Amazon's Drone Delivery System Design

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Executive Summary

Amazon's 1-day shipping promise currently relies on the usage of third-party services as one of the main last-mile delivery methods. Last-mile delivery is one of the most cost-ineffective parts of delivery systems. As such, relying on a service that charges a premium can prove to be very costly in the long-term. To solve this problem, we have chosen an alternative last-mile delivery method for Amazon, a drone delivery system.

The drone delivery system design we discuss throughout this report could prove to be beneficial for Amazon, it represents a move away from third-party reliance and human capital liability. One of the main issues to fulfill the 1-day shipping promise currently is the high workload needed from employees. This has led to substantial employee unhappiness and burnout, which have been important factors leading to many protests. A drone system for last-mile delivery would offload some of the high workload required for high levels of efficiency during delivery. In fact, a drone system can deliver small packages in less than thirty minutes, reducing delivery time substantially.

In the following pages of this report, we discuss the different stages involved for the creation and implementation of a drone delivery system for last-mile delivery. The most important factors we would like to emphasize in this project are the design and development of the infrastructure that will support our system. These include the creation of a network infrastructure to provide communication between drones and operators, the use of a combination of GPS and cellular technologies for accurate real-time location for the devices, and a real-time feedback information using metrics for data analysis meant to aid in decision-making.

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1. Introduction

This document contains a detailed description of the system design for a drone delivery system specialized in last-mile delivery for Amazon. The information portrayed in it is divided into several categories: scope, business case, systems planning, systems analysis – logical modeling, systems architecture and design, data design, network model, application development, management system implementation plan, managing system support and security, conclusions, and recommendations.

2. Scope

When customers buy products through the Internet, they expect deliveries to be as quickly as possible, especially after Covid-19. Amazon's push towards 1-day shipping is leading the move towards almost instantaneous shipping. To do this, Amazon's delivery methods are constantly changing. One potential delivery method for last-mile delivery is a drone system. This project will deal mainly with the design, planning, and implementation of such system. We expect this project to be fully implemented within one year from the initial proposal and beginning of work for planning and implementation.

3. Business Case

a. Constraints

One of the constraints Amazon faces is the sheer number of packages they need to deliver daily, which creates a need for hiring new employees constantly in order to fulfill demand. Hiring so many employees incur a high cost, especially due to all the paid benefits that Amazon provides for them. Another limitation would be Amazon's requirement to fly during the day to

deliver packages to their distribution centers. An additional constraint would be the amount of distribution centers needed to keep the 1-day delivery promise. Also, the fact that Amazon relies on external third-party delivery systems such as USPS presents a risk for the 1-day delivery promise as they lack control of this part of the process. If Amazon implements a drone delivery system, the number of drones needed and the electricity needed for them could become a constraint, as they would have to invest in charging stations, maintenance, etc.

b. Initial SWOT analysis

Strengths

- Competitive, fast delivery
- Automation in distribution centers
- High investing in research and development of new technologies
- Implementation of proprietary, new technology
- Various delivery systems
- High stipend (double than competitors)

Weaknesses

- High workload needed to fulfill 1-day shipments
- Stringent rules and policies employees must follow that makes them unsatisfied
- Dangerous working conditions for employees, especially pilots (schedule requirements)
- Weaknesses in drones' systems, such as transportation problem in harsh weather condition

Opportunities

- Providing programs or services to employees to improve their happiness

- Recruiting more employees to divide the workload
- Facilitating policies to make them more flexible for employees to cope with workload
- Continue embracing new areas of technology that can make shipments faster

Threats

- Competition from other stores such as Walmart and Target in fast delivery
- Local stores' delivery systems
- Increased amount of employees' protests due to lack of employee satisfaction (bad brand reputation)
- Additional app-based delivery systems for all kinds of stores (Uber, Instacart, etc.)

c. Problems and solutions

• The last-mile delivery part is the most expensive because it relies on third parties to complete the delivery. To solve this, an in-house drone system completely controlled by Amazon would provide lower costs in the long-term even if it requires an initial investment.

• A drone system could encounter issues with navigation because of its inability to distinguish wires and cables, which may cause frequent accidents or package damage. To solve this, the areas that involve last mile delivery could be surveyed and mapped using software that can be fed to the drone system. By doing so, flight paths could be designed to avoid potential hazards.

• Another problem may arise with harsh weather conditions. This external, uncontrollable threat may require temporary pauses to the drone delivery system. Since this problem may cause drones to crash if they are allowed to fly, we would recommend Amazon to state the possibility

of pausing this service when a customer is opting in for this kind of delivery. By doing this, Amazon would set realistic expectations for clients to keep them content in the case of bad weather. In the case of harsh weather conditions, Amazon may have to deliver packages using a different method or postpone drone delivery accordingly.

- The flex app is an alternative to the drone system currently existing in Amazon for last-mile delivery. It consists of a service similar to Uber in which drivers sign up to pick up and deliver packages using their own vehicles. This alternative, however, presents problems mainly dealing with driver safety and possible legal issues in the case of accidents. The app requires drivers to tap the refresh button frequently to use it, which is a big distraction that may lead to car accidents. We recommend Amazon should use the drone system instead of this service to avoid possible legal, monetary, and reputational damages that may be incurred in the case of accidents involving a real person. The worst-case scenario with a drone accident would be to replace the drone and the package being delivered. On the other hand, the worst-case scenario of using humans to deliver while being distracted by the app they are required to use could be catastrophic and irreparable.

- Finally, Amazon's culture is a highly competitive, highly efficient one that requires employees to sustain a heavy workload with little to no rest while working. This kind of culture is encouraged greatly by Amazon's management, and not everybody is prepared for this environment. The amount of work and efficiency required from employees may lead to exhaustion and burn out, which can lead to accidents at work that may prove costly for Amazon. To diminish this risk, Amazon could allocate part of this workload to the drone system for last-

mile delivery. By relying on drones instead of humans, otherwise potential, costly accidents can be avoided.

4. Systems Planning

a. Observe operations

At this stage of the project, we decided to investigate multiple videos available online to analyze the current operations at Amazon. After doing so, we realized that for the most part, Amazon relied on third parties' services for last-mile delivery. These third parties included companies such as FedEx and UPS. While this method can be effective because it does not require Amazon to design, plan, and implement its own infrastructure, it can be very costly in the long-term. At the end of the day, most of these service providers are for profit companies, which means they will be charging a premium for the services offered.

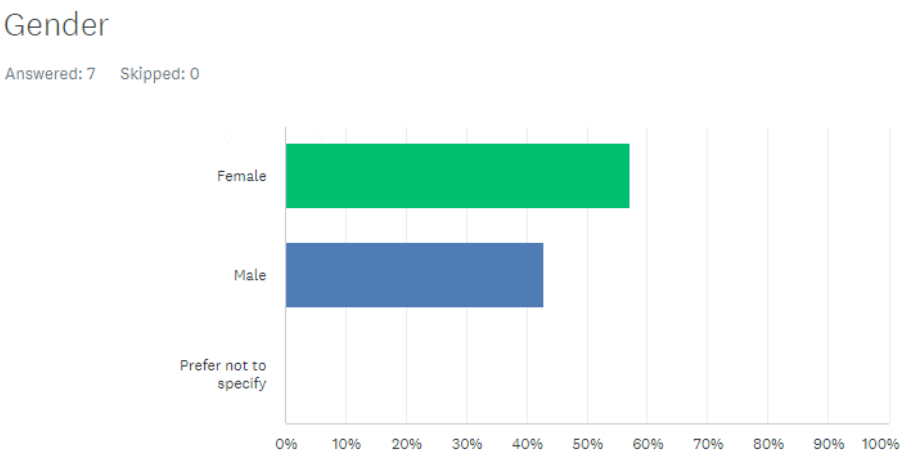
Another method that was currently used as an alternative to third parties was Amazon flex. While this was an attempt to replace external reliance with in-house methods, it could still prove to be costly as Amazon flex drivers are required to use an app that needs constant refresh button taps to work properly. This issue may lead to accidents that can damage Amazon by incurring losses with potential sues.

