in the company?

Research Question #5: Is there a difference in the respondents' response based on their years of experience?

Research Question #6: Do the respondents' response vary based on the complexity of using a drone?

Research Question #7: Do the respondents' response vary based on interoperability?

Research Question #8: Do the respondents' response vary based on the size of the company?

Limitations of the Study

There are currently no complete laws written on the commercial use of drones below 400 feet. The mandate of having legislation written by the end of 2015 has passed and only partial law has been written. It is also expected that the law will be a work in progress and revisions to the law will take place to further define the law as the UAS. When the legislation is complete it is expected to be favorable to the commercial use of drones.

Because this topic is in the forefront of technology, there is limited use of commercial drones which is allowed based on a case by case basis from the FAA. Peer reviewed and scholarly journals were extremely limited at the start of this study: however, each month new articles may be published which cannot be captured in this study. Much of the information obtained in this dissertation was gained through interviews with professionals as well as journals and articles in available le publications that have been considered knowledgeable even though they may not be peer reviewed.

Other constraints include the rapid acceptance and technology as it relates to drones and the time frame of completing the dissertation. As the dissertation progresses, so does the changes in drone technology, laws and acceptance. Chapter five covers changes that have taken place since research has started and the completion of this study.

Definition of Terms

- *Accelerometer*: a device that measures proper acceleration ("g-force"). Proper acceleration is a measure an acceleration g= 9.81 m/s^2 straight upwards. By contrast, accelerometers in free fall orbiting and accelerating due to the gravity of Earth will measure zero.
- *Artificial Intelligence (AI):* is the intelligence exhibited by machines or software. It is an academic field of study which studies the goal of creating intelligence, whether in emulating human-like intelligence or not.

- *Attitude*: individual's positive or negative feeling about performing the target behavior (e.g., using a system).
- *Behavioral intention:* the degree to which a person has formulated conscious plans to perform or not perform some specified future behavior.
- *Computer anxiety:* the degree of an individual’s apprehension, or even fear, when she/he is faced with the possibility of using computers.
- *Computer self-efficacy:* the degree to which an individual belief that he or she has the ability to perform specific task/job using computer.
- *Construction Industry*: a sector of the workforce that is engaged in the preparation of land, new construction, alterations and repair of buildings, structures and other real property
- *Drone*: remote controlled unmanned aircraft or UAV or UAS
- *Effort expectancy:* the degree of ease associated with the use of the system.
- *Extensive Markup Language (XML):* a markup language that defines a set of rules for encoding documents in a format which is both human-readable and machine-readable and is an open protocol.
- *Facilitating conditions:* the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.
- *Gyro*: a rotating device in the form of a universally mounted spinning wheel that offers resistance to turns or changes in direction.
- *Intellectual Assets*: the knowledge a person has gained in their industry during their business career

- *International Alliance of Interoperability (IAI):* is an international organization which aims to improve the exchange of information between software applications used in the construction industry.
- *Industry Foundation Class (IFC):* a neutral and open specification for Building Information Models (BIM).
- *Interoperability:* the ability of making systems, software or equipment work together
- *Job relevance:* individual's perception regarding the degree to which the target system is relevant to his or her job.
- *Magnetometers:* any instrument for measuring the intensity or direction of a magnetic field (esp. the earth's field).
- *Mechanical, Electrical and Plumbing (MEP):* specialty trades in the construction industry. Plumbing in most cases is considered to be associated with mechanical.
- *Micro drones:* a drone that is small enough to be transported and launched by a person without the use of additional equipment.
- *Objective usability*: a comparison of systems based on the actual level (rather than perceptions) of effort required to complete specific tasks.
- *Output quality*: the degree to which an individual believes that the system performs his or her job tasks well.
- *Parametric Modeling*: a cad design that maintains specific information on objects drawn and that information is maintained as the objects are moved to interact with other models
- *Performance expectancy:* the degree to which an individual believes that using the system will help him or her to attain gains in job performance.

- *Pressure Sensors:* a device that measures pressure gases or liquids or other pressure of force required to stop a fluid or gas or other forms of measurement from changing, expanding or contracting and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.
- *Result demonstrability*: tangibility of the results of using the innovation.
- *Social influence:* the degree to which an individual perceives that important others believe he or she should use the new system.
- *Specialty Trades:* a sector of the construction industry that perform new construction, alterations and repairs of buildings or other real property specifically to plumbing, heating, air conditioning, masonry and carpentry.
- *Unmanned Aerial System (UAS):* a powered vehicle that does not carry a human operator uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload.
- *Unmanned Aerial Vehicle (UAV):* is an unmanned aircraft piloted by remote control or onboard computers

Assumptions of the Study

The following assumptions were made in pursuit of this research: (1) FAA will write law favorable for the use of commercial use of UAS in construction as well as other industries. (2) Manufacturing companies will continue to modify and produce UAV's for specific use in the mechanical, electrical and plumbing construction industry, and (3) Written law specific to commercial use, will allow construction industry to use UAV's beyond the current hobby law that drones have been required to follow, line of sight and below 400 feet.

The selected contractors interviewed or surveyed will have sufficient knowledge of drone use in commercial environment to participate in the study. A pilot study was conducted to assure the validity and clarity of the questions so they could be easily understood and interpreted the same way for each person responding.

Research Hypothesis

The following are the hypothesis proposed including the research hypothesis and the null hypothesis. The research hypotheses suggest a positive relationship between the conditions and outcomes of the research survey. Null hypotheses involve the use of statistical treatments to suggest that there is no relationship between the conditions and outcomes, other than those due to errors in measurement or chance.

H_{01}: $\beta_1 = 0$. There are no risks associated with the use of drones on commercial construction projects in the United States.

H_{A1}: $\beta_1 \neq 0$. There are risks associated with the use of drones on commercial construction projects in the United States.

H_{02}: $\beta_2 = 0$. There is no significant use of drones in the construction industry.

H_{A2}: $\beta_2 \neq 0$. There is significant use of drones in the construction industry.

H_{03}: $\beta_3 = 0$. There are no significant factors that influence the use of drones by commercial specialty construction companies in the United States.

H_{A3}: $\beta_3 \neq 0$. There are significant factors that influence the use of drones by commercial, specialty construction companies in the United States.

H_{04}: $\beta_4 = 0$. There is no difference in the respondents' perception of risk in the use of drones based on their position in the company.

H_{A4}: $\beta_4 \neq 0$. There is a significant difference in the respondents' perception of risk in the use of drones based on their position in the company.

H_{05}: $\beta_5 = 0$. There is no difference in the respondents' perception of risk based on their years of experience.

H_{A5}: $\beta_5 \neq 0$. There is a statistically significant difference in the respondents' perception of risk based on their years of experience.

H_{06}: $\beta_6 = 0$. There is no difference in the respondents' perception of risk based on the complexity of using a drone.

H_{A6}: $\beta_6 \neq 0$. There is a statistically significant difference in the respondents' perception of risk based on the complexity of using a drone.

H_{07}: $\beta_7 = 0$. There is no difference in the respondents' perception of risk based on drone operability.

H_{A7}: $\beta_7 \neq 0$. There is a statistically significant difference in the respondents' perception of risk based on drone operability.

H_{08}: $\beta_8 = 0$. There is no difference in the respondents' perception of risk based on the size of the company.

H_{A8}: $\beta_8 \neq 0$. There is a statistically significant difference on the respondents' perception of risk based on the size of the company.

Summary of the Chapter

In this chapter, the introduction including the statement of the need, statement of the purpose, limitations of the study, research questions, null hypotheses and definition of terms are described. This study is divided into five chapters. Chapter two presents a review of the related literature. Chapter three contains the methodology and procedures employed within this proposal. These specific areas include: type of study, the population, research design, instrumentation and the statistical analysis used.

CHAPTER 2

REVIEW OF LITERATURE

Background

The construction industry involves multiple trades that engage in the preparation of land, new construction, alterations and repair of real property. These trades are providing and installing building materials such as pipe, wire, bricks, roofing, etc. Drones, also known as unmanned aerial vehicles (UAV), are old technology as it relates to the military, but new technology as it relates to construction. As formulated by Adam Smith, technology can exponentially increase capital and labor (Smith, 2003). Between 1890 and World War I proponents of radio communication took a foothold in the US Navy. During this time the naval consulting board developed a research center that adapted commercial inventions for military use. After much debate in 1923, the National Research Laboratory (NRL) was founded. This division opened with 19 engineers and 4 physicists dedicated to the promotion of radio technology. One of the engineers was Carlos Mirick, an electrical engineering graduate from Cornell University. In February 1922, the Bureau of Engineering recruited Mirick to work on linking transmitting radio stations and remotely piloted aircraft. That winter Mirick, with other experts, began construction on the first remotely piloted aircraft which was intended to be a guided bomb. Many argued this was the birth of unmanned aerial vehicles. Many people worked on refining the radio frequency technology and between July and September of 1924, Chief Radioman Elmer Luke, with the assistance of Lieutenant John Ballentine, was assigned the task of piloting the aircraft "Wild Goose" (see Figure 3) using various degrees of remote radio control. Through those experiments

Figure 3. Wild Goose
(nrl.navy.mil/media)

Mirick took the information and in September 1925, Mirick received a patent for an Electrical Distant – Control System, which is now known as a "joy stick". The United States Bureau of Avionics, Bureau of Engineering, NRL and the Navel Aircraft Factory started pursuit of field ready mass produced target drones to aid in the training of sailors and pilots. This was the first time the name drone was used, even though it was not the first use of a radio controlled aircraft (Callahan, 2014). Since that time drones have been a significant part of the military arsenal from Vietnam to the current deterrent of terrorist in Afghanistan.

Military personnel have been the primary user of drones and recently, state government divisions such as police and sheriff departments have started implementing the use of drones. Drones have taken many shapes, sizes and styles which have led to the development and eminent use of drones in the private sector including construction. The use of drones in construction will allow UAV to perform many tasks that are currently performed by human workers. This will allow for a faster, less expensive and safer work environment for specific task that can be performed by drones.

With new technology come new laws and regulations. Drone use in construction is not included in current FAA rules and regulations, except through special application, so new legislation is being written. The FAA must integrate unmanned aircraft into the national airspace system, while making sure safety is in the forefront ("FAA Safety," 2013). Upon direction of the President of the United States, the FAA has selected six institutions that are authorized to operate UAV test at specific designated locations. The test conducted will explore how to set safety standards, train and certify ground-based pilots, ensure safety devices are in place for failure and most important, how to assure avoiding collisions with other aircraft, especially passenger airlines. Integrating UAV into the nation’s airspace has been targeted for the end of 2015 by Congress and will be phased in gradually (Wald, 2013). Many institutions applied to be chosen as a registered test site for drones. The locations were narrowed to a field of twenty-five. Included in the allowable sites are Griffiss International Airport, a former Air Force base near Rome, N.Y., which fly some tests from Cape Cod in Massachusetts, and Virginia Tech, which fly in Virginia and has an agreement with Rutgers University in New Jersey for testing there as well. Virginia Tech plans to conduct “failure mode” testing — finding out what happens if the aircraft’s control link is lost (Wald, 2013). The other sites chosen were the University of Alaska, which plans to perform their test in Hawaii. Oregon, the State of Nevada, the North Dakota Department of Commerce, and Texas A&M, University Corpus Christi, are the other areas that were selected for testing. Michael P. Huerta, the administrator of the Federal Aviation Administration said the reason for picking these particular sites was because of the diverse geography, climate and air traffic density. The selection of these six institutions marked a milestone for drones, whose proponents prefer to call them “unmanned aerial systems.” President Obama mandated in 2012 for the FAA to write law and set September of 2015 as the year by which UAS should be integrated into an airspace shared with manned aircraft. The process will be a staged process as more information is learned on how UAS interacts with other aircraft. Research is expected to continue until 2017 (Wald, 2013).

The basic concept of integrating UAV into the current controlled airspace is that everything in the sky — manned or not — will use the Global Positioning System (GPS) to determine its location, and will transmit that information to the ground, where a computer will develop a complete picture and send that to all pilots. Sophisticated drones could use that data without human intervention to sense conflicts with other aircraft.

The FAA has issued to ConocoPhillips, an oil company in Alaska permission to use a Scan Eagle (see Figure 4) off the Alaska coast. These permissions are through application for special use permits that individual companies may apply for through the FAA (Wald, 2013).

Figure 4. Scan Eagle
(Boeing.com)

When new technology is introduced so is the potential of additional risk. Risk can come in many forms and each company must determine how the risk of a new product could impact their company. When a construction company analyzes risk, it looks at how many variables are involved in a project that could impact its profitability. Decisions, designs and actions of others have a large impact on how a company produces and the time frame it takes to produce.

Before a construction company can identify risk, the FAA must identify the risk. Currently a drone considered for hobby purposes cannot fly over 400 feet and must be in line of sight. When drones are legal for commercial use, they could fly at much higher altitudes and could possibly interfere with airplanes and other aviation vehicles (Hill, 2011). Drone manufacturers are working on technology that would allow for avoidance with other objects which are not in line of sight (M. Brooks, 2012).

Another risk involved with drones is the risk of failure. Failure can come in many forms such as loss of battery, loss of signal and hacking to name a few. Even with the challenges and risks that are associated with using drones, the rewards and savings of using drones will be determined by individual companies based on their risk analysis. Being able to reduce time, cost and negative environmental impacts will result in increased use of drones, allowing activities to be performed faster and more accurate in less time with fewer resources; however, the risk must be evaluated.

How Drones Operate

Many companies are preparing for the new law to be commercial friendly and are investing in technology to meet the needs of the regulations and position themselves in the marketplace. Though the FAA has not released the regulations providing specific requirements, the drone manufacturing industry is anticipating the requirements and is working to overcome what they expect the FAA to write in law (Seyed Mohammadreza, Kamal, & Seyed Amir Hassan, 2011). Drones are controlled by a wireless tether called the “command and control” radio frequency link between the operator and the aerial vehicle. This wireless link allows the drone to maneuver up, down, sideways, forward and backwards. Operators typically configure the drone with a “lost link protocol”, which tells the drone to return to its original take off point if a signal is lost for more than 30 seconds or whatever time frame the operator wishes to program (Wesson & Humphreys, 2013). Payloads affect weight and power requirements which affect fuel, speed and range of flight. Advancements in battery technology and hydrogen cells might help increase the stamina of UAV (Hipple, 2014). A solar-powered drone currently in development by Boeing Corporation is scheduled to make its inaugural demonstration flight by early 2015. The Solar Eagle (see Figure 5) is being developed and financed under the terms of an $89 million contract with the Defense Advanced Research Projects Agency (DARPA). It is being designed to store solar energy harvested during the day for use overnight. Its 122-meter wing provides a large area for energy collection, as well as good aerodynamic performance. The DARPA intends for the Solar Eagle to be able to carry out persistent communications, intelligence, surveillance and reconnaissance missions from above 60,000 feet, with the aircraft able to remain at operational altitudes for five or more years (Boeing Media Release Haddox 2010).

Figure 5. Solar Eagle
(Boeing.com)

Many other drone functions are being researched and developed to anticipate industry specific use. Ongoing technology advances are allowing developers of drones to include tiny sensors that can transmit an array of information using accelerometers, gyros, magnetometers and pressure sensors (Anderson, 2014). These functions include collision avoidance which include sensors that can comprehend images being received, distinguishing between a person a car or other objects (M. Brooks, 2012). The controller used to maneuver these drones can be a stand-alone joy stick type controller or can be controlled by an IPad or IPhone that has the proper application downloaded (Zenko, 2012). The key to drone development is to produce a light weight battery that can produce a large amount of energy. Moore's Law states that microchip performance doubles every 18-24 months; however, the battery performance does not follow this law. Unmanned systems are more about the payload and less about the machine (Warwick, 2010). Other technologies being developed and incorporated into unmanned systems are sensors which can detect anything from moisture to potential collisions. These sensors can distinguish between images such as people, aircraft and boats. Laser radar, electro-optical and infrared sensors have also taken huge advances and assist in detection and collision avoidance (Warwick, 2014).

Robots have typically been fitted with central processing units (CPU) just like personal computers, but the more sophisticated drones will be fitted with graphic processing units (GPU), which can handle larger data sets more quickly and process several of them at one time. This is similar to how the human brain operates, but until now, GPU were too expensive and too large to incorporate into a weight sensitive drone. Using GPU means drones will not just be able to navigate, but will soon be able to make decisions during navigation such as navigating through congested areas of terrain or buildings or ultimately avoiding other objects or aircraft. Successful tests have already been conducted at the Neuromorphic lab at Boston University, where drones have avoided objects in its path without hesitation (Hodson, 2014). Drone technology has ridden on the wings of consumer technology such as cell phones and gaming technology. Smart phone technology of small batteries, vibrating motors, GPS receivers, accelerometers, gyros and memory chips have all been incorporated into how the drones work. Software is just as important as the hardware since it dictates the paths of the drone’s flight. Instead of GPS, some drones may have a laser rangefinder which allows the drone to determine where it is located and avoid obstacles during flight. However, many of the lab type test have been successful because of the technology that is available in labs that may not be available outside of the lab (M. Brooks, 2012).

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Types of Drones

There are many types of drones that have been developed or currently in development and there will continue to be drones developed to address specific industry needs. Drones are far more versatile than one could imagine, ranging from the size of an insect (see Figure 6) such as the ones researchers at Wake Forest University are developing to explore the Peruvian cloud forest, an area about the size of the continental United States, to that of a commercial passenger aircraft (Anand, 2013).

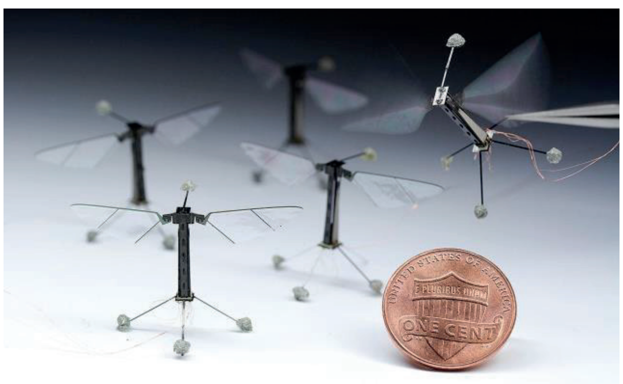


Figure 6. Insect Drones
(Popularscience.com)

Drones are placed into two categories, fixed wing drones such as the predator (see Figure 7) and rotorcraft type drones (see Figure 8) which resemble helicopters such as the K-max. Both of the drones identified, predator and K-max are much larger and more expensive than many of the more commercial functional drones that exist. Since the Mechanical, Electrical and Plumbing (MEP) industry as well as other specialty trades use will be mainly comprised of rotorcraft type UAV, the type of drones that are addressed will be limited to the rotorcraft type. Rotorcraft type

UAV range from a single type rotor, resembling a helicopter, to a quadrocopter (see Figure 9), which has 4 rotors to increase payload and maintain maneuverability and stability.

Figure 7. Predator Drone
(General Atomics Aeronautical ga-asi.com)

Figure 8. K-Max Drone
(Lockheedmartin.com)

Figure 9. Quadrocopter
(4rfv.co.uk)

Spider Drones are quadrocopter that include a spool style peonage under its body housing spools or wire or other type of material similar to nylon line. These type drones can loop cables around each other when the computer directs two drones to fly through certain points at an exact time. The two drones can tie complicated knots and form large, regularly repeating patterns strung between fixed structures or individually lay line or wire behind them in small places such as above ceiling cavities (Hodson, 2013). These spider drones can include a pair of six-inch wheels protecting the rotors and allowing them to climb walls and roll across a ceiling stabilized by an accelerometer and gyroscope and guided by a downward-facing camera and ultrasonic sensor (Iozzio, 2014).

Swarm Drones (see Figure 10) are rotor type drones with grippers (talons) that allow the drones to pick up objects and place in specific places or stack on top of each other such as bricks. The term swarm is used when there are multiple drones working together on the same task designed to avoid each other when going back and forth from the stock pile to the project such as stacking of foam bricks to build a structure such as the one successfully completed by the Swiss Federal Institute of Technology in Zurich (Hodson, 2013).

