Potential Unmanned Aircraft Systems Based Operations within a Department of Transportation: Findings from a Focus Group Study

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State Departments of Transportation (DOTs) have recently been investigating the implementation of Unmanned Aircraft Systems (UAS) for operations, such as highway construction, bridge maintenance, and intermodal transportation facility construction and inspection. The Georgia DOT (GDOT) is currently investigating the integration of UAS in their operations in order to develop guidelines for safe and effective operations. This paper presents initial findings from Focus Group (FG) sessions with 17 professionals from three GDOT divisions including, (1) Construction, (2) Bridge Maintenance Group (BMG), and (3) Intermodal. Current operations performed by the three divisions were identified as well as potential UAS assisted tasks. Issues to be considered during field tests have been identified from the FG interviews. Issues related to Federal Aviation Administration (FAA) requirements for the Pilot-in-Command (PIC) as well as permitted operations have been also recognized as one of the most important concerns for UAS integration. The next step of the ongoing study involves the design of field experiments to be conducted in a variety of environments including active construction zones as well as existing bridges and airport and rail infrastructure.

Key Words: Unmanned Aircraft System (UAS), Construction, Bridge Inspection, Department of Transportation (DOT), Infrastructure

Introduction

Unmanned Aircraft Systems (UAS) are increasingly being considered for government and civilian applications in the United States. In 2016, the Federal Aviation Administration (FAA) established policies and certification requirements for UAS integration into the National Airspace System (NAS). The established regulations are so recent, that the effectiveness of UAS for civilian applications has not been determined under these new conditions, specifically for tasks such as those performed by the Georgia Department of Transportation (GDOT). The majority of the tasks performed by GDOT divisions with the greatest potential for benefitting from UAS technology, are centered around collecting data, providing information, and decision-making based on the data. Each task is also characterized by attributes (e.g. locations where the tasks are performed and the time required for completing a given task) that yield a better understanding of environmental conditions during task performance. Thus, UAS technical requirements that consider the operational and technical requirements of task to be performed have been investigated and potential UAS platforms have been identified (Gheisari, Karan, Christmann, Irizarry, & Johnson, 2015; Karan, Christmann, Gheisari, Irizarry, & Johnson, 2014). In order to determine the operational implications of UAS use by the GDOT, field tests of previously identified potential UAS systems should be performed. This paper will present findings from Focus Group (FG) sessions with...
GDOT personnel; including current tasks as well the potential UAS applications. The following sections provide the background for investigating UAS applications for various uses within DOTs in the United States.

**UAS Applications in Construction, Bridge Maintenance, and by State DOTs**

IHart and Gharaibeh (2011) explored an UAS equipped with a digital imaging and a Global Positioning System (GPS) in order to improve the effectiveness and safety of roadside conditions and construction inventory surveys. They also considered weather and field conditions to evaluate the operational performance of a UAS during field tests on 10 sample roadways in Texas. Blinn and Issa (2016) explored the possible applications of UAS for the construction industry in their study. The study compared the current tasks without UAS and aerial images obtained from UAS through a survey of industry personnel. They concluded that aerial photos and videos captured by UAS could be used for project management and controls on construction sites. Irizarry and Costa (2016) also investigated the potential UAS applications for construction management tasks. The results of this study concluded that construction work progress monitoring and jobsite logistics could benefit from UAS applications and the visual assets captured by UAS. Kim, Irizarry, and Costa (2016) identified the performance factors, user requirements, and operational challenges of UAS applications for construction inspection, particularly for safety on construction sites. A total 31 factors and 17 measures were derived to evaluate the performance of UAS operations. In addition, the appropriate UAS flight plan was identified as the most important user requirements, and FAA regulations and pilot certification were considered the most significant challenges for safe UAS operations in construction environments. Hallermann and Morgenthal (2014) attempted to develop a method for visual bridge inspection with aerial photography taken by UAS and to develop an autonomous or semi-autonomous flight inspection method for detecting damage on the bridge. Khan et al. (2015) investigated the use of UAS applications for inspecting the bridge structure at inaccessible locations. They conducted a pilot test on a mock-up bridge model as well as actual highway bridges. The aim was to understand the process of providing inspectors with a multi-spectral imagery-based preliminary assessment of bridge elements. Chan, Guan, Jo, and Blumenstein (2015) reviewed the current state of bridge inspection with UAS platforms. This study aims at understanding the historical UAS development, capabilities for inspections with aerial visualizations, and requirements of UAS-based bridge inspections. The case study also supported the evaluation of UAS performance for bridge inspections.