b. User survey

After observing Amazon's operations, we decided to get insight on the main reasons why Amazon users used its services. To do this, we created a user survey with multiple questions that could provide us with an idea of what services are preferred and what are the important competitive advantages Amazon possess. The survey consisted of ten questions. We tried to get

as many respondents as possible from our environment (classmates, family, and friends) but only managed to find seven volunteers who were Amazon prime members and willing to provide answers for the survey. The questions and answers can be found below:

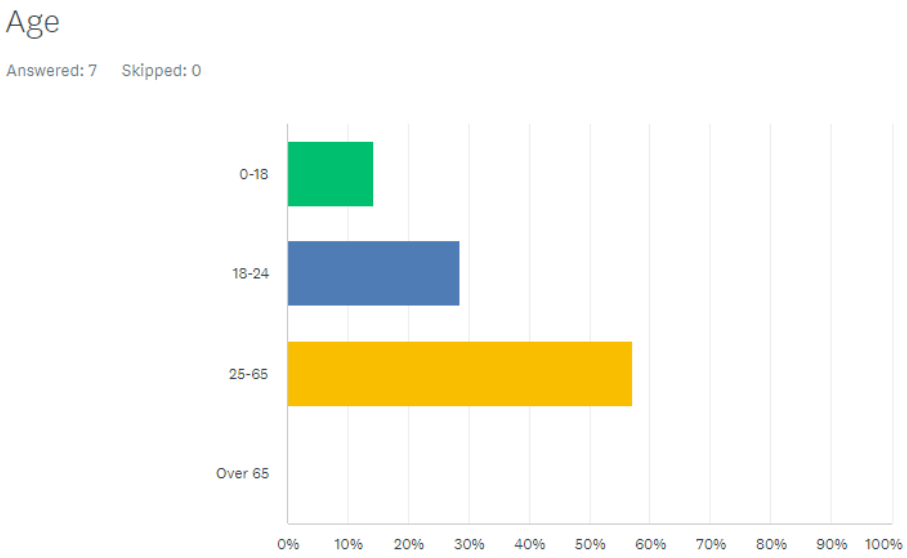
- **What is your gender?**



ANSWER CHOICES	RESPONSES	
Female	57.14%	4
Male	42.86%	3
Prefer not to specify	0.00%	0
TOTAL		7

Fig. 1 - Out of the 7 respondents, 4 were female (57%) and 3 were male (43%).

- **What is your age?**



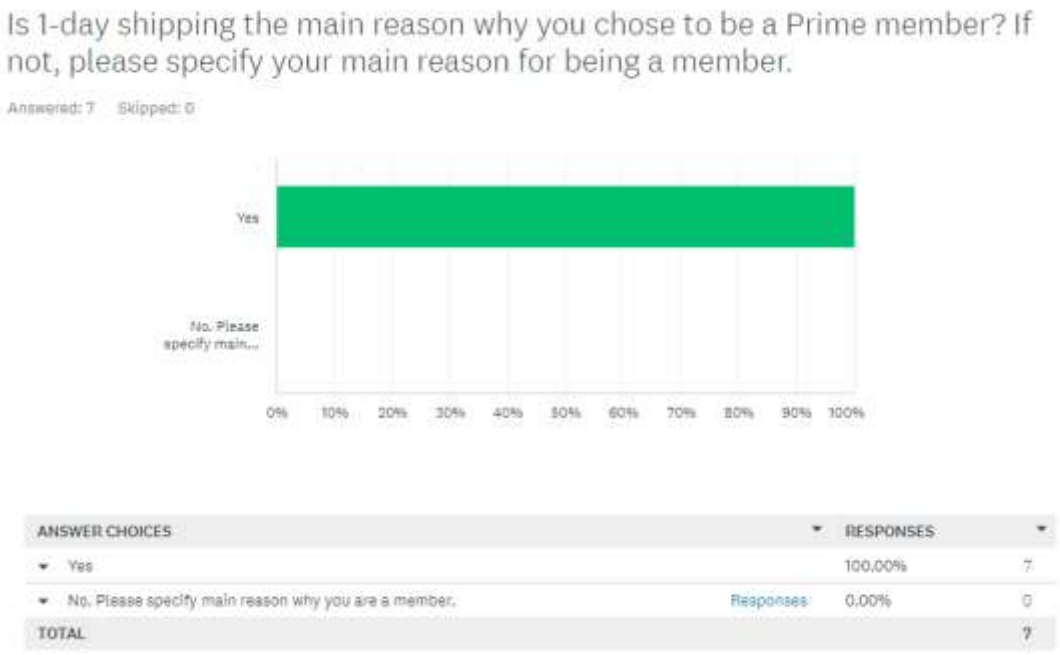
ANSWER CHOICES	RESPONSES	
0-18	14.29%	1
18-24	28.57%	2
25-65	57.14%	4
Over 65	0.00%	0
TOTAL		7

Fig. 2 - 57% were adults between 25 and 65 years old, 29% were young adults between 18 and 24, and 14% were under 18.

- **Why did you choose to be an Amazon Prime member? (number of responses)**
  - Free delivery (3)
  - Quick delivery, 1-day shipping (2)
  - High usage, lots of orders (1)
  - Free student membership (1)
  - Gift options (1)
  - Prime video (1)

- Many services (1)

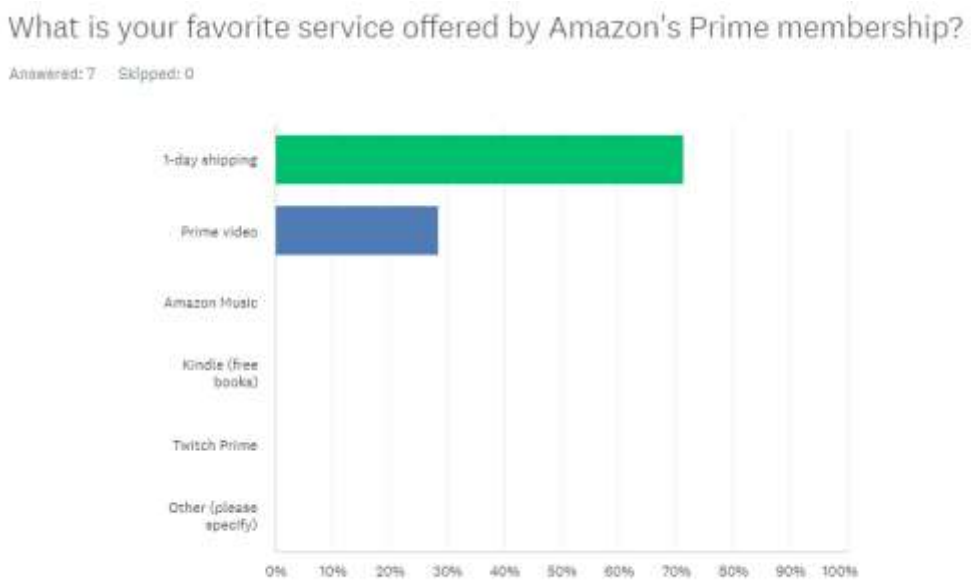
- **Is 1-day shipping the main reason why you chose to be a Prime member? If not, please specify your main reason for being a member.**



ANSWER CHOICES		RESPONSES	
Yes		100.00%	7
No. Please specify main reason why you are a member.	Responses	0.00%	0
TOTAL			7

Fig. 3 - 100% of respondents chose to be a Prime member mainly due to 1-day shipping.

- **What is your favorite service offered by Amazon's Prime membership?**



ANSWER CHOICES		RESPONSES	
1-day shipping		71.43%	5
Prime video		28.57%	2
Amazon Music		0.00%	0
Kindle (free books)		0.00%	0
Twitch Prime		0.00%	0
Other (please specify)	Responses	0.00%	0
TOTAL			7

Fig. 4 - 71% of respondents chose 1-day shipping as their favorite service included with Prime, 29% chose Prime video.

