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Unmanned Aircraft Systems in Construction and Agriculture: Uses, Benefits, Challenges, and Why Companies Choose to Invest

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***Abstract:** The use of Unmanned Aircraft Systems (UASs) in the construction and agriculture industries continues to gain in popularity and use. Firms within these industries have begun to utilize UASs to perform many of the traditional processes and procedures, which can result in a reduction in total work force and costs needed for a task. However, as with any technology, there is a learning curve and UASs do change the way certain activities are completed. Due to this, there exist firms and individuals that have not or are not willing to invest in UASs yet. The objective of this study is to explore the applications of UASs in construction and agricultural industries to discuss the benefits, challenges, and reasons of investing in UASs. This paper conducted an in-depth literature review of current topics on UASs in construction and agriculture. Additionally, six expert interviews were conducted with individuals from construction and agricultural industries in the southeastern United States. Ultimately, this study successfully found several benefits and challenges to using UASs and discussed the reasons that some firms invest in UASs while other still do not.*

***Keywords:** UAS, Construction Management, Agriculture, Benefits, Challenges*

I. Introduction

The utilization of Unmanned Aircraft System (UAS) throughout the construction and agriculture industries is rapidly gaining popularity worldwide. As technology advances, microchips become “smarter” and components “shrink” allowing more and more information to be obtained by using this type of system. The modern UAS has the ability to collect vast amounts of data while covering large areas in a short period of time [7].

UAS is one of many various names used for unmanned aircraft. Hobbyists typically refer to them as drones while other names include unmanned-aircraft vehicle system (UAVS); remotely piloted aerial vehicle (RPAV); and remotely piloted aircraft systems (RPAS). Although these names are typically used interchangeably, Austin [2] differentiates them by stating: A radio-controlled model aircraft is used for sport and the operator must maintain line-of-sight while a drone aircraft usually is required to fly out of sight of the operator, but has limited intelligence as it is sent on a pre-programmed course with a return to base at the end of the mission. It usually does not communicate the results of the mission, until it is recovered at the base. An UAS, on the other hand, usually has greater intelligence as a UAS has the ability to communicate with its operator and send real-time information such as position, airspeed, heading, and altitude, and will also transmit information such as video or photographs [2].

The Federal Aviation Administration (FAA) and Department of Defense (DOD) have adopted the name “Unmanned Aircraft System” as a UAS incorporates more than just the aerial vehicle. DOD defines a UAS as a powered, aerial 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 non-lethal payload. Ballistic or semi-ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles [19]. This definition of UAS differs from cruise missiles and other guided munitions because of the fact that UASs have some means of recovery at the end of a flight [12].

The word “aircraft” defines a machine capable of flight, which describes the main unit of a UAS. However, the word “system” encompasses the many other components that can be added to the aircraft including the aircraft itself. These other components include but are not limited to the ground control system, camera/video equipment, gimbal, GPS or GIS equipment, electro-optical sensing systems and scanners, infra-red systems, radars, dispensable loads (e.g., Munitions, flares), environmental sensors, and transport equipment. Additionally, new technologies are improving the usability, stability, and safety of UAS by including components such as GPS guidance, gyroscopic sensors, and ultrasonic sensors that help prevent collisions.

Clearly, UASs are becoming more sophisticated and complex, which enables them to perform tasks that are

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more advanced and tailored for industries besides aviation and national defense. For example, The Louisiana State University Agricultural Center (LSU Ag Center) has recently experimented with attaching spray nozzles to custom built UASs. Unwanted vegetation growth on fence rows and rice levees can be sprayed with herbicides, decreasing the amount of fuel, equipment, and labor needed to control vegetation using conventional methods. Additionally, through a series of processes, overhead images from UASs can be converted into normalized difference vegetation index (NDVI) data, which indicate the health of the crops [5].

In the construction arena, studies have been completed for the purposes of utilizing UASs on jobsites for safety, environmental applications, as well as routine inspections for Operations and Maintenance (O&M) functions [8]. From a safety perspective, UAS can offer direct observation and interaction providing the safety managers with a communication tool enabling them to give and receive real-time feedback on potential issues [7]. Concerning environmental applications, UASs are being used for inspection of pipeline washouts, which could potentially leak and quickly become a hazardous situation. O&M based UASs can easily provide 3-D imaging and models of facilities or other information required in the post-construction documentation processes. Trimble Navigation Limited has developed a fleet of UASs, including two fixed-wing units and one multi-rotor unit for survey, construction, and agricultural applications. In addition, DJI has developed the Agras MG-1 octocopter, which can accurately spray crops with pesticides [4]. These state of the art UAS also come with global navigation satellite system (GNSS) receivers, 16, 24, or 36 megapixel cameras, capabilities of providing survey quality accuracy without ground control, geo-referenced photos for aerial mapping, and orthomosaic imagery resolution down to 1 cm.

As these examples show, UASs are becoming a viable tool for the construction and agricultural industries to assist in improving business practices and procedures. However, there is a lack of knowledge as to why companies decide to invest in UASs for their businesses. The aim of this study is to collect data from construction and agricultural businesses located in the southeastern United States that are using or not using UASs to determine the perceptions and reasons that some companies are investing or not investing in this up-and-coming technology. Before discussing the research methodology, data collection, and results, the next sections present the history and current standing of UASs, particularly in the agricultural and construction industries.