Figure 10. Swarm Drones
(businessinsider.com)

Military Use

The use of armed drones in the military did not actually take a presence until the "war on terror" gave birth to armed drones. Abraham E. Karem, the inventor of the MQ-1 Predator Drone which is already on permanent display at the Smithsonian Institution's National Air and Space Museum, and hardly looks like an aircraft that will be destined to change the world. The original predator was constructed of graphite epoxy composites and lighter than a compact car, the MQ-1 Predator, built by General Atomics Aeronautical Systems Inc. (GA-ASI) of Poway, California, is powered by a motor used in ultralight sport aircraft and cruises at 84 mph. Another distinguishing feature is the laser-guided AGM-114 Hellfire missiles (added by the Air Force in 2001) under the wings. No matter how simple the Predator looks, its success has changed military aviation (Whittle, 2013).

Although armed drones striking targets get the major headlines, the majority of the time drones are used for intelligence, surveillance and reconnaissance (ISR). Drone usage by the military continue to advance and more uses are being considered. Infantry troops now use 5 pound "backpack" drones (see Figure 11) to release as needed. In April of 2012, the Pentagon had a fleet of approximately 7500 drones which is up from 50 just a decade ago. One year later the Pentagon had over 8000 drones. A congressional report shows that manned aircraft totaled 95% of all aircraft for the department of defense in 2005, and in 2012, that percentage has reduced to 69%. Since drones are becoming smaller, cheaper and more sophisticated, manufacturers of military drones, as well as independent manufacturers are developing drones for the commercial market. While drones such as the predator may not be feasible to utilize on construction projects due to the size and speed, the predator type of drone may be beneficial to utility companies to monitor transmission lines for potential repairs. The technology used in "backpack drones", which are easier to transport and store would be more adaptable to the construction industry; however, rotor type vertical takeoff and landing UAV (rotorcraft) will account for the preferred type vehicle for use in the construction industry.

Figure 11. Backpack Drone
(complex.forignpolicy.com)

In 2011, Lockheed Martin and Kaman developed an unmanned helicopter (rotor) called K-Max (see Figure 8), which has transported over 3 million pounds of cargo to the marines, only in the areas of theater. A K-Max has the ability to lift and carry 4000 pounds. The K-Max production almost came to a halt because of the niche platform was too expensive to be used in the commercial market place. Lockheed and Kaman redesigned the rotorcraft to be used in civilian applications ("In for the Long Haul," 2013). It would be possible to use this type of UAV to set mechanical equipment on the roof of buildings that may otherwise have to be set by a limited number of commercial helicopter companies that lift equipment for the commercial mechanical and electrical industry.

International Use of Drones

The United States is far ahead of other countries in drone technology though they are lagging in drone use. The United States is projected to account for 77 percent of drone research and development and 69 percent procurement in the coming decades. There are 44 to 70 other countries that have drone capabilities and an expected total of 680 drone programs around the world, which is an increase from 195 programs that existed in 2005 (Micha Zenko). Though the United States of America is ahead in technology and sends many drones overseas, other countries civilian drone population and use is exploding and surpassing the United States. Aerial video is commonplace and professional cinema quality movie cameras are placed in special drones made by the UK, such as the Cinopro which has eight rotors for stability. Costa Rica uses drones to study volcano activities and Japan uses drones to crop dust for the agricultural industry and also to track schools of tuna for the fishing industry (Grossman, 2013).

China has been experimenting with drone deliveries over the past few years to deliver small packages in crowded urban areas with badly congested roads. These delivery drones are octorotors and can currently only carry 6.6 pounds. SF Express has received approval to make package deliveries and are currently expanding these flights. The United Kingdom has given experimental approval to Domino’s Pizza which is making pizza deliveries by drones (Atherton, 2013). The list of countries using drones is projected to be 89 and Japan has been the longest user of drones in the agricultural industry since the 1990’s (Garling 2013).

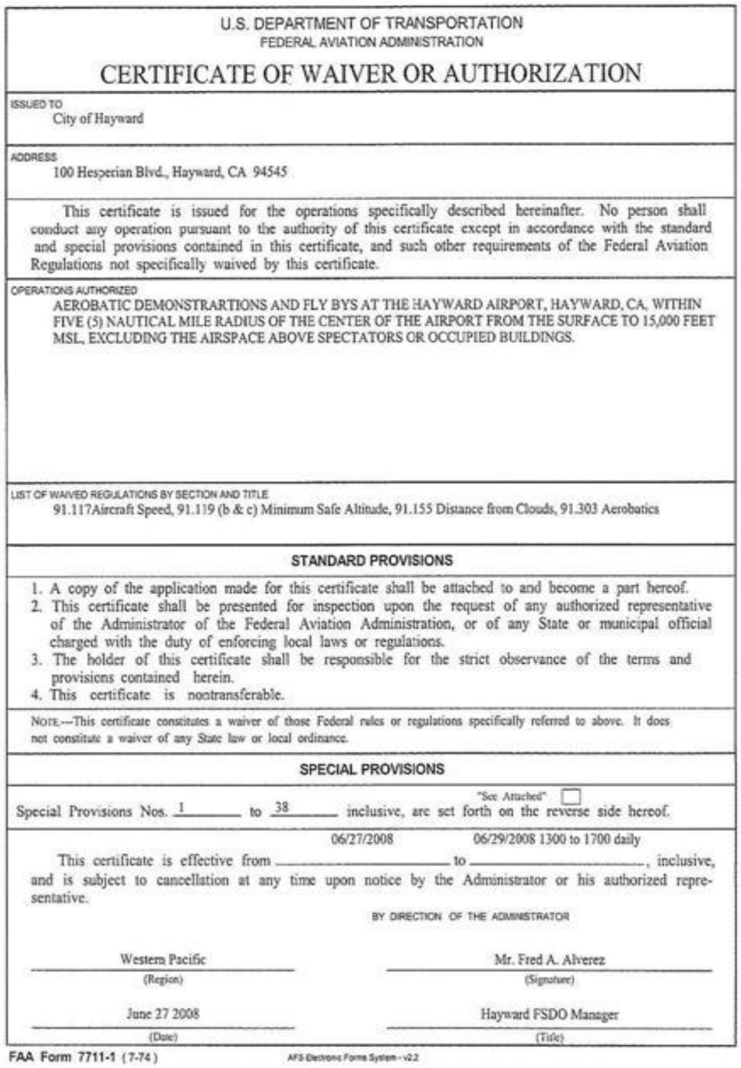
The development of spider drones by architects and roboticists in conjunction with the Swiss Federal Institute of Technology (ETH) in Zurich, is experimenting with a drone that can weave cables into high-rise structures on civil construction projects (Hodson, 2013).

The first recorded incident of a lifesaving drone was in May of 2013 when the Royal Canadian Mounted Police were searching for a 25-year-old man that had left the scene of an accident. The inclement weather had the police concerned so they sent up a quadrocopter drone with infrared cameras to search for the missing man, which ended as a successful mission (Whittle, 2013). Israel has successfully flown a UAV called the Heron TP (see Figure 12), also known as the Eitan, which is the size of a 737 that can take off and land itself. This UAV is full of cameras that weigh it down, but removal of the cameras and the 737 could become a transport aerial vehicle for equipment delivery (By Patrick Hruby, 2012).

Figure 12. Heron TP
(defense-update.com)

National Use of Drones

On February 8, 2014, FlowerDeliveryExpress.com a brick and mortar business in Detroit Michigan, delivered its first order by drone through testing and experimenting with alternate delivery methods. This testing was expected to continue for an extended period of time but was brought to a halt by the FAA on March 8, 2014 because commercial use of drones is only authorized on a case by case basis upon submitting an application (Newswire, 2014). LunaTech 3D LLC is a marketing firm that integrates aerial images with Google Earth and other media to create presentations and tours of websites. They have been given a short duration approval to use drones and have been getting many requests from clients including golf courses and real estate agencies. Detroit Aircraft Corp specializes in drones for first responders and is working with customers from government agencies that can operate drones with a certificate of authorization in conjunction with the Detroit Fire Department to develop a drone training center for first responders (Vis, 2014). The state of Hawaii has bought several drones to conduct aerial surveillance over Honolulu Harbor. Even though the drones use was being conducted by government agencies, the FAA grounded the flights because the harbor was too close to the airport. The United States Geological Survey (USGS) operates a fleet of 21 drones that can reach the altitude of 8000 feet to be able to reach cliff art, track wildlife, and inspect dams and to fight forest fires. These flights were approved after submission of a Certificate of Authorization (COA) (Whittle, 2013) (see Figure 13). In June of 2011, the sheriff of North Dakota was tracking some men for theft and had thought to be carrying weapons. Since there was so much open ground to cover, the sheriff requested a drone from the nearby air force to track the men. The Air Force sent out a predator drone and not only found the men but was able to determine what the men were carrying. This is be the first recorded incident that the predator drone was involved in an arrest of a US citizen (Grossman, 2013). Industries in the United States such as agriculture, construction, marine, film and real estate are ramping up for the law to be passed for commercial drones. The Association for Unmanned Vehicle Systems' International Trade show in Las Vegas had 500 companies presenting their drones for audiences in the filming industry; as well as agricultural, power lines, construction sites and gas spills (Grossman, 2013).



U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

CERTIFICATE OF WAIVER OR AUTHORIZATION

ISSUED TO
City of Hayward

ADDRESS
100 Hesperian Blvd., Hayward, CA 94545

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED
AEROBATIC DEMONSTRARTIONS AND FLY BYS AT THE HAYWARD AIRPORT, HAYWARD, CA, WITHIN FIVE (5) NAUTICAL MILE RADIUS OF THE CENTER OF THE AIRPORT FROM THE SURFACE TO 15,000 FEET MSL, EXCLUDING THE AIRSPACE ABOVE SPECTATORS OR OCCUPIED BUILDINGS.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE
91.117Aircraft Speed, 91.119 (b & c) Minimum Safe Altitude, 91.155 Distance from Clouds, 91.303 Aerobatics

STANDARD PROVISIONS

1. A copy of the application made for this certificate shall be attached to and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Administrator of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein.
4. This certificate is nontransferable.

NOTE.—This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.

SPECIAL PROVISIONS

Special Provisions Nos. 1 to 38 inclusive, are set forth on the reverse side hereof. "See Attached" ☐

This certificate is effective from 06/27/2008 to 06/29/2008 1300 to 1700 daily, inclusive, and is subject to cancellation at any time upon notice by the Administrator or his authorized representative.

BY DIRECTION OF THE ADMINISTRATOR

Western Pacific (Region) | Mr. Fred A. Alverez (Signature)

June 27 2008 (Date) | Hayward FSDO Manager (Title)

FAA Form 7711-1 (7-74) AFS Electronic Forms System - v2.2

Figure 13. Certificate of Authority
(FAA)

The agricultural industry is currently the second prominent industry for drone use. Ryan Kunde, is one of many winery owners in California that uses drones to irrigate less, use less pesticide and ultimately produce better wine. The imagery created by time series animation can show changes in the crop revealing trouble spots that need to be tended to without addressing the entire vineyard. These drones are equipped with many types of sensors including infrared, moisture and chemical sensors (Anderson, 2014). The first commercial use approval by the FAA was for AeroVironment, INC on July 26 of 2014 which used the UAV for monitoring oil spills and perform ocean surveys. The FAA restricted their use to the following categories: agricultural, pipelines, power lines, canals, and aerial advertising (Anderson, 2014).

Drones in Education

Colleges and universities are also experimenting with technology through grants, private, public and corporation funding. A University of North Dakota aviation professor John Bridewell, began the first college program in unmanned aerial systems in 2009. There are currently 130 students working towards a B.S. in Aeronautics with a major in unmanned aircraft systems. These courses give the students the skills to lead industry in a technology that has potential for many areas of expertise including design, operation, research, manufacturing to just name a few (Hipple, 2014). Universities are specializing in specific research and functions of the UAV. Rochester Institute of Technology (RIT) has been providing research on cameras for aircraft and are now adapting their research to include miniature cameras with the same quality that can fit into a smaller UAV. David Messinger, associate professor at RIT said there are many research projects being conducted that are examining how UAS can collect data in disaster situations such as natural disasters caused by hurricanes and floods and man-made disasters as in the case of chemical spills (Hipple, 2014). The University of Denver is offering a minor in UAS to 25% of their engineering graduate students. Dr. Kimon Valavanis directs the Universities Unmanned

Research Institute and Chairs the electrical engineering department. Dr. Valavanis explained that students with qualifications in the unmanned program can work in many areas, including design electronics, sensors, controls, software and flight control systems. Currently 90% of the budget has gone to military applications but this same technology can be used for commercial use once the FAA opens the market through legislation. The University of Denver is offering a graduate certificate and graduate degrees to their students in unmanned systems as of the fall of 2014. The focus of the program is to offer the multiple career possibilities in unmanned system technology. There are a number of other colleges and universities that offer courses and majors in UAS including Embry-Riddle Aeronautical University and Kansas State University (Sheila, 2014). Brigham Young University (BYU) has developed a "smart object recognition algorithm". This algorithm allows recognition of images from photos and video without the assistance of human presence. BYU engineer Dah-Jye Lee and his team of students performed several test that resulted in the computer choosing the correct images in the 95 to 98 percent range and has also tested at 100 percent. These tests recognized the difference between motorcycles, human faces, automobiles and airplanes and was issued in a press release on January 15th, 2014 (Hipple, 2014). University of Pennsylvania has developed a drone that can plot a trajectory through a hoop tossed into the air and fly through the hoop without making contact. (Grossman, 2013). It is calculated that by the end of 2015, over 100,000 jobs will be injected in the US job market relating to drone production and development (M. Brooks, 2012).

Drones in Construction

Examples of the use of UAV (drones) in the construction industry include using simple image-capture with photogrammetric software to create 3D environments such as buildings, landscapes, terrains. These images can be consumed by the Autodesk portfolio for conceptual design, volume measurements, and visualization of projects in their real context. Dominique Pouliquen is Marketing Director for the Reality Solutions Group at Autodesk and is the co-founder that develop photogrammetric software and solutions that are being adapted to drones (Johnson, 2014) .

UAV are becoming increasingly cheaper and easier to fly and can carry equipment ranging from small Go Pros to more expensive digital SLRs and video cameras. Some companies have already embraced such capturing devices to monitor their construction sites or to provide roof layouts for new equipment. Autodesk has developed a software platform called Fusion 360, used for Open Source collaborations on CADDrones.com (Johnson, 2014).

Karl Sachs, CEO of R4 robotics has been developing drones since 2011 and has run a pilot program with major utility company to test how drones can be used to inspect power poles and power lines (Vis, 2014). Christopher Korpela with Drexel University in Philadelphia is developing a quad rotor drone to perform tasks such as bridge repair using hand tools. The UAV have limbs that can perform the same functions as a ground based robot, but has the latitude to work in a three dimensional workspace (Marks, 2013). In July 2014, AeroVironment, Inc., was the first ever certification that allowed an UAV to be used commercially for patrolling pipelines and power lines to assess maintenance and provide areas in need of repair (Anderson, 2014).

Drones are increasing in construction sites around the world, even though in the United States laws do not allow commercial use of drones without a submitted application and approved on a case by case basis. The cost of drones along with the advancing technologies and mobile devices make using drones for inspections or hard to reach areas more common. Dragonfly Innovations is a Canada based company that makes drones for the construction industry. They have clients that use drones to inspect bridges and large cranes that use to be inspected by helicopters. The bridge inspections include pipeline joints as well as structural members. Javier Irizarry, assistant professor at the School of Building Construction at Georgia Tech received a grant to include possible uses of drones in bridge inspections. McCarthy Building Construction is assisting in carrying out some of the research for Irizarry which consist of getting a drone to the bottom of an excavated wall and reviewing placement of concrete for the foundation (Joyce, 2013). Most foundations include pipes that penetrate through or are tunneled under a foundation. The location of these pipes as well as placement of sleeves for future penetrations can be reviewed for accuracy and placement as well. Drones are thought of as eyes in the sky or surveillance vehicles; however, these eyes in the sky are now being developed with newfound limbs that can pick up and place items and even change light bulbs. Inspired by the bald eagle clutching its prey, Justin Thomis and colleagues at the University of Pennsylvania have developed a quick closing gripper for small UAV that can pick up objects. The UAV legs will swoop back, just like an eagle and then grab an object without having to slow down. Concurrently, Christopher Korpela of Drexel University is developing flight stability software for rotor driven drones with arms that will allow the limbs to carry objects without the added weight that could cause them to fall out of the sky. The software will allow the drone to reposition the load to achieve better flight control. This technology once it is fully developed will be instrumental in use in construction (Marks, 2013). Trimble has already developed a drone, Trimble UX5 (see Figure 14), with working software that can be used to incorporate ground based survey data into the design and construction workflow. This technology is adaptable with scanners and translate data to AutoCAD drawings and incorporate 2D and 3D scan to a 3D model in real time (Rubenstone, 2014). Unmanned Aerial Vehicles (UAV) are also being used for visual inspection and damage detection on civil structures. The quality of photos and videos taken by using such airborne vehicles is strongly influenced by numerous parameters such as lighting conditions, distance to the object and vehicle motion induced by environmental effects. These devices are fitted with highly sophisticated sensors and control algorithms intended to allow for each in civil structures inspections (Morgenthal & Hallermann, 2014), but there is no reason why the same inspections cannot be used for pipe welds and installation inspections for hard to reach areas. Currently there are companies that have air monitoring sensors on drones to determine air quality around or in a building and import data into most engineering software. The FAA has tried to fine these companies for using drones for commercial use but the cases were dismissed because the judge ruled that there were no rules for the FAA to enforce (Hampton, 2014). Some of these cases have been overturned and other companies have been found guilty. This type of inconsistent legal results can be contributed to the infancy of the technology and the lack of precedents.

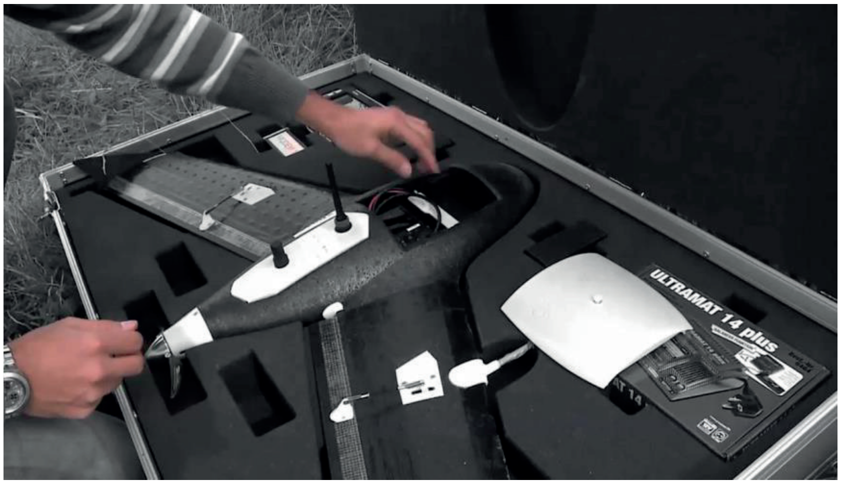


Figure 14. Trimble UX5
(Trimble.com)

Laws Governing the Commercial Use of Drones

The Federal Aviation Administration has banned flight of UAV for commercial use, expect through special applications as found under section 333 of the FMRA due to the safety impacts that uncontrolled aerial vehicles could have on the current national airspace. Currently, only hobbyist can operate drones. Hobbyist drones must fly in line of sight and below 400 feet during the daylight hours and be at least three miles from any airport. These current laws are for hobbyist and were written in 1981 for model aircraft, which the FAA has adopted to include drones (Alba, 2014). Government agencies, researchers and universities may operate drones if they apply for a Certificate of Authorization (COA) which was initiated in 2003 and started with the Department of Defense. Researchers may apply for an experimental special airworthiness certificates (SAC); however, the COA is the most common method. These certificates grant permission for specific aircraft to be used in specific locations, times and operations. The FAA Modernization and Reform Act of 2012 (FMRA), signed by President

Barack Obama, requires the FAA to develop rules and regulations permitting commercial and civilian use of drones. The FAA is working with companies on key technologies such as sense and avoidance systems, to make it safe for manned and unmanned vehicles to be in the airspace together and prevent potential collisions. The FAA is required by the 300 page Act to provide these rules and regulations by September 30 of 2015 (Carey, 2012). Certificates of Authorization that have been issued over the past five years to universities, police departments, aerospace companies and municipalities are as follow:

Year	No. Issued
2009	146
2010	298
2011	313
2012	257
2013	327

The 2013 COA that were issued is based on January and February only (Whittle, 2013).

