Report No. K-TRAN: KSU-15-3 ▪ FINAL REPORT ▪ August 2016

A Study of How Unmanned Aircraft Systems Can Support the Kansas Department of Transportation's Efforts to Improve Efficiency, Safety, and Cost Reduction

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Kansas Department of Transportation

1 Report No.	2 Government Accession No.	3 Recipient Catalog No.
K-TRAN: KSU-15-3		

4 **Title and Subtitle** A Study of How Unmanned Aircraft Systems Can Support the Kansas Department of Transportation's Efforts to Improve Efficiency, Safety, and Cost Reduction	5 **Report Date** August 2016 6 **Performing Organization Code**
7 **Author(s)** Melissa McGuire, Malgorzata Rys, Ph.D., Andrew Rys, Ph.D.	7 **Performing Organization Report No.**
9 **Performing Organization Name and Address** Kansas State University Transportation Center Department of Electrical and Computer Engineering 3094 Engineering Hall Manhattan, Kansas 66506	10 **Work Unit No. (TRAIS)** 11 **Contract or Grant No.** C2058
12 **Sponsoring Agency Name and Address** Kansas Department of Transportation Bureau of Research 2300 SW Van Buren Topeka, Kansas 66611-1195	13 **Type of Report and Period Covered** Final Report October 2014–March 2016 14 **Sponsoring Agency Code** RE-0654-01

15 **Supplementary Notes**
For more information write to address in block 9.

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Based on the literature review, survey responses, and SWOT analysis, the use of a UAS for KDOT's operations will improve safety, efficiency, and possibly reduce costs. Out of the nine areas considered for implementing UAS, seven could realize benefits in safety, efficiency, and a possible cost savings. The recommended UAS applications are in bridge inspection, radio tower inspection, surveying, road mapping, high-mast light tower inspection, stockpile measurement, and aerial photography. While UAS cannot replace many of the current activities that KDOT performs, it could greatly enhance them both from a safety and technical point of view.

17 **Key Words**	18 **Distribution Statement**
Unmanned Aircraft Systems, Unmanned Aerial Vehicles, Drones	No restrictions. This document is available to the public through the National Technical Information Service www.ntis.gov.

19 Security Classification (of this report)	20 Security Classification (of this page)	21 No. of pages	22 Price
Unclassified	Unclassified	105	

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A Report on Research Sponsored by

THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

and

KANSAS STATE UNIVERSITY TRANSPORTATION CENTER
MANHATTAN, KANSAS

August 2016

PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

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Abstract

Regulations for using Unmanned Aircraft Systems (UAS) are not yet standardized by the Federal Aviation Administration (FAA). This creates tedious obstacles for those who wish to utilize the technology. The goal of this research is to provide a justified recommendation to the Kansas Department of Transportation (KDOT) on whether or not it is beneficial to implement UAS into routine operations, as well as advice on specific UAS equipment that best fits the needs of KDOT. This report includes a literature review which lists the commercial companies currently using UASs after gaining a Certificate of Authorization (COA) exemption and research done by other DOTs. Potential applications of and concerns about UAS usage are also included in the literature review. Please note that in the literature review, the term UAS and unmanned aerial vehicles (UAV) are used interchangeably since the terms vary within each source. A survey was created and sent to all state Department of Transportation offices. A SWOT (Strengths, Weaknesses, Opportunities, and Threats/Challenges) Analysis was carried out looking at different areas of interest for KDOT.

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Chapter 1: Literature Review

In the twentieth century, human controlled aerial vehicles were not very common. However, the twenty-first century sparked a rapid increase of unmanned aerial vehicles. Large-size drones[*] have been utilized by various countries for military purposes. Today, the capabilities of small drones have greatly increased, and their manufacturing costs have been significantly reduced. This has led to additional investments and a larger market of small drones, and resulted in significant increase in drone functionality comparing to costs (Clarke, 2014b). According to Clarke, recent technologies have resulted in performing some pilot's functions automatically, such as the stability of aircraft in response to turbulence. However, some of these capabilities from reduced pilot control lead to certain risks. Clarke stated that drone use in military applications has been and continues to be a strong driving force for improvements and development of the drone industry.

Rapid advancement in technology and its applications to aerospace industries resulted in attracting public interest in unmanned aerial vehicles (UAVs; Ro, Oh, & Dong, 2007). There are two types of UAVs: Remotely piloted vehicles (RPVs) and drones (Bolkcom, 2004). Both drones and RPVs are pilotless. Drones can be interpreted as "an unmanned aircraft that can fly autonomously" (Villasenor, 2012). The difference between RPVs and drones is that the RPVs are flown remotely by a controlling operator from the ground; in contrast, drones are programmed for autonomous flights. UAVs are essential parts of military applications, and have been used in military applications outside of the United States. They provide surveillance, reconnaissance, search and rescue, target acquisition, and damage assistance in battles (Bolkcom, 2004). The civil applications of UAVs are lagging behind for non-technical reasons associated with regulations, security concerns, liability and safety, civil rights and privacy, and others (Ro, Oh, & Dong, 2007).

According to Clarke (2014b), the following are some terms used to refer to the drones, including their supporting equipment and devices: Unmanned Aerial Systems/Unmanned

[*] Note: In the literature, the terminology UAV, UAS, and drone were used to describe the same technology. Referenced information will use the corresponding term from its literature. KDOT prefers the term UAS since "aircraft" can be regulated by the FAA, but "aerial" in UAV can't necessarily be regulated.

Aircraft Systems (UASs) which is commonly used in United States, and Remotely Piloted Aircraft Systems (RPASs) which is used in Europe. The difference between these drone groups is that the RPASs exclude fully autonomous drones; in contrast, UASs may include or exclude fully autonomous drones (Clarke, 2014b).

Generally, drones are classified into four categories according to their size: (1) large drones with a size close to that of a conventionally piloted aircraft, usually of 100 kg in weight for rotorcraft and 150 kg for aircraft; (2) mini-drones of weight between 20-25 kg and 100-150 kg, or of 1-meter maximum size in the length dimension; (3) micro-drones of weight between 0.1 kg and 7 kg (the Civil Aviation Safety Authority [CASA] in Australia is an exception, classifying the weight of micro-drones to be 2-7 kg as of 2013); and (4) nano-drones of weight that is smaller than the weight of the mini-drones (Clarke, 2014b).

UAVs can be transported by small vehicle and are often launched from a small vehicle or a road, and they can be large enough to accommodate some equipment such as sensors and cameras (McCormack, 2008). In addition, UAVs have the ability to carry communication hardware to relay data to the ground, are able to cover larger areas with fewer resources, and can travel with higher speed than ground vehicles (Coifman, McCord, Mishalani, Iswalt, & Ji, 2006).

Civil UASs have been used by police for monitoring large crowds, helping with incident responses, and monitoring particular spaces or small groups to detect or prevent a crime, as well as surveillance for the United States' northern and southern borders since 2002 (Finn & Wright, 2012). Micro-drones have been used by United Kingdom police for monitoring the festival in Staffordshire in 2007. Drones could be used for checking roof lofts for planting cannabis by use of thermal imaging and air sampling equipment, for safety inspections of high rise buildings, and as a perimeter patrol for prisons (Bowcott & Lewis, 2011).

Other general civil applications of drones include two categories: dangerous civilian functions and dull civilian missions (Clarke, 2014b). Examples of "dangerous" civilian missions include searching for missing persons and vessels in extreme weather, firefighting, emergency management for monitoring and surveying fires, earthquake damage, volcanic activities, etc. Routine or "dull" civilian missions include staying in well-defined zones to perform static surveillance, or staying on specific paths to identify lost hikers, sea-farers, vessels in the sea, aircraft wreckage, etc. Other categories of "dull" civilian missions include transporting goods or collecting data for weather, traffic, and more. Specifically, drones can be used to perform the following functions according to Clarke: load delivery, passenger transport (not applied yet because the safety level of drones is unproven against the existing norms for civil aviation), journalism, law enforcement, civilian neighborhood watch, hazardous materials handling, and entertainment and hobby uses.

European countries have flexible rules for using drones, leaving the UAV industry in the United States lagging behind those countries and many others (Goodwin, 2013). This is expected to change since Congress mandated the Federal Aviation Administration (FAA) in 2012 to safely integrate civil UAS into the National Airspace System (NAS; FAA, 2012). The FAA is currently studying how to safely integrate the unmanned aircraft into the United States airspace, originally to be done by 2015 (Yamanouchi, 2013). Formal regulations are due by mid-2016. Small drones (UAVs) have been regulated by the FAA since 2007 (Goodwin, 2013). In the United States, drones cannot be used by businesses for commercial use, research, or by public safety agencies unless granted an exemption. For commercial uses, the current process for earning an exemption is rather extensive per Section 333, which determines whether or not the company must obtain a Certificate of Authorization (COA). The COA application requests every detail about the UAV, its intended use, and the level of skill of the Pilot in Command (PIC). An example COA application is available in Appendix A. For public uses of a UAS, the expedited Section 334 can be used to earn a COA. The time spent in approving drone usage is due to the risk of an accident that might hinder the progress of UAV integration into the NAS (FAA, 2012).

1.1 Companies with FAA Exemption

Since the beginning of this research in January 2015, the UAS industry has experienced many dynamic changes in the level of interest in the technology. By February 10th, 2015, the first 25 companies received FAA permission to utilize UAS technology in their business operations through a Section 333 exemption and COA (FAA, 2015e). The exemption is for civil operation and allows a commercial entity to use UAS to benefit its business. These 25 businesses are listed below and show how they vary in the goods and services they provide, as well as how they use UASs.

1) Astraeus Aerial
2) Aerial MOB, LLC
3) Pictorvision Inc.
4) HeliVideo Productions LLC
5) Snaproll Media LLC
6) RC Pro Productions Consulting LLC
7) Flying Cam LLC
8) AeroCine, LLC
9) Trudeau, Antigua Realty
10) Burnz Eye View, Inc.
11) Advanced Aviation Solutions
12) VDOS Global, LLC
13) Clayco, Inc
14) Land Surveying – Trimble Navigation, Limited
15) Woolpert, Inc I
16) Woolpert, Inc II
17) Slugwear
18) Total Safety U.S.
19) Team 5
20) Hellinet Aviation Services, LLC
21) Alan D. Purwin
22) Pravia, LLC
23) Viafield
24) Blue-Chip UAS
25) Asymmetric Technologies

Of the first 25 companies, the focus ranges from consulting and construction industries to photography and cinematography industries. The construction companies use UAV technology to survey land, monitor for safe practices on jobsites, and ensure existing structures are in good condition (Grayson, 2014). An interesting application of commercial UAV use is in the real estate industry. In granting the exemption for Trudeau Realty, it clearly states that they are now allowed to use a quadcopter to "to conduct aerial videography and cinematography to enhance academic community awareness for those individuals and companies unfamiliar with the geographical layout of the metro Tucson area," meaning that real estate agents can help customers see residential areas near schools for their children (FAA, 2015b). Finally, movie directors and photographers now have the ability to hire some of these companies who can use high-quality UAVs for the "purpose of scripted, closed-set filming for the motion picture and television industry" (FAA, 2014a). Appendix B contains company information with the industry area and the UAS model utilized.

Great detail must be taken when operating UAVs for business purposes according to the exemption forms granted by the FAA. For the 25 companies, the specifications in the exemption forms are nearly identical, except for small variations to correspond with the UAV type (fixed wing or rotary). The following references are excerpts of Burnz Eye View Inc.'s permissions in using UAV technology. It is likely that similar regulations will apply to KDOT's potential uses of UAVs (FAA, 2015a).

- The UA may not be flown at an indicated airspeed exceeding 30 knots.
- The UA must be operated at an altitude of no more than 400 feet above ground level (AGL).
- The UA must be operated within visual line of sight (VLOS) of the pilot in command (PIC) at all times. This requires the PIC to be able to use human vision unaided by any device other than corrective lenses.
- All operations must utilize a visual observer (VO) that assists the PIC in maintaining a VLOS.
- The PIC must possess at least a private pilot certificate and at least a current third-class medical certificate.
- UAS operations may not be conducted during night.
- The UAV may not operate within 5 nautical miles of an airport.
- The UAV may not be operated less than 500 feet below or less than 2,000 feet horizontally from a cloud.
- If the UAV loses communications or loses its Global Positioning System (GPS) signal, it must return to a predetermined location within the planned operating area.

The remaining 14 conditions and limitations to this exemption are available in Burnz Eye View's exemption file (FAA, 2015a).

This laborious process in gaining exemption may discourage UAS use or discourage companies from seeking exemption. If a company uses drone technology without considering the COA application process, serious consequences may apply. In 2014, the FAA has granted all law enforcement permission to investigate suspicious UAV use. This includes permission to bring in the UAV pilot in for questioning and investigation. If law enforcement realizes the company has not fulfilled the COA requirements, the FAA can file a lawsuit against the company. The consequences become especially dire if the UAS is operated "in a way that endangers the safety of the NAS" (FAA, 2014b).

The year 2015 was busy for the UAS market and since February 2015, the number of Section 333 exemptions has dramatically increased. As of December 2015, the FAA has granted 2,614 petitions and closed 399 petitions for Section 333 exemption. This number is expected to continue growing daily, and the most updated information is on the FAA website.

As part of the Freedom of Information Act (FOIA), the FAA has published the list of government entities that have completed their COA process. As of December 2015, there are 75 completed COAs for government entities. The members on the COA list are very diverse; for example, there are COAs granted to Air Force research, university research, sheriff offices, and emergency services.

To help regulate the use of UAS, the FAA has published a set of proposed rules to homogenize the UAS permission process. These proposed rules are in the following section.

1.2 FAA Small UAS National Proposed Rule Making (NPRM)

The following lists are the proposed rules for UAS regulation in the United States that have yet to be finalized, but are available for reference (FAA, 2015d).

1.2.1 Operational Limitations

- Unmanned aircraft must weigh less than 55 lbs (25 kg).
- Visual line of sight (VLOS) only; the unmanned aircraft must remain within VLOS of the operator or visual observer.
- At all times the small unmanned aircraft must remain close enough to the operator for the operator to be capable of seeing the aircraft with vision unaided by any device other than corrective lenses.
- Small unmanned aircraft may not operate over any persons not directly involved in the operation.
- Daylight-only operations (official sunrise to official sunset, local time).

- Must yield right-of-way to other aircraft, manned or unmanned.
- May use visual observer (VO) but not required.
- First-person view camera cannot satisfy "see-and-avoid" requirement but can be used as long as requirement is satisfied in other ways.
- Maximum airspeed of 100 mph (87 knots).
- Maximum altitude of 500 feet above ground level.
- Minimum weather visibility of 3 miles from control station.
- No operations are allowed in Class A (18,000 feet and above) airspace.
- Operations in Class B, C, D, and E airspace are allowed with the required ATC permission.
- Operations in Class G airspace are allowed without ATC permission.
- No person may act as an operator or VO for more than one unmanned aircraft operation at one time.
- No careless or reckless operations.
- Requires preflight inspection by the operator.
- A person may not operate a small unmanned aircraft if he or she knows or has reason to know of any physical or mental condition that would interfere with the safe operation of a small UAS.
- Proposes a micro UAS option that would allow operations in Class G airspace, over people not involved in the operation, provided the operator certifies he or she has the requisite aeronautical knowledge to perform the operation.

1.2.2 Operator Certification and Responsibilities

- Pilots of a small UAS would be considered "operators."
- Operators would be required to:
    - Pass an initial aeronautical knowledge test at an FAA-approved knowledge testing center.
    - Be vetted by the Transportation Security Administration.

    - Obtain an unmanned aircraft operator certificate with a small UAS rating (like existing pilot airman certificates, never expires).
    - Pass a recurrent aeronautical knowledge test every 24 months.
    - Be at least 17 years old.
    - Make available to the FAA, upon request, the small UAS for inspection or testing, and any associated documents/records required to be kept under the proposed rule.
    - Report an accident to the FAA within 10 days of any operation that results in injury or property damage.
    - Conduct a preflight inspection, to include specific aircraft and control station systems checks, to ensure the small UAS is safe for operation.

1.2.3 Aircraft Requirements

- FAA airworthiness certification not required. However, operator must maintain a small UAS in condition for safe operation and prior to flight must inspect the UAS to ensure that it is in a condition for safe operation. Aircraft Registration required (same requirements that apply to all other aircraft).
- Aircraft markings required (same requirements that apply to all other aircraft). If aircraft is too small to display markings in standard size, then the aircraft simply needs to display markings in the largest practicable manner.

1.2.4 Model Aircraft

- Proposed rule would not apply to model aircraft that satisfy all of the criteria specified in Section 336 of Public Law 112-95.
- The proposed rule would codify the FAA's enforcement authority in Part 101 by prohibiting model aircraft operators from endangering the safety of the NAS.

Following the federal rule-making process, numerous public comments have required analysis and response. The process has continued into early 2016. Adoption of the rules is anticipated by mid-year 2016. Certain details of these proposed rule changes are more controversial than others. The survey section of this report has more information on comments from transportation offices regarding the proposed rulings. The proposed rule includes setting a maximum flying altitude of 500 feet, and some transportation offices believe UAS flying height should be well below the altitude where manned aircraft are operating. Benefits of these proposed rules include an expedited process for approving UASs intended for use at or below 200 ft. In addition, rather than requiring the operator to have a private pilot license, the operator must pass a knowledge test created by the FAA and be vetted by the Transportation Security Administration (TSA; FAA, 2015c).

