Exploring the Viability of Unmanned Aerial Vehicles in the Private Sector

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Noah DeMatteo
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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature ________________________________ Date 5/1/2020
Noah DeMatteo

Approved ________________________________ Date 5/1/2020
Bryn Seabrook, Department of Engineering and Society

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Unmanned Aerial Vehicles

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, are the products of an emergent aerospace industry aimed at producing remote-controlled, pilotless aircraft for military, commercial, and recreational purposes. This technology is extremely useful in a military setting as it bypasses the possibility of pilot endangerment while increasing the maneuverability and scanning efficiency of the craft. However, due to airstrikes in many developing countries UAVs have become synonymous with the term "disaster drones," and as a result several ethical concerns associated with the technology have been raised (Shahid, 2016). As the public dialogue regarding UAV use is dominated by their controversial military applications, there are several less contentious applications in the commercial sphere. Incorporating UAV technology in the agricultural and delivery industries would inevitably increase energy efficiency and access to commodities while reducing the vast amounts of pollution created by these industries. However, there are several economic, cultural, and legal obstacles which have prevented their widespread adoption outside of military and recreational use. In order to explore this topic, the STS frameworks being employed are social construction of technology (SCOT) as well as actor network theory (ANT). These frameworks are useful as they show how societal forces have led to a lack of UAV technology in the private sector while identifying and linking the key actors in this field.

Research Question and Methods

What are the economic and environmental benefits of UAV technology in the agricultural and urban delivery industries and what are the obstacles preventing their widespread implementation? The main objective of this research is to determine whether or not drones are a commercially viable undertaking based on the potential costs and gains of their implementation. The methods being employed in this research are policy and network analysis as well as wicked problem framing. In addition to these methods, existing studies have been cited in order to annotate their methods and emphasize their findings. As the use of drones in these sectors is still in the developmental stage, these methods can outline and highlight the potential outcomes of employing UAVs in these industries. By comparing the economic costs of current farming and delivery technology using a cost-benefit analysis, the economic feasibility of this enterprise can be understood. By conducting an analysis of the detrimental ecological effects of agriculture and delivery in contrast to the benefits posed by recent drone performance studies, the environmental necessity of this technology will become more apparent. Additionally, through the analysis of legislation on both sides of the drone debate one can grasp whether or not commercial UAVs are a logistical possibility from a legal perspective. The analysis will employ primary and secondary resources in addition to surveys in order to answer this question. The major resources used to conduct this research were found in aerospace, agricultural, and environmental databases provided by the University of Virginia. The surveys used were conducted by the Pew Research Center and in order to contextualize how the survey questions were framed, they have been cited in the appendix at the end of this document.

Economic and Environmental Context

The first modern UAV technology was developed by the United States military during the First World War in 1916 (O'Donnell, 2019). Since then, there have been tremendous innovations in the field that have turned it into a multi-billion-dollar industry. In 2014 a projected market growth of $12 billion by 2023 was made for the rapidly advancing field of commercial

UAVs (Gebicke & Krout, 2014). A year later Goldman Sachs estimated a $100 billion UAV market forecast for the year 2020. However, only $13 billion were devoted to commercial applications with military and consumer markets comprising $70 billion and $17 billion respectively (Goldman Sachs Research, 2015). In a more recent projection, assessed three years later in 2018, it was reported that the commercial drone market is "estimated to skyrocket to $127 billion by 2020" (Ludwig, 2020). While each of these projections estimated that the market for drones with commercial applications would expand in upcoming years, it is clear that these estimates have increased exponentially each year. This market growth is due to new, cutting-edge applications as well as revolutions in the speed, precision, and payload capacity of formative commercial drone technology. Yet, as of January 2020 the Federal Aviation Administration (FAA) has reported a total of 1,533,596 drones registered for commercial and recreational purposes with commercial drones comprising less than 28% of this figure (FAA, 2020). While there are several explanations for this phenomenon, the three major obstacles are economic viability, legal restrictions on drone usage, and cultural stigmas derived from their military origins.

While the anthropogenic effects of the agricultural and delivery industries differ in source, they each comprise a large portion of total U.S. emissions. The emission of greenhouse gases such as carbon dioxide, nitrous oxides, and methane creates several environmental problems as these gases are transparent to incoming (short-wave) radiation from the sun but block infrared (long-wave) radiation from leaving the Earth's atmosphere (EIA, 2019). The resulting effect is that heat energy gets trapped within Earth's atmosphere contributing to rising global temperatures and rapidly changing climates. The two main sources of greenhouse gas emissions in the agricultural industry are crop cultivation and livestock production (EPA, 2017).

