

PARCEL DELIVERY IN AN URBAN ENVIRONMENT USING UNMANNED AERIAL SYSTEMS: A VISION PAPER

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ABSTRACT:

This vision paper addresses the challenges and explores the avenue of solutions regarding the use of Unmanned Aerial Systems (UAS) for transporting parcels in urban areas. We have already witnessed companies' delivering parcels using UAS in rural areas, but the challenge of utilizing them for an urban environment is eminent. Nevertheless, the increasing research on the various aspects of UAS, including their battery life, resistance to harsh weather conditions and sensing its environment foresee their common usage in the logistics industry, especially in an urban environment. In addition, the increasing trend on 3D city modelling offer new directions regarding realistic as well as light 3D city models that are easy to modify and distribute. Utilizing UAS for transporting parcels in an urban environment would be a disruptive technological achievement as our roads will be less congested which would lead to less air pollution as well as wasted money and time. In addition, parcels could potentially be delivered much faster. This paper argues, with the support of the state-of-the-art research, that UASs will be used for transporting parcels in an urban environment in the coming decades.

1. INTRODUCTION

The logistics sector is one of the key sectors in today's world having close ties with spatial information science as parcels are transported from one location to another. Various types of parcels are transferred ranging from letters to chemicals, some of which had to be kept at certain temperatures and should be kept still during the transportation. Consequently, various forms of logistics exist, but the wide usage of e-commerce leads to the fact that the majority of urban logistics comprise of parcels that are transferred between businesses to businesses or customers in an urban environment (Lindholm, 2013).

There are several important issues that logistics industry is facing in an urban environment. First, local carriers usually use old vehicles that emit large amounts of pollutants in order to reduce the increasing costs. For instance, in Paris the trucks that serve as the medium of logistics companies cause 15-20% of vehicle congestion and nearly 60% of particle emissions (Dablanc et al., 2011). Second, researchers have identified that logistics companies may not operate efficiently leading to a higher than optimal vehicle-kilometers due to ineffective planning (Jiang and Mahmassani, 2014). In addition to not effectively incorporating the temporal dimension whilst route planning (Nha et al., 2012), finding parking spaces in already congested urban environments also contribute to this inefficiency (Jean-Marie Boussier et al., 2011). Third, in today's mobile world, businesses or customers often require express or urgent deliveries; hence, forcing the logistics companies to be more flexible as well as provide just-in-time delivery.

The proliferation of Unmanned Aerial Systems (UAS) for civil markets would have an added value both in terms of economy as well as job creation. The economic impact of the integration of UAS is estimated to add more than \$13.6 billion in its first three years and will grow to \$82.1 billion in the next 10 years. In addition, the emergence of utilizing UAS for civil markets is estimated to create 34000 manufacturing jobs and more than 70000 new jobs in the first three years of the integration (Jenkins and Vasigh, 2013). The main reason for this prospect is

that UAS can perform tasks similar to those that can be done by manned vehicles but often faster, safer, and at a lower economic and environmental cost.

This paper provides a vision towards the utilization of UAS (or drones) in the logistics industry, specifically delivering of parcels in an urban environment. The second section provides the related work, and third section provides the vision towards the delivery of parcels in an urban environment using UAS. The last section is the conclusion.

2. RELATED WORK

The research agenda on UAS have started, as with most of the other technological advancements, through military needs. However, the prospects of deploying UAS have attracted many other domains including, but not limited to, photogrammetry and surveying (Colomina and Molina, 2014), agriculture (Yang et al., 2016), environmental monitoring (Ni et al., 2017), entertainment (Quiroz and Kim, 2017), forestry (Casbeer et al., 2005), construction surveillance (Javier Irizarry and Dayana Bastos Costa, 2016), infrastructure protection (Gómez and Green, 2017) and rescue operations (Efrat et al., 2012). These various application domains, coupled with the increasing R&D activities regarding UAS leads to a positive loop of productivity.

Those research areas which had already demonstrated the applicability of UAS; however, are limited to research and the wide usage of UAS for any civilian domain has still not been realized. This is because there are three facades of UAS: i) public acceptance, ii) regulations, and iii) technology; often in relation with each other as illustrated in Figure 1 (Heutger and Kückelhaus, 2014). However, progress has been achieved in all these, sometimes conflicting, facades. Now, companies and legal bodies are working towards the realization of wide usage of UAS in a civilian context.

