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A cost-benefit analysis of Amazon Prime Air

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Acknowledgments

I would like to thank my parents for supporting me through school and for encouraging me to do my best.

I would like to thank my director, Bruce Hutchinson, for always believing in me. Your encouragement and guidance helped me find a passion for economic research that I never knew I had.

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Abstract:

This paper analyzes the costs and benefits of the newly proposed Amazon Prime Air delivery system that uses drone technology to deliver packages to customers' doorsteps. The paper sets forth a benefit-cost analytical framework to examine the technology for the benefits of labor-saving technology, faster delivery, and the advantage of being first versus the costs of operating the drone system. This analysis is conducted by modeling the Prime Air system for Chattanooga, TN. The model addresses FAA regulations, drone design, logistics, and related factors to predict how Amazon might set up and operate the drone system. Amazon's goal is to increase its profitability through the application of new technology resulting in a better product (a delivery system) for a subset of its customers.

Through this analysis, the paper weighs the potential costs and benefits associated with the innovation and implementation of the Prime Air drone delivery system. This analysis will determine if delivery by drone is more cost effective than ground delivery as well as how Amazon could gain revenue to fund the system. As discussed, the drone delivery system has the potential to give Amazon a comparative advantage over its competitors as well as revolutionize the transportation and delivery industries.

Introduction:

In December of 2013, Amazon President Jeff Bezos made an innovative announcement on an episode of 60 Minutes. In the video, Bezos amazed the host of the show by showing him Amazon's new Octocopters or drones. These drones, Bezos says, are the future. He proposes that in a few years Amazon will be able to use drones to deliver packages to a customer’s front door. As far-fetched as it sounds, critics of Bezos and skeptics alike expressed their concerns and opinions while supporters stood firm. Yet no one besides Bezos himself and perhaps other elites within Amazon know how this proposed drone delivery system will happen. Despite commercial drone operation being illegal, Bezos made his announcement well in advance of the drone program’s implementation. This could only be for two reasons: to gain community and consumer support or to threaten UPS and FedEx with future loss of business. Either way, Amazon now has the opportunity to expand the transportation and delivery service in a way we previously only imagined. As Paul Misener, Amazon Vice President of Global Public Policy, commented, “one day, seeing Amazon Prime Air will be as normal as seeing mail trucks on the road today, resulting in enormous benefits for consumers across the nation” (Amazon.com, 2014).

As mentioned previously, the use of commercial drones is currently illegal in the United States. Knowing this, Amazon executives have written the Federal Aviation Administration (FAA) to ask for special exemption from the current regulations in order to test their drones in the US. If granted, this special permission does not give Amazon the power use the drones for commercial purposes. The exemption would be granted exclusively for testing purposes. In order for Amazon to implement their proposed drone delivery system, the FAA will eventually have to change existing legislation to allow commercial drone flights. This is an option the administration is currently exploring.

Amazon's Business Model:

Amazon revolutionized the online marketplace when the company was founded in July of 1994. Amazon continues to abide by its original mission statement to "be Earth's most customer-centric company, where customers can find and discover online anything they might want to buy, and endeavors to offer its customers the lowest possible prices" (Amazon.com). In order to fulfill this mission, Amazon offers products at prices consistently lower than traditional retail stores. This has created a strong customer base for the company and has led to Amazon's dominance of the e-commerce market, the online marketplace for commercial transactions.

Amazon also has an advantage over other online retailers in the speed at which the company can send a package out for delivery. The company created and held this advantage with massive increased investment in capital stock and fulfillment centers across the country. Amazon now has a fulfillment center within five miles of most metropolitan areas (Davis, 2013). Amazon currently has over

10 million Amazon Prime Members, loyal customers that buy frequently from the online retailer and enjoy free shipping and other benefits after paying a yearly fee. As large as that number might seem, the number is projected to increase 150% from 10 million in 2013 to 25 million by 2017 (McCorvey, 2013). How has Amazon created such a loyal customer base? Fast delivery. How else might an online retailer compete with physical stores? Amazon provides speedy delivery. Within two and a half hours of your placing an order, your package has been shipped (Wohlsen, 2014). Amazon accomplishes this speed with an efficient packaging process and proximity to consumers through fulfillment centers. In 2012, the company had 89 fulfillment centers worldwide, and announced they were building 5 more in the US. Their fulfillment centers are equipped with Kiva Robotics Systems that are programmed to pick and move items around the warehouse (Wohlsen, 2014). Though the Kiva robots have been a successful investment for Amazon, human labor still plays a huge part in fulfilling orders. Amazon continues to look for more ideas to increase the speed of their fulfillment time and thus, be better able to compete with other retailers.

Since Amazon began, other companies such as Walmart and Target have entered the online marketplace with considerable success. To remain competitive, Amazon continues to promote low prices across all of their products in order to retain the trust and loyalty of customers. However, over the last few years, with delivery costs rising as a result of rising gas prices, Amazon's profit margins have shrunk to ever lower levels as the company strives to maintain high levels of customer satisfaction. Seeing the struggle ahead, Amazon strives to differentiate itself from its competitors, both in product and service. To remain competitive, the company looks to cut costs rather than raise prices. One major expense for Amazon is delivery.

Amazon currently relies on Fed Ex, UPS, and the postal service to deliver its packages. This means that Amazon currently has no foothold in the delivery/transportation market. By entering this market, Amazon would cut out the middle man (its current delivery service) and complete a customer's order all the way to their doorstep. Amazon would effectively eliminate the profit that UPS and FedEx currently skim off the top. This also would give Amazon the opportunity to directly access its customers. By entering the transportation market and reducing delivery costs, Amazon has the potential to pass on some of its savings to consumers by continued low prices while increasing its profit margin.

Another profitable aspect of the drones is the potential for saving on labor costs. Amazon's Business Model relies on labor-saving technology to increase their efficiency and effectiveness as an online retailer. The drones would replace most of the need for human labor to deliver packages to the doorstep of customers. The only human labor required would be for operational management and drone maintenance. By eliminating some and reallocating other labor costs, the drone technology has the potential to save Amazon money through increased efficiency and error reduction.

Literature Review:

Very little written literature exists regarding the commercial use of drones for pick-up and delivery. However, a few economists have studied other various commercial and civil applications of drones. That research covers a range of topics and uses for drones, but is usually focused on aerial surveillance. There is minimal published research on commercial drone usage for package delivery.

In the paper titled, "Analysis of Unmanned Aircraft Systems and Application in the Civil Field", Kharchenko and Prusov consider the various uses for drones, breaking them down into three groups: safety control, scientific-research, and commercial. They highlight a number of various commercial uses, but do not touch on cargo delivery/transport. The article talks mainly of aerial photography and surveillance opportunities. However, Kharchenko and Prusov do mention specific requirements needed in the structure of an Unmanned Aviation Complex (UAC) or drone station. These requirements are as follows:

- the unmanned aircraft itself;
- control stations (management) of unmanned aircraft and antennas system;
- software and systems of on-board monitoring of the unmanned aircraft;
- communication means (earth/air and air/earth) for air traffic control and unmanned aircraft payload;
- terminals of data processing;
- landing system;
- launch system and systems of the flight refreshment;

- maintenance equipment and the support of unmanned aircraft and its systems;
- systems of storage and transportation of unmanned aircraft complex.