II. A Short History of UAS

Early types of UASs have been in operation since the First Italian War of Independence in 1849, when Austria launched air raids via unmanned balloon bombs, which floated over Venice, Italy [12]. Two hundred balloons were launched at the same time and only two found their target [16]. Since the balloons were controlled by the wind, the remaining balloons floated back upon the Austrians in a laughable fiasco [11]. Balloon bombs were used again during the American Civil War [9], but the origin of UASs using autonomous navigation is a completely different story.

Although the idea of unmanned aviation originated approximately the same time as manned aviation, [12], due to insufficient technology at the time, the unmanned aviation idea remained mostly in the laboratory. The development of unmanned aircraft hinged on the confluence of three critical technologies, in addition to that of flight itself: 1) automatic stabilization, 2) remote control, and 3) autonomous navigation [12]. The combination of these ideas was eventually shelved but regained interest with the development of Elmer Sperry's gyrostabilizer in 1909. The gyrostabilizer was capable of stabilizing and navigating pilotless aircraft, which garnered the attention of the U.S. Navy and resulted in Sperry being credited with the establishment of the unmanned branch of aviation [12]. Unfortunately, after several failed attempts and the start of WWI, the U.S. Navy decided to concentrate on other needs for the war.

Early in the 20th Century, another key player emerged in the advancement of unmanned aircraft. Charles Franklin "Boss" Kettering (famous for inventing the cash register and the automobile self-starter), convinced the Aircraft Production Board that drones had military value and that his company could build them [12]. On January 8, 1918, the U.S. Army awarded a contract for the development of 25 Liberty Eagle aerial torpedoes to Kettering's company, the Dayton Wright Airplane Company [12]. His team included Orville Wright, C. H. Wills (Henry Ford's chief engineer), Ralph Depalma (a race car builder), Elmer Sperry (for his gyro-stabilization expertise), and the Aeolian Player Piano Company (for their vacuum system knowledge). Kettering's design, called "The Bug", was only partially successful, but the end of WWI prompted the Army to discontinue the funding [12]. Some flight tests were continued in Florida throughout the 1920s, but the challenge of remotely controlling unmanned aircraft remained unsolved. Lawrence Sperry, Elmer Sperry's son, continued production and development of unmanned flights in conjunction with U.S. Army contracts from 1920 to 1924 [12]. Using radio-control, flights were successful but interest waned after Lawrence Sperry's death from a test flight over the English Channel.

A model hobbyist by the name of Reginald Denny ultimately created the Radioplane (RP-1) in 1935, which was commanded by transmitting audio tones via a rotary telephone dial [12]. This unmanned aircraft was initially designed as a training tool for anti-aircraft gunners [13]. Denny's original design eventually evolved into the RP-19 and by 1946 became the definitive model with 48,000 being produced between 1946 and 1984 [16]. This design was responsible for leading unmanned aviation into the role with which UASs are most strongly associated today [12].

WW II saw the development of target drones by the US and UK, while Germany commissioned an unmanned vehicle for combat (called the V-1) which was more of an early cruise missile than a UAS [9]. Further interest in unmanned aircraft was increased after the U-2 incident in 1960 when American pilot Francis Gary Powers was shot down over the Soviet Union [9]. Additionally, the United States used Firebee UAVs to conduct frequent surveillance missions during the Vietnam War to locate targets that piloted aircraft later destroyed [9].

Over the next several decades, the militaries from the United States, Great Britain, Japan, and Germany all experimented with different types of unmanned aircraft mostly focusing on aerial torpedoes [12]. The famously named Predator drone was utilized in the 1990s by the United States for surveillance in the Third Balkans War [9]. Slow progress occurred throughout the 1990s up until the terror attacks of 9/11, although much of this time was spent improving technologies supporting UAS capabilities [16]. Immediately following 9/11, the U.S. moved to arm the Predator drone when it deployed with Hellfire missiles in Afghanistan [9]. At the turn of the 21st century, the U.S. Army had a fleet of only 30 unmanned aircraft, however, in 2010, and as a direct result of the terror attacks on the U.S., that number had increased to over 2000 [19].

UAS can be classified based on several different standards. It usually can be classified by size (Micro or Nano UAS, mini UAS, small UAS, medium UAS, and large UAS), or by the ranges they can travel and their endurance in the air (very low cost close range UAS, close range UAS, short range UAS, mid-range UAS, and endurance UAS), or by a tier system that is employed by the military. According to the U.S. Department of Defense (U.S. DOD), UASs are classified into five categories, as shown in Table I.

III. Literature Review of UAS Application

The UAS industry has grown tremendously over the past few decades, yet applications are still restricted by flight duration, user interface, and FAA regulations among other things. Additionally, since its use in the civilian arena is relatively new, businesses do not quite know yet what UASs can do to improve their services. More recently, the potential of UASs as tools in civilian environments has gained significant attention in domains such as agriculture, construction, forestry, archaeology, and architecture [10]. Due to recent advancements, many speculate as to the countless uses UASs will offer in the future. As an example, in the agriculture industry, imagery can be gathered to determine crop growth, distribution of pesticides and fertilizers, and lack of or presence of adequate irrigation.

