A Feasibility Study of Uncrewed Aircraft System (UAS) Material Delivery in Commercial Vertical Construction

Charles Stodter[1], Mark Tatum[2] , Junshan Liu[3]

[1] Auburn University, Auburn AL 36830, USA
mtatum@auburn.edu

Abstract
Advancements in the UAS (Uncrewed Aircraft Systems) sector have led to a plethora of new technologies utilized in the commercial vertical construction industry. To date, this largely includes incorporating drones into BIM (building information modeling) related technologies and three-dimensional scanning, monitoring and surveillance, and quality control. The use of UASs for construction material deliveries is so far an untapped possibility. UASs have made their way into the commercial retail logistics space in certain highly populated areas for package delivery. Still, to date, the use of this technology to deliver construction materials is effectively unutilized. This analysis will show that while the short-term feasibility of material and tool delivery via UAS is extremely limited, long-term adoption of UASs in construction material delivery is highly likely as technology and regulation progress.

Keywords
UAS, Drone, Material Delivery, Vertical Construction, UAS Regulations.

1. Introduction

Uncrewed aircraft systems have a long history, starting in the late 20th century, seeing a majority of early advancements in the defense and weapons sector. UASs were developed and heavily utilized in the global war on terror (Elish 2017) (Fig. 1). Concurrent to that advancement in the early 2000s was a growing sector of non-military use, multi-rotor type UASs colloquially referred to as “drones”. Since then, the private sector has fully embraced the utilization of small-type drones for photography, videography, recreation, etc. The construction industry was no different. Since the development of small UASs the construction industry has fully embraced that utilization. The vertical construction sector has found highly effective use of UASs for aerial photography, surveying, quality inspections, security and surveillance, and the incorporation of BIM technologies via photogrammetry and LiDAR systems (Tatum et al, 2017).

Fig. 1. Early US Predator Drone.

In the current era, the idea of UASs for last-mile delivery in the e-commerce and retail spaces is not a foreign or uncommon idea. Large retail corporations like Amazon and Walmart, as well as a number of medical companies have talked about utilization of drone delivery for the past few years, with no mass commercial adaptation as of yet (Papandreou 2024).

In building construction, as discussed above, utilization of drones has almost exclusively been utilized for BIM related and surveillance technologies (Tatum et al, 2017). These uses include 3D scans with point clouds, LiDAR scanning using drone mounted cameras and scanners, daily progress tracking with overhead photographs and video, and job site surveillance with UAS mounted cameras. The building industry's utilization of UASs for various tasks, enhancement of design and monitoring, etc., increases every year, but to date has not included any substantive logistical component. There is a clear desire in the industry for material and tool delivery via UASs, but to date this technology has not emerged in mass, or beyond typical research and development of delivery drones from the retail sector.

This analysis aims to broaden the understanding of the current feasibility of construction material delivery by UAS by analyzing four key areas on the topic. Those four key areas are the following:

- Current Usage vs Practical Utilization
- Regulatory Hurdles
- Safety Considerations
- Immediate Capability vs Full Utilization Timescale

A full understanding of these areas will yield a clear picture of short and long-term feasibility, with supporting sources, expert input, and analysis.

2. Current Usage vs Practical Utilization

The first focus area this analysis will review is current usage of UASs for material delivery in construction vs the optimal utilization of UAVs in the vertical construction industry.

As discussed in the introduction above, material delivery with UAVs is effectively nonexistent. There are unverified examples on various social media and video-sharing platforms of material delivery using UAVs to remote project sites in the mountains, but these efforts are clearly not in the commercial space, and also appear to be in China, where the regulatory landscape is extremely different. That being said, UAVs used for delivery of goods is an expanding sector in the retail and medical space, that will undoubtedly have carryover into construction. Companies like UPS, Amazon (Fig. 2), Matternet, Flirtey, Alphabet's Wing, and Zipline all have research and early programs for UAV delivery operations, with success being clearly shown by UPS, Amazon, and Alphabet's Wing (Google Subsidiary). These programs all so far rely on light loads for the UAV to carry, with Amazon working with a majority of packages being less than 5 pounds (Madani 2022).

Fig. 2. Early Prototype of an Amazon Package Delivery Drone.

Practical utilization for drone delivery of construction material is only something of imagination at this point. Likely, though, the most practical utilization of material delivery would be to have a wide capability of options for delivery to include small packages and large packages like mechanical equipment and structural components. This will be discussed in a further section, however, the idea that a drone could lift a few thousand pounds is not something out of a science fiction novel. Though no longer in great favor and rarely used, helicopter picks for rooftop mechanical equipment were once a fairly regular occurrence in the commercial construction and maintenance sectors, so the idea of a drone doing the same is perfectly reasonable, as the technology and regulatory environment changes to allow such large UAVs and loads.