After a 10-month selection process, six locations out of 24 were selected on December 30, 2013, by the FAA to develop drone test sites (Straw, 2013). According to the FAA, the following are approved UAV testing sites: (1) University of Alaska, which became operational on May 5, 2014, with test ranges in Hawaii and Oregon; (2) State of Nevada, which became operational on June 9, 2014; (3) New York's Griffiss International Airport, which became operational in August, 2014, including test ranges in Massachusetts; (4) North Dakota Department of Commerce/University of North Dakota, which became operational on April 21, 2014; (5) Texas A&M University-Corpus Christi, which became operational on June 20, 2014; and (6) Virginia Polytechnic Institute and State University (Virginia Tech), including test ranges in New Jersey in partnership with Rutgers University (FAA, 2015e).

Clarke (2014c) published another review of research literature to enhance a comprehensive understanding of drone technologies. Clarke started this research by reviewing critical computing literature, especially the parts which are related to decisions made with computers, data communications, robotics, cyborgs, and surveillance. Clarke believes that the main function of drones is surveillance. Since drones are dependent on remote data and control-feeds from sensors they carry, it is "essential that drones have a contingent fail-safe operations designed-in" (Clarke, 2014c).

1.3 Potential Applications of UAS Technology

Drones surveillance applications include but are not limited to tracking of wildlife and livestock, measurements of geophysical and meteorological phenomena, monitoring the environment, monitoring large scale construction projects such as buildings, observing energy infrastructures such as gas and water pipelines and electricity networks, and monitoring road, air, and sea traffic (Clarke, 2014a).

Many government agencies believe drone application will benefit civilian needs, despite the obstacles involved in drone usage. They might be used to help with accident investigations for clearing roads faster or to monitor congested highways for backups (Yamanouchi, 2013). According to Yamanouchi, Georgia Tech is receiving funds from the Georgia Department of Transportation (GDOT) to investigate the applicability of improving GDOT's online navigation map of highway congestion using drones. Dr. Javir Irizarry, a researcher at Georgia Tech, anticipates this to be much more beneficial than the limited field of vision provided by existing stationary cameras on highways. Georgene Geary, a GDOT research engineer, also believes that drones can improve the speed, safety, and cost of bridge inspections compared to the current costs of workers and equipment (Yamanouchi, 2013).

Based on Ro et al. (2007), a promising application of drones is to enhance the systems of traffic monitoring which serves as an important component in the Intelligent Transportation System (ITS). In rural areas, the sparse traffic monitoring systems are used only for observing simple traffic counts at specific locations. Comprehensive traffic operations are obviously not recorded in rural areas. The reason behind this limited use of the traffic monitoring system in rural areas is cost effectiveness. Because of that, UAVs provide a cost-effective mode that meets rural traffic surveillance system needs.

Ro et al. (2007) investigated the feasibility of using UAVs in monitoring urban highway traffic as an important part of the ITS infrastructure including the current regulatory and technical issues. A small UAV system called MLB's BAT III was used to evaluate UAV capabilities in performing civil applications. The necessary requirements to improve UAV systems include: (1) Improve see-and-avoid capabilities of the UAV by adding a lighting beacon, a transponder, and other technologies; (2) improve UAV applicability in urban/suburban areas, short landing, and special recovery system; and (3) prevent communication failures with redundant communication systems.

Coifman et al. (2006) investigated the use of UAV for monitoring traffic on roadways and demonstrating and developing many other applications by using data collected via a UAV in an urban location. They presented methodological developments to use the UAV's data for multiple applications. These applications include annual average daily traffic, service level, original destination flows on small network, intersection operations, and the utilization of a parking lot. All of these applications were obtained from a UAV flight of less than 2 hours. Data analysis was done manually with the aid of a computer to simplify tasks. The evaluation of these measures reflects the feasibility of obtaining beneficial information from images that are sampled from a UAV for both real-time management applications and off-line planning. It is recommended that if UAVs will be used in large scale for any of the applications mentioned, an additional aid might be required to support analysis, such as software tools to keep the field of view (FOV) on the road or make measuring distances within the FOV easier, and using hardware such as multiple cameras or lenses to extend the FOV.

Based on Karan, Christmann, Gheisari, Irizarry, and Johnson (2014), state Departments of Transportation (DOTs) in the United States have considered the integration of UAS technology for different applications including monitoring the environmental conditions of roadsides, tracking construction projects on highways, traffic safety and management applications, and structure inventory performance for road maintenance. Some DOTs are focusing on specific scenarios of using UASs. According to Karan et al., UAVs can carry several sensors and/or equipment, such as video cameras equipped with near and far infrared, specialized communication devices, range finders based on radar or laser, and with sensors currently being used in the functions and operations of several DOTs.

UAVs may be used in a wide range of planning applications and transportation operations, including monitoring the traffic, weather, and pavement conditions of freeways and roadway networks. UAVs also support emergency vehicle guidance, incident responses, measuring the usage of roadway, monitoring the utilization of parking lots, estimating origin and destination, traveler information, tracking vehicle movements at an intersection, and coordinating among a traffic signal network (Coifman, McCord, Mishalani, & Redmill, 2004). UAVs have several advantages over manned vehicles in that most operations can be performed at a much lower cost, safer, and faster (Puri, 2005). Based on Barfuss, Jensen, and Clemens (2012), it is expected that UAV can be used to split construction zones into different intervals of construction time, with the potential of additional benefits throughout construction zones by identifying the best methods for moving traffic safely.

High resolution highway photographs can be taken using UAVs guided via satellite. These images could allow for efficient ways in providing required information to monitor and follow up ongoing roadway construction, inventory different features of highways, evaluate the existing conditions of roadways, and classify plant species that would be removed while constructing a future highway. In addition, benefits of UAV images may include providing the Geographic Information System (GIS) database with aerial photos faster by reducing the time between taking a photo and adding it to the GIS database. This is a benefit over satellite images that are usually updated every few years. Other benefits of UAV imagery would be monitoring wetlands and weeds along corridors of highway, inventorying highway structures, retro-reflectivity of roadway painting and stripping, stream crossing, and bank erosion (Barfuss et al., 2012).

Zhang and Elaksher (2012) introduced research on using a UAV-based digital imaging system to collect efficient surface condition data over rural roads in United States. A three-dimensional (3D) surface model was used to measure distress over a road distress area. The system that was used consisted of a low-cost helicopter, an onboard digital camera, a GPS receiver, an Inertial Navigation System (INS), and a geometric sensor. They developed a set of processing algorithms to generate 3D road surface models, and to generate accurate and precise orientation of the images. They tested the developed model in several testing sites of rural roads that have different surface distresses near Brookings, South Dakota. The results of testing and experimentation demonstrated that the adopted UAV-based digital imaging system is highly promising, with a high degree of reliable and accurate results.

1.4 Concerns of UAS Usage

Drone technologies can negatively impact the economy by displacing human jobs and income distribution as a result of automation. Drones have an expected negative impact on the environment, as determined by the drone's source of energy and usage level. Regardless of the benefits of drone usage, the technology also creates new sources of harm such as accidents and violent usage (Clarke & Moses, 2014). Clarke and Moses discussed the public safety issues of drone usage in civilian missions and suggested that negative effects could be minimized using regulatory regime that control and evaluate the usage of drones.

As mentioned earlier, the FAA relies on law enforcement to intervene in suspicious UAV use in both civil and commercial applications. The FAA Modernization and Reform Act of 2012, Public Law 112-95, states that FAA approval is not necessary for hobby UAV use, but "all model aircraft operators must operate safely and in accordance with the law" (FAA, 2012). Law enforcement has the authority to shut down any UAV use that is operated in a way that poses potential danger to people or property (FAA, 2014b).

Safety and privacy must be considered when standardizing drone usage. The public's opinion of civilian use of UAVs is growing in concern for privacy. For example, Jennifer Lynch, attorney for Electronic Frontier Foundation, believes that there will be privacy concerns when UAVs are commonly used because, "It's easy to see the drone (in flight, so) it's easy to recognize the privacy implications," meaning people who see the UAV may believe they are being watched or "spied on" (Serna, 2014). Researchers Finn and Wright (2012) analyzed the surveillance, ethics, and privacy impacts of civilian UAS use. They claimed that current regulatory mechanisms related to UAS do not sufficiently address civil liberties and privacy concerns because UASs consist of complicated multi-modal systems of surveillance that employ several capabilities and technologies. Higher regulations of civil applications could help with privacy concerns, but the problem is that the definition of privacy is vague and varies for each individual. These researchers suggest legislated requirements and impact assessments to address these privacy concerns.

The main topic of privacy discussions related to drones is the protection of data (Clarke, 2014a). Clarke conducted research on civilian drone use to examine regulations and how important privacy is to civilians while they conduct their normal activities and behaviors. Clarke mentioned that specific regulations should be agreed upon by involving the public, governmental, and non-governmental agencies since drones have an important impact on the privacy of civilian behavior.

Unmanned aircraft systems are flying under highly controlled conditions in the NAS. Several tasks are being performed by different types of UAVs including border and port surveillance by the Homeland Security Department, supporting public safety by agencies of law enforcement, assisting in scientific research and environmental monitoring by the National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA), assisting state universities in conducting research, and supporting other public entities and governmental missions (FAA, 2015e).

1.5 UAS Applications Related to DOT Operations

Irizarry, Gheisari, and Walker (2012) discussed the initial application of drone technology in the construction industry. They used a small-scale drone as a tool to investigate the potential benefits of drones to safety managers in the inspection of construction sites. The drone they used was an aerial quadcopter that can be piloted remotely using a tablet device, smart phone, or a computer. Because this drone was equipped with video cameras, it had the ability to provide the safety manager with fast access to images as well as the real-time videos from several locations around the inspection site. They performed expert analysis (heuristic evaluation) and user participation analyses to determine the different features to be installed on the drone used for inspection of the construction sites. The results of the two evaluations lead to the recommendation of adding advanced features to the safety inspection drones, which include autonomous navigation, cameras with high resolution, vocal interactions, and a collaborative user-interface environment. The authors also concluded that the application of drones has the potential to improve construction practices and safety inspection for sites.

Metni and Hamel (2007) conducted research on using UAVs in a bridge inspection and for traffic surveillance. They used a UAV that has the ability of performing quasi-stationary flights to inspect bridges and detect defects and areas with cracks. The UAV that was utilized was equipped with a camera, image transmitter, and a vision system that included GPS and the Inertial Navigation System (INS). The UAV followed a predefined path and was controlled by a vision-based robot control. The captured images were processed to detect cracks and defects on bridges. To validate the concept of inspecting bridge defects using an onboard UAV visual device, Metni and Hamel performed an on-site experiment with the assistance of a helicopter that flew for a few minutes around a bridge in France and recorded a video. This was considered a test for applicable regulations and security measures for using UAV. The selected bridge carried high traffic and was located in an urbanized area, functioning as a connection of two neighboring airports. The captured images were presented to experts in bridge inspection. These images represented promising potential in obtaining useful information compared to visual inspections.

1.6 UAS Studies in Transportations

1.6.1 Utah Department of Transportation

Barfuss et al. (2012) performed a project for the Utah Department of Transportation (UDOT) to improve the usability of UAV applications for highway related problems. They used a UAV to take high-resolution images in two phases of the project. In the first phase, the UAV was used to take high-resolution aerial images for the Southern Parkway Highway corridor project. These images were taken before, during, and after the completion of the highway. In the second phase, they used the UAV at a Utah lake wetland mitigation bank to classify wetland plant species. In both phases' locations, several UAV flights were made. Digital images were taken by UAV onboard cameras. These high-resolution images were used to allow accurate utilization in the UDOT GIS database and as a classification tool of USDOT plant species.

In the Southern Parkway UAV task by Barfuss et al. (2012), the images assisted researchers in observing the construction progress, cut and fill regions, and construction phases' areas. These high resolution images assisted researchers in updating the UDOT GIS database along with updating roadway signage and structures of highway documentation and inventory, and also provided construction records over time. In the Utah lake wetland mitigation bank phase, the UAV was used to take images in Near Infrared (NIR) and Red-Green-Blue (RGB) to help classify plant species that may be removed when constructing a future road. The image helped in accurately determining most classified species accurately for many types of plants; however, for other plant species, the images provided rather low classification accuracy.

For the Utah project, it's worth mentioning that the initial draft of the scope of work included the additional objective to fly and map the corridor of State Route 6 highway in order to update its aerial images after construction of the road. Unfortunately, this part of project was abandoned because of some safety concerns and later was replaced by the Utah lake wetland mitigation bank project. Reasons included disrupting traffic due to the slow movement of the ground station, distracting drivers during takeoff and landing, and not having enough area for takeoff and landing (Barfuss et al., 2012).

Barfuss et al. (2012) concluded in their research that UAVs could provide benefits to UDOT for those tasks that require immediate aerial images which will update aerial images on UDOT's GIS database, which resulted in improving functions and providing newer images for decision making. These tasks may include roadways that are under construction, proposed roadways, roadways that require repair and maintenance, and the structures of existing roadways. The UAV images could also be a beneficial and an economic means for wetland monitoring and classification of plant species, saving time and reducing costs.

1.6.2 Georgia Department of Transportation

Irizarry and Johnson (2014) started performing a feasibility study of using UAS in the operations of the Georgia Department of Transportation (GDOT) in April of 2013. In their study, Irizarry and Johnson introduced several UAS applications to be adapted for performing some DOT operations in transportation, traffic management, and construction. These UAS applications include the ability to get digital photographs or videos, to obtain real time images and videos, integrating aerial data into GDOT drawing software programs, providing the "bird's eye view" that is obtainable through the assistance of manned air vehicles, accessing complicated areas of terrain, and performing hard and difficult tasks for the GDOT personnel.

Irizarry and Johnson (2014) studied all GDOT divisions and offices to find those that can benefit from using UAVs in accomplishing the different operations. Of the 12 GDOT divisions, four divisions have the highest potential to benefit from adapting UASs to perform several operations such as construction, engineering, intermodal, and permits and operations. Irizarry and Johnson conducted 24 personnel interviews in the selected GDOT divisions focusing on three main objectives: (1) the division information requirement, (2) operators' basic tasks in each division, and (3) operators' main decisions to accomplish their tasks in their divisions.

Based on the results of these interviews, and after validating the interview information, the researchers developed the required design characteristics of UAVs to accomplish the requirements of users in the four GDOT divisions. The particular UAV platform may call for a system with rotary wings or fixed wings, the appropriate sensors, the payload component, the vehicle sizing according to capacity of the needed payload to match with the airframe choice, and finally the means of propulsion for the UAV such as gasoline or electric power.

Irizarry and Johnson (2014) divided the UAV into three parts: vehicle, control station, and system. The vehicle component includes the UAV requirements that are basically the airframe hardware and related equipment. The control station component includes the hardware and software requirements for the control station of the UAS operator. The guidance, navigation, and control (GNC) aspects, including specialized software, represent the system component.

1.6.3 Washington Department of Transportation

McCormack (2008) performed a study to test two models of UASs for applications in data collection and surveillance. The two models tested are the MLB Bat and Yamaha R-max. The first test used the MLB Bat in harsh winter weather in the state of Washington. The initial launching of this fixed-wing aircraft failed due to human error and the next successful launch only resulted in a 22-minute flight due to weather restrictions. The MLB Bat was able to autonomously follow a pre-determined altitude of 600 feet, but was unable to fulfill demands for flying up to 1,500 feet due to turbulence. The next test was the rotary-wing Yamaha R-max. Over the course of 2 days, a total of nine flights were completed in order to test different UAS applications such as package delivery, surveying, and search and rescue. This testing found GPS inaccuracies, weight restrictions, and safety precautions that limit the distance the UAS may fly.

Both tests faced problems in human error as well as some technology glitches. These problems were severe enough for the test crews to avoid pushing the UAVs to certain altitudes and distances that they originally wanted to test. Comparisons between these test flights are difficult to analyze because of the substantial impact the weather had on testing these aircraft. Perhaps the technology has improved enough since the 2008 test that another round of test flights could reach the limits not met in WSDOT's original tests. Regardless of research inconsistencies, the University of Washington was able to produce the following benefits and drawbacks to both fixed and rotary-wing UAS models.

- Fixed-wing
    - Pro: Thoroughly tested by other universities, better endurance, and easier to operate.
    - Con: Less mobile, poorer quality of images because it does not hover, and requires a longer launching runway area.
- Rotary-wing
    - Pro: Vertical landing and takeoff capabilities, hovering capabilities allow for clearer pictures and live streaming video.
    - Con: Less testing done on this model, and short-term endurance.

The report from WSDOT leaves much to be desired in the section on cost estimates. The only reported values for costs associated with purchasing of aircraft and equipment, training, and replacement cost of destroyed or lost UAVs is $97,500. Furthermore, this section fails to provide cost savings from eliminating roadside cameras, reducing worker hours, avoiding incidents from structure failure, etc. Much more information and analysis is necessary for WSDOT to weigh the options of utilizing UAV technology, or for other state DOTs to utilize research findings.

1.6.4 Arkansas Department of Transportation

In November of 2014, Arkansas State Highway and Transportation Department (AHTD) published a report on visual aids to assist in corridor analysis (Frierson, 2014). The original topic of AHTD's research was to measure the cost effectiveness of using UASs to monitor traffic. However, the focus shifted to the use of Lighter-Than-Air Surveillance (LTAS) once it became clear how limited UASs are in terms of FAA regulations and equipment restrictions, e.g., short flight times. The two types of LTAS systems tested in the research were the mobile mast camera and helium balloon system. Highway traffic flow was recorded and analyzed using VisSim software.