Drones may not have as much utility in livestock production but offer significant benefits to existing crop cultivation processes. By monitoring crop growth with drones, farmers can determine the optimal period to harvest, leading to a greater yield per quantity of greenhouse gases emitted. The result would make farming much more efficient. According to the Environmental Protection Agency (EPA), the agricultural industry contributes 9% of total emissions and the delivery industry contributes 11%. In total this is 20% of total U.S. emissions that could be reduced by the implementation of emission-free drone technology (EPA, 2017).

In addition to greenhouse gases, the agricultural industry generates an even more insidious form of pollution to the environment. This source of pollution is known as eutrophication which occurs when runoff carries pesticides, herbicides, and fertilizers away from the farmlands and into external ecosystems. The consequences of this contaminated runoff are catastrophic in aquatic ecosystems as it causes an increase in algae production which displaces the oxygen in the water. When the oxygen levels drop below a certain level, what is known as a dead zone is created and no organisms can survive (NOAA, 2020). Drones have the potential to greatly reduce the impact of eutrophication by using far less chemicals to treat crops. This can be accomplished using advanced scanning technology, enabling them to target areas in greater need of these chemicals as opposed to crop dusting planes that spray vast quantities over the entirety of croplands. Furthermore, irrigation drones can be used to apply water to specific areas of cropland reducing the overuse of water in addition to runoff.

Social Construction of Technology and Actor Network Theory in UAV Development

The STS framework that is most useful in analyzing the adoption of drones in the private sector is social construction of technology (SCOT). The SCOT framework essentially states that society and societal forces direct the course of technological history but not vice versa. The STS scholars who were most influential in expanding upon this framework are Hans K. Klein and Daniel Lee Kleinman. In their text, relevant social groups are defined as "embodiments of a particular interpretation" of a given technological artifact (Klein & Kleinman, 2002). When analyzing the development of a technological artifact through the SCOT lens, the sentiments of several relevant social groups come to a head creating the resulting technology. The framework is especially useful to this research because it aims to uncover the various societal forces that have affected the adoption of drones into the private sector and determine whether they can be resolved. The SCOT framework traces its roots to Trevor Pinch and Wiebe Bijker but since their original text was written there has been a lot of criticism. Most of the criticism comes from the fact that the idea views society as composed as groups which fails to account for the unequal distribution of power between groups. Additionally, the framework is contradicted by supporters of technological determinism which states that it is technology which shapes society, not the other way around. However, since this research explores the effect of societal forces on an economic, legislative, and cultural basis, it is clear that SCOT is the more appropriate framework.

The second framework being employed to support this argument is actor network theory (ANT), which considers the effects of both human and non-human actors on the development of a given subject. This framework is useful as it provides a more complete analysis of the problem at hand. Only by "following the actors" can one determine how the key players interact in order to shape a given problem (Cressman, 2009). While some critiques of ANT contend that it is ignorant to believe that human and non-human actors have the same impact, the theory is still useful from an analytical perspective. The framework still has utility because in the case of drone implementation, the non-human actors such as laws, social constructs, and economic forces have as much if not more of an impact than the related human actors. Another criticism of ANT is that the network can become convoluted when there are too many actors in question. However, in the analysis of drone adoption, only the major actors will be evaluated and as a result the subsequent network will be clear and concise. This framework is especially useful when used in conjunction with SCOT because the impact of the entire network can be weighed against the course of this technology.

Analysis & Discussion

Although there are several financial, legal, and societal obstacles that have prevented the adoption of UAV technology into the commercial sphere, this research shows that the implementation of UAVs into the agricultural and delivery industries is indeed an economically viable enterprise with several environmental advantages to previous technology. Nevertheless, due to the complex network of actors comprised of agriculture and delivery firms, government organizations, and UAV providers the implementation of this technology into the commercial sphere has largely stagnated. The specific actors being explored in this discussion are farmers, delivery companies, the Federal Aviation Administration (FAA), the Environmental Protection Agency (EPA), and drone producing aerospace companies. When viewed through the SCOT framework each of these actors can be seen as a relevant social group and together, they have shaped the limitations and outcomes of this development. As such, this research will explore the current economic, legal, and societal status of the agricultural and delivery industries in order to show that this development can improve the economic production of these industries while simultaneously reducing their environmental effects.