A. UAS in Construction Management

In terms of UAS applications in construction, Irizarry and Costa [10] conducted an exploratory case study to identify potential applications of visual assets obtained from UASs for construction management tasks. UAS test flights were conducted on three construction sites located in the United States and one site located in Brazil. Then, the authors interviewed and assessed the project personnel's perception of the benefits and usefulness of the visual data gathered. In addition, the authors analyzed the costs associated with UAS use in construction environments. The study was divided into the following sections based on the stages and activities on the project sites: 1) UAS flight on construction jobsites; 2) development of the visual asset database and visual asset subset for interviews; 3) distribution of a questionnaire; and 4) interviews with project personnel.

The four building projects selected were of various sizes and included an academic office building, a research building, a school building, and a residential high-rise building. By choosing a project located in Brazil, the authors were able to include an international perspective where UAS regulations were more lenient from those in the United States. Site visits were conducted at each of the project locations between the months of May and November 2014; each lasting between 30 to 60 minutes. Utilizing a DJI Phantom 2Vision + UAS® , a total of 200 visual assets were collected between all four projects [10]. All of the visual assets collected made up the database from which certain assets were selected for use in the personnel interviews. Bias related to project familiarity was reduced by dividing the assets into two groups, the first being assets from a respondent's project and the second being assets not from a respondent's project. Eight videos and seven pictures were selected as the subset for use in the interviews.

The questionnaire included the following sections: descriptions of visual assets with relation to logistics, safety, progress, quality, and managerial and technical issues; indication of the participant's level of agreement based on usefulness of the visual assets; and comparison of the assets obtained with current or traditional methods of acquiring visual assets. During the interviews, participants were asked to provide their perception of various aspects related to the visual assets collected while completing the questionnaire [10].

TABLE I
UAS Classification According To The U.S. DOD (derived from [19])

Category	Size	Maximum Gross Takeoff Weight (MGTW) (lbs)	Normal Operating Altitude (ft)	Airspeed (knots)
Group 1	Small	0-20	<1,200 AGL*	<100
Group 2	Medium	21-55	<3,500	<250
Group 3	Large	<1,320	<18,000 MSL**	<250
Group 4	Larger	>1,320	<18,000 MSL	Any airspeed
Group 5	Largest	>1,320	>18,000	Any airspeed

*AGL = Above Ground Level

**MSL = Mean Sea Level

The results indicated that there are several potential applications for UAS use in construction management tasks such as project progress, jobsite logistics, safety conditions, and quality control. Important issues, such as worker distraction, revealed the importance of training and communication while using UASs on jobsites to avoid unsafe conditions [10].

In terms of costs, the authors found that additional information is required to fully determine a more detailed cost analysis compared to current jobsite imaging methods. However, based on the cost information provided, the initial investment for the type of UAS used ranged from $8,000 to $12,000 including the equipment, regulatory fees, and insurance [10]. The researchers recommended further research on the regulatory aspect concerning UASs, the impact of the learning curve by construction personnel, privacy, and safety concerns that may be related to UAS use on jobsites.

B. UAS in Surveying

A performance evaluation by Siebert and Teizer [17] was conducted utilizing a custom-built UAS, which provided rapid and autonomous 3D mapping data. This evaluation lends its use to the current work by incorporating survey methods in the construction industry while utilizing UASs. The assessment was conducted on three sites that consisted of a landfill, a road construction site and a high speed rail and spoil site project.

The UAS was specifically designed for successful completion of surveying tasks in civil engineering applications. Considerations for its assembly and use were its low purchase price, ease of operation, low maintenance costs, reliability in pilot and autonomous modes, and ease of control in harsh environments. The design resembled the Mikrokopter Quad XL® and was assembled with a low cost differential GPS receiver and a 16.1-megapixel camera system [17].

The purpose for the landfill site was to compare the UAS survey to a conventional "ground-based" survey by obtaining information on cost effectiveness and surveying accuracy. Additional goals were to gain an understanding of the process of UASs in civil engineering, and to point out improvements for replacing ground-based surveying with UAS surveying. On the road construction project, the objectives were to measure the UASs error of performance, highlight its advantages and limitations, and to generate 3D point clouds from aerial photogrammetry relating to earth moving activities. Considering the landfill and high speed rail and spoil sites, the assignment was to obtain and provide unique data to aid in construction engineering and management tasks.

From the study's results, the main advantage for utilizing a UAS for land fill operations was time – the total amount of time needed to complete the survey with the UAS was 70% less compared to the amount of time needed for a conventional survey [17]. This total amount of time included preparation, recording, evaluation, and post processing. Another advantage was a geometrically corrected aerial photograph projected similarly to a topographical map. An advantage noted on the high-speed rail and spoil site was the UAS allowed the project manager to accurately forecast additional fill material at the beginning of the work week as compared to waiting until the end of a work week using conventional methods [17].

