

Risk Considerations in the Use of Unmanned Aerial Vehicles in the Construction Industry

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Abstract

The use of unmanned aerial vehicles (UAVs) in the construction industry is swiftly growing worldwide. UAVs are changing the way construction companies do business. Contractors are increasingly using camera-mounted UAVs to monitor the full range of activities. Rapid advances in camera, sensing, aeronautics, battery and autopilot navigation technologies have helped make UAVs affordable, reliable and easy to operate. The US Federal Aviation Administration predicts that UAVs hold tremendous promise and commercial drone sales could increase from 600,000 to 2.7 million over the next four years. On the one hand, UAVs are extremely cost-effective in conducting aerial surveys, worksite surveillance, real-time inspections, and monitoring jobsite safety. On the other hand, with UAV ownership rapidly rising, the number of reported UAV safety, risk, and liability incidents is increasing. With this new technology use in the construction industry, construction companies must be aware of all regulations, legislations, privacy liability, and risks for construction related businesses. Operating a drone or hiring a subcontractor to operate it is not something to do on the spur of the moment. Emphasis and effort should be placed on safety, risk control, training and education. The goal of this paper is to provide construction professionals with timely and pertinent information on UAV use with a focus on risk management based on current industry practice, experience and literature review.

Keywords: Construction, Drone, Management, Risk, Unmanned Aerial Vehicle (UAV), Unmanned Aircraft System (UAS)

1. Introduction

An unmanned aerial vehicle (UAV), also known as a drone is a pilotless aircraft: a flying machine without

an on-board human pilot or passengers. Control functions for unmanned aircraft may be either on-board or off-board (remote control). The US Federal Aviation Administration (FAA) defines an unmanned

aircraft as “an aircraft operated without the possibility of direct human intervention from within or on the aircraft” (GOP, 2016). The term unmanned aircraft systems (UAS) also used by the FAA, the European Aviation Safety Agency (EASA), and the US Department of Defense (DoD) includes the entire system, i.e., around control stations, communication links, launch and retrieval systems in addition to the aircraft itself (Dalamagkidis, Valavanis, and Piegler, 2009).

In a broad sense, there are three major market segments for UAVs: military, civil government, and commercial, all of which share common objectives: to provide a service that cannot be accomplished by manned aircraft and/or to perform an existing manned operation at a lower cost, with less noise and fewer emissions. Because of increased interest and activity, UAS are becoming a major part of the commercial aerospace industry within the United States and countries such as Australia, Canada, and the United Kingdom.

UAVs were first used for military purposes when the United States Air Force (USAF) operated drones from 1964 to 1973 until the end of the Vietnam conflict for strategic intelligence gathering. In later conflicts in Kosovo and Afghanistan, the USAF operated the Ryan Model 147 drones in missions at 12,000ft (3,658 m) and 24,000ft (7,315m), in support of the tactical (ground) forces. High altitude (40,000ft; 12,192m) long range little aircraft were used for strategic purposes (Irwin, 2003). A further, more recent use has been the \$17 million "Reaper" surveillance attack drone (DoD, 2005; 2014; Babel, 2015).

For many years, UAVs or Remotely Piloted Aircrafts (RPAs) have been used safely for commercial purposes in Australia, initially for agricultural purposes, but now extensively in urban land development, insurance assessment, mining and waste management, aerial mapping, construction, infrastructural engineering and surveying. Regulations in Australia require commercial RPA operators to demonstrate their ability to fly the vehicle, and each must meet minimum standards set by the Australian Civil Aviation Safety Authority (ACAA, 2016). The commercial UAV has not had a major accident in over 10 years of operation in Australia.

In Canada, UAVs have been used for a variety of government-related and commercial applications including agriculture surveys, movie shoots, police investigations, meteorology, and search and rescue. Recently, Canada Post has conducted research on the application of drones in mail delivery (CBC, 2016).

The US Federal agencies, state and local governments are increasing their use of UAVs to aid in law enforcement and firefighting. Commercial uses include construction management, real estate photography or pipeline inspection, and commercial goods delivery (FAA, 2010). Rapidly increasing numbers of units operated by civil and commercial users, especially in construction related applications, is changing the way conventional construction management for civil infrastructure construction management is undertaken.

The UAS has evolved from remotely-piloted vehicles with limited capabilities to semi and fully autonomous systems for industrial, commercial and scientific applications.