It is expected that the rules and regulations that will be presented from the FAA will address drone flights for each classified FAA airspace just as it does for manned aircraft. These airspaces are as follows:

Airspace	Altitudes- Feet
Class G	0 – 1,200
Class B,C,D	0 - 10,000
Class A	18,000 – 60,000

Class E Undefined below 18,000

and everything above 60,000

Class B airspace is around airports, Class C airspace must have control tower clearance and Class D airspace must be in contact with tower but no transponder is required which gives the tower elevation of aircraft.

The legislation states the FAA must "provide for safe integration of civil unmanned aircraft systems into the national airspace systems…". In addition to the specific mandate and final deadline of September 30, 2015, the FMRA also states individual milestones such as:

May 12, 2012: Enter into agreements with public agencies to expedite approvals and allow public agencies to operate UAS weighing less than 4.4 pounds.

August 12, 2012: Establish six tests range locations at which UAS could operate and establish a process allowing for less restricted use for all UAS in the Arctic.

November 12, 2012: Expedite the issuance of a COA to public agencies and provide guidance to facilitate the use of UAV.

November 12, 2012: Develop a comprehensive plan to safely accelerate civil UAS into the National Air System.

August 13, 2013: Publish a final rule governing operations of small a UAV weighing less than 55 pounds.

August 14, 2014: Issue a notice of proposed rulemaking on all other UAV.

Though the milestones set forth in the FMRA are specific, there are no penalties for not meeting the milestones (Anand, 2013). The FAA is aware of the daunting challenges that lie ahead and have sought the expertise of other federal agencies such as the Department of Defense (DOD), National Aeronautics and Space Agency (NASA) and the Department of Justice (DOJ). They are also working with private and nonprofit organizations such as ASTM International, who are preparing consensus based standards for UAS (Anand, 2013). The FAA predicts that 30,000 drones will be airborne in the skies over the United States by the year 2030. For comparison, there are 350,000 registered public and private aircraft and 50,000 of them are flying over the United States on a daily basis. That is a 60 percent increase in objects in the sky over the next fifteen years (Whittle, 2013). There have been several court cases in which the National Transportation Safety Board (NTSB) has dismissed fines from the FAA to companies using drones for surveying and construction stating there are no rules for the FAA to enforce. There are several engineering and survey companies that continue to operate drones and hiding under the NTSB ruling (Hampton, 2014).

Risk Associated with Drone Use

Since drone use is in the experimental stage for commercial use, there are many risks that are associated with their use. The federal administration expects 10,000 unmanned aerial vehicles to be flying in the United States airspace by the year 2020. There are currently no precedents for legal outcomes of claims so the legal aspect of drone use is also in its pioneer stage. One of these risks is when a fake Global Positioning System (GPS) signal takes the place of the intended GPS signal, this process is known as spoofing. In 2001, the Department of Transportation issued a report in the dangers of spoofing. In June of 2012, experiments took place at the White Sands

Missile Range in New Mexico, verifying the spoofing of an $80,000 drone took place. Technical fixes are not completed but research continues in this area (Wesson & Humphreys, 2013). There are other risks similar to spoofing such as signal jamming which will not allow another person to take control of the aerial vehicle, but will cause the user of the vehicle to lose control by confusing the devices navigational system (Rash, 2013) .

Collision avoidance is a major concern that can result in a mid-air collision between an unmanned vehicle and another unmanned or manned vehicle. Drones have a bigger challenge in staying clear of other aircraft since they cannot accommodate existing airborne radar systems. No suitable technology has been deployed that would furnish an unmanned vehicle the capability to sense and avoid other aircraft while complying with the FAA regulations to assure that an avoidance system exist and a signal cannot be lost (Wesson & Humphreys, 2013). Though avoidance technology does not currently comply with the FAA, there has been ongoing successful experimentation of avoidance systems (M. Brooks, 2012).

Other risks included are the liability of the drone itself in case there is an accident or damage to other property caused directly by a drone. According to Safran Law Firm (Safran, 2014) of Raleigh, NC, there is no insurance currently available for commercial drones since there is no policy written to date that includes the use of commercial drones without special authorization. The Occupational Safety and Health Administration (OSHA) is another government agency that does not address the risk of drones. The current manuals published by OSHA do not include reference to drone use or list safety requirements because the use of drones in construction, civil or commercial applications is in the beginning stages of use. In addition to our national law addressing drone use is the broader challenge of international law which hinges on the existence of shared lexicon accepted by the international systems. With no independent judicial system capable of determining the meanings of words and concepts as it relates to drones, international law must be written as well (R. Brooks, 2014).

Finally, there is the fourth amendment right to privacy that is being challenged due to the increased use in drones. Not only is the privacy a concern from drone use by police departments, but any drone that flies over someone's property taking pictures, or even on the edge of someone's property taking pictures of people on their property. Historically, courts have permitted aerial surveillance from navigable airspace where civilian planes or helicopters routinely fly, prohibiting surveillance if it occurred from unusually low altitudes (Brinkerhoff, 2013). Advances in surveillance and optical technology have made it possible to detect very small objects from high altitudes. Stealth technology enables drones to hover above us, silently monitoring everything we do in areas exposed to the eyes in the sky. Drone technology, when carried to its extreme, threatens to diminish our privacy, overcoming the fenced-in backyard or private estate. Many local law enforcement agencies have already begun implementing aerial surveillance and the Supreme Courts will be busy refining privacy laws due to increased drone use (Molko, 2013). Currently there are 42 states that have proposed legislation imposing limitations on drone use including surveillance without a warrant by law enforcement agencies (Wesson & Humphreys, 2013).

Anticipated Law Changes

Currently no law is written to govern drones for commercial use. Drone use law is considered to be within the confines of the law written for drone use by hobbyists. The Federal Aviation Administration has banned the use of drones for commercial use until a law can be written to govern the commercial use. The exception to this ban is to submit an application under the FMRA section 333 for a case by case approval to operate of drone under specific restrictions. This case by case approval can take up to 120 days and applications can be denied. Safety in the airways is the major concern. Once a complete commercial law for drones is written and it is favorable, there are many companies poised to start selling drones to the public for commercial use. The potential benefits of commercial drone use can lead to decreased labor cost and increased productivity. A favorable law written for commercial drone use will also affect the US economy. It is anticipated that over 100,000 jobs and $90 billion in economic activity will be generated within 3 years of a favorable law (Sorcher, 2013).

Potential Setbacks

Based on the number of companies poised to use drones and the increased amount of activity in the airways by drones, if a law is passed to allow commercial use of drones, the FAA could slowly adopt the laws, postponing full commercial use easing into allowing commercial drones into the airways that would include many restrictions. The FAA does not have the personnel to police all of the anticipated new drone users to make sure they do not break the new law so safety is still the largest concern. The longer the FAA takes to write the safety rules, the more difficult it will be to regulate the industry. The FAA had previously planned to release regulations in 2011 for drones under 55 pounds and that did not happen. The Congress imposed deadline of September 2015 does not have any consequences against the FAA if the FAA does not have a law ready for publication on that date. If the law anticipated for September 2015 only addresses drones of 55 pounds or less and line of sight, then the construction use of drones will be limited (Levin, 2014). Even if a law is passed in 2015, there will be an evolution of the law over the next ten years which could favor or be against commercial use. Many companies that have developed commercial drones and are waiting for a favorable law to be written to allow open market sales, could end up in bankruptcy if the law is postponed or is too restrictive (Bachman, 2013). The public perception of privacy and the invasion of their civil liberties is also a key factor in the wording and timing of law. It is anticipated the United States will lose $10 billion in potential economic impact for each year the law is delayed. If the laws become too stringent, the overhead cost of insurance, licensing and certification may not be worth the investment of using drones in business. The September 2015 deadline could be more of a starting point in the regulation of drones slowly increasing airspace and weight limits and less of a grand milestone (Sorcher, 2013). Ensuring safety is not only a regulatory challenge but is also a technical challenge (Dillow, 2013) . Currently there is no sense and avoid technology that exists to avoid mid-air collisions between manned and with unmanned vehicles, even though there has been successful experiments (Grossman, 2013).

Summary of the Chapter

This chapter includes the research for drones including an introduction to drones and then providing research on the types of drones and use of drones by military, international countries and the United States. Also included are several universities that have a curriculum on drones and the use of drones in the construction industry. The lack of a current commercial drone law and anticipated laws on drone use are described along with potential use of drones.

CHAPTER 3

METHODOLOGY

Overview of the Research

This chapter will address the research design and strategies of the data collected in a concise and detailed approach. This study employs a qualitative technique to investigate the factors influencing the use of drones by specialty construction companies in the United States of America. This study includes data collection and analysis from 400 specialty construction companies as identified in the October 20, 2014 issue of the Engineering News Record (ENR) that contained the Top 600 Specialty Contractors in the United States of America. The analysis also determines if any significant difference was detected based on geographical location.

To assist in formulating the survey, interviews were conducted with two mechanical contractors, two electrical contractors, two general contractors and two construction attorneys. These interviews helped to design the survey to formulate the questions to assure the respondents have a clear understanding of the questions which is critical to the data analysis. Since these interviews were to provide a valid test instrument and the information was not considered to be qualitative information used in the results of the study.

This chapter addresses the research methodology used for this study. Other topics addressed in this chapter are included respectively: research approach, validity of the study, rationale for the research design, study of the research design, rationale for the survey research design, instrument validation, selection of the target population of respondents and the analysis of the data collection.

Research Approach

Research can be categorized as quantitative, qualitative or mixed methods research (Creswell, 2003). Quantitative research involves an epistemological approach in an objective reality where the variables are measurable and the sample studies represent a defined population relying on statistical methods to analyze the data (Gall, 1999). Qualitative research is a multi-method approach usually occurs in a natural setting and attempts to interpret the meanings of the subject matter humans bring to them from their opinions, reasoning and motivations. The mixed methods research involves a combination of both the quantitative and qualitative research. This study utilizes the quantitative approach relying on the survey method as the strategy of inquiry to support the study through quantitative research and statistical analysis of the survey which is categorized in the qualitative approach (Creswell, 2003). This mixed method lean heavily toward the quantitative approach associated with strategies involving complex experiments with many variables such as a two-way ANOVA.

This research study identified and described the factors influencing the use of drones by specialty construction companies within the United States. The research started out using qualitative research through interviews with several people working in the mechanical, electrical and plumbing contracting businesses as well as several construction attorneys. This approach was being used since the data collection included opinions of several of the respondents that hold different positions within an organization. The qualitative research was then used to generate the survey of the sample population. The data from the survey was analyzed through a quantitative statistical approach.

Technology Assessment Theories

Technology assessment theories provide a basis for predicting technology acceptance and examining the barriers preventing the use of technology (Peansupap, 2005). The framework of this dissertation proposal is diffusion of technology and the conceptual research model was used to identify and categorize the data. The theories used are Technology Acceptance Model and the Task Technology Fit model, which are both considered to be conceptual research models. These models address the human, technological and risk factors associated with the acceptance of technology and respondents of the survey were categorized and reported accordingly. These models explain human behavior as it relates to the responses and examines the intentions of usage (Peansupap, 2005).

Conceptual Research Model

The factors influencing the use of drones in the MEP trades are identified in the conceptual research model. This model was used because it is a proven model for diffusion of technology and model adoptions such as technology acceptance model (TAM) (see Figure 15) and task technology fit (TTF) model. These models consist of factors that are classified into three groups consisting of human factors, technological factors and legal/risk factors. TAM was developed with two major objectives in mind, first being to improve our understanding of the of the user's acceptance process and second to provide the theoretical basis to assist in a "user acceptance testing" methodology that would allow survey designers and technology implementers to evaluate the new technology before implementation (Davis, 1986).

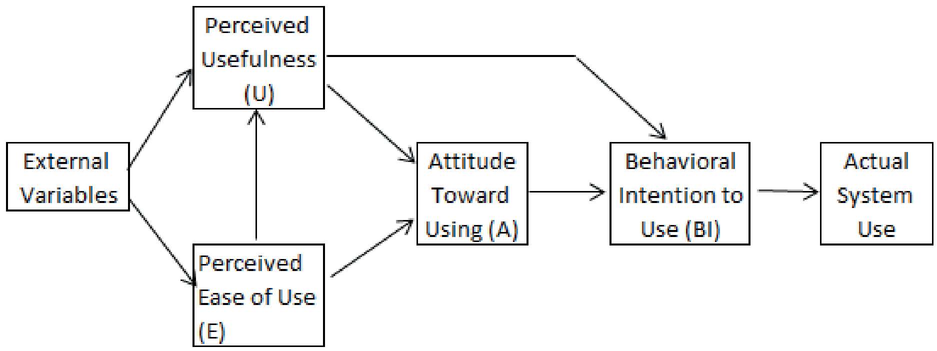


Figure 15. Technology Acceptance Model (TAM)
(Davis, F. 1986)

Task-Technology Fit model (see Figure 16) matches the capabilities of technology to the task demands. TTF is designed to evaluate an organization's overall technology architecture and not an individual technology. Rational experienced users will choose technology and methods that benefit them the most in completing a task. Technology that does not offer a sufficient advantage will not be used. The cognitive concepts of FIT explains how technology fits the needs of the tasks the individual performs (Goodhue, 1995).

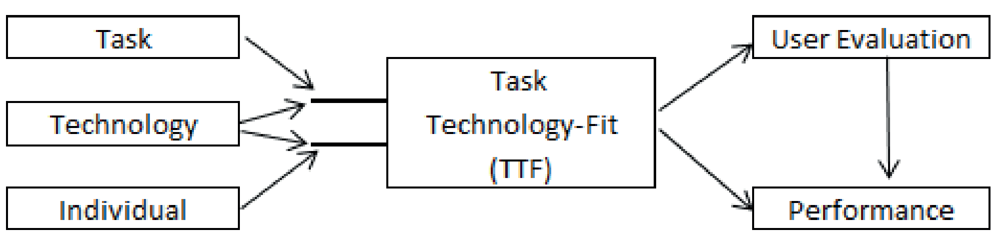


Figure 16. Task-Technology Fit (TTF)
(Goodhue, 1995)

Goodhue and Thompson have proposed a model that combines both utilization and task-technology fit since there were so many limitations to each model individually. They identified a new model called Technology-To-Performance Chain (TPC), utilizes both lines of research and recognizes that technologies must be utilized and fit the task they support in order to have a performance impact. The TPC model (see Figure 17) gives a more accurate picture of the way in which technologies, user tasks, and utilization relate to changes in performance (Goodhue & Thompson, 1995).

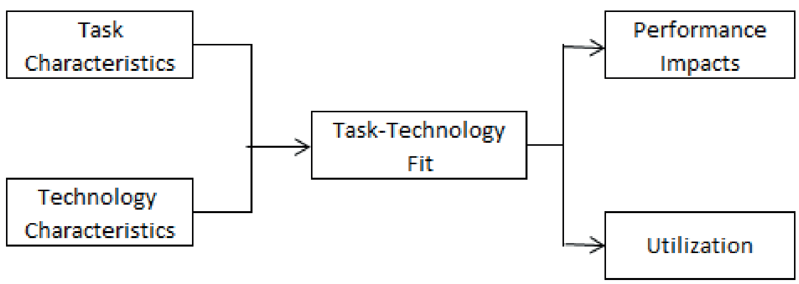


Figure 17. Technology Performance Chain (TPC)
(Goodhue and Thompson, 1995)

Human Factors

Management Support

Top management support is a major factor in the success of any technology implementation in an organization. Support and involvement by top management provides the following; organization strategic vision and clear direction emphasizing the importance of the technology and enhancing the success of adaption by others (Kunz, 2007). Plans to utilize new technology must be aligned with the organization's needs and implementation must be integrated with the strategic plan of the company and include all departments (Williams, 2007).

Training

Training is a primary factor affecting the adoption of technology within an organization. Training can be equated to cost and time and could be minimized by previous experience. Without appropriate training most technology users will only utilize and understand parts of the technology's capabilities which could lead to frustration and termination of adaption (Peansupap, 2005). It is important to provide the proper resources in the implementation of new technology; these resources include money and manpower necessary for the proper training. Adequate training and positive attitude towards new technology are important factors in determining the success of implementation in a construction firm (Williams, 2007).

Experience

Every new technology includes an underlying risk associated with the technology. However, the diffusion of technology cannot exist without an organization's existing technology infrastructure and capabilities and skills that exist to implement the technology. Therefore, construction companies that have a greater degree of expertise on the use of technology are more likely to adapt new technology (Premkumar, 1995). Experience is defined as the opportunity to use a target technology and is typically defined operationally as the passage of time from the initial use of a technology by an individual to their current use. Experience is the passage of chronological time resulting in the formation of differing levels of habit depending on the extent of interaction and familiarity that is developed with a target technology (Venkatesh, L. Thong, & Xu, 2012).

Education

Prior studies show that educated workers have a comparative advantage to the implementation of new technology. As education increases the probability of adopting new technology increases; however, education does not influence the use of technology but formal education increases the use of technologies that require or enable workers to carry out higher order tasks, but not those that produce routine workplace tasks (Riddle, 2012). Perceived Usefulness (PU) is the belief that technology will improve performance, Perceived Ease of Use (PEU) convinces the users of an effort-free usage of technology (Davis, 1986). It could be argued that different education levels have different perceptions as to ease of use.

Compatibility

Compatibility of an innovation is defined by Rogers (1982) as the “degree to which innovation is perceived as being consistent with the existing values, past experiences, and needs of the potential adopter.” Compatibility is an important variable that influences the adaption of an innovation (Premkumar, 1995). Research in this area is good at explaining technology usage based on a personal preference, but they have not adequately examined the role of technology in organizations and thus are limited. Use of technology in an organization tends to maximize usage and to derive performance benefits from it. Technology usage models should include the perceived work compatibility in shaping users’ usage intentions as it relates to their work settings (Sun, 2009).

Job Relevance

Job relevance is an individual's perception as to the degree to which the specified technology applies to their duties. Other studies have documented a correlation between user acceptance and variables similar to job relevance such as determined importance as it relates to their job (Davis, 1986). People that perceive a higher need of innovation in their job are more likely to use it than people that do not need it. Use of technology can also be related to job relevance or job perceived performance (Leonard-Barton, 1988).

Age

It is important to understand the differences between the older and younger work force and the importance each group attaches to extrinsic factors as it relates to the use of new technology. Research shows that younger workers are more focused on job related outcomes such as task accomplishments. It is expected that age is a major variable in the attitude towards using new technology and young workers would be more salient (Morris, 2000). During the early stages of using a new technology, younger men tend to exhibit a greater tendency to seek innovativeness and increase the relative importance of hedonic motivation in technology use decisions (Venkatesh et al., 2012).

Technological Factors

Cost

The less expensive an innovation is, the more likely it will be adopted (Rogers, 1983). Innovation expense includes not only the cost of the technology, but also the training, operations and overall cost associated with the technology (Premkumar, 1995). The price value is considered positive when the benefits of using a technology are perceived to be greater than the monetary cost of the technology and such price value has a positive impact on implementation. Thus price value is a predictor of behavioral intention to use a technology but is categorized as a technological factor (Venkatesh et al., 2012).

Complexity

The complexity of an innovation is the degree in which the innovation is perceived to be difficult to understand and use (Rogers, 1983). Even if the technology is useful, being difficult to use will cause the employees to perceive it as too complicated and prevent adoption. Complexity is an important factor in technology adoption (Premkumar, 1995). Ease of use refers to the user's belief that the technology in question is not difficult to use. Specifically, it is the evaluation of the degree to which using the technology is free of effort (Davis, 1989). If a given piece of technology or a system is overly complex or otherwise difficult to use, it is not likely to be used when an alternative method exists. These difficult to use technologies are judged by the operator to be less useful under voluntary conditions.

