Applications and Issues of Unmanned Aerial Systems in the Construction Industry

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Abstract The adoption of innovative technologies in the construction industry is necessary for the industry development. Such technologies can help in reducing the time needed to accomplish tasks, increase work quality, improve safety standards, and lower expenses. Unmanned aerial systems (UAS) have various applications on construction sites. They provide a bird's eye view for supervising construction site personnel as well as providing live feedback on actions taking place on-site. Given the high potential of UAS use in the construction industry and their recent wide usage, this study and literature review aims to summarize the current applications of UAS on construction sites. Furthermore, it will also identify the issues resulting from UAS use in the construction industry. The findings will enhance understanding of the implementation of UAS in the construction industry.

Keywords Applications, Issues, Unmanned aerial systems, Construction industry

1. Introduction

Proven innovative technologies are very beneficial to any industry, as they are mainly developed to increase work efficiency. The implementation of such technologies can result in faster task-completion time, higher work quality, enhanced safety standards, and cost reduction. Unfortunately, the rate of adoption of innovative technologies by the construction industry is far behind that of several other industries [1]. Technology use on construction sites poses a challenge for construction management [2]. This is due to several constraints and barriers as well as the dynamic nature of construction sites.

Unmanned aerial systems (UAS), also referred to as unmanned aerial vehicles or drones, are innovative technology that can be very useful in different applications in the construction industry. The term "UAS" is being increasingly used to accommodate the broad range of technological applications [3]. Today, several UAS are controlled by Smartphone devices, linked by Wi-Fi networks, and their locations can be pinpointed via global positioning systems [4]. UAS can be used to perform data collection and processing; they can also be operated with or without a pilot [5]. The following tools can be mounted on UAS: cameras, infrared, radar, and communication devices [5]. Live data transfer with control stations is possible with most types of UAS; certain UAS may have data storage options [5].

The earliest adoption of UAS was for military applications [6, 7]. However, the current situation has changed, and UAS are now involved in civilian applications. An increasing number of researchers have explored UAS use in construction applications [8]. This can be seen in the recent growing number of research publications on UAS use on construction sites. The present interest in UAS use for civilian and commercial purposes is due to the broad range of applications along with savings in labor, time, and cost, and even enhanced performance [3]. UAS can perform in a number of construction applications, replacing traditionally used techniques [9]. Moreover, UAS can assist in conducting construction applications with an enhanced and faster approach [9]. For example, UAS can provide geometric information on actual construction site conditions frequently and with low error rates [10]. UAS are also used for transportation and construction site monitoring [2]. Although there is potential for using UAS on construction sites, the construction industry has been slow to adopt it [11]. Furthermore, there is a demand for further exploration to understand how UAS can be used in the various construction management activities [12]. Operational procedures for effective UAS use, specifically for construction site safety monitoring, still require development [2]. Thus, it is important to study the issues related to UAS use in the construction industry. The literature on research on UAS applications in civil engineering are scant [6]. There is a need for scientific exploration and evaluation of UAS performance in the construction environment [6]. This study was conducted with the aim of summarizing the applications and issues of

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UAS use in the construction industry, which will aid in recognizing several areas for improvement and future research.

2. Methodology

This study was conducted to identify the applications and issues of UAS use in the construction industry through a systematic literature review. The findings will aid understanding and summarizing of the latest research on the integration of UAS with the construction industry. Here, focus was given on the most recently identified applications and issues of UAS use in the construction industry. The relevant literature was obtained via Google Scholar, Science Direct, the Taylor & Francis publishing group, the American Society of Civil Engineers, and Springer publications. The search terms included "construction", "drones", "UAS", "unmanned aerial vehicles", "applications", "issues", "problems", "risks", and "barriers". Only articles that discussed the topic or those that covered an area related to the topic were selected and cited. In this study, 33 articles were obtained, which included journal articles, conference papers, magazine articles, and reports. One article was published in 2012, and the other 32 articles had been published between 2014 and 2017. This shows that the research topic is a relatively new concept and that more research is warranted. Two research questions were investigated in this study, these are:

1. What are the applications of UAS in the construction industry?
2. What are the issues in UAS use in the construction industry?

3. Applications of UAS in the Construction Industry

The use of UAS in the construction industry is a relatively new concept, and industry stakeholders are still discovering its applications. This section will answer the first research question, i.e., What are the applications of UAS in the construction industry? Examination of the literature identified nine main applications of UAS in the construction industry (see Table 1). Of the nine identified applications, five were mentioned in at least 12 articles each, and included *monitor construction activities*, *site surveying*, *aerial photography and surveillance*, *visual inspection of hard-to-reach locations*, and *safety inspection*. The other four applications were not widely discussed in the literature: *interaction with workers*, *quantity take-off and estimation*, and *construction site security* were mentioned in two articles each, while *defect and damage detection* was mentioned in a single article. The number of articles that mention an application does not indicate the application's importance, but rather the more widely used application of UAS in the construction industry that drew the interest of researchers.