In recent years, UAV uses for commercial purposes have been increasing rapidly. The Aerospace Forecast Report released by the FAA for Fiscal Year 2016 to 2036 finds a sustainable increase in overall air travel and the use of UAS. The FAA estimates that small, hobbyist UAS purchases may grow from 1.9 million in 2016 to as many as 4.3 million by 2020. Sales of UAS for commercial purposes are expected to grow from 600,000 in 2016 to 2.7 million by 2020. The combined total of hobbyist and commercial UAS sales are expected to rise from 2.5 million in 2016 to 7 million in 2020. Predictions for small UAS (sUAS) used in the commercial fleet are more difficult to develop given the dynamic, quickly-evolving nature of the market (FAA, 2016A). By 2020, 90% of UAV prices will be approximately \$2,500 or below, while most expensive ones can be as high as \$40,000. On June 21, 2016, the FAA issued new rules for non-hobbyist small UAS operations - Part 107 of Federal Aviation Regulations which covers a broad spectrum of commercial uses for drones weighing less than 55 lb (25 kg) (FAA, 2016B). The new rule requires that the small UAS operator manipulating the controls of a drone should always avoid manned aircraft and never operate in a careless or reckless manner. Each operator must keep the drone within sight. If First Person View or similar technology is used, the

operator must have a visual observer always keep the drone within unaided sight, e.g., no binoculars. Neither the operator nor a visual observer can be responsible for more than one UAV operation at a time.

UAVs also vary widely in size, shape and capability. They are generally categorized in two different categories: fixed-wing and rotary-blade. Rotary-blade UAVs are able to take off and land vertically; they are able to hover and to change direction and orientation when maneuvering in a small space. In contrast, fixed-wing UAVs can stay aloft longer, but may require short runways for takeoff and landing. As a result, most construction applications prefer using rotary-blade types which do not need runways (Babel and Brown, 2015). Rotary-blade UAVs may use single or multiple rotors, typically with an even number. Multi-rotor UAVs normally offer better maneuverability and robustness. Fig. 1 shows a fixed-wing UAV; Fig. 2 is a Rotary-blade UAV.



Fig. 1. A fixed-wing UAV.

As UAVs can be easily equipped with camera or light detection and ranging (LiDAR) instruments they have great potential on construction jobsites. The use of high-density (HD) cameras for video (real time and recorded) and still images is common. UAVs can be controlled through joysticks, PC and laptop software, iPad and iPhone apps and are connected by Wi-Fi (Schriener and Doherty 2015). Many of today's UAVs use Global Navigation Satellite Systems (GNSS) for positioning, in combination with inertial measurement unit (IMU) that consists of accelerometers and gyroscopes. These sensors are integrated in a navigation computer, which allows them to follow designated routes or orientation autonomously.



Fig. 2. A Rotary-blade UAV.

With drones in construction research, there are two primary uses: construction jobsite reconnaissance and surveillance, using photogrammetric or LiDAR data. Both use UAVs to create a 3D model of the jobsite that is compared with site plans and construction documents, allowing significant deviations in construction progress, process, materials and methods to be evaluated. A simple report can be used to superimpose the site plans and construction documents over live images or LiDAR point cloud, where deviations can be indicated by colored patterns. Using this report, construction teams can adapt plans to the current needs.

The drivers and impediments to the growth of the use of UAVs in commercial purposes arise from (i) technology development and maturation; (ii) costs of UAS systems; (iii) government regulations; and (iv) risk minimization, training, and education. With the issuance of new regulations and rules, the use of drones on construction sites is compelling and likely to be increasingly adopted. As drone functionality improves, construction professionals are building on their first-hand experiences and concomitant with this, an awareness of the importance of understanding risks and regulations is imperative.

2. Government regulations

On February 14, 2012, the US Congress passed a law to compel the FAA to issue rules making commercial UAV use legal by 2015. The 2012 law, called the *FAA Modernization and Reform Act*, contains a seven-page provision known as the *Drone Act* requiring the FAA to fully integrate unmanned aircraft into the National Airspace System by September 2015. Additionally, the *Drone Act* allows law enforcement agencies, including local police forces, to buy and use unmanned aircraft for evidence gathering and surveillance. In February 2013, the FAA released a memorandum in response regarding the selection of test sites for an Unmanned Aircraft

System Test Site Program. According to the FAA, the UAS program will help the FAA gain a better understanding of operational issues such as training requirements, operational specifications, and technology considerations ensuring the safety and efficiency of the entire aviation system. By law, any aircraft operation in the national airspace requires a certificate and registered aircraft, a licensed pilot and operational approval. Section 333 of the FAA Modernization and Reform Act (FMRA) of 2012 grants the Secretary of Transportation the authority to determine whether an airworthiness certificate is required for a UAS to operate safely in the NAS.