Public acceptance is one of the facades of using UAS at a large scale; since citizens have safety and privacy concerns.

Researchers consider that the appearance, routing, level of autonomy affect the citizens' view towards UAS. For example, whereas laypeople fear the violation of their privacy, active UAS pilots consider more of a risk in possible accidents (Lidynia et al., 2017). Therefore, it is important to inform citizens beforehand regarding the routes of UAS. Another public concern is due to the security of these systems. UAS controlled by WiFi use IEEE 802.11 standards, which is vulnerable to security breaches (Vattapparamban et al., 2016). The outcome of a recent research suggests that, although the commercial use of UAS can improve lifestyle and increase efficiency, there is a need to invest more attention to convince the citizens (Luppicini and So, 2016). Even though most people would enjoy the improved lifestyle offered by technology, there should be clear and concise guidelines addressing the public concerns on the wide usage of UAS.

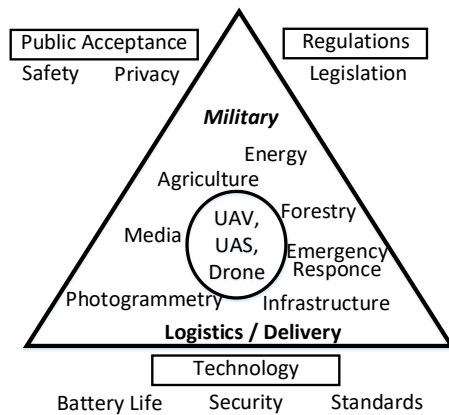


Figure 1 Three Facades of UAS

The legal bodies such as Federal Aviation Administration (FAA) of US or Civil Aviation Authority (CAA) of the UK are working towards providing the regulations of flying UAS for commercial purposes. For instance, FAA, amongst other, requires that UAVs must have onboard “detect, (sense) and avoid” capabilities (Shively, 2014). In addition, they classify UAS –therefore the relevant regulations– based on their takeoff weight (Oliver, 2017). On the other hand, CAA “requires drone flights to stay away from persons not actually involved in the flight operation and to be at least 150 metres from structures” which prevent the mass use of UAS for logistics in an urban environment (Harrington, 2015). Consequently, at the moment, the regulations in developed countries do not allow the mass use of UAS for civilian use. Nevertheless, it is safe to state that these regulations are subject to change depending on the progress in science and technology.

There is an increasing coverage with respect to UAS both in the media or scholarly databases indicating the positive trend for their common use. In one of the main scholarly databases, SCOPUS, the number of papers including the terms “unmanned aerial systems”, “unmanned aerial vehicles” and “drones” (it should be noted that “drone” also refers to a male bee; hence, the results are overestimated) is searched and the total number of papers for each year is denoted with “UAS” in Figure 2. More than five thousand papers had been published in 2016, which almost doubled the previous year’s record. Similarly, the term “logistics” is added to these three terms and the total number of papers for this search is denoted with “UAS + Logistics”. Even though the “logistics” account for about 1% of the total publications within the broad area of UAS, the involvement of big companies including Amazon, DHL, and JD

(one of the biggest online retailers in China) and Google foresee that there would be an increasing research for UAS monitoring and management systems (Itkin et al., 2016). Therefore, it is not surprising to hear NASA’s senior engineer for air transportation systems stating that “we need to accommodate drones” in air traffic control systems (Schneider, 2017).