In addition, several State DOTs have explored possible uses for UAS technology. The California Department of Transportation (Caltrans) developed a Vertical Takeoff and Landing (VTOL) aerial robot called an Aerobot in order to closely inspect the underside of highway bridges and elevated structures quickly, safely, and effectively (Moller, 2008). The goal of this research was to improve the capabilities and performance of the Aerobot. The Illinois Department of Transportation (IDOT) and the Task Force in the State of Illinois worked on providing an overview of comprehensive laws and rules for UAS operations within the state of Illinois (IUASOTF, 2016). This study aimed at understanding the concept of UAS, its applications, FAA regulations, insurance for UAS operation, as well as safety and privacy issues. The Kansas Department of Transportation (KDOT) studied UAS implementation on their operations (McGuire, Rys, & Rys, 2016). This study conducted a survey and a Strengths, Weakness

http://www.ascpro.ascweb.org
Opportunities and Threats (SWOT) analysis in order to determine how to improve the safety and efficiency of UAS operations and to reduce the cost of the applications for KDOT operations. They concluded that UAS could be used for bridge inspection, radio tower inspection, surveying, road mapping, high mast light tower inspection, and stockpile measurement among KDOT’s various responsibilities. The New Hampshire Department of Transportation (NHDOT) proposed new research for investigating how to increase safety and efficiency and to decrease the cost of UAS operations in the NHDOT (Hunt, 2016). The purpose of this study is to analyze the cost benefit, data process and security, and human safety factors and aspects of the DOT’s transportation projects. The expected outcome of this study is enhancing the performance of traffic flow monitoring and assessment of infrastructure conditions, and educating the NHDOT employees to use the UAS for their tasks. These studies lay the groundwork for the current research at the GDOT. Its contribution is not only the detailed field experimentation with traditional DOT related tasks, but the definition of the experimental tasks based on a methodological approach that incorporates user knowledge and experience. In addition, the study will yield guidelines for UAS integration that are not currently available and have not resulted from previous studies.

**Research Methodology**

The scope of this paper includes the work and findings related to the first activity of the current research at GDOT, specifically the FG sessions with various of its operational groups. The analysis of data obtained from three FG sessions is included. The sessions took place between mid-July 2016 and early August 2016. The FG meetings occurred once per division and each meeting took about two to three hours. A total of 17 management level professionals in each group participated. The first FG took place with five participants from GDOT District 1 Construction division at their Gainesville office on July 12th, 2016. The second FG sessions were performed with seven interviewees from three teams, including (1) Top-side, (2) Specialized, and (3) Underwater inspection, in BMG at Georgia Transportation Management Center on July 19th, 2016. The last FG session took place with five professionals from Intermodal Group at Georgia One Center on August 1st, 2016. The participants included managers from two departments: (1) Aviation and (2) Railway. During the FG session, the research project goal and the objective of the FG were explained to participants. In addition, an attendance sign-up sheet with a unique numeric identification code per participant, demographic questions, and data collection sheet were distributed to all participants. All participants were somewhat familiar with the basic concept of UAS and the idea of integrating this technology with their tasks, however most of them did not have UAS flight experience. Only three out of 17 participants had UAS flight experience for either recreational or research purposes. During the session, participants provided information on how their group currently works on specific tasks and what potential tasks could be integrated with UAS. The questions and procedure for FG sessions was evaluated and approved by Georgia Tech Institutional Review Board (IRB) which is charged with the protection of human research subjects. The objectives of the FG sessions included:

1. To compile a list of current tasks with detailed descriptions of the process as well as the resources needed to perform the tasks;
2. To define the UAS-integrated tasks that will be used in the field test activity;
3. To determine the appropriate UAS platform and related technology to be integrated into the task; and
4. To develop the experimental design of the field test based on defined the tasks.