According to the FAA, there are over 7,000 aircraft over US skies at any given time. Adding thousands of UAVs into already-crowded skies is why the FAA has been slow to recognize commercial use of the devices, or create regulations pertaining to their use. The FAA is rightly concerned with sharing of limited airspace and with related homeland security issues, e.g., use by extremist groups and illegal surveillance. There are also concerns about the potential for hacking UAV controls or loss of drone power, which could result in personal injury, death or physical damage to vehicles or structures.

In 2015, the FAA developed comprehensive rules for drones and regulated unprecedented, epoch-making regulations. The regulation requires all drones between 250 g (0.55 lb) and 25kg (55lb) UAVs to be registered. There is a distinction between recreational use and commercial use of the UAVs. The FAA permits recreational use of UAV's but stipulates that for drone hobbyists, the UAVs must weigh less than 55 lb (25kg), cannot fly higher than 400ft (122m) above the ground, or interfere with manned airplane traffic. For commercial or non-hobbyist drones, the maximum allowable altitude is 400 ft, or higher if the drone remains within 400 ft of a structure. The maximum speed is 100 mph (161 kph; 87 knots). Drones can fly only during daylight or in twilight (30 minutes before official sunrise to 30 minutes after official sunset, local time). If the craft is operated within 5 mi (8km) of an airport, the operator must have the air-traffic control tower's permission. Remote drone pilots must also keep their aircraft within sight and fly only during the day (Jansen, 2015; FAA, 2016B).

2.1 FAA Section 333 Exemption

The FAA Section 333 Exemption program is a document required by the FAA in order to be legally flying UAVs commercially. Without it ones are operating illegally and are liable to be fined by the FAA.

The FAA interim policy to speed up airspace authorizations with Section 333 exemptions for small (55 lb or less) commercial UAVs has sparked considerable interest in the infrastructure and building construction industry. In July 2015, the FAA granted over 150 exemptions under Section 333 (Speed, 2015). By the end of November 2016, approximately over 6,500 petitions had been granted, with many more requests under review. This program allows the use of a drone for a commercial purpose provided certain requirements are met, primarily that a licensed pilot operates the drone. Many of these exemptions were for construction related applications such as aerial surveying, construction site inspection and monitoring, oil/gas exploration and pipeline inspections, and aerial photography and 3D mapping.

2.2 Other rules

Under the current regulations by the FAA, it is illegal to fly drones for commercial purposes unless the operator has the specific exemption from the FAA for testing, commercial, or government uses. Commercial drone flights should abide by specific guidelines: (i) commercial pilots must pass an initial aeronautical knowledge test to obtain an FAA UAS remote pilot operator certificate rated for flying a small unmanned aircraft; (ii) operators must be at least 16 years old; (iii) commercial drones have to stay under 400 ft, as well as within the operator's line of sight; (iv) the operators are responsible for ensuring a drone is safe before flying including checking the communications link between the control station and the UAS; (v) The UAS must be registered.

2.3 Regulations concerning UAVs in Canada

UAVs in Canada are regulated by the government body called Transport Canada, and principally under the federal legislation called the Aeronautics Act and the Canadian Aviation Regulations. The requirements for flying UAVs vary based on the weight of the UAV. UAV flights normally require a Special Flight

Operations Certificate from the Minister of Transport. Operation of the UAV may be exempted from the special flight operations certificate if the UAV weighs less than 35 kg. If the UAV is less than 2 kg, the flight may be exempted from certification as long as the UAV is operated within the operator's visual line of sight, is kept away from built-up areas, and away from controlled airspaces, among other conditions. If the UAV is between 2 kg to 35 kg, it may also be exempted if the operator also has insurance coverage, the UAV is travelling less than 87 knots or less, the operator has completed a pilot ground school program, and notification of the flight to Transport Canada has been made, among other requirements. Operators must also comply with any applicable privacy, trespassing, and any provincial or municipal laws applicable.

Proposed amendments to the current regulations governing UAVs are expected to be publicly available in spring 2017. It is anticipated these regulations will create more exempted categories of very small exempted UAVs under 1 kilogram and/or unregulated UAVs weighing under 250 g or less (Chong, 2016).

2.4 Regulations concerning UAVs in Australia

In Australia the use of UAVs is regulated by a federal government agency, the Civil Aviation Safety Authority (CASA). UAVs are generally classified as remotely piloted aircraft (RPA) and depending on the weight and use, RPAs fall under different control mechanisms. Classifications is considered under the broad heading of recreational or commercial purposes with research activities falling under the commercial category.

Authorization to fly commercially comes via either the use of licensed pilots flying for registered RPA operators or flying within the exemption rules as detailed by CASA. In their modified regulations of 29 September 2016, some low-risk RPA operations are permitted without the need for licensing – but under very restrictive operations bounded by a strict set of conditions. Exclusions are based around the size of the UAV (very small RAVs, 100g < 2kg), flying over private land, maintaining line of sight, the height and proximity to people.