In this list, Kharchenko and Prusov highlight the various technological and capital needs of operating a drone complex. They also bring up an important issue to consider in the future. As drone usage becomes more and more popular, problems may arise in the use of airspace and the "allocation of frequency range for unmanned aircraft control and data transfer from the [aircraft] to the earth and vice versa" (Kharchenko, 2012). Similar to radio frequencies, competition over UAS frequency usage may become an issue that will need to be solved legally. In their conclusions, Kharchenko and Prusov predict that the market for drones and drone systems will expand in the future as technical and administrative barriers are reduced.

In his article, "An Investigation into the Suitability of the Use of Unmanned Aerial Vehicle Systems (UAVS) to Support the Initial Needs Assessment Process in Rapid Onset Humanitarian Disasters," Peter Tatham addresses the uses of UAVS in drones in providing aerial surveillance and reconnaissance in areas in need of immediate action. He quotes M. C. Christopher from *Logistics and Supply Chain Management*, saying, "there is broad agreement that timeliness of delivery is a key order-winning criterion," before explaining how this is especially crucial to disaster zones (Tatham, 2009). Tatham believes that drones can lead to earlier and better quality aid to areas suddenly struck by a disaster.

Tatham uses his paper to analyze the benefits and downfalls of using manned versus unmanned methods of surveillance. He begins this analysis by discussing the differences in cost, data quality, and other requirements for each type of aircraft. In his analysis of the UAVs, he writes that “the cost/hour is similar to a manned aircraft, and less than a helicopter; [UAVs] require less launching/landing area; can operate at low levels in cloud(s) and medium precipitation conditions that would not be allowed or safe for manned aircraft” and have a greater endurance levels (65). The benefits of using a UAVS could outweigh the cost of developing and operating the technology. This is both relative and important. Tatham has no doubt that in the coming years, the cost of UAVS will become very inexpensive.

In his analysis, Tatham compares the costs of operating a fixed-wing light aircraft, helicopters, and UAVs and finds that UAVs are less expensive to obtain and operate by looking at capital cost, operating speed, and mission cost. All of this points to the fact that as technology in UAVS advances and the capital costs become lower and lower, the possibility of using UAVS for commercial purposes becomes more and more likely.

FAA History and Regulations:

The Federal Aviation Agency (FAA) was established in 1952 to maintain the safety and efficiency of United States airspace. The Agency was renamed the Federal Aviation Administration in 1966, when the organization was placed under the then newly created Department of Transportation (FAA.gov, History). Each year, as airspace traffic and security risks grew, so did the responsibilities of the FAA. Today, the FAA has legal authority over all US airspace. Though the use of drones for private use has not been regulated, currently, the FAA has restricted the use of drones for commercial businesses.

As part of a budget bill passed in 2012, in Section 332 of the FAA Modernization and Reform Act of 2012, Congress ordered the FAA to open US airspace to the use of commercial drones in the next five years. Section 332. Integration of Unmanned Aircraft Systems into National Airspace System reads:

> Not later than 270 days after the date of enactment of this Act, the Secretary of Transportation, in consultation with representatives of the aviation industry, Federal agencies that employ unmanned aircraft systems technology in the national airspace system, and the unmanned aircraft systems industry, shall develop a comprehensive plan to accelerate the integration of civil unmanned aircraft systems into the national airspace system. (FAA Modernization and Reform Act of 2012)

As a part of this comprehensive plan, the FAA must establish rules and regulations concerning operations, a certification system, and a timeline for integration no later than September 20, 2015. This was to create a “5-year roadmap” for the integration of civil UAVs (unmanned aerial vehicles) into national airspace. Under Section 333, the FAA is currently allowed to give certain companies special permissions to operate in US airspace before the completion of the plan in 2015. The Act reads:

> The Secretary of Transportation shall determine if certain unmanned aircraft systems may operate safely in the national airspace system before completion of the plan and rulemaking required by section 332 of this Act. (FAA Modernization and Reform Act of 2012)

Therefore, in order to comply with regulations, each entity that wishes to use drones for commercial purposes must submit an application for exception to the FAA and be granted special permission. Through this process, the entity seeking exception must provide drone specifications (such as size, weight, flight speed, etc.) so that the entity’s respective drone model may also be approved to fly. This exemption is given only when the “FAA Administrator has identified this as a high priority project to address demand for civil operation of UASs for commercial purposes” (FAA.gov, Section 333). However, few companies have been granted such exemptions.

The FAA recently granted eight more requests for exemption, bringing the total number of requests granted, both individual and commercial, to 342

(FAA.gov, News and Updates). BP plc is one of the few commercial entities to achieve such permissions. Even then, only two unmanned aerial vehicle models have been approved, the Scan Eagle and Aerovironment's Puma, and both may only fly in the arctic (FAA.gov). Subsequent restrictions on unmanned aerial vehicle flights are not uncommon with exception grants. CNN recounts that when Douglas Trudeau became the first realtor to obtain an FAA exception on January 5, 2014, that the permission came with detailed restrictions in a 26-page letter. The restrictions required Trudeau to obtain "a regular pilot's license, pass an aviation medical check, be assisted by a spotter, request permission two days in advance, and limit flights to less than 35 mph and below 300 feet" (Cooper, 2015). It is important to point out that all of these exemptions granted were for aerial surveillance/photography. The FAA seems hesitant to grant drone exemptions for other applications.

The prospect of gaining exceptions and using drones commercially has many companies, including Amazon and Google, anxiously awaiting approval. Eager to implement its Prime Air delivery system, Amazon wants to begin testing drones in Seattle, WA, near its headquarters and existing facilities. Since Washington is not one of the six approved test sites (Alaska, Nevada, New York, North Dakota, Texas, and Virginia), the company must seek special FAA permission (Walker, 2014). Ironically, in order to comply with current regulations, Amazon had to shoot its demo video, both for press and FAA permissions, outside of the United States. On July 9, 2014, Amazon submitted its letter to Michael P. Huerta, the Administrator of the FAA with hopes to be the one of the first companies granted authorization for conducting research and development in the US (Bowman, 2014).

Recent events have affected Amazon's plans for research and development. In December, in the House Aviation Subcommittee, Peggy Gilligan, Associate Administrator for Aviation Safety, stated that Amazon could pursue an alternative form of exemption in the form of "experimental certificate" (McNeal, 2015). Experimental certificates are "issued to operate an aircraft that does not have a type certificate or does not conform to its type certificate and is in a condition for safe operation" (faa.gov). Amazon, despite their misgivings, started to pursue this route as well, however, the company quickly became frustrated by the impracticality of this option. The following is taken from a letter Amazon subsequently wrote to the FAA and was later published in Forbes Magazine.