This paper presents findings from the first three objectives of the FG sessions.
Focus Group Results

Current and Potential Tasks with UAS Integration for Construction Group

According to the Construction Group, the main responsibility of construction managers is to survey and inspect highway construction environments. Construction managers usually take videos or photos of site logistics, including pipeline inspection, from the roadside area. However, this method might cause potential accidents and is limited by the capability to get needed safety signs to do this work on the jobsite. In addition, they also inspect and measure sidewalks for the safety of pedestrians and workers on the construction jobsite. They inspect and measure the speed of all traffic in order to avoid severely dangerous situations and accidents on the jobsite. The managers are in charge of verifying the volume of excavation when they process payments to subcontractors. However, the problem is that GDOT uses a simple calculation method to measure the amount of excavation. The method involves multiplication of the height by the square footage of the excavation, or the number of dump trucks by the load capacity of each truck. In addition, project personnel are required to control the project limits and work areas to manage erosion. They need to wear special boots and walk around the earthwork area in order to inspect erosion control measures. This work was regarded as the one of the most important concerns of this group.

Potential tasks with UAS integration on GDOT’s Construction Group were also discussed during this FG session. According to the FG participants, UAS integration can have advantages when documenting existing conditions (i.e. progress monitoring and documentation) as well as to use at the beginning stages of a project. An UAS also has the capacity to inspect or monitor the site conditions with higher frequency (daily or weekly). UAS integration could be used to quantify the volume of excavation. Three-Dimensional (3D) models developed through photogrammetry could be developed since an UAS is equipped with sensors that capture geo-referenced information as well as geo-located points. Based on the geo-referenced point cloud, GDOT personnel can measure the volume and elevation of excavation with greater accuracy. The 3D model and point cloud data can assist erosion control efforts. In addition, the UAS is capable of verifying actual traffic speed on construction work zones. GDOT personnel would also be capable of performing traffic speed checks from UAS flights. Table 1 summarizes the identified current and potential operations with UAS integration for the Construction Group.

Current and Potential Tasks with UAS integration for BMG

The BMG is mainly involved in performing inspection tasks on an estimated 15,000 bridges in the State of Georgia. This group has three teams responsible for inspections based on the section of the bridge to be inspected (Figure 1). The group develops and uses internal references as well as standard specifications, such as the Bridge Structure Maintenance and Rehabilitation Repair Manual (BMRM - checklist) (GDOT, 2012) based on the AASHTO Guide Manual for Bridge element inspection and Bridge Maintenance Unit (BMU) (AASHTO, 2010)
Table 1

**Current tasks and potential operations with UAS integration (Construction Group)**

<table>
<thead>
<tr>
<th>Division</th>
<th>Current Tasks</th>
<th>Potential Operations with UAS Integration</th>
</tr>
</thead>
</table>
| Construction | 1. Site monitoring/inspection and assessment (photo or video)  
2. Excavation volume measurement  
3. Erosion control inspection  
4. Traffic speed evaluation  
5. Pipeline and sidewalk inspection (logistic) | 1. 3D model generation with photogrammetry  
- Erosion control  
- Excavation measurement (quantification)  
2. High-frequency site monitoring/inspection (daily or weekly inspection) |