Siebert and Teizer [17] also noted challenges of UASs for surveying which consist of wind – thermal wind gusts over 40 km/h, which caused turbulence and blurred photos, and point classification – the UAS software does not analyze the point cloud information automatically and must be manually annotated. Additionally, the UAS method had a similar average height error of 4.2 cm when compared to the traditional ground survey method, but the UAS method was considered more accurate since it recorded 122,275 points compared to 202 using the ground based robotic total stations (RTS). Reasons for this amount of error were due to thickness of ground control points, general tendency to measure low with the RTS rod, impact of vegetation and surface conditions that could not be measured by RTS, and the sheer number of points measured [17].

The authors were able to demonstrate the successful applicability of UAS and photogrammetric surveying for civil engineering applications. Additionally, they were able to focus on the magnitude of errors of a UAS based approach compared to conventional surveying techniques. Though the results demonstrated improvements compared to previous research, the study noted limitations such as battery life, need for increased coverage areas, proper flight planning, and use of cameras with high shutter speeds [17].

C. UAS in Agriculture

Technology utilized in precision agriculture has evolved tremendously in recent years. This evolution, as Adrian, Norwood, and Mask [1] note in their study titled "Producer's perceptions and attitudes toward precision agriculture", has prompted many farmers to adopt UASs and other technologies for reasons such as profitability, environmental compliance, improved decision-making, and risk reduction potential. Although research analyzing the impact of producer's perceptions in agriculture is rare, the authors' study investigated the perception and attitudinal characteristics of farmers who plan to adopt new technologies.

The study measured constructs of perceptions of usefulness, ease of use, and confidence of net benefit gained for the use of technology in precision agriculture [1]. The dependent variable analyzed was the number of different tools the farmers planned to use within the following year such as remote sensing, grid sampling, yield monitors, variable rate applicators, auto steer equipment, and GIS computer mapping systems. The study found that farmers who intended to adopt new technology tools had higher attitudes of confidence and perceived net benefits compared to those farmers who did not intend to adopt precision agriculture technologies. Limitations identified were additional constructs needed, failure to address environmental advantages, negatively worded constructs, and limited sample size.

Adrian et al. [1] found that various combinations of tools, steep learning curves for technologies, and initial investment for the tools complicated farmers' decisions to invest in these technologies and reduced their confidence. However, the findings can help extension agents and vendors provide adequate training, service, and products to improve confidence.

Another study conducted by Rasmussen, Nielsen, Garcia-Ruiz, Christensen, and Streibig, [14] experimented with a rotary-wing UAS that gathered imagery for practical applications in weed research mainly on perennial weeds. The advantage of a UAS-borne sensor was that it could cover much larger areas in shorter periods of time prior to applying weed control. Additionally, UAS imagery is relatively easy to integrate as a tool in weed research and provides higher accuracy. Conversely, utilizing ground-based sensors mounted on sprayers or tractors only offer real-time assessments of weeds with no possibility of prior planning of the weed control [14]. The authors discovered other disadvantages including automated analysis or interpretation of the data, and ensuring the aircraft flew as it was supposed to fly. In order for the UAS systems to provide maximum desired results, key issues should be solved such as geo-referencing, mosaicking, and information extraction workflow [14].

D. Point of Departure

All of the studies mentioned in the previous sections provide details on the use of UASs for different applications in construction and agriculture related industries. However, the studies lack certain details about why organizations and individuals decide to invest in UAS technology while others do not. The objective of this research is to investigate the uses of UASs in construction, surveying, and agriculture and to gain an understanding of the benefits and challenges while determining reasons that organizations choose to invest and use UASs and why other organizations choose to not invest in UASs and continue to use traditional industry methods. The next three sections that follow detail the methodology to this research as well as the findings and a discussion of the results from conducting this study.

IV. Research Methodology

In order to achieve the goals and objectives of this study, the researchers designed the study to focus on conducting in-depth interviews with selected organizations and expert individuals. This study takes into account various companies and agencies in the southeastern part of the United States including a civil engineering firm, a surveying firm, an environmental engineering firm, a state agriculture agency, and a surveying equipment supply company. The breadth of the organizations to interview will provide the research team with differing views on the decision to use or not to use UASs for construction and agriculture applications.

To begin the study, the researchers conducted an extensive literature review of topics relating to this work. Some of the specific articles include: "Exploratory Study of Potential Applications of Unmanned Aerial Systems for Construction Management Tasks", "Potential Uses of Small Unmanned Aircraft Systems (UAS) in Weed Research", "Producer's Perceptions and Attitudes Toward Precision Agriculture Technologies", "UAS4SAFETY: The Potential of Unmanned Aerial Systems for Construction Safety Applications", and "Mobile 3D Mapping for Surveying Earthwork Projects Using an Unmanned Aerial Vehicle (UAV) System". These articles were evaluated in the literature review section and provided the overview and background information necessary to conduct this study.

Building from the information collected in the literature review, the next step in the research was to conduct a series of interviews, either in person or via telephone communication as the main data collection source for this project.

