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Drones in Logistics: A Feasible Future or a waste of effort.

Andrew Lotz

Honors Project

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I. Abstract

On December 1st, 2013 news around the world was filled with headlines about E-Commerce website Amazon.com. CEO of Amazon Jeff Bezos announced to the world that Amazon was designing a drone delivery program called Amazon Air that could deliver packages to customers in just 30 minutes. Consumers were all too excited for the program to launch while many business and air traffic savvy people were highly skeptical. Now two years later research to look back at the feasibility of drone flight and whether investment into the technology is worth it for small deliveries straight to customers is needed to track the progress of drone technology.

Current research on using drones for delivery tools lacks a complete and well thought out perspective on drones. A majority of articles argue heavily against the idea or for the idea. For example, the article “FAA's Proposed Rules Would Cripple Domestic Drone Industry” (*Lomberg, J. (February 17, 2015).*), is solely blaming the FAA for problems with drone technology and makes the assumption from the start of the article that commercial drones are both feasible and profitable. On the flip side of this, articles like “Who Controls the Drones?” (*Harrington, A. (2015)*) tend to take a more negative view on drones stating that Amazon and Google are just using talk of drone delivery for press. Neither side of the argument of whether drones are a feasible tool for delivery seems to be well informed on all of the facts and research on drones either. When researching drones, it is incredibly hard to find articles on drones that is unbiased and contains a completed argument. Each article seems to only focus on one aspect of the drones such as cost, technological limitations or FAA regulations. Using drones as a delivery

service is a complex task that requires a large amount of planning in a multitude of areas and focusing on only one of these areas is simply not an effective way to evaluate their feasibility. The strangest omission from all of the articles to be whether consumers really want drones to be used commercially. Drones would cause Americans to lose even more privacy due to on board cameras and the data that they would collect. This could lead to major backlash against drones and the services they provide. Failing to account for what the consumers want could lead companies investing drones to be wasting their money.

With these shortfalls of research on drones present in almost all publications, this research's purpose is to present the facts on drones in a non-bias manner and weight the benefits and the risk of drones to try and come up with a clear answer to whether or not drones are feasible, cost-effective, and demanded by consumers in the delivery industry. In addition to this main goal, the research has a secondary goal of providing any innovations which could make drones more feasible, cost-effective or demanded by customers in the delivery industry. These innovations presented must be both feasible to be launch within the next ten year as new technologies beyond that could be unpredictable in what they can do. For example, no one in the early 2000s would have predicted that we now have a smart watch that cans text and make calls. Drones are an important topic particularly in retail and e-commerce because if they can be done for the right cost, the right amount of effort, and consumers choose to use them, drones could be a game changer in logistics. In order to determine whether the technology is worth the cost and the legal hurdles this research will focus on four areas of drones that are considered to be the most important to answering the question of whether drones are a feasible delivery system or not. Those six areas are legal, finance, light limitations, and fulfillment of customer satisfaction.

These four areas were chosen to be the focus of this research due to be of high importance to the future of the commercial drone industry. Legality remains to be one of the biggest hurdles to drone technology. The FAA has ruled out the use of commercial drones completely and testing is very limited. That said, the FAA themselves have said that they want to try and have commercial drones be able to fly safely and legally as soon as fall 2015 (“Busting Myths about the FAA and Unmanned Aircraft.” (March, 7 2014)). Finances are obviously a huge concern for companies when it comes to a drone. If each flight were to cost a consumer \$30 the majority of users aren’t going to use the service often if they even do at all especially if they can get other shipping options for a much cheaper rate. This means that companies have to find a way to make drones cheaply and efficiently while still meeting FAA standards as well as their own. Flight limitations are really important to understanding if we can effectively use them since it gives industries an understanding of what the potential of these drones deliveries are. The discussion of flight limitations will also cover liability issues that arise from flight errors as well as look at the durability of drones. It will also cover Sense and avoid Technology. Sense and avoid technology is probably the second biggest hurdle to overcome when it comes drones. Sense and avoid technology is programming within a drone to scan its surrounding and assess whether it needs to change course to avoid objects in the sky. Currently someone must pilot a drone with their eyes or watch it through a camera to control it. This is not a feasible model since it requires too much reliance on human monitoring and leaves too much room for error. Instead, what needs to be done is that drones must have sense and avoid technology to prevent them from running into foreign objects and birds. This will be the most important and the most in-depth piece of the paper because this section is the most important piece to the puzzle of understanding whether drones are feasible or not.

There are two major limitations to this research which is that there is no inside information in this research. Sources for the research are all public documents and that makes it little harder to write about since the information out there isn't the whole story. Particularly, information when it comes to finance information on building commercial drones is extremely scarce and vague. The other issue in the research have come across is that there is not a large amount of content out there when it comes to drones being used as a delivery service since the idea was not popular up until two years ago.

II. Introduction

Imagine ordering a package online and it arriving just 30 minutes after you order. While this may sound as if it's impossible, companies such as Amazon.com and Google believe that they can accomplish this feat with the use of drones (McNeal, G. (November 7, 2014)). Drones are remotely controlled aircraft and until the idea to use them for deliveries was made popular by Amazon.com, they were mostly associated with the military. Now two years on from Amazon's announcing their plan to launch a drone based delivery systems and fast approaching the end of the 2015 goal date for initial runs of the program, Amazon is still struggling to get any further in the process of the first launch of program This has brought doubt in the program into to an all-time high and raises the question of if and when this program will be launched (Keeney, T. (April 17, 2015)).

To answer this question this research will take a look at four key areas; legal, finance, flight limitations, and fulfillment of customer satisfaction, in order to reach a conclusion on to investigate whether or not drones are in fact the delivery system of the future. Before looking into these areas, however, it is important to first take a look at E- Commerce, advances in delivery and reaction to logistics drones, and a short history on drones is in order.

Since the dawn of the E-Commerce, online retailers have had two major advances over big box stores; they are convenient and they allow for bargain shopping. A shopper could go on Amazon.com order a product in a matter of minutes just by entering a password. Bargain shopping is an especially useful tool that E-commerce promotes the use of. Consumers can compare the prices for a product at hundreds of online stores. Alternatively smart phone apps also allow for customers to scan the bar code of products to see if they can find a better deal online.