**Figure 1:** GDOT’s BMG team structure.

The BMG performs visual observations when performing inspections of the various bridge elements. They may consider performing more specific visual inspections with close-up views of the bridge deck, superstructure, substructure, and bearings, joint elements (bridge joint sealing or header joint), and curb/rail/pipe, etc. Depending on the type of bridge, structural elements, size and traffic on the bridge, the inspection may have different sequence and frequency. The topside team regularly conducts inspections in two-year cycles per bridge. The specialized team has three different routines at three, six, and 48 month cycles depending on bridge size, location, and condition. The underwater team has a 60-month cycle to inspect the bridge elements located below the water surface. The average time required to inspect a bridge ranges from 15 minutes to three or four hours depending on the structure, size, and type of bridge. GDOT BMG has been measuring vertical clearances and surveying permanent capacity as scheduled. In addition, the team has been using hammers to inspect connection points in hard to access locations. An infrared camera can sometimes be used to detect problems at the connections between the deck and superstructure using temperature differences. The temperature profile can be used to detect cracks on bridge elements. This group also has contingency plans to deal with accidents or problems during inspections to maintain the safety of their personnel. The inspection process typically involves the topside team or specialized team, or both teams inspecting the points of interests on the bridge. In order to control the traffic on the subject bridge, the group coordinates with authorities with jurisdiction over the bridge or third parties, such as a traffic control companies or Federal Highway Agency in charge of managing and controlling traffic on the road. It usually takes an average of 15 to 20 minutes to set up the equipment upon arrival to the site, and the team is able to start inspecting the points to be observed.

Integration of UAS on bridge maintenance could save time, particularly on bridges with tall columns. In addition, an UAS is capable of performing inspections underneath bridges as well as the underside of decks, including bearings,
connections, column caps, and other structural elements. However, GPS sensors would present a challenge since satellite signals are difficult to lock on to when the UAS is under the bridge. In addition, an UAS should be equipped with a special camera that is capable of looking up and have a light to be able to capture images of the underside of the bridge. A UAS could assist to produce 3D model visualizations that could be used to measure cracks on the bridge as well as vertical clearances without interrupting traffic on the bridge. In addition, 3D models developed through UAS-based photogrammetry could be used to compare the accuracy of the original plans. If the 3D model has significant deviations from the original design, these could be addressed. When considering the use of UAS for bridge inspections, the GDOT BMG should consider the presence of power lines close the bridge for the safety of the operation. Another potential task with UAS integration on bridge inspection and maintenance is to inspect the inside of box-beam structural elements in order to test the air quality and to detect cracks on the walls inside the element. Since the inside of the element does not have sufficient light to allow observation and detection of cracks is a manual process, this requires greater time to conduct accurate inspections. A small light-equipped UAS could fly inside the tunnel, and collect a visual profile of the inside wall. However, this task still requires more complex and/or manual controls as well as sensors, such as vision sensors and lights to collect and process the visual data from confined space flights. The UAS equipped with a sonar sensor could be considered for use in underwater inspections. The sensor could measure depth when it comes into contact with the water surface, measure the distance from the deck to water surface, or from water surface to bottom of underwater surface (river or lake bed). This would aim at reducing the use of human divers to perform inspections of submerged bridge elements as well as the time to needed to conduct measurement of depth of water. Table 2 summarizes the identified current and potential operations with UAS integration for the GDOT BMG.

Table 2

<table>
<thead>
<tr>
<th>Division</th>
<th>Current Tasks</th>
<th>Potential Operations with UAS Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDOT BMG</td>
<td>1. Visual observation (sequence and frequency)</td>
<td>1. Time saving on bridges with tall columns (An upward looking camera and illumination is required)</td>
</tr>
<tr>
<td></td>
<td>- Depends on bridge type, structures, size and road traffic conditions</td>
<td>2. 3D model generation with photogrammetry</td>
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<tr>
<td></td>
<td>- Regular inspection (2yrs), specialized team (3, 6, or 48 months), underwater team (60 months)</td>
<td>- Detect and measure cracks, conduct vertical clearance assessment</td>
</tr>
<tr>
<td></td>
<td>2. Vertical clearance measurement</td>
<td>- Develop 3D steel beam model for precision comparison of as built structure.</td>
</tr>
<tr>
<td></td>
<td>3. Hammer sounds to inspect the points where hard to access and inspect in person.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Accident or problem reaction plan</td>
<td>3. Inspection of underneath bridge and underside of deck using various sensors (i.e. IR or thermal sensor)</td>
</tr>
<tr>
<td></td>
<td>- Call related BMG–traffic control (30 mins.) – setup equipment (15-20 mins.) – inspect</td>
<td></td>
</tr>
</tbody>
</table>