> At the FAA's suggestion, and again in-line with our desire to pursue fast-paced innovation in the United States, we also have been exploring another regulatory path to accommodate our research and development needs, an Experimental Certification under 14 C.F.R. § 21.191. However, this alternative entails a lengthy process that was designed for manned aircraft and bears little practical application to small UAS(s). This process requires certification for each individual vehicle, which is burdensome considering how fast we are designing new Prime Air vehicles. Our first Experimental Certification application has been delayed multiple times as we try to work with the FAA to simplify the process. Disconcertingly, there

> is no guarantee that this alternative process will provide us the flexibility we need or at the pace we need it. Therefore, we are maintaining our Section 333 petition, and hope that we have not lost time pursuing this alternative (McNeal, 2015).

Clearly, Amazon is becoming more and more frustrated with the delays the FAA is putting in its way. Additionally, the FAA has requested that Amazon further explain why the company is still pursuing an exemption under Section 333 rather than an experimental certificate as well as how this operation would benefit society. The frustration Amazon feels is clear in Amazon's letter of response to the FAA shown below.

> There is nothing in our reading of Section 333 that requires exhaustion of other regulatory provisions before the FAA grants petitions for exemption. Moreover, the FAA has concluded that an airworthiness certificate, experimental or otherwise, is not required to operate a small UAS under Section 333, which Congress created to get small UAS(s) safely flying as soon as possible in the United States. Requiring exhaustion of alternatives before granting our Section 333 petition would impede that goal. […] Of equal concern is your letter's request for us to further explain "why granting [Amazon's] request would be in the public interest." I have responded to this question in detail below, but I fear the FAA may be questioning the fundamental benefits of keeping UAS technology innovation in the United States. Simply put, Prime Air

> has great potential to enhance the services we already provide to millions of our customers by providing rapid parcel delivery that will also increase the overall safety and efficiency of the transportation system. We want approval to conduct outdoor testing operations with our small UAS in the United States to help realize this goal (McNeal, 2015).

All of these excerpts demonstrate the legal frustrations Amazon and other companies pursuing exceptions are currently dealing with by trying to work with the FAA. McNeal writes that, as the process continues to become more and more frustrating, Amazon may choose to take their research and job potential outside of the US. He reasons that Amazon will realize that fighting the FAA is taking too much time, energy and money. Therefore, they will pursue researching drones elsewhere. Many other countries would be glad to let Amazon conduct research in their airspace in return for the jobs and technology the company will bring. In his article, McNeal cites numerous times that this is not a solution that Amazon wants and that the company would rather stick to US soil. He reasons that if Amazon cannot gain experimental rights, how would the company expect to gain operational rights in the future? Therefore, Amazon must continue to reason with the FAA to keep testing in the US. However, recent news does not bode well for Amazon.

On February 15, 2015, the FAA released their proposed rules for integrating small, commercial UASs into US airspace. If you remember, the FAA was required to release these rules by September 15, 2015. The proposed basic parameters for commercial drones taken from the FAA website are as follows:

- UASs must weigh less that 55lbs and fly at a maximum speed of 100 mph and a maximum altitude of 500ft above ground level.
- UASs must remain in sight of operator, in daylight hours only, and not over a person (cannot fly over people).
- UASs cannot operate near airports.
- Pilots/Operators of UASs would be required to: pass an initial aeronautical knowledge test at an FAA-approved knowledge testing center as well as a recurrent test every 24 months, be vetted by the Transportation Security Administration, obtain an unmanned aircraft operator certificate with small UAS rating, and be at least 17 years old.

There are further rules and regulations released in a 195 page document that can be found on the FAA's website.

Of particular importance are the requirements of operational sight and flight occurrence only during daylight hours. Amazon's proposal involved drones with pre-programmed flights that fly without direct instruction from an operator. If these rules are approved in the coming years, Amazon will have to modify its system to operate within line of sight (a maximum of 3 miles) and use individual operators limited by the requirements stated previously. Also, if drones are only able to fly during daylight hours, Amazon is severely limited in their window for package delivery possibilities, especially during the winter in areas that have little sunlight. Instead of operating their system at 24 hours a day, seven days a week, Amazon would be forced to operate during the approximate 10 hours a day of sunlight. Needless to say, Amazon's Vice President of Global Public Policy, Paul Misener, was not pleased in his public statement to ABC news after the FAA's rules were released. According to Misener, "'The FAA needs to begin and expeditiously complete the formal process to address the needs of our business, and ultimately our customers. We are committed to realizing our vision for Prime Air and are prepared to deploy where we have the regulatory support we need,'" (Newcomb, 2015).

With these latest developments making headlines, many critics of the FAA say that the administration is causing the US to lag behind other countries such as China, Canada, and Australia. These three countries are some of the first to allow the use of commercial drones (Canada has only granted experimental permits). Zookal, a textbook rental company based in Australia, partnered with Flirtey (a startup tech company) to develop a drone system to deliver textbooks starting in March of 2014. The Australian company uses an app to deliver within a 2-kilometer (1.24 mile) radius (Mckenzie, 2013). Zookal hopes to begin solving the problem of delivery logistics, saving time and money, just as Amazon proposes to do in the US. Zookal's chief executive, Matt Sweeney, claims that, as the program is implemented, and with economies of scale, "we expect to see long term reduction of costs in delivery and a strong environmental benefit with the reduction of vans on the roads doing deliveries,'" (USA News, 2014). As of now, there is no information available on whether the company has implemented the drone program or regarding its success.

Zookal isn't the only innovator worldwide. Flirtey is also working with New Zealand to implement Airshare, "a hub for UAV information, which will allow commercial operators to log their flights to ensure maximum safety" (Lim, 2014). All across the world, countries are beginning to experiment and research the possibilities of commercial drone systems. China is working on a drone based postal system and Dominos ran tests in Europe using their "Domicopters" to delivery pizzas to a customer's door (Smith, 2013)

Benefits and Downfalls:

There are many uses of drones that could benefit society. Mentioned above, BP sought approval to use drones to survey oil fields in Alaska. Some realtors have used drones (illegally, as drones are not permitted for commercial use) to capture aerial views of properties. Forestry services want to use drones for mapping and general surveying. A group in Texas has employed the use of drones to search for missing persons (Laing, 2014). All of these services of drones offer benefits to society, saving on costs of piloted flights, and time. However, some people are hesitant to embrace these benefits when made aware of the possible downfalls of this new technology.

Many critics fear abuses such as the paparazzi trying to capture photos/footage of celebrities in private locations. Others fear the drones will spy on them. In October 2014, California banned the use of drones to take celebrities' photographs for fear of privacy violations (Stone, 2015). Like California, some cities have banned drone flights for both privacy and safety reasons. With threats to shoot drones out of the sky, CNN consulted associate MIT professor and drone expert Missy Cummings in "Amazon's Drone Delivery: How Would It Work?" She explains that those people looking to shoot down drones for fun or fear are not the only issue, but that people could want to steal packages in transit. If this is so, she suggests that flights over 300ft should protect the drones.