While there is no shortage of economic interest in the field of commercial UAVs, the ability of drones to replace existing technology in the agricultural and delivery industries is largely dependent on cost analysis. Although this technology is more efficient, requires less human intervention, and runs on emission free technology, their employment in the two spheres of interest is occurring very gradually. However, by demonstrating the cost-saving capabilities of these applications, the process will inevitably accelerate. In the agricultural sphere, UAVs with herbicide, pesticide, and fertilizer distribution systems typically cost between $1,500 and $25,000 (Vilvestre, 2016). The current industry standard is known as crop dusting, and the aerial application of these chemicals by crop dusting planes will usually cost farmers between $15 to $25 per acre (Wilde, 2010). While crop dusting seems significantly cheaper on the surface, this discrepancy in price can be mitigated by the fact that once an agricultural UAV is purchased, it is a sunk cost that is independent of acreage as well as service fees from outside companies. As such, farmers could treat their crops in-house without relying on outside providers. Additionally, crop dusting providers could switch to this technology and charge roughly the same rate for their services since a crop-dusting plane can cost anywhere from $100,000 to $900,000 with pilots making between $60,000 and $100,000 annually (Welsh, 2009). Furthermore, the autonomy and scanning capabilities of drones has become so advanced that current technology uses visible and near-infrared light to produce multispectral images to track changes in plants and indicate their health (Mazur, 2016). As such, the scanning and operation of this technology requires significantly less human input for operation while vastly reducing the quantity of chemicals needed to be purchased by crop dusting providers. In urban delivery, the use of drones has a similar economic barrier but is slightly more nuanced. For urban delivery services, providers need to pay for the wages of laborers, trucks, and energy inputs. According to the U.S. Bureau of Labor Statistics, the median delivery salary is $30,500 per year, the cost of a delivery truck is roughly $40,000, and the average trucking cost per mile in the U.S. is $1.69 (RW Elephant,

2014) (Ronan, 2018). By contrast, a delivery drone costs between $20,000 and $60,000 with operators predicted to make roughly $50,000 (Maksel, 2015) (Wang, 2015). Although, the cost of drones appears to be higher due to the relatively large range of drone prices and high cost of operation, as the level of autonomy becomes more legally tolerated the operating cost is guaranteed decrease. In a case study of Amazon's Prime Air program, they estimated to charge a miniscule cost of $1 for 30-minute delivery for a small package within 10 miles. When compared

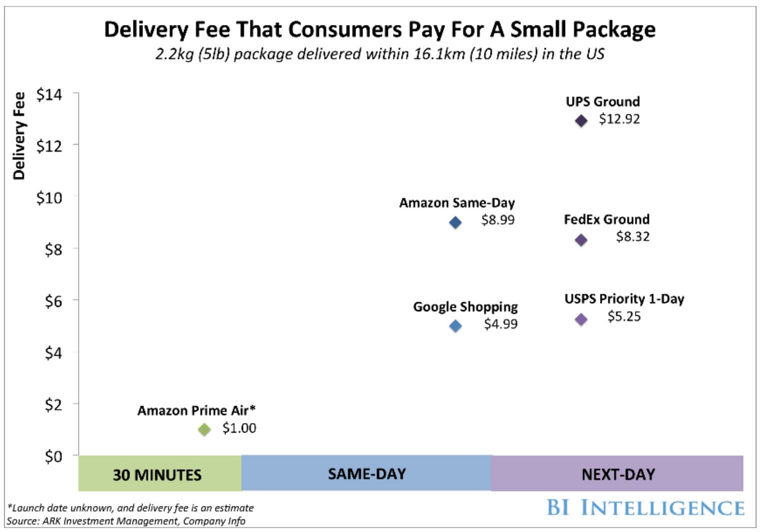

Figure 1: Delivery Fees of Various Services

to their same-day ground transport which costs $8.99 or FedEx next day shipping which costs $8.32, it is clear that drone applications can deliver much faster at a fraction of the cost (Smith, 2015). As such, drones can significantly drive down costs in these industries while providing emission free alternatives crop dusting planes and delivery trucks.