To better their shopping experience even further, online stores allow products to be reviewed on their website. This allows customers to no longer have to trust the name brands they know and but trust other consumers. Not only is this a huge advantage for customers as these reviews can lead to cheaper products and a better guarantee of customers' satisfaction, it also helps businesses to break through new markets by word of mouth and better quality products. It allows for small businesses, through outlets such as Etsy, to thrive and grow without ever having to build or go through a physical store. Using the Internet to sell goods gives businesses the ability to reach a larger consumer base as well.

However, E-commerce is not without its faults though. The single biggest problem with E-Commerce is that it takes longer to receive a package than to go to the store because the product must be shipped from a location to the house. This prevents items with short expiration dates from being delivered through E-Commerce. Furthermore, fresh foods are even harder to sell through the internet as most consumers want to examine products that are fresh particularly fruits for blemishes. Even clothing is tough to sell online because it doesn't allow consumers to try apparel on before they purchase it.

Finding ways to decrease the time it takes customers to receive online orders is key for online stores to becoming even more competitive with large retail stores. Another major issue with having goods delivered is the risk of them getting damaged or lost in transportation. Customers may be wary of buying anything breakable online due to the possibility of damage. These two issues are by far the largest; there are also some smaller issues that plague E-commerce as well.

One of the first successful companies to combat these issues was Apple. Apple is known now for Macs and iPhones but perhaps there must underrated achievement is iTunes itself. iTunes simultaneously turned the music industry's business model upside down and solved the issue with online retail in the music market by creating a legal store to download music on to what was at the time the top-of-the-line music player, the iPod. TV shows and Movies also could be instantly downloaded allowing viewers to an easy way to enjoy all media by purchasing media to be downloaded straight to their devices.

Other companies such as Walmart and Amazon.com followed Apple's lead with their own online music stores. However without their own iPod, they struggled to take the market share away from Apple. Walmart closed its music store in 2011 but Amazon.com continues to run there's and gain market share by employing a different strategy than Apple did with the use of Audible which allows for music lovers to download the album while the physical CD or vinyl is shipped to them and offering better pricing deals by having limited time offers on popular albums (An area that iTunes is extremely lacking in). The biggest key to their success was that unlike music bought on iTunes, music bought on Amazon.com is for the most part universally compatible with all kinds of music players.

Ultimately both Apple and Amazon.com suffered a major lose in market share in both the music and Movies markets due to the popularity of streaming services such as Netflix and Spotify (Guinness, Harry. (January 15, 2015)). Amazon.com more so than Apple has tried to combat this with Amazon Prime. Amazon Prime is a premium customer service built on the idea of solving the online retail launch in 2005. Originally it was simply a flat \$79.00 a year for 2 day shipping then it grew into something much larger. It now allows for free streaming of select TV shows and movies as well as music streaming for older releases. All of these features come back to trying to solve the issues that prevent E-commerce from always being the go-to choice for receiving goods. But CEO Jeff Bezos and Amazon.com don't want to stop there. Bezos is determined to find new creative ways to expand Amazon.com's E-commerce dominance by exploring new and creative ways. In areas near Amazon Warehouses, two hour shipping to locations such as Dallas has been introduced for additional fee. Amazon also ships produce in cities such as Philadelphia and Seattle. Even with these developments, Bezos still is determining how to make the wait time for orders even shorter. This determination leads led to an announcement on 60 Minutes that made national news. Bezos claimed that by 2015 Amazon.com would have 30 minute deliver drone delivery (McNeal, G. (November 7, 2014)).

Reactions to the Amazon's announcement were mixed. Some customers were eagerly awaiting the arrival of the technology. Others were extremely opposed to the idea stating that is was an invasion of piracy privacy to have drones filling everywhere. Other businessmen and women questioned whether or not they were bluffing and if it was truly possible due to technological and legal restraints on such a program (Talbot, David. (December 2, 2013)).

Before diving further into the four key areas for drones to succeed in to become a relative and successful transportation method, it is necessary to first take about how drones are currently

being used both in the military and recreationally. Looking further into drones as they are used right now can help explain how the idea to use them as a delivery service came about. Other benefits of this are to look at design features that both types have that may carry over well into logistics drones. Finally, looking at these other models will provide us with the strengths and weaknesses of using that model as a possible logistics drone model.

The military's history with drones is a surprising long since a drone is technically is anything that is an Unmanned Aerial Vehicle (UAV). By this rule, the first recorded use of a drone is in 1849 when balloons with booms were used to attack the city of Venice (Shaw, Ian (2014)). These balloon drones also would be used in the American Civil War by both sides as deadly weapons (Shaw, Ian (2014)). Throughout the 20th Century, drones became more accurate and more deadly with inventions as the remote control being. However, it wasn't until 1995 that the modern day drones was born. (Shaw, Ian (2014)) General Atomics, a defense contractor based in San Diego, developed a drone call the Gnat which is pictured at the bottom of this paragraph (Bowden, Mark (2013)). Despites the bizarre and unappealing design, the Gnat had technology that not only would make drones a vital military resource but also be a key feature on the proposed logistics drones, the video camera. Now military could see over the hill without having to risk the lives of soldiers and pilots. Conversely, the video camera is one of the most controversial pieces of technology on delivery drones. This is an issue that will be further explored when talking about how to use drones as customer satisfaction tools.



Figure 1: The Gnat. Taken from FAS.org. Retrieved from <http://fas.org/irp/program/collect/gnat-750-hires980014.jpg>

The Gnat was eventually given a new name and a redesign that matched its new deadly purpose, The Predator. The shift from spy units to the United States government's go-to target-hunting devices, was a response to the terrorist attacks on September 11, 2001 (Bowden, Mark (2013)). Predator drones are extremely large with a wingspan of 48.7 ft, length of 27 ft, and clocking in at 2,300 lbs when fully loaded. Predator drones have capabilities unmatched by other drones. Able to carry up to 450 pounds and capable of staying in the air for over 40 hours at speeds of 70kt, the Predator is unmatched by anything in the reactional market and with its high price point, it will stay that way ("Predator RQ-1 / MQ-1 / MQ-9 Reaper UAV, United States of America").