2.5 Regulations concerning UAVs in the United Kingdom

The Civil Aviation Authority (CAA) of UK is the regulator for commercial use of drones. Articles 166 and 167 of the Air Navigation Order (ANO) provide specific guidance for drones weighing less than 20 kg: (i) Control – the person in charge of a small unmanned aircraft may only fly the aircraft if reasonably satisfied that the flight can safely be made; (ii) Line of sight – the person in charge of a small unmanned aircraft must maintain direct, unaided visual contact with the aircraft sufficient to monitor its flight path in relation to other aircraft, persons, vehicles, vessels and structures for the purpose of avoiding collisions; (iii) Commercial purpose – The person in charge of a small unmanned aircraft must not fly the aircraft for the purposes of aerial work except in accordance with a permission granted by the CAA (Juty and Morris, 2015).

3. UAV uses in construction applications

The use of UAVs in the construction industry is in the early adopting stage, but the number of users is rising rapidly and the current results are exciting, as these devices are very cost-effective and can be used in several capacities.

The primary role of UAVs is to provide real-time reconnaissance and surveillance from the jobsite in the form of HD video, still images, and LiDAR to create 3D models. These images and models can be superimposed over existing plans and each other in order to: (i) survey large areas; (ii) track and identify daily changes; (iii) provide real-time data on job progress and evidence; (iv) proactively solve or prevent issues; (v) identify potential hazards or quality issues; (vi) communicate more effectively and efficiently; (vii) make basic repairs; and (viii) report cost, time and energy savings. The use of UAVs could also potentially make skilled laborers more productive, improve the efficiency, and lead to a faster construction process.

UAS devices provide a way to obtain real-time data on job progress; they may identify potential hazards and safety issues and help acquire other useful information in a very expeditious and cost-effective manner. The larger the construction site the more helpful they are in monitoring the project.

One of the promising emerging applications for UAVs will be to gather as-built data and verify installed systems as a structure is built. Drones can be equipped to take HD or 360 photos and video, take multispectral imagery, or scan sites with LiDAR. In pursuit of delivering a perfect product, construction managers can communicate installing work to contract specifications and design intent quickly, easily, and accurately.

As the number of human resources on the jobsite declines through prefabrication, robotics and automation, the number of drones and the size of drones on the jobsite will increase. There is an inverse relationship between humans and onsite technology.

Current and emerging data gathering capabilities in the air and on land by UAVs have also sparked greater need to focus on data management and integration. The workflow to gather UAV data safely on a construction project, plus the infrastructure to post-process the data, which often includes several thousand photos, photogrammetry, laser scans and so forth, into a useful map requires planning. It is a challenge to create a system that collects and compiles all the data in a useful, easily shareable format in a live collaborative environment. Data crunching can be complex. For instance, many systems, such as Skycatch, include online services for post processing data can be implemented by using UAVs.

More complex manifestations of drones including Boeing CH-47 Chinook helicopters (without a pilot) or automated synchronous cooperation of many UAVs can conduct complex tasks such as lifting material to any point on a construction site function as cranes. Drones have the immediate potential to make construction more efficient through lifting materials and tools like a crane, but in a different and more productive way (Zucchi, 2015).

AECOM, a global engineering and construction firm, is one of a number of companies who received an FAA 333 waiver in 2015. The waiver allows the company to use UAVs for aerial photography, acquisition and construction site inspection and fits nicely in the company's growing efforts to commercialize the technology in the construction sector.

Barrick Gold Corporation uses UAVs primarily for volumetric change measurements in the ore

stockpiles. They also used drones to manage construction projects on the sites, including tailings storage facilities and leach pads which are vital to our business. One case was where engineers had a problem with the construction of a leach pad. It is critical that the "over-liner" is always placed with a thickness of at least 70cm. This was proving problematic until the team deployed a UAV to track daily progress. This aerial view, and the volumetric data provided by the drone, allowed the engineers to resolve the issue. Using UAV data, daily status reports in 3D can be reported, allowing engineers to effectively manage and fine-tune leach pad construction.

DPR Construction has used high-definition aerial imagery captured by UAVs to create project site maps to communicate scheduled work, coordinate site logistics, such as material deliveries and equipment movement, while capturing project progress for owners, subcontractors, and the surrounding community. They also explored the use of UAVs equipped with laser scanners for exterior inspections and equipped with thermal imaging sensors for mapping water or air intrusions. These applications will strongly depend on the rapidly advancing market of powerful, lightweight sensors.

AECOM, Barrick and DPR are also tracking advancements in GPS-equipped and GPS-free solutions as well as lighter weight, higher resolution cameras and sensors.