3. Regulatory Hurdles

The second, and most substantial area of this analysis will review the regulatory hurdles involved with the utilization of UAVs for material delivery in the vertical construction space, such as the Airspace Guidance and UAS classifications (Fig. 3). The following discussion will aim to explain the main items involved in the current regulatory environment, as well as those that may be seen in the future as UAV utilization increases.

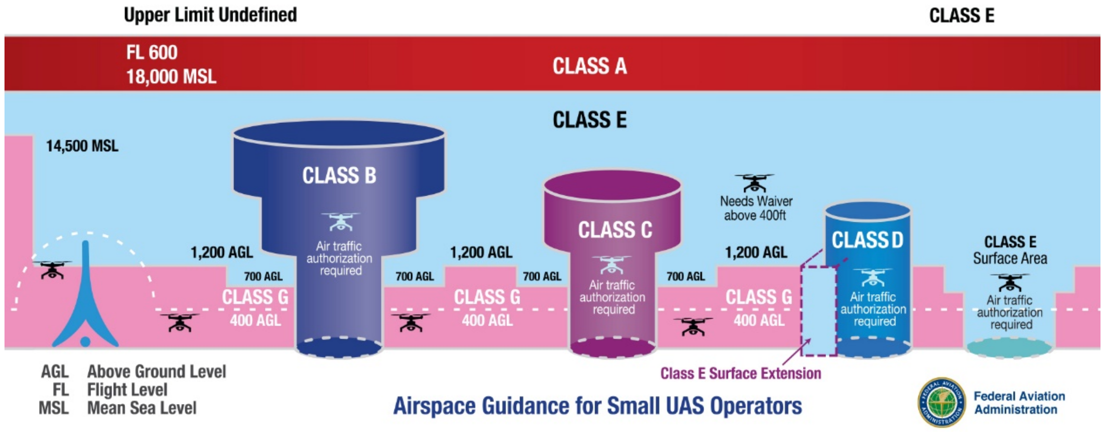

Fig. 3. FAA's Airspace Guidance and UAS Classifications.

The drone delivery space is governed by a number of federal regulations, including US Code Title 14, CFR Part 47 Aircraft Registration (Chain 2024), FAA Part 107, FAA Part 135, among others. Part 135 is the Air Carrier and Operator Certification, and currently is a requirement for all commercial carriers that wish to operate in the drone delivery space. As a part of these regulations, operators must obtain a part 107 remote pilot certificate, pass medical examinations, request exemptions under the regulation for specific UAS, follow airspace regulations, and obtain FAA tracking numbers for oversight by the FAA (FAA Regulations) (Chain 2024).

The part 135 process, in particular, is essential for package delivery by UAS. It is a 5-phase certification process as follows:

1) Pre-application
2) Formal application
3) Design Assessment
4) Performance Assessment
5) Administrative Functions

To date, there are only 6 companies to receive their part 135 Air Carrier Certificate. Those are Wing Aviation LLC, UPS Flight Forward Inc, Amazon, Zipline, Causey Aviation, and Drone Up LLC. For construction material delivery to become a regular practice, one of these companies would need to take up the work, or a construction-focused delivery company would need to go through the part 135 process.

In addition, there are special regulations that pertain to drones operating with a takeoff weight exceeding 55 pounds. Drones at this weight not only are regulated by the same rules as drones from 0.5 pounds to 55 pounds but come with extra requirements. Drones over 55 pounds require a commercial type certificate, or a 49 U.S.C. 44807 grant of exemption. In addition, they require a special airworthiness certificate, as well as special pilot requirements.

There is also air traffic control to consider. Currently, drones are required to operate in airspace under 400ft in elevation, unless provided with a waiver to fly above that height, and largely have not been incorporated into the larger air traffic control environment. As stated by David Schneider in volume 54 Issue one of the IEEE Spectrum "Avoiding a collision with a full-size aircraft is job No. 1, of course. But the more typical danger is much more mundane running into a tree or a wall." (Schneider 2017) One way that these issues and requirements are being experimentally handled is through detect and avoid software for the aircraft. This capability is still being developed and while the standards for such systems have been accepted by the FAA for the certification of these avoidance systems, certified avoidance systems are not in regular use yet (Bleakley et all, 2023). Fig. 4 illustrates Amazon's UAS package delivery system.