While the military drone market shows the extent that drone technology can reach, the recreational market shows about the extent to which companies such as Amazon are willing to go. Recreational drones range in price from \$400- \$1,200 and are commonly in the octocopter design pictured at the bottom of the paragraph. Assuming that recreational octocopters have similar specifications to Amazon octocopter they will have a range of 10 miles, carry packages

of 5 pounds or less, and a maximum flight time of 30 minutes altogether (Gross, Doug (December 2, 2013)).



Figure 2. The Octocopter. Retrieved from http://i01.i.aliimg.com/wsphoto/v0/2054389565_1/SkyhawkRC-F900-Octocopter-frame-Kit-RTF-Multicopter-aerial-photography-professional-rc-drone-hobby-model-aircraft-VS.jpg

III. Flight Limitations

Drones just like any technology have limitations to what they can do. These limitations restrict how effectively drones can be used for delivery and create risk for using the technology. The first flight limitation in drones is the most nerve wracking for smaller business that cannot expose themselves to high risk. Drones are not extremely durable (Paul, Fredrick (March 23, 2015)). All it takes is one person to decide to start shooting at the drones and you could not only lose the drone but also the packaging (Paul, Fredrick (March 23, 2015)). Worse yet is that drones cannot on their own avoid obstacles so all it takes is for the operator to not being paying close attention to wreck the drone (INSINNA, V. (2014)). Outside interference on the signal

could potentially cause havoc on drone delivery services (Paul, Fredrick (March 23, 2015)). If someone were able to take control of the drone they could intentionally cause it to run into something like a jet turbine or simply cause the drone to drop its package for the hacker to retrieve. The delivery itself poses a major problem as there is no safe way to deliver the package. Releasing the package by a quick tether causes the risk of someone pulling on it damaging the drones. However, this is better than the alternative of landing the drone where someone could grab it or get cut on the blades. In both cases though there is a massive flaw that could potentially turn the public off from using drones. Drones cannot ensure that the right person picks up the package only that is delivered to the right place. This means the larger the population density the more at risk an item is to be stolen. That is assuming that the household can even get drone delivery in their area since drones have an extremely limited range of roughly 10 miles for an octocopter design (Gross, Doug (December 2, 2013)). The weight limits to achieve this range, 5 pounds and under also means that this limits the amount and size of packages that can be delivered (Gross, Doug (December 2, 2013)). While these issues plague drones taking a deeper look into each problem shows that there may in fact at least theoretically be some solutions to most of these problems.

Durability is a big concern with drones. If a company is going to invest in having a fleet of drones they need to be built to last. One of the biggest arguments against drones is that they could be shot down by thieves or people who don't want them near their properties (Paul, Fredrick (March 23, 2015)). Even without people shooting down drones the weather could certainly take out drones. Daniel Johnson of The Telegraph explains the problem the weather poses by saying that,

“If the weather can ground Boeing 747s, which can deploy 43,500 pounds of thrust per engine, then even at their low level of flight, the weather can easily stop an Amazon drone from taking off, or at least blow it off course. It is difficult to imagine Amazon customers being satisfied after having selected the Amazon Prime delivery option, they are told they will have to wait longer than half an hour just because it is a bit windy”
Johnson, Daniel (March 26, 2015).

Worse yet, if the weather got too bad for the drones to flight during a delivery it could cause the drone to crash or even if it just knocked it off course causing it to run out of battery before it could return to the delivery center.

Perhaps the best solution to this problem is to go with drones that are top of the line in durability. For example, the company, Game of Drones, builds a drone called the VF Sumo Quad that was able to flight right through glass and fire as well as fall from 400 feet and be shot with a shotgun with minimum and easily repairable damage (*Game of Drones*). Even with these extremely durable frames the damage is enough that someone or something would have to retrieve the drone leaving a window of opportunity for someone to steal the drone. While drones may be able to get there faster than a person, odds are whatever took down the first drone will take down the retrieval as well. This means as of right now that means that the best solution for damage drones retrieval is to send someone to get it. Even with the damaged drones needing to be retrieved using durable frames it's still a better alternative than the drone being completely destroyed and unusable after a crash. The only potential downside is that using a durable frame is going to cost more than using cheap material and involves very careful customization for delivery as to not make the delivery mechanism a weak spot. However, paying a little extra upfront is nothing in comparison for paying for entirely new drone later.

Another thing that companies can do in order to have to worry less than about the durability of the drones is to have full time drone maintenance and repair positions. The person in this position would be responsible for fixing damaged drones and as well as making sure all drones are performing at top capability. This will keep drones running longer and more effectively. Companies should treat drones just like factories treat their tooling, regular maintenance with a scheduled obsolescence. Obviously, this adds to the cost of using drones but is absolutely vital to having a successful drone program. Especially when failures of drones could cost the company hundreds of dollars, preventive maintenance will always be more cost effective than waiting until something goes wrong..

One final thing that could improve durability is the addition of a black box. A drone black box would need to be a very secure recording that could be traceable by GPS so that investigators could understand why a drone failed. This would be crucial to finding and charging anyone who shot down or stole from a drone. Due to how secure it would need to be the black box will most certainly be a costly addition to drones but is absolutely necessary to prevent companies for paying for malfunctions due to outside inference or a glitch from the manufacture of the drone.

Weather and people aren't the only problem that drones face while flying. Anything that is in the drone's path could cause a wreck and potentially harm another living thing if the operator of the drone can't notice the problem fast enough to avoid it. This could be anything from a balloon, to a tree limb, to a duck. This is why the topic of sense and avoid technology is almost always brought up when talking about when talking about improvements needed before drones can be used for delivery (INSINNA, V. (2014).)

Companies such as Amazon and Walmart would be thrilled if they didn't need operator for their drones and the two biggest hurdles to doing that are government regulations and the lack of sense and avoid technology (INSINNA, V. (2014).) Sense and avoid technology is exactly what it sounds like, it is technology that allows drones to sense obstacles and then avoid them all on their own. NASA is currently working on sense and avoid technology and has had moderate success using a modified predator drone which is much larger than a delivery drones (INSINNA, V. (2014).)