A common definition of complex systems is those composed of many interacting elements that interact in complex ways (Simon 1969). The structure of interactions between elements is of main interest giving the construct that complex systems can be described as a graph with nodes (elements) and edges (interactions). These interactions are then given by the topology of a graph and the more complex is identified by the number of interactions that exist between elements. The maximum complexity of a system can then be expressed as a function of the number of elements N (Franken, 2005).

Interoperability

Interoperability is defined as software compatibility of the technology (drone) to the other software applications a company may be using. The seamless transfer of information between applications are a significant factor in innovation acceptance. An interoperability interface protocol allows technology or devices to interact with other technology or devices and sharing information. Inconsistency and data mismatch can be mitigated by defining data layer in a platform independent manner (*Government Transformation: Agenda for EGov 2.0*, 2011). The basic idea of data interoperability is that shared data are stored only once and maintained by the producer of the data in one location to assure data definitions used are always up to date and no redundant versions exist which requires a single data definition for all similar services. Data layer needs to be structurally interoperable to reuse existing definitions. Following are some common approaches to achieve data interoperability:

- Object orientation: This is an approach for developing data definitions by encapsulating the internal details of the data.
- Extensible data model: This approach uses an extensible data model and standardized interface
- Extensible Markup Language (XML): This approach requires agreement on the contents and meaning of the XML schema for entities. Schema can be extended for the structure of the database to provide structural consistency. This approach can be combined with the "Object Orientation Approach" where Extensible Markup Language is used to define object which will widen the scope of conventional entities and include methods and other object oriented feature to give versatility to entities and also define

their scope and behaviors more precisely within application context (*Government Transformation: Agenda for EGov 2.0*, 2011).

Output Quality

Output quality is defined by how well the technology performs in achieving the job goal of the employee. The relationship between perceived output quality and perceived usefulness providing that output can significantly impact the overall perceived usefulness of the technology (Davis, 1986). Perceived usefulness is the perception that a given technology will help a user achieve his or her work goals. Within the context of adopting and using a new technology in the workplace, Venkatesh, Morris, and Ackerman (2000) provide evidence that the most important determinant of an employee's attitude toward adopting and using a new technology is his or her perception of the usefulness of the technology (perceived usefulness).

Risk Factors

Legal

There are many risk associated with the use of drones, and no precedents have been established as to the extent of risk as it relates to insurance, damage or privacy invasion. As with previous new technologies, anticipated liability related issues are important to innovation adoption and is therefore included in this study. Safran Law Firm (Safran, 2014) has held several conferences and is preparing for the legal risk that contractors face when using drones. Regardless of the known or unknown risk of using drones on construction sites, risk managing consists of potential risk source identification of risk impact including assessment and analysis with a risk management response. All of the variations of potential risk on a project must be managed in a systematic approach, though not always sequential (Nigel Smith, TonyMerna, & Jobling, 2006).

Validity of the Study

The use of drones in construction has not been regulated by the government and the concept is still fairly complex, making it necessary to share some of the conceptual uses of drones within the construction industry with the respondents. The survey (instrument) was subjected to a qualitative testing so a valid instrument was produced. Interviews were conducted with several MEP contractors and attorneys to determine the level of knowledge that should be expected of the selected group of construction companies to be able to answer the questions of the survey and addressing the data needed for the study. These interviews helped to understand the opinions and interpretations of the drone law and use of drones in commercial applications. Validity of the interviews pointed out areas of questions that did not add to the knowledge of the study and allowed the revision to the questions to derive at a concise survey.

Population Target

This study focused on the development and implementation of drones in the construction industry, with the majority being specialty trade contractors that perform installation of mechanical, electrical and plumbing contracts within the commercial construction industry ("Top 600 Specialty Trade Contractors," 2014). While most drones are being used for survey and photography purposes, there are many possible uses that can be adapted by the mechanical, electrical and plumbing trades (MEP). These trades are a similar type trade that performs similar functions using pipes AutoCAD and labor production tracking. Other specialty trades such as glass, utility and inspections can also benefit from the use of drones. These companies are identified from the Engineering News Record (ENR).

Statistical Technique

A variety of statistical analysis techniques were used to analyze the data. These techniques included descriptive statistics, reliability test, factor analysis and analysis of variance. To explain the characteristics and portray important features of the sample data, descriptive statistics was also used. The main focus of descriptive statistics was to arrange, summarize and process a set of data in a meaningful way through frequencies and proportions illustrated in graphs and charts (Minium, 1998). The survey was interpreted by using the Likert scale of 1 to 5 to determine the variable means of importance as identified in the survey. Responses with a mean below 3 were considered to be low, the mean between 2.5 and 3.5 was considered natural and the mean between 4 and 5 was considered to be high. The results of the means or score provided a correlation of the respondents but did not identify the reliability of the scores. A reliability analysis or test was conducted to examine whether multiple items measure the same construct which could vary based on the population administered. Cronbach's alpha is the most common test theory to use which determines true score and error due to question specific factors. As a standard, the validation above a .74 is acceptable in obtaining reliability (Norusis, 2012). Another statistical technique used is the factor analysis. A factor analysis was used to identify a small number of factors that explain observed correlations that may not be otherwise measured on a scale. The analysis was used to reduce a large number of correlated variables to a more manageable number of independent or smaller set of unobserved factors that were used in subsequent analysis (Norusis, 2012).

Kolmogorov-Smirnov tests were completed to test normality with significance level results. The null hypothesis for significance of normality is, “if $p > .05$, do not reject the hypothesis”. Histograms were used to test for normality.

Descriptive statistics were used to describe respondents’ demographic and organization data. These techniques were also used to define other results as appropriate.

Analysis of Variance (ANOVA) was performed to determine the results of the effect of four categorical independent variables on the different factors listed in the study (multiple dependent interval variables) (Norusis, 2012). The ANOVA technique allowed two types of variation, one of which is individual responses and the other is between groups variations and sample means (Minium, 1998). The ANOVA determined if there are any relationships between the factors identified and the following independent variables.

Company Position: Analysis was completed to establish if respondents’ opinion in regards to the future use of drones in construction, varied based on their respective positions within the companies surveyed. This analysis was performed to determine the underlying differences in opinions based on positions held within an organization such as estimator, AutoCAD operator, project manager, project engineers and upper management.

Drone Knowledge: Analysis was completed to establish the respondents’ opinion in regards to the future use of drones in construction varied based on their perspective regarding knowledge of drone use from other industries or media exposure. Knowledge categories include internal company knowledge, knowledge obtained through others’ experience, knowledge obtained through news from television, internet or magazines excluding reference to military use;

however, response to military use was identified as responded but not included in the calculations except as missing data.

Drone Experience: Analysis was completed to establish the respondent's opinion in regards to the future use of drones in construction varied based on their perspective regarding their experience in the use of drone use either by experience with others' devices or their own device. Knowledge categories include internal company drone experience, personal experience associated with others using drones or personal experience of using a drone themselves. Drone experiences include military use if the respondent was previously responsible for drone operations in the military.

Future Use: Analysis was completed to establish the respondent's opinion in regards to the future use of drones in construction varied on how drones could be used to increase productivity of profitability of their organization.

Research Instrument

Restatement of the Research Questions

Research Question #1: What are the risks associated with the use of drones on commercial construction projects in the United States?

Research Question #2: How widespread is the current use of drones in the construction industry?

Research Question #3: What are the factors that influence the use of drones by commercial specialty construction companies' in the United States?

Research Question #4: Is there a difference in the respondents' perception of risk in the use of drones based on their position in the company?

Research Question #5: Is there a difference in the respondents' response based on their years of experience?

Research Question #6: Do the respondents' response vary based on the complexity of using a drone?

Research Question #7: Do the respondents' response vary based on interoperability?

Research Question #8: Do the respondents' response vary based on the size of the company?

Pilot Test

A pilot study was conducted to test the reliability and content validity of the instrument and to determine whether some of the items of the instrument should be modified for the actual study. The pilot survey was designed using commercially available internet software, www.surveymonkey.com and emailed to two mechanical contractors, two electrical contractors, two general contractors and two construction attorneys. The email as well as the questionnaire contained information that participation is voluntary and that privacy and confidentiality will be respected and strictly adhered to. Respondents' were given the opportunity to comment on the items in the questionnaire and/or to offer feedback. The feedback from the pilot test was used to improve the survey instrument used for the study. The respondents were given the opportunity to critique the survey and provide feedback on the wordings, clarity, and ease of taking the survey in attempt to alleviate any ambiguities. The respondents were told to call the researcher if they needed clarifications on any of the items or for clarity on the purpose of the survey, if necessary.

Reliability

It is important to assess how reliably the survey measures the results as intended (Norusis, 2012). Good tests produce values that correlate well with an unknown true score. Cronbach's alpha, a measure of internal consistency, was used to assess how reliable the survey questions are designed to measure the construct. Cronbach's alpha values range from 0 to 1. Higher values suggest higher internal consistency, indicating questions are correlated and measure the same construct. Tests are considered good if a score of .74 or higher are reached.

Statistical Variables

To enhance comparison, the demographic dimensions or variables were broken down into three broad groups with two subgroups for each as shown below.

Dimensions	Subgroups
Age	1= < 25 / 2 = 25-35 / 3= 36 – 46 / 4= > 46
Geography	1= East / 2= Central / 3= West / 4= No Response
Education	1= High School / 2 =Technical school / 3= 2-year school
	4= 4-year School / 5= Post Graduate

a. Age: All people under the age of 25 are coded as 1, all people 25 to 35 years old are coded as 2, all people 36 years old to 46 years old were coded as 3, and all people above the age of 46 were coded to 4.

b. Geography: Respondents' that were located in the eastern part of the United States based on a map designating the Mississippi river east, were coded as 1, respondents' that were located in the central United States based on the map were coded as 2, respondents' that were located in the western part of the United States were coded as 3. Any person that did not answer to the question were coded as 4 designating that they did not respond.

c. Education: Respondents'' that had a high school education were coded as 1, respondents' that had a technical certificate were coded as a 2, respondents' that graduated from a 2 year or community college were coded as a 3, respondents' that graduated from a 4-year college or university were coded as a 4, and respondents' that graduated with a post graduate degree were coded as a 5.

Statistical Assumptions

Microsoft Excel and SPSS 23.0 were used as the statistical analysis tools. Raw data recorded in the survey tool was exported to the Microsoft Excel and SPSS applications for analysis comparison on results to confirm accuracy. SPSS 23.0 can only run analysis on ordinal data and not string data. All of the string data was coded to ordinal data and the coding format for each string can be seen in Appendix F.

Normality

Kolmogorov-Smirnov tests were completed to test normality with significance level results. The null hypothesis for significance of normality is "if $p > .05$, do not reject" (Kales, 1998). The test was utilized for the nonparametric test to quantify a distance between empirical distribution and the cumulative distribution function of the samples. Histograms were used to test for normality and are presented in Figure 2.

Descriptive Statistics

Descriptive statistics was used to describe respondent demographic and organization data. The techniques were also used to detail other results as appropriate. It is assumed the respondents answered the questions truthfully.

Summary of the Chapter

In this chapter, the research methodology and design components were presented and described; as well as the research questions and null hypothesis, data sources, research design, instrumentation, data collection process, and the statistical analysis used. The conceptual drone research model based on the framework of the research, diffusion of technology, was categorized and defined. The pilot test was outlined as to the approach for validating the instrument. All variables analyzed in Chapter 4 were defined and data collections were outlined for answering the questions of the research.

CHAPTER 4

FINDINGS AND DATA ANALYSIS

Introduction

This chapter provides the statistical analysis of the data collected from the survey and presents this data as results inferred from the survey. The research questions presented in Chapter 1 are being answered through the following statistical techniques:

Descriptive analysis: used to provide general characteristics of the variables included in the research and the data sample.

Reliability analysis: used to check the reliability and validity of the survey instrument.

Factor analysis: used to group numerous variables determining the factors that influence the use of drones into smaller coherent groups of variables.

Mann-Whitney U test and Kruskall-Wallis H Test: used to identify the differences and similarities among the survey respondents based on experience, position, job relevance, cost and interoperability.

Restatement of the Problem of the Study

The problem of this study was to determine the significance of the human, technological and risk factors influencing the use of drones by United States based specialty construction companies.

Restatement of the Research Questions

Research Question #1: What are the risks associated with the use of drones on commercial construction projects in the United States?

Research Question #2: How widespread is the current use of drones in the construction industry?

Research Question #3: What are the factors that influence the use of drones by commercial specialty construction companies in the United States?

Research Question #4: Is there a difference in the respondent's perception of risk in the use of drones based on their position in the company?

Research Question #5: Is there a difference in the respondents' responses based on their years of experience?

Research Question #6: Do the respondents' responses vary based on the complexity of using a drone?

Research Question #7: Do the respondents' responses vary based on interoperability?

Research Question #8: Do the respondents' responses vary based on the size of the company?

Restatement of Research Hypothesis

$H1_0$. There are no risks associated with the use of drones on commercial construction projects in the United States.

$H1_a$. There are risks associated with the use of drones on commercial construction projects in the United States.

$H2_0$. There is no significant use of drones in the construction industry

$H2_a$. There is significant use of drones in the construction industry

$H3_0$. There are no significant factors that influence the use of drones by commercial specialty construction companies in the United States.

$H3_a$. There are significant factors that influence the use of drones by commercial specialty construction companies in the United States.

$H4_0$. There is no difference in the respondents' perception of risk in the use of drones based on their position in the company.

$H4_a$. There is a significant difference in the respondents' perception of risk in the use of drones based on their position in the company.

$H5_0$. There is no difference in the respondents' perception of risk based on their years of experience

$H5_a$. There is a statistically significant difference in the respondents' perception of risk based on their years of experience.

$H6_0$. There is no difference in the respondents' perception of risk based on the complexity of using a drone.

$H6_a$. There is a statistically significant difference in the respondents' perception of risk based on the complexity of using a drone.

$H7_0$. There is no difference in the respondents' perception of risk based on drone operability.

$H7_a$. There is a statistically significant difference in the respondents' perception of risk based on drone operability.

$H8_0$. There is no difference in the respondents' perception of risk based on the size of the company.

$H8_a$. There is a statistically significant difference on the respondents' perception of risk based on the size of the company.

Pilot Study

A pilot study was conducted on the survey instrument but it was not conducted in a traditional manner. The pilot study was not used to get a sample population to determine the results of the investigation; instead, it was conducted to determine the relevance and understanding of the survey. The population sample of 400 specialty contractors was identified from the Engineering News Record (ENR) magazine list of 600 Top Specialty Contractors in the United States of America, published on October 20, 2014. Before the survey was sent out to the 400 ENR respondents, it was sent to eight companies in four different areas of the construction industry to determine if there was a clear understanding of each question and to avoid misinterpretation errors that could lead to inconsistent responses from the respondents. Table 1 below shows the pilot study participants.

Table 1

Pilot Survey Participants by Area of Expertise (N = 8)

Variables	Law Firm	Commercial Mechanical Contractor	Commercial Electrical Contractor	Commercial General Contractors
Number of Survey Participants	2	2	2	2

The response to the pilot study resulted in several of the questions being reworded to clear up any ambiguities as well as to reorganize the questions to group them into Likert-type questions. Conducting this type of pilot study was instrumental in making sure each respondent understood and would come closer to interpreting each question the same way.

Results of the Investigation

The investigation resulted in 67 respondents or a 16% response. The goal was to reach 100 respondents or 25% response. The first week the survey ran, there were 4 respondents, the second week there were 10 respondents and the third week there were 25 respondents. After the third week, a second email was sent out asking for respondents to take the survey. By the fourth week the survey had 40 respondents and the fifth week there were over 55 respondents. The sixth week there were already 60 respondents and the by seventh week there were 67 respondents. The survey remained open for 10 weeks or two and one half months in an effort to obtain the desired 100 respondents. Between weeks seven and 10, no more responses were received from the survey.

Statistical Analysis of the Investigation

The survey was sent out by email on October 9, 2015 and was active until December 20, 2015. The population sample of 400 specialty contractors was identified from the Engineering News Record (ENR) magazine list of 600 Top Specialty Contractors in the United States of America, published on October 20, 2014. The target population was targeted to the first 400 contractors in attempt to receive a 25% response or 100 respondents. The actual results achieved were 67 respondents or a 16% response. The names of the respondents and companies that completed the survey are not identified and remain anonymous.

The data was collected and sorted by geographical location, experience and position within their organization. A calculation for margin of error for the sample population of the target market resulted in an $\alpha = .1$ and power of .9 required at least 52 sample size of responses. The 67 responses received in the study falls within the required minimum sample size of 52 cases. See

Appendix G for the analysis using G*Power 3.1. The result is there is a 90% confidence level that 10% of the population sample represents the 400 of the population target.

After collecting the data, data coding was used to assign character symbols or numerical values before it was entered into SPSS to allow for proper categorization. Each of the questions on the survey was given a unique variable name so each variable could be coded and analyzed. This coding is identified in Appendix G. The coded values were then analyzed for missing data and outliers before any analysis was performed. Analysis of missing values was conducted by computing frequencies for each variable.

Several survey questions that had “Other” as one of the response options asked for additional information from the respondents. However, survey respondents failed to add more information in these fields and these fields had missing values of over 50%. Nevertheless, these variables had no direct bearing on the outcome. The missing variables were removed from the data before the analysis was performed. The information that was provided under the variable of “other” was used in the descriptive analysis.

The missing variables were removed from the data before the analysis was performed. The information that was provided under the variable of “other” was used in the descriptive analysis.

Collection of Data

The survey was conducted on line through Survey Monkey and was limited to 28 questions (See Appendix D). Based on research performed by Survey Monkey, it was determined that each question would take approximately 19 seconds per question for a total of 9 to 10 minutes to complete the survey. If the survey had more questions or took longer than 10 minutes, there was the concern that the responses would be less accurate and the respondent would tend to not spend as much time on each question.

The survey was organized into three sections with each section consisting of Likert-type questions. The first section comprised of questions 1 to12 in the survey related to the respondents' information such as the number of employees within the organization, position within the organization, geographical location and experience in drone use. The second section which comprised of survey questions 13 to 23 of the survey were multiple choice questions that related to the respondents' knowledge or perception of drone use within their organization. The third section of questions consisted of survey questions 24 to 28 were a series of Likert scale questions ranking the perceived importance of each question. Responses ranged from 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) to 5 (strongly agree). The five questions were formulated to explore five constructs, namely: experience of drone use, cost of drone use, drone complexity, interoperability of drones and legal use of drones.

Respondents Information

This section briefly describes respondent personal and professional demographics through the use of tables and narrative format.

Description of Trades Provided by the Organizations Surveyed

The organizations surveyed varied in the type of trades that performed commercial construction for their clients. Table 2 below indicates that roughly one-third of respondents belonged to the Other group ($n = 21$) while one-fourth of respondents worked as electrical contractors ($n = 17$). Respondents who worked as roofing contractors comprised of 22.4 percent of total respondents. Lastly, mechanical contractors comprised approximately one-fifth of total respondents (*n* = 14).

Table 2

Respondents by Construction Services (N = 67)

		Survey Participants	Percent
Valid	Mechanical	14	20.9
	Electrical	17	25.4
	Roofing	15	22.4
	Other	21	31.3
	Total	67	100.0

Description of Positions Held by Survey Respondents

The survey respondents were classified into two groups, lower level employees and upper level management. About eighty percent of the survey respondents held positions in upper management (*n* = 54*)* while roughly one-fifth of survey respondents were lower level employees. There was one participant who had no response and this was considered as a missing value. Table 3 below illustrates the respondents by company position.

Table 3

Respondents by Company Position (N = 67)

		Survey Participants	Percent
Valid	Lower	12	17.9
	Upper	54	80.6
	Total	66	98.5
Missing	System	1	1.5
Total		67	100.0

Description of Company Size Based on Employee Count

Around half of the respondents were employed in companies with 101-400 employees (*n* = 33) while more than one third of the survey participants worked in companies with more than 400 employees (*n* = 24). 10.4% of the respondents were employed in companies with 51-100 employees (*n* = 7) and 4.5% had less than 50 employees (*n* = 3). Table 4 below illustrates companies by number of employees.