Amazon is just one of the many companies seeking to explore drone technology and many argue that is it simply too soon. Despite opposing societal discussions, Amazon continues to make arrangements for improving and implementing the technology.

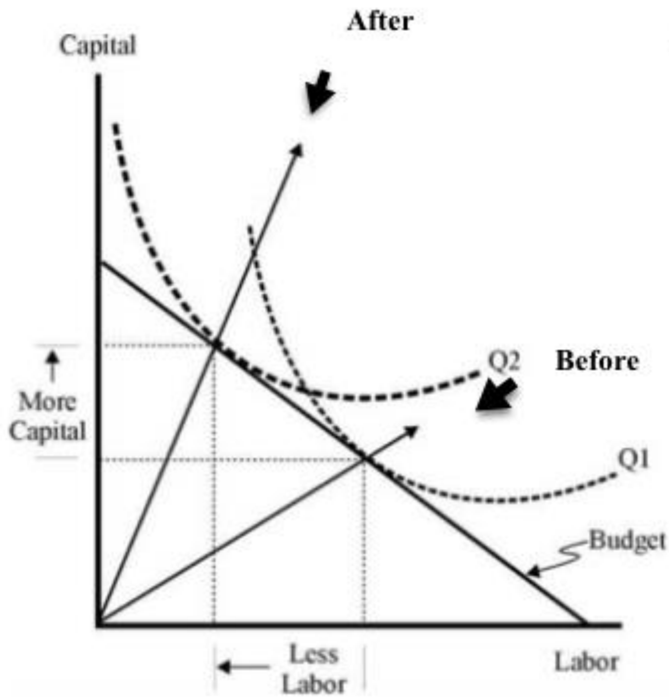
Theory:

Adoption of New Technology:

According to economic theory, a new firm “has an incentive to seek out and use the best available production technique” (Browning, 1983). However, new technology is not always the best production technique. Basic microeconomic theory states that a firm will only adopt a new technology if it is deemed more profitable than the current method (Browning). Therefore, this paper aims to discover whether Amazon’s proposed drone system has the potential to become more profitable by reducing spending on delivery service through changes in technology.

According to Salvatore in his book *Economic Growth and International Trade,* improvements in technology are classified intro three different categories: neutral, labor-saving, and capital-saving. Amazon's drone technology would be considered labor-saving/capital-using technology; thereby, substituting more capital inputs in the place of labor inputs. Meaning, the drones would replace some labor with capital in the production of Amazon's delivery service. See diagram.

Labor-Saving Innovation



As seen in the graph above, Amazon would switch from isoquant Q1 to isoquant Q2, using more capital and less labor in production. As a result, the ratio of capital to labor is higher than before. Amazon will use this shift from labor to capital to increase drone production and thereby create a new delivery product line. Increasing the budget and thus raising the budget line would lead to a higher isoquant.

It is important to note that Amazon will set up this system only in areas where the system would be efficient and profitable. Drones in rural areas with lower populations per square mile would be much less profitable that in urban areas with higher population densities per square mile. For example, the drone system would be more costly and less profitable in Estill Springs, TN, which has a population of 2,000 and an average population density of 430 people per square mile, compared with Chattanooga, TN which has a population of 171,279 and an average population density of 1,267 people per square mile (City-Data.com). This means that Chattanooga has three times as many people per square mile and a population more than 85 times larger than Estill Springs. Thus, Amazon can potentially deliver many more packages to a larger population of customers in a fixed amount of time in Chattanooga than it ever could in Estill Springs. Based on this example, Amazon will have to weigh the costs of setting up and operating the drone system based on population, population density, and the number of customers and potential frequency of use in the area.

First-mover:

If Amazon succeeds in its venture to apply the use of drones to deliver their products, then the company will be the first in the US to enter the commercial delivery drone market. In the business world, Amazon would be defined as a first-mover. A first-mover is the first firm in a market to introduce a new product, service, or system. As the first firm in the market to make this move, the firm experiences a theoretical first-mover advantage. Lieberman and Montgomery explain how a firm gains first-mover advantage in their article, “First-mover Advantages.” They state that the advantage occurs from three possible sources: technological leadership, preemption of assets, and buyer switching costs (Lieberman, 1988).

With their innovation and use of drone technology, Amazon could achieve a first-mover advantage through technological leadership. According to Lieberman and Montgomery this can be accomplished through successful patenting or research and development (R&D) races. “When technological advantage is largely a function of R&D expenditures, pioneers can gain advantage if patented or maintained as trade secrets,” (Lieberman, 1988). This means that Amazon must be looking to patent their drone technology/system or keep the logistics secret. It is important to note, that according to Lieberman, first-mover advantage does not apply to every firm and is “firm specific.” Lieberman was also quoted as saying, “firms like Amazon and Yahoo that have patents, tend to be more successful as measured by market value,” (Rehder, 2005).

One would assume that Amazon will seek a patent for its drone system to curb their competitors’ ability to construct copy-cat drones and thereby profit off of Amazon’s hard earned R&D success. But, as stated earlier, in order to maximize their advantage, Amazon must rely on secretiveness as well as patents to gain the best possible advantage. So far, Amazon has released few details on how the company plans to implement and operate their proposed system. When asked for comments or details, Amazon declined to give further information or details about their drones, systems, or programs.

Lieberman explains further that R&D is not limited to simply technological innovations but could apply to improving managerial systems. Technology development provides experience that facilitates continued R&D in some areas, keeping the company ahead of competitors. By implementing a drone delivery service, Amazon would be making both a competitive and radical change to its current business model.

First-movers also experience the marketing advantage of recognition. The firm often becomes distinguishable as “the original” and thereby “better” than other firms that may enter the market at a later date. This novelty fades overtime, giving way to more widespread competition (Barnett, 2014). Amazon will most likely be the first firm to ever offer home drone delivery, a technology that one assumes, if adaptable, could diffuse into other areas of the economy, not just the transportation market. But for the first few years, Amazon will experience an advantage in being the first firm to ever offer such an innovative technology. One could imagine that a customer might buy an Amazon product for the sole purpose of watching the drone deliver it to their doorstep.

Location Theory:

The location of a firm is determined by the principle of median location. According to this principle, “the optimum location for a firm with several inputs and outputs is the median transport location, the location that splits the total monetary weight of the firm into two equal halves. At the median transport locations, half of the monetary weight comes from one direction and half the monetary weight comes from the other direction," (O'Sullivan, 2007). Currently, Amazon has plants nation-wide that serve multiple states. One example of such a plant is the Amazon plant in Chattanooga, TN, which serves the surrounding Tennessee, Georgia, and Alabama areas. The fulfilment center serves as a median location where the cost of getting packages to the fulfillment center is equal to the cost of getting packages from the fulfillment to consumers. In this way, the total monetary weight is split into half each way. This is why Amazon has chosen to locate their fulfillment center on the outskirts of a city.

The same principle will apply when Amazon chooses where to place their drone stations around the city. Each location will have to be chosen, keeping in mind the cost of both transporting the goods to the station and transporting the goods to customers. Ideally, the cost would be split halfway.