Success for delivery sized drones has been very minimum until Andy Barry, a doctoral student at MIT, hit a breakthrough. He was able to design a drone that used software to detect obstacles when the drone was 10 meters away while still flying at speeds of 30 mph. All this was done with off the shelf parts that cost about \$1,700 and an algorithm that Barry created (Daud, Khawaja (November 6th, 2015)). Barry explains why he chose to use an algorithm by saying that "Sensors like lidar are too heavy to put on small aircraft, and creating maps of the environment in advance isn't practical. If we want drones that can fly quickly and navigate in the real world, we need better, faster algorithms" (Darrow, Barb (November 3rd, 2015)). However, his sense and avoid system is not perfect though. If something that was not previously detected appears such as an animal when the drone is closer than 10 meters the drone will crash right into it (Daud, Khawaja (November 6th, 2015)). Currently there is no way for Barry to make this range less without decrease the speed of the drones. This is because the computation of the algorithm would take longer than it would to reach the area in question. There is hope for this problem to fixed easily though. Moore's law an idea that the number of transistors in technology doubles every two years due to smaller sizes and thus so does the speed of computers " (Darrow, Barb (November 3rd, 2015)). It truly is a matter of time before sense and avoid technology reaches the point where algorithms can be process on drones in a matter a meter before it reaches that point.

Barry's algorithms and those that continuously improve on it will form the foundation for a future of autonomous UAV's.

The idea that delivery drones can be hacked is a pretty frightening one. What's more frightening is that one of the first result when searching Google for hacking drones is a website called Skyjack which offers free software so that users can take control of other drones (*SkyJack*). Hacking threats are not a new thing for companies. Sony faced a major hack that devastated the company that resulted in the leak of five upcoming movies, the reveal of employee and celebrity's private information, emails containing everything from controversial remarks for high officials to sensitive negotiations with Marvel Studios on a deal to share the rights to Spiderman. Even that though pales in comparison to what a hacked drone could do (Boorstin, Julia (November 24, 2015)). Drones could be lost along with customers trust and the drones could be used for malicious purposes such as ramming them into things like jet engine turbines, power lines, and just about anything else that can be disrupted. Not only will this cause companies to lose their drones and their packages but it could result in a major PR disaster since their name would be all over the news of the crash. It's well known that drones rely on a signal from an operator to work. That signal is why drones can be easily hacked. All that a hacker needs to do is cut off the signal of a drone and replace it with false one (*SkyJack*). This situation leaves only one solution that can protect companies from these kinds of attacks.

Just like with companies' computer databases, they must secure the connection between the drone and the operator with the absolute best in class anti-hacking measures. Yes, this is a more costly measure but it's vital to prevent a disaster that could lead to federal investigation, possible temporary shutdown of the drone program, or heavy fines. Using an encrypted connection that cannot be shutoff wirelessly is the best bet to prevent drone takeover as in the

case of Skyjack shutdown is necessary to take over. Coding also needs to contain no pattern from to drone as drone as much as possible (*SkyJack*). This also contributes to Skyjack's success as they were able to take advantage of coding that was strikingly similar for all drones across a single brand (*SkyJack*). As cyberattacks become an increasing threat drones need to be secured just by physical means but also digital means.

Protecting the drone while it's in the sky is only half the battle. Actually delivering the package has been one of the most criticized parts of particularly the Amazon model. The biggest issues that are that packages are easy to steal and the drones are in easy reach of those nearby. The big problem with the Amazon Prime Air drones is that it has to land to deliver the package (Johnson, Daniel (March 26, 2015)). This leaves it at risk to be attacked by pets which could leave both the drone and the pet injured or worse. Children could also try and grab the drones getting hurt on them. Those are just accidents; drones would be at their easiest to steal at this point as well. Not to mention that taking off would use more of the precious power that will be discussed later (Johnson, Daniel (March 26, 2015)). Google's Project Wings recognized this problem and instead used a tether design in there drones (Madrigal, Alexis C. (August 28th, 2014)). This prevents most accidents, saves power and greatly reduces vulnerability to theft. It also greatly reduces delivery time since the drones would no long have to land. Interestingly enough, Google has claimed that their model has an increased range of over 100 miles even with this change (Madrigal, Alexis C. (August 28th, 2014)).

The problem that all drone deliveries still face though is that the drones will leave packages where they are easy enough to grab and steal. Now to be fair Fedex and UPS do this with its packages leaving them on doorsteps and there is quite a bit more uncertainty on when they will get there. However, they only do this with large packages that won't blow away and are

too big for the mailbox. Drone packages could fit in mailboxes however opening and closing the mailbox is simply too complicated for drones. In this case there are two possible solutions. The first solution would be for consumers to have a special drone landing area that is secure for the drone to land and safe for the package. This would be like a mailbox specially made for drones. The problem is that this is both an expense and an inconvenience for consumers. If this were the route that was chosen, Companies should offer just to land it on the porch at the customer's risk as well so they don't lose customers. Obviously proof that the package was there would be easy to obtain from the drone's camera. Another option would be for the drone to have to see the person it's delivering to through its camera before leaving the package. This would be the equivalent of signing for a package. This method has its downside as well though both for the customer and for the delivery company. If the customer misses the delivery window they are going to be extremely upset that they have to wait longer for their package and the company also will have to waste precious flight time. Still this should remain an option for customers who are concerned about package theft and want the peace of mind knowing the drone must see them. Altogether, using all three of these delivery methods is the best way to go as it will please the majority of customers.

Lastly, two technical limitations that go hand and hand are the biggest constants on the profits and market share in the drone industry, payload and battery life. The reason that they go together is that there is an adverse relationship between the two. If a company adds to the payload of the drone then that will take more energy and thus drain the battery quicker causing a smaller range for drones to fly (Gross, Doug (December 2, 2013)). On the other hand in order to have more battery life you either need a more powerful battery or to lessen the payload. To add to this

each drone has its on maximum payload that is the absolute limit to what the structure can carry in batteries, unloading equipment, and packages.

For example, E-Commerce giant Amazon has stated their plan is to have drones that can carry up to five pounds and have a range of 10 miles (Gross, Doug (December 2, 2013)). Amazon choose to have a payload of five pounds because they have stated that most of their packages are under 5 pounds in total weight. The problem the Amazon is facing is the range of their drones and is the same problem that many online only stores. Amazon's distribution centers are few and far between meaning that there is a large portion of the American population that will be out of range for their drones. Amazon's solutions to this has been simple, build more distributions centers. Since their inception Amazon has gone from 2 distribution center in the United States to 87 of which over 75% were introduced or are planning to be introduced within five years of 2015 (Amazon in North America). The problem with doing this is that it's an extremely expensive endeavor that most companies wouldn't do just to have faster delivery times as the operating cost for those warehouses won't be worth the gain in revenue. However, for Amazon this strategy makes perfect sense as gaining market share in the retail industry by being able to deliver products fast is something that Amazon has always tried to improve on through programs such as Amazon Air and Amazon Fresh, A mobile fresh food delivery truck in cities such as Philadelphia and Seattle (*Amazon.com*).