What do you enjoy the most about Amazon? (number of responses)

- Product variety (3)
- Easy to use (2)
- Cheaper prices (2)
- Quick delivery (1)

- Prime video (1)
- Additional services offered (1)

What frustrates you the most about Amazon? (number of responses)

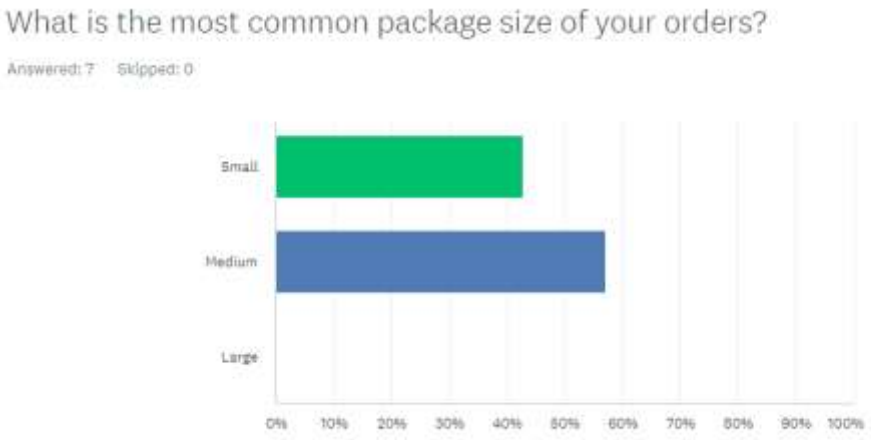
- Delayed orders (3)
- Lack of stock (2)
- Lack of option to hide orders such as presents (1)
- Lack of some brands (1)

- **Approximately, how often do you shop at Amazon?**

ANSWER CHOICES		RESPONSES	
Every three months		0.00%	0
Every month		71.43%	5
Every week		14.29%	1
Everyday		0.00%	0
Other (please specify)	Responses	14.29%	1
TOTAL			7

Fig. 5 - 71% of respondents shop at Amazon every month, 14% every week, and another 14% during Christmas.

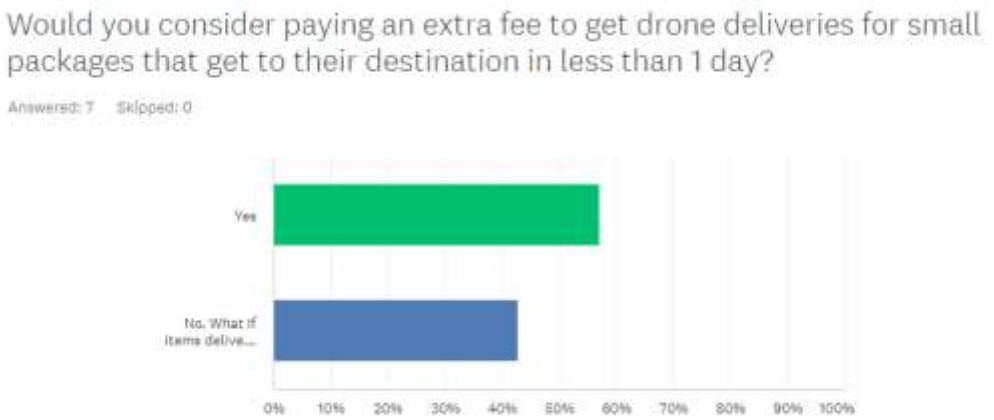
- **What is the most common package size of your orders?**



ANSWER CHOICES	RESPONSES	
Small	42.86%	3
Medium	57.14%	4
Large	0.00%	0
TOTAL		7

Fig. 6 - 57% of respondents shop for medium size packages while 43% shop for small size packages.

- **Would you consider paying an extra fee to get drone deliveries for small packages that get to their destination in less than 1 day?**



ANSWER CHOICES		RESPONSES	
Yes		57.14%	4
No. What if items delivered by drone had to be picked up from an Amazon hub but a special discount was applied? Please specify below:	Responses	42.86%	3
TOTAL			7

Fig. 7 - 57% of respondents would consider paying an extra fee to get packages delivered by Drone in less than 1 day. From the other 43% that said no, 66% would consider drone deliveries if a discount was applied to the order.

After concluding the user survey, we realized that most respondents were members of Amazon prime mainly because of free shipping and quick delivery or 1-day shipping. Most respondents also claimed to mainly shop for medium and small sized packages. This information is useful for us to justify the possible success a drone system may have as it would reduce shipping time as well as mainly carry medium to small size packages.

5. Systems Analysis – Logical Modeling

a. Requirements gathering and documentation

i. Current system

Amazon's current system for 1-day delivery relies on availability of products throughout multiple warehouses across the country. To keep their promise of 1-day deliveries, only certain products are labeled as "Prime" products, which ensure the delivery can be done in such a limited time. In addition, the customer needs to be a Prime member to access this option. In other words, only customers that are subscribed to this service by either paying a monthly or an annual fee can opt in to buy Prime products that get delivered in 1 day. Currently, Amazon's delivery system is composed of complex distribution centers that use robotics to sort products for initial delivery to another warehouse. With Amazon's own fleet, the delivery can be done by lorry or by plane. Once it reaches the warehouse, the product can be sorted again for final delivery via vehicle. For this last part of the system, Amazon uses multiple options such as Amazon Flex (the delivery service anyone that meets certain criteria can opt for), Amazon's own fleet, or rely on third-party delivery services such as USPS, UPS, FedEx, etc.

ii. Requirements for new system

A drone system would require multiple processes to be fulfilled as well as an underlying infrastructure. First, Amazon would need to invest in acquiring a fleet with enough drones to cover the areas in which last-mile delivery can be used. Second, Amazon would need to either allocate space within existing distribution facilities or invest in new facilities that specialize in storing, charging, and maintaining drones. Third, Amazon would need to hire drone operators that could pilot drones manually in case this option is chosen. Alternatively, flight paths and

maneuver controls could be automated by hiring software engineers who would create an automatic navigation system for the drones. In addition, a communication system between the drones and a control center should be created by implementing a central control server and terminals that may use cellular or radio frequency technology to communicate with and control drones.

To understand the user requirements, one needs to understand customers' expectations based on e-commerce industry standards. Amazon customers use Amazon to create an account and buy products online that get delivered directly to their homes. One of the main reasons they choose Amazon is the delivery time promise offered by its membership, Amazon Prime. Amazon ensures products categorized as Prime products get 1-day deliveries. Thus, one can determine one of the main user requirements is minimized delivery time. A drone delivery system for last-mile delivery provides faster delivery time than traditional methods. In a big American city setting, using traditional delivery methods would require Amazon to rely on third-party auto delivery services that have to deal with high population density areas with high traffic. On the other hand, drones can pick up a package from a warehouse and deliver directly to a customer's home through air, reducing inefficiencies and costs massively. Amazon is developing in a drone system and estimates it will be able to change their 1-day delivery promise to 30 minutes or even less in certain areas, which is a huge benefit of implementing such a system.

In addition to fast delivery time, Amazon provides its users with tracking information. To do this, each package is assigned a specific code, and each stop it makes along the way from the warehouse to the customer's home is tracked, updated, and given as feedback information to the client. For this reason, one can assume tracking information is expected by the user. To

implement tracking in a drone delivery system, the drones should be equipped with GPS capabilities and capable of sending feedback information to a centralized server in a control system. This server would then update the location information of the Drone and update it in real time to provide it to the customers.

Output

This subsystem would facilitate Amazon's commitment to 1-day delivery by providing efficiency. The main benefit from this system would be reduced workload in sortation centers as well as having less time-consuming tasks for employees to do. This system would work especially well with small packages. In addition, investing in robotics to box packages would make this system even more efficient.