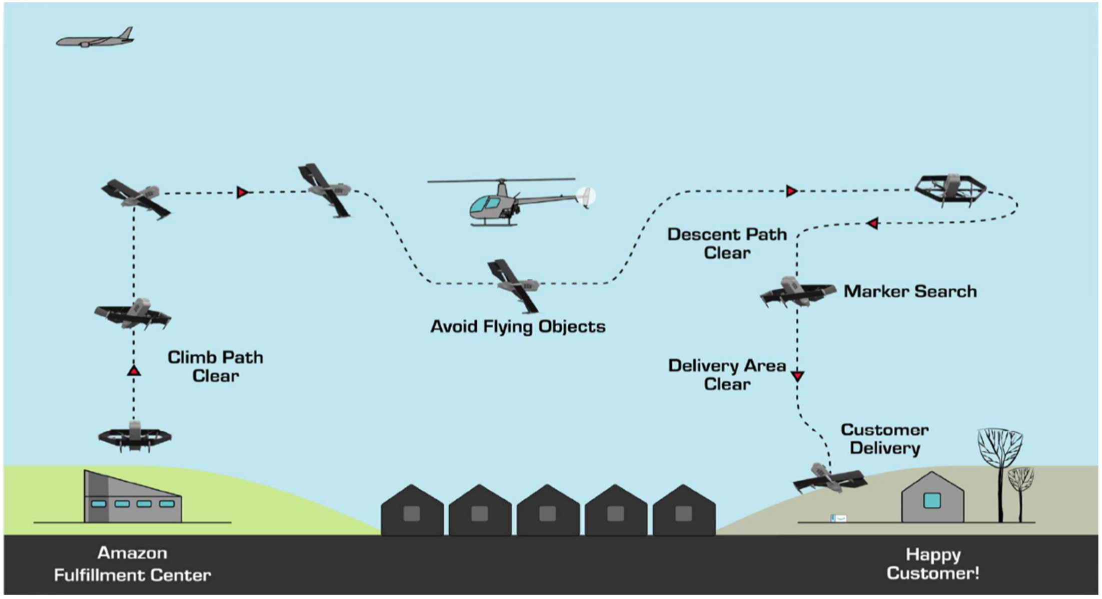

Fig. 4. Illustration of Amazon's UAS package delivery.

Considering the significant regulatory challenges for UAV entities to go through to enter and operate in the current market, it is reasonable to expect that the same challenges would exist for a material delivery entity to enter the market for construction purposes. The hurdles are being overcome in the retail market, so undoubtedly, they will be overcome in the eventual construction material delivery market as well.

4. Safety Considerations

Safety is the number one consideration on all projects in the construction industry, and the delivery and handling of material associated with the projects is no different. Safety requirements for drones are largely outlined by the FAA in their regulations listed above, but in general, considerations beyond the operator include weather conditions for flying, takeoff and landing areas free of obstructions and hazards, battery life, and pilot visual capabilities. Generally speaking, pilots must have line of site to the aircraft, which makes material delivery currently extremely limited. Part 135 addresses this requirement in detail, and the process to acquire an exemption for a single pilot to operate multiple UASs remotely. In addition, wind conditions make a significant impact on UAS flights, with winds above 15 MPH being very difficult to fly in (Chain 2024).

Another safety, and operational, consideration is battery life of the systems. The majority of UAS's operate on large lithium-ion batteries, due to their longevity and performance. These batteries, despite their positive attributes, however, can cause a risk to drone operations. Many batteries do not have the life span to support long flights, especially on drones that operate with heavier loads. For the construction industry, which will mean that heavier loads will rely on larger and heavier batteries. Batteries of this scale for UASs are still developing and will require more research and development before flight times and loads are optimized.

The biggest safety consideration, specifically to construction material delivery though, is carrying loads above populated areas with people and property below. It is feasible that over time loads for drones will increase and significant loads will be able to be carried like construction materials, mechanical equipment, etc. This will incur significant risk to those under the flight path. This kind of risk is comparable to a crane or helicopter pick on a job site. In those instances, site specific crane plans are generated, and any activity below is ceased unless necessary to the execution of the crane work. Currently similar requirements exist for UAV flights. A future without these precautions, however, will be possible as automation and detect and avoidance software is refined and utilized more uniformly. This technology was recently heavily reviewed and researched for the 2024 International Conference on Unmanned Aircraft Systems, and Maalouf et all concluded the following regarding avoidance technologies, "Moving forward, future work should focus on extensive testing of airspace user detection technologies to enable seamless transitions between different SysCons (Fig. 5). Additionally, exploring ADS-L technology holds promise for enhancing ASA and facilitating early conflict detection, thereby maximizing operational feasibility" (Maalouf et all, 2024).