Table 4

Survey Respondents by Company Size (N = 67)

		Survey Participants	Percent
Valid	Less than 50	3	4.5
	51-100	7	10.4
	101-400	33	49.3
	More than 400	24	35.8
	Total	67	100.0

Description of Respondents Based on Age

Respondents within the companies were categorized based on age to determine if the age of an employee had any significance on the respondent's perception on the use of drones in construction shown in Table 5. 77.6% of the survey participants were in the 36 and above age range (*n* = 52) while roughly one-fifth of the respondents were aged 35 and below (*n* = 14).

Table 5

Survey Respondents by Age (N = 67)

		Survey Participants	Percent
Valid	Less than 35	14	20.9
	36 and above	52	77.6
	Total	66	98.5
Missing	System	1	1.5
Total		67	100.0

Description of Respondents Based on Years of Experience

Respondents within the companies were categorized based on the years of construction experience to determine if employee experience had any significance on the respondents' perception on the use of drones in construction industry. The respondents' years of experience is shown in Table 6. Roughly half of the respondents had more than 20 years of experience (*n* = 33) while 22.4% had 6 to 10 years of experience (*n* = 15). 17.9% of participants had 11 to 20 years of experience (*n* = 12) while approximately one-tenth had 1 to 5 years of experience (*n* = 6). There was one respondent who had no response and this was classified as missing data.

Table 6

Survey Respondents by Years of Experience (N = 67)

		Survey Participants	Percent
Valid	1-5	6	9.0
	6-10	15	22.4
	11-20	12	17.9
	More than 20	33	49.3
	Total	66	98.5
Missing	System	1	1.5
Total		67	100.0

Descriptive Statistics:

To determine the significance of the human, technological and risk factors influencing the use of drones by United States based specialty construction companies, the researcher analyzed the descriptive statistics relevant to the eight questions that guided the study.

Research question 1, "What are the risks associated with the use of drones on commercial construction projects in the United States?"

The construct, legal use of drones, was composed of a series of three questions. Responses ranged from 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) to 5 (strongly agree). Respondents were asked if they were aware of the risks associated with the use of drones. Risk was not defined and was left up to the respondents' individual perception. The means of the different tests indicated that they have roughly the same values ranging from *M* = 2.48 to *M* = 3.60 with relatively similar standard deviations ranging from .827 to .947. There were 7 respondents with no responses and these cases were excluded from the analysis. Table 7 below shows the descriptive statistics for the construct legal use of drones.

Table 7

Descriptive Statistics for Study Variables Legal Construct (N = 60)

	Mean	Std. Deviation	Number of Participants
Const_legal_A	3.60	.827	60
Const_legal_B	2.48	.873	60
Const_legal_C	3.47	.947	60
Valid N (listwise)			60

a. Listwise deletion based on all variables in the procedure

The Legal construct which consisted of 3 survey questions indicates a low level of internal consistency with a Cronbach's Alpha of .226. Table 8 shows the summary of Cronbach's Alpha for risks associated with the use of drones.

Table 8

Cronbach's Alpha for Risks associated with the Use of Drones (N = 60)

Cronbach's Alpha	N of Items
.226	3

Figure 18 presents the histogram for the legal construct. The numerical value 6 was assigned the value of "no response" by the survey participants and these values were deleted from further analysis. The mean was generated by combining results from 60 valid responses focused on the three questions associated with the legal construct questions designed to analyze the risks associated with the use of drones in commercial projects in the United States. The mean response for the legal construct was $M = 3.18$, $SD = .554$. A mean score of 3.18 suggests respondent's perceptions were neutral regarding the risks associated with drone use in commercial construction projects in the United States.

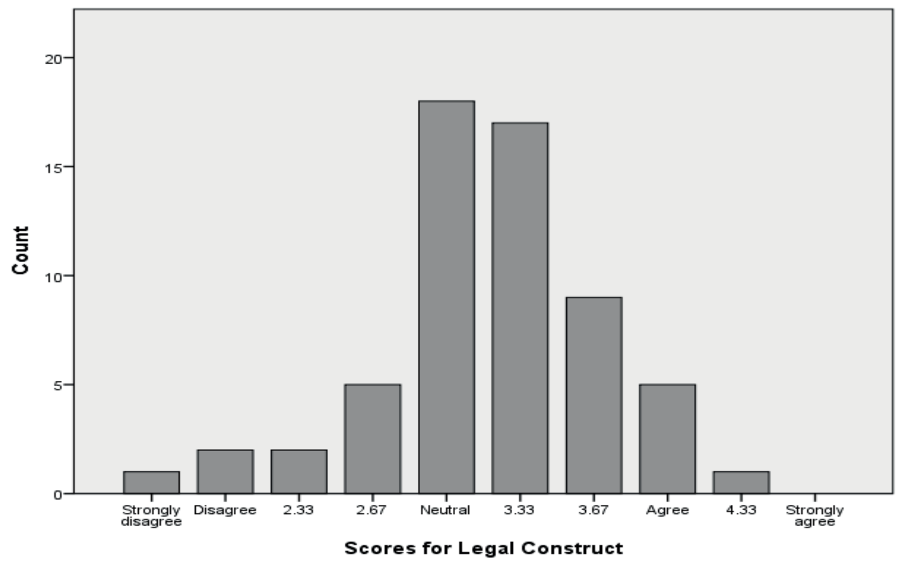


Figure 18. Histogram for legal construct

Research Question #2: How widespread is the current use of drones in the construction industry?

Question 24 which consisted of a series of three questions (experience of drone use) designed to study the current use of drones in the construction industry. Responses ranged from 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) to 5 (strongly agree). The means of the different tests indicated that they had a wider range with values from M = 1.97 to M = 3.08 with standard deviations ranging from 1.154 to 1.416. There were 6 respondents with no responses and these cases were excluded from the analysis. Table 9 below shows the descriptive statistics for the construct experience of drone use.

Table 9

Descriptive Statistics for Study Variables Legal Construct (N = 61)

	Mean	Std. Deviation	Number of Participants
Const_exp_A	1.97	1.154	61
Const_exp_B	2.84	1.416	61
Const_exp_C	3.08	1.370	61
Valid N (listwise)			61

The construct, experience of drone use, consisted of three survey questions indicated a moderate level of internal consistency with a Cronbach's Alpha of .731. Table 10 shows the summary of Cronbach's Alpha for risks associated with the use of drones.

Table 10

Cronbach's Alpha for experience with the Use of Drones (N = 61)

Cronbach's Alpha	N of Items
.731	3

Figure 19 is a histogram showing the distribution of the survey data relative to the participants' experience in the use of drones in the construction industry. The numerical value 6 was assigned the value of "no response" by the survey participants and these values were deleted from further analysis. The mean was generated by combining results from 61 valid responses focused on the three questions associated with the construct of experience of drone use questions designed to study the current use of drones in commercial projects in the United States. The mean response for the construct experience in drone use was $M = 2.63$, $SD = 1.064$. A mean score of 2.63 suggests respondents' perceptions were slightly negative with regard to the prevalence of the use of drones in construction projects in the United States.

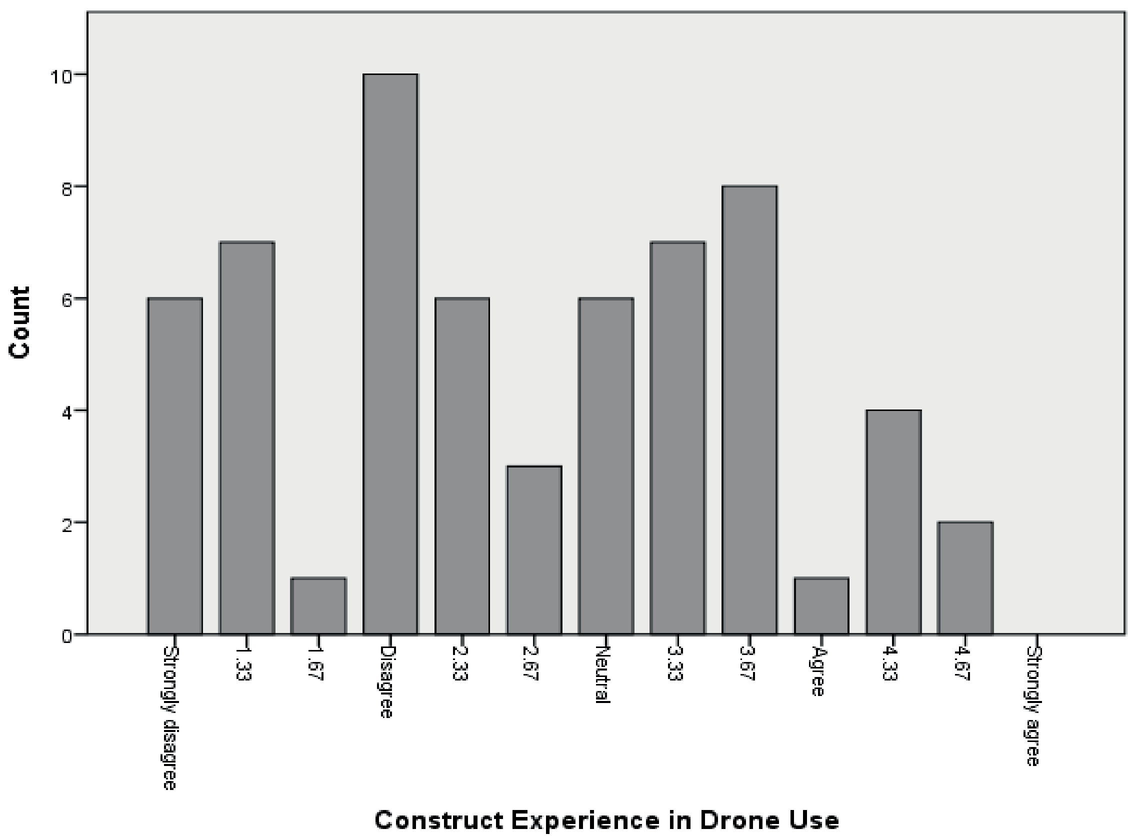


Figure 19. Survey data distribution

Research Question #3: What are the factors that influence the use of drones by commercial specialty construction companies in the United States?

A factor analysis was performed on the second section of the survey questions which was composed of questions 13-23 to determine the factors that influence the use of drones by commercial specialty trade construction companies in the United States. Questions 16 and 17 were excluded from the analysis since missing data counts for these questions were more than 50% of the number of respondents.

The correctness of using a factor analysis was first assessed prior to analysis. The overall Kaiser-Meyer-Olkin (KMO) measure was .709, which according to Kaiser (1974) was categorized as “middling” to “meritorious”. Bartlett’s test of sphericity was statistically significant, $p < .001$ which suggests that the data is factorable.

Analysis revealed that three factors that had Eigenvalues greater than one and explained 31.405%, 14.350% and 11.533% of the total variance, respectively. Visual inspection of the scree plot indicated that three components should be retained. In addition, a three component solution met the interpretability criterion. Thus, three factors were maintained.

The three-factor solution accounted for 57.288% of the total variance and the researcher used a Varimax orthogonal rotation in the analysis. Results from the factor analysis were consistent with the factors the second section of the questionnaire was designed to measure. Component one relates to technological factors while component two relates to risk factors. Finally, component three relates to human factors. Table 11 shows the factor loadings and communalities of the rotated solution.

Table 11

Factor Analysis with Varimax Rotation for a Three Component Questionnaire

Items	Rotated Component Coefficients			
	1	2	3	Communalities
Q13	.766	.174	.184	.651
Q14	.753	-.087	.025	.575
Q22	.609	.439	-.298	.436
Q23	.540	.420	-.229	.519
Q19	.133	.707	.034	.595
Q20	.222	.664	-.325	.842
Q15	.176	.577	-.048	.653
Q18	.294	-.564	-.178	.520
Q21	.070	-.011	.915	.366

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

The researcher conducted exploratory analysis to satisfy the necessary assumptions of normality and homogeneity. The researcher conducted a Kolmogorov-Smirnov test of normality and found that the data was normally distributed, $p > .05$. Levene's test for homogeneity of variances also indicated that there were equal variances, $p > .05$. The researcher used an Analysis of Variance (ANOVA) to answer the succeeding research questions.

Research Question #4: Is there a difference in the respondents' perception of risk in the use of drones based on their position in the company?

An Anova was performed on the respondents' risk perception based on their company position and There was no statistically significant difference based on their company position, $F(1,58) = .766$, $p > .05$. Therefore, the null hypothesis is retained.

Table 12

Analysis of Variance (ANOVA) for Risk Perception based on Participant Position (N = 60)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.236	1	.236	.766	.385
Within Groups	17.857	58	.308		
Total	18.093	59			

Research Question #5: Is there a difference in the respondents' responses (on risk perception) based on their years of experience?

An Anova was run on the respondents' responses on risk perception compared against the respondents' based on their years of experience. Table 13 below shows the results of the analysis. There was no statistically significant difference in respondent answers based on their experience, $F(3,56) = 1.881$, $p > .05$. Therefore, the null hypothesis is retained.

Table 13

Analysis of Variance (ANOVA) for Risk Perception based on Participant Experience (N = 60)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.657	3	.552	1.881	.143
Within Groups	16.437	56	.294		
Total	18.093	59			

Research Question #6: Do the respondents' responses (on risk perception) vary based on the complexity of using a drone?

An Anova was run on the respondents' responses on risk perception compared against the complexity of using a drone. Table 14 below shows the results of the analysis. There was no statistically significant difference in respondent answers based on their experience, $F(3,56) = .331$, $p > .05$. Therefore, the null hypothesis is retained.

Table 14

Analysis of Variance (ANOVA) for Risk Perception based on Complexity of Drone Use (N= 60)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.316	3	.105	.331	.803
Within Groups	17.778	56	.317		
Total	18.093	59			

Research Question #7: Do the respondents' responses (on risk perception) vary based on interoperability?

An Anova was run on the respondents' responses on risk perception compared against the respondents' based on interoperability. Table 15 below shows the results of the analysis. There was no statistically significant difference in respondent answers based on their experience, $F(4,55) = .349$, $p > .05$. Therefore, the null hypothesis is retained.

Table 15

Analysis of Variance (ANOVA) for Risk Perception based on Interoperability of Drone Use (N=60)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.448	4	.112	.349	.843
Within Groups	17.645	55	.321		
Total	18.093	59			

Research Question #8: Do the respondents' responses (on risk perception) vary based on the size of the company?

An Anova was run on the respondents' responses on risk perception compared against the company size. Table 16 below shows the results of the analysis. There was no statistically significant difference in respondent answers based on their experience, $F(3,56) = .1.208$, $p > .05$. Therefore, the null hypothesis is retained.

Table 16

Analysis of Variance (ANOVA) for Risk Perception based on Company Size (N = 60)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.100	3	.367	1.208	.315
Within Groups	16.994	56	.303		
Total	18.093	59			

Results Summary of Chapter

The goal of this study was to determine the significance of the human, technological and risk factors influencing the use of drones by United States by specialty construction companies in the United States. The study found that the respondents' perceptions were neutral regarding the risks associated with drone use in commercial construction projects on the United States. On the other hand, respondents' had a slightly negative view on the prevalence of the current use of drones in the United States. Further analysis also determined that the survey questionnaire had three constructs (technical, risk and human factors) that influenced the use of drones by commercial mechanical and electrical construction companies in the United States.

Further analysis also indicates that there were no statistically significant differences on the respondents' risk perceptions based on company position, years of experience, complexity of using a drone, interoperability of drone use and company size.

CHAPTER 5

CONCLUSION

Introduction and Summary of the Findings

The problem of focus in this study is that despite the potentially beneficial impact of new technologies such as drones in the construction industry, barriers exist to the adoption of drones in the construction industry. The purpose of this study was to facilitate the understanding of the potential benefits, uses, and risks of Unmanned Aerial Vehicles (UAV's) in the construction industry, as well as pending legislation that will impact their usage. The current study was conducted in order to investigate factors influencing the utilization of drones in the U.S. commercial construction industry. The key findings from the survey are summarized below, organized by research question.

Perceptions of Risks of Drones in the Construction Industry

The first research question focused on survey respondents' perceptions of risks associated with the use of drones on commercial construction projects in the United States. The hypotheses associated with this research question are as follows:

$H1_0$. There are no risks associated with the use of drones on commercial construction projects in the United States.

$H1_a$. There are risks associated with the use of drones on commercial construction projects in the United States.

The mean of the responses to the questions corresponding to this research question revealed that survey respondents overall had neutral perceptions of the risks of drones for us in the construction industry (on a scale of 1 through 5, the average score was 3.18). Due to this result, the researcher failed to reject the null hypothesis. The results corresponding to this research question were somewhat unique in that neither the null hypothesis nor the alternative hypothesis accurately captured the neutral nature of the results.

Perceptions of Commonality of Drones in the Construction Industry

The second research question focused on the extent to which the current use of drones is widespread in the construction industry. The hypotheses associated with this research question are as follows:

$H2_0$. There is no significant use of drones in the construction industry

$H2_a$. There is significant use of drones in the construction industry

The mean of the survey responses corresponding to this research question revealed that respondents held slightly negative perceptions of the widespread use of drones in the construction industry (the mean was 1.97 on a scale of 1 to 5). In other words, respondents indicated that the widespread use of drones in the construction industry was not yet a reality. Due to this result, the researcher failed to reject the null hypothesis, that there is no significant use of drones in this industry.

Perceptions of Factors Influencing Drone Use in the Construction Industry

The third research question focused on the factors that influence the use of drones by commercial mechanical and electrical construction companies in the United States. The hypotheses associated with this research question are as follows:

$H3_0$. There are no significant factors that influence the use of drones by commercial specialty construction companies in the United States.

$H3_a$. There are significant factors that influence the use of drones by commercial specialty construction companies in the United States.

Following a factor analysis, three main factors accounted for 57.29% of the total variance, with (1) technological factors accounting for 31.41%, (2) risk factors accounting for 14.35%, and (3) human factors accounting for 11.53% of the variance. Due to these results, the researcher failed to accept the null hypothesis, instead finding support for significant factors that influence the use of drones in the construction industry in the US (the alternative hypothesis).

Perceptions of Risks of Drones in the Construction Industry Based on Position

The fourth research question explored whether there was a difference in the respondents' perceptions of risk regarding the use of drones based on their positions within the construction industry. The hypotheses associated with this research question are as follows:

$H4_0$. There is no difference in the respondents' perception of risk in the use of drones based on their position in the company.

$H4_a$. There is a significant difference in the respondents' perception of risk in the use of drones based on their position in the company.

Following an analysis of variance statistical test, it was found that there was no statistically significant difference regarding respondents' perceptions of drone-related risks based upon their positions within the construction industry. Due to this result, the researcher failed to reject the null hypothesis.

Perceptions of Risks of Drones in the Construction Industry Based on Experience

The fifth research question explored whether there was a difference in the respondents' perceptions of risk regarding the use of drones based on their years of experience within the construction industry. The hypotheses associated with this research question are as follows:

$H5_0$. There is no difference in the respondents' perception of risk based on their years of experience

$H5_a$. There is a statistically significant difference in the respondents' perception of risk based on their years of experience.

Following an analysis of variance statistical test, it was found that there was no statistically significant difference regarding respondents' perceptions of drone-related risks based upon their years of experience within the construction industry. Due to this result, the researcher failed to reject the null hypothesis.

Perceptions of Risks of Drones in the Construction Industry Based on Drone Complexity

The sixth research question explored whether there was a difference in the respondents' perceptions of risk regarding the use of drones based upon the complexity of using a drone. The hypotheses associated with this research question are as follows:

$H6_0$. There is no difference in the respondents' perception of risk based on the complexity of using a drone.

$H6_a$. There is a statistically significant difference in the respondents' perception of risk based on the complexity of using a drone.

Following an analysis of variance statistical test, it was found that there was no statistically significant difference regarding respondents' perceptions of drone-related risks based upon the complexity of drone use. Due to this result, the researcher failed to reject the null hypothesis.