Input

The main inputs for the drone system would be provided by drone operators and software engineers. Drone operators could use control terminals that are connected to a central control server to override drone navigation systems and pilot them manually using software from a remote location. On the other hand, software engineers could create software that automates flight paths and serve as input for the drones to pilot themselves from point A to point B. A combination of these two types of input could be implemented for the drone system.

Process

The process for the drone system to be implemented would consist of a design phase, a planning phase, a testing phase, an implementation phase, and an evaluation or feedback phase

that can lead to changes for the system. The design phase would include the tasks involved with the design of the system, including infrastructure and network designs. The planning phase would include tasks such as determining the amount of time to be allocated for each part of the process. The testing phase would consist of developing a prototype system and testing it with users and receiving feedback to adjust the system accordingly. The implementation phase would consist of choosing a final, effective system design and infrastructure and applying it to all the areas where Amazon plans to implement efficient last-mile delivery. And finally, the evaluation phase would consist of receiving constant feedback and using this information to adapt and change the system according to arising needs.

Performance

Amazon's drone fleet would require electricity for them to work reliably. In addition, drones acquired will have to meet a threshold of efficiency. A maintenance team will be required to supervise Drone's functionality and reliability. Drones will be expected to deliver products in less than 30 minutes according to Amazon's claims after initial tests, however, this time could and probably will be reduced as newer, more efficient versions are developed. One issue to consider is that weather conditions might affect drones' performance.

Control/Security

Like airplanes or other methods of air traffic, drones will require a navigation system that relies on a fix schedule of deliveries. This system will be controlled by a navigation system that can be automated with preprogrammed flight paths and software, or manually overridden by drone operators. In addition, this system will need security measures to avoid the existence of

perpetrators that may hack into the system to cause harm. Another security measure needed would be an automatic gate system within each amazon hub that only lets the Drone assigned to a delivery access the storage facility.

b. Data and process modeling

i. Data Flow Diagram (DFD)

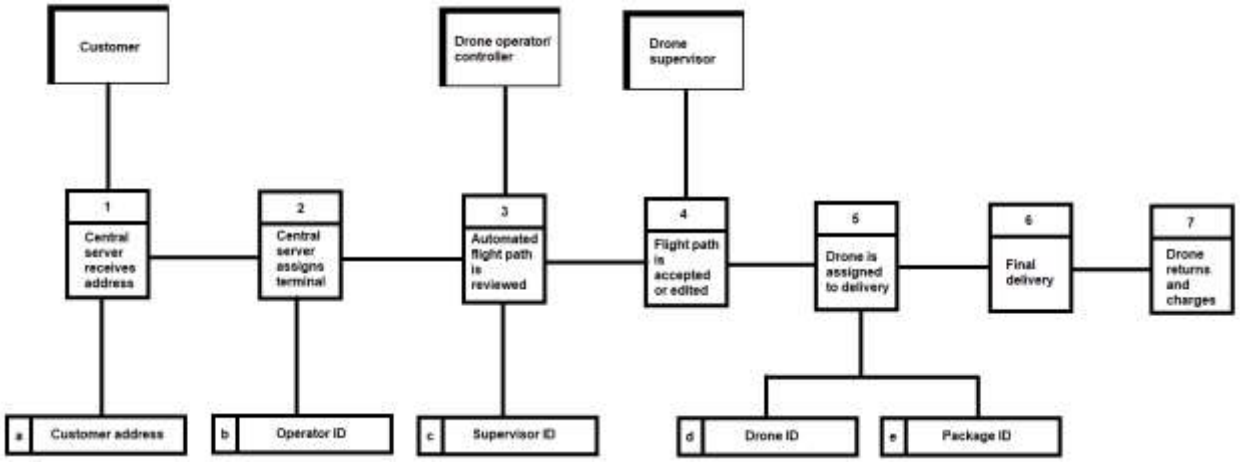


Fig. 8 – Data Flow Diagram (DFD)

ii. Data dictionary

Name	Definition	Data Type	Size
Central server receives address	Address is received from customer and fed into the system	Varchar	-
Central server assigns terminal	Central server checks availability of terminals and assigns free terminal for delivery	Varchar	-
Automated flight path is reviewed	Flight path is automatically assigned and terminal operator reviews it	Varchar	-
Flight path is accepted or edited	Drone supervisor accepts or edits the flight path prior to acceptance as needed	Varchar	-
Drone is assigned to delivery	Drone ID and package ID are assigned	Varchar	-
Final delivery	Assigned drone lifts off facility with attached package and performs final delivery	Varchar	-
Drone returns and charges	Drone returns after delivery is completed and lands in available charging station	Varchar	-
Customer	External entity that provides address information	Varchar	-

Drone operator/ controller	External entity that reviews flight path prior to supervisor's acceptance	Varchar	-
Drone supervisor	External entity with authorization to accept or edit flight path prior to acceptance	Varchar	-
Customer address	Destination information	Varchar	-
Operator ID	Operator information used to assign individual employee to a delivery	Varchar	-
Supervisor ID	Supervisor information used to assign individual supervisor to a delivery	Varchar	-
Drone ID	Drone information used to assign individual drone to a delivery	Varchar	-
Package ID	Package information used to assign individual package to a delivery	Varchar	-

6. Systems Architecture and Design

This section describes the systems architecture and design that supports a new drone delivery system for Amazon. It details multiple subsections, including the system's architecture, data design, network model, and application development.

a. Design specification

This subsection includes the project overview, the main goals of the project, the target client with an ideal customer profile (ICP), the functions and features, the aesthetics, and the performance of the system.

i. Project overview

The objective of the project is to create and design a system that improves last-mile delivery time while minimizing inefficiencies and costs compared to the current delivery systems available at Amazon. Last-mile delivery "is less efficient and comprises up to 28% of the total delivery cost" (Wang, Zhang, Liu, Shen, and Lee, 2016). Another study shows last-mile delivery can be up to 53% of the total shipping cost (Dolan, 2022). Currently, Amazon relies heavily on third parties for last-mile delivery, which proves to be inefficient and costly. Thus, the company

could benefit greatly by designing an in-house drone delivery system to rely on for last-mile delivery. A drone delivery system would increase Amazon's control over shipping costs, and it could diminish inefficiencies and unnecessary costs produced by other types of delivery.

ii. Main goals

The main goals of the new drone delivery system are listed below:

- **Improve delivery time**
- **Reduce shipping costs**
- **Mitigate inefficiencies**
- **Increase control, rely less on third parties**
- **Increase security, rely less on external human capital**
- **Automate last-mile delivery**
- **Improve customer's satisfaction**
- **Brand recognition**
- **Increase revenue and profitability**

iii. Target client – Ideal Customer Profile (ICP)

To attract customers to the idea of last-mile drone delivery, Amazon could choose one of the following options:

- Include delivery option for subscription-based customers (Amazon Prime members) without an additional cost
- Include delivery option for subscription-based customers (Amazon Prime members) with an additional cost
- Include delivery option for all customers without an additional cost

- Include delivery option for all customers with an additional cost
- Include delivery option for all customers with a discount

The e-commerce industry relies heavily on fast delivery service and affordability of products. A drone delivery system would increase speed of delivery greatly. If it was built by Amazon in-house, relying less on third parties and having control over the whole shipping process could reduce costs, and this could lead to reduced prices or offering discounts in the future, which would increase affordability. Becoming an early adopter of this technology would be a competitive advantage for Amazon, which would be raising industry standards while increasing the industry's entry barriers for upcoming competition.