In addition to the economic benefits of UAVs, the environmental advantages are also quite compelling. The agricultural and delivery industries each contribute a substantial portion of total U.S. emissions and other forms of pollution. As stated earlier, these industries comprise roughly 20% of the total U.S. emissions (US EPA, 2017). However, drones are typically electrically powered and as such their carbon footprint is limited to the systems that charge their batteries. According to the Center for Climate and Energy Solutions, the United States emitted 6.5 billion metric tons of greenhouse gases in the year 2017. As an emission-free technology, this value could be reduced by roughly 1.3 billion metric tons by replacing formative combustion-dependent agricultural and delivery technologies with UAVs. Additionally, UAVs can deliver at much higher speeds in urban areas by bypassing traffic and taking more direct routes to designated locations. The scanning capacity of agricultural UAVs can also greatly reduce the impact of eutrophication by exponentially cutting down on the quantity of herbicides, pesticides, and fertilizers used. According to the United States Department of Agriculture, the U.S. applied roughly 516 million pounds of pesticides in 2008. However, with scanning technology that can discern between crops and weeds, herbicides can be deposited in specific locations contrasting the vast quantities used in crop dusting. The scanning technology can also determine areas that are growing optimally, and place supplementary fertilizer or pesticides on select areas of cropland that are falling behind. Aside from ecological effects of eutrophication, the process also creates an annual economic burden of $2.2 billion as a result of losses in recreational water usage, waterfront real estate, spending on recovery of threatened and endangered species, and drinking water (Dodds, 2009). By incorporating UAV technology, the total emissions of these industries as well as the quantity of agricultural chemicals deposited on American farmland can be greatly reduced.

While the economic and environmental benefits of UAVs have become quite apparent, there are several unsettled financial obstacles in this field. These obstacles pertain to the initial cost that farmers and delivery companies would have to incur by disposing of existing equipment and replacing them with UAVs. According to the USDA in 2015, 90% of U.S. farms were small family operations with under $350,000 in annual gross cash farm income. Though the cost analysis shows that UAVs would be less expensive in the long-run, the short-term cost of this initial investment may deter many family farmers from altering their procedure. This issue is not as prevalent in the delivery industry which is dominated by large corporations that have access to an abundance of liquid capital. But since the technology has several environmental benefits, it is conceivable that the federal or state government would subsidize this development or provide tax incentives for small farmers in order to make the change more feasible.

As for legal obstacles, there are several FAA regulations that form the basis for the legal restrictions that inhibit the adoption of drones in these two arenas. The main laws are that commercial drones must: weigh less than 55 lbs. including payload, can't fly over 100 mph, must only fly during daylight hours, and cannot fly above 400 ft (US FAA, 2020). Additionally, it is required that the UAV has an operator that maintains a visual line of sight with the aircraft, which makes the autonomous scanning capacity of these devices virtually obsolete. This issue is critical because by restricting the full technical capabilities of commercial UAVs they also limit their ability to compete with crop dusting planes and delivery trucks that are not subjected to strict regulations. Nevertheless, there have been several attempts to temporarily loosen these regulations for certain applications. One such example is a bill proposed by Senators Cory Booker and John Hoeven of New Jersey and New Hampshire that is aimed at temporarily relieving the legal tension of commercial drone usage (McMillin, 2015). The bill, known as the Commercial UAS Modernization Act, is aimed at setting interim safety rules, helping speed up the process for commercial users seeking to fly UAVs, and preserving the FAA's rulemaking authority while providing them the flexibility to make changes in the final rule as necessary. According to a press release from the U.S. Senate, "the Federal Aviation Administration (FAA) has taken some encouraging early steps to safely integrate UAS technology into American airspace, but other countries have outpaced the U.S. in developing and finalizing safety rules that allow commercial unmanned aircraft systems to operate" ("Booker and Hoeven," 2015). With adequate evidence of safety in conjunction with the environmental benefits that they will create, it is likely that legal remedies can be achieved. Furthermore, as the precise environmental benefits become statistically outlined, social pressure placed on the FAA by environmental lobbyists and government agencies will hasten the process.

The cultural stigma surrounding drone usage is very closely related to the strict legislation that is associated with their use. According to Pew Research, there is a slight majority of Americans that think drones should not be allowed to fly near private homes, and the specific question can be found in the first question of the appendix. While this question mostly pertains to recreational drone usage, the two are very closely related when it comes to legislative proceedings. Nevertheless, this data is not relevant to the use of drones in the agricultural industry as the farms that would utilize UAVs are typically isolated from residential areas. As such, these statistics would only affect the application of drones in urban delivery which requires that the UAVs can fly in residential air space. Nevertheless, as drone technology was adapted from military origins, the majority of public debate surrounding drone usage is in regards to their controversial military applications. Surveys show that in 39 out of 44 countries surveyed, pluralities oppose U.S. drone strikes targeting extremists, and the specific question is cited in appendix question two. Although this survey explicitly refers to the use of drones in airstrikes, the public discourse regarding drone technology often gets saturated or altogether diverted into a conversation about their military applications.