Perceptions of Risks of Drones in the Construction Industry Based on Operability

The seventh research question explored whether there was a difference in the respondents' perceptions of risk regarding the use of drones based upon the operability of drones. The hypotheses associated with this research question are as follows:

$H7_0$. There is no difference in the respondents' perception of risk based on drone operability.

$H7_a$. There is a statistically significant difference in the respondents' perception of risk based on drone operability.

Following an analysis of variance statistical test, it was found that there was no statistically significant difference regarding respondents' perceptions of drone-related risks based upon the inoperability of drones. Due to this result, the researcher failed to reject the null hypothesis.

Perceptions of Risks of Drones in the Construction Industry Based on company Size

Finally, the eighth research question explored whether there was a difference in the respondents' perceptions of risk regarding the use of drones based on company size. The hypotheses associated with this research question are as follows:

$H8_0$. There is no difference in the respondents' perception of risk based on the size of the company.

$H8_a$. There is a statistically significant difference on the respondents' perception of risk based on the size of the company.

Following an analysis of variance statistical test, it was found that there was no statistically significant difference regarding respondents' perceptions of drone-related risks based on company size. Due to this result, the researcher failed to reject the null hypothesis.

Overall, the results from the current study indicated that survey respondents were neutral in terms of their perceptions of the risks associated with utilizing drones in commercial construction projects. Participants had slightly negative responses to the widespread use of drones in the construction industry, [indicating that such use is not yet widespread]. Another notable result is that the following factors were most commonly mentioned as the most influential in terms of the adoption of drones in the construction industry in the US: (1) technological, (2) risk, and (3) human factors. No significant differences among respondents' perceptions of risk of drones in the construction industry were found based upon the following factors: position in the company, level of experience, complexity of using drones, the inoperability of drones, and the size of the company. The next section will interpret the findings of the study in light of existing knowledge in the peer-reviewed body of literature.

Interpretation of the Findings

Given the insights from the existing literature on the risks relating to drone use, particularly legal risks (Safran, 2014; Smith et al., 2006), it was expected that survey respondents would indicate concerns with the risks involved in the adoption of drones into the construction industry. However, the results from the survey showed that participants were neutral regarding drone-related risks, indicating that they neither disregarded nor were concerned with such risks. Instead, survey respondents help a generally nuanced view on the risks of drones in the construction industry. These results could be due to the vague wording of these survey items, which did not specify what type of risks. In addition, participants may not have been knowledgeable regarding the use of drones commercially.

A review of the literature revealed that many of the drones that would be most beneficial for the construction industry are still in the process of being researched, refined and developed. Because of this, it was expected that survey respondents would report little current use of drones in the construction industry, despite the potentially beneficial uses of drones as described in existing research on the topic (Anderson, 2014; Marks, 2013; Morgenthal & Hallermann, 2014). Consistent with the literature, survey respondents reported little current widespread use of drones in commercial construction activities. However, the literature review showed that drones are increasingly developing capabilities that would be useful for the construction industry, including the following: bridge repair (Marks, 2013), assess and identify areas of pipelines and power lines that are in need of repair (Anderson, 2014; Vis, 2014), the ability to carry heavy objects while maintaining flight control (Marks, 2013), the inspection and identification of damage in civil structures (Morgenthal & Hallermann, 2014), monitoring air quality and the incorporation of building data into engineering software.

Consistent with the three major factors of focus in the present study regarding factors influencing drone use in the construction industry, respondents reported that technological factors, risk factors, and human factors were the most influential. This was also consistent with the themes in the literature and the theoretical framework (Technology Acceptance Model and Task Technology Fit Model), in which information was available surrounding technological (Davis, 1989; Franken, 2005; Government Transformation, 2011; Rogers, 1983; Simon, 1969), human (Davis, 1986; Leonard-Barton, 1988; Premkumar, 1995; Venkatesh et al., 2012), and risk factors associated with drone use (Safran, 2014; Smith et al., 2006).

Insights from the existing literature indicated that an individual’s position within a company may influence their acceptance of new technology through the relevance of the new technology to his/her job duties (Davis, 1986; Leonard-Barton, 1988). Contrary to this expectation, respondents’ positions were not significantly related to their perceptions of risk of drones in commercial construction-related duties. This could be because perceptions of drones in general within the construction industry were assessed, without relevant background information indicating the specific types of construction-related duties that would be fulfilled by these drones. In addition, drone technologies are largely still being researched, particularly regarding their use in commercial activities. Due to the lack of drones specifically marketed for construction-related activities, it could be difficult for survey respondents to assess the meaning of drones in their field as well as potential risks that would be associated with their adoption. Another possibility is that since the majority of respondents were in upper-level positions (80.6%), they would not be as concerned with drones overtaking their professional duties.

The existing literature regarding the role of experience in technology acceptance, which refers to an individual’s expertise and experience with new drone technologies (Premkumar, 1995; Venkatesh et al., 2012), led to the expectation that respondents with more experience would be more likely to be accepting of drones in commercial construction activities. Contrary to this expectation, survey results indicated no statistically significant differences in perceptions of drone-related risks in terms of the level of experience. This could be due to a combination of positive and negative experiences involved in their drone-related experience, which would lead participants to not necessarily be more accepting of new technologies despite their prior exposure to such technologies. Although no statistical tests were completed assessing the significance of age on risk perception, through the assumption that more experienced individuals tend to be older, the existing literature on age and technology acceptance can be useful in understanding how the findings of the current study fit into the existing literature. While prior research has shown that younger individuals tend to be more accepting of new technologies and innovative practices (Morris, 2000; Venkatesh et al., 2012), the present study did not provide evidence for this, as measured through the level of experience.

Prior research has suggested the significance of the complexity of a given technology (Davis, 1989; Franken, 2005; Rogers, 1983; Simon, 1969), particularly in the adoption of new technologies (Premkumar, 1995). The significance of complexity in the literature led to the expectation that perceptions of drone complexity would be related to perceptions of drone-related risks in the construction industry. Contrary to this expectation the results from this study indicated that there were no significant differences in perceptions of drone-related risks based upon perceptions of drone complexity. This could be due to a lack of knowledge of drones, as well as a lack of knowledge regarding risks related to drone use.

Two of the findings involved in the current study were not informed by the existing literature. Although the existing literature on interoperability has proposed solutions to this challenge (Government Transformation, 2011), there was little guidance in prior research regarding how perceptions of operability would impact either technology acceptance or perceptions of risk. Thus, the finding that perceptions of operability were not statistically significantly related to perceptions of risk, was a new finding in the body of research; this was one original contribution of the present study to the existing literature. Similarly, there was a lack of relevant literature regarding the influence of company size on perceptions of risks of drones, so the finding in the current study that company size was not statistically significantly related to risk perceptions was a new finding and a contribution to the existing body of research.

Consistent with expectations in the theoretical framework, findings from the current study indicated that technological, human, and risk factors were all influential in the adoption of new technologies. Previous research exploring the acceptance of new technologies have also utilized the Technology Acceptance and the Task Technology Fit models in their analyses. The quantitative approach was largely consistent with the results in the existing literature, and the sample of individuals in the construction industry was relatively new. However, the type of country from which respondents were recruited was largely consistent with the existing literature, as prior research tended to focus on individuals from developed, western countries, particularly the United States. The next section will discuss the social, methodological, theoretical, and practical implications that follow from the findings of this research.

Implications of the Findings

Contrary to the expectations in the existing literature, many of the human factors of focus in the present study were found to be insignificant regarding the perceptions of drone risk. This could be explained by the knowledge that the human factors of focus in the current study were related to risk perception, rather than to the adoption of new technologies (which was found in the existing literature). Even though perceptions of risk could be related to the acceptance of new technologies, the present study showed that these should be approached as separate constructs have different types of relationships with human factors. The current study also contributes to the existing literature by establishing that drones are not yet widely used in the construction industry. In addition, survey respondents, who largely were employed in construction-related industries, held a nuanced view of the adoption of drones in the construction industry, particularly regarding the risks that they pose.

To the extent that drones could be utilized in the construction industry to mitigate and/or prevent dangerous and health risks of construction workers, the findings of the current study could facilitate positive social change. If the wide replacement of construction workers by drones could be prevented, and instead drones could be employed together with existing workers to improve their productivity and mitigate risks encountered on the job, drones could be beneficial in the commercial construction industry. From the point of view of construction businesses, drones could potentially enhance the efficiency of construction-related tasks. From a societal point of view, the increase of drone sales could contribute to the growth in Gross Domestic Product, and to the extent that drones can enhance efficiency, this could facilitate greater productivity in the construction industry.

Due to the potential increase in efficiency and productivity in the construction industry through the complementary utilization of drones with the existing population of construction workers, commercial construction businesses, as well as legislators and drone sales companies, could be interested in the results of this study. If these parties are interested in integrating the use of drones into the construction industry, the findings of the current study inform the relationship between human factors and perceptions of the risk that drones pose in the construction industry. As a result, the findings of the current study could inform efforts at integrating drone technologies into similar commercial industries.

The findings of the current study, particularly regarding the importance of human, technological, and risk factors in the acceptance and adoption of new technologies, was informed by the theoretical framework. The Technology Acceptance and Task Technology Fit models (Peansupap, 2005) inform the results of the current study. The Task Technology Fit Model (Goodhue, 1995) posits that tasks, technologies, and individuals contribute to the tack-technology fit; although relevant drones are still being researched, examples from the literature in the task-technology fit of drones and construction-related tasks include equipment delivery (Hruby, 2012), integrating cables into high-rise structures (Hodson, 2013) and identifying areas in need of repair (Anderson, 2014). The Technology Acceptance Model (Davis, 1986) posits that external variables impact the perceived usefulness and perceived ease of use of a new technology, which in turn influence attitudes toward use, the behavioral intention to use, and the actual adoption of such technologies. The focus on the current study on risk perceptions supports the integration of this variable into the framework of the Technology Acceptance Model. In addition, the insignificant relationship between technological and human factors involved in the current study and perceptions of drone risk indicate a need to focus on different human and technological factors that might have a significant relationship with perceptions of drone-related risks. The next section will discuss the limitations involved in the current study in order to inform the interpretation, application, and generalizability of the findings from the current study.

Limitations of the Study

One of the limitations of the current study is that it involved a relatively small sample size for a quantitative study (n=67), short of the study target of 100 participants. This was partially due to a low response rate (16%). Although this was a large enough sample size to run the statistical tests, it was not as large as was desired. Another potential limitation is that the survey was self-developed. In order to address this limitation, a pilot test was conducted and Cronbach's alpha was assessed for each of the survey questions in order to measure the internal consistency of survey items. Although Cronbach's alpha for experience with drone use was moderate, with a score of 0.731, the risk/legal survey items had a Cronbach's alpha of 0.226, which indicates low internal consistency. This reveals a limitation commonly associated with the development of new survey instruments: variable internal consistency. In addition, the level of significance utilized to determine statistical significance was relatively low for some disciplines: 0.10, or a 90% level of confidence. This could result in the acceptance of a false positive result. Due to the focus in the current study on a wide variety of human and technological factors, a factor analysis and analysis of variance were determined to be most appropriate for the current study. If the focus on the current study had been on the incremental impact of particular variables on the dependent variable (risk perception), a logistic regression could have been selected. However, the statistical tests utilized in the current study were the most appropriate given the nature of the research questions.

Another limitation is related to the type of study conducted. A quantitative study does not allow for an in-depth exploration of the perceptions of participants regarding the study topic. As such, it is possible that certain survey questions could have been misunderstood, misinterpreted, or that the answers available to choose from did not accurately reflect the sentiments of all survey respondents. Additionally, since there was no control of confounding variables and no control group involved, there is no claim of causation involved in the present study, as it was not experimental in nature. Due to the purposive sampling approach employed in the current study, individuals with knowledge on the topic were recruited; however, since random sampling was not utilized, the results of the current study are not necessarily representative of professionals working in the construction industry.

Given the small sample size, and that all participants involved in the study resided in the United States, care should be taken to generalize only to similar locations and contexts; for example, the results of the current study may not apply to developing countries, or in countries with cultures different from the United States (i.e. non-Western). In addition, the survey respondents were involved in construction-related industries, so the results of this study may not be generalizable to different disciplines. Next, opportunities for further research will be described.

Recommendations for Future Research

The first recommendation for further research regarding the adoption of drones in the construction industry relate to technological factors, particularly those that were supported in the existing literature but were not included in the current study. Prior research has indicated the importance of technological cost in the likelihood that a given technology will be adopted (Premkumar, 1995; Rogers, 1983; Venkatesh et al., 2012). Previous studies have also shown that perceptions of output quality of a new technology impact the perceived usefulness and thereby the likelihood of adoption of a new technology (Davis, 1986; Venkatesh et al., 2000). Since drone-related technologies are still being developed, particularly for commercial domestic uses (e.g.

commercial construction), there is a shortage of research focusing on the costs and perceived adequacy in such technologies within the context of the construction industry.

The second recommendation for further research relates to human factors that have been identified as important in the adoption of new technologies in the literature, but were not included in the present study. The level of management support in adopting new technological capabilities is one such factor (Kunz, 2007; Williams, 2007). The implementation and adequacy of training in the use of a new technology (Peansupap, 2005; Williams, 2007), as well as the level of education of individuals who will be engaging with such innovations (Davis, 1986; Riddle, 2012), are also related to the smooth adoption and implementation of such technologies. Another factor that has been identified as useful in the adoption of a new technology is compatibility (Premkumar, 1995; Sun, 2009), or the extent to which such technologies are consistent with the existing needs and values of the company and/or industry that would adopt the technology (Rogers, 1982). Although a few studies exist on these topics, none have thus far been applied to use in the construction industry in particular. In addition, exploring the human factors related to the adoption of drones in the construction industry is one area of study that could benefit from in-depth, qualitative research involving interviews. Considering that the adoption of certain technologies could impact the availability of construction-related jobs in the future, it is essential for the human impact and potential negative ramifications of drone adoption in the construction industry to be explored as well.

The third recommendation for further research is to extend similar studies on drone adoption in the context of manual labor to other populations. In particular, there is a lack of research regarding the adoption of drones in developing or non-Western countries. In settings where individuals are more poverty-stricken, it is possible that there would be more opposition to the adoption of technologies into blue collar jobs that have traditionally provided opportunities for the working class. In addition, different cultures with lower levels of education, in which societies have differing collective experiences, including exposures to war, it could be true that there would be greater opposition to the widespread use of drones.

In light of the literature review which included legal hurdles to the adoption of drones in the United States, the fourth recommendation for further research is to explore reasons for legal restrictions on the adoption of drones in a domestic, commercial setting. Future studies focusing on this topic could complete interviews with law makers who were involved in the passage of such restrictive legislation, as well as technological experts who have publicly opposed the widespread commercial use of drones. If the widespread adoption of drones in commercial activities such as the construction industry would be beneficial, then it would first be necessary to not only identify obstacles to such widespread use, but also to understand the reasons behind such hurdles in order to overcome them. Next, the conclusions of the current study, as discussed in Chapter 5, will be summarized.

Summary and Conclusions

Although the technological capabilities of drones have advanced over the years, there is a lack of widespread use of drones in the construction industry. The purpose of this survey-based, quantitative study was to facilitate the understanding of the potential risks, benefits, and uses of Unmanned Aerial Vehicles in commercial construction activities, as well as pending legislation that would likely impact their widespread adoption. The present study was conducted in order to investigate factors that influence the acceptance and adoption of drones in the U.S. construction industry. After a review of the relevant literature, it was expected that the following human and technological factors would impact perceptions of risks posed by the adoption of drones for use in the construction industry: position type, level of experience, company size, drone complexity, and interoperability. Contrary to these expectations, the influences of all of these factors on risk perceptions of drones were found to be statistically insignificant. Consistent with insights from the literature as well as the theoretical framework, survey respondents indicated that technological, human, and risk factors were the most influential in the adoption of new technologies in the construction industry. It was also expected that survey respondents would have risk-related concerns regarding the adoption of drones, which was not supported by the current study; instead, participants were neutral in regards to the risks of drones. Finally, a finding that was consistent with the literature-based expectations was that survey respondents would indicate that there is a lack of current widespread use of drones in the construction industry. Although many of the human factors of focus in the current study were expected to be significant regarding the perceptions of risk of drones, this was not the case. This could be because the human factors of focus in the current study were found to be related to the adoption of new technologies in the existing literature, rather than to risk perception. Although perceptions of risk could be related to the adoption of new technologies, the current study revealed that these are separate constructs that are differentially impacted by human factors. Another contribution of the current study is that not only are drones not widely in use in US commercial construction activities, but survey respondents of the current study, largely employed in the construction industry, held a nuanced view of the utilization of drones in the completion of commercial construction duties. Chapter 5 concludes this research.

Recommendations of Future Studies

This research focused on the factors influencing the use of drones by specialty trades as listed in the October of 2014 addition of the ENR. Most of the responses came from companies that were the same size, larger than 200 employees, etc. Since drone technology is at its infancy as it relates to being used in the construction trade, it would be useful to provide the same research to determine how companies have change and adopted drone use as exposure of drones over time has allowed greater knowledge of the technology uses.

Secondly, conducting research on companies from a different target market would be useful in comparing smaller companies to larger companies as conducted in this research to compare technology acceptance based on the size of the companies. This research could give a correlation of drone use based on size, volume or number of employees to determine if the percentages are the same or differ.

Thirdly, another recommended study would be to conduct research on residential companies and determine any correlations within specific types of residential companies as well as comparing those results to results from commercial companies. Residential companies may have different needs as commercial companies which could result in drone uses not identified by commercial contractors.

Fourthly, it would be useful to isolate the type of drone research is being conducted on to determine the usefulness of that drone in the construction industry. Currently most drones are being used with cameras to perform task associated with visual needs and specializing in drones that may lift objects or take the place of a specific human task to determine if those tasks are generally useful to specific target market weather that market is residential or commercial regardless of the size of the company. One of the main variables on any future research will be the element of time as it relates to any new technology introduced within an industry, as well as the legislation that is currently developing and changing on the use of drones for commercial use.

Lastly, drone technology and laws governing drones are changing on a continual basis and therefore this research cannot keep up with the current changes. The FAA Modernization and Reform Act of 2012 (FMRA), signed by President Barack Obama, requires the FAA to develop rules and regulations permitting commercial and civilian use of drones by September of 2015, which has already passed. Drone legislation is evolving and even though the required date has passed, progress is being made. Drone’s must now be registered with the FAA and each state is adopting legislation to govern drone laws in each individual state until a comprehensive Federal law has been passed addressing all of the elements originally set forth in the FMRA. There are also applications for case by case approvals to operate drones commercially as provided in section 333 of the FMRA. Each month new information is published so information in this study can change significantly by the time it is formalized. A current study of this same research would be useful in determine how the drone laws are progressing as well as how the adoption of drones in construction is progressing.

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APPENDIX A:

INSIANA STATE REVIEW BOARD APPROVAL (IRB)

Indiana State University
More. From day one.

Institutional Review Board

Terre Haute, Indiana
47809
812-237-3092
Fax 812-237-3092

DATE:	December 7, 2015
TO:	Glenn Graham, Doctorate
FROM:	Indiana State University Institutional Review Board
STUDY TITLE:	[819617-1] Factors Influencing the Use of Drones by Specialty Construction Companies in the United States of America
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS DECISION DATE: December 7, 2015
REVIEW CATEGORY:	Exemption category #*1*

Thank you for your submission of New Project materials for this research study. The Indiana State University Institutional Review Board has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations (45 CFR 46). You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exempt categories, you will have to reapply to the IRB for review of your modified study.

Internet Research: If you are using an internet platform to collect data on human subjects, although your study is exempt from IRB review, ISU has specific policies about internet research that you should follow to the best of your ability and capability. Please review Section L. on Internet Research in the IRB Policy Manual.

Informed Consent: All ISU faculty, staff, and students conducting human subject's research within the "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report:

a) respect for persons; b) beneficence; and c) justice. These three principles are best reflected in the practice of obtaining informed consent.

If you have any questions, please contact Dr. Ryan Donlan within IRBNet by clicking on the study title on the "My Projects" screen and the "Send Project Mail" button on the left side of the "New Project Message" screen. I wish you well in completing your study.