In the beginning of implementing this new system, the ideal customer for this service would be clients that participate in e-commerce often while incurring high expenses in the industry. Additionally, geographical location and government regulations should be considered. To acquire the greatest number of customers willing to try this new service, Amazon should perform a market study to find the geographical location with the perfect target audience. Some important factors to consider would be GDP per capita, and e-commerce activity in the region. Regional laws will affect the effectiveness of the drone delivery system and should be considered as well. Most countries have restricted aerial space, which will most likely affect this service. Ideally, Amazon would focus on customers with enough capital to spend on e-commerce who live in a free market economy with mid to low government regulations. Also, the presence of Amazon's built infrastructure would be a plus to avoid incurring additional implementation costs.

iv. Functions and features

Some of the main functions and features of the drone delivery system are a navigation system, a control system, and a feedback information dashboard application for data analysis and decision-making.

A built-in navigation system needs to be developed to allow drones to follow preplanned air routes or to give feedback information about real-time location and height to a control system. This could be done by implementing the global positioning system (GPS) and providing each Drone with cameras and sensors for feedback information. Furthermore, connecting each Drone in the fleet to the Internet using radio frequency or a third-party cellular network may prove very useful for exchanging information within an internal network built for this service.

Depending on the level of automation achieved, a control system may or may not be needed. An automated system would consist of preplanned air routes and scheduled drone deliveries that do not need a controller's input to function. In this case, this system should be fully integrated with Amazon's ordering system, and it should be designed with a focus on coordination and total lack of calculation errors for flight paths. Since this level of automation may prove difficult to design and implement, an alternative option would be to hire a drone operator to act as controllers who supervise the drone delivery system and may even pilot drones manually if needed from a server in a control center.

Finally, an application to provide feedback information to managers for this system should be developed to aid in the data analysis and decision-making process. This application could be designed to automatically calculate important metrics and build graphical dashboards

with which managers could interact. Having access to metrics and data is crucial to monitor the correct functioning of the system. Issues and problems that arise should be easily identified with the use of this application, which would add value to the drone delivery system.

v. Aesthetics

The design of the visual concepts for the drone fleet should be representative of Amazon's brand. The idea here would be to use Amazon's name and/or logo in addition to a specific color selection for the exterior of the drones. Additionally, Amazon could create a branded name for this service like what it has done previously with other services such as Amazon Flex. These options could be used to further Amazon's brand recognition, which would help acquire new customers willing to use their service.

vi. Roll out plan

We hypothesize the initial, best geographical location for this service would be North America and more specifically the greatest, most crowded cities with existing Amazon's infrastructure within the United States. We anticipate this service to perform well in an environment where Amazon is already well known and relied upon by many customers when choosing to participate in e-commerce. Big cities are also difficult to navigate through for delivery services as traffic tends to cause delays, which can be avoided through trafficless air delivery. Furthermore, GDP per capita and Amazon's Prime membership base in the United States are important factors contributing to this decision. We suggest one possible city for testing this service could be Los Angeles, California. The vehicle traffic in this city is well known and it can cause package delivery delays. The drone system could solve this problem by avoiding traffic completely.

b. User requirements

In this subsection, we describe requirements for different stakeholders in the company. The main stakeholders we are concerned with for this project are the customers and the controllers for the drone delivery system.

As shown before by our user survey, most respondents stated the main competitive advantage offered by Amazon membership services was a speedy delivery. Thus, we consider speedy delivery to be one of the most important goals that the drone system can achieve. As mentioned previously, the drone delivery system can complete deliveries in under 30 minutes, and with further developments in technology, this time will be reduced over time.

On the other hand, controllers, which are composed of drones' operators and supervisors, will require a real-time feedback system that provides them with the necessary information to make important decisions. The drones will be equipped with cameras and sensors that send information back to the central control server. This information can then be relayed to individual terminals where operators and supervisors can supervise the correct functioning of the drone. To perform deliveries, the drones will need to be preprogrammed with flight paths and obstacles information. Software for the drones' control should also be developed and installed in the terminals operators will use to potentially override the system and pilot drones manually if needed. Furthermore, preprogrammed drones can also record and provide metrics to an in-house application that employees can use to visualize and analyze data. This last function can be beneficial for effective analysis of performance efficiency and to be notified of possible maintenance or replacement needs.

c. Usability testing

Before deciding to implement the system, Amazon should develop a prototype and test it with the intended user base. The purpose of usability testing is to receive critical feedback information from the end user about the system to implement in its design.

One way to do this would be to choose a strategic geographical location based on customer membership loyalty where Amazon should invest in developing a small-scale version of the system. Amazon could start by investing in a small drone fleet and offering the additional delivery option to Amazon prime members living close to a distribution center or warehouse of the chosen area.

Amazon could set up an online user survey to allow eligible candidates to communicate back about what they enjoy about the service, what they do not enjoy, which features are they missing, etc. Furthermore, Amazon could decide to hire human capital as testers for this system during this stage if more opinions are needed.

6.1 Data Design

This section describes the data design for the new drone delivery system for Amazon. It details multiple subsections, including the system's data structure, data elements, and data design.

a. Data structure

The system's data present and acquired is organized into six categories or subsystems that form tables: customer, order, payment, warehouse, transport, and drone delivery system. These

tables are connected using Crow's Foot notation to determine their cardinalities. Customers order products and, after payment, wait for verification. While they are waiting, the order center checks customers' validation and payments. Then it sends a verification note for customers and the warehouse (Fulfillment Center) to start packaging. After packing the ordered products, boxes are sent to transportation centers to be sent to warehouses for delivery. Once boxes have been categorized by size, small boxes are assigned to the drone delivery system. In the last-mile delivery section, order details, including address and availability for sending packages, are checked, and packages are delivered to customers.

b. Data elements

Data elements within the system are organized by labels: primary key (PR) and foreign key (FK). These elements are User ID, Order Num, Name, Address, Payment Num, Order Num, Order Detail, W. ID, Payment Num, Payment Detail, T. Num, and Drone Num. Some primary keys are also used in additional tables as foreign keys.

c. Entity Relations Diagram (ERD)