Initially, the authors contacted dozens of construction and agricultural firms based on the authors' knowledge and familiarity with firms in the southeastern US. The authors then received interest in participating in the study from ten of the contacted companies. The firms and associated interviewees were chosen based on their type of industry/service, level of expertise, availability, and location. Further, the authors looked to select various firm types to help understand UASs from different sectors in construction and agriculture. Based on the qualifications, availability, and variation in services offered by a firm, a total of six interviews were conducted using a case study approach and open-ended questions. Information concerning the qualifications of the interviewees is shown in Table II and the participants consisted of the following individuals:

- Participant 1 – An engineer at a state agricultural research agency who specializes in UAS remote sensing for agricultural applications
- Participant 2 – A professional civil engineer and part owner of a regional surveying company
- Participant 3 – A principal owner/CEO of an environmental engineering and construction firm and professional photographer
- Participant 4 – A professional land surveyor and co-owner of a regional surveying company
- Participant 5 – A senior consultant for a large survey equipment provider and software developer
- Participant 6 – A registered professional engineer and branch manager of a local geotechnical consulting firm.

The interview participants were asked a series of questions relating to the use of UASs in their respective industry or profession. One question set was directed toward companies who already employ UASs, while a separate question set was developed to focus on those companies who have not invested in these systems. The top portion of Table III lists the questions directed towards companies using UASs, while the bottom of Table III lists the questions directed towards companies not using UASs.

TABLE II
QUALIFICATIONS OF INTERVIEWEES USED IN THIS STUDY

Expert Interviewee Qualification Criteria	Participant					
	#1	#2	#3	#4	#5	#6
At least 3 years of advanced knowledge of UAS	X		X		X	
Professional registration as a professional engineer (PE), professional land surveyor (PLS) or other certification		X		X	X	X
At least 10 years of professional experience in industries of agriculture, engineering, environmental and/or construction	X	X	X	X	X	
Considered as UAS expert in current position of employment	X		X	X	X	
Multiple degree disciplines (PhD., M.S., B.S., Minor)	X					X
Size of company more than 50 employees	X	X	X		X	

TABLE III
QUESTIONS USED FOR CONDUCTING INTERVIEWS WITH UAS EXPERTS

Question Set 1: Companies using UASs	1. Does your company use UAS technology for business operations?
	  a. If so, can you describe some of the operations that your company uses UAS technology for?
	2. What kind of system do you have? Type? Brand? Model?
	3. Would your company be interested in upgrading or expanding your UAS fleet?
	4. What specifically is the UAS used for?
	5. What types of deliverables are generated? How?
	6. What other areas of business operations would you like to use UAS technology?
	7. What are the benefits of using this system?
	  a. Cost benefits?
	  b. Manpower benefits?
	8. What are some drawbacks to your UAS system? How do you think these drawbacks can be improved?
	9. What are the maintenance/operating costs for this system? Would you be willing to share any maintenance/operating data for this research study?
	10. What was the learning curve needed to understand and operate the UAS system?
	11. Is there any background or other experience required to operate and maintain?
	12. Why did your company decide to invest into this system?
	13. Why should other companies invest?
	  a. Value?
	  b. Reduced crew sizes?
	  c. Deliverables?
	14. In your opinion, how has the use of UAS technology improved your business operations?
	15. What other applications in construction do you think would benefit from UASs?
	16. What other industries do you think these systems can be useful for?

Question Set 1: Companies not using UASs	1. Does your company use UAS technology for business operations? If not, are you considering UAS for your business operations in the future? 2. Have you considered using UASs? If so, what type? Brand? Model? 3. How do you think UAS technology could help your business? Industry? 4. What advantages/disadvantages do you foresee with these types of systems in your company? In the construction industry? 5. If you could use this system, what types of deliverables would you require? 6. Why has your company decided not to invest into a UAS system? 7. Why have other companies invested in UAS systems but not yours? 8. What other applications in construction do you think would benefit from UASs? 9. What other industries do you think these systems can be useful for?

Subsequently, the participants were encouraged to provide their own opinions as to the advantages and disadvantages of the use of this technology, as well as, additional applications in which UASs could be utilized. Manual thematic coding was conducted by the researcher to analyze the responses and identify patterns and themes from the qualitative answers as well as differences in the information obtained. The results of this study, detailed in the results and discussion sections below, provide information about the benefits and challenges of UASs in construction and agriculture, in addition to why companies choose to invest or not invest in this technology. A better understanding of why companies choose to invest or choose not to invest may provide insight for future industry needs related to UAS use in construction and agriculture.

V. RESULTS

The utilization of UASs in the construction, surveying, and agriculture industries, though relatively new, promises to yield worthwhile and vast applications. This study utilized expert interviews and an in-depth literature review to obtain information surrounding the use of UASs in the construction and agriculture industries. The expert interviews were conducted between February and May 2016. Time and schedule restraints prevented the researcher from conducting in-person interviews with all participants, and those interviews were conducted via a conference call. Each of the interviews is summarized below.

A. *Participant #1*

Along with conducting the interview with an agricultural engineer using the questions in Table III, this interview also included a brief UAS flight demonstration. Uses for this technology were discussed and current agricultural experiments are in progress for fencerow and levee vegetation control as well as crop assessment for NDVI and irrigation. For instance, utilizing an UAS for crop imaging in order to aid in the identification of proper fertilization and irrigation as more space recognized on the images between the crop vegetation indicates there may be an issue. This helps researchers determine exactly how and where to apply the fertilizer and/or water.