This project ran into some difficulties when analyzing the recorded video. Stabilizing equipment was used on a helium balloon to get better footage. Unfortunately, this made the video sizes too large for the software to analyze quickly. Even though the balloon could maintain an altitude of 500 feet, the AHTD determined this method infeasible because it would simply not produce quality images or video. The helium balloon was also a costly option since it needed almost $300 worth of helium, and at least 6 people to set up.

The AHTD determined that the best option for monitoring traffic flow was to use a 58-foot-tall mobile mast-mounted camera. Benefits of this surveillance method include lower cost, less equipment, ease of use, and better photo/video quality.

This AHTD report did not go into much detail about specific costs for the project. For the purposes of corridor surveillance and data collection, this report suggests a mounted camera will provide effective results in a much more cost effective way than by using UAS technology.

1.6.5 North Carolina Department of Transportation

The research conducted on UAS applications by North Carolina included optimistic views on the growth of the aviation industry. An economics report from the Association for Unmanned Vehicle Systems International (AUVSI) predicts that approximately 1,200 jobs will be created in North Carolina by 2025 as a result of emerging UAS technology (Jenkins & Vasigh, 2013). North Carolina is expecting its aerospace manufacturing sector to expand as a result of commercialized UAS technology. The open farmland and maritime access means North Carolina can provide thorough UAS testing and research, so this state is well suited for the increase in aviation technology.

A “UAS Working Group” in North Carolina discussed all of the possible pros and cons of either purchasing a UAS for the state or to use a third party for UAS operations. The pros and cons of purchasing a small UAS for state use are listed below. Note that this is taken directly from the North Carolina Unmanned Aircraft Report (Estes, 2014).

1. Pros:
    i. Small UAS (less than 55 pounds) can be cost-efficient for state and local agencies that have aerial asset needs, and the costs of operations and maintenance can be relatively low.
    ii. Sensors, data collection, and processing techniques that are not proprietary to vendors.
    iii. Self-containment of UAS capabilities – staff, equipment, policies.
2. Cons:
    i. Maintaining flight currency could be added to existing employee workloads.
    ii. The cost of dedicated crews (if needed) must be factored into new programs, including maintaining medical certificates for pilots and observers.
    iii. The capabilities of the agency-owned UAS potentially limit what missions could be performed.
    iv. The design life for a robust small unmanned aircraft system is typically 75-100 flights between major repairs/replacement. That lifecycle can be anywhere from 2 to 3 years. Although the system is more affordable than a manned aviation asset, asset management costs must be factored into the purchase decision analysis, not just the initial acquisition.
    v. More difficult to maintain common processes and resources for data management, equipment logistics, potential inter-agency sharing, and reporting.

As mentioned earlier, the alternative to purchasing a UAS for the state is to contact a third party to conduct the UAS task. This option comes with its own pros and cons as listed in the North Carolina report (Estes, 2014), which are shown below.

1. Pros:
    i. A leasing arrangement allows the state to benefit from the latest technology and provides agencies with access to various types of aircraft that are appropriate for a wide range of missions.
    ii. A leasing arrangement relieves the agencies of the cost and burden of having to maintain aircraft and continue to prove airworthiness.
    iii. The vendor would be responsible for the purchase, care, and maintenance of the payload on board its own aircraft, whether video camera, still camera, infrared sensor, or other technology.
    iv. The vendor who offers UAS services would have to provide a manned pilot in instances when the FAA requires UAS to be operated by a trained and FAA-licensed manned aircraft pilot.
    v. UAS aircraft are flown with an operations core (transmitters, equipment, vehicles, data storage devices, sensors). A leasing arrangement gives the vendor responsibility for logistics and maintenance of that equipment.
2. Cons:
    i. The costs associated with a vendor's lease option are not yet known. A by-hour or by-day arrangement with a vendor for end-to-end services could be cost prohibitive.
    ii. The possibility of vendors utilizing proprietary sensors, algorithms, techniques that have public use restrictions.
    iii. Under current conditions, the state as the public agency is still responsible for confirming the airworthiness of the UAS, ensuring the crews are properly trained, and obtaining a COA for every potential flight location.

The Next Generation Air Transportation Center (NGAT) of North Carolina has provided a detailed cost estimate of implementing UAS usage at NCDOT. The cost analysis table from the North Carolina report is shown in Table 1.1. The program costs include cost of startup, recurring costs, data storage, analysis, and upkeep (Estes, 2014).

Table 1.1: Cost Estimate of Implementing UAS at North Carolina

UAS Program Costs		up Costs	Annual Recurring	Description
Equipment				
	Fixed Wing Aircraft system	$ 150,000	$ 22,500	complete aircraft system (2 aircraft) with HD camera payloads
	Multi-copter Aircraft system	$ 65,000	$ 9,750	complete aircraft system (1 aircraft) with HD payload
	Infra-red payload	$ 20,000	$ 3,000	small IR payload for use on both systems
	Mobile Command Vehicle	$ 50,000	$ 7,500	response vehicle with connectivity, radio gateway, storage, display and computing racks
	Radios	$ 5,000	-	for field communications
	4x4 vehicle	$ 10,000	-	for operational area mobility
	Data Management System	$ 130,000	$ 65,000	for video analytics, storage, cataloguing, sharing, audits
	Flight Ops Management Software	$ 130,000	$ 65,000	for resource, crew, and flight ops management, supports FAA/state reporting requirements
	Computing hardware	$ 25,000	$ 3,750	data repository
	Field Supplies	$ 15,000	$ 3,750	Generators, batteries, tents, binoculars, tools, etc to support field operations
		$ 600,000	$ 180,250	
Staffing		salary		
	Chief Pilot	$ 65,000	$ 65,000	This is a UAS pilot. Recommend at least an FAA instrument rated pilot.
	Observer #1	$ 25,000	$ 25,000	Ground observers must have Class 2 FAA Medical certificates.
	Observer #2	$ 25,000	$ 25,000	Ground observers must have Class 2 FAA Medical certificates.
	Data Analyst	$ 55,000	$ 55,000	This position will manage the UAS captured data providing mission analysis and meeting state policy requirements.
	Mission Coordinator (Range Manager, Airspace Coordinator)	$ 50,000	$ 50,000	This position will oversee flight operations, coordination with FAA, flight crew training and currency status.
		$ 220,000	$ 220,000	
Resources				
	Travel for UAS operations	$ 5,000	$ 10,000	
	NGAT Consulting Support	$ 25,000	$ 25,000	
	TOTAL	**$850,000**	**$ 435,250**	

Chapter 2: Drone Registration

The most recent news for drone applications occurred Monday, December 15, 2015, when the FAA announced a registration plan for drones. Comments by Deputy FAA Administrator Michael Whitaker were published by the Associated Press in the Manhattan, Kansas, Mercury newspaper (December 16, 2015) saying that hundreds of reports are filed each month about close calls between drones and manned aircraft. No matter the experience level of the aviator, "They have the responsibility to fly safely and follow the rules and regulations that apply to them" ("FAA to require," 2015).

This new FAA requirement of registration applies to UASs that weigh anywhere between a half-pound to 500 pounds. The article includes comments from the Muncie, which is an Indiana based Academy for Model Aeronautics. Their comment is that the registration is an "unnecessary burden to those who have been operating safely for years." However, they agree that requiring registration of drones owned by the general public makes sense. For commercial and government entities, the registration is just a time-waster since they already require a 333 Exemption or COA ("FAA to require," 2015).

Chapter 3: General Applications of UAS

Throughout the duration of this research, new applications of UAS drones and increased news coverage emerged. The information that has been available to the general public regarding commercial UAS applications is summarized below.

3.1 Connecticut Department of Transportation Testing

A recent news story that applies very closely to this research is the announcement of the Connecticut Department of Transportation (ConnDOT) testing drones for bridge inspections. ConnDOT Commissioner James Redeker believes that keeping an open mind to innovative ideas is "critical if we are to find better ways of doing business." The selected bridge for this test has a history of being difficult to inspect with snooper trucks and climbers. The results of the effectiveness of the drone application will be assessed, and hopefully shared with other DOT offices (Hill, 2015).

3.2 Burns & McDonnell and Black & Veatch

In October 2015, the Kansas City Star published an article about Burns & McDonnell's addition of a drone to its operations (Hack, 2015). The firm's manager of geospatial services speaks highly of drone application in the work that they do. The manager claims that the imagery and videos collected from a drone are much higher quality, collected faster, and are a fourth of the cost of traditional methods. Burns & McDonnell is looking to apply the drone to examine vegetation health, wetland areas, and surface temperatures to assist in their projects. This company is expanding the drone applications to its other offices in Houston, Connecticut, California, Denver, and Minneapolis.

Also in this article, Black & Veatch published their statements on drone usage for tower inspections. Their chief technology officer spoke in detail about the apparent advantages of using a drone to inspect cell towers. The advantages are in the reduced time, increased safety, and higher quality of images (Hack, 2015).

3.3 Amazon Announcement

Amazon has not kept their drone research a secret and continues to release statements to the media about their plans for package delivery via drones. The company's "Prime Air" drones are already built and being tested; however, numerous regulations and functional restrictions must be satisfied before they can be deployed operationally. The United States will have to finalize its regulations before Prime Air can launch, and the aircraft being tested only has a payload of 5 pounds and 30 minutes of flight time. Instead, Amazon announced that the first test site will be in Chiba City, Japan, given its lax regulatory environment ("Amazon unveils," 2013).

3.4 Security and Search-and-Rescue

Another recent news article in USA Today mentions the potential application of drones in security and search-and-rescue missions (Weise, 2015). Drone manufacturer DJI is pairing with FLIR, the company named for its thermal imaging technology used in systems of "forward-looking infrared radar," to produce drones that can be used in search-and-rescue, firefighting, security, and surveillance. The current application of thermal imaging by police is on helicopters when searching for suspects at night. This collaborative project is named Zenmuse XT and will be available in 2016.

Chapter 4: Survey Response

A 36-question survey was distributed to leaders in Department of Transportation offices across the country. A detailed list of survey recipients is available in Appendices D and E. The first half of the survey inquires about the DOT's current methods and technology. In the second half of the survey, the questions explore the stance of the DOT on UAS applications. These questions allow us to see if the states have considered using this new technology and the motivation behind implementing it. In addition, the survey requests advice on traversing the regulations for an FAA exemption.

A 60% response rate was achieved in this survey. The figure below indicates the responses from different areas of the United States. As indicated in Figure 4.1, four DOTs claim to currently be utilizing UAS technology, which will be addressed later.

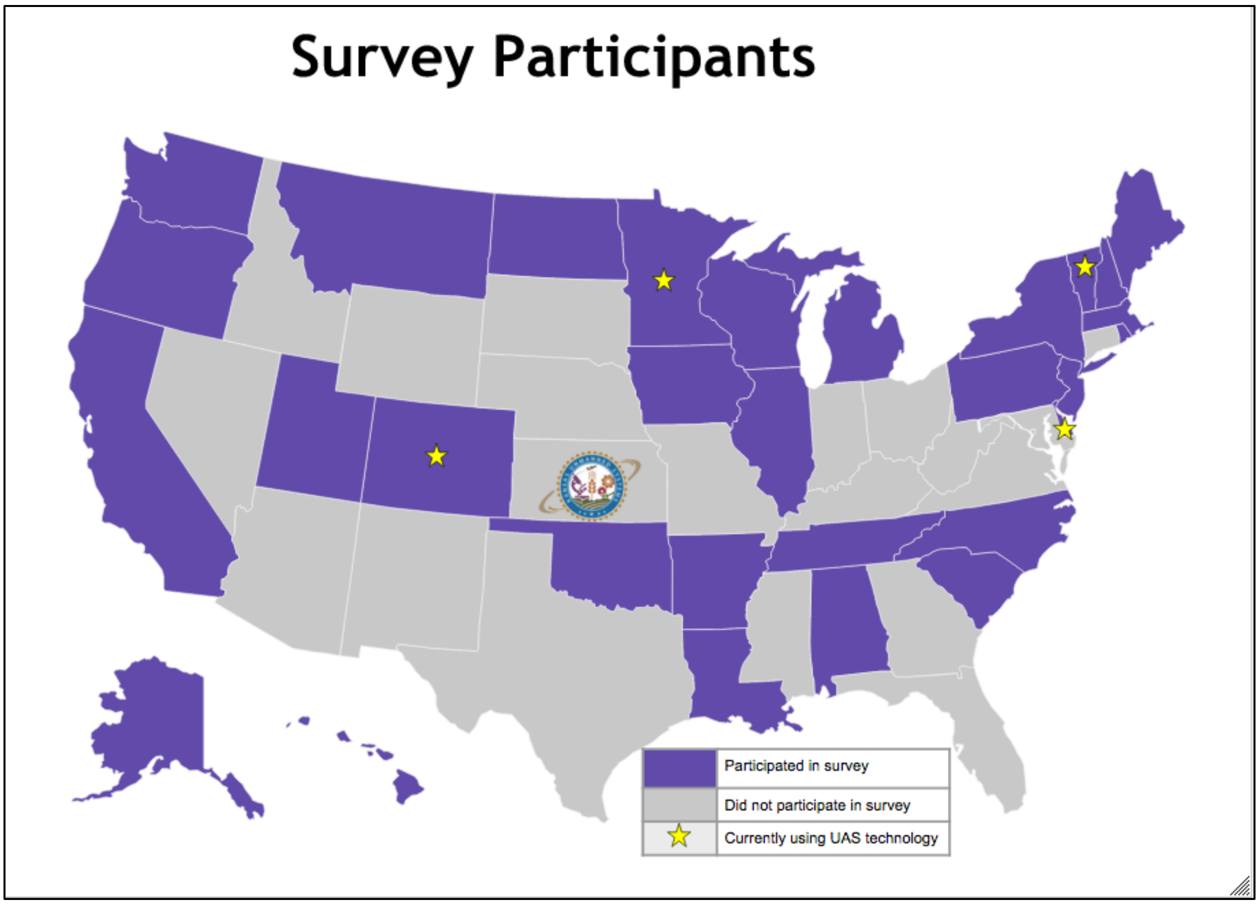

Figure 4.1: Map of Survey Participants

The 30 survey respondents are from the states listed in Table 4.1; the job title of the survey respondent is listed as well.

Table 4.1: Job Titles of Survey Respondents

State	Job Title
Alabama	State Maintenance Engineer
Alaska	Deputy Commissioner of Aviation
Arkansas	Division Head
California	Chief
Colorado	Interim Director
Delaware	Transportation Planner and Aeronautics Coordinator
Hawaii	State General Aviation Officer
Illinois	Director
Iowa	Systems Operations Bureau Director
Louisiana	Aviation Director
Maine	Assistant Director, Bureau of Planning
Massachusetts	Administrator
Michigan	Engineer of Operations and Maintenance
Minnesota	Photogrammetric Unit Supervisor
Montana	Chief Engineer
New Hampshire	Aviation Planner
New Jersey	Manager
New York	Civil Engineer II
North Carolina	State Photogrammetric Engineer
North Dakota	Director
Oklahoma	Engineering Manager
Oregon	Agency Director of Oregon Department of Aviation
Pennsylvania	Aviation Safety Specialist Supervisor
Rhode Island	Aeronautics Inspector
Tennessee	ITS Program Manager
South Carolina	Executive Director
Utah	Deputy Maintenance Engineer
Vermont	Aeronautics Administrator
Wisconsin	Photogrammetry Unit Supervisor
Washington	Avalanche Forecast Supervisor

Questions 1 through 4 gather information regarding the participant's location, division, and employment title at a given DOT. Survey answers start at Question 5 below.

Question 5: What technology or methods does your state's DOT currently use for maintenance of transportation structures?

Table 4.2 shows that the most common methods of maintaining structures such as highways, bridges, railroads, and others are through physical labor and LiDAR.

Table 4.2: Responses to Question 5

Answer	Responses	Percentage
Physical Labor	28	96.55%
LiDAR	13	44.83%
Live Feed Video Camera	12	41.38%
Magnetic Field Sensors	6	20.69%
Infrared/thermal Imaging	6	20.69%
Other	5	17.24%
Radar	5	17.24%

Question 6: If "other," state here.

There were four responses to Question 5 that indicate "other" sources of maintenance that were not listed as options in the questions. The "other" responses are shown below.

- Visual inspection
- The Bridge Management System (BMS) which is a component of the States Asset Management System, a database technology
- Helicopter photos
- Mobile data collection apps, and field tools for data capture

Question 7: What technology or methods does your state's DOT currently use for surveillance?

Table 4.3 indicates the two most used methods of surveillance of state property and structures are through live feed video camera and physical labor.

Table 4.3: Responses to Question 7

Answer	Responses	Percentage
Live Feed Video Camera	24	88.89%
Physical Labor	17	44.83%
Laser Distance Meter	6	41.38%
Other	4	20.69%
Magnetic Field Sensors	4	20.69%
LiDAR	4	20.69%
Radar	4	17.24%

Question 8: If "other," state here.

There were four responses to Question 7 that indicate "other" sources of surveillance that were not listed as options in the questions. The "other" responses are shown below.

- Van with various video cameras including GPS
- INRIX & traditional direct and indirect customer notification (phone calls/e-mails)
- Bluetooth
- Aerial photography

Question 9: What environmental challenges does your state's DOT commonly face during routine operation?