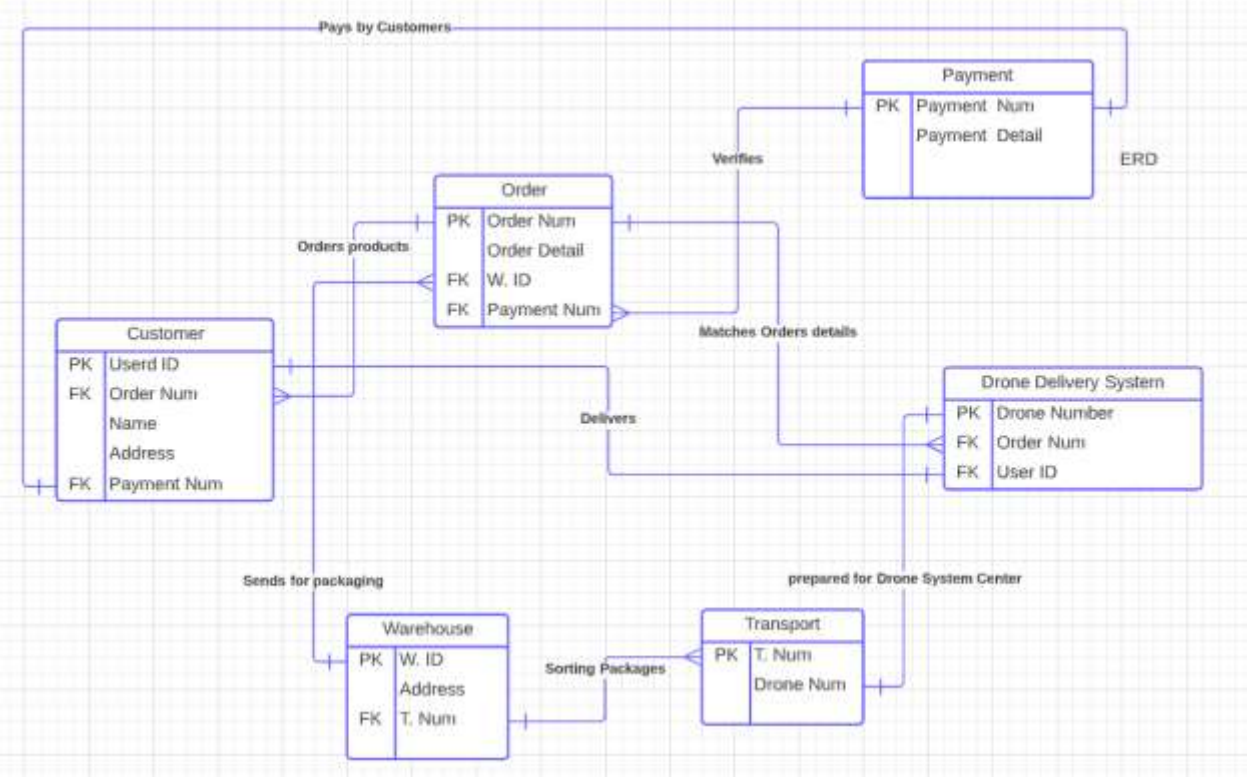


Fig. 9 – ERD showing the different tables used for this system

6.2 Network Model

a. Network topology

As you can see on Fig. 10, one way to achieve drone deliveries would be to rely on third-party internet service providers to communicate between the drones and a central control server using the Internet. For this, the drones would be equipped with a transmitter and receiver using radio frequency to connect to the Internet via cellular towers. This option offers Amazon the ability to locate and communicate with its drone fleet on real time with an already existing infrastructure, however it can prove costly and less secured than other options.

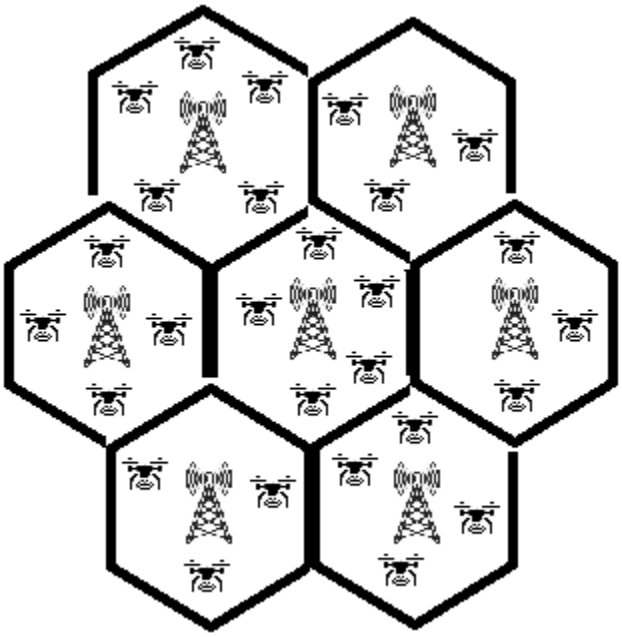


Fig. 10 – Cellular network topology with hexagonal coverage areas, cellular towers, and drones

Another option would be to use a peer-to-peer network infrastructure such as the one offered by the third-party provider, Helium. These networks use peer-to-peer reward systems that encourage individuals to create and maintain nodes, which can prove less costly. The topology of such network would look like that shown in Fig. 10, with the only difference being that cellular towers are replaced by individual devices placed in peers' homes that are equipped with radio frequency transmitters and receivers. These devices are then connected to the Internet through the peers' internet service provider. This option would again allow Amazon to operate drones in real time, but it would rely on a third party for security.

Finally, the last option would be to create in-house infrastructure to support the drone delivery service. To do this, Amazon would need to have central control systems placed among different locations within a city to avoid signal loss for their drones. This could be done again

using radio frequency transmitters and receivers in the drones and central control centers. The main advantage of such system would be having absolute in-house control over the whole system, including security. However, this would come at the cost of additional maintenance costs and initial implementation costs.

b. Network model

As you can see in Fig. 11, all drones within the fleet would be equipped with radio frequency transmitters and receivers to communicate with cellular towers or peer-to-peer/in-house devices. The latter would communicate with a central control server via the Internet after packets get accepted or rejected by a firewall. The server would then communicate with individual clients that use a control app or software for the drones. Any communication from the clients would then be transmitted backwards through the network until it reaches the necessary Drone's receiver. In addition, both the drones and the central control server should encrypt the information intended to be transmitted and use keys or certificates to ensure access to the network is limited and protected.

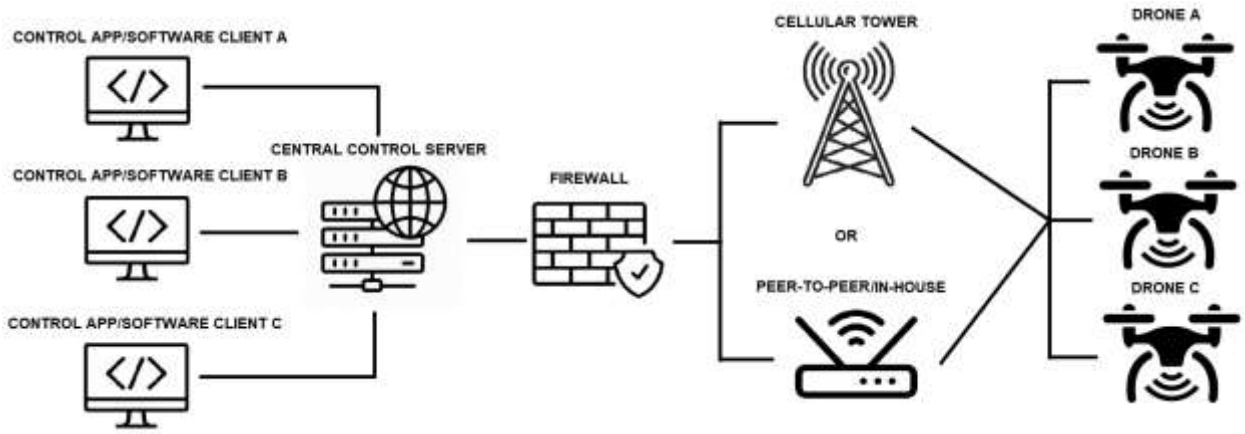


Fig. 11 – Drone delivery system's network model

6.3 Application Development

a. Content of the application

The navigation system mainly works by the GPS, so it can be an application based on GPS and send the accurate location every 10-15 seconds. It assists from different areas: First, it sends signals of the taken path to customers and the Control center simultaneously; That is to say, they track their packages by using the system. Moreover, the operator can find the suitable path before and during flight by using GPS. For instance, sending information about air traffic or harsh weather can help Drones have a safe flight or use alternative paths. It also can use signal to memorize the best path for movement. Finally, it is pretty practical for emergency circumstances; when the Drone is damaged or stolen, the Control Center can find the location or navigate it manually.

b. Workflow

GPS satellites in Earth orbit send out a unique signal and orbital data that GPS devices can decode and calculate the accurate location. GPS uses this information to determine a user's location. The receiver can identify a user's position and display it electronically to measure distances with distance measurements. Both Drone and Control centers have a receiver, and the sender can have signals and get information about the situation. Then signals are shown in the application, and customers can access the Drone's location via the Internet. Here is a simple diagram of how a GPS works in Drones.