One specific attribute of the UAS used by participant #1 is that images acquired for imagery purposes must be taken straight down. In other words, there can be no oblique angles. Three dimensional features on matching imagery helps stitch images together (called "mosaicking") without lots of sensor data embedded in the image files. This post-processing method requires lots of processing power but has been reduced from 10 hours to 2 hours with the utilization of higher powered processing computers. The images were captured using a DJI Phantom 3® quadcopter with a self-generating Wi-Fi signal and an additional tablet for the user interface costing approximately $1,200 for the system. The additional high powered computer for image processing cost of $3,000 and the FAA certification fees of approximately $300 yield a total investment of around $4,500. The agency's team has also assembled several do-it-yourself (DIY) UAS kits priced in the $1,500 range, and has designed and constructed its own version of a larger x-wing shaped UAS designed to incorporate ultra-low volume spray nozzles for the purposes of vegetation control on fencerows and rice levees. Other uses mentioned by the interviewee for the agriculture industry could be on dairy farms. For instance, farmers with large numbers of livestock can employ an UAS equipped with software that scans and detects the livestock markers for easy identification, as well as location of any at-large animals.

B. Participant #2

Although this participant was aware of UAS technology, his company has not considered investing in UAS equipment. The main reasons cited were investment costs and that his clientele currently does not require the types of deliverables that UASs provide. They typically conduct various types of construction, boundary, and stakeout surveys, large and small, and utilize traditional land-based equipment to accomplish what is requested of clients. For instance, participant #2 mentioned that locating, setting and referencing property corners cannot be accomplished with a UAS. Although UAS technology may be useful with certain surveying activities and may be quicker to provide a picture of what is going on at a construction site, the type of work participant #2's organization has done does not mesh with the current UAS trends in this particular arena.

To own and operate this type of system requires enough significant and relevant work to employ UASs in order for it to be profitable and worth the investment, in addition to having the expertise to properly extract the data and manipulate it into the required deliverable. Participant #2 stated that his company would consider investing in UASs if the system could provide similar information as obtained by traditional GPS or land-based equipment. For example, hovering over a point and transmitting data to obtain workable and accurate benchmark coordinates would be extremely beneficial for current and future work. Ultimately, this participant did not have the confidence in these systems to be able to perform what is needed for his clients and felt the learning curve was too steep. When asked what other industries could benefit from UAS technology, participant #2 mentioned that utility companies could use them to locate and inspect power poles, fire hydrants and other types of utility components for the purpose of gathering GIS information compiled in a database.

C. Participant #3

Identification, monitoring and repair of underground pipeline erosion problems are the main services that participant #3's company performs. The participant's company owns a fleet of UASs, in which they employ several different types of UASs for the purposes of surveying problem areas and creating 3-D models for visual referencing for clients. These tasks, as participant #3 stated, can be completed in less than half the time and cost compared to the use of a conventional surveying firm for a similar product. The participant stated that, as an example, a large project completed with the use of an UAS was found to be 1/20th of the cost compared to estimates for ground-based conventional methods.

Participant #3's company UAS systems and associated pricing include: a fixed wing UAS called the EBEE senseFly® for surveying and mapping operations that is priced around $12,000, a DJI Phantom 4® quadcopter, for overhead visual images and real-time videos costing $1,400, an upgradable DJI Inspire 1 Pro® quadcopter that costs $3,900, and a DJI Spreading Wings S-1000® octocopter with a full size digital single-lens reflex camera which cost $10,000. These UASs are primarily utilized for site reconnaissance before, during, and after construction for an erosion repair project.

Furthermore, the participant noted that some of their UASs can be outfitted with thermal imaging cameras for detecting leakage in underground pipelines. The participant decided to invest initially based on early experience with flying model airplanes and eventually, participant #3 was introduced to UASs that utilize cameras and other equipment. With previous experience in professional photography, participant #3 saw value in coupling photography technology such as thermal imaging cameras with his current position in the environmental engineering and construction arena.

Overall, the participant noted that other companies should invest in UASs because they add value, reduce labor costs, provide exceptional deliverables to the client, provide a broader scope of services, and provide knowledge to clients that companies are utilizing the latest technology. The participant also noted an additional application for UASs as a marketing tool for company growth. Other applications of use for UASs involve anything where a height perspective is needed like roof inspections, tall building inspections, and visually inspecting real estate. Finally, participant #3 stated that upgrading their current systems is a consideration always on the table as they are continuously looking for longer flight times, better quality camera systems, object avoidance, longer transmission capabilities and smaller and lighter aircraft to improve their system's efficiency and effectiveness.