Table 1.   Applications of UAS in the construction industry

Application	Reference
Monitor construction activities	[1, 3-5, 7, 9, 13-21]
Site surveying	[3, 4, 6, 11, 15, 16, 19, 21-28]
Aerial photography and surveillance	[3, 5-9, 14, 16, 17, 19, 21-23, 29, 30]
Visual inspection of hard-to-reach locations	[3, 5, 8, 9, 13, 14, 16, 17, 19, 21, 23, 31]
Safety inspection	[1-3, 5, 13, 14, 16, 17, 19, 25, 31, 32]
Interaction with workers	[1, 14]
Quantity take-off and estimation	[9, 19]
Construction site security	[9, 23]
Defect and damage detection	[26]

UAS are changing the manner in which construction companies do business [4], and UAS can be integrated into construction tasks in several ways [11]. Generally, the UAS is used to provide a bird's eye view for construction site supervisory personnel. In the fields of architecture, engineering, and construction, UAS has become an emerging research topic for three-dimensional mapping [22]. Three-dimensional mapping enables the monitoring of site progress, surveying and measuring tasks, and the performance of quality control [22]. There has been exponential growth in UAS use in visual construction monitoring and in the visual operation of many types of buildings and civil infrastructure systems [16]. For example, UAS can be used to create interactive maps of buildings and sites by conducting site surveys and constructing three-dimensional models of these locations [11, 15]. Furthermore, for tasks that include the mapping of wide areas such as excavations, UAS have been accepted as both dependable and efficient devices [15]. Contractors are increasingly monitoring their construction activities using UAS [4]. This is because UAS offer live streaming on job progress and can assist in identifying potential hazards or quality concerns, as well as other helpful information in a quick and cost-saving manner [4]. UAS are also helpful for monitoring large construction sites [4]. A larger construction site becomes more difficult to monitor and it is here that UAS can play a role; UAS can survey and map landfills [4]. Several studies on UAS use for project progress monitoring have reported the potential of using UAS in such an application [5, 7, 15].

Aerial photography inside and outside construction sites is presently the most common UAS application [9]. UAS equipment capabilities have advanced significantly, providing enhanced high-resolution imagery from diverse angles while being both cost-effective and efficient [7]. Typically, construction sites install fixed surveillance camera systems [13]. However, as construction sites are typically very busy, it becomes impossible to view the fixed camera range fully without a structural element, equipment, or on-site material blocking it [13]. In such situations, UAS can maneuver around any obstacles present at a construction

site and cover all required locations. Thus, UAS provide aerial views from a variety of elevations and angles [9]. Consequently, UAS can be considered more flexible compared to fixed cameras [9]. In addition, UAS can be piloted manually (controlled by a pilot) or autonomously (predefined path with no pilot) [22].

UAS can be used to regularly survey construction sites, monitor current activities, generate safety documents, and examine structures, in particular, the areas that are hard to reach [16]. UAS can access difficult locations in construction sites and allow safety managers to interact with workers during critical situations [14]. Researchers view UAS as a low-cost aerial photography tool for construction inspection, specifically for locations that are hazardous or unfeasible, such as roofs and building façades [5]. Using UAS for inspecting construction and infrastructure guarantees appropriate performance and user safety against structure collapse, and at the same time, prevents worker exposure to injury [3]. Obscure locations such as the exterior building envelope or locations with major personnel safety issues are frequent constraints for inspectors conducting visual surveillance [9]; UAS make it possible for inspectors to view these locations from a safe distance [9]. For example, in the case of structural fire on a roof, a UAS will allow the inspector to safely view still images and video of the damaged areas and perform an accurate assessment [9]. Moreover, UAS mounted with thermogtaphic cameras can capture heat flow, which allows the mapping of roof insulation or pipe insulation issues [9]. Furthermore, the size of a UAS allows it to access the interior of construction projects, which is not possible by helicopter due to size restrictions and the limited ability to access open venues such as stadiums [9]. A UAS would provide safety managers live contact with workers through a communication tool, including video and voice transmitters [1, 17]. This is highly beneficial, as it allows safety managers to oversee the construction site and provide workers with live feedback [1]. Another application of UAS is conducting roof estimates. Some contractors use UAS for estimating roofs, as some roofs are difficult to walk on and may be easily damaged, such as those made with slate or clay tiles [9].

Construction workforces are exposed to accidents that lead to financial losses, disabilities, and casualties [1]. UAS can enhance construction practices and facilitate safety inspections of the jobsite [1]. Furthermore, they can instantly alert operators to accidents and assist safety managers in identifying the accident location and injured workers [17]. UAS can be used as an effective and cost-saving safety inspection tool for high-rise structures [31]. This is because high-rise structural inspection is very dangerous and is considered time-consuming, costly, and difficult to diagnose [31]. Visual data collected by UAS can enhance the safety inspection of a site through improved visualization of working situations [2]. Moreover, night security shifts can use UAS by flying them regularly over the site and detecting heat signatures via thermographic cameras, which can assist in detecting hiding burglars [9].