Model:

Technology:

In order to discuss the various cost components of the project, Amazon's large scale drone operation must be broken down into smaller segments. To do this, I propose to model Amazon's drone system in a single city. In this way, it is possible to analyze the individual operational costs per city. However this also identifies many of the factors that vary among cities. Since there are many aspects and logistics of Amazon's drone delivery system that are still being withheld, we must infer and sometimes guess the most logical decision Amazon would make in order to complete the model and produce results for analysis. For instance, we do not know precisely how much each drone costs, how long their batteries last or logistically how the drones will land, etc.

In Amazon's letter to the FAA, the company released a few details about their 8th and 9th generation drones that we will use in this model. The drones will weigh less than 55 pounds, fly at speeds of up to 50 miles per hour, and carry packages of 5 pounds or less. The drones will carry packages within a ten mile radius of a drone station. While traveling at 50 miles per hour, a drone can reach a customer in 12 minutes or less:

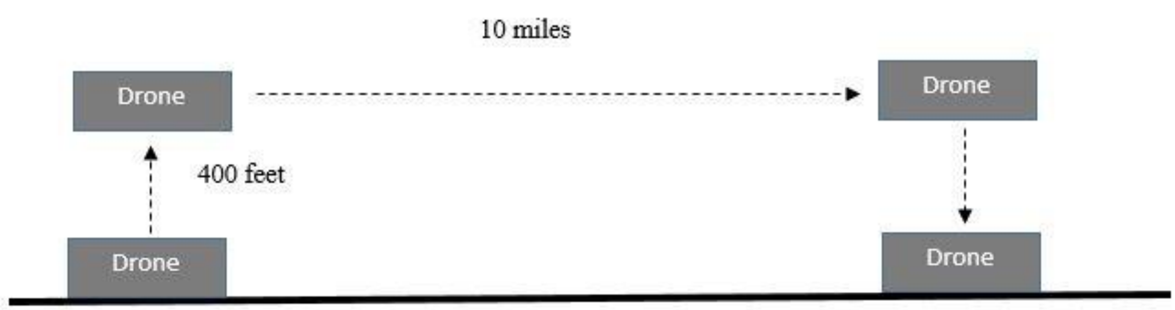
$$\frac{50\text{ miles}}{1\text{ hour}} = \frac{50\text{ miles}}{60\text{ minutes}} = \frac{1\text{ mile}}{1.2\text{ minutes}} = \frac{10\text{ miles}}{12\text{ minutes}}$$

Thus, a drone can fly to and from a customer's location 10 miles away in 24 minutes. However, extra time of an estimated 6 minutes must be allowed for flight acceleration, deceleration, loading of packages, and unloading of packages, as well as flight ascent and descent. For the basis of our model then, we will assume the drone can deliver a package to a customer and return to the drone station within 30 minutes or less (24 minutes of flight time + 6 minutes of extra time). Now, with an established range of 0-30 minutes for a drone flight, we will assume an average of 18 minutes for a complete drone flight.

[If flight time is 0-12 minutes, the average would be a 6 minute flight to a location and a 6 minute flight back (totaling 12 minutes average flight time), + 6 minutes extra time = total average trip time of 18 minutes]

The drones will be pre-programmed for flights, giving them the capability to fly to a customer's household and back without any need for human flight control. This means that there will be no human operator controlling the drone, but rather a series of computer codes transmitted from the drone station to the drone, directing it to its exact landing location. This is why the drones are commonly referred to as small unmanned aircraft systems or "sUAS". The sUAS are equipped with additional programming such as anti-collision technology which prevents the drones from flying into anything that might obstruct their flight path. In other words, there should be no issues stemming from drones crashing into each other or someone's cat, for example. The drones are also programmed with other basic safety protocols. For instance, if communication is lost between the drone station and the drone, the drones are programed to return to a secure location (Amazon.com). Despite such high levels of programming, human labor will still be needed for monitoring drone flights as well as performing drone maintenance. Employees can be trained to monitor multiple drone flights at once, thus reducing the amount of labor needed to operate this delivery system.

Amazon petitioned the FAA to run test flights at heights up to 400 feet (approximately the height of a 40 story building). Drone expert, Missy Cummings, estimates that the drones will have to fly at 300 feet or higher to prevent humans from interfering with drone flights. For the model, we will estimate flights will occur at 350-400 feet above the ground. Please reference the graphic below.



A drone will first ascend vertically to an altitude of 400 feet. Then the drone will fly in a straight line without changing altitude on a set path. Once it has reached the appropriate coordinates, the drone will descend. When it touches the ground, the drone will release its package. After delivery, the drone will once again ascend vertically to 400ft and make a direct flight back to the drone station. With this flight path, we assume that drones will make deliveries to one customer at a time, dropping off a package before returning to the drone station for its next delivery.

There are also many extraneous factors to consider, and I hope to mention many; but in all practicality, these cannot be formulated into the model. For instance, poor weather conditions such as snow, rain, and sleet, may very well have an effect on the system's efficiency, causing flight delays and longer delivery times. Drone expert Missy Cummings theorizes that the drones will be equipped to fly in light rain or snow, but nothing heavy because the precipitation would obscure the sensors (Gross, 2013). From this argument, one could argue that if precipitation is too heavy for drone flights, it would be too heavy for safe ground delivery as well. Either way, weather may delay flights for an hour or so on days with heavy precipitation. But for the sake of analysis, we will assume fair weather for all drone flights.