APPENDIX B

EMAIL NOTICE

Survey Questionnaire

From: Glenn Graham glenng9999@aol.com
Subject: Factors Influencing the Use of Drones by Construction Companies in the United States of America

Dear Contractor,

I am a graduate student at Indiana State University in Terra Haute, IN, conducting research on the factors influencing the use of drones by Specialty Construction Companies in the United States of America. This research is being conducted with companies such as yours that are identified in the Engineering News Record (ENR) list of top specialty contractors. This study is focused on identifying factors that influence the use of drones within your organization as well as to introduce the use of drones in the construction industry and the risk they may impose.

All respondents to the survey will remain anonymous. Your name or organization name will not be included on any documents. You may give the survey to multiple people within your organization. Knowledge of drone use is not a requirement to complete this survey. Thank you in advance for your consideration and time in making this a successful study.

Attached at the top and bottom of this email is a link to a survey that will be used for the research. We greatly appreciate your completing the survey allowing our research to include a sample population of the construction industry.

LINK: https://www.surveymonkey.com/r/Constdrone

Glenn Graham
Doctoral Candidate
College of Engineer and Technology
Department of Construction Management
East Carolina University
Email: glenng9999@aol.com
grahamg77@students.ecu.edu

Dr. David L. Batie PhD., NCARB, RA
Associate Professor / Undergraduate Director
College of Engineer and Technology
Department of Construction Management
East Carolina University
Email: batied@ecu.edu

APPENDIX C

EMAIL FOLLOW UP NOTICE

Survey Questionnaire Second Request

Please read the following and provide 10 minutes of your time to take a 28 question survey or forward to someone within your organization that would take this survey to help educate and identify a disruptive change in the construction industry.

Dear Contractor,

I am a graduate student at Indiana State University in Terra Haute, IN. Two weeks ago a sent a request for at least one person's email within your organization that would be willing to take a 28 question survey on Drones in Construction. I have not received a response from you. Could you please provide me with at least one email to help me complete my construction research in conjunction with East Carolina University? Your participation will be greatly appreciated and will add to the knowledge of drones in the industry.

All respondents to the survey will remain anonymous. Your name or organization name will not be included on any documents. You may give the survey to multiple people within your organization. Thank you in advance for your consideration and time in making this a successful study.

Attached at the top and bottom of this email is a link to a survey that will be used for the research. I can also send you an invitation direct from the survey site if you provide me with an email address. We greatly appreciate your completing the survey allowing our research to include a sample population of the construction industry.

LINK: https://www.surveymonkey.com/r/Constdrone

Thanking you in advance,

Glenn Graham
Doctoral Candidate
College of Engineer and Technology
Department of Construction Management
East Carolina University
Email: glenng9999@aol.com
grahamg77@students.ecu.edu

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Associate Professor / Undergraduate Director
College of Engineer and Technology
Department of Construction Management
East Carolina University
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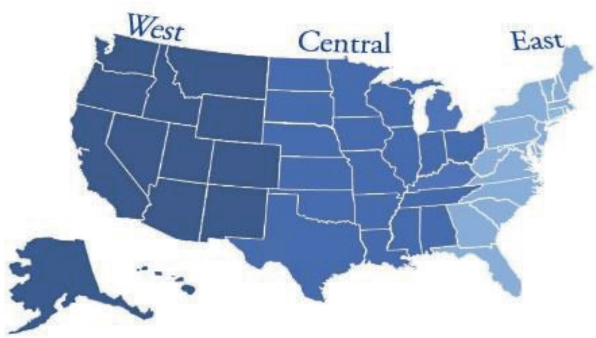
APPENDIX D

RESEARCH INSTRUMENT

Knowledge gained through this project will help construction managers understand industry developments of drones and will also add to the body of knowledge on this topic that is in its infancy as it relates to the construction industry. Participation in this survey is voluntary and will take no more than 10 minutes of your time. The survey is 5 pages with a total of 28 questions.



1. What geographical area is your company located?
    - Eastern United States
    - Central United States
    - Western United States
    - Other (please specify)

2. What construction services does your Company offer?
    - Mechanical Contractor
    - Plumbing Contractor
    - Electrical Contractor
    - Other (please specify)

3. How many people are employed by your Company?
    - Less than 50
    - 51 to 100
    - 101 to 400
    - Over 400 employees

4. How long has your Company been in existence?
   - 1 to 5 years
   - 6 to 10 years
   - 11 to 20 years
   - Over 20 years

5. Which comment best relates to your perception of your Company's support of drone use?
   - It is important for your company to learn more about drones in construction
   - Your company would never support the use of drones
   - I do not have sufficient information about the use of drones to comment

6. Compared to your competitors, which comment best describes your Company?
   - Technology use in our company is superior to our competitors
   - Our technology knowledge is the most advanced in the industry
   - Technology use in our company is lacking as it relates to our competitors

Demographics

7. What are your individual years of experience in the construction industry?
   - 1 to 5 years
   - 6 to 10 years
   - 11 to 20 years
   - Over 20 years

8. To which age group do you belong?
   - Less than 25 years' old
   - 25 to 35 years' old
   - 36 to 46 years' old
   - 47 years old or older

9. Please indicate the last school year you completed?
   - Primary School
   - High School
   - Technical School / Certification
   - Community College (2 years)
   - Graduate or University (4 years)
   - Post-Graduate (Masters / Ph.D.)
   - Other (please specify)

10. Which of the flowing categories best describes your position within your Company?
   - o CAD / BIM Manager or modeler
   - o Principle or Upper Management
   - o Project Manager or Senior Project Manager
   - o Estimator
   - o Project Engineer
   - o IT Manager

11. Which comment best relates to your perception of your Company's stance on training for drones?
   - o Training employees in our company to use drones will not be encouraged
   - o Training employees in our company to use drones will be encouraged and structured.
   - o There is not enough technical expertise in our company to train employees to use drones

Multiple Choice Questions

12. How would you rate your Company's knowledge of drone use in the construction industry?
   - o No Knowledge
   - o Very Little knowledge
   - o Occasionally Use drones
   - o Consistently Use drones
   - o Other (please specify)

13. Which of the following technology does your company use? (Check all that apply)
   - o Building Information Modeling
   - o BIM 360 for Field or other collaborative site software
   - o Trimble or Total Station Layout
   - o Auto Cad
   - o NavisWorks

14. Is your company interested in technology that can take the place of a human task?
   - o Yes
   - o No

15. Does your company utilize drones in any capacity?
    - Yes (Proceed to question #16)
    - No (Proceed to question #17)

16. Which of the following best describes why your company uses drones?
    - Perceived productivity gains
    - Perceived cost saving gains
    - Perform Human task

17. Which of the following describes best why your company does not use drones?
    - Not familiar with the use of drones in construction
    - Cost of drones
    - Drones are too complicated to use
    - Risk and legal related issues
    - Lack of management support
    - Cost of training
    - Other (please specify)

Multiple Choice

18. Pick one activity that you believe would be the best use of a drone in construction as it relates to your Company.
    - Project Pictures
    - Inspections
    - Productivity Monitoring
    - Sleeve or Hanger Layout
    - Security

19. Are you aware of the possible risks and liabilities associated in the use of drones in construction?
    - Not aware
    - Somewhat aware
    - Very aware

20. Are you aware of government legislation as it relates to using drones for commercial use?
    - Not aware
    - Somewhat aware
    - Very aware

21. What statement best relates to your perception of top management as it relates to drones?
    - Drone technology will not be implemented unless top management supports it
    - Top management encourages employees to embrace new technology and would welcome drone use
    - Top management in our company would not support the use of drones in our company

22. Which comment best describes your perception of the relevance of drones in construction?
    - Drone technology is not relevant to our company
    - Drone technology could be utilized in our company
    - I do not know enough about drone use in construction to understand the benefits

23. Which comment best relates to your perception in result oriented use of drones in construction?

    - Our company has difficulty in understanding the advantages of drone use
    - The benefits of drones in apparent to our company
    - Drone use has been or is being considered in our company

(1 = Strongly Disagree, 2= Disagree, 3= Neither agree or disagree, 4= Agree, 5= Strongly Agree)
Rank each statement

24. Experience of Drone Use

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Strongly Agree	Agree
I am very experienced with the use of drones	O	O	O	O	O
There are people in our organization that are experienced with the use of drones	O	O	O	O	O
There has been discussion in our company about the use or future use of drones	O	O	O	O	O

25. Cost of Drone Use

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Strongly Agree	Agree
Cost associated with the purchase of drone's outweighs the benefits	O	O	O	O	O
The cost of training employees to use company about the use drones outweighs the benefits	O	O	O	O	O
The cost of maintenance and up keep of drones outweighs the benefits	O	O	O	O	O

26. Drone Complexity

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Strongly Agree	Agree
Drone use is too complicated to be used in our company	O	O	O	O	O
The learning curve of drone use in construction makes this technology prohibitive	O	O	O	O	O
Our company may adapt a basic drone and then develop into a more complex one	O	O	O	O	O

27. Interoperability of Drones

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Strongly Agree	Agree
If drones were compatible with our accounting and project management software, we would consider using them	O	O	O	O	O
If drones were compatible with our BIM/CAD, or Trimble layout software, we would consider using them	O	O	O	O	O
Interoperability is important to our company in the adaption of technology or drones	O	O	O	O	O

28. Legal Use of Drones

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Strongly Agree	Agree
The use of drones introduces unknown liability and risk	O	O	O	O	O
The use of drones on jobsites will increase the chance of injury to employees	O	O	O	O	O
The use of drones could help minimize risk by performing human task	O	O	O	O	O

Survey is Complete

Thank you for taking the time in providing information that will enhance the current body of knowledge on the subject of drones and help educate the Construction Industry on the potential ofusing drones in construction.

APPENDIX E

ENR TOP 600 SPECIALTY CONTRACTORS 2014

Key To Type of Firm

A=asbestos abatement; **C**=concrete; **D**=demolition/wrecking; **E**=electrical; **F**=fire protection and sprinklers; **G**=glazing/curtain wall; **M**=mechanical; **MA**=masonry; **O**=other; **P**=painting; **R**=roofing; **SH**=sheet metal; **ST**=steel erection; **U**=utility; **W**=wall/ceiling; **X**=excavation/foundation.

RANK 2014/2013	FIRM	FIRM TYPE
1/2	Quanta Services Inc., Houston, Texas	E
2/1	EMCOR Group Inc., Norwalk, Conn.	M/E
3/3	MasTec Inc., Coral Gables, Fla.	O/U/E
4/4	Brand Energy and Infrastructure Services, Kennesaw, Ga.	O
5/5	APi Group Inc., New Brighton, Minn.	F/O/M
6/6	The Brock Group, Houston, Texas	O/P
7/8	Henkels & McCoy Inc., Blue Bell, Pa.	U
8/7	Comfort Systems USA Inc., Houston, Texas	M
9/9	Safway Group, Waukesha, Wis.	O
10/11	MDU Construction Services Group Inc., Bismarck, N.D.	M/U
11/16	MMR Group Inc., Baton Rouge, La.	E
12/13	Performance Contracting Group Inc., Lenexa, Kan.	W/O/F
13/10	MYR Group Inc., Rolling Meadows, Ill.	E
14/14	Baker Concrete Construction Inc., Monroe, Ohio	C
15/12	Rosendin Electric, San Jose, Calif.	E
16/15	Greenstar Services Corp. (Tutor Perini), Sylmar, N.Y.	E
17/17	Acco Engineered Systems Inc., Glendale, Calif.	M
18/18	M.C. Dean Inc., Dulles, Va.	E
19/19	Cupertino Electric Inc., San Jose, Calif.	E
20/28	Northstar Group Services Inc., New York, N.Y.	D/A
21/20	McKinstry, Seattle, Wash.	M/E
22/23	Hayward Baker Inc. (a Keller co.), Hanover, Md.	X
23/24	Bergelectric Corp., Los Angeles, Calif.	E
24/22	CentiMark Corp., Canonsburg, Pa.	R
25/25	IES Inc., Houston, Texas	E
26/40	Ceco Construction Group, Kansas City, Mo.	C/M
27/30	TDIndustries, Dallas, Texas	M
28/33	Southland Industries, Garden Grove, Calif.	M

29/38	Furmanite Corp.., Houston, Texas	O
30/39	SteelFab Inc., Charlotte, N.C.	O
31/26	Schuff International Inc., Phoenix, Ariz.	ST
32/35	Aldridge Electric, Libertyville, Ill.	E
33/31	Tecta America Corp., Rosemont, Ill.	R
34/65	Terra Millennium Corp., Richmond, Calif.	M/O
35/32	Harder Mechanical Contractors Inc., Portland, Ore.	M
36/44	Energy Services Holdings LLC, Houston, Texas	E
37/37	Morrow-Meadows Corp., Industry, Calif.	E
38/27	The Newtron Group LLC, Baton Rouge, La.	E
39/59	Faith Technologies Inc., Menasha, Wis.	E
40/36	Helix Electric Inc., San Diego, Calif.	E
41/29	Nooter Construction Co., St. Louis, Mo.	M/E
42/34	Structural Group, Hanover, Md.	C
43/43	E-J Electric Installation Co., Long Island City, N.Y.	E
44/48	Limbach Facility Services, Pittsburgh, Pa.	M
45/60	Cache Valley Electric Co., Logan, Utah	E
46/41	Miller Pipeline, Indianapolis, Ind.	U
47/58	Fisk, Sylmar, Texas	E
48/42	Brandt, Carrollton, Texas	M/E
49/49	Team Fishel, Columbus, Ohio	U
50/54	U.S. Engineering Co., Kansas City, Mo.	M
51/50	Gerdau Reinforcing Steel, San Diego, Calif.	O
52/55	The State Group Inc., Evansville, Ind.	E/M/C
53/46	Wayne J. Griffin Electric Inc., Holliston, Mass.	E
54/56	KHS&S Contractors, Tampa, Fla.	W
55/75	ISC, Baton Rouge, La.	E
56/**	Conti Corp., Sterling Heights, Mich.	E
57/88	Motor City Electric Co., Detroit, Mich.	E
58/66	Sachs Electric Co., St. Louis, Mo.	E
59/73	McKenney's Inc., Atlanta, Ga.	M
60/71	Malcolm Drilling Co. Inc., San Francisco, Calif.	X
61/52	JH Kelly LLC, Longview, Wash.	M
62/61	ISEC Inc., Englewood, Colo.	O
63/64	Shaft Drillers International LLC, Mt. Morris, Pa.	M/x
64/**	Allison Smith LLC, Atlanta, Ga.	E
65/67	The Hill Group, Franklin Park, Ill.	M/SH
66/83	Walters & Wolf, Fremont, Calif.	G/O
67/117	Titan Contracting/Horn Industrial Services, Owensboro, Ky.	M
68/62	Hunt Electric Corp., St. Paul, Minn.	E

69/87	Berkel & Co. Contractors Inc., Bonner Springs, Kan.	X
70/69	Harris Cos., St. Paul, Minn.	M/Sh
71/95	Enclos, Eagan, Minn.	G
72/80	Penhall Co., Anaheim, Calif.	D
73/77	Apollo Mechanical Contractors, Kennewick, Wash.	M/SH
74/81	Murray Co., Rancho Dominguez, Calif.	M
75/57	MMC Contractors Inc., Overland Park, Kan.	M/SH
76/70	Davis H. Elliot Co. Inc., Lexington, Ky.	E
77/78	J.F. Ahern Co., Fond du Lac, Wis.	M/F/SH
78/120	Ardent Services LLC, Covington, La.	E
79/91	Manafort Brothers Inc., Plainville, Conn.	X/D
80/96	Critchfield Mechanical Inc., San Jose, Calif.	M
81/45	Barnhart, Memphis, Tenn.	O
82/76	Irex Contracting Group, Lancaster, Pa.	O/A/W
83/124	Largo Concrete, Tustin, Calif.	C
84/82	Egan Co., Brooklyn Park, Minn.	E/M/G
85/**	Suncoast Post-Tension Ltd., Houston, Texas	O
86/90	INTREN Inc., Union, Ill.	U
87/51	Miller Electric Co., Jacksonville, Fla.	E
88/100	P1 Group Inc., Lenexa, Kan.	M/E
89/98	Parsons Electric LLC, Minneapolis, Minn.	E
90/68	Murphy Co. Mechanical Contractors & Engineers, St. Louis, Mo.	M
91/74	Hatzel & Buehler Inc., Wilmington, Del.	E
92/92	Harmon Inc., Bloomington, Minn.	G
93/110	T.A.S. Commercial Concrete Construction LLC, Houston, Texas	C
94/94	Beaver Excavating Co., Canton, Ohio	X
95/85	Brandenburg Industrial Service Co., Chicago, Ill.	D
96/**	Danella Cos. Inc., Plymouth Meeting, Pa.	U
97/86	Walker Engineering Inc., Irving, Texas	E
98/79	Sargent Electric Co., Pittsburgh, Pa.	E
99/114	The Morse Group Inc., Freeport, Ill.	E
100/102	Veit, Rogers, Minn.	X/U/D
101/108	New River Electrical Corp., Cloverdale, Va.	E
102/154	Northeast Remsco Construction Inc., Farmingdale, N.J.	U/M/O
103/162	Cochran Inc., Seattle, Wash.	E
104/97	YTG LLC, Philadelphia, Miss.	E
105/222	Paynecrest Electric Inc., St. Louis, Mo.	E
106/105	Bigge Crane & Rigging Co., San Leandro, Calif.	O
107/106	Baker Roofing Co., Raleigh, N.C.	R
108/128	Gaylor Electric Inc., Indianapolis, Ind.	E

109/47	John E. Green Co., Highland Park, Mich.	M
110/103	EC Co., Portland, Ore.	E
111/130	Guarantee Electrical Co., St. Louis, Mo.	E
112/122	McCarl's Inc., Cranberry Twp., Pa.	M
113/112	Total Facility Solutions Inc. - a Co. of the M+W Group, Plano, Texas	M/E
114/116	J.C. Cannistraro LLC, Watertown, Mass.	M/F
115/**	Wachter Inc., Lenexa, Kan.	O/E
116/84	SME Steel, West Jordan, Utah	O/ST
117/119	Standard Drywall Inc., Lakeside, Calif.	W
118/153	Clean Earth Inc., Hatboro, Pa.	O
119/101	Western Construction Group, St. Louis, Mo.	M/SH
120/107	D.H. Griffin Wrecking Co. Inc., Greensboro, N.C.	D
121/125	AZCO Inc., Menasha, Wis.	M
122/139	Worth & Co. Inc., Pipersville, Pa.	M/SH
123/134	Coastal Mechanical, Melbourne, Fla.	M
124/165	CSI Electrical Contractors Inc., Santa Fe Springs, Calif.	E
125/118	Sprig Electric, San Jose, Calif.	E
126/**	Miller Electric Co., Omaha, Neb.	E
127/113	Acousti Engineering Co. of FL, Orlando, Fla.	W
128/167	Independence Excavating Inc., Independence, Ohio	X/D
129/132	Capform Inc., Carrollton, Texas	C
130/258	Casey Industrial Inc., Westminster, Colo.	M/E/ST
131/157	Cleveland Electric Co., Atlanta, Ga.	E
132/137	Sauer Holdings Inc., Pittsburgh, Pa.	M
133/164	Lee Co., Franklin, Tenn. 133	M
134/136	Inglett & Stubbs LLC, Mableton, Ga.	E
135/115	The Roberts Co., Winterville, N.C.	M/E
136/201	Baker Group, Des Moines, Iowa	M/SH
137/508	Winter Environmental, div. of Winter Constr. Co., Norcross, Ga.	O/A
138/131	Ivey Mechanical Co. LLC, Kosciusko, Miss.	M
139/142	Gate Precast Co., Jacksonville, Fla.	C
140/176	The Raymond Group, Orange, Calif.	W
141/143	Rogers Electric, Alpharetta, Ga.	E
142/159	Precision Walls Inc., Cary, N.C.	W
143/127	JMEG LP, Farmers Branch, Texas	E
144/192	Tri-City Electrical Contractors Inc., Altamonte Springs, Fla.	E
145/145	Mechanical Inc., Freeport, Ill.	M/S
146/172	BakerTriangle, Dallas, Texas	W
147/129	McKinney Drilling Co., Landsdale, Pa.	X
148/**	Charter Mechanical Contractors, Portland, Ore.	M