Current and Potential Tasks with UAS Integration for Intermodal Group

Intermodal Group has four departments: (1) Aviation, (2) Railway, (3) Port, and (4) Transit in order to manage each facility and resource in the state of Georgia (Shown as Figure 2). Only Aviation and Railway departments were considered in identifying current tasks and potential tasks with UAS integration. The Aviation department can be
categorized in two specific teams: (1) inspection and (2) construction team. The inspection team under Aviation is mainly in charge of inspecting the pavement condition of airport runways, as well as performing observations of general conditions around the runway and the airport. A total of seven inspectors in this team are involved in working on a total of 104 registered airports in Georgia. The construction team in the airport group is involved in monitoring the construction progress of airport related facilities. However, this team has been hiring third party inspectors to inspect pavement conditions. The Railway team is contracted by six railway operators in the state in order to conduct daily inspections at railways and surrounding environment.

**Railway Department**

The Railway department has contracts with six railway consultants in order to conduct inspections. The general inspection process has four steps: (1) walk through the railway, (2) check general conditions, (3) take pictures at the points of interests, and (4) address issues that have to be improved and document issues and solutions. The Railway department has also been using a truck equipped with a camera for inspections. The truck can be operated to take video of the rails and the surrounding environmental conditions at an average speed of 5 mph. This truck is used for the inspection of about 30 to 50 miles per day. With low altitude and long distance flight capability, an UAS has great potential to inspect track elements along the railway right-of-way according to the railway manager. In addition, a UAS equipped with a thermal camera could be able to generate a temperature profile of the railway in order to inspect for cracks, expansion, or contraction of the railway. Another possibility to integrate UAS on the Railway department is to inspect railway crossings from a different, clear, and effective perspective. Table 3 summarizes the identified current and potential operations with UAS integration for the Railway department.

![Intermodal Group Structure](image-url)

**Figure 2:** GDOT’s Intermodal Group Structure.
Table 3

Current tasks and potential operations with UAS integration (Railway)

<table>
<thead>
<tr>
<th>Division</th>
<th>Current Tasks</th>
<th>Potential Operations with UAS Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermodal</td>
<td>1. Manual visual observation (once a month)</td>
<td>1. Low altitude and long distance flight with low speed for UAS flight inspection</td>
</tr>
<tr>
<td>(Railway)</td>
<td>- Walk through the railway – check the condition – take pictures – document</td>
<td>2. Temperature profile</td>
</tr>
<tr>
<td></td>
<td>- Railway including wood ties, and the surrounding environment conditions</td>
<td>- Thermal camera-based</td>
</tr>
<tr>
<td></td>
<td>2. Special truck equipped with camera used (30-50 miles per day, average 5 mph</td>
<td>- Inspect railway condition: railway’s expansion, contraction, and cracks</td>
</tr>
<tr>
<td></td>
<td>speed)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Railway Crossing Inspection with UAS</td>
<td>3. Railway Crossing Inspection with UAS</td>
</tr>
</tbody>
</table>

Aviation Department

The Aviation department is mainly in charge of inspecting the runways at airports. Inspectors or managers drive to the airport and onto the runway to perform visual inspections. This work requires human resources for conducting ground level inspection and equipment such as range finder, inclinometer, and measuring wheel. The time required to inspect a runway is dependent on the size of the airport. Runway inspection includes the runway markings or signs, the height and angle of trees located around the runway, and pavement conditions on the runway. In particular, the pavement inspection uses internal resources or hires external inspectors from time to time. All data collected from the inspection is processed and reported to the airport manager to compare visual data before and after inspection as well as when corrective measures taken. For the safe operation of aircraft on the runway, obstacles or cracks on the runway should be precisely inspected. The UAS is capable of taking precise photography of the obstacles and cracks at airports as well as observing the approach path to the runways allowing the inspection of the tree line outside the airport. In addition, an UAS equipped with certain sensors could collect topographic data of the runway and/or airport construction areas with acceptable precision for management applications and thus reducing man-hours required for this task. Aerial photography can provide pre- and post-survey comparisons of the runway and facilitate monitoring of construction work progress at airports. According to the aviation department manager, UAS integration could overcome the cost issues associated with inspecting a total of 104 airports in Georgia relying on outdated tools and human perception and judgment. Table 4 describes the identified current and potential operations with UAS integration for the GDOT Intermodal Group, particularly the Aviation department.
Table 4