Table 4.4: Responses to Question 9

Answer	Responses	Percentage
Flooding	22	78.57%
High Wind	20	71.43%
Very Low Temperatures	20	71.43%
Very High Temperatures	13	46.43%
Other	8	28.57%
High Altitudes	7	25.00%
Avalanches	5	17.86%
Earthquakes	5	17.86%

Figure 4.1 shows that the DOTs that responded to the survey are located from coast to coast in the US, so it makes sense that a wide variety of environmental challenges are commonly faced by the DOTs. The flooding, high wind, and low temperature answers had the most responses, and suggest that a UAS must be able to operate in those situations, or moderate versions of those environmental challenges.

Question 10: If "other," state here.

There were eight responses provided for the "other" category and are listed below.

- Snow
- Ice storms
- Freeze-thaw cycles
- Salt air
- Tornados
- Wildlife
- Poisonous vegetation
- Endangered species protection

Question 11: Has your department considered the use of UAS?

There are nine survey respondents highlighted below that claim their DOTs are not considering the use of the UAS technology at this time. The remaining 21 DOT offices are considering using UAS. The Yes/No answer of each DOT survey respondent is shown in Table 4.5.

There are 21 survey respondents that answered "yes" to Question 11, and the following question asks at which areas they would most likely apply UAS technology. The nine respondents who answered "no" to Question 11 were still asked which areas they would apply the UAS, but the responses were separated to see how the responses differed.

Table 4.5: Responses to Question 11

Alabama	Yes
Alaska	Yes
Arkansas	No
California	Yes
Colorado	Yes
Delaware	Yes
Hawaii	No
Illinois	Yes
Iowa	Yes
Louisiana	Yes
Maine	Yes
Massachusetts	No
Michigan	Yes
Minnesota	Yes
Montana	Yes
New Hampshire	Yes
New Jersey	No
New York	Yes
North Carolina	Yes
North Dakota	No
Oklahoma	No
Oregon	Yes
Pennsylvania	No
Rhode Island	No
Tennessee	Yes
South Carolina	Yes
Utah	Yes
Vermont	Yes
Wisconsin	No
Washington	Yes

Question 12: If yes, at which areas would you apply UAS technology?

Table 4.6: Responses to Question 12

Answer	Responses	%
Aerial imaging to support Geographic Information System (GIS) database	14	46.67%
Evaluating existing road conditions	12	40.00%
Inspecting defects and cracks of bridges, towers, railways, and highways	11	36.67%
Improving safety of labor when working on highways	10	33.33%
Other	10	33.33%
Monitoring the conditions of the freeway	8	26.67%
Supervision of ongoing roadway construction	7	23.33%
Surveillance of collisions	6	20.00%
Signage inventory	5	16.67%
Tracking vehicle movements at intersections	5	16.67%
Classifying plant species to be removed for constructing future highway	5	16.67%
Emergency vehicle guidance	4	13.33%
Monitoring traffic conditions in rural areas	3	10.00%
Monitoring parking lot utilization	3	10.00%

Question 13: If "other," state here.

- Surveillance of protected species
- Estimation of construction quantities
- Airfield obstruction inspections
- Crash reconstruction
- Confined spaces (culverts and pump stations)

Question 14 and Question 15 are the same for those respondents who input “no” into Question 11.

Question 14: Has your department considered the use of UAS? If no, at which areas would you apply UAS technology?

Table 4.7: Responses to Question 14

Answer	Responses	%
Surveillance of collisions	7	23.33%
Aerial imaging to support Geographic Information System (GIS) database	7	23.33%
Inspecting defects and cracks of bridges, towers, railways, and highways	6	20.00%
Evaluating existing road conditions	5	16.67%
Monitoring traffic conditions in rural areas	5	16.67%
Supervision of ongoing roadway construction	5	16.67%
Emergency vehicle guidance	5	16.67%
Improving safety of labor when working on highways	4	13.33%
Monitoring conditions of the freeway	4	13.33%
Tracking vehicle movements at intersections	4	13.33%
Other	4	13.33%
Monitoring parking lot utilization	3	10.00%
Signage inventory	3	10.00%
Classifying plant species to be removed for constructing future highway	2	6.67%

Question 15: If "other," state here.

- Damage assessment at airports
- Avalanche detection and viewing avalanche start zones
- Damage Assessment
- Construction as-built
- Exhibits for public meetings
- Design of construction projects

Note that the responses in Table 4.7 are from DOTs that have NOT yet considered the use of UAS, and the top responses for where to apply UAS are completely different from the top responses in Table 4.6.

Question 16: What is the biggest motivator for implementing UAS technology in your DOT?

Table 4.8: Responses to Question 16

Answer	**Response**	**%**
Improve safety	21	70.00%
Decreasing cost	18	60.00%
Aerial viewpoint	17	56.67%
Completing projects faster	13	43.33%
Accurate data collection	12	40.00%
Other	2	6.67%
Creating jobs	0	0.00%

Question 17: If "other," state here.

- UAS adds a different viewpoint for surveillance and enhances existing monitoring.
- Cost, safety, and efficiency are all part of a formula for resource investment.

Question 18: Which division in your state will utilize the UAS technology the most? What are these operations?

Table 4.9: Responses to Question 18

Alabama	Maintenance, design, and construction
Alaska	Department of Public Safety - Alaska State Trooper. Assessing accident sites for reconstruction purposes
Arkansas	Surveys, System Information and Research, and Construction
California	Maintenance: highways and bridge structures
Colorado	Bridges, Avalanche control
Delaware	Natural Resources and Environmental Department
Illinois	Department of Transportation, Highways, Aerial Surveys, Bridges, Aeronautics
Iowa	Highways
Louisiana	Agriculture and Forestry, Wildlife and Fisheries, Transportation
Maine	Maintenance & Operations
Massachusetts	Highway Division
Michigan	Operations/Maintenance, Construction, and Asset Management
Minnesota	Bridge Inspection and Photogrammetrics
Montana	Engineering and Surveying
New Hampshire	Department of Safety - traffic and accident monitoring, search and rescue, missing people Department of Resources and Economic Development - State land management Division of Aeronautics, Highway, Bridges, Rail & Transit Fish and Game - conservation and wildlife management
New York	Aviation, Construction, Traffic, Bridge Inspection, Environmental, Public Relations, and Emergency Operations
North Carolina	Photogrammetry Unit, Location & Surveys Unit, Transportation Mobility and Safety, Structures Management Unit, Geotechnical Engineering Unit
Oregon	Forestry, Fish and Wildlife, Agriculture, Department of Transportation Highway Division
Pennsylvania	Safety
Rhode Island	Commercial applications video/photos
Tennessee	Design, Aerial Mapping and Survey, Incident Management, Surveillance/traffic monitoring/Collision Surveillance Structures, Inspection Construction, Survey and Construction Inspection
South Carolina	Surveying approaches/obstructions around airports within the state
Wisconsin	The Bureau of Structures for bridge inspections
Washington	Traffic operations

Question 19: Has your department done any research on potential use of UAS technology?

Fifty percent of the survey respondents have done research on UAS application. Some of their research is summarized in the literature review section.

Table 4.10: Responses to Question 19

Answer	Response	Percentage
Yes	15	50.00%
No	15	50.00%

Question 20: Have you performed a cost benefit analysis for implementing UAS technology? If yes, would you mind sharing your findings with us?

Question 20 had an option for a file upload. Three resources were provided from survey respondents that helped with the literature review and cost analysis. The three reports uploaded in the survey are included in the references section (Caltrans Division of Research, Innovation and System Information, 2014), (Frierson, 2014), and (Lundquist, McCormack, White, Gauksheim, & Vagners, 2013).

Question 21: Have you submitted a COA request, or contacted the FAA about implementing UAS usage?

Note that there are only 29 responses to this question. There were 30 survey respondents in total, and one state did not answer Question 21. The next question asks about COA rejection or approval, and only seven of the nine states that answered yes to this question responded.

Table 4.11: Responses to Question 21

Answer	Response	Percentage
Yes	9	30.00%
No	20	66.67%

Question 22: Was your COA application rejected in your first request? If yes, what changes would you have to make for it to be accepted?

In Table 4.12, only seven states claim to be in the process of completing a COA. This survey was concluded in July of 2015, so these answers do not represent the most current progress. The states who are currently in the COA process do not report any difficulties other than the time commitment.

Table 4.12: Responses to Question 22

State	**Response**
California	We inquired about UAS usage, but have not submitted a COA application to date.
Colorado	No
Delaware	Our COA is still pending.
Louisiana	N/A
Michigan	In process.
Minnesota	We inquired about UAS usage, but have not submitted a COA application to date.
New York	N/A
North Carolina	The COAs are under review at the FAA at this time.
South Carolina	We are in the COA process now.
Tennessee	Created an online account with the FAA to start submitting COAs.

The responses to the next two questions are combined in Table 4.13.

Question 23: Are you currently using UAS technology to aid in your DOT procedures?

Question 24: If yes, how many did you purchase?

The states who answered "Yes" to the question about currently using UAS technology for their DOT were contacted for further information. Colorado is using a QAV500 quadcopter and an S800 hexacopter for inspections of highways, wetlands, debris flow, landslides, and rock fall. In Delaware, their DOT is using an Atlas 1 quadcopter for surveying and photographing environmental resources. The Minnesota DOT has a homemade quadcopter and is in the testing phases of an aerial mapping project. Minnesota also plans to use UAS for photographing mine wall, cracks, and joints in the future. The fourth state, Vermont, was not available for contact to gather this information.

Table 4.13: Number of UAS Models Purchased for States Currently Using UAS

State	**Response**
Colorado	Yes, 2.
Delaware	Yes, 1.
Minnesota	Yes, 1. We have a current project utilizing a UAS to take pictures of a mine wall as part of a rock joint study to estimate stability as the mining operation gets closer to the roadway. This is being done by a consultant.
Vermont	Yes, Unknown.

Question 25: Are you currently using UAS technology to aid in your DOT procedures? If yes, what areas do you use the UAS?

Question 26: If "other," state here.

Table 4.14: Responses to Question 25

Response	Responses	Percentage
Construction	2	6.67%
Inspecting defects and cracks of bridges, towers, railways, and highways	2	6.67%
Inspection	2	6.67%
Aerial imaging to support Geographic Information System (GIS) database	1	3.33%
Classifying plant species to be removed while constructing a future highway	1	3.33%
Evaluation of existing road conditions	1	3.33%
General data collection	1	3.33%
Other	1	3.33%
Surveying	1	3.33%
Emergency vehicle guidance	-	0.00%
Improving safety of labor when working on highways	-	0.00%
Intermodal (railroads/airports)	-	0.00%
Monitoring road conditions in rural areas	-	0.00%
Monitoring the utilization of parking lots	-	0.00%
Monitoring traffic conditions of freeways	-	0.00%
Signage inventory	-	0.00%
Supervision of ongoing roadway construction	-	0.00%
Surveillance of collisions	-	0.00%
Tracking vehicle movements at an intersection	-	0.00%
Traffic data collection	-	0.00%
Traffic surveillance	-	0.00%

Table 4.15: Responses to Question 26

State	Response
Delaware	So far, our only proposed use for our UAV is for aerial photography of our capital projects before and after.
Minnesota	Many of the applications above would be restricted depending on the language of the COA. The cameras technical ability will also play a factor in deciding if it is the best tool for any particular job or project. I am sure that other applications will emerge given a less restrictive air space and a more open attitude from the public.

An interesting observation from the previous questions is that none of the state DOTs have completed a COA, but four states are already using UAS for their operations.

Question 27: What supplier did you purchase the UAS from? Include model.

The only response with specific details was from the Minnesota DOT.

- "We are looking at both a fixed wing, like the Trimble X5 and multi-rotor, like the AirGon Av-900 MMK. We are looking to purchase our first one in Fiscal Year 2016."

Question 28: Which add-on equipment do you require in your UAS applications?

Table 4.16: Responses to Question 28

Answer	Responses
Live Feed Video Camera	2
Other	2

Question 29: If "other," state here.

Table 4.17: Responses to Question 29

State	Responses
Delaware	High resolution still camera
Minnesota	Imagery and video would come standard, other sensors would be evaluated at a later date.

Question 30: What software do you use to analyze the data collected from the UAS?

The only response with specific details was from the Minnesota DOT.

- "Flying software aside, we have evaluated the two models above, both are capable of being exported to current software, this was a requirement and part of being financially effective."

Question 31: Is your DOT considering purchasing a small UAS once regulations allow for their commercial use?

Table 4.18: Responses to Question 31

State	Response
Alabama	Yes
Alaska	We are considering the possibility. Conducting rural airport aeronautical surveys, bridge inspections, avalanche monitoring/control are just a few of our potential opportunities
Arkansas	Currently just monitoring the technology
California	Yes
Colorado	Unknown
Delaware	Unsure
Hawaii	Not yet
Iowa	Yes
Louisiana	No
Maine	Possibly
Michigan	Yes
Minnesota	No
Montana	Maybe
New Hampshire	Not at this time. A demonstration is planned for interested departments in the spring to help build interest.
New Jersey	No
New York	Too early in the process to determine
North Carolina	Yes, and NCDOT also plans to advertise to for contract UAS services from the private sector
North Dakota	Not at this time
Oklahoma	No
Oregon	No
Pennsylvania	No
Rhode Island	No
Tennessee	We are considering the purchase as of now
South Carolina	Yes
Utah	Maybe
Wisconsin	No decisions have been made about this since we are still in the process of studying and evaluating UAS
Washington	I don’t know for certain

Question 32: Did your DOT comment on the FAA proposed ruling? If so, what is your opinion/comment?

This question produced long responses, which are available in Appendix H. To paraphrase, many DOTs believe that the FAA's proposed rules are too restrictive. Specifically, the rule against flying over people is too harsh, and many believe the COA process should be expedited.

Question 33: Has your state hosted any UAS related conferences to discuss implementation of this technology?

Question 33 also involved long responses, and all responses are included in Table 4.19.

Table 4.19: Responses to Question 33

State	Response
Alabama	No
Alaska	Yes. We host an Alaska UAS Interest Group conference that addresses a variety of topics associated with UAS integration, operations, etc. The public continues to gain support and understanding of the potential.
Arkansas	No
California	Yes. The California Film Commission sponsored a UAS Flight Demonstration at Malibu Creek State Park on January 8, 2015. Numerous FAA certified operators attended to show the audience the capabilities and potential uses of UAS, including their performance capability and safety parameters they use to operate the aircraft. We continue to explore practical options to use UAS to support Department functions.
Colorado	Only meetings
Delaware	We are planning one for the Fall of 2015. It will be our first UAV event.
Hawaii	No
Iowa	No
Louisiana	No
Maine	No
Michigan	Yes, our Aeronautics Division and Michigan State Police will lead usage and FAA COA process.
Minnesota	Yes, a symposium was organized by MnDOT and the University of Minnesota, it was held last fall and about 150 attended. It was to promote a public conversation and to dispel myths about the COA process. We also brought in some folks from North Dakota where the Air Force, Customs and the University are all flying drones. We wanted people to know where this technology was going and who was leading the charge.
Montana	No
New Hampshire	Planned for spring
New Jersey	No
New York	New York is host to one of the six federal UAS test centers at Griffiss International Airport. NYSDOT has only recently joined the discussion, and has not hosted any conferences, yet.
North Carolina	No
North Dakota	Grand Forks UAS Summit is hosted every year.
Oklahoma	No
Oregon	Yes. Great turnout and emphasis on the need for the FAA to accelerate the process for commercial use UAS. Failure to do so makes the US uncompetitive in the world market.
Pennsylvania	No
Rhode Island	No
Tennessee	I have given presentation on the UAS uses for transportation purposes and attended several ones by TRB, ITS World Congress, Online webinar and latest was a presentation by a Law firm on the legal aspects.
South Carolina	No
Utah	No
Wisconsin	No

Question 34: Additional comments on your state's involvement in UAS technology?

Table 4.20: Responses to Question 34

State	Responses
Alaska	As one of the six test sites, we feel we are on the leading edge of NAS integration. We've had a legislative task force dedicated to the subject for the last two years, and provide a friendly environment to industry wanting to take advantage of testing and operational opportunities.
Minnesota	Because we have taken so much time to get from where we started to now, we have looked at a number of models and evaluated the pros and cons of each. Each one brings something different to the table, you will find that as different applications appear, your needs may change and a different model might emerge.
North Dakota	Currently one of the six test sites in the US.
Delaware	Delaware is considering state legislation to supplement the federal rules.
Utah	Exciting potential, just waiting for the market to more fully develop.
Hawaii	Hawaii is a partner with Alaska and Oregon in the Pan Pacific UAS Test Range Complex. As such, we will participate in the NAS integration effort.
Iowa	Interested in this technology when regulations allow use.
Wisconsin	There are many issues with UAS that we are attempting to deal with. They include the following: • Public perception - privacy and safety are sensitive issues with the public. • At this time, a special FAA permit is required, is very difficult to obtain, and includes many restrictions. • The FAA currently restricts UAS operations to sparsely populated, remote areas to keep the risk of injury to people or property very low. • The FAA has proposed rules for small UAS that will eliminate the need for a special permit if the operator conforms to them. This will make it much easier to operate UAS, but the rules may not be finalized until 2017 and contain many restrictions. • The proposed rules currently include the following operating restrictions: must operate below 500' AGL, must maintain minimum distance of 500' from people not involved in the UAS operation, must maintain visible line of sight at all times, no night-time operations allowed, and more. • Many firms are promoting their UAS capabilities to us, but not all firms have FAA permits to operate. • UAS technology is evolving rapidly. • We need a better understanding of UAS capabilities, limitations, and costs.
Tennessee	Use of aerial LiDAR on crash scene documentation.
Colorado	We are looking at promoting facilities that would handle UAS.
California	We are working with and monitoring the activities of other universities, state agencies, departments, and offices to coordinate our efforts to use UAS. We are also monitoring what UAS research is being done to see if there are potential uses and applications that could benefit us as well.
Michigan	We have just completed our UAS technology research project. We have the full report on our Michigan DOT website, www.michigan.gov/mdot (Brooks et al., 2015).
Rhode Island	We in RI are mainly concerned with safety. UAS are here to stay and will provide a number of opportunities for commercial applications. They do however, pose a safety concern for the 1% of people who do not follow the FAA guidelines. From experience, the FAA is absent when the time comes to enforce the rules. The state then has to pick up the enforcement burden. Educating law enforcement is also left up to the states.