Google and their program, Project Wings, handled the power problem in a different way. Project Wings was originally meant as a program that delivered goods to areas that were either too risky or unreachable by land so distance was a must Madrigal, Alexis C. (August 28th, 2014)). According to the head of the program the drone can fly 100 miles thanks to its unique design (Madrigal, Alexis C. (August 28th, 2014).) However, this claim has yet to be documented

and how Google achieves this feat is still unclear due to the secretive nature of Project Wings (Madrigal, Alexis C. (August 28th, 2014).

A third option for dealing with the payload and battery problem is to have battery replacement centers at the very edge of where a drone could go on a one way trip. This could double the reach of a drone network without having to create an entirely new distribution center. This is a much more effective program for smaller businesses wanting to use drones since two companies could partner and simply send the swap drones when the delivery is over thus greatly benefiting both companies. The downside of this is that if a company can't find another company at the end of your range to partner with they will have to waste an entire battery to get the drone back to from the recharge point to headquarters. Another issue is that the company would have to pay employees at the recharging station to simply just swap out batteries unless they can find a way to automate the process in a cost effective manner.

One possible solution that simply may just be too complicated to use despite its advantages is to use a gas powered engine in the drones instead of a rechargeable battery. This will provide significantly more range and even allow for some extra payload. For example the hybrid gas- electric powered Yeair drone can reach up to speeds of 60mph, last an entire hour, and carry up to 12 pounds (Prindal, Drew (May 26, 2015). So why aren't companies using these drones in their test? The big problem: noise. Gas powered drones are loud as opposed to their battery powered counterparts which means people are going to get really annoyed hearing the engines especially in big cities where there could be thousands of drones at any time (Frey, Thomas (January 27, 2015)). This annoyance would most likely lead to banning of them which would cost companies that heavily use them thousands, possibly millions of dollars. In addition to this the price of gas also is now a factor in drone delivery. Now as mentioned before the Yeair

drone is not a pure gas drone (Prindal, Drew (May 26, 2015)). It is hybrid gas-electric drone and that is the key to the battery problem with drones. If a drone was able to switch between gas and electric this would allow the drone to fly in areas where gas powered drones are not allowed while still having the advantages of gas powered drones. The only downside to this that while the drone is flying on the restriction zone, the drone will lose power just like a pure battery operated drone thus limiting the range.

While some of the technical limitations of drones may seem frustrating, the key is that most problems surrounding the technical side of drones can be solved with creative thinking and ingenuity. Companies that employ workers with this skills and talents will undoubtedly become the leaders in the delivery drone field. Even for those problems that can't be solved this way such as sense and avoid technology are simply a waiting game for technology to catch up and it will fast. When this research was first being compiled in early January 2015 sense and avoid had been an absolute failure and was set to be years away until the story of Mr. Barry broke in November of 2015 (INSINNA, V. (2014)). Technical limitations may delay drones from being used in delivery but unlike the other key areas of drones, finance, legal, and customer satisfaction, technical limitations will never prevent delivery drones from becoming a reality eventually especially when companies are so incredibly close to success in drone delivery.

IV. Financial

Using drones for delivery like all business concepts must make financial sense for a company in order for them to move forward with the idea. Perhaps the most concerning cost is the drones themselves. Drones can range from cost of \$400 all the way to \$14,000 and that is without being equip to handle packages. Max Lewontin of the Christian Science Monitor stated that Walmart will be using the DJI's S900 which is a \$3,800 drone (Lewontin, Max. (October 27,

2015)). This gives an idea of about where on the spectrum expenses for the drones will be for all companies. The drones themselves aren't the only financial issue though. Amazon.com already offers free two day shipping to its prime members with other companies offering similar deals to Amazon the use of drones because a question of whether or not consumers are willing to pay more to get a package in 30 minutes instead of two days (*Amazon.com*). Another financial issue with drones is caused by the flight limitations is there small range makes for a small market available that is dependent on locations of the company's distribution centers (Talbot, David. (December 2, 2013)). Finally, there are the costs associated with damage to packages and legal risk.

The cost of drones should be major concern for many businesses wanting to invest in using drones for delivery. Part of the reason is due to the need for a fleet instead of just single drones due to the short battery life and need for recharging or battery swap outs. Another issue that drones will need to be heavily modified in order to complete deliveries. This will include a way to drop packages, monitor their movement, and to extend the battery life. Each of these will add expenses to the drones and will require engineering expertise. For companies such as Walmart and Amazon this will mean that they will have to pay someone, either employees or a third party to help design and install the necessary changes. This will added even further expenses just to have a usable delivery drone.

The battery life of drones presents a cost dilemma that could be handled in several different ways. The DJI's S900 that Walmart is using only has 18 minutes of battery life (*DJI.com*). This is with a payload of 6.8kg and hovering at a measly height of 2 meters (*DJI.com*). Even if it were to be able to maintain this flight time for an actual flight it still would only have halve of that time to drop off the package in order to make it back before the power

runs out. This would mean that if the drone were to fly at 30mph, the speed that MIT flew their drone that was discussed in the flight limitations section, the drone would only have a reach of 4.5 miles which would mean that companies would need invest in having small locations where they launch drones and store goods as well as charge the batteries after every use(Darrow, Barb (November 3rd, 2015)). This leads to three key costs that companies using drones for delivery will incur due to the short battery life. These costs are storage locations and material cost, the cost to keep drones near customers, and the cost of the spare batteries or extra drones.