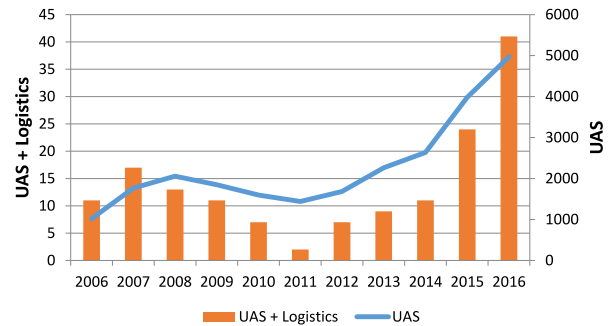


Figure 2 Total number of articles including the terms UAS and Logistics

Delivering, especially medical, products using UAS has already been researched. For instance, researchers have simulated that it would be economically viable to transport vaccines using UAS if they are used frequently enough to overcome the capital costs (Haidari et al., 2016). In addition to the economic viability, such a scenario has also proven to improve supply chain performance since higher vaccine availability would be provided to those living on rough terrains. Researchers have also identified the necessity of relying on UAS especially in disaster relief scenarios where roads are damaged or cannot be effectively used to provide medical relief, also known as “humanitarian logistics” (Chowdhury et al., 2017; Fikar et al., 2016). As different situations have different requirements, researchers have investigated numerical analysis to determine the tradeoffs between using faster speeds versus longer endurance of UAS (Murray and Chu, 2015). Even though the problems associated with delivering parcels in an urban environment, such as noise emission, security and safety risks and local ecologic impacts are known (Kunze, 2016); the advancements in science and technology could potentially provide solutions to these issues.

The progress in other aspects of UAS would also add further support with respect to their usage for logistics. Currently, most of the small UASs are powered by lithium-ion or lithium polymer batteries and their flight endurance is limited to a few hours. Consequently, prolonging the battery life of UAS is one of the key research agendas, and methods like wireless charging (Choi et al., 2016), developing effective UAS designs (Larsen et al., 2017) and investigating the use of fuel-cells (Kim et al., 2011) contribute to this agenda. Another prominent research area in geographical information science having close ties with research on UAS is the 3D urban modelling (Biljecki et al., 2015). Open standards like Geographic Markup Language (GML) and its specialized version CityGML offer the means to develop and distribute such 3D city models (Belussi et al., 2015; Gröger and Plümer, 2012). However, there are still open research issues including the utilization of accurate elevation data (Biljecki et al., 2017) and how these models could effectively be incorporated in an UAS.

3. UTILIZATION OF UAS FOR LOGISTICS

In an urban environment delivery of parcels using UASs would be achieved through three main steps: i) dispatch, ii) shipment

and iii) delivery. During dispatch the parcel to be delivered is removed from the repository to be sent to the customer. Shipment is the transportation of the parcel to the customer and delivery occurs when the parcel is delivered to its destination as depicted in Figure 3. Here, the UAS is assumed to have the capability of Vertical Take-Off and Land (VTOL) due to their ease of use in an urban environment. Last, autonomy, in all three aspects of the process, is desired in order to provide a faster and probably secure delivery.

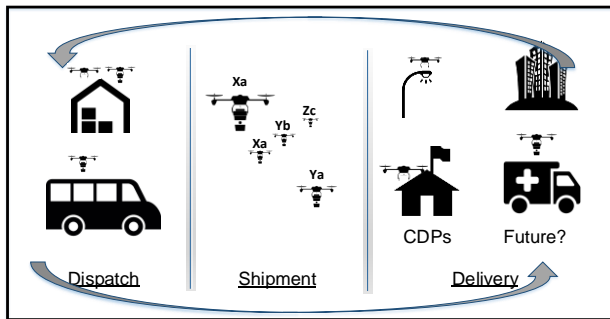


Figure 3 Parcel delivery using UASs in an urban environment

During dispatch the relevant parcel is loaded to an UAS with the address of the customer. There might be new UAS where more than once parcel could be loaded to serve more than one customer in a single launch. The dispatch could occur through a stationary repository or a vehicle. Repositories could hold more parcels and UAS; however, they might not be well spatially distributed to cover an entire urban environment leading to some areas being uncovered. In that case mobile repositories could be utilized containing several UAS to serve more than one customer at a time; hence, still improving today's state-of-the-practice. Nevertheless, mobile repositories might even not be needed in the likely progress of UAS having longer trip distances and battery life. Dispatch is mostly related to a single company's operation. However, there would be several logistics companies delivering parcels in an urban environment.