149/161	E.M. Duggan Inc., Canton, Mass.	M
150/133	S&F Concrete Contractors Inc., Hudson, Mass.	C
151/156	American Technologies Inc., Orange, Calif.	O
152/173	Delta Diversified Enterprises Inc., Tempe, Ariz.	E
153/147	O'Connell Electric Co. Inc., Victor, N.Y.	E
154/104	Midwest Steel Inc., Detroit, Mich.	ST
155/160	The Williams Group, Merrifield, Va.	O/ST
156/140	Suntec Concrete, Phoenix, Ariz.	C
157/158	Lake Erie Electric Inc., Westlake, Ohio	E
158/168	Continental Electrical Construction Co., Oak Brook, Ill.	E
159/303	Piping & Equipment Co. Inc., Wichita, Kan.	M
160/179	MCM Management Corp., Bloomfield Hills, Mich.	D/A
161/181	Nations Roof LLC, Lithia Springs, Ga.	R
162/163	W.A. Rasic Construction Co. Inc., Long Beach, Calif.	U
163/175	Letsos Co., Houston, Texas	M
164/141	Chapel Electric Co. LLC, Dayton, Ohio	E
165/**	H.J. Martin & Son, Green Bay, Wis.	O/P
166/169	Fresh Meadow Mechanical Corp., Fresh Meadows, N.Y.	M
167/212	J Derenzo Cos., Brockton, Mass.	X
168/226	California Drywall, San Jose, Calif.	W
169/171	VSC Fire & Security Inc., Ashland, Va.	F
170/200	W&W Glass LLC, Nanuet, N.Y.	G
171/**	Roger & Sons Concrete Inc., LaGrangeville, N.Y.	C
172/237	L.P.R. Construction Co., Loveland, Colo.	ST
173/**	Foley Co., Kansas City, Mo.	M/C
174/166	Interstates Cos., Sioux Center, Iowa	E
175/**	Nicholson Construction Co., Cuddy, Pa.	X
176/151	Pacific Rim Mechanical Contractors Inc., San Diego, Calif.	M
177/**	Case Foundation Co., Roselle, Ill.	X
178/182	VEC Inc., Girard, Ohio	M/E
179/150	ERMCO Inc., Indianapolis, Ind.	E
180/215	Tri City Electric Co. of Iowa, Davenport, Iowa	E
181/187	Collins Electrical Co. Inc., Stockton, Calif.	E
182/93	Greenberry Industrial, Vancouver, Wash.	M/ST
183/144	Freestate Electrical Service Co., Laurel, Md.	E
184/**	Alex E. Paris Contracting Co. Inc., Atlasburg, Pa.	U/X
185/135	E.S. Wagner Co., Oregon, Ohio	X
186/223	Newkirk Electric Associates Inc., Muskegon, Mich.	E
187/210	Commonwealth Electric Co. of the Midwest, Lincoln, Neb.	E
188/184	Crown Corr Inc., Gary, Ind.	SH/G

189/205	Shapiro & Duncan Inc., Rockville, Md.	M
190/**	Progressive Roofing, Phoenix, Ariz.	R
191/202	West Valley Construction Co. Inc., San Jose, Calif.	U
192/155	A.O. Reed & Co., San Diego, Calif.	M
193/186	Alterman, San Antonio, Texas	E
194/188	Grunau Co., Oak Creek, Wis.	M
195/207	Cherry Demolition, Houston, Texas	O/D
196/193	Kalkreuth Roofing & Sheet Metal Inc., Wheeling, W.Va.	R
197/227	Ruttura & Sons Construction Inc., West Babylon, N.Y.	X
198/366	Coffman Excavation Inc., Oregon City, Ore.	X
199/185	National Construction Enterprises Inc., Ypsilanti, Mich.	W
200/**	Enterprise Electric LLC, Nashville, Tenn.	E
201/270	Magnus Pacific Corp., Rocklin, Calif.	X
202/242	Midstate Mechanical Inc., Phoenix, Ariz.	M/E
203/190	Prism Electric Inc., Garland, Texas	E
204/194	Rex Moore Electrical Contractors & Engineers, Sacramento, Calif.	E
205/**	Staff Electric Co. Inc., Butler, Wis.	E
206/**	Arden Building Cos. LLC, Pawtucket, R.I.	M/E/F
207/123	Ludvik Electric Co., Lakewood, Colo.	E
208/235	Kelso-Burnett Co., Rolling Meadows, Ill.	E
209/218	Buckner Cos., Graham, N.C.	ST/O
210/208	Condon-Johnson & Associates, Oakland, Calif.	X
211/284	Miller Insulation Co. Inc., Bismarck, N.D.	O
212/177	Plateau Excavation, Austell, Ga.	X
213/**	The BP Group, Glendale, N.Y.	M
214/204	Hussung Mechanical Contractors Inc., Louisville, Ky.	M
215/213	Mobley Industrial Services, Laporte, Texas	P/O
216/219	Foundation Constructors Inc., Oakley, Calif.	X
217/121	Cummings Electrical LP, Fort Worth, Texas	E
218/**	Humphrey & Associates Inc., Fort Worth, Texas	E
219/336	ElDeCo Inc., Greenville, S.C.	E
220/247	Port Morris Tile & Marble Corp., Bronx, N.Y.	O
221/170	NASDI LLC, Waltham, Mass.	D/A
222/**	Valley Electric Co. of Mount Vernon Inc., Everett, Wash.	E
223/216	Concrete Strategies LLC, St. Louis, Mo.	C
224/189	Dorvin D. Leis Co. Inc., Kahului, Hawaii	M
225/209	Bierlein Cos., Midland, Mich.	D
226/221	Vee-Jay Cement Contracting Co. Inc., St. Louis, Mo.	C
227/**	USA Environment LP, Houston, Texas	O/D
228/228	Wilson Electric Services Corp., Tempe, Ariz.	E/M

229/236	Kent Cos., Grand Rapids, Mich.	C
230/198	W.A. Chester LLC, Lanham, Md.	U
231/183	Mona Electric Group Inc., Clinton, Md.	E
232/262	Drill Tech Drilling & Shoring Inc., Antioch, Calif.	X
233/267	Oklahoma Electrical Supply Co., Oklahoma City, Okla.	E
234/214	Ryan Inc. Central, Janesville, Wis.	X
235/265	Hermanson Co. LLP, Kent, Wash.	M
236/**	JE Richards Inc., Beltsville, Md.	E
237/234	Universal Builders Supply Inc., New Rochelle, N.Y.	O
238/347	Frank M. Booth Inc., Marysville, Calif.	M
239/358	E Light Electric Services Inc., Englewood, Colo.	E
240/**	F.L. Crane & Sons Inc., Fulton, Miss.	W
241/290	Brent Scarbrough & Co., Fayetteville, Ga.	U
242/269	The Farfield Co., Lititz, Pa.	M/E
243/241	T E C Industrial, Kingsport, Tenn.	E
244/**	L. Keeley Construction Co., Sauget, Ill.	C/E/O
245/244	Baker Electric Inc., Escondido, Calif.	E
246/264	The Beldon Group, San Antonio, Texas	O/R
247/243	Muth Electric Inc., Mitchell, S.D.	E
248/199	Stark Excavating Inc., Bloomington, Ill.	X/C/ST
249/275	McGee Brothers Co. Inc., Monroe, N.C.	MA
250/197	Oil Capital Electric, Broken Arrow, Okla.	E
251/283	Sure Steel Inc., South Weber, Utah	ST
252/**	Westside Mechanical Group, Naperville, Ill.	M
253/203	Geo-Solutions Inc., New Kensington, Pa.	O
254/260	Van Ert Electric Co. Inc., Wausau, Wis.	E
255/196	E.S. Boulos Co., Westbrook, Maine	E
256/250	Wayne Brothers Inc., Kannapolis, N.C.	C
257/**	Hi-Tech Electric Inc, Houston, Texas	E
258/**	Corrigan Co., St. Louis, Mo.	M
259/217	Matco Electric Corp., Vestal, N.Y.	E
260/257	R.W. Warner Inc., Frederick, Md.	M
261/206	Ducci Electrical Contractors Inc., Torrington, Conn.	E
262/231	TOPCOR Cos. LLC, Baton Rouge, La.	O/P
263/335	Panelized Structures Inc., Modesto, Calif.	O
264/332	DGC Capital Contracting, Mount Vernon, N.Y.	O/D
265/271	Marina Landscape Inc., Anaheim, Calif.	O
266/**	Nead Electric, East Rutherford, N.J.	E
267/268	Rachel Contracting, St. Michael, Minn.	X/D
268/389	Beard Construction Group LLC, Port Allen, La.	X

269/669	Marathon Electrical Contractors Inc., Birmingham, Ala.	E
270/254	Edwin L. Heim Co., Harrisburg, Pa.	E
271/293	Precision Concrete Construction Inc., Alpharetta, Ga.	C
272/180	Best Contracting Services Inc., Gardena, Calif.	R/SH
273/277	Traffic Control Devices Inc., Altamonte Springs, Fla.	E
274/281	Midasco LLC, Elkridge, Md.	E
275/298	B. T. Mancini Co. Inc., Milpitas, Calif.	SH/O
276/195	University Mechanical Contractors Inc., Mukilteo, Wash.	M
277/340	John A. Penney Co. Inc., Cambridge, Mass.	E
278/191	KSW Mechanical Services Inc., Long Island City, N.Y.	M
279/249	Faulconer Construction Co. Inc., Charlottesville, Va.	X/U/C
280/248	A.C. Dellovade Inc., Canonsburg, Pa.	SH/G
281/**	BCH Mechanical Inc., Largo, Fla.	M/O/SH
282/229	The Tri-M Group LLC, Kennett Square, Pa.	E
283/239	G.M. McCrossin Inc., Bellefonte, Pa.	X/M/C
284/323	Basden Steel, Burleson, Texas	ST
285/238	J. Ranck Electric Inc., Mount Pleasant, Mich.	E
286/289	Wayne Automatic Fire Sprinklers Inc., Ocoee, Fla.	F
287/224	Birdair Corp., Amherst, N.Y.	R
288/230	J.B. Henderson Construction Co. Inc., Albuquerque, N.M.	M
289/**	Century Fire Protection LLC, Duluth, Ga.	F
290/272	Alakai Mechanical Corp., Honolulu, Hawaii	M
291/253	ComNet Communications LLC, Bethel, Conn.	O
292/266	Bauer Foundation Corp., Odessa, Fla.	X
293/232	Steiny & Co. Inc., Baldwin Park, Calif.	E
294/282	Great Lakes Plumbing & Heating Co., Chicago, Ill.	M/F
295/395	Pittsburg Tank and Tower Co. Inc., Henderson, Ky.	ST/P
296/307	Latite Roofing & Sheet Metal Co., Pompano Beach, Fla.	R
297/349	Ferguson, Plainville, Conn.	M/E
298/148	McHugh Concrete Construction, Chicago, Ill.	C
299/361	Markham Contracting Co. Inc., Phoenix, Ariz.	X
300/295	Edgerton Contractors Inc., Oak Creek, Wis.	X
301/355	Feyen-Zylstra LLC, Grand Rapids, Mich.	E
302/279	National Steel City LLC, Plymouth, Mich.	ST
303/313	Greenwood Industries Inc., Millbury, Mass.	R/SH
304/**	Fiore & Sons Inc., Denver, Colo.	X/O/U
305/327	Buist Electric Inc., Byron Center, Mich.	E
306/291	Techno Coatings Inc., Anaheim, Calif.	P
307/396	Royal Electric Co., Sacramento, Calif.	E
308/312	Enterprise Properties Inc., Omaha, Neb.	C

309/286	Charles E. Jarrell Contracting Inc., Earth City, Mo.	M
310/378	Thompson Electric Co., Sioux City, Iowa	E
311/294	Douglass Colony Group, Commerce City, Colo.	R
312/296	Thomas Industrial Coatings Inc., Pevely, Mo.	P
313/309	Bruce & Merrilees Electric, New Castle, Pa.	E
314/**	Nevell Group Inc., Brea, Calif.	W
315/437	Mountain Top Enter. dba Saratoga Roofing., Oklahoma City, Okla.	R
316/305	Poynter Sheet Metal, Bloomington, Ind.	SH
317/292	United Forming Inc., Austell, Ga.	C
318/328	Systems Contracting Corp., El Dorado, Ark.	M
319/329	A-C Electric Co., Bakersfield, Calif.	E
320/**	Modern Cos. Inc., Cedar Rapids, Iowa	M
321/263	GSL Electric, Sandy, Utah	E
322/321	Karas & Karas Glass Co. Inc., So. Boston, Mass.	G
323/276	Tri-State Drilling Inc., Hamel, Minn.	X
324/302	FD Thomas Inc., Sacramento, Ore.	P
325/255	Holland Roofing, Florence, Ky.	R
326/451	Gregg Electric Inc., Ontario, Calif.	E
327/**	Morley Moss Inc., Sunnyvale, Texas	E
328/330	Mid-City Electric Co., Columbus, Ohio	E
329/324	Cannon & Wendt Electric Co. Inc., Phoenix, Ariz.	E
330/299	Schreiber Corp., Wixom, Mich.	R
331/405	KenMor Electric Co. LP, Houston, Texas	E
332/211	W.G. Tomko Inc., Finleyville, Pa.	M
333/325	HEPACO LLC, Charlotte, N.C.	O/A
334/319	Bayside Interiors Inc., Fremont, Calif.	W
335/310	IMCOR, Phoenix, Ariz.	M/SH
336/233	Dunbar Mechanical Inc., Toledo, Ohio	M
337/374	Network Infrastructure Inc., Hempstead, N.Y.	U
338/318	Northland Concrete & Masonry Co. LLC, Burnsville, Minn.	C/MA
339/326	Taylor Electric Inc., Salt Lake City, Utah	E
340/174	Durr Mechanical Construction Inc., New York, N.Y.	M
341/338	Gregory Electric Co. Inc., Columbia, S.C.	E/M
342/331	McDade-Woodcock Inc., Albuquerque, N.M.	E
343/348	Dunkin & Bush Inc., Kirkland, Wash.	P
344/350	Group Builders Inc., Honolulu, Hawaii	W
345/343	Schlouch Inc., Blandon, Pa.	X
346/402	Gaines and Co., Reisterstown, Md.	U
347/308	Daley's Drywall, Campbell, Calif.	W
348/**	Corbins Electric, Phoenix, Ariz.	E

349/315	MBR Construction Services Inc., Reading, Pa.	E/M
350/450	Gardner Zemke Co., Albuquerque, N.M.	E
351/401	R.T. Moore Co. Inc., Indianapolis, Ind.	M
352/251	Superior Gunite (Tutor Perini), Sylmar, Calif.	C
353/436	H.T. Sweeney & Son Inc., Brookhaven, Pa.	X
354/**	Slack & Co. Contracting Inc., Houston, Texas	U/X
355/341	Premier Electrical Corp., Brooklyn Park, Minn.	E
356/240	Richard Goettle Inc., Cincinnati, Ohio	O
357/385	Sunwest Electric Inc., Anaheim, Calif.	E
358/362	The DiGesare Group, Schenectady, N.Y.	M/F
359/351	Berger Engineering Co., Dallas, Texas	M
360/311	Superior Air Handling, Clearfield, Utah	SH/M
361/368	Seretta Construction, Apopka, Fla.	C
362/380	C.A. Lindman Cos., Jessup, Md.	MA
363/288	Tower Glass Inc., Santee, Calif.	G
364/339	HACI Mechanical Contractors Inc., Phoenix, Ariz.	M
365/370	Environmental Remediation Services Inc., Schnectady, N.Y.	D
366/344	Frischhertz Electric Co. Inc., New Orleans, La.	E
367/372	The Bulldog Group Inc, Winston-Salem, N.C.	R
368/416	Desert Mechanical Inc., Sylmar, Calif.	M
369/273	Wyatt Inc., Pittsburgh, Pa.	W/O/F
370/398	Sierra Detention Systems, Brighton, Colo.	O
371/**	Paso Robles Tank Inc., Paso Robles, Calif.	ST/M/P
372/445	APG Electric Inc., Clearwater, Fla.	E
373/399	Broadway Electric, Elk Grove Village, Ill.	E
374/**	Denison Landscaping Inc., Ft. Washington, Md.	O
375/482	Shelley Electric Inc., Wichita, Kan.	E
376/**	W. L. French Excavating Corp., North Billerica, Mass.	X
377/345	J & S Mechanical Contractors Inc., Draper, Utah	M
378/367	Meisner Electric Inc. of Florida, Delray Beach, Fla.	E
379/360	Koontz Electric Co. Inc., Maumelle, Ark.	E
380/541	Thomarios, Akron, Ohio	O/ST
381/278	Cleveland Cement Contractors Inc., Cleveland, Ohio	C
382/356	CAID Industries Inc., Tucson, Ariz.	O/M
383/387	icon Mechanical Construction & Engineering LLC, Granite City, Ill.	M
384/354	Philips Bros. Electrical Contractors Inc., Glenmoore, Pa.	E
385/472	Ace Electric Inc., Valdosta, Ga.	E
386/**	Florence Electric LLC, Canton, Mass.	E
387/304	Ershigs Inc., Bellingham, Wash.	M
388/**	Barnum & Celillo Electric Inc., Sacramento, Calif.	E

389/**	Montana Construction Corp. Inc., Lodi, N.J.	U
390/464	Buesing Corp., Phoenix, Ariz.	X/O
391/409	Flagger Force-Traffic Control Services LLC, Hummelstown, Pa.	O
392/526	D.W. Nicholson Corp., Hayward, Calif.	M/E
393/376	PerLectric Inc., Fairfax, Va.	E
394/365	Southern Contracting Co., San Marcos, Calif.	E
395/261	PIC Group Inc., Atlanta, Ga.	M
396/417	Boyett Construction Inc., Hayward, Calif.	O/W
397/316	Avalotis Corp., Verona, Pa.	P
398/443	Superior Rigging & Erecting Co. Inc., Atlanta, Ga.	ST/O
399/**	Thermal Concepts Inc., Davie, Fla.	M
400/301	Shaw Electric Co., Southfield, Mich.	E

APPENDIX F

CODING OF VARIABLES

HUMAN FACTORS

<u>Classification</u>

Mechanical	1
Electrical	2
Roofing	3
Other	4
No response	5

<u>Years</u>

1 to 5	1
6 to 10	2
11 to 20	3
>20	4

<u>Age</u>

<25	1
25 to 35	2
36 to 46	3
>46	4

<u>Position</u>

Accounting	1
Bus Development	2
Cad/BIM	3
Project Management	4
Project Engineer	5
Sales	6
Upper Management	7
Marketing	8
Estimator	9

<u>Experience</u>

1 to 5	1
6 to 10	2
11 to 20	3
>20	4

<u>Size</u>

< 50	1
51 to 100	2
101 to 400	3
> 400	4

<u>Management</u>

Not Enough Info	1
Encourage	2
Support	3
Other	4
No Response	5

<u>Education</u>

High School	1
Technical	2
2 year	3
4 year	4
Post Graduate	5

<u>Geography</u>

East	1
Central	2
West	3
No Response	4

TECHNOLOGICAL FACTORS

Results		**Why Not Use**		**Relevance**	
Not Familiar	1	Not Familiar	1	Not Enough Info.	1
See Benefit	2	Risk Issues	2	Possible	2
Being Considered	3	Upper Support	3	No Response	3
No Response	4	Training	4		
		Cost	5		
		No Response	6		

Why Use		**Use**		**Knowledge**	
Cost Savings	1	Pictures	1	None	1
Human Task	2	Inspections	2	Occasional	2
Productivity	3	Productivity	3	Very Little	3
Reduce Risk	4	Layout	4		
No Response	5	Security	5		
		Other	6		

RISK FACTORS

Risk		**Legislation**	
Not Aware	1	Not Aware	1
Somewhat Aware	2	Somewhat Aware	2
Very Aware	3	Very Aware	3
No response	4	No Response	4