D. Participant #4

Similar to Participant #2, this interviewee's company performs land surveying and civil engineering design for his clients. This company is a recent purchaser of a Trimble® ZX5 Multirotor UAS and utilizes it for site imagery and topographic land surveying. With the included and integrated UASMaster software, they are able to provide full 3-D modeling, imaging, and referenced deliverables to clientele. This system used by participant #4 cost approximately $30,000 but has the potential to be offset by hours or days of reduced field time and manpower costs using traditional methods. However, a temporary ground crew is still required to set control points, launch, and receive the aircraft. The UAS allows participant #4's firm to obtain much more data compared to ground-based methods, which makes for improved surface appearances and more accurate estimates of volumes.

Drawbacks mentioned by participant #4 are the FAA requirement for an operator to have a pilot's license and the lengthy processing time of the FAA 333 exemption form needed for using an UAS. Additionally, flight time is limited to around twenty minutes, meaning that the firm must purchase extra batteries and chargers for larger projects. Training provided by the equipment supplier was completed during a three-day workshop and was sufficient to provide operators confidence during their first actual project flight. Finally, participant #4 mentioned that the decision to invest was to keep up with technology in order to improve their operations and services to clients.

E. Participant #5

Participant #5 is a senior consultant and expert in UASs for surveying and mapping operations and provides UASs to a diverse customer base including engineering and surveying firms, environmental and coastal organizations as well as precision agriculture equipment dealerships. His company's UAS product base consists of two fixed wing aircraft and one multi-rotor aircraft. All products are available with many different options based on the customer's needs and consist of:

- The UX5, a fixed wing aircraft providing surveying and mapping procedures, aerial imaging applications and image processing systems (cost = $40,000);
- The UX5 HP, similar to the UX5, this system provides the highest accuracy and precision for data collection and imaging (cost = $50,000);
- The ZX5, a multi-rotor, vertical take-off and landing (VTOL) system that is easily deployable and convenient for tighter spaces (cost = $30,000).
- Flight times vary from 40 to 50 minutes on the fixed wing systems and up to 20 minutes for the multi-rotor system.

Participant #5 noted that his company put the word "system" in Unmanned Aircraft System, referring to the full-blown packages available with their UAS products. The packages consist of the aircraft, imaging components, software, user-interface, and complete photogrammetry and powerful image processing to provide various types of deliverables for clients. Participant #5 expects that the current prices for these systems will decline in the near future as demand increases and technology allows lighter components, smaller processors and smaller, more efficient GNSS receivers. Along with these factors as well as the realization of reduced labor costs and improved safety, when compared to traditional methods, participant #5 stated that customers should consider purchasing these systems to stay competitive in the marketplace.

F. Participant #6

This interview with participant #6 was conducted via telephone and discussed a brief assessment of the technology and its uses. This participant's firm conducts geotechnical engineering consulting and construction materials testing services throughout the southeastern United States. They do own and operate a small UAS, a DJI Phantom 2® , but only for overhead pictures at larger project sites. This provides them with current site conditions where the images can be overlaid onto engineered drawings. The company appreciates the current technology they have but participant #6 noted that the company is not in the, market to upgrade because of the types of projects and clientele do not require specific uses for advanced UAS deliverables, and the initial investment costs are currently not worth the effort required. As of the date of this interview, the FAA required operators to have a pilot's license if operating "for profit", and participant #6 noted that the registration and exemption process was quite burdensome. To participant #6's knowledge, no other similar firms have invested in these systems, likely for similar reasons.

TABLE IV
BENEFITS AND CHALLENGES IN USING UASS

Benefits	Challenges
Cost savings related to reduced crew sizes and reduced manpower required to complete a project compared to a similar project with conventional methods	Increased initial investment costs compared to traditional methods causes lack of interest
Cutting edge technology	Battery life, which results in shorter flight times
Deliverable output includes a larger range of products and less time to produce	Complex operability of hardware and software
Speed of obtaining data and producing deliverables from beginning to end was significantly increased	The perceived levels of accuracy and position tolerances
Increased project safety by not putting as many personnel at risk as compared to employing traditional methods	Training personnel to perform tasks using UASs rather than employing traditional methods
Marketability based on the fact that clients like to see companies who employ the latest technology	FAA regulations and requirements being a large hurdle and additional costs to overcome

VI. DISCUSSION

This section considers all of the information collected in the literature review and expert interviews and brings to light the similarities and differences noted. In addition, this section includes the major benefits realized and challenges to deal with that the six interview participants stated during their interview.

A. *Similarities*

Considering all of the interviews conducted, similarities were noticed when compared to the information collected in the literature review. Of those companies who do own and operate UASs, the overwhelming factor to invest was that the UASs produced a valuable product related to the services provided by the respective firm. Moreover, their decisions to invest in these systems were mainly consistent with the need to set the standard of or remain at the forefront of technology.

Additionally, this study found that the interview participants stated that time and manpower costs were reduced when utilizing UASs for production of their respective deliverables. These results are consistent with the findings from a performance evaluation conducted by Siebert and Teizer [17]. As mentioned in the results section above, two of the interview participants listed a degree of cost savings as a result of using UASs for surveying and 3-D modeling tasks. The amount of time to complete a survey was 70% less compared to the amount of time needed to complete a conventional survey using traditional methods [17].