If drones had an endless supply of energy or the ability to flight at high speeds safely smaller localized locations would not be necessary. But due to the constraints on power and speed it is necessary and costly step in order to have an effective drone delivery system. This is what makes Amazon being the first to go public with the idea very peculiar. Other investors in drone technology such as Google and Walmart had clear reason why drones were valuable to them. Google will be more concerned with getting businesses to sign up for their service while Walmart wouldn't need any more locations to use drone technology since 96% of the United States Population is already within 20 miles of a Walmart (Dylan. (July 26, 2015).) Amazon on the other hand has only recently added to its distribution centers for a total of 87 that are to be complete by 2017 and has no store locations (Amazon in North America). Even with these additions, Amazon still will have a much smaller available market for drones than Google or Walmart because of the battery constraints. This model causes for Amazon to have a much higher capital investment in order to use drone technology because of the new facilities. Not only will Amazon need to keep inventory in storage at all of the facilities but pay to keep them running as well.

Adding more facilities is not all bad for companies like Amazon though. Even without drones, more facilities will allow Amazon and companies like it to offer faster delivery services. Amazon has already taken advantage of this opportunity by offering 1 hour delivery in big cities that also have Amazon distribution centers around them such as Dallas and Seattle (Amazon.com) Being closer to the customer has allow given Amazon the opportunity to sale perishable goods such as product to their consumers in cities like Seattle and Philadelphia (Amazon.com) So even if drone delivery doesn't turn out to be a very profitable service companies can still improve the satisfaction of their customers with the added facilities.

The other financial issue that is caused by the battery is that companies need to keep multiple drones and batteries in order to successfully fulfill customers' needs quickly. Each drone can take anywhere from 30 minutes to 4 hours to charge so in order to keep a drone constantly delivering a company would need to anywhere two to 12 extra batteries per drone (DJI.com) On average batteries cost about 100 dollars apiece so that would mean the cost in extra batteries for drones would be anywhere from 200 to 1,200 per drone (DJI.com) Even if a drone is keep constantly in air by this method it still won't be enough to make every delivery. Assuming a new drone delivery request is made every two minutes and a drone takes 20 minutes to deliver the package. That would mean that the absolute minimum amount of drones a company could have would be ten. Assuming that it take an hour and thirty minutes to charge one of these drones, which is about the average, each drone would need to have five batteries in order to keep in continuous flight. This would bring the total cost just in drones and batteries assuming each drone cost \$3,800 to be \$43,000 per locations.

But that isn't where the cost ends for drones. The second biggest cost with drones is directly related to the unreliability of sense and avoids technology. Since drones cannot avoid

obstacles on their own they have to have an operator. Each operator has to be certified with the FAA (FAA). This process involves a background check and a written exam. Since certification is involved that means operator will have to be paid more than regular hourly employees and will need to be incentivized to stay longer than regular employees due to the training. In addition maintenance personal will be needed to keep the drones running. This further raises the personnel cost of using drones.

. One of the hardest costs of drones to predict is legal fees. Especially in the early stages of actual drone use the legal fees of drone will unpredictable. This will cover everything from the lobbying congress to change regulations on drones to court cases. Since there are those that fell that drones are an invasion of privacy their will undoubtedly be resistant to drones and may cause damages to the drones that result in lawsuits or they may simply go straight to suing companies that are using drones. Eventually precedents will be set in cases like these that will make the need for court case to be greatly reduced. People will eventually get use to the drones and not be afraid of them which will help to keep legal fees low.

The last major cost of drones isn't a measurable one in terms of money. That is the extra time it takes to use drones for retail purposes. It takes time for employees to load drones with the correct materials replace the batteries after each use. This will be especially true for retail giants like Walmart whose inventory is mostly on display in their shelves. They will need an employee to run and get items for the drone to delivery from the shelves which takes up time from the employee that could be stocking shelves or helping in store customers. There are two ways to combat this problem. The first is to hire new workers whose sole job is to work with drones as opposed to just getting associates who aren't busy to do it. This is the sensible plan as the labor is

cheap and it helps to ensure timely deliveries and better accuracy. The second thing that companies can do is to keep items that are frequently ordered by drones in the back.

Obviously, drones don't just take money to use but they intended to be a revenue stream for companies. The ways that drones create revenue is made up of four main areas. The first thing that drones can do for a profit is to collect on a delivery charge. This is the biggest source of profit for drones. The second area of profit for drones is the increase in sales due to the convenience of drone delivery. The data that drones collect is also extremely important to a company and can lead to increase sales by allowing companies to better understand a customers needs. The last thing that companies save money with drones on is on the minimized reliance on third party logistics companies such as UPS and Fedex to delivery their packages for them.

Since the drone is the fastest way for a customer to get their goods this charge can be higher than for a normal delivery. However, companies will want to watch exactly how much they charge because eventually the cost will reach the point where customers will deem the cost to be not worth it. Food delivery might be a good indicator of how much customers are willing to pay since the option to go get themselves and not face the delivery charge or the obligation of a tip. Most restaurants have some sort of delivery charge that ranges from \$1.50 to \$3.00 depending on how far away the restaurant is. On top of that is the tip which can range from anywhere from 10% to 20%. If the meal cost \$30 that means that on top of the food price a person could spend anywhere from \$4.50 to \$9.00 on delivery cost alone. Each drone could then potentially make up to 27 dollars per hour if this model was followed for drones.

Drones will undoubtedly lead to an increase in sales especially for e-commerce companies as it allows them to reach their customers better than ever. No longer is going to the store to get an item always going to be the quickest way to get goods fast. With a click of a

button a drone could have the package to the customer in 30 minutes. This will force retail stores to enter the drone market or simply become irrelevant for shopping trips that customers only need small items in. The one downside for retail stores entering the drone business is that they lose the ability to try and make customers impulse buys while they are at the business. However, this doesn't matter too much as the E-commerce companies like Amazon are already intent on using drones to eliminate those small trips to the store by using drones.

Data collecting with drones is great advantage over the competition. Drones allow you to see a person's life and from that specialize their discounts and offers with certain indicators. For instance if a company sees that the customer is outside shoveling snow by hand this could lead operators to indicate to send that customer a coupon for a snow blower with their next drone delivery. But visual cues like this aren't the only important information that drones can receive. What people buy with drones is important and if customer regularly has a product delivered, a company could offer to have that person subscribe to getting that item automatically delivered on certain days. This would make the company the guaranteed supplier of that item to that customer and thus allow them to possibly gain some of their competitors business.

Finally, the last area of profit that drones give companies is the reduction in reliance on third party logistics companies. With drones, companies can expedite goods from one store to another as long as they are in range of each other without going through a third party or using their own fleet when needed. Companies can also eliminate any shipping charges that they were paying on small orders that are now being handled by drones. While these savings are small they do add up quickly and could help a company out immensely.