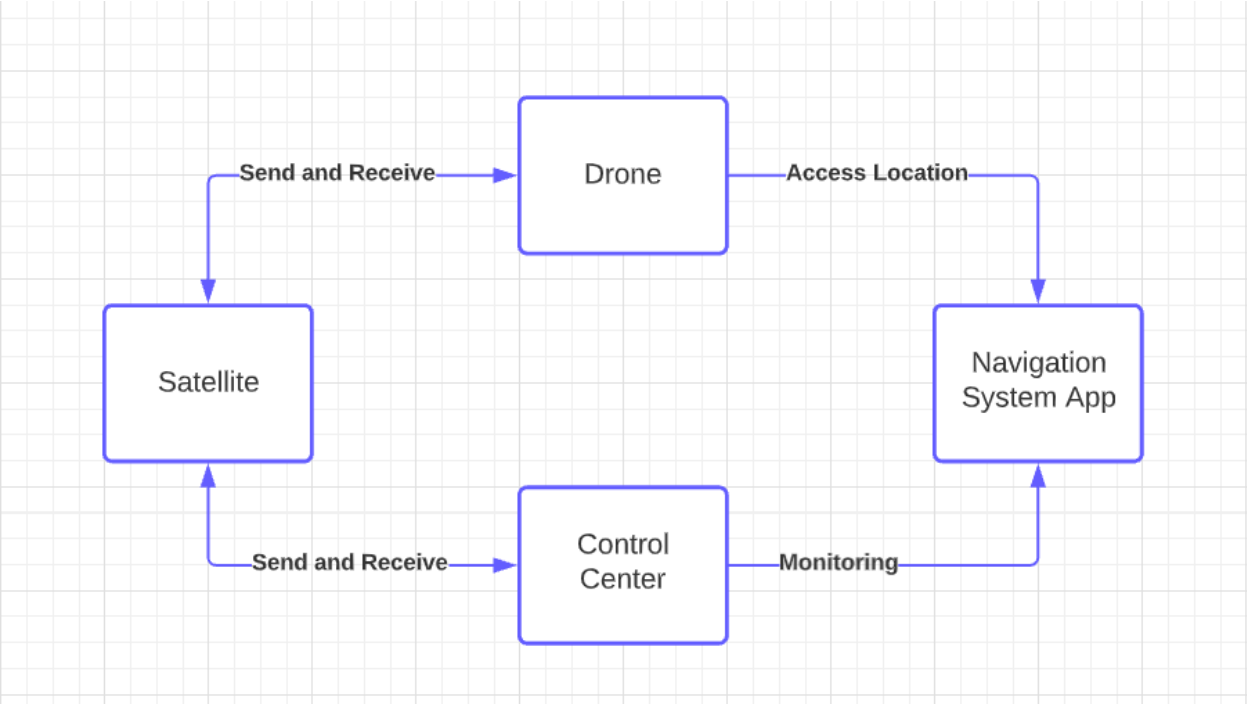


Fig. 12 – GPS navigation workflow

c. User interfaces

The Navigation System software for the Drone is similar to the Waze application, so it can be easy to use. Customers mostly seem not to have any specific problems while using it. The structure and working system have no main differences.

An additional feature for this application could be real time drone tracking. Customers would be able to monitor exactly where their package is and how long it will take to reach its destination. This system could have an alert or notification for delivery, and it would show the path to delivery the Drone is taking in a similar fashion to Uber's application tracking of drivers.

Finally, the drone system's last feature would be a control system for customers to help the drone land. This feature would only be available if needed during a small-time interval to

secure a safe landing. Also, the amount of control given to the customer would be limited to avoid equipment damage.

7. Management System Implementation Plan

a. Application development tasks

The analysis step is where numerous data is collected relating to the basics of drone delivery systems, and processed items are examined, the pros and cons of a drone, how a drone can carry a product, the weather condition analysis, movement path analysis, etc. Analysts also need correlated data to accurately analyze how, when, and why Amazon requires a new system implemented on its own delivery system.

The criteria will be broken down further during the design phase to anticipate the project's schedule and estimate the degree of effort and resources required. Designing different methods with various drones, and maybe analyzing the paths that guarantee the Drone will be safe during flight are two activities that could be done at this stage. Any special designs and workflows for the application should also be identified at this phase. Accurate data and categorization applied by analysts is also required in this step.

User notification, user training (in some cases), hardware and software installation, and integration into everyday work activities are all part of the implementation process. This phase continues until the conclusion is reached, at which point the testing phase begins.

b. Testing plan

The testing plan should consider what to test and, what not to test, how and who will do tests? What is the test environment, and what makes it compatible with a real flight area? What are the resources and test techniques? What are the risks a user or IT staff will face, and what should they do to avoid potential hazards?

The main tests for the new drone delivery system are listed below:

- Testing air traffic, especially in big cities.
- Testing the path drones take to find their destination: this test has two-part, one is autonomously, and the other is done while the drone's GPS system is activated.
- Testing the load drones will undergo while carrying products for a certain period.
- Testing battery performance as the battery is the heaviest part of a drone.
- Testing for possible package damage during delivery.
- Testing for systems that detect obstacles in the flying path of drones.
- Motion – speed and reaction testing of drones.
- Testing flight areas to ensure no-fly zones and mountainous areas with severe weather conditions are avoided.
- Testing for the optimal number of drones needed at each depot/station.
- Testing for receiving and sending signals by navigation software

- Testing software for security in emergency circumstances, finding GPS, delivery application

- Testing operating system of the drone, syncing software and hardware, digital compass to find the path.

- Testing software in terms of techniques, coding, usability, efficiency, affordability

c. Training plan

Tests-related staff should be tasked with preparing their aircraft prior to flight, loading the packages, delivering the packages, and returning safely. After finding the problems while testing, the next phase would be the training phase. When failing a test, it is required to train and improve the system. In Amazon's last-mile drone delivery system, three groups of people should be trained.

First, the technical staff, who focus on programming and mechanical parts of the system. Training can involve implementing a new part, improving the product, or training staff to increment knowledge.

Second, the drone navigation system may need to navigate through paths several times to recognize existing obstacles. The trainees would be IT staff or Drone operators in the control center.

Moreover third, drone operators are trained to understand how to work with drones, how drones work, how products should be placed inside delivery boxes for drones, how drone navigation is implemented, what they should do in emergencies such as package damage, etc.

d. System changeover plan

Amazon should evaluate the results and the fixed problems and take trained employees in this stage. At the same time, Amazon needs to consider system changeover methods and what should be the best decision for the company. The preferred method for Amazon is parallel operation, as it is almost impossible to set aside other last-mile delivery options. After gaining the required qualifications and improving the drone delivery system defects, including limited weight drones can carry, Amazon can use drones for most deliveries. Prior to that, the Amazon drone delivery system can facilitate this journey. The drone delivery system still cannot completely replace by the other last-mile delivery methods, including Amazon vans and third-party services such as USPS, UPS and FedEx.

8. Managing System Support and Security

a. User support

The main users of the drone system would be Amazon's operators and customers. The customer side can be easily implemented by creating additional options within the already existing Amazon's website and applications. The employees, on the other hand, would need to interact with new systems. To become familiar with the new applications and features, the IT department or the developers of the system should also create a user training package to offer employees the guidance they may need when interacting with the drone's system.

Also, as an additional user support system, a help or service desk with the most knowledgeable employees could be set up for other employees to submit tickets and get solutions to any problem that may arise. This system could be developed with a ticket submission program

where employees can allocate the urgency of the issue based on a numerical scale (for example from 1 to 5, 1 being the most urgent).

Another option would be to outsource user support. Offshore call centers can prove to be very productive and cheaper than other options. However, tech support quality should be encouraged to remain high, as employees and customers may become frustrated with this service otherwise.

b. Maintenance management

i. Plan

The system maintenance should be managed by a maintenance team. Within this team there will be a system administrator, system analysts, and programmers. The system administrator will oversee managing the network as well as the control server and control terminals that provide the necessary infrastructure for the Drone's system. The systems analysts will have the role of monitoring the systems that support the Drone's system to find the source of any possible problems or inefficiencies that they present. Finally, programmers will be needed to develop, maintain, and update the applications that are needed to interact with and use the systems.

ii. How to implement maintenance plan

As mentioned previously, drone operators will be able to upload maintenance requests via a ticket submission system. When a ticket is submitted, a request will be created with a unique identifier (ID) and an automatic email will be sent to the operator to notify the receival of the request. When the operator fills the questionnaire to submit the request, he will be prompted

to establish a priority for this issue in a scale from 1 to 5. The requests then will be available for the maintenance team through software. This software will filter requests according to a combination of weights between their priority within the priority scale and their time of submission. The highest priority issues will come on top while the lowest ones will appear at the bottom.