This evidence supports the use of the SCOT and ANT frameworks because the social constructs pertaining to drones are shaped by a wide network of actors that have ultimately created the logistical status of UAV operation in these sectors. This research aims to point out deficiencies in certain perceptions of UAVs and illustrate how these applications can produce both economic and environmental benefits. As the technology is still emerging, there are several advancements that are underway. But, even in the present state there is sufficient evidence to shift the societal perceptions that have established barriers preventing their adoption into the commercial sector. By demonstrating that this is a viable option to the major economic, environmentalist, and legal actors in these two sectors it is possible to expand state of conventional drone usage.

Although the data leads to conclusions that are quite clear, there were still several limitations to the research. First, new applications of UAV technology are still in the developmental stage so there is limited access to published works. Additionally, there was a limited timeframe of nine months that was given to conduct this investigation. For future research, STS scholars, environmentalists, and economists should work together in order to perform a more detailed cost benefit analysis and provide a more precise outline of the ecological benefits that will be created by their implementation. Moreover, mechanical, agricultural, and systems engineers should work together to develop the optimal UAV designs for agriculture and delivery. Lastly, in order to bring this application to fruition, lobbying and advertising would be useful in gathering support from environmentalists in order to get legislatures to further alleviate the legal strain placed on commercial UAV technology.

Conclusion

As illustrated in this paper, the implementation of UAV technology in the agricultural and delivery industries is indeed an economically and environmentally viable initiative. While there are several obstacles that continue to obstruct their adoption, with the support of lobbying campaigns and further research it is plausible that the technology will become more prevalent in the near future. This research is significant because it poses an economic opportunity that utilizes an existing technology in new and innovative ways. Additionally, drone usage in agriculture and delivery can raise awareness about the environmental concerns of these industries while demonstrating that steps toward sustainability can have economic advantages. Using this research as an example, it is promising that engineers and STS scholars will find other applications to existing technologies that can reduce the anthropogenic effects of various industries while also serving as an economic stimulus.

Appendix

1. U.S. adults were asked if private citizens should or should not be allowed to pilot drones: in public parks, on beaches, at events, near crime scenes or traffic accidents, and near people's homes (Hilton, 2017).

2. Individuals from 44 nations were asked if they approve or disapprove of the use of U.S. drone strikes targeting extremists in countries such as Pakistan, Yemen, and Somalia (Pew Research Center, 2014).

Works Cited

A Short History of Unmanned Aerial Vehicles. (n.d.). Retrieved January 30, 2020, from https://consortiq.com/media-centre/blog/short-history-unmanned-aerial-vehicles-uavs

Applications of UAV in Daily Life | AIAA SciTech Forum. (n.d.). https://doi.org/10.2514/6.2016-1895

Booker and Hoeven Introduce Legislation to Support Commercial Drone Innovation | Cory Booker | U.S. Senator for New Jersey. (n.d.). Retrieved February 20, 2020, from https://www.booker.senate.gov/?p=press_release&id=236

Cressman, D. (2009). *1 A Brief Overview of Actor-Network Theory: Punctualization, Heterogeneous Engineering & Translation*.

Dodds, W. K., Bouska, W. W., Eitzmann, J. L., Pilger, T. J., Pitts, K. L., Riley, A. J., Schloesser, J. T., & Thornbrugh, D. J. (2009). Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages. *Environmental Science & Technology*, *43*(1), 12–19. https://doi.org/10.1021/es801217q

Drones: Reporting for Work. (n.d.). Goldman Sachs. Retrieved January 30, 2020, from https://www.goldmansachs.com/insights/technology-driving-innovation/drones/

Fernandez-Cornejo, J., Nehring, R. F., Osteen, C., Wechsler, S., Martin, A., & Vialou, A. (2014). Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960-2008. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2502986

Gebicke, S., & Krout, T. (2014). Unmanned Aircraft Must Rise Above Barriers for Commercial

Applications. *NASA Tech Briefs; New York*, 36–40.

Hilton, P. (n.d.). How Americans feel about drones and ways to use them. *Pew Research Center*. Retrieved February 18, 2020, from https://www.pewresearch.org/fact-tank/2017/12/19/8-of-americans-say-they-own-a-drone-while-more-than-half-have-seen-one-in-operation/

Ludwig, S. E. (2018). Drones: A Security Tool, Threat and Challenge. *Security; Troy*, *55*(3), 36,38,40.