4. Issues in UAS Use in the Construction Industry

Equations Similar to any technology, UAS use on construction sites has its issues. This section will answer the second research question, what are the issues in UAS use in the construction industry? Examination of the obtained literature identifies 10 issues in UAS use in the construction industry (see Table 2). The most commonly mentioned issues were *accidents resulting in deaths, disabling injuries, and property damage*, and *weather condition constraints*, which were discussed in eight articles each. These issues were followed by the issue of *laws and regulation restrictions*, which was discussed in six articles. Subsequently, *battery life and limited flight time* was mentioned in five articles. Next, four articles mentioned *privacy concerns*. The following three issues were mentioned in three articles each: *must be operated by a competent person*, *labor and work distraction*, and *communication loss/interference/low-quality images*. Finally, two issues were mentioned in one article each: *does not function well at extreme temperatures*, and *analysis of large database of visual assets*.

Table 2. Issues in UAS use in the construction industry

Issue	Reference
Accidents resulting in deaths, disabling injuries and property damages	[1, 3, 5, 9, 12, 15, 23, 29]
Weather condition constraints	[2, 8, 9, 15, 22, 27, 29, 33]
Laws and regulation restrictions	[2, 5, 11, 19, 23, 33]
Battery life and limited flight time	[6, 13, 14, 21, 33]
Privacy concerns	[3, 5, 12, 23]
Must be operated by a competent person	[2, 9, 12]
Labor and work distraction	[1, 5, 12]
Communication loss/interference/low-quality images	[21, 22, 29]
Does not function well at extreme temperatures	[9]
Analysis of large database of visual assets	[2]

Any innovative technology would typically encounter a number of issues, and it is necessary to identify these issues and try to find the means to avoid them. Further research is needed on issues related to UAS use, including regulatory impact, construction personnel learning curve impact, privacy concerns, and jobsite safety issues [5]. Uncertainty regarding the laws and regulations of UAS use represent a barrier to UAS integration into construction projects [11]. Unclear or changing laws and regulations might also drive users away from adopting UAS. Another issue in UAS implementation on construction sites is the need for well-trained pilots. To conduct an effective safety inspection flight, it is necessary for the pilot, observer, and project personnel to know their flight objective [2]. An effective UAS operation requires experienced personnel to fly it [9].

Meteorological factors and pilot training are barriers that affect UAS use for safety inspection [12]. The literature also mentioned the issue of having too much visual data to analyze. A study that tested UAS for safety inspection found difficulty in analyzing the large amount of visual data collected in a single visit [2]. Moreover, worker distraction by the operation of a UAS at a construction site represents an issue [1]. This is why it is important to provide project staff with training and communication about UAS operation prior to its commencement, including information on the technology and objectives [5].

Although not frequent, the exposure of the pilot and others to UAS operational accidents may result in death and disabling injury [9]. A mechanical malfunction or loss of power can cause a UAS to rapidly fall to the ground with little or no warming [9]. Thus, the operator should avoid flying the UAS over areas where people are working whenever possible [9]. Generally, UAS do not function well at extremely hot or cold temperatures [9], and thus might cause an accident. Extremely cold temperatures can cause problems with the mechanical controls of UAS, and their batteries lose their effectiveness [9]. Another issue in UAS operation is the limited flight time. Therefore, the limitations of UAS use include restricted flight time and battery life [6, 13]. UAS flight time is approximately 30 minutes and is restricted by the battery capacity [13].

Weather conditions are a challenge for UAS operation on construction sites. UAS are incapable of functioning at high wind speeds [2, 9, 22]. The case is the same for rainy days [2, 22]. Furthermore, these weather conditions can affect the quality of the visual data collected. For example, sunlight and time of flight may affect image specifications [22]. Moreover, shadows and glare from reflective surfaces can affect three-dimensional mapping conducted by UAS [22].

Magnetic sources around a UAS may result in communication interference, which is due to the electrical sensors in the UAS, such as the gyroscope or compass, being affected [22]. Thus, the UAS takeoff location and flight path should be away from large metal objects or reinforced concrete structures [22]. Furthermore, loss of connection between the UAS and controller has occurred a number of times during UAS testing, resulting in missing images and consequently affecting three-dimensional mapping [22].

5. Conclusions

The use of new innovative technologies such as UAS in the construction industry is greatly needed for developing various aspects of the industry, such as safety. As UAS use at construction sites is relatively new, a number of issues might arise, affecting the on-site operation. This illustrates the importance of conducting in-depth research on UAS use in the construction industry. The present study examined 33 articles from the available literature on UAS applications and issues in UAS use in the construction industry and summarized them. Moreover, nine applications and 10 issues

were identified in UAS use in the construction industry. Future research might include investigating areas that increase the applications of UAS in the construction industry; furthermore, it may cover the methods and means of reducing issues in UAS use in the construction industry.

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