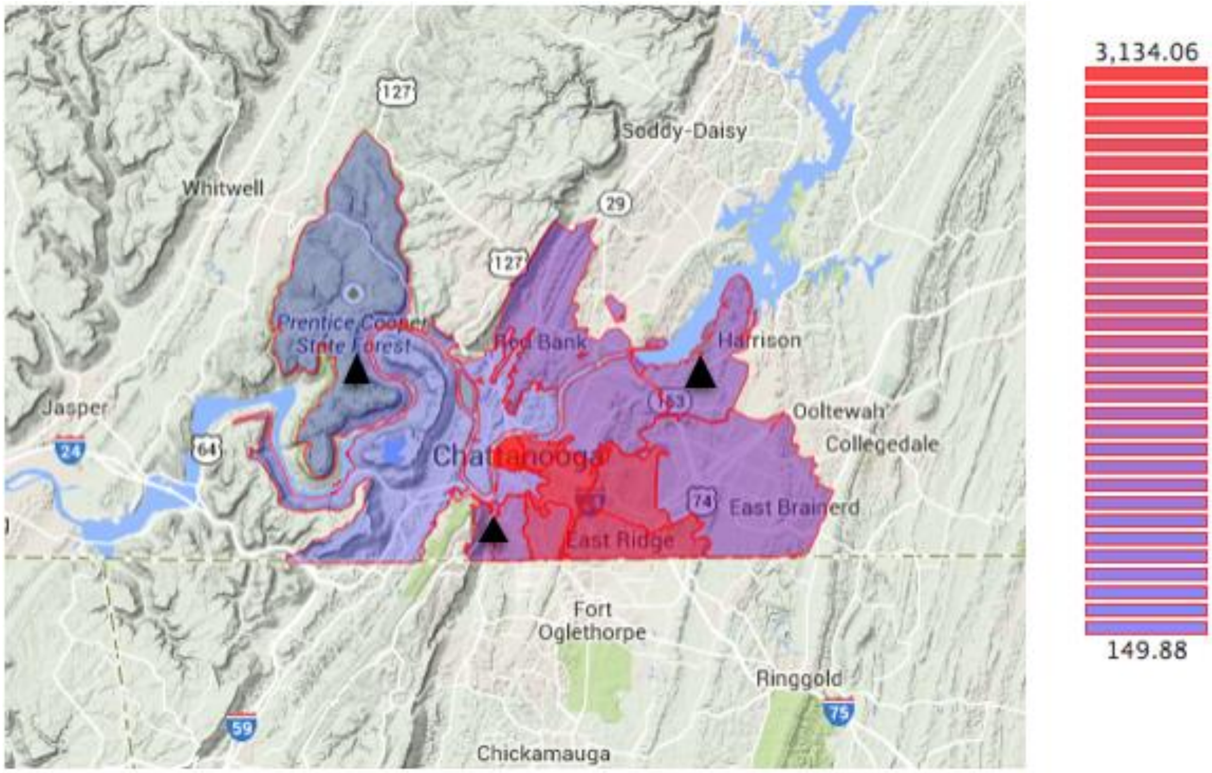
Another argument to be made is that the drones will increase operational hours of delivery by a substantial enough amount to more than make up for potential delays due to weather. FedEx and UPS deliveries begin at 8am in the morning and end at 7pm at night. Therefore, packages can only be delivered 11 out of 24 hours in a day. With proper legislation in place, Amazon could increase their potential delivery capacity by more than 100% just by offering drone delivery

24 hours a day. Also, in most areas of the country, packages are only delivered Monday through Saturday. Not offering delivery service on Sundays reduces that amount of delivery days available by 52 days a year. Amazon drone delivery could operate all 7 days of the week. The drones also have the ability to fly on a direct path, avoiding normal road delays such as construction, detours, accidents, traffic, etc.

Demographics:

Since there already exists an Amazon distribution center and thus, a supply chain management system in Chattanooga, this city would be an optimal choice for a potential test site. Chattanooga is the fourth largest city in Tennessee. The city's population exceeds 171,000 with over 470,000 living in the Chattanooga Metropolitan Statistical Area (CEC-ICMC 2007). The altitude of the greater Chattanooga area ranges from 1,800 feet in the valley where the downtown area sits to 2,300 feet up on Signal Mountain. Parts of the city, like East Ridge, spill over into Georgia.

A map of the population density of Chattanooga by zip code



#	Zip Code	Location	City	Population	People / Sq. Mile
1.	37402	35.046090, -85.314720	Chattanooga, Tennessee	4,302	3,134.06
2.	37404	35.029159, -85.274304	Chattanooga, Tennessee	13,721	2,700.84
3.	37403	35.046837, -85.295350	Chattanooga, Tennessee	3,846	2,630.45
4.	37412	34.997030, -85.228921	Chattanooga, Tennessee	20,574	2,453.75
5.	37411	35.025867, -85.230184	Chattanooga, Tennessee	17,778	2,410.48
6.	37407	35.001943, -85.289724	Chattanooga, Tennessee	7,949	2,287.17
7.	37410	35.001899, -85.314220	Chattanooga, Tennessee	4,822	1,492.24
8.	37409	35.000173, -85.334570	Chattanooga, Tennessee	2,719	1,263.23
9.	37421	35.031635, -85.147624	Chattanooga, Tennessee	40,827	1,248.61
10.	37406	35.075375, -85.242970	Chattanooga, Tennessee	14,717	1,187.44
11.	37416	35.099412, -85.173466	Chattanooga, Tennessee	14,620	1,160.57
12.	37415	35.127353, -85.282509	Chattanooga, Tennessee	23,112	1,135.73
13.	37408	35.029019, -85.310872	Chattanooga, Tennessee	1,935	909.50
14.	37405	35.124186, -85.405866	Chattanooga, Tennessee	13,229	236.15
15.	37419	35.031519, -85.392888	Chattanooga, Tennessee	5,498	149.88

(Map and data from zipatlas.com)

As the data shows, the population density of Chattanooga ranges from 149.88 people per square mile up to 3,134.06 people per square mile with Downtown and East Ridge being the most densely populated areas.

The Chattanooga area is divided into many different regions and edge cities; Downtown, East Ridge, Hamilton Place, Lookout Mountain, Signal Mountain, Hixson, Red Bank, etc. In order to cover the largest possible area with its current drone model, Amazon will need three drone stations. By the location theory mentioned earlier, these stations will serve as drone headquarters, where drones fly to and from, delivering packages. Since the Amazon distribution center is located near Hamilton Place, it would be logical to establish one drone center there. Another drone center would need to be located near Lookout Mountain and the third near Red Bank. These three stations would cover all Chattanooga citizens living inside city limits as well as many others living in the greater Chattanooga area. Looking at the map shown previously, the three triangles indicate the areas where the proposed drone stations would be located in the model.

Chattanooga includes a variety of geographical and political issues that might be encountered. Though city limits are technically located in Tennessee, Chattanooga spills over into Georgia. If Amazon wants to implement a drone system in Chattanooga, the company will have to seek legal permission from both Tennessee and Georgia to effectively reach the entire population of the greater Chattanooga area. This demonstrates the model's ability to address cross-state border issues within the Chattanooga metropolitan area.

According to the National Weather Service, Chattanooga experiences rainfall an average of 120 days out of the year. Of these days, Chattanooga's main forms of precipitation occur as light rain, moderate rain, and thunderstorms. The likelihood of a thunderstorm or moderate rain occurring on a day with precipitation is 61% according to WeatherSpark.com. Since drones might have trouble operating in moderate rain or thunderstorms, the drones might experience some flight delays 73 days out of the year. This means that that the drones could potentially operate at 100% capacity on 292 days of sunshine or light rain in Chattanooga each year.

One might wonder how many packages would need to be delivered per day to make the system cost effective. On its peak day in 2012, November 26th, Amazon centers worldwide shipped over 15.6 million packages, selling a record breaking 306 items per minute (Cheredar, 2012). Granted, this includes international transactions. If we assume that just 1/4 of those packages were shipped in the US (population 318.9 million), then more than 3.9 million of the packages shipped worldwide on November 26th were shipped in the US. When dividing 3.9 million by the population of the US (318.9 million) we get an average of 0.0122295 Amazon packages per person shipped in the US. If this average is applied to the population of the greater Chattanooga area (470,000), then, within Chattanooga, approximately 5,748 packages were shipped that day alone. Even though this is a record high and not a daily average, this number of packages demonstrates the potential for a drone system in Chattanooga and other metropolitan areas across the country.