Shipment process, therefore, requires the technology guided by well-defined regulations and standards so that the security of UASs sharing the same aerial resources is guaranteed. In addition, there would probably be different UAS models in operation. For instance, in the Figure 3, the companies "X" and "Z" has the single UAS model "a" and "c" respectively; whereas company "Y" has two types of UAS models; "a" and "b". Different companies using different UAS models to ship parcels would require aviation agencies to have strict and clear requirements. First, there should be air corridors, just like for aircrafts to have a better management of the UAS flocks (Feng and Yuan, 2016). These air corridors would be defined by the agencies and followed by the companies. The increasing research efforts on modeling flocks of UASs in order to prevent collision between each other add further support to the realization of this requirement (Leonard et al., 2012; Sanchez-Lopez et al., 2017). In addition, monitoring such a large scale trajectory data would necessitate aviation agencies to rely on the state-of-the-art spatial analytics methods (Tahboub and Rompf, 2016). Second, UAS should be aware of its surrounding and take decisions accordingly in real-time. In other words, it should well sense its environment in order to avoid unexpected crashes with natural and/or man-build structures (Muñoz et al., 2015). Third, issues regarding the localization of an UAS should be addressed and precise location of an UAS should be obtained at all times in an urban environment. The high-rise buildings

might block the GPS signals leading to the "urban canyon problem" or GPS signals could get reflected by different objects including buildings or the ground. However, recent researches indicate that positional accuracies as low as an average of 0.36 meters could be reached allowing us to detect the lanes in which a vehicle is travelling (Zabihi et al., 2015). Last, progress in machine vision and deep learning provide solutions so that UAS can navigate through GPS-denied environments (Pestana et al., 2013; Smolyanskiy et al., 2017).

Finally, the parcel should be delivered. The most plausible scenario for delivery is to rely on "Collect and Delivery Points" (CDPs), where customers can pick up their parcel. These stationary locations are believed to be the best way to solve urban end-distribution problems (Jesse W.J. Weltevreden, 2008). There are two main types of CDPs: i) attended and ii) non-attended. In attended CDPs an officer is employed whom the customer interacts, whereas in non-attended CDPs customers use some sort of identification (e.g. PIN number) to pick up their parcel. The parcels could be delivered to both types of CDPs. Indeed, Amazon has already issued a patent application to use lamp posts as a CDP, which could also be used to recharge UASs, adding further support to the realization of this concept (Coulton et al., 2017). Apart from having a more organized way of delivery, relying on CDPs would also have the advantage of delegating the recognition of the customer to CDPs. Once the technology to deliver parcels to CDPs is established, the next leap would be towards delivering parcels (especially food deliveries which are quite common in the UK which is expected to reach £200 billion in 2019 (Zissis et al., 2017)) to residential buildings or even moving emergency vehicles in an urban road network.

There are many challenges to utilize UAS for parcel delivery in an urban environment, but there is a growing amount of research to overcome these challenges. The challenges are classified under three categories: i) societal, ii) public authorities and iii) technological. Some of the challenges are intertwined (e.g. the manoeuvres that an UAS should take to "sense & avoid" would directly affect its battery life). Nevertheless, Table 1 provides an overview to these challenges and explores the avenue of solutions for each challenge.