Question 35: Do you have any helpful advice for a DOT attempting to utilize UAS technology?

Table 4.21: Responses to Question 35

State	Responses
Alaska	As we're still very early in the process, my only advice would be to work arm in arm with the local FAA office to ensure the COA process is followed. Simultaneously, public apprehension necessitates focused education on the mission, safeguards, and comment opportunities so that they feel part of the process.
California	Be tenacious and proactive. Perseverance will pay off.
Colorado	Don't run out of money.
Michigan	Regulation, policy, procedure, and specifications are needed as well as more research on data collection, storage, analysis, applications, etc. Issues with receiving FAA COAs. State control and authority.
Minnesota	We see time and again where some UAS operator has done something that makes it more difficult for responsible users to gain acceptance. If you plan on going forward with implementing a UAS program, please promote operations at the highest and safest use possible.
New York	We are keeping an open mind for all possible uses for UAS. To date, after putting out a general request within the department, we have been pleasantly surprised to see the creativity for UAS potential within the department.
Oregon	Get started early and learn the FAA minefield of regulation.
Rhode Island	Contact and work closely with the state aeronautics inspectors first, FAA second.
Tennessee	Choose the right platform for your application. Start by presenting on the capabilities of the UAS and uses to the department. Survey the needs of the department. Choose one straightforward easy task to achieve similar to aerial photography and inspection. Survey approved systems by FAA to select a system that is familiar to the approval division. Purchase a system that satisfies the need and a little more on the payload to get better maneuverability and handling. The System vendor should have well documentation of Airworthiness of the UAS to facilitate the approval process. To minimize failure, start with incremental steps to fly and test the system and do not test two new things at once.
Utah	Get multiple division support early on, and provide continuous feedback to the group.

4.1 Survey Conclusions

Current results of the survey reveal that 11 DOT offices (73.33%) are considering using UAS technology in their state's DOT and seven (46.67%) are considering purchasing a UAS once regulations allow for commercial use. At this time, only six DOTs (40%) have submitted requests for a COA exemption from the FAA. None of the DOTs that responded to the survey are currently using UASs in their operations, meaning they are all still in the research/FAA approval stage. However, the Michigan DOT claims to currently own three UASs, but have not reported any active usage of the UAS. We have contacted this DOT for further information on the UASs they own, but were not able to get a response. There are five DOTs (33.33%) that have submitted extensive feedback to the FAA's proposed ruling on UAS usage which are available in Question 32 of survey results in Appendix H.

Chapter 5: SWOT Analysis (Strengths, Weaknesses, Opportunities, and Threats/Challenges)

When considering any new proposal or practice, a SWOT analysis is beneficial to help guide decision-making efforts. Normally addressing pros and cons or advantages and disadvantages, the typical SWOT use of "threats" is better characterized here by "challenges" since there's no traditional threat such as business competition. Thus, after administering a national survey, the operating procedures of various KDOT units were reviewed to consider the potential for efficiencies (or pros and cons), new applications (opportunities), and execution (challenges) of UAS. These areas of KDOT represent the areas where UAS technology has the greatest potential to be applicable. The divisions and bureaus contacted are shown in Table 5.1.

Table 5.1: Critical Contacts Utilized in Collecting Information on KDOT Procedures

Area	Task	Contact
Bureau of Structures and Geotechnical Services	Bridge Inspection	Don Whisler
Bureau of Maintenance	Radio Tower Inspection	Edwin Geer
Bureau of Right of Way	Surveying	Bill Haverkamp
Bureau of Right of Way	Road Mapping	Bill Haverkamp
Bureau of Transportation Safety and Technology	High-Mast Light Tower Inspection	Connie Eakes
Bureau of Construction and Materials	Stockpile Measurement	Sandra Tommer
Office of Support Services	Photography and Videography	Bob Stacks
Bureau of Transportation Planning–Rail and Freight	Road and Railroad Intersection Inventory and Inspection	Darlene Osterhaus
Bureau of Transportation Planning	Traffic Data Collection	Alan Spicer

5.1 Bridge Inspection

The Bridge Inspection group is located within the Bureau of Structures and Geotechnical Services and was contacted first, since the initial idea of using UAS concerns bridge inspections. KDOT is responsible for the inspection and maintenance of 5,115 state owned bridges, which are required to have inspections once every 2 years. In addition to these state owned bridges, KDOT provides assistance for privately owned bridges through the use of a consultant. By implementing UAS technology, it appears that the physical and logistical demands of bridge inspections may be eased in many locations: 4,665 bridges are inspected by the methods of "general routine" and "routine snooper" (trucks with articulated booms/buckets that suspend workers in the air by the sides of and underneath bridges). Both methods employ personnel and vehicles for lengthy periods of time. Early estimates from tests in other states suggest a bridge can be fully inspected in about an hour with UAS. However, the time required to analyze images and other data can still remain significant. Also, operational issues remain challenging when UAS regulations restrict UAS flights over people not associated with the operation, and impose the requirement to maintain visual contact with the UAS device. The potential for efficiencies in labor deployment and costs via UAS are shown in Table 5.2, with necessary notations for certain conclusions that remain pending. While UAS will not replace current bridge inspections, it will enhance and provide a significant tool that will add assurance for making sound and safe decisions.

Table 5.2: New Bridge Inspection Method

<table>
<tr><td>DEPARTMENT:
Bureau of Structures and Geotechnical Services</td><td>KDOT CONTACT:
Don Whisler</td><td>TASK:
Bridge Inspection</td><td colspan="2">COST AFTER UAS IMPLEMENTATION</td></tr>
<tr><td>Procedure</td><td colspan="2">The National Bridge Inspection Standards are part of a federal regulation that applies to all structures defined as highway bridges on public roads. KDOT inspects bridges on the state system for compliance with the NBIS standards.
The 5,115 state owned bridges must be inspected every 2 years. The type of inspection varies depending on the structure design. Today, bridge inspections are performed through physical labor and large equipment.</td><td>New Procedure</td><td>Bridges that are in categories “general” or “snooper” inspection and “fracture critical” currently must be physically inspected but UAS can offer a significant tool that can be utilized to enhance current inspection methods.</td></tr>
<tr><td>Time per Bridge Category</td><td colspan="2"><table><tr><td>Type of Inspection</td><td>Number of Structures</td><td>Approximate Inspection Time per Structure (in hours)</td></tr><tr><td>General Routine</td><td>4,346</td><td>1 to 4</td></tr><tr><td>Routine Snooper</td><td>319</td><td>10</td></tr><tr><td>Fracture Critical</td><td>47</td><td>80</td></tr><tr><td>Scour Critical/ Underwater</td><td>392</td><td>32</td></tr><tr><td>Pin and Hangar</td><td>11</td><td>1 to 4</td></tr></table></td><td>Safety Enhancement</td><td>5,115 bridges can be inspected through a combination of UAS and manual inspections. The use of UAS should help to reduce the risks associated with physical demands and large equipment operation.</td></tr>
<tr><td>KDOT Equipment</td><td colspan="2">CC-100 Crack Detector, DM 2E Thickness Gauge, Magnetic Particle Crack Detector, Ultrasound Sonic 1,000, Dye Penetrant, and a “Snooper” inspection vehicle.</td><td>Increased Efficiencies</td><td>Subject to proof of concept with respect to analyzing UAS footage and incorporating it into current inspection methods.</td></tr>
<tr><td>KDOT One-Time Equipment Cost</td><td colspan="2">$707,470</td><td>Challenges</td><td>FAA regulations to avoid operating UAS over people not associated with the flight; determining employee interest in UAS pilot training, or hiring new staff; maintaining visual line of sight, and inspectors’ ability to analyze UAS flight video.</td></tr>
<tr><td>KDOT Recurring Equipment Cost</td><td colspan="2">$300,000</td><td></td><td></td></tr>
<tr><td>KDOT Inspector Labor Cost</td><td colspan="2">$37,000 annually. At least 2 inspectors must be on-site during bridge inspections for safety reasons.</td><td></td><td></td></tr>
<tr><td>Cost per inspection according to GT research</td><td colspan="2">$2,862</td><td>Annual Cost Savings</td><td>Subject to proofs of concept.</td></tr>
</table>

5.1.1 Bridge Inspection Recommendation

Time management and safety for personnel via the use of UAS for bridge inspections justifies integrating the new method. UAS presents a learning curve typical with new or innovative practices, but training the current bridge inspection team in UAS flight operations and image and data analysis yields no loss of jobs.

5.2 Radio Tower Inspection

To further maximize the effect of the UAS, other departments within KDOT were then considered. Currently, KDOT oversees the inspections of radio towers throughout Kansas. The people doing the physical inspections are both internal employees and outsourced consultants, with KDOT managing these consultant projects. Using the hourly consultant cost, it is estimated that each outsourced tower inspection costs at least $364. These inspections take place 20 times per year.

A UAS could help to reduce the time it takes to inspect the tower, and the physical inspectors may spend less time climbing a tower. The details of the improvements to the radio tower inspections are shown in Table 5.3.

5.2.1 Radio Tower Inspection Recommendation

Using today's radio tower inspection methods requires a lot of physical labor and climbing. Reducing the amount of time a worker spends climbing a tower will have huge benefits for safety concerns and time constraints.

Table 5.3: New Radio Tower Inspection Method

DEPARTMENT: Bureau of Maintenance	**KDOT CONTACT:** Edwin Geer	**TASK:** Radio Tower Inspection	**COST AFTER UAS IMPLEMENTATION**	
Procedure	KDOT must oversee the inspections of 80 large radio towers that have an average height of 400 ft. Visual and structural analysis of these towers are performed manually to determine its structural integrity.		**New Procedure**	UAS technology can be a valuable tool to look for damage after a storm in case of damages to antenna, misalignment of microwave dishes, etc. The UAS may also provide tower climbers with pictures when doing the inspections; however, normal inspections require checking tensions of guy wire, tightness of hardware on the tower, etc. This will still require an inspector to climb the tower.
Task Duration	KDOT owns 80 large towers in Kansas, and 20 towers inspected each year.		**Safety Enhancement**	The use of a UAS may reduce the amount of time an inspector spends on the tower.
KDOT Equipment	Climber safety equipment, camera, wrenches, Dillon tension meter, RF personal safety monitor		**Increased Efficiencies**	Subject to proof of concept.
KDOT Inspector Labor Cost (Outsourced)	Vehicle = $43.00/hr, Technician 1 = $53.00/hr, Technician 2 =$43.00/hr, Technician 3-5 = $43.00/hr. There must be at least two technicians on site during the inspection for safety reasons.		**Challenges**	Battery life may not last long enough for inspection; multiple battery packs needed. Adjusting to new software will take time.
Cost per inspection	$364 minimum		**Annual Savings**	Subject to proof of concept.

5.3 Surveying

Similar to the radio tower inspections, the cost involved in KDOT's surveying efforts are from using an outsourced consultant. UAS technology can reduce the time needed to gather imaging for land surveying, not necessarily using a consultant. Both safety and efficiency improvements can be realized in the new method, but improvements remain difficult to quantify since reducing or eliminating consultant use is still to be determined. Table 5.4 summarizes surveying/aerial imaging.

Table 5.4: New Surveying Method

DEPARTMENT: Bureau of Right of Way	**KDOT CONTACT:** Bill Haverkamp	**TASK:** Surveying	**COST AFTER UAS IMPLEMENTATION**	
Procedure	A four person crew performs land surveying through the use of surveying equipment and reference points placed by on-foot rovers. The time and equipment needed for a survey depends on the specific project. The data collected from these traditional surveying methods are combined with the imaging provided by a contracted company.		**New Procedure**	A UAS equipped with either 18-megapixel camera or photogrammetry camera will fly an autonomous or piloted pattern over the area to be surveyed. The photos collected will then be analyzed using software similar to PostFlight Terra 3D.
Survey Duration	1 to 3 weeks		**Safety Enhancement**	Surveyors may be spending less time near highways, construction sites, or in unfavorable weather conditions.
KDOT Equipment	GPS, electronic total station, rover equipment, level, and two trucks for transportation		**Increased Efficiencies**	Traditional surveying only covers 3-4 hectares per day. With UAS, 40 hectares can be surveyed in 60 minutes + setup time.
KDOT One-Time Equipment Cost	$13,500 + Cost of two vehicles		**Challenges**	Aerial imaging can only occur during winter months when vegetation is dormant/dead. Rules do not allow flight above people/cars.
KDOT Recurring Equipment Cost	Fuel to travel to survey site			
Surveying Outsourced Projects Cost	For large surveying projects, Wilson Company provides imagery for six to 12 projects a year. This service usually costs $20,000 to $30,000 annually. Assume half of consultant cost is applied to surveying projects.		**Annual Savings**	Subject to proofs of concept.

5.3.1 Surveying Recommendation

The current surveying method at KDOT is a combination of traditional surveying on foot and aerial imaging. Applying a UAS to this task may reduce the need of both traditional methods and outsourced aerial imaging. Even though the benefits from reducing traditional survey methods cannot be quantified, the evidence of successful UAS surveying in the literature review makes this application very appealing. The outsourced aerial imaging from the Wilson Company comes at a high annual cost, and the UAS is able to capture the imaging needed for much less, although it is hampered by not being able to fly over traffic unlike current methods. Integrating the UAS into the current surveying methods and reducing the reliance on outsourced images is a sensible way for KDOT to be innovative while potentially saving time and money.

5.4 Road Mapping

Road mapping is a subset of the surveying department at KDOT. This road mapping task collects aerial images to support the GIS database and create updated Kansas maps. The same consultant used for surveying is used for road mapping. Assuming that KDOT chooses to use a UAS to internally generate aerial images for this task, the consultant could be eliminated. However, as summarized in Tables 5.5, cost savings remain difficult to quantify because UAS regulations prevent flights over people not associated with the UAS operation.

5.4.1 Road Mapping Recommendations

The costs associated with the road mapping task are mostly in the outsourced imaging. KDOT is annually paying for the aerial images that serve both surveying and road mapping tasks. Once again, the safety improvements and time savings are not easily quantified, but there still remains the potential for cost savings in performing this task internally at KDOT.

Table 5.5: New Road Mapping Method

Department: Bureau of Right of Way	**KDOT Contact:** Bill Haverkamp	**Task:** Road Mapping	**COST AFTER UAS IMPLEMENTATION**	
Procedure	Road mapping is a function of the work done by the surveying group at KDOT. To develop 2D and 3D models, KDOT utilizes photogrammetric equipment for large-scale projects. During the post-processing, mapping technicians use field control data from the surveying teams and imagery from a consultant.		**New Procedure**	KDOT may be able to integrate imagery from the UAS in some steps of the road mapping process rather than using outsourced imagery.
Task Duration	Based on a face-to-face meeting with the Surveying department at KDOT, imagery for a road mapping project can take anywhere between half a day to 1 week to complete.		**Safety Enhancement**	Surveyors may be spending less time near highways, construction sites, or in unfavorable weather conditions.
KDOT Equipment	Photogrammetry camera and software, survey equipment		**Increased Efficiencies**	Performed internally so there is no delay in getting information
KDOT Inspector Labor and Equipment Cost	Field team salary = $40,000 Survey equipment = $13,500		**Challenges**	Aerial imaging can only occur during winter months when vegetation is dormant/ dead. Rules do not allow flight above people/ cars.
Outsourced Project Cost	For large surveying projects, Wilson Company provides imagery for six to 12 projects a year. This service usually costs $20,000 to $30,000 annually.		**Annual Savings**	Subject to proofs of concept.

5.5 High-Mast Light Tower Inspection

The next KDOT task identified is the high-mast light tower inspection. These structures are the tall light towers seen along the interstate highways in Kansas. Employees in the Bureau of Transportation Safety and Technology oversee the outsourced inspections of 1,500 high-mast light towers. The cost of outsourcing inspections for 1,500 towers is approximately $550,000. These inspections can be enhanced with the use of UAS, but cannot be replaced with UAS. Physical inspections of bolts at the bases of each of the towers are required. FAA regulations preventing UAS flights over people not associated with the UAS operation—knowing many masts are in highway medians—also present unique challenges to overcome.

Table 5.6: New High-Mast Light Tower Inspection Method

DEPARTMENT: Bureau of Transportation Safety and Technology	**KDOT CONTACT:** Connie Eakes	**TASK:** High-Mast Light Tower Inspection	**COST AFTER UAS IMPLEMENTATION**	
Procedure	KDOT contracts the inspection of 1,500 high-mast light towers in Kansas. These structures are inspected once every 4 years.		**New Procedure**	KDOT and/or its contractor could supplement inspections of high-mast light towers with UAS.
			Safety Enhancement	Less time near highways, construction sites, or in unfavorable weather conditions.
Equipment Based on KDOT	Telescope, Camera, Hammer, Thickness Gauge, Magnetic Particle Crack Detector, Ultrasound Sonic		**Increased Efficiencies**	UAS can quickly collect images of many towers in one flight, but bolts at the bases of each tower require manual inspection.
One-Time Equipment Cost Based on KDOT	$2,000		**Challenges**	KDOT will need to find someone to process the data and aerial imaging.
KDOT Contracted Labor Cost	$550,000 to inspect the 1,500 towers once every 4 years.		**Annual Savings**	$0

5.5.1 High-Mast Light Tower Inspection Recommendation

KDOT cannot replace the current inspection method with UAS, but UAS can be a valuable tool in some locations to enhance current inspection methods.