Operation:

With over 4,900 (5,748 x 86%, only 86% of packages are eligible for drone delivery) packages to be potentially delivered by drone across Chattanooga on the busiest day of the year, an Amazon UAVs must be able to operate multiple drones at once. Thus on their busiest day of the year, the number of package deliveries by drone would average out to 204 packages delivered in Chattanooga every hour. If you divide this number by 3.3 trips per hour, we find that 62 drones would be needed every hour to complete an average of 204 deliveries per hour. When splitting this number among all three drone stations, we find that each drone station needs at least 21 drones in operation to fulfill these delivery requirements. Remember, this is considering drone delivery on the busiest day of the year. Let us conduct an everyday analysis.

If we assume that the drones can fly continuously for a maximum 10 hour period, then drones will be able to rotate in shifts. The drone station can run 3 8-hour shifts of drones around the clock for fast, reliable delivery. With an average time of 18 minutes per trip (or 3.33 trips per hour), each drone can make an average of 26 deliveries per shift. If each shift used 10 drones continuously, then the drone stations could make an average of 32.5 deliveries an hour. Obviously, on some days and some peak hours, this will not be enough to deliver in 30 minutes or less. Therefore, to avoid risk of running short on drones, the station would need to have reserve drones (estimated 10) to be used during peak hours and for backup if some drones are out of commission for needed repairs. Another 10 drones would need to be charging for the night shift while different drones are running during the daytime hours. Another 5 or so drones will be needed as back-up drones in case an operating drone malfunctions or needs maintenance. A potential strategy to help increase delivery speed during peak hours would be to have more drones on the day shift when packages are ordered more frequently and fewer drones on the night shift when packages are less likely to be ordered. Either way, Amazon will have to increase and decrease the number of operational drones depending on the time of day and number of orders needing fulfillment.

Upon this analysis, one can assume that Amazon could operate as many as 20-25 drones at a time per station if peak hours required it, facilitating the need for at least 35 drones in each station. Thus everyday requirements should be enough to handle most busy days of the year. This could be a potential cause for many different problems. As Kharchenko and Prusov discussed, as the number of drones in the sky increases, the competition for unique frequencies will also increase. Concerned citizens might worry about the potential noise pollution multiple drones could cause. Many wonder about the potential need for increased air traffic control, granting different drones different types of altitude permits. The FAA is still far from granting the type of access to drone use that could cause such problems, but the issues could arise in the near future as companies are eager to jump into the drone market.

A few theories already exist about how a drone will know exactly where to land. The idea of having “helipads” for the drones to land and drop their package has been put forth. Other ideas such as an app, with GPS locating ability could call the drone to the person’s phone. Either way, Amazon must somehow find a way to program specific coordinates that are deemed “safe landing spots”. One idea Missy Cummings offered in her interview with CNN, was the idea of “drop spots,” or safe locations distributed throughout the city where the drones will land, drop off the package, and resume flight (Gross). A person could then approach and pick up their package from this specific location rather than at their front door. However, for the model, we will assume that, since the original promotion detailed delivery directly to their customer’s doorstep, Amazon will create a system that accomplishes just that.

With this assumption, however, comes legal questions of where Amazon drones could land in public spaces. Would they need permits to public grounds? Rooftops of buildings? Etc. All of these questions will need to be addressed both by Amazon and the FAA. Rights to public airspace and landing sites will cause issues in the future as more and more companies invest in the drone market.

Costs:

When deciding whether the drone system will be a cost-effective form of technological development for Amazon, one must consider all costs required for implementing and running a drone delivery system. One of the first and most costly expenses associated with the system will be the initial capital investment in the drones. For the Chattanooga model, with 35 drones at each station, Amazon would need to invest in at least 105 drones at the start of the program. As drone delivery becomes more popular and logistical issues are examined, Amazon may have to invest in more drones for the Chattanooga area; but for now we will assume at total of 105 drones. Drones can range in cost from a few hundred dollars to millions of dollars. We will assume that Amazon's drones cost between $3,000 to $5,000 dollars each. With an average of $4,000 multiplied by the required 105 drones, the total capital investment is predicted to be around $420,000.

In an article posted on his blog, John Swope conducted his own analysis of how much it would cost a drone to deliver a package versus a UPS driver. He assumed that a UPS driver makes around $25 an hour delivering packages, 10 hours a day. After factoring gas and tolls, the cost of a driver comes to around $30 an hour. Swope also found that, according to a UPS driver forum, drivers delivered up to 250 packages per day. To calculate the average cost per package, his formula was simply:

$$\frac{\text{Cost of driver}}{\text{\# of packages delivered}}$$

With this calculation, Swope found the cost of package delivery by a human to be $1.20 an hour.

$$\frac{\frac{\$30}{\text{hour}} \text{ x } \frac{10 \text{ hours}}{\text{day}}}{\frac{250 \text{ packages}}{\text{day}}} = \frac{\$1.20}{\text{package}}$$

Keep in mind that this is only the cost of the UPS driver delivering packages. This does not include Amazon's cost of getting the packages to the UPS center or any other contractual costs associated with UPS delivery.

When calculating the cost of drone delivery, Swope estimated that a drone costs around $3,000 and has a lifespan of 5 years. When considering maintenance and other costs, he figured that average cost of the drone was $4,000 over its lifespan. Though he assumed the drones made 2 deliveries per hour, we calculated that the drones could make an average of 3.3 trips per hour. Using this information we can get the following calculation:

$$\frac{3.3 \text{ trips}}{\text{hour}} \text{ x } \frac{14 \text{ hours}}{\text{day}} \text{ x } \frac{7 \text{ days}}{\text{week}} \text{ x } \frac{52 \text{ weeks}}{\text{year}} \text{ x } 5 \text{ years} = 84{,}084 \text{ trips}$$

Looking at this calculation, it assumes that drones will make deliveries 14 hours a day (24 hours – 10 hours for charging), making the total number of packages delivered by a drone 84,084 over 5 years. If drones are going make deliveries for, say, 10 hours a day like UPS drivers, the number of deliveries would be:

$$\frac{3.3 \text{ trips}}{\text{hour}} \text{ x } \frac{10 \text{ hours}}{\text{day}} \text{ x } \frac{7 \text{ days}}{\text{week}} \text{ x } \frac{52 \text{ weeks}}{\text{year}} \text{ x } 5 \text{ years} = 60{,}060 \text{ trips}$$

This still gives a total of 60,060 deliveries over 5 years. This means, that operating 14 hours a day, Chattanooga, with 105 drones could potentially conduct 8,828,820 flights over the course of 5 years. With 10 hours of operation, the Chattanooga drones could make 6,306,300 trips in 5 years. Looking at the cost calculation shown below, either way, drone delivery is cheaper than UPS delivery.