Current tasks and potential operations with UAS integration (Aviation)

<table>
<thead>
<tr>
<th>Division</th>
<th>Current Tasks</th>
<th>Potential Operations with UAS Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermodal</td>
<td>1. Visual inspection (manually performed)</td>
<td>1. 3D model generation with photogrammetry</td>
</tr>
<tr>
<td>(Aviation)</td>
<td>• Runway markings and signs (general condition) and pavement condition</td>
<td>• Runway pavement condition (i.e. detect and measure cracks) and obstructions</td>
</tr>
<tr>
<td></td>
<td>• Tree heights and approach angle around runway</td>
<td>inspection/assessment</td>
</tr>
<tr>
<td></td>
<td>• Equipment: range finder, and inclinometer, measure wheel</td>
<td>• Airport area topography (reduced man-hour and increased accuracy)</td>
</tr>
<tr>
<td></td>
<td>2. Pavement condition inspection: external or internal inspector</td>
<td>2. Different perspective (aerial photography)</td>
</tr>
<tr>
<td></td>
<td>3. Data processing and reporting to airport manager: pre-/post- visual data</td>
<td>• Construction progress monitoring</td>
</tr>
<tr>
<td></td>
<td>comparison</td>
<td>• Pre/post survey comparisons of runway</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. More cost effective airport inspection with reduce reliance on outdated</td>
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<tr>
<td></td>
<td></td>
<td>equipment</td>
</tr>
</tbody>
</table>

Issues to be considered with UAS Integration within GDOT operations

According to the three FG sessions with GDOT Construction Group, BMG, and Intermodal Group, three main additional issues need to be considered for UAS integration within GDOT operations.

1. **FAA Regulations and Certified Pilot**
   The FAA requires that any UAS operation within a 5-mile radius of an airport must be coordinated with the airport operator. The UAS operator should communicate with the airport or heliport administrators and obtain permission in order to perform legal flight if the facilities are located within five miles from flight locations. In addition, the pilot should be certified, and the visual observers are required to keep track of the UAS flight within Visual Line of Sight (VLOS) in order to avoid the loss of control or a crash of the UAS platform during flights. As for the aspect of human resource development, GDOT would need to pursue one of two options: (1) hiring a certified pilot-in-command on a contract basis, or (2) train one of their own personnel as pilot-in-command so they can obtain a pilot certification.

2. **Weather Conditions**
   Weather conditions (rain, snow, and thunder storms, etc.) and temperature should be considered for high performance of UAS flights.

3. **Road Traffic Control**
   By integrating a UAS on construction sites or bridge maintenance work it could be possible to perform real-time scanning without interrupting roadway traffic. However, the UAS flight still has potential for dangerous situations, such as crashing the platform where there is vehicular or pedestrian traffic.
Conclusion

This paper presented preliminary findings from FG sessions with GDOT personnel focused on current and potential tasks with UAS integration for GDOT’s operations in three divisions, (1) Construction Group, (2) BMG, and (3) Intermodal Group. This paper aims at understanding the current work process and resources of each division as well as the operations that UAS could be integrated with in a safe, effective and efficient manner. As result of the FG sessions, each division’s work environment has been documented. 3D photogrammetry for visual inspection was also commonly identified as the potential UAS application that could be used by all divisions. In particular, the BMG could use specialized sensors, such as Infrared or thermal sensors for underneath inspections of bridges, and the railway team indicated a need for UAS capable of low altitude and long distance flight along the railroad right-of-way. In addition, FAA rules, weather conditions, and road traffic control were identified as additional issues to be considered. Based on these results, the next step of the current study involved experimental design and performance of field tests at a variety of environments including active construction zones as well as existing bridges and airport and rail infrastructure.

Acknowledgement

The research team would like to acknowledge the support of the GDOT through Task Order No. 2014-30 for Research Project No. 16-09. The analysis presented does not represent the views of GDOT and is solely those of the research team.

Reference