The maintenance team will be able to look at a dashboard with all pending maintenance requests with color and numerical indicators for priority. The role of each individual employee within this team will be to look at these issues and initiate steps towards their solution. Once an employee presses the button to initiate work on the problem, its ownership will be personally assigned to him/her with an identifier and an automatic email will be sent to the operator who submitted the request with this information. When the issue is resolved, the maintenance employee will be required to press another button to finish the maintenance request and provide a brief description of how the problem was solved. Then, the system will send a final, automatic email to the operator who submitted the request stating the issue has been solved.

Naturally, as these systems develop over time, there will be software bugs that need fixing. To deal with this, the programmers will have to use configuration management solutions. The main reason for this would be to control changes and keep track of version control. It is very important to test new versions before they get pushed as well as keeping prior versions archived in case a newer version fails.

c. Security

i. Overview

The systems that support Amazon's drone delivery system should include security. The most important aspects of security in this case are physical, network, and user security. Physical security would include drones' security during deliveries as well as storage facility security. Network security would include security in the systems that support communication between the drones, the central control server, and the control terminals. And user security would include managing user accounts and privileges to ensure only approved users can manipulate the system.

ii. Plan

To tackle physical security, Amazon should equip drones with cameras that send video footage on real time to a central server where it is stored. By doing this, drones would be constantly recording their surroundings from different points of view to ensure their safety. If a perpetrator attack one of the drones, the recorded footage could be used to prosecute him/her. Additionally, the storage facility where drones land and charge overnight should have cameras installed and security guards should be hired to make sure potential risks and losses are diminished.

For network security, Amazon should focus on developing a system that uses firewalls and possibly third-party software to disable possible, incoming attacks such as viruses. Since Amazon Web Services is already one of the main service providers for cloud storage and services, Amazon could reuse this infrastructure and the information systems already established to support the drone system. Another option would be to create a whole new system equipped

with a firewall to detect and stop unwanted, incoming packets. In addition, Amazon could use third-party software to detect and quarantine unwanted requests.

Finally, Amazon should allocate some resources towards developing user security and user accounts policies. The focus of this area would deal with employees' use of the systems put in place to support the drone system. To do this, Amazon should set up a team to monitor and oversee user accounts and privileges to ensure old, unused accounts are constantly being deleted. Also, another big factor in user security would be employee training. Employees should be required to pass training courses regularly. By doing this, Amazon would make sure employees are constantly up to date with the latest updates in technology as well as policies being implemented within the company for the drone system.

9. Conclusions

While the task of designing and implementing a drone delivery system for last-mile delivery can seem challenging and may need a substantial initial investment of resources, we believe doing so could prove very beneficial for Amazon in the long-term. The initial costs of this implementation can be incurred to diminish the reliance on third-party services and to increase delivery efficiency. This can lead to higher customer satisfaction that can lead to more sales, which translate into more revenues. Furthermore, as Amazon already did with cloud services, extra availability of inactive drones could be leased for third-party usage, which could create an additional revenue stream.

a. Final SWOT analysis

For the final SWOT analysis after the drone system implementation, we emphasized additions using the blue color, and crossed the statements that were no longer valid.

Strengths

- Competitive, fast delivery
- Automation in distribution centers
- High investing in research and development of new technologies
- Implementation of proprietary, new technology
- Various delivery systems
- High stipend (double than competitors)
- In-house drone delivery system and infrastructure
- Capacity to deliver small packages in under 30 minutes

Weaknesses

- ~~High workload needed to fulfill 1-day shipments~~
- Stringent rules and policies employees must follow that makes them unsatisfied
- Dangerous working conditions for employees, especially pilots (schedule requirements)
- Weaknesses in drones' systems, such as transportation problem in harsh weather condition

Opportunities

- Providing programs or services to employees to improve their happiness
- Recruiting more employees to divide the workload

- Facilitating policies to make them more flexible for employees to cope with workload
- Continue embracing new areas of technology that can make shipments faster
- Investing in R&D to continue development of newer, better versions of drone system

Threats

- Competition from other stores such as Walmart and Target in fast delivery
- Local stores' delivery systems
- Increased amount of employees' protests due to lack of employee satisfaction (bad brand reputation)
- Additional app-based delivery systems for all kinds of stores (Uber, Instacart, etc.)
- Competitors copying drone delivery methods

10. Recommendations

Our main recommendations for the future would be to further develop and improve the systems we discussed throughout this report as new user requirements may arise over time. The focus should be improving drone efficiency by investing in research and development related to drones' own weight, capacity to carry more weight, movement speed with better aerodynamics, and battery life.

Furthermore, Amazon should improve the infrastructure that supports the drone system over time. This could include adding new features to the control application and the real-time metrics application, improving the user interfaces according to users' feedback to make them more user friendly, and improving the control centers with new technologies as they develop.

References

Amazon Delivery Driver Interview Questions & Answers. *CareerVidz*. Web. Extracted from: https://www.youtube.com/watch?v=TwSJbWRRoKM

Amazon Organizational Chart. *The Org*. Web. Extracted from: https://theorg.com/org/amazon/org-chart

Delivery and Logistics. *Amazon*. Web. Extracted from: https://www.aboutamazon.com/what-we-do/delivery-logistics

Demonstration Of Visual Navigation System For Autonomous Drones. *Everdrone*. Web. Extracted from: https://www.youtube.com/watch?v=e_aGS1pEDIw

Dolan, S. (2022). The Challenges Of Last Mile Delivery Logistics And The Tech Solutions Cutting Costs In The Final Mile. *Business Insider*. Web. Extracted from: https://www.businessinsider.com/last-mile-delivery-shipping-explained

Drone Testing Checklist. *Process.st*. Web. Extracted from: https://www.process.st/checklist/drone-testing-checklist/

How Amazon Delivers On One-Day Shipping. *CNBC*. Web. Extracted from: https://www.youtube.com/watch?v=Yiafb0-gqF4

How Amazon Drone Delivery Will Work. *Tech Vision*. Web. Extracted from: https://www.youtube.com/watch?v=mzhvR4wm__M

How Amazon's Super-Complex Shipping System Works. *Wendover Productions*. Web. Extracted from: https://www.youtube.com/watch?v=2qanMpnYsjk

How Drones Could Change The Shipping Industry. *CNBC*. Web. Extracted from: https://www.youtube.com/watch?v=tXjTQuxC5_g

Is Drone Delivery Practical? *Interesting Engineering.* Web. Extracted from: https://www.youtube.com/watch?v=qjnRxdfoP2U

Planning And Navigation For Drone Flight. *Mitcsail.* Web. Extracted from: https://www.youtube.com/watch?v=dpNV-zmjvkc

Top 5 Reasons Why People Quit Being An Amazon Delivery Driver. *Victor Fuentes*. Web. Extracted from: https://www.youtube.com/watch?v=I_b30z4a5AU

Wang, Y., Zhang, D., Liu, Q., Shen, F., and Lee, L.H. (2016). Towards Enhancing The Last-Mile Delivery: An Effective Crowd-Tasking Model With Scalable Solutions. *Transportation Research Part E: Logistics and Transportation Review*, Pages 279-293. Web. Extracted from: https://www.sciencedirect.com/science/article/pii/S1366554516300783?via%3Dihub

What Are the Rules To Fly Your Drone In 2022? *Pilot Institute.* Web. Extracted from: https://www.youtube.com/watch?v=oyE2x9B0CVA

What Is GPS? *Garmin*. Web. Extracted from: https://www.garmin.com/en-US/aboutgps/

Wilke, J. (2019). A Drone Program Taking Flight. *Amazon.* Web. Extracted from: https://www.aboutamazon.com/news/transportation/a-drone-program-taking-flight