V. Legal

If companies want to use drones for delivery, they will find ways to work through the technical limitations and the financials. What companies can't work around is regulations on drones set by the Federal Aviation Administration. The Federal Aviation Administration or FAA is the overseeing body for drone technology and makes regulations on delivery drones and how they can be used. They also happen to be the major reason why drones aren't currently used for delivery and would be the group that decides whether the technology can legally be used commercially. The FAA has yet to give official guidelines on how to use drones commercial and until they do drones can't be used commercially (FAA.gov) Contrary to popular belief though, the FAA does have a plan for bring drones into the sky that can be seen by what regulations and rules have been passed so far for the technology (FAA.gov) To prove and show this, it is necessary to take a look at the regulations that the FAA has passed already to understand the path that they are pushing drone technology toward with their influence. From there a logical timeline of future regulations can be predicted.

The best place to start with regulations is the probably is a regulation that is very simple, longstanding, and could cause problems for delivery, no fly zones. Generally, to be classified as a no fly zone an area must fall into one of three categories, a military facility, a national park, or an airport (FAA.gov) In addition to these, some business will have no fly zones around their facilities for various reasons. Generally, these areas aren't too big of deal as they are typically large areas that are already secluded from most residential housings. However, if any of these areas are partially in the range of a company's drone operation it will reduce the operational area of a drone and potentially cause the loss of some potential customers near the restricted areas. Unlike other drone regulations there is no chance that companies can get no fly zones removed

as they are a matter of safety and security. Just like passenger aircraft, companies using drones will simply have to live with avoiding these areas.

Laws specific to drones or even outlines of potential laws for commercial use are pretty much non-existent before February of 2015. Since the rules have not been set yet, the only ways that a company can use drones commercially is by having an exemption to Section 333 granted by the FAA (FAA. Gov) Of the 600 that have been requested the FAA has only approved 66 which is roughly 10% of all applications (FAA.gov) Most of these exemptions are not granted for delivery purposes but instead they are to shoot movies and televisions shows. Companies are even having a hard time testing drones for delivery in the United States because of the lack of regulations. Google chose to test their drones in Australia whose drone regulations are much more lax than that of the United States. Amazon also left the United States to test drones by going to Canada (Madrigal, Alexis C. (August 28th, 2014)).

Realizing that the United States would need areas to test commercial drones so that technological advancement could be made to better the technology, the FAA chose six testing facilities from a short list of 27 locations (Janson, B. (December 30, 2013)). These test sites are the University of Alaska, the State of Nevada, New York's Griffiss International Airport, the North Dakota Chamber of Commerce, Virginia Polytechnic Institute and State University, and Texas A&M University (Janson, B. (December 30, 2013)). Each location was given a specific component of drones to test and improve on as well as provide different climates for testing. Topics that are to be researched across the test sites are the development of safety and operational standards, understanding the human factor in drones, and understanding the risk associated with drones and how to minimize them. These test sites have a contract with the FAA to remain active until

February 13, 2017. At this time the FAA will decide whether further research at these locations will be needed (Janson, B. (December 30, 2013)).

In February of 2015, the FAA announced their long awaited proposed regulations on commercial drones (FAA.gov) Drone delivery companies had prepared for most of these limitations such as a limit of 500 feet maximum for attitude, age and knowledge restrictions on who can fly drones, and a speed limit of no more than 100 miles per hour (FAA.gov) All of these were consider very fair and reasonable restriction but the other two purposed restrictions would shut down delivery drones all together. These are that drones could only be flown during daylight hours and must be visible to the operator. Limiting drones to daylight hours means no evening deliveries which would probably the most oportune time on the weekdays since that's when customers are getting back from school and work (FAA.gov). Limiting drones use to daylight only doesn't even matter for delivery drones because having to keep the drone in the line of sight of the operator would result such a small market possible that drone delivery wouldn't be worth it (FAA.gov).The FAA has made it very clear that they want have rules that promote safety and fairness (FAA.gov). Only do these last two cause companies to protest the rulings and claim that the rules are too excessive. Companies can continue to protest these rulings and try and get the FAA to revise them until the rules are finalized sometime in the middle of 2016 (FAA.gov) Until the rules are finalized companies will still have to request a Section 333 exception to use drones in the United States (FAA.gov). In the mean time companies like Amazon and Google have found ways to insert themselves into the drone regulation decision making (FAA.gov).

The biggest way companies like Google and Amazon have inserted themselves into drone regulations decision making is by lobbying to be a part of the Unmanned Aerial Systems Registration Task Force (FAA.gov). The UAS Registration Task Force is a group of leaders in

the drone industry and several government agencies coming together in order to form a plan for which drones should be registered and how the process should take place (FAA.gov).

Registering drones with the federal government will allow the government to have a full list of drones and who owns them. This will allow better knowledge on who to prosecute in the event of an incident and exactly how many drones are in use and where. Most of discussion is supposedly on which drones need to be registered. For instance, questions that could arise are, does a small compact drone need to be registered or do consumer drones need to be registered at all. In addition, to figuring out who needed to be registered, the task force must also decide on what operators must do in order to register their drones (FAA.gov)/ For instance, they could say that operators must pay a fee or take a knowledge test in order to register a drone in their name. Not much has been said about how the discussions have progressed aside from the fact that the results of the committee are due to be released on November 20, 2015 (FAA. Gov)

Future regulations on drones will have to be updated as the technology for drones improves. If the purposed rules do in fact go into effect even with Amazon and Google trying to prevent them from, drone delivery will be delayed until new technology and studies show that drones are safe to fly out of the view of an operator and at night. This is why sense and avoid technology is the key to drone delivery. If drones can act completely autonomously, than operating a night and flying away from operators sight should be just as safe as being near an operator and flying during the day. The question then becomes how far of the technology is and how long will it take the FAA to make a new ruling on drones. It is quite possible that this could take decades before the technology reaches a point where it is up to the standards of the FAA and even longer for the FAA to approve its use. This would mean that an alternative plan must be put in place for companies to convince the FAA that drone delivery can be carried out safely. The

argument that companies have against the FAA in this regard is that operating a drone at a computer desk is just as safe as operating the computer within eye sight. Offering to add cameras for a full 360 degree view of the drone and its surrounding may help sway the FAA toward allowing drone delivery. It is a reasonable argument and the best shot that companies will have in order to complete drone deliveries before sense and avoid technology has reached a usable point.