MacDonald, J., & Hoppe, R. (n.d.). *USDA ERS - Large Family Farms Continue To Dominate U.S. Agricultural Production*. Retrieved February 17, 2020, from https://www.ers.usda.gov/amber-waves/2017/march/large-family-farms-continue-to-dominate-us-agricultural-production/

Maksel, R. (n.d.). *Delivery by Drone*. Air & Space Magazine. Retrieved February 17, 2020, from https://www.airspacemag.com/flight-today/delivery-by-drone-180955988/

Mazur, M. (n.d.). *Six Ways Drones Are Revolutionizing Agriculture*. MIT Technology Review. Retrieved February 17, 2020, from https://www.technologyreview.com/s/601935/six-ways-drones-are-revolutionizing-agriculture/

McMillin, M. (2015). Proposed Bill Would Allow U.S. Commercial Drone Operations. *Aviation Daily; Washington*, *401*(37), 5.

Pew Research Center. (2014, July 14). Global Opposition to U.S. Surveillance and Drones, but Limited Harm to America’s Image. *Pew Research Center’s Global Attitudes Project*. https://www.pewresearch.org/global/2014/07/14/global-opposition-to-u-s-surveillance-and-drones-but-limited-harm-to-americas-image/

Ronan, D. (2018, October 4). *Cost of Operating a Truck Up 6% to $1.69 Per Mile, ATRI Report Says*. Transport Topics. https://www.ttnews.com/articles/cost-operating-truck-6-169-

mile-atri-report-says

RW Elephant. (n.d.). *Calculating The Real Delivery Costs In Your Rental Business: Trucks—RW Elephant*. Retrieved February 18, 2020, from https://rwelephant.com/blog/calculating-the-real-delivery-costs-in-your-rental-business-trucks/

Smith, C. (n.d.). *Amazon's delivery drones could make 30-minute deliveries a reality (and for a $1 fee)*. Business Insider. Retrieved February 17, 2020, from https://www.businessinsider.com/delivery-fee-for-amazon-prime-air-2015-4

The Social Construction of Technology: Structural Considerations—Hans K. Klein, Daniel Lee Kleinman, 2002. (n.d.). Retrieved January 30, 2020, from https://journals.sagepub.com/doi/10.1177/016224390202700102

UAS by the Numbers. (n.d.). [Template]. Retrieved January 30, 2020, from https://www.faa.gov/uas/resources/by_the_numbers/

U.S. Bureau of Labor Statistics. (n.d.). *Delivery Truck Drivers and Driver/Sales Workers: Occupational Outlook Handbook: : U.S. Bureau of Labor Statistics*. Retrieved February 17, 2020, from https://www.bls.gov/ooh/transportation-and-material-moving/delivery-truck-drivers-and-driver-sales-workers.htm

US Department of Commerce, N. O. and A. A. (n.d.). *What is nutrient pollution?* Retrieved January 30, 2020, from https://oceanservice.noaa.gov/facts/eutrophication.html

US EPA, O. (2015, December 29). *Sources of Greenhouse Gas Emissions* [Overviews and Factsheets]. US EPA. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

US FAA. (n.d.). *Certificated Remote Pilots including Commercial Operators* [Template]. Retrieved February 17, 2020, from https://www.faa.gov/uas/commercial_operators/

Vilvestre, J. (n.d.). *The Farming of the Future: Agriculture Drones Take to the Skies*. Futurism. Retrieved February 17, 2020, from https://futurism.com/the-farming-of-the-future-agriculture-drones-take-to-the-skies

Wang, D. (n.d.). *The Economics of Drone Delivery * Retrieved February 18, 2020, from https://www.flexport.com/blog/drone-delivery-economics/

Welsh, J. (2009, August 15). Flying Low Is Flying High As Demand for Crop-Dusters Soars. *Wall Street Journal*. https://www.wsj.com/articles/SB125020758399330769

What are greenhouse gases and how do they affect the climate? - FAQ - U.S. Energy Information Administration (EIA). (n.d.). Retrieved January 30, 2020, from https://www.eia.gov/tools/faqs/faq.php?id=81&t=11

Wilde, M. (n.d.). *Dusting crops a boon, necessity for farmers | Business—Local News | wcfcourier.com*. Retrieved February 17, 2020, from https://wcfcourier.com/business/local/dusting-crops-a-boon-necessity-for-farmers/article_a8b5380e-a64c-11df-9408-001cc4c002e0.html