In Ontario Canada, drones has been used successfully in major civil infrastructure projects in recent years. Fermar Paving Limited in Toronto use UAVs to monitor and inspect Regional Road 150bridge structures across West Humber River during construction (Figs. 3 and 6). The drones helped the contractor to plan, monitor and inspect girders installation within a congested and environmentally sensitive West Humber River catchment. The drone video can be actively uploaded onto smart phones and share with team members on site and in head office. The contractor intends to use drones for all major projects in the future. Figs. 4 and 5 are pictures taken by the drone used for the full range of inspection during the construction.

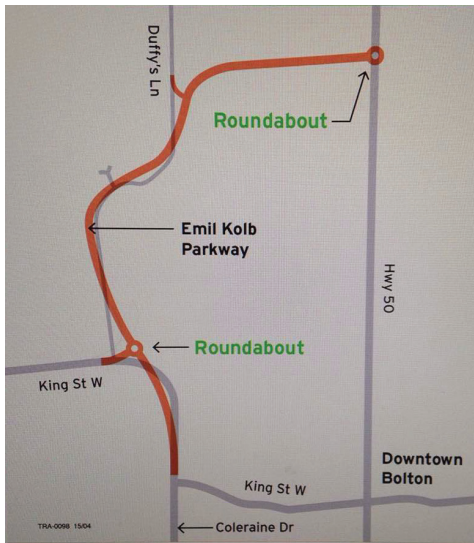


Fig. 3. New Regional 150 Arterial Road route near Toronto, Canada.

In Australia, fixed-wing UAV has been recently used in St. Ives Gold Mine (Fig.7). Trimble UX5 has now become the primary survey tool used for surveying, project monitoring and detailed planning of project work (Steven, 2016).

The drone (Wedge Tail Eagle) has a wingspan between 182 and 232 cm (6ft and 7ft7in.); weighs between 3 and 5.77kg (6.6 and 12.7lb); length varies between 81 and 106cm (32 and 42in).

3.1 Industry perspectives

A surveys conducted in 2015 on the use of UAVs revealed the perspectives from the industry (Navigant, 2015). 50% of the respondents are contractors, construction managers and design builders; 14% are architects and engineers. The rest of the respondents represents the rest of broad spectrum of industry.



Fig. 4. Video-taking by drone assists girder installation during construction.



Fig. 5. Drone helps conduct site inspection of the arterial road construction.

In addition to inspection, safety monitoring, surveying and transportation, more than a dozen other uses were suggested, including security monitoring, defense against claims, and use in education to observe construction methods via virtual field trips.

Using the drone for estimating some roof work, using a drone to assist in locating a new structure on a large parcel of land, building envelope inspection, thermal imaging, and site overview on multiple-facility projects were also mentioned by active users.

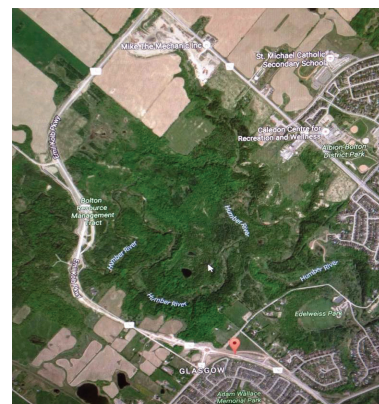


Fig. 6. Google satellite image after construction of the arterial road.

About 69% of respondents stated they would deploy drone usage in-house, leaving 31% preferring to hire a service. Some were on the fence, depending on what the cost would be. Others would consider both, depending on the circumstances of the project and the availability of a service provider.

As for the main reasons holding back drone usage, legal status was at 57%, safety, cost, risk and insurance issues were secondary reasons holding back usage, in the 30% range each. Unfamiliarity with the technology was one of the reasons by some.

The types of drones are commonly used include DJI Phantom, Yuneec Typhoon, and GoPro cameras. From the survey, it is clear that drones are providing a multitude of solid benefits, and a few surprises. For starters, users are impressed with the low cost, quick turnaround and, most of all, the quality of the photos and videos captured.

Drones have proven the respondents to be a useful tool on construction sites. 100% of those surveyed that have actually used a drone on a project reported it to be a success and are very satisfied with both the experience of using a drone and the quality of the results obtained.



Fig. 7. Fixed-wing UAV has been recently used in St. Ives Gold Mine survey in Western Australia.