VI. Customer Satisfaction

While the legal, technical, and financial limitations weigh heavily on whether delivery drones can actually be a successful part of businesses, the real test of whether drones will be used lies with what the American people decide delivery drones will actually improve their life in some way. Companies have a desire to increase profits while customers are looking for satisfaction. Customers have constraints on their spending and are looking to maximize their happiness with their money. The key to drones is bringing happiness and satisfaction to the customers. All of the companies that are working on drone technology have the same strategy in this regard. The companies have positioned drones to prospective consumers as a way to pay a little more to have packages delivered to them faster than ever before to a point where ordering by drone might be faster and in some cases cheaper than going to the actual store. Consumers don't want to wait as they find it to be a major inconvenience. This is part of the reason why On Demand services and Amazon Instant Video have had such a success against long standing rental companies like Blockbuster and Family Video despite being more expensive. Even though drones take around a half an hour to deliver goods by Amazon standards, they still are about the closest that companies can get to instantaneous delivery of physical products. However, despite fulfilling the customers desire to have good delivered quicker than ever, drones still are highly

controversial among consumers with some people going to extremes to prevent delivery drones from being reality. The majority of these complaints arise from the issues of privacy and potential reliability of on time delivery.

When Edward Snowden leaked the NSA spying to the world it made many people feel violated and that they no longer had privacy. This feeling lead to angry for many and stronger than ever desire to protect their privacy from being further violated (How the World Has Responded to the Snowden Leaks) .Drones have the same effect because they carry cameras that are constantly recording what they are doing and sending it back to the drone operator where it can be recorded. This is great for companies like Amazon because seeing where and how their customer lives allows them to better target them with promotions and ads that match their lifestyle. For instance, if a drone where to go to a house with a sign for a Christian Church in front yard, Amazon would be to target them with ads and promotion on items dealing with the Christian faith. This is not so great for people who have a core value of privacy. With drones flying around, privacy becomes harder and harder to obtain. Even if a person were to never order a package with drones, drones would still be flying over their house and potentially collecting data while doing so. To make it worse the NSA will undoubtedly have access to this information as well seeing as they have already have access to cell phone and computer data thus furthering privacy valuing consumers panic and anger. This anger could lead to entire towns turning on drone delivery. Should this be allowed to happen drones could become infeasible simply because no fly zones would prevent fast travel from place to place.

There aren't any guaranteed solutions to solve the concerns of privacy but there a ways to minimize it. The first is an ad campaign focusing on the company's commitment to privacy and explaining that the company does not share or doesn't collect the data from the drones. This

approach however will still leave many of those who value privacy unhappy and could cause the company to lose potential sales if they don't use the information from the drones. The best thing that a company can do is in addition to an ad campaign is to lobby congress and state governments to insure that shooting down drones is illegal, prosecution is strictly enforced by the local police, and as previously mentioned that no fly zones remain only those that are absolutely necessary. Unfortunately neither of these solutions can convince all of those who have hesitations about drones due to privacy matters that drones will do no such thing but they can prevent those who are threaten by drones from becoming violent towards them.

The most daunting task any company faces is to maintain the trust of its customers. Many people are skeptical of the advantages of drones and will be quick to give up on them if the perception of them becomes negative. Companies can't afford drones to fail especially during their first months of launch. It is absolutely vital that companies are as honest as possible about the delivery times, do not take flight risk such as flying during poor weather, or fly over unsafe areas. If companies fail to be honest about delivery times and arrive times end up being much later than promised customers may become unsatisfied and may begin to believe that drones are unreliable. However, on the flip side of these companies should not be so concerned with being on time that they take risk that could cause the package to be lost and the delivery delayed even worse than it already was. A late delivery is better than no delivery at all. One way to ensure that can improve customer satisfaction pertaining to delivery times is to live cast the drones feed to the customers so that they can see their drone is on its way and how close it is. This helps the customers to manage expectations for when the drone should arrive by giving them a visibility into the delivery.

Customer satisfaction may seem to be a very simple and straight forward but it truly is a complex and ever important part of any business. Doing everything possible to try and show potential customers that drones do not invade on their privacy will be key to marketing the drones. Keeping to this promise will be key to maintaining consumers trust and business. Any information leaks would cause customers to distrust the company and possibility stop using drone services. Maintaining delivery time promises will also be a key factor in customer satisfaction and will be crucial to drone delivery's successes. This can be better achieved by allowing our customers to see a real time feed from the drones that are delivering their package. By showing that privacy and commitment matter to a company, they gain the trust, satisfaction and loyalty of the customers.

VII. Conclusion

When looking at the key four areas to drone technology, it's clear that each area has its effect on drone technologies future. Legal and Flight limitations will be the most important to whether drones will be implemented in the future. On the flip side issues of financial matters and customer satisfaction determine whether they will be a profitable industry or not. It's easy to see by looking at the facts and possible solutions to drones that only three things prevent drones from being a reality; sense and avoid technology, FAA regulations and customer satisfaction. Of these three only customers satisfaction is a true deal breaker for drone technology. If customers don't want it then it won't make sense for companies to invest in. However, if customers do find that they like the idea of drone delivery then companies will push to advance sense and avoid technology and regulations forward so that drones can become a reality. The future of drones is in the hands of the customers that will use them.

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This article talks about the FAA regulations and the effect that they have on the Amazon as well as a smaller company Amp. The article presents an excellent view on the state of drones and is very useful especially when used with the information from Lomberg's other article.

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Shaw, Ian (2014). The Rise of the Predator Empire: Tracing the History of U.S. Drones.
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SkyJack. Retrieved from <http://samy.pl/skyjack/>

This website talks about hacking drones.

Talbot, David. (December 2, 2013). Separating Hype from Reality on Amazon's Drones.

Technology Review. Retrieved from

<http://www.technologyreview.com/news/522121/separating-hype-from-reality-on-amazons-drones/>

This article presents a well backed opinion on why commercial drones will not work. They talk about the FFA and there issues with drones as well as the financial issues facing drones. I think this source works best when talking about the downside of drones and what society needs in order to make them work.