If drones operate 14 hours a day:

$$\frac{\$4{,}000}{84{,}084\text{ trips}} = \frac{\$0.05}{\text{trip}}$$

If drones operate 10 hours a day:

$$\frac{\$4{,}000}{60{,}060\text{ trips}} = \frac{\$0.07}{\text{trip}}$$

As seen above, whether drones operate 14 hours a day at $0.05 per trip or 10 hours a day at $0.07 per trip, the drone is clearly more cost effective than UPS delivery, $1.20/package, when just considering drone capital input. The cost of the drone is spread among the number of deliveries over the span of 5 years. Therefore, the costs of 105 drones is spread over millions of packages delivered over the lifespan of the drones. Additionally, as the drone market expands, the cost of drones will decrease in the future, making the cost per trip decline over time. However, there are more costs to running drone delivery stations than the capital costs of the drones.

Despite the fact that Amazon will have invested millions of dollars into research and development as well as lobbying the FAA, this paper will only analyze those costs involved in set up and operation of the drone system. Some of these costs may include:

- The drones themselves
- Buildings and land associated with the drone stations
- Computers and monitoring software systems for drone flights
- Computer technicians and drone monitors on site
- Robotics Engineers for maintenance and upgrades to drones on site
- Utility costs of running the building
- Logistics management team to oversee operations
- Potential insurance and legal fees associated with drones
- Potential air and/or frequency rights for drones, etc.

There is also the potential for legal costs in some of the following situations: drones are found in unauthorized airspace, drones are shot down by civilians (however unlikely), a drone lands in an unauthorized space (perhaps on someone's cat), etc. The potential legal ramifications for being the first company to implement the use of commercial drones is immeasurable. Though there are extra costs associated with operating drones versus handing packages over to UPS, the potential extra revenue might entice more companies to join Amazon in their endeavors.

Revenues:

How Amazon expects to account for the revenue needed to support this operation is a mystery, but educated guesses can be made. Amazon already has an optional membership club called Amazon Prime. With this entry fee of $99 per year ($49 for students after the first 6 months free) Amazon Prime membership includes free two-day shipping on all Prime eligible items, access to Prime Instant Video, unlimited photo library storage, Prime Music, and the Kindle Owners' Lending Library. If customers shop right, they may never have to pay extra shipping costs with their Prime Membership. Customers also have another option; buying over $35 worth of Amazon's items earns them free shipping on their entire order. This is a very economical choice for customers who do not want to pay for the Prime Membership but still want free shipping. The last option is where customers choose to pay the standard shipping rates, anywhere from $5.99-24.99, instead of a membership fee. In this last method alone, Amazon assumes no cost burden for shipping its products. However, with the $35 bargain and Prime Membership, Amazon takes on some of the shipping cost and diffuses it with either extra profit off extra items ordered or through the Prime Membership fee. This demonstrates that Amazon is already taking on the shipping costs of its customers presently. The drone system could alleviate some of this cost burden by generating its own revenue. With a cheaper delivery method available, Amazon has the potential to save on operational expenses with the new drone system.

To generate the extra revenue to fund drone delivery, Amazon could simply increase their Prime Membership fee or offer an additional Prime Air Membership to current Prime members for the air-delivery service. Amazon could also make a separate Prime Air Membership for customers who are not already Prime members. Another option would be to charge a nominal fee per drone delivery or even per item delivered by drone. With this last method, Amazon would be sure to cover costs of drone delivery with less assumed risk than a membership fee. How to determine this fee is another question.

Benefits:

Besides monetary gains, Amazon stands to gain other benefits if its venture is successful. As stated in the theory previously, Amazon would essentially be the first mover in the e-commerce world. With the economic benefits of being the first to innovate comes the prestige and impression that follows. Amazon would always be recognized as the first online retailer to use drone delivery. As such, Amazon would gain the trust of their customers through originality. This gives Amazon recognition and status in the drone delivery market. There are other factors that could contribute to Amazon's future domination of the drone delivery market.

The idea itself is a novelty. Many persons within range of drone delivery are likely to be excited by the very idea of receiving a package delivered by drone, to the point that they might choose to order an item from Amazon instead of a retail store for the sole purpose of seeing a drone land in their backyard. Through this innovative system, Amazon will not only deliver a product, but a novel service to its customers.

Another advantage Amazon will develop is faster speeds of delivery. The time required for a drone delivery (less than 30 minutes) could potentially be faster than driving to a physical retailer. Currently, customers are faced with a decision between driving to a physical retail store and buying the product or waiting for a product to be delivered to their door in a 2-5 of days for a lower cost. This choice forces a customer to choose between time and money. With drone delivery, a customer no longer sacrifices time by ordering a lower cost product over the internet. Amazon will have a considerable advantage over not only online retailers, but physical retailers as well.

Amazon will also be able to advertise green practices with their drone system in place. The drones will run on batteries, presumably cutting down on fuel costs and air pollution normally associated with postal delivery. The battery powered drones are arguably more environmentally friendly and a more sustainable choice even considering the increase in electricity consumption. Many environmentally conscious customers may choose to have goods delivered by drones rather than drive a fossil fuel-consuming vehicle to the store.

In short, Amazon could make a name for itself through implementing drone delivery that will not only bring in revenue, but lead to a larger number of customers and higher customer satisfaction due to faster delivery.

Conclusion:

Amazon has much to gain if their drone project becomes operational in the near future. Though current FAA regulations do not allow commercial drone use and the proposed new rules are not very cooperative, the possibility that Amazon will be able to implement their system in a reasonable amount of time remains high. With Amazon's current business model and customer base, the company could gain a strong competitive advantage over both online and physical retailers. The quick delivery and novelty of drone delivery will bring more business to the e-commerce giant. The benefits and potential revenues of the drone delivery far outweigh the operational and start-up costs of the system as whole. The logistics of the drone delivery system are still a mystery to those outside of the inner workings of corporate Seattle, WA, but the assumptions in this paper were all made using knowledge available to the public. Naturally, as information is released and regulations updated, the specifics and logistics of this paper are likely to change. For now, these predictions tell us that Amazon should seriously consider this venture, leaving many consumers with much to consider about the future use of commercial drones.

In conclusion, this paper is the first of its kind, analyzing the potential for commercial drone delivery systems in today's marketplace. This analysis supports the implementation of commercial drone delivery systems in transportation markets and especially the e-commerce segment. As more information is released, this analysis can take a more complete form and be further developed. For now, the drones are coming.

Appendix:

After the completion of this paper, announcements were made and I felt a subsequent update needed to be provided. In late March, the FAA finally approved Amazon's application for exemption. However, Amazon is displeased in the lateness of the FAA's reply. The company claims that the FAA is moving too slow for American businesses to innovate. In a Senate Subcommittee on Aviation meeting, Paul Misener claimed that the drone model the FAA approved for testing is now obsolete. Amazon has already moved past their model 9 octocopters and developed new and better models. The FAA approval came almost one and a half years after Amazon's announcement of the project in December 2013. Misener explained that, "Nowhere outside of the United States have we been required to wait more than one or two months to begin testing" (Mac, 2015). One might wonder if the FAA is stalling Amazon's development of the Prime Air program in an effort to prevent innovation before prohibitive legislation is put into place. Nevertheless, Amazon will have to continue to fight the FAA for testing permission and deal with the significant time lag caused by the administration if the company is to succeed in its venture.

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