3.2 Research need for the use in construction

Research has been rapidly advanced in UAV related filed in recently years which will definitely impact

the use of UAVs in construction fields in the “drone era” coming. The related research areas include the theoretical framework for pseudo spectral optimal control theory that can be used for design of new maneuvers for UAVs (Fahroo and Ross, 2013); the modified Bayesian analysis that can be used to treat decentralized control of unmanned air sensing assets (Fitzpatrick, 2103); Han and McEneaney (2013) dealt with the problem where one wishes to intercept a vehicle before it reaches a specific target; the model checking for verification in several UAV related applications, including a centralized cooperative control scheme, a decentralized cooperative control scheme, and a scenario involving a human operator (Humphrey, 2013); optimal control policies by solving Markov decision problem (Krishnamoorthy, Park, Darbha, Pachter, and Chandler, 2013); interconnected system kept track of reference signals issued by a coordinator (Pham, 2013); and fast deployments, robustness against uncertainties and adversaries (Wang and Yin, 2013).

A drone captured aerial views of Apple's new Cupertino campus. SkyCatch has created a fully automated drone system with flight reservation, flight data streaming and battery changes. The same can be found with cranes, as Trimble has shown with its automated crane system. In the near future, materials will be tagged with Radio Frequency Identifiers (RFID) that will identify location and automatically instruct the crane to pick up and deliver to the construction site with computer-aided efficiency. With the power of these two automated devices, the construction site will change forever.

Currently, the Department of Engineering at East Carolina University (ECU) is conducting UAV-related research projects. The research is focused on the safety of UAV operations in an urban environment, and real-time data processing for 3D mapping and modeling. Safe operations rely on accurate navigation and precise control of a UAV, which is difficult when GNSS is completely or partially blocked in urban areas. Compact LiDARs and cameras are used for alternative navigation to aid and replace GNSS, and for sense and avoidance. These sensors are also used to create point cloud and geo-registered images, which are used to create 3D models in the reports of construction sites and internal inspections.

4. Risk, safety considerations and ethical issues

The definitions of the terms that are frequently used in safety analysis are listed here since somewhat ambiguity exist in their meaning and they may have been used interchangeably or in the wrong context in literature.

- *Damage* - An undesired outcome that may include injury, fatality as well as physical, functional and/or monetary loss.
- *Accident* - an accident as an occurrence incidental to flight in which, as a result of the operation of an aircraft, any person (occupant or non-occupant) receives fatal or serious injury or any aircraft receives substantial damage.
- *Hazard* - hazards include events and conditions that start an adverse chain of events that can lead to an accident. Primary hazards are events that directly and immediately cause an accident. Finally contributory hazards are the hazards that are not initiating or primary.
- *Risk* - A measure of potential loss from the occurrence of an accident which is calculated based on the probability of its occurrence and the severity (FAA, 2000).
- *Invasion of privacy* - Drones provide an opportunity for disreputable users to secretly film members of the public. This may be without the permission or approval of those being surveyed.

With the new technology of UAVs rapidly developed and fast rising numbers of commercial users, governments and public concerns are rising. These concerns are specifically related to privacy liability, safety issues including in the NAS, risk, and insurance. In the above-mentioned survey regarding the areas of concerns, the primary concern is legal status to operate at 56.6%, followed by safety of jobsite personnel at 41.8%, safety of adjacent public 31.9%, and privacy at 20.7%, insurance at 28.4%.

A recent Reuters Ipsos poll cited that 73% of respondents wanted regulations for drones and 71% thought that drones should not be allowed to operate over someone else's home. Even the US President weighed in by ordering the FAA and other US agencies to make sure drones are not dangerous and do not violate people's privacy.

In the meantime, the FAA has reported 582 incidents of possible UAS encounters by pilots, air traffic controllers and citizens between August 22, 2015 and January 31, 2016. An analysis of the data on UAS encounters by the Center for the Study of the Drone at Bard College showed slightly more than a third of the incidents could be classed as "close encounters" that means incidents that present a level of potential hazard.

According to the report, there were 24 incidents in which drones reportedly came within 50 ft of a manned aircraft and 11 instances where aircraft made evasive maneuvers to avoid a drone. 60% of the incidents were within 5 mi of an airport and 90% occurred above 400 ft. The rate of reported incidents continues to be higher than in previous years, and this period saw over three times as many incidents as the same period of the previous year.

The Academy of Model Aeronautics (AMA) stated that an overall increase in the number of sightings of consumer drones is not surprising given FAA's projections of an influx of nearly a million new UAVs by the end of 2015, and presumably many of these sightings constitute legitimate UAS activity. A more definitive analysis of the data is needed to separate out the lawful operations from those that pose a true safety concern. The AMA will closely review the FAA's latest data on drone sightings and call on the agency to release not only its preliminary reports, but also "investigative findings and any other information associated with these reports" (Miller, 2016).