Another factor to note is that participants that are not investing in UASs are basing their decision on the lack of confidence they have in the systems performing as they should. One participant states that they are unsure that an UAS can accomplish what is required of their clients. An agricultural UAS study by Adrian et al. [1] supports this lack of confidence as the authors investigated producer's perceptions and attitudes toward precision agriculture technologies. That study found that farmers planning to use precision agriculture tools had higher attitudes of confidence than those who did not plan to use the tools. The perception is that as technological improvements continue, perhaps so will the accuracy and versatility of UASs and in turn increase the confidence in individuals to trust and begin using UASs.

The researcher also found that post processing issues existed when utilizing a UAS for agriculture crop assessments. As mentioned by interview participants, image stitching requires several post processing steps and requires lots of processing power to accomplish. This finding is consistent with a study completed by Zhang and Kovacs [18] that surmises that the time to process and deliver final products to the users is a main concern for UAS technology. Deliverable development requires several procedural steps for processing data obtained from UASs. As a result, image processing procedures have been developed for specific applications, but a generalized procedure has not been defined [18]. For larger areas of assessment, hundreds of images are captured, which increases the amount of images and can create distortions. Additionally, the factors of wind and thermal waves that can lead to reduced image quality and processing this data can require massive computing capabilities.

B. *Differences*

Although this study was able to identify many similarities, not many differences were recognized. The major reason for this is that the focus of this study differed from the focus of the studies analyzed in the review of literature. One study noted that producers with more education tended to have higher confidence levels of precision agriculture tools [1]. This study, even though the intent was different, found no correlation between levels of education and levels of confidence in the use of UASs.

C. *Benefits and Challenges*

In conducting the six interviews, many benefits and challenges of UASs were discussed. Table IV lists the common benefits and challenges discussed with the interview participants.

Of the benefits listed, the cost savings due to reduced labor and overall reduced activity costs was the major benefit mentioned in the expert interviews. However, a challenge noted was that initial investment costs tend to be higher than initial investment costs for traditional equipment. However, the participants that manage fleets of UASs noted that the higher initial costs are eventually offset by the use of the UASs and reduction in labor and crews needed.

Another major benefit was the use of cutting-edge technology that results in higher precision for certain project activities. The higher precision factor is based simply on the increased amount of data obtained with UASs when compared to traditional methods of data gathering. More points for comparison yields more accurate results. Another similar benefit of those participants who utilize UASs and the associated software for production of surveys and 3-D models was shorter time to produce the deliverables. One of the interview participants mentioned that on an emergency pipeline project, access to the site had been severely hindered due to a washout the previous evening. The participant was able to utilize a UAS with the client, and provide a real time assessment of the current conditions, which prompted a quicker response time and ultimately a faster successful repair of the site.

In contrast, one recurring challenge noted was battery life of the UAS, specifically with multi-rotor platforms. The fixed wing systems similar to the Trimble® UX5 or the EBEE senseFly® , have only one propeller motor to power and are capable of flight by generating lift caused by the UASs forward airspeed. VTOL units on the other hand, have a minimum of four propeller motors requiring power. Another distressing drawback mentioned in nearly every interview, was the tedious amount of paperwork required to meet FAA requirements and regulations to obtain the proper certificates of waiver or authorization (COA). One interviewee noted that the process time was in excess of nine months and his firm was forced to cancel a project due to not having the approval in time.

VII. Conclusion

Throughout the course of this study, the researchers aimed to obtain information that may help in determining what factors influence construction, engineering, surveying, and agricultural agencies to choose to invest or choose not to invest in UAS technology. Although limited information is available from the emerging area of using UASs, the study was able to highlight some factors that may help firms with the decision-making processes to invest and use or not invest and use UASs. Additionally, several benefits of this technology were discovered as well as challenges these users face when using these systems.

In reviewing the process for this study, a few limitations must be noted. For one, the intention for this research study was to conduct as many interviews as possible. Although the researcher did conduct six in-depth interviews with qualified UAS experts, the researcher hoped to conduct more interviews to provide additional validity to the findings. This did not occur due to time constraints. Another limitation to note is the difficulty in finding information on UASs for construction and agriculture. UASs are a relatively new tool for these industries and limited information is currently available. As more information becomes available and more firms continue to potentially invest in these systems, this study can be improved with the use of other research data collection tools such as conducting a survey or in-depth case studies of organizations using and not using UASs.

From the analysis of the available information related to UAS use in the construction, surveying and agricultural industries, and the decision of companies to invest or not to invest in these systems, it was determined that additional data are needed to perform a more detailed analysis and comparison. As UAS use becomes more widespread, additional data may be available to study the implications of these decisions. At this time and with the information available, the author can conclude that for many companies, UASs could be a good investment. This is supported by a study conducted by Irizarry et al. (2016) who noted that acquired UASs for one project can be used on several other projects at no additional significant cost.

The impact of the complex operation of the hardware and software may be related to companies' decisions not to invest. Another related factor may be that considering the UAS technology is relatively new in these industries, a lack of knowledge may exist for those companies who have not considered or have considered and chose not to invest. Future research should evaluate the decision factors considered when companies elect to invest in this technology compared to companies who elect not to invest. Considering all the benefits and challenges, the innovative application of UASs has the potential to improve practices in the construction, agriculture and surveying industries [7].

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