5.6 Stockpile Measurement

At this time there does not seem to be any activity related to stockpile measurement within KDOT. Research of other DOT construction methods shows that there are many benefits to keeping more detailed records of construction stockpiles. Currently, the volume of stockpiled material is noted by keeping track of the truckloads of material dropped off at a site. This method does not account for material lost through wind, rain, or poor security. New UAS software has the ability to estimate the volume and moisture content of a stockpile from a quick scan. Even though there are no immediate cost savings by applying UAS technology to stockpile measurement, there are benefits that create potential cost savings in the future. Close inventory inspection of stockpiles ensures that the supplier provides the correct amount, avoids stock-outs of material, and proper moisture amounts for road construction. A review of this task is detailed in Table 5.7.

5.6.1 Stockpile Measurement Recommendation

Based on the literature review and survey, stockpile management is a common task for DOT offices. However, KDOT does not closely record stockpile data other than the number of truckloads of material delivered. A quick UAS flight will allow the construction teams to record the volume, temperature, and moisture to ensure proper delivery amounts and monitor loss to wind or extreme weather. Since this task is not currently taking place at KDOT, there are no specific cost savings in Table 5.7. With no major difficulties in starting this method, it can be easily attempted at KDOT to determine UAS viability for managing construction stockpiles.

Table 5.7: Recommended Stockpile Measurement Method

DEPARTMENT: Bureau of Construction and Materials	**KDOT CONTACT:** Sandra Tommer	**TASK:** Stockpiles	**COST AFTER UAS IMPLEMENTATION**	
Procedure	Materials needed for construction projects are stockpiled in a way that their security and inventory can be maintained. The delivered material is accounted for by recording the number of truckloads delivered. KDOT currently does not maintain more specific stockpile information such as temperature or moisture content.		**New Procedure**	UAS equipment (PhotoModeler) will be used to create a 3D model for stockpile volume inventory. This new method will let the construction managers know exactly how much material is left after construction, loss to wind, water content, etc. Adding this inventory procedure will help realize potential cost savings and efficiency in construction projects.
Time per inspection	None. KDOT is not actively recording stockpile inventories.		**Safety Enhancement**	N/A
KDOT Equipment	Dump trucks, personnel		**Increased Efficiencies**	Reconciling actual volume with expected volume will be easier, increases accountability of supplier and management.
Task Cost	$0		**Challenges**	Learning new software and enforcing workers to actually use the information.
			Annual Savings	N/A

5.7 Photography and Videography

The Office of Support Services provides an internal service of photography and videography of KDOT activities. The subject matter of the photos and videos could be anything from construction projects, accidents, damage to KDOT equipment, signage, or anything requested for the benefit of a presentation. The employees who drive to the site of the photos or videos use KDOT vehicles and are paid a per diem for travel. Adding a UAS will not reduce these expenses. The UAS will only enhance the photography and videography by providing more flexibility and a new point of view, therefore no cost savings can be recorded for this task. The qualitative benefits, however, are nearly limitless since a photographer's creativity can help with clearer communication of the subject matter in KDOT presentations. Table 5.8 outlines the suggested procedure for applying a UAS to this task.

Table 5.8: Implementing UAS for KDOT's Photography/Videography Needs

Department: Office of Support Services	**KDOT CONTACT:** Bob Stacks	**TASK:** Photography and Videography	**COST AFTER UAS IMPLEMENTATION**	
Procedure	Construction, bridge demolitions, commercial accidents, and other requested video and pictures are recorded by this department and are used to evaluate construction sites and/or determine root cause of accidents.		**New Procedure**	Any photos or videos requested for KDOT projects and presentations can be collected through the use of a UAS equipped with photography/videography equipment.
			Safety Enhancement	N/A
KDOT Equipment	KDOT vehicles, personnel		**Increased Efficiencies**	Identify issues/errors early on
KDOT One-Time Equipment Cost	$15,000		**Challenges**	Rules do not allow flight above people
KDOT Recurring Equipment Cost	Travel costs, per diem, labor hours		**Annual Savings**	N/A – UAS is addition to photography, not replacement.

5.7.1 Photography and Videography Recommendation

Many people purchase a UAS for photography and videography alone. There is no question on the capability of the UAS to perform photography and videography, but the safety, efficiency, and cost savings are what determine the overall impact of the application in KDOT. Photos and videos provided by this department are supplemental to construction, surveying, maintenance, and other KDOT divisions as needed. The only major cost associated with this department is the initial cost of equipment, and no major time or safety improvements exist in UAS application for this task. The photography and videography task alone does not justify purchasing a UAS, but the capabilities of the UAS will greatly benefit the task. It is recommended that if KDOT chooses to purchase a UAS for other tasks, they should also apply the UAS to the photography and videography department.

5.8 Railroad Intersection Inventory

The Rail and Freight Section at KDOT works closely with the corporate rail owners to ensure that safety standards are met at intersections of Kansas owned roads and railroads. A total of 5,950 street and railroad intersections are inspected by KDOT. The annual goal is to complete 1,500 crossing inventory and inspections over 21 counties. These inspections are updated with the records at the Federal Railroad Administration. Since the inventory and inspection at these crossings are mostly through visual inspection, a UAS is applicable to this task. However, there were no realized cost savings by adding a UAS. The details of this task with UAS are shown in Table 5.9.

5.8.1 Railroad Intersection Inventory Recommendation

Current methods of this task involve visual inspection of the gates and intersections of railroads. These structures are not difficult to access and inspection takes a relatively short amount of time. Using a UAS for this task does not present any major safety improvements, increased efficiencies, or annual savings. For these reasons, it is not recommended for KDOT to use a UAS for railroad intersection inventory.

Table 5.9: New Rail Intersection Method

Department: Bureau of Transportation Planning – Rail and Freight	**KDOT CONTACT:** Darlene Osterhaus **TASK:** Railroad intersection inventory and inspection	**COST AFTER UAS IMPLEMENTATION**	
Procedure	KDOT employees manage crossing inventory of 1,500 road and railroad crossings in 21 counties per year. An inventory task sheet is filled out, seven pictures taken, and indication of any gouge marks, damaged surfaces, as well as gate, signage, or light damage. There are 5,950 rail crossings in Kansas that have an inventory kept and updated with the Federal Railroad Administration's records.	**New Procedure**	KDOT employees tasked with taking rail crossing inventory will utilize images taken from the UAS to satisfy the seven photos requirement. When rail companies request rehabilitation projects, photogrammetry can be applied for identifying additional problem areas in need of repair.
Task Duration	Two inspectors can complete 20 railroad-crossing inventories in a day.	**Safety Enhancement**	Inspectors will not be spending extended amounts of time near highways or in unfavorable weather conditions.
KDOT Equipment	Pencil, paper, surveyors wheel, KDOT vehicle	**Increased Efficiencies**	N/A
KDOT One-Time Equipment Cost	$80	**Challenges**	Proposed rules do not allow flight above people.
KDOT Recurring Equipment Cost	$37,500 in annual labor cost of three person team inspecting 1,500 per year	**Annual Savings**	N/A

5.9 Traffic Data Collection

Another potential area within KDOT for UAS application is traffic data collection. A common idea for UAS application is to observe traffic and conduct a queueing analysis. KDOT's current method for data collection is through the use of weight sensors as well as loop and piezo sensors in the pavement. This method provides continuous data collection and presents less safety hazards than other areas within KDOT. The recommended procedure for this task is detailed in Table 5.10.

Table 5.10: Traffic Data Collection Methods

Department: Bureau of Transportation Planning - GIS	**KDOT CONTACT:** Alan Spicer	**TASK:** Traffic Data Collection	**COST AFTER UAS IMPLEMENTATION**	
Procedure	Short-term traffic counts and vehicle classification data is collected by stretching road hose across the road for 24 or 48 hours. Short-term truck weight capacitance data is collected by mat weight sensors installed on the pavement to get truck weight. Continuous traffic and continuous vehicle classification data is collected by installing loop and piezo sensors in the pavement.		**New Procedure**	A UAS is not recommended to replace the current methods of traffic data collection. However, UAS can be used as an addition to data collection projects to gather data in small increments of time in certain traffic areas.
Task duration	Data collection is continuous. Minimal time spent setting up short-term traffic sensors.		**Safety Enhancement**	Data collectors will spend less time on or near roadways.
KDOT Equipment	Pencil, paper, KDOT vehicle		**Increased Efficiencies**	None
			Challenges	Battery life and flight time of UAS may limit the samples of traffic data. UAS cannot collect 24-hour continuous data. UAS cannot fly over traffic.
			Annual Savings	N/A – UAS is addition to current methods and does not eliminate costs.

5.9.1 Traffic Data Collection Recommendation

Table 5.10 describes the current method that KDOT uses to collect traffic data. The type of data collected is over long periods of time. For this reason, the restricted flight time of the

UAS does not make a feasible source of data collection. A UAS may be an added benefit to traffic data collection by taking very short samples, but it is not feasible to replace or modify current methods. It is not recommended that KDOT use a UAS for the purposes of traffic data collection unless a small sample is needed.

5.10 SWOT Analysis Conclusion

There is potential for savings in all three key areas associated with KDOT missions, safety, efficiency, and cost, when utilizing Unmanned Aircraft Systems. The potential is applicable to the work conducted directly by KDOT and those assignments outsourced to contractors. But the spectrum between these two poles is a dynamic environment that makes estimating cost savings difficult. Therefore, cost savings and other benefits, both tangible and intangible, can only be considered theoretically. For example, through safety improvements that could be realized with UAS applied to the most difficult or extreme tasks, less physical labor can benefit the well-being of KDOT employees. Also, many of the tasks recommended for UAS application can improve efficiency; for example, data and imaging can be collected much faster. However, the costs associated with software acquisition and updates, data analysis and integration, and managing new data files simply redirect labor hours from their present course to a new direction without necessarily realizing net savings. FAA regulations to avoid operating UAS over people not associated with the flight significantly reduce the possibility of utilizing UAS in many scenarios. While UAS cannot replace many of the current activities that KDOT performs, it could greatly enhance them both from a safety and technical point of view. Table 5.11 summarizes the UAS applications at KDOT.

Table 5.11: Summary of UAS Applications

KDOT Tasks	UAS Application (Yes/No)	Cost Savings	Safety Enhancement (Yes/No)	Increased Efficiencies (Yes/No)	Challenges (What challenges will KDOT face with regulations, etc.)
Bridge Inspection	Yes	TBD	Yes	Yes	Learning new software, changing roles, regulation of not flying above people not involved in operation.
Radio Tower Inspection	Yes	TBD	Yes	Yes	Learning new software, changing roles, battery life, and flight time ability.
Surveying	Yes	TBD	Yes	Yes	Learning new software, changing roles, battery life and flight time of UAS can't provide continuous data collection, regulation of not flying above people not involved in operation.
Road Mapping	Yes	TBD	Yes	Yes	Can only use photogrammetry in November-April (less vegetation), regulation of not flying above people not involved in operation.
High-Mast Light Tower Inspection	Yes	TBD	Yes	Yes	Learning new software, changing roles, flight time ability, regulation of not flying above people not involved in operation.
Stockpile Measurement	Yes	No	No	No	Learning new software, changing roles, regulation of not flying above people not involved in operation.
Photography and Videography	Yes	No	No	No	Regulation of not flying above people not involved in operation.
Railroad Intersections Inventory	No	No	No	No	Flight time ability, and regulation of not flying above people not involved in operation
Traffic Data Collection	No	No	No	No	Battery life and flight time of UAS can't provide continuous data collection.

Chapter 6: UAS Startup and Recurring Cost

To begin using UAS for the tasks explained above, a one-time cost of equipment will occur and the amount is shown in Table 6.1. The equipment list includes two different UAS models, extra batteries, generators for battery charging, controllers, cameras, and a tablet for use with the controls. Recommended models in the table below were chosen after consulting the literature review, survey responses, and Kansas State University (K-State) Salina's Chief UAS pilot, Travis Balthazor. The two UAS models recommended for KDOT are the DJI S900 and DJI Inspire.

Table 6.1: Cost and Quantities of Recommended Equipment for Startup

UAS STARTUP COST			
	Price per unit	**Recommended units**	**Total**
Honda EU2000 Generator	$999.00	1	$999.00
Revolectrix 24VDC 55A Power Station 1320W	$250.00	1	$250.00
Battery iCharger 308DUO 1300W Dual Channel	$259.00	1	$259.00
DJI S900 UAV, A2 controller, Z15 gimball	$3,400.00	1	$3,400.00
DJI S900 UAV – backup unit and extra parts	$1,350.00	1	$1,350.00
Li-PO battery 1,500mAh	$373.00	4	$1,492.00
Futaba 10CAG 2.4GHZ Airplane MD 2 with R6014HS Receiver	$629.00	2	$1,258.00
DJI Inspire1 - with controllers - a complete kit	$3,498.00	1	$3,498.00
iPad Air 3 Mini or Samsung Galaxy Tab S2 - 8"	$499.00	2	$998.00
Sony a5100 camera with a standard lens	$598.00	1	$598.00
Sony a5100 camera with Infra-Red conversion	$798.00	1	$798.00
Total	**$12,653.00**		**$14,900.00**

Table 6.2 shows optional equipment for the DJI products if necessary. The DJI Phantom is an alternative UAS model if desired. On the right side of Table 6.2, the annual costs of UAS implementation are shown. It is recommended that KDOT hires a licensed UAS pilot for all tasks involving UAS flights. A UAS pilot will expect a salary around $65,000, this does not include fringe benefits. An additional recommendation is that ground observers obtain a Class 2 medical certificate to ensure that their physical capabilities are adequate for maintaining visual line of sight. These recommendations are not required by the FAA, but are in the best interests of KDOT to reduce the risk of damaging the UAS or surrounding structures.

Table 6.2: Additional Startup Cost and Annual Costs

UAS STARTUP COST – OPTIONAL EQUIPMENT AND SUPPLIES		UAS ANNUAL COSTS	
	Price per unit		**Price per unit**
Li-PO battery 2,100 mAh	$450.00	Pilot Salary	$65,000
DJI LightBridge for Live Video Downlink	$1,159.00	Class 2 medical certificate per Ground Observer (Optional/Recommended)	$100
DJI Phantom 3 Pro with 4k Camera	$1,249.00	Fringe Benefits (Health insurance, social security, workman’s comp etc.)	$32,500
DJI P-3 Battery for Phantom 3	$149.00		
Total	**$3,007.00**	**Total**	**$97,600**

Chapter 7: Software Recommendations

The equipment shown in Table 6.1 does not address additional software. The included equipment in the DJI Inspire and DJI S900 is for basic photography and videography. Additional software must be included to perform the more technical tasks such as bridge inspections and surveying. The most applicable software found for UAS are Agisoft PhotoScan, Pix4Dmapper, VisSim, and PhotoModeler.

The top two recommended software programs are the Agisoft PhotoScan and Pix4Dmapper since these two programs are used for research at K-State Salina with the same brand of UAS. The Agisoft PhotoScan provides the capabilities and special features that are needed for technical projects. The professional version of Agisoft PhotoScan can be purchased for $3,499.

The Pix4Dmapper software is compatible with DJI equipment and will provide necessary analysis for the tasks of bridge inspection, surveying, road-mapping, stockpile measurement, tower inspections, and more. This software is considered to be more of a "plug-and-play" program and is user friendly. Postflight Terra 3D is a software owned by Pix4D and has photogrammetric capabilities. The Postflight software is more common on fixed-wing drones, but could be configured for rotary-wing drones as well. Purchasing the Pix4Dmapper can be completed through monthly or yearly payments to first test out the software, or it can be bought outright for $8,700. Assuming the short term leases are non-renewable, a 1-month license is $350, and a 1-year license is $3,500.

From the literature review, recall that the Arkansas Department of Transportation utilized PTV VisSim software to record and analyze traffic data (Frierson, 2014). For KDOT, the information gathered from a UAS can be analyzed with VisSim to perform queueing analysis of roads, rail intersections, traffic engineering, and other transportation systems. The cost of this software is still to be determined as a customer inquiry is required to get cost information.

Another software option is the PhotoModeler software. This program takes photos from any source and creates a 3D model online for photogrammetric analysis. Since this software is compatible with a UAS, it is a reasonable method of performing almost all tasks outlined in the economic analysis. The PhotoModeler software can be purchased for $2,495.

7.1 Summary of Recommended Software

Table 7.1 lists the four main software programs described in the previous section. The hyperlinks in the table will direct you to the pricing and download page for the software.

Table 7.1: Recommended Software Prices and Online Download Link

Software	Price	Link
Agisoft Photoscan	$3,499	http://www.agisoft.com/buy/online-store/
PhotoModeler	$2,495	http://www.photomodeler.com/store/index.php?cPath=28
Pix4Dmapper	$8,700	https://pix4d.com/buy_rent/
VisSim	Consultation Needed	http://www.vissim.com/downloads/vissim_software.html

Notice that the cost of Pix4Dmapper is much more than the other options. If you follow the link provided for that software, there are rental options for the software if KDOT desires a trial before committing to the $8,700 price outright. Additionally, the VisSim software price is unknown since there isn't information on the website unless you contact the company for a consultation.