With drone ownership rapidly rising along with the number of UAS incidents reported, the FAA continues to emphasize its efforts on safety and education including the free B4UFLY app which is available for iOS and Android smart phones.

In the use of commercial drones, basically there are two major areas of concerns:

- The potential to view drone-based reconnaissance as spying, leading to legal action based on privacy issues.
- The potential liability of UAV-induced injuries due to failure, misuse, distraction or operator error.

4.1 Privacy, ethics and legal related issues

The national attention and concern over privacy has been warranted as drones become more mainstream, especially for contractors looking to be more economical. For instance, a contractor could be building a highway or bridge, and while surveying it, the drone inadvertently takes images of nearby homeowners in their backyards. This invasion of privacy could mean an expensive lawsuit.

Although the rule issued in June 2016 does not specifically deal with privacy issues in the use of drones, the FAA is acting to address privacy considerations in this area. All UAS pilots and users are required to check local and state laws before gathering information through remote sensing technology or photography. As part of a privacy education campaign, the FAA provides all drone users with recommended privacy guidelines as part of the USA registration process and through the FAA's B4UFLy mobile app.

4.2 Safety and other risk-related issues

Even with the FAA rule changes, UAVs still carry a host of jobsite safety to employees or people near the jobsite, and other risks for construction companies, for example bodily injury and property damage. Also, UAVs could strike people, buildings, cars and other property, especially if "loss of link" happens, where the operator loses contact with the drone.

Risks could result from technical reasons. When a drone is close to a building or other structure, it may lose the connection with the operator. An obvious way to prevent this is for users to remain in line-of-sight when operating drones.

4.3 Insurance Related Issues

As this industry continues to evolve and utilize more technology, the biggest challenge for insurers will be evaluating three key areas of risk:

- the quality of the equipment;
- the qualification of the operator of the equipment; and
- what is the environment in which the UAV is being operated.

For companies that utilize UAVs, addressing the key underwriting risks and implementing best practices will ensure the use of UAVs remains

practical and cost-effective (Alberico and Shelton, 2015).

One of the concerns is that current commercial general liability policies generally exclude aviation risk.

Commercial UAV users for construction purposes have raised the question that whether contractors have coverage for liability arising out of their UAV use. The current situation is, in general, the standard commercial general liability (CGL) policy and many non-standard CGL policies excludes liability arising out of the insured's "ownership, maintenance or use" of an auto, aircraft, or watercraft.

Contractors thinking of using UAVs should consult with their broker and/or carrier to verify if a UAV would constitute an aircraft (and thus trigger the exclusion). The FAA only defines aircraft used for manned general aviation and recreational aircraft, which include light sport aircraft, small airplanes, e.g., Cessna 124, ultra lights, amateur built, and vintage/surplus aircraft. If the FAA is the agency responsible for defining what is an aircraft in the US NAS, drone owners, users, and insurance companies may have to wait for the new FAA regulations mandated by Congress for a definition of whether a UAV is an aircraft.

The FAA's use of the term Unmanned Aircraft System may also provide an indication on how the FAA will define a UAV in the future, which may indeed affect the definition in terms of the CGL Policy.

Until rules for commercial use of UAVs are developed by the FAA, the legality of using them commercially in the US will likely remain murky. In the absence of a federal definition or regulatory framework, contractors should determine what the laws are in the states where they operate, as many states are considering bills, and several have already passed legislation governing the commercial use of UAVs.

4.4 Minimizing risk for the use of UAVs in construction-related businesses

There are a few ways construction companies can mitigate the risks associated with UAVs. For instance, a company operating UAVs should understand the FAA rules prior to operation and remain fully compliant. If hiring a company that operates UAVs, make sure there is a contract that

indemnifies the company from losses that occur as a result of UAV operations.

Finally, implement a financial backstop from losses by purchasing UAV insurance. Some companies may offer the standalone policy, as well as an endorsement on existing policies.

Many operators are small entities and may be able to wrap all of their insurance into one policy that has professional, general and aviation liability together.

5. Discussions and recommendations

Drones add value to the construction process by conducting many activities. The versatility, flexibility and the ability to be automated are too valuable to ignore. It is clear that UAVs will be apart of that the solutions of many construction activities and challenges. Technology firms have been quick to act and provide opportunities, but in doing so, they have disrupted the entire industry, allowing competition to come from anywhere. Construction firms must think outside the box and find answers to shrinking profit margins, increased liability, higher labor costs and faster build schedules (Zucchi, 2015).

Education is the first step in use of drones. The US FAA has a number of educational initiatives with the government and industry partners to teach drone operators how to fly safely, including the drone registry launched recently.

There are more than 406,000 people have registered their drones. The FAA also continues to work closely with its industry partners through the "Know Before You Fly" campaign.