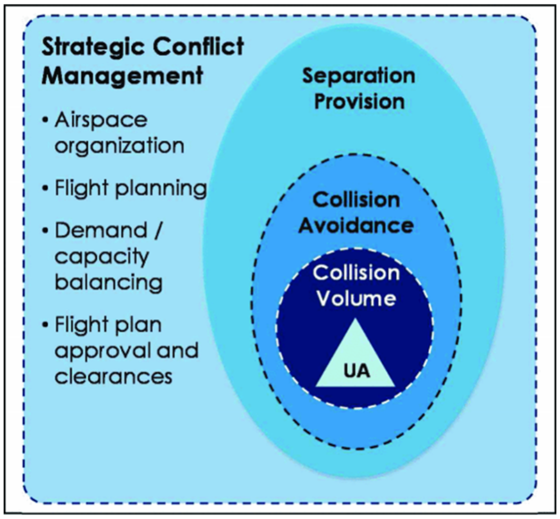

Fig. 5. Spheres of avoidance for UAS's automatic detection systems.

This research, and others, indicates that the safety considerations for future drone delivery systems of construction material include automation as well as drone detection and avoidance systems. This will enable one operator to manage multiple drones from a single location that does not have direct line of sight to the UAS.

It is not currently feasible to safely transport construction materials and tools via UAS. The risks over occupied areas and job sites are too great and not yet well-managed or fully understood. In addition, the requirement for the operator to be within sight or controlling the system remotely are not developed enough for practicality, making this focus area unfeasible. Long term, however, the research clearly shows that avoidance and detection systems are advancing every day, so a day will come when delivery via remote pilot over longer distances will not only be safe, but likely safer than the risks of current standard material delivery via trucks and material handlers.

5. Immediate Capability vs Full Utilization Timescale

There are several companies that have worked through the part 135 process and are testing drone delivery, so that technology and process could be directly applied to construction and the delivery of things like fasteners, small tools, measuring devices, etc. This technology is likely to be enabled soon on jobsites all over the US, as utilization of Amazon for small tools and items on jobsites is not an uncommon occurrence.

Full utilization of UAS delivery of construction material is a much harder thing to speculate. The timeline to reach full capability of UASs to deliver significant-sized commercial HVAC equipment, steel framing members, lumber deliveries, etc., is likely to be exceptionally long and will not be pinpointed effectively or accurately. On the flip side, while it is not cost-effective or utilized in the US, as shown in Fig. 6, man-piloted helicopters can deliver equipment and materials now for the vast majority of commercial job sites, so the concept is there and works, it just requires refinement, regulation, and planning.

Fig. 6. Man-piloted helicopter performs a large mechanical unit pick.

While this analysis has largely focused on the delivery of construction material from off-site sources to on-site areas, there is likely a middle ground between no current utilization and full-blown heavy material load and equipment delivery via UAS. With current regulations as they are, there is a use case for a very near-term capability to use UASs for intra-site delivery of materials. If limited to one site, UASs could be used to deliver small tools, equipment, and material to tradesmen on upper floors or further parts of the site. In this scenario, the operator could still be line of sight, the altitude could be less than 400 feet, and currently accepted and certified drone systems could be utilized to handle these loads. Regulatory steps are known for this use and easily managed, and safety could be handled in the same manner as crane work. In summary, UAS utilization for material delivery will be a spectrum as technology and regulation advance.

6. Conclusion

This feasibility study analyzed four key focus areas in relation to the overall topic of construction material delivery via UAS. Those areas were current usage vs. practical utilization, regulatory hurdles, safety considerations, and immediate capacity vs full utilization timescale. The study attempted to assess short and long-term feasibility in each focus area, with a heavy emphasis on the cross-section between the retail drone delivery market and the needs of the vertical construction industry. Many of the concepts are heavily qualitative due to the early stage of the overall industry and lack of existing data on the subject.

The overall answer on feasibility will be two part as well. The short-term feasibility of material and tool delivery via UAS is extremely limited. The current drone market cannot support a drone large enough to deliver large pieces of construction material safely. In addition, a very limited number of large companies have successfully navigated the part 135 certification process with the FAA, and none of them have implemented large-scale programs within the US. Additionally, the airspace and coordination technologies have not advanced enough to safely navigate low airspace with material delivery and detect and avoid automation software is still a fledgling technology and needs significant improvement before seeing large-scale implementation. Added to that, most vertical construction sites are rife with new emerging airspace hazards as building frames go up, adding a layer of complexity to the market.

Long-term feasibility, however, is the opposite answer. It is highly likely, based on the progress of the UAS industry in the last two decades, adoption of UASs in the construction industry, and the market demand for automation, that construction material delivery will be heavily adopted as technology and regulation progress. The part 135 process is being worked through by more and more companies, smaller scale implementation of UAS delivery of small parcels is being implemented outside of the US, and experimentally in the US, and air traffic control safety programs are being heavily studied for use in the coming years. Detect and avoidance software is used now in commercial drones with some success and is being improved as artificial intelligence tools advance over time. It is impossible to pinpoint when the overall market will be able to implement large scale UAS material delivery for vertical construction, but it is simply a matter of time for a fully feasible system as the market improves technology and safety at a rapid pace.

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