Agisoft PhotoScan and PhotoModeler are the top two recommended software programs since it has a lower price and K-State Salina is using these programs for their research and getting good results.

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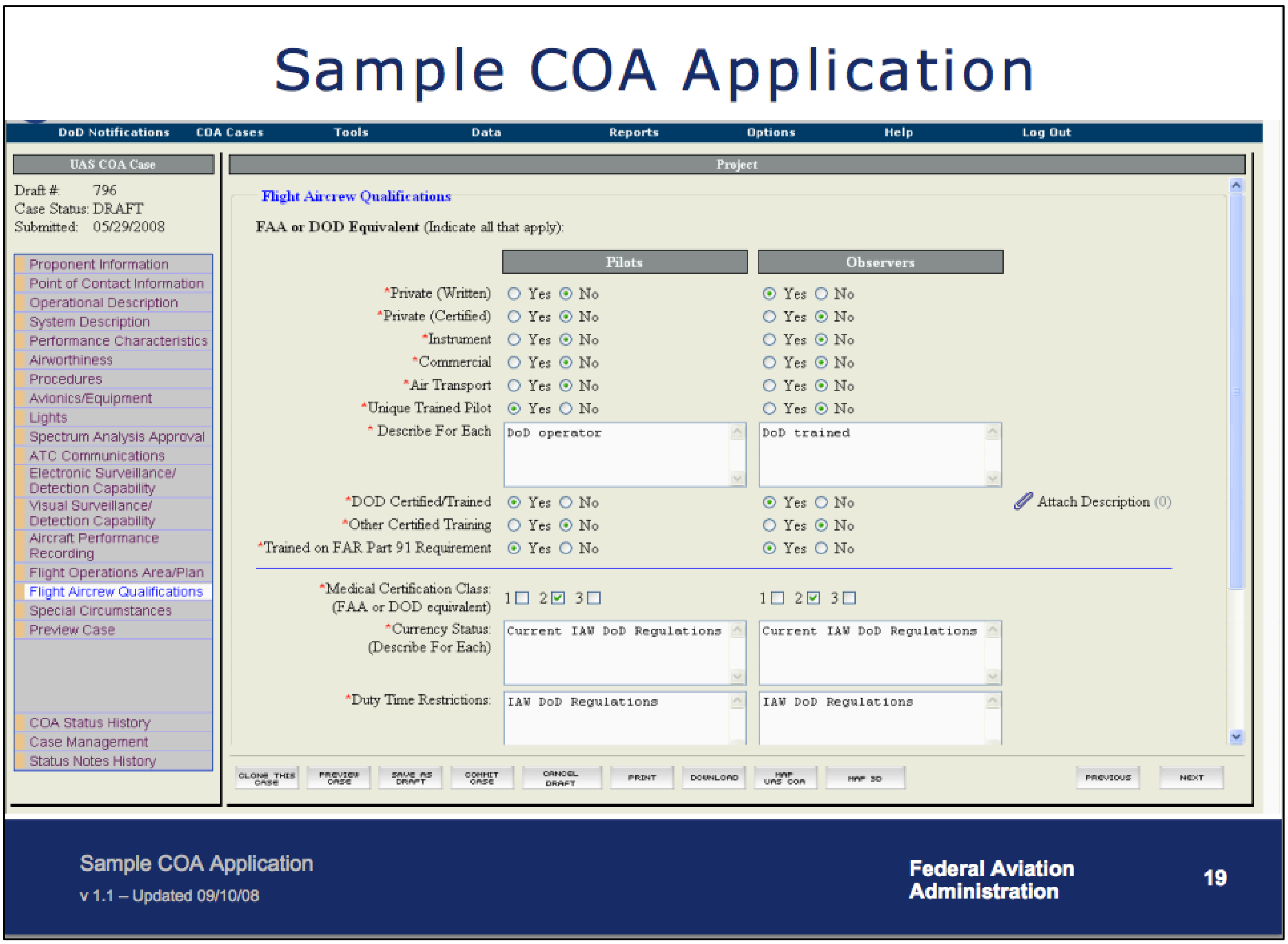
Appendix A: Sample Page of COA Application

(Note the number of pages of the application in the left sidebar.)

Hyperlink to full example application:
https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/media/COA%20Sample%20Application%20v%201-1.pdf

Hyperlink to apply for COA online: https://ioeaaa.faa.gov/oeaaa/Welcome.jsp



Appendix B: Current Companies Granted Exemption from Section 333 for Commercial UAS Use as of February 10, 2015

Date of Exemption	Name	Operation/Mission	UAS Fixed/ Rotary Wing?	UAS Model
1/6/15	Advanced Aviation Solution	Precision agriculture	Fixed wing	eBee drone
9/25/14	Aerial MOB	Closed set filming	Rotary wing	MOB Mid Range Lifter AND a DJI Phantom2
1/23/15	AeroCine	Aerial Filming	Rotary wing	Alexa XT micro aerial flight
2/3/15	Alan D. Purwin	Aerial Filming, motion picture and television	Rotary wing	Gryphon Dynamics X8 and DJI S1000
9/25/14	Astraeus Aerial	Closed set filming	Rotary wing	Supplier: Hoverfly
2/10/15	Asymmetric Technologies	Bridge inspections	Rotary wing	Microdrones MD4-1000
2/10/15	Blue-Chip UAS	Aerial photography	Fixed wing	Sensurion Aerospace Magpie MP-1
1/23/15	Burnz Eye View	Aerial photography, inspection	Rotary wing	Phantom 2 Vision+
12/10/14	Clayco	Aerial imaging, construction	Rotary wing	Skycatch multi-rotor drones
10/10/14	Flying Cam	Closed set filming	Rotary wing	Flying-cam Sarah 3.0
2/3/15	Helinet Aviation Services LLC	Aerial Filming, motion picture and television	Rotary wing	Gryphon Dynamics X8 and DJI S1000
9/25/15	Helivideo	Closed set filming	Rotary wing	EPIC 6k Dragon and Rotorcraft Model ERX12
9/25/14	Pictorvision	Closed set filming	Rotary wing	Multi Rotor No. 14817
2/6/15	Pravia, LLC	Agriculture analysis, high-resolution aerial imagery	Fixed wing	eBee drone
9/25/14	RC Pro Productions Consulting	Closed set filming	Rotary wing	Vortex Aerial
1/29/15	Slugwear	Aerial photography	Rotary wing	Phantom 2 Vision+
9/25/14	Snaproll Media	Closed set filming	Rotary wing	Astraeus Aerial Cinema System - V.3CS
1/29/15	Team 5	Aerial Filming, motion picture and television	Rotary wing	Gryphon Dynamics X8 and DJI S1000
1/29/15	Total Safety U.S.	Flare Stack inspection	Rotary wing	DJI S1000 sUAS
12/10/14	Trimble	Precision aerial surveying, agriculture	Fixed wing	Trimble UX5 Aerial Imaging Rover
1/6/15	Trudeau, Tierra Antigua Realty	Real estate photography/videography	Rotary wing	Phantom 2 Vision+
12/10/14	VDOS, LLC	Flare stack inspection	Rotary wing	Aeryon SkyRanger
2/9/15	Viafield	Precision agriculture	Fixed wing	eBee drone
12/10/14	Woolpert (I and II)	Precision aerial surveying	Fixed wing	Nova Block III UAS

Appendix C: Survey Sent to All US Department of Transportation Offices

Q1.

Thank you for taking the time to provide helpful information about new technology in the Department of Transportation.

Your response will help with research on implementing new aviation technologies at the Kansas Department of Transportation.

The Industrial and Manufacturing Systems Engineering (IMSE) department at Kansas State University is currently conducting research for the Kansas Department of Transportation (KDOT) involving feasibility studies of implementing the use of Unmanned Aircraft Systems (UAS). This technology is also referred to as Unmanned Aircraft Vehicles (UAV) as well as "drones". The UAS's are pilotless and can be programmed to perform autonomous duties. The purpose of this research is to determine which UAS equipment to use and where it can be applied in KDOT's operations. Acquiring information on the current use of UAS technology is vital to present a justifiable recommendation to KDOT. Thank you for your participation.

Kansas
Department of Transportation

Q2. **What state do you work for in the Department of Transportation?**

____

Q3. **Which division of your state's DOT do you work in?**

____

Q4. **What is your position title?**

____

Q5. **What technology or methods does your state's DOT currently use for maintenance of transportation structures? (Select all that apply)**

- ☐ Lidar
- ☐ Infrared / thermal imaging
- ☐ Live feed video camera
- ☐ Magnetic field sensors
- ☐ Radar
- ☐ Physical labor
- ☐ Other

Q6. **If you selected "other" in the previous question, please state the technology used here.**

____

Q7. **What technology or methods does your state's DOT currently use for surveillance? (Select all that apply)**

- ☐ Lidar
- ☐ Infrared cameras
- ☐ Radar
- ☐ Physical labor

https://kstate.qualtrics.com/WRQualtricsControlPanel/Ajax.php?action=GetSurveyPrintPreview&T=1T85rhvLhWoVZmZEcNIX2j 1/5

☐ Live feed video camera
☐ Magnetic field sensors
☐ Laser distance meter
☐ Other

Q8. **If you selected "other" in the previous question, please state the technology used here.**

Q9. **What environmental challenges does your state's DOT commonly face during routine operation?**

☐ High wind
☐ Very high temperatures
☐ Very low temperatures
☐ High altitude
☐ Avalanches
☐ Earthquakes
☐ Flooding
☐ Other

Q10. **Please mention any other environmental factors your state's DOT faces.**

Q11. **Has your department considered the use of UAS?**

◯ Yes
◯ No

Q12. **If yes, which areas would you apply UAS technology? (Select all that apply)**

☐ Monitoring the conditions of the freeway
☐ Monitoring parking lot utilization
☐ Tracking vehicle movements at intersections
☐ Inspecting defects and cracks of bridges, towers, railways, and highways
☐ Emergency vehicle guidance
☐ Supervision of ongoing roadway construction
☐ Classifying plant species to be removed for constructing future highway
☐ Evaluating existing road conditions
☐ Aerial imaging to support Geographic Information System (GIS) database
☐ Signage inventory
☐ Monitoring traffic conditions in rural areas
☐ Improving safety of labor when working on highways
☐ Surveillance of collisions
☐ Other

Q13. **Note: If you chose "Other" in the previous question, please state the area of application here.**

Q14. **If no, do you think any of the below areas would benefit from UAS application?**

☐ Monitoring conditions of the freeway
☐ Monitoring parking lot utilization
☐ Tracking vehicle movements at intersections
☐ Inspecting defects and cracks of bridges, towers, railways, and highways
☐ Emergency vehicle guidance
☐ Supervision of ongoing roadway construction
☐ Classifying plant species to be removed for constructing future highway
☐ Evaluating existing road conditions
☐ Aerial imaging to support Geographic Information System (GIS) database
☐ Signage inventory
☐ Monitoring traffic conditions in rural areas
☐ Improving safety of labor when working on highways
☐ Surveillance of collisions
☐ Other

Q15. **Note: If you chose "Other" in the previous question, please state the area of application here.**

Q16. **What is the biggest motivator for implementing UAS technology in your DOT? (Select all that apply)**

- ☐ Improve safety
- ☐ Decreasing cost
- ☐ Completing projects faster
- ☐ Accurate data collection
- ☐ Creating jobs
- ☐ Aerial viewpoint
- ☐ Other

Q17. **If you selected "other" in the previous question, please state the motivating factor here.**

Q18. **Which division in your state will utilize the UAS technology the most? What are these operations?**

Q19. **Has your department done any research on potential use of UAS technology?**

- ◯ Yes
- ◯ No

Q20. **Have you performed a cost benefit analysis for implementing UAS technology?**

If yes, would you mind sharing your findings with us? We would appreciate any helpful documents sent to Malgorzata Rys at her e-mail: malrys@ksu.edu

Q21. **Have you submitted a COA request, or contacted the FAA about implementing UAS use?**

- ◯ Yes
- ◯ No

Q22. **Was your COA application rejected in your first request? If yes, what changes would you have to make for it to be accepted?**

Q23. **Are you currently using UAS technology to aid in your DOT procedures?**

- ◯ Yes
- ◯ No

Q24. **How many of the UAS's did you purchase?**

Q25. **If yes, which area do you use the UAS?**

- ☐ Inspection
- ☐ Construction
- ☐ Surveying
- ☐ Emergency vehicle guidance
- ☐ Supervision of ongoing roadway construction
- ☐ Classifying plant species to be removed while constructing a future highway

- ☐ Traffic data collection
- ☐ Traffic surveillance
- ☐ Intermodal - (railroads/airports)
- ☐ Monitoring traffic conditions of freeways
- ☐ Monitoring the utilization of parking lots
- ☐ Tracking vehicle movements at an intersection
- ☐ Inspecting defects and cracks of bridges, towers, railways, and highways
- ☐ Monitoring road conditions in rural areas
- ☐ Aerial imaging to support Geographic Information System (GIS) database
- ☐ Signage inventory
- ☐ Improving safety of labor when working on highways
- ☐ Surveillance of collisions
- ☐ Other

Q26. **If your DOT's method of using UAS's was not mentioned in the previous question, please mention the area of application here.**

Q27. **What supplier did you purchase the UAS from? Please include model.**

Q28. **Which add-on equipment do you require in your UAS applications? (Select all that apply)**

- ☐ Lidar
- ☐ Infrared / thermal imaging
- ☐ Live feed video camera
- ☐ Magnetic field sensors
- ☐ GPS
- ☐ Other

Q29. **Note: If you chose "Other" in the previous question, please state the UAS equipment here.**

Q30. **What software do you use to analyze the data collected from the UAS?**

Q31. **Is your DOT considering purchasing a small UAS once regulations allow for their commercial use?**

Q32. **Did your DOT comment on the FAA proposed ruling? If so, what is your opinion / comment?**

Q33. **Has your state hosted any UAS related conferences to discuss implementation of this technology? What was the outcome?**

Q34. **Is there anything else you would like to add about your state's involvement in UAS technology?**

Q35. **Do you have any helpful advice for a DOT attempting to utilize UAS technology?**

Q36. **May we contact you with further questions? Please leave your contact information below.**

Name

Email

Phone number

Appendix D: First Round Recipients of Survey

(Note: Some of the first round email addresses were outdated, so the survey was sent again to the corrected contact list in Appendix E.)

Date sent: March 30th, 2015				
First Name	**Last Name**	**Email**	**State**	**Title**
John	Eagerton	eagertonj@dot.state.al.us	Alabama	Bureau Chief
Martha	Hutsler	hutslerm@dot.state.al.us	Alabama	Aeronautics Specialist
John	Binder	john.binder@alaska.gov	Alaska	Deputy Commissioner
Michael	Klein	maklein@azdot.gov	Arizona	Aeronautics Group Manager
John	Knight	John.Knight@Arkansas.gov	Arkansas	Director
Gary	Cathey	gary.cathey@dot.ca.gov	California	Chief
Stanley	Buck	stanley.buck@state.co.us	Colorado	Interim Director
James	Redeker	james.p.redeker@ct.gov	Connecticut	Acting Bureau Chief
Shalien	Bhatt	shalien.bhatt@mail.dot.state.de.us	Delaware	
Abdul	Hatim	abdul.hatim@dot.state.fl.us	Florida	Aviation Engineering Manager
Todd	Long	todd.long@dot.ga.gov	Georgia	Deputy Commissioner
Amanda	O'Brien-Rios	amandar@guamairport.net	Guam	
Glenn	Okimoto	glenn.okimoto@hawaii.gov	Hawaii	Director
Rodger	Sorensen	rodgerls@cs.com	Idaho	Chairman
Mike	Pape	mike.pape@itd.idaho.gov	Idaho	Division Administrator
Steve	Young	aero@dot.il.gov	Illinois	Director
Kevin	Rector	krector@indot.in.gov	Indiana	Manager, Aviation
Michelle	McEnany	michelle.mcenany@dot.iowa.gov	Iowa	Director
Winn	Turney	phankla@ky.gov	Kentucky	Commissioner
Craig	Farmer	Craig.Farmer@ky.gov	Kentucky	Engineering Branch Manager
Bradley	Brant	brad.brandt@la.gov	Louisiana	Director of Aviation
Ashish	Solanki	asolanki@bwiairport.com	Maryland	Director
Paul	Shank	pshank@bwiairport.com	Maryland	Chief Engineer
Chris	Willenborg	christopher.willenborg@mac.state.ma.us	Massachusetts	Administrator
Mike	Trout	troutm1@michigan.gov	Michigan	Executive Administrator
Cassandra	Isackson	cassandra.isackson@state.mn.us	Minnesota	Director Aeronautics Program
Sue	Mulvihill	sue.mulvihill@state.mn.us	Minnesota	Deputy Commissioner and Chief Engineer

Thomas	Booth	aeronautics@mdot.state.ms.us	Mississippi	Director
Debbie	Alke	dalke@mt.gov	Montana	Aeronautics Administrator
Ronnie	Mitchell	ronnie.mitchell@nebraska.gov	Nebraska	Director (Aviation)
Matthew	Furedy	mfuredy@dot.state.nv.us	Nevada	Aviation Manager
Patrick	Herlihy	pherlihy@dot.state.nh.us	New Hampshire	Director of Aeronautics
Steve	Summers	steve.summers@state.nm.us	New Mexico	Aviation Division Director
Gerardo	Mendoza	gerardo.mendoza@dot.ny.gov	New York	Bureau Director
Bobby	Walston	bwalston@ncdot.gov	North Carolina	Aviation Director
Jay	Lindquist	ndaero@nd.gov	North Dakota	Chairman
Kyle	Wanner	kcwanner@nd.gov	North Dakota	Director
James	Bryant	james.bryant@dot.state.oh.us	Ohio	Aviation Administrator
Joe	Harris	oac@oac.ok.gov	Oklahoma	Chairman
Victor	Bird	vbird@oac.ok.gov	Oklahoma	Director
Mitch	Swecker	mitch.t.swecker@aviation.state.or.us	Oregon	Director
Jean	Granger	jegranger@pa.gov	Pennsylvania	Acting Director
Robin	Suckley	rsukley@pa.gov	Pennsylvania	Division Chief
Peter	Fraizer	infodesk@pvdairport.com	Rhode Island	
Paul	Werts	pwerts@aeronautics.sc.gov	South Carolina	Executive Director
James	Stephens	jstephens@aero.sc.gov	South Carolina	Executive Director
Bruce	Lindholm	bruce.lindholm@state.sd.us	South Dakota	Program Manager
William	Orellana	Bill.orellana@tn.gov	Tennessee	Director
Said	ElSaid	said.elsaid@tn.gov	Tennessee	Intelligent Transportation Systems (ITS) Program manager
David	Fulton	dfulton@dot.state.tx.us	Texas	Director (aviation)
Pat	Morley	pmorley@utah.gov	Utah	Director
Guy	Rouelle	guy.rouelle@state.vt.us	Vermont	Aviation Program Administrator
Randall	Burdette	director@doav.virginia.gov	Virginia	Director
Tristan	Atkins	atkinstk@wsdot.wa.gov	Washington	Director
Rob	Hodgman	HodgmaR@wsdot.wa.gov	Washington	Aviation Senior Planner
Susan	Chernenko	susan.v.chernenko@wv.gov	West Virginia	Director
David	Greene	david.greene@dot.state.wi.us	Wisconsin	Director
Dennis	Byrne	dennis.byrne@dot.state.wy.us	Wyoming	Administrator

Appendix E: Second Wave of Survey Recipients

This list of contacts updates the outdated information to the previous list.