Although there is Exemption 333 issued in 2016, lack of regulations is still one of the concerns for expanding the use of drones in construction. There are drones flying without registrations. Enforcement goes hand-in-hand with education, training, and cooperation, anyone who operates drones irresponsibly should be prohibited.

Several recent court cases against the FAA dispute their jurisdiction over commercial UAV use in the absence of regulations. In March 2014, a federal administrative judge held that the FAA has no legal authority to regulate UAVs used for commercial purposes. Judge Patrick Geraghty of the National Transportation Safety Board (NTSB) ruled that the FAA had issued internal guidance on UAVs, but had not followed the required rulemaking to restrict the use of them by the public. He ruled the FAA lacked

authority, concluding that UAVs are model aircraft, which FAA excludes from regulation. The case involved a vendor providing aerial video footage of the University of Virginia for promotional purposes.

The vendor was hit with a \$10,000 fine for "reckless operation" of the UAV while filming (the fine was overturned by the judge). Interestingly, the director of "Wolf of Wall Street" did not receive any fines for his use of UAVs. Sales of UAVs have surged 25% ever since the ruling. The FAA is appealing to the full NTSB board. Pending the outcome, the agency maintains that use of a UAV for anything other than hobby or recreational purposes is "unauthorized" and subject to regulatory action.

In another case, Texas based Eqqearch has been conducting searches for missing persons since 2000 and using UAVs since 2006. The organization was recently ordered by the FAA to stop using a hand-launched UAV.

The company responded to the FAA with a letter asserting the agency has no legal authority to prohibit UAV use, and threatened to take legal action if the agency didn't rescind its order. The FAA asserted that Eqqearch should find one of the police departments, public universities, or other public entities that already hold FAA certificates for non-emergency use of UAVs for their searches.

Currently, a large segment of potential users are sitting on the fence waiting to see how the new FAA regulations shape up, while concurrently researching drone technology, insurance issues and safety practices.

Hourigan Construction based in Virginia and North Carolina has put a few things in place to mitigate the business risks associated with their use of the drones (Harrison, 2016):

The following language has been added to the subcontracts:

Hourigan Construction is authorized by the Federal Aviation Administration to own and operate Unmanned Aerial Vehicles (UAV or drones) in its business operations. This Project is subject to our use of UAV's at all times. The purpose of our use of any UAV is to obtain photographic and video-graphic real-time data of the Project's status and progress, identify potential hazards and quality issues, increase worker safety, promote efficient use of materials and manpower and ensure construction is in accordance with the Project requirements. The UAV operators

will be easily identified by their attire and equipment. Access to any images retrieved will be limited and will be stored only as long as commercially reasonable to archive project records as required by law and pursuant to our corporate policy. No image that could be reasonably used to identify an individual will be used for a commercial purpose without the consent of the individual(s) depicted.

By accepting this Scope of Work you represent that your company and all of its employees, officers, directors, agents, consultants, representatives, subcontractors, suppliers and guests are aware of and consent to our use of UAV's on this Project.

The company also instituted the sUAS Operations Manual and Company Use Policies.

They procured the following lines of insurance as related to the UAV:

- UAV coverage
- Property coverage
- Personal injury coverage
- Privacy coverage

6. Concluding remarks

Drones are clearly beneficial for construction projects, particularly for surveying, mapping, inspection and aerial photography. The current effectiveness of drones will certainly increase, and will likely remove humans from processes in order to reduce costs, increase efficiency, reduce liability, increase building speed, reduce errors. The imperativeness to increase safety will continue and will be amplified by automated systems in drones and other construction equipment, cranes, for instance (Zucchi, 2015). The fully automated construction yard will operate as a system of systems and will reshape competition within the construction industry by erasing the boundaries between traditional building roles and other industries.

It is noted that some contractors are complying by obtaining an FAA exemption or using service providers, others are flying drones at their own risk without proper documents.

Expanding the application of UAVs is more about education. Most construction managers do not fully understand the extent of UAV capabilities, available sensors, and the evolving applications. The UAS can do much more than take pictures. Construction managers understand daily and hourly production rates, UAVs can help manage construction jobs

smarter and better. They will also permits construction companies to bid for future projects with a better understanding of production costs and timing. It cannot be over-emphasized that many construction activities can be done more efficiently and effectively than ever before if safety and risk issues are controlled and properly managed.

In addition to these positive aspects, there is the potential for drones to be used inappropriately to film activities of people without their permission. Unless public endorsement is obtained, we believe that the future of drone use in urban settings will be significantly compromised. Public approval will only be achieved if drone users are able to demonstrate that they function in both a safe, responsible and an ethical manner.

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