Challenges	Rationale	Avenue of solution
Societal		
Physical safety	UAS carrying a parcel could fall or land to unintended destinations, which might then harm civilians.	The collision impact of an UAS on humans or man-made structures is an open research area. A recent report identified 23 knowledge gaps in this domain ranging from battery fires to defining new blade standards that are more appropriate for ground collisions (Arterburn et al., 2017).
Privacy	As we are moving towards a “sensor society”, most of the surveillance tasks are done via these sensors raising privacy concerns (Siedschlag and Alperen, 2017). The common use of UAS would exacerbate this concern.	Smart vehicles have on-board “black-boxes” (aka “event data recorder”) that store critical information about the UAS itself (Andrejevic and Burdon, 2015). In addition, researchers indicate that privacy could be satisfied by applying seven design principles (Cavoukian, 2012). Nevertheless, researchers argue that current legislation is not sufficient in modern world to protect civil liberties (Finn and Wright, 2012).
Perception	Public perception and acceptance of UAS is an open research area, as most of what people know about UAS is relevant to their military use.	Recent research on a group of Australians indicates a relatively neutral attitude towards the utilisation of UAS. The authors also state that this is an on-going process and the public has yet to form clearer position regarding their use (Clothier et al., 2015).
Public Authorities		
Tracking of UASs	It is important that an authoritative agency monitors the whereabouts of each and every UAS carrying a parcel on a national aerospace. In this way, the health of the each UAS (both software- and hardware-wise) could be monitored.	Recent researchers shed a light on the health of an UAS by integrating various methods from Kalman filtering to Bayes reasoning (Schumann et al., 2013). Transmission of such data to the authoritative agencies would ease the tracking of all UAS sharing the same aerospace.
Identification of non-authorized UAS	Non-authorized UAS should immediately be identified. Otherwise, it would be straightforward to design an UAS to attack civilians (Steele, 2017).	Researchers have already begun to simulate the reliability of UAS to various security threats by introducing a novel hybrid monitoring architecture consisting of software and hardware based modules (Moosbrugger et al., 2017).
Transparent process	Once the data about UAS are collected, it should be shared with stakeholders so that incidents could be resolved in a scientific manner and research could be taken to enhance the overall process.	The “Sensor Web Enablement” standards by OGC are: i) Observations & Measurements Schema, ii) Sensor Model Language, iii) Sensor Observations Service, iv) Sensor Planning Service, v) Sensor Alert Service and vi) Web Notification Services (Percivall et al., 2015). These standards are still yet to mature, but they add further support to the ubiquitous use of UAS in a transparent way.
Identification of “UAS” hackers	UAS could be hacked by jamming its receiver or GPS spoofing (Shepard et al., 2012). The identification of such hackers is important for law enforcement.	To the best of my knowledge, there is no published evidence on this research area. However, if the state of all UAS could eventually be monitored (Schumann et al., 2013), then the obtained data could be investigated to identify the hackers.
Identification of routes	The most efficient and safe routes for UAS should be determined under the approval of government agencies. These routes should well consider the static phenomenon (airports, high-rise buildings etc.) as well as dynamic ones (e.g. high-wind areas).	NASA conducted a Concept-of-Operations (ConOps) research to identify UAS routes in the presence of traditional aviation operations (e.g. aircraft, helicopters, gliders, balloons, and parachutists). In this UASs could safely operate at low altitude and uncontrolled airspace. The authors also highlight to gain flexibility by relying on open protocols (Kopardekar et al., 2016).
Technological		
Battery life	To ensure the economic feasibility of UAS carrying parcels, long lasting batteries are desired. In this way, maximum time would be spared for delivery and minimal time for recharging an UAS.	Wireless charging is one of the key areas offering a solution to this challenge as UAS leaving a parcel on a CDP could effectively benefit (Choi et al., 2016). In addition, exploration of the electro-chemical properties of Li-ion batteries has shown to enhance the battery recharging time as well as its duration period (Wang et al., 2016).
Sense & avoid	UAS must detect natural and man-made structures and respond with appropriate avoidance manoeuvres in order to maintain minimum separation distances (Camie et al., 2006).	Various methodologies have been used to develop “sense & avoid” technologies including machine vision (Lai et al., 2011) and radar based methods (Accardo et al., 2013). However, most of these researches have not focused on VTOL UAS and also flight altitude, meteorological and illumination conditions and UAS model as well as the automation level has found to play an important role that require further research (Fasano et al., 2014; Prats et al., 2012).

Table 1. Challenges and avenue of solutions of utilizing UAS for parcel delivery in an urban environment

4. CONCLUSION

Most of the societal changes, especially those backed up by technological advancements; might initially seem to be frightening or improbable. Yet, they would eventually get realized due to economic necessities. Even though there is a substantial R&D activity in the broad area of UAS, we still have not yet experienced their wide usage in a civilian context. This paper envisions that the first wide usage of UAS for civilian purposes would be in the area of logistics, specifically delivery of parcels in an urban environment. This is because regardless of our differences including age, gender, citizenship or occupation; we rely on some “things” to be delivered. Whether a doctor waiting for a medicine or a teenager waiting for a meal; we all expect some “one” will deliver what we seek for. Consequently, using UAS to deliver parcels would have the largest societal impact. The very recent purchase of Whole Foods by Amazon also signal the fact that e-commerce would revolutionize in the coming years. Considering that the technological advancement is almost there and that the societal acceptance and legislation to follow up; there is no reason preventing the fact that we will be seeing hundreds of UAS carrying our parcels in the coming decades.

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