Date Sent: April 1st, 2015				
First Name	**Last Name**	**Email**	**State**	**Title**
Jerry	Chism	jerry.chism@arkansas.gov	Arkansas	Director
Gary	Cathey	gary_cathey@dot.ca.gov	California	Division Chief
Kevin	Dillon	kdillon@bradleyairport.com	Connecticut	State Aviation Administrator
Roberta	Geier	roberta.geier@state.de.us	Delaware	Assistant Director of Planning
Aaron	Smith	aaron.smith@dot.state.fl.us	Florida	State Aviation Manager
Carol	Comer	ccomer@dot.ga.gov	Georgia	Director, Division of Intermodal
Charles	Ada	chuckada@guamairport.net	Guam	Executive Manager
Ross	Higashi	ross.higashi@hawaii.gov	Hawaii	Deputy Director - Airports
Steve	Young	steve.m.young2@illinois.gov	Illinois	Acting Director
Winn	Turney	winn.turney@ky.gov	Kentucky	Commissioner
Scott	Rollins	scott.rollins@maine.gov	Maine	Director
Paul	Wiedefeld	pwiedefeld@bwiairport.com	Maryland	Executive Director
Cassandra	Isackson	cassandra.isackson@state.mn.us	Minnesota	Director
Thomas	Booth	tbooth@mdot.ms.gov	Mississippi	Director
Amy	Ludwig	amy.ludwig@modot.mo.gov	Missouri	Administrator of Aviation
Talvin	Davis	talvin.davis@dot.state.nj.us	New Jersey	Acting Manager
Rolando	Torres	rtorres@prpa.pr.gov	Puerto Rico	Acting Executive Director
Kelly	Fredericks	kfredericks@pvdairport.com	Rhode Island	President & CEO
Randall	Burdette	randall.burdette@doav.virginia.gov	Virginia	Director

Appendix F: Introduction Email Sent with Survey

Hello,

You're invited to participate in a survey concerning the use of Unmanned Aircraft Systems (UAS) in department of transportation activities. The Industrial Engineering department at Kansas State University is conducting a feasibility study for implementing UAS technology at the Kansas Department of Transportation.

If your DOT is currently using unmanned aircraft or has ever considered it, we would like to hear your input! Please follow the link below for the electronic survey. Completing the survey takes approximately 15 minutes.

If you feel that you are not the correct contact for this topic, please forward this email to who you think has the most helpful information on unmanned aircraft.

This survey has been approved by the Institutional Review Board of Kansas State University. There are no risks associated with participating in this study, and no personal information will be recorded unless you choose to provide contact information. Your participation in this study is voluntary and you are free to withdraw your participation from this study at any time, or leave any questions blank that you don't wish to answer.

If you have any questions regarding the survey or this research project in general, please contact Melissa McGuire or her advisor Dr. Margaret Rys with the contact information below. If you have any questions concerning your rights as a research participant, please contact the IRB of Kansas State University at (785) 532 -1483.

The link below will take you to the survey and we would appreciate your response on or before April 10th.

Follow this link to the Survey:
<Generated hyperlink>

Thank you for your assistance in this important endeavor.

Appendix G: Background Information

G.1 Tower Inspection

A cost analysis of tower inspections was initiated after gathering data from a KDOT employee and project manager who used a UAS in a tower related project. Edwin Geer in the Bureau of Maintenance provided important information for cost analysis of tower inspections and maintenance. This information includes current inspection methods, equipment needed, and a recommendation to seek out their contractor, Hayden Tower Service. The information from this inquiry is shown below. The next step in gathering information on tower inspection is to contact the Hayden Tower Service for archived records.

Tower Inspection Inquiry

How many communication towers must KDOT maintain and inspect in Kansas?
Currently, KDOT has ownership of 80 large towers that require inspections.

Where are these towers located?
These towers are located throughout the state. Only one county has two towers in it.

How often are these towers inspected? Is there a maintenance schedule?
KDOT will try to inspect a certain amount of towers each year.
There is no fixed percentage of towers inspected each year. This year the contractor has a purchase order to inspect 20 towers.
An inspection of 20 towers each year would be desired.

Is there a historical log of inspections and maintenance?
Inspection reports are maintained by our contractor Hayden Tower. Inspection data is online and available for review by KDOT.
Maintenance is completed as needed. If inspection shows work that needs completed the contractor is then issued a purchase order to complete the work.

What characteristics are looked for during inspection? (Damage, cracks, rust, dents, etc.)
Visible structural damage, rust, bolt tightness, guy wire tensions, lighting systems damage, antenna/coax damage. Whether the tower is plumb, anchor heads, inspections of turnbuckles and hardware.

How is the structural integrity tested to determine if maintenance is needed or not?
Visible damage, cracked welds. These towers are solid legs to prevent rusting internally. Guy wire tension. Structural reports are completed whenever additional equipment is added to a tower.

How many people are needed to perform tower inspection and/or maintenance?
There must always be two people at the tower site if someone is going to be on the tower. The second person must be able to contact emergency services if necessary. We prefer they are capable of tower climbing/rescue.

What materials and equipment are needed during inspection and maintenance?
Climber safety equipment, camera, wrenches, Dillon tension meter, RF personal safety monitor.

Are there any safety concerns regarding these inspections? If so, what?
Anytime someone is climbing a tower there are concerns. Is the proper safety equipment utilized, weather conditions, daytime or nighttime climbing, hoisting equipment and securing it properly. If using UAVs, obstacles that would be of concern would be the guy wires.

What is the height of the towers? (The average? The tallest?)
These towers range in height from 120’ to 480’. The average height of towers is 400’. Most of the towers are guyed, but KDOT has a number of self-supporting towers.

How much does contractor charge per hour for tower repair?
We have a service contract with Hayden Tower. Here is their pricing:
The vehicle is $43.00 per hour. Technician 1 = $53.00, Technician 2 = $43.00 per hour,
Technicians 3-5 = $41.00 per hour.

Is it possible for me to get permissions to view the online inspection data?
I will try to get you a hard copy of an inspection report.

You mentioned climbing and rescue abilities for inspections. Is there training involved for these skills? How much time does it take for someone to complete this training?
Would suggest you talk with the contractor. Do not have information on their policies. For our tower climbers, they attend a training program which is only 2 days. We also have a technician who is certified to train others who attended a class (approximately 5 days).

How much time on average does it take to perform the inspection?
Not sure, would suggest visiting with our contractor. You may contact Mark Stanley with Hayden Tower to get this information.

When driving to the site of the tower to be inspected, do the workers always leave from the Topeka office? Are there other locations in Kansas where workers would leave to minimize driving distance?
When doing tower inspections they are given to the contractor as a group to be completed in the fiscal year. You would need to contact the contractor to determine if they always leave from Topeka or if they utilize a crew already working in the vicinity of the tower.

Can you direct me to an injury history report for tower inspections?
Not sure of any injury reports for tower inspections. OSHA would be the agency to keep records of this type.

Motorola Project

The project manager for Motorola, Tim Tierny, was contacted and information on commercial UAS application was recorded. An overview of the phone conversation is available below. An external company called Von Arden Productions performed the process of recording the aerial footage and editing the video for Motorola. Von Arden Productions must be contacted for further details about their UAS specifications. An important discovery from this phone call is that a UAS cannot perform a structural analysis and a worker would still have to climb the tower for the analysis.

Did you get FAA permission for this project? Did you have to fill out a COA?

Do not need permission up to 400 ft. Drones have built in limitations for height.

Equipment: Drone brand, specs, supplier, cost, time to charge batteries?

UNKNOWN – hires external company

How many do you have? Did you have to hire pilot trained employee?

Used external company to perform drone flight. Motorola employees not in charge of operating drone.

How is video analyzed?

Hired a company to do the analysis. Von Arden productions. Operate drone, edit video. Not qualified to get technical/structural comments. Charges cost per tower.

Who makes decisions? You or another company/person?

Video is edited and sent to Tim. Decisions made by Motorola. Von Arden only supplies drone video.

How does this method (using drones) compare to the old method of tower inspection? (Time, safety, money).

Does not replace structural analysis, but the video is good discussion tool. Adds to quality in communication in projects

Are you using the drone in any other areas of Motorola?

This was the first project that used drones at Motorola. Not many other companies are using them. So far they like using drones in their projects, will most likely use them in future projects.

G.2 Bridge Inspection

An additional cost analysis will be completed about bridge inspection and maintenance performed by KDOT. The following list of questions has been sent to the bridge inspection team. To gain a better understanding of the bridge inspection processes, an in person meeting has been arranged in Topeka on May 5th. The aim is to acquire enough information to answer the questions below as well as a cost analysis.

How many bridges are managed by KDOT?
How many people are needed to perform inspection?
What equipment is needed for the current inspection method?
How much time does it take to perform inspection?
For highway bridges, how do you deal with traffic?
Can you share an inspection report with me?
Has the “Kansas Local Bridge Task Force” considered using drones/UAS?
Could an inspection be done completely by visual observation? (including structural analysis?)
About Bridge Plan:
Can you provide an estimate of how much the consultants charge/hr to do inspections?
Can you send me the material from the “In-house Bridge Inspection School”?
Can you send me the “guidelines for inspections” which was implemented by the Kansas Local Bridge Task Force?
Are there any safety concerns regarding these inspections? If so, what?

Appendix H: Comments on Proposed Rules

Extended responses to Question 32. The question asks survey respondents if they have an opinion of the proposed rulings, and to provide comments and opinions on the FAA's proposed rules on UAS regulation.

David Esse supplied the following comments:

UAS/UAV NPRM Comments: In general, I do not see any new concerns based on the info in the NPRM. There is an ongoing issue that under the COA process the State would need to own and operate the UAS/UAVs. Between the expense of the technology and the need to train/certify staff, this process is cost prohibitive and will postpone the use of this technology from within WisDOT. With that said, I am looking towards the operation of these vehicles from an industry perspective and hope that the NPRM supports the industry and allows for our state to take advantage of the technology through other channels. Here are some brief questions regarding the NPRM as written:

1. In reference to the statement written in the Overview of Small UAS Notice of Proposed Rulemaking: "Small unmanned aircraft may not operate over any persons not directly involved in the operation." Is it a violation of the rule above if an operator is flying an UAS above a water way (for purposes of conducting a bridge inspection over a river for example) and a water craft travels downstream under the device while in operation?
2. In reference to the statement written in the Overview of Small UAS Notice of Proposed Rulemaking: "Small unmanned aircraft may not operate over any persons not directly involved in the operation." Is there any special exemption for state agencies or law enforcement agencies when using UAS for incident management, search and rescue, or traffic control?

- Operational Limitations

  State and Federal Agencies using a small UAS, prior to or in the event of an emergency or in the interest of public safety (search and rescue, damage assessment, etc.), are exempt from these rules even without a Certification of Waiver or Authorization. The suggested notification of operations to ATC when operating in specified airspace should apply to this exception and an additional notification of operations to airport manager/owners in the vicinity should also apply.

    - The FAA should provide clarification on how small UAS airspeed and altitude limitations are to be calculated and observed. By what means will an operator know when he/she has reached 87 knots and/or 500 feet AGL?
    - Prohibiting small UAS commercial operations over any person not directly involved with the operation is excessive and will limit the abilities and improvements that UAS would be able to provide. A height restriction similar to aircraft operations might be a better option.
    - The FAA should define the term "over any person." A specified three-dimensional space that a small UAS is prohibited from when "operating over any person not directly involved with the operation" should be included in the final version of this rule.
    - Small UAS operations are limited to 500 feet AGL but should also be limited to operations within 3 miles of an airport (similar to hobbyist), unless permission from ATC and the airport manager is obtained and a NOTAM is filed.
    - Opportunities to allow advanced geo/GIS software equipped UAS to deviate from the line of sight should be included in this rule. Software that allows for geo-fencing and automated UAS return should be considered mitigation for line of sight operations. To not allow for these technological advances will limit ingenuity, UAS engineering and manufacturing, and slow the economic impact these innovations can have on the US.

- UAS should be permitted to transport property for payment. Prohibiting this action prevents modernization and technological progress. These types of operations will generally involve flights over people not involved with the operation and out of visual line of sight. Advanced UAS software should be utilized to fly a detailed flight plan that avoids populated areas. The filing of this flight plan with FAA would also advise ATC of the UAS operations and flight path.
- FAA should address the ramifications of any person tampering with or altering the geo-fencing abilities of any UAS software.
- A UAS equipped with GIS software, not operating over a group of people, and operating under a filed flight plan should be allowed to use a first-person view device instead of meeting the visual line of sight requirement. Mitigating risk with a properly lighted and equipped UAS, a filed flight plan, a visual observer, and GIS software should allow for low-light and nighttime operations.
- The suggested line of sight is an appropriate area of operation unless a first-person view devise is allowed. A horizontal numerical boundary is unnecessary and seems unreasonable for these types of operations.
- A 500-foot AGL ceiling for UAS operations not operating under a COA is reasonable and will potentially keep risk of accidents low. In light of FAA's interim policy to allow small commercial UAS to fly under a "blanket COA" so long as the UAS flies no higher than 200 feet AGL is also reasonable as an interim step.
- A flight plan and NOTAM should be filed by the operator for any out of visual line of sight operation, should it be allowed.

- Operator Certification and Responsibilities
  - Recurrent aeronautical testing for operators should be free and available online rather than in an FAA-certified testing facility.
  - No certification of the visual observer should necessary but an online training on safe operations should be suggested prior to participating in any small commercial UAS operation.
- Micro UAS Operations
  - Frangibility of micro UAS may add unnecessary cost to the manufacturing process and should be eliminated from any future NPRM for micro UAS. Damage caused from micro UAS is potentially low risk if the category is kept under the 4-pound weight limit.
- Miscellaneous
  - What is considered personal property? If a property owner does not want operations in his/her backyard, what are the personal property rights to the airspace over their home or land? How would this concept fit into the proposed rule?

Other comments from the survey responders are below.

1. It is an average response from the FAA. Safety may be addressed but little to no enforcement will be offered by the FAA. Privacy issues are not addressed. It does however, give state and local police a starting point to address safety issues with UAS operators. If a police officer observes someone operating a UAS in a careless manner then the officer may ask the person to stop. We retain the right to arrest and charge the individual under existing careless and reckless operations.
2. Yes, we did submit some comments through a consolidation effort by the National Association of State Aviation Officials (NASAO). We are supportive of the commercial rule, except for the requirement that UAVs not fly over any person not directly involved with the flight operations. We feel this is an unrealistic request. We

also believe that all airport managers should be notified when UAVs operate near any airport. The FAA rule proposed only airports with control towers operating in controlled airspace.

3. NYSDOT did not comment.
4. Yes. The FAA should expedite the process for approval of UAS.
5. Yes. We consolidated comments with the other states and submitted via AAAE and NASAO. We primarily focused on the need to move ahead quickly, focus on airspace confliction, sense and avoid technology, and education.
6. We support decreasing (but not eliminating) FAA restrictions to allow government and commercial UAS operators to safely use this emerging technology to achieve cost savings, and to improve safety and productivity for routine functions performed by Department staff.
7. Yes, safety, training, and aircraft registration were the major concerns of our Office of Aeronautics. Otherwise they are supportive.

K-TRAN

KANSAS TRANSPORTATION RESEARCH AND NEW-DEVELOPMENT PROGRAM

AD ASTRA PER ASPERA

Kansas

Department of Transportation