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Blood Delivery by Drones: A Case Study on Zipline

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ABSTRACT: Countries in Africa are one of the most densely populated countries and with the presence of substandard and inefficient infrastructures in the world. Because of the bad infrastructure, the hospitals face difficulties in obtaining medical supplies required by the patients at a particular time and in a particular quantity. Due to this, many people die even if they encounter easily curable diseases. Zipline, an American company is solving this problem by using fully automated high speed drones in an East African nation, Rwanda. This paper discusses about the origination of the company along with their process of delivery. The paper talks about supply chain of Zipline along with the innovation done by them to ensure safe and faster deliveries. Future plans along with challenges that Zipline faces is also discussed. As the company's Founder and CEO puts it “Zipline isn't a drone company, it's a healthcare logistics company.”

KEYWORDS: Drone delivery, Zipline, Supply chain management, blood delivery.

I. INTRODUCTION

A modern drone, also known as an Unmanned Aerial Vehicle (UAV), was first introduced in 2006 by US Customs and Border Protection Agency to protect the US and Mexico border. (1) They were originally used for military applications, but today drones are extensively used in commercial, scientific, agricultural and many other activities. Now, because of the changing scenario, the commercial and civilian usage of drones exceeds the military usage. Commercial activities like surveillance, aerial photography, disaster management, crop monitoring, product deliveries and many more emerging applications are increasingly becoming popular.

For instance, in 2012, following the hurricane in Haiti, drones were used for mapping and damage control by comparing the before and after images of the flooded areas through generated images (2). They were also used to deliver medicines and other supplies in the affected areas. Deliveries of medications, vaccines and blood through drones in locations with difficult access is becoming very crucial. These locations are inaccessible due to the lack of proper infrastructure, poor transportation facilities, traffic congestion or blocked roads. Since, a drone can fly over all the limitations which a regular means of transport hold, many organizations have started using them to deliver the supplies. The leading companies which are involved in the delivery of medicinal supplies include DHL Parcel, Matternet, Flirtey, Swoop Aero, Wingcopter, Hiro, Wing and the list is topped by Zipline. (3) This paper will focus on the operations of Zipline and how this company is solving problems related to the supply chain of blood in Africa.

Zipline is an American company founded by Keller Rinaudo, Keenan Wyrobek and William Hetzler in 2014. It designs the drones and operate them in Africa in order to deliver medical products. The further sections of the paper talks about problems in the supply chain in Africa, emergence and operations of Zipline, supply chain functions of Zipline, challenges faced by the company, impacts and challenges of Zipline and finally, the future plans of the company.

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II. ORIGINATION OF ZIPLINE

It all started with a database of deaths. When company's co-founder CEO Keller Rinaudo went on a trip to Tanzania. He had a meeting with a public healthcare researcher Zachary Mtema who had built a messaging system. This system helped doctors identify the areas which possess a lack of essential supplies of medicines and blood which led to high number of diseases and deaths among people. Not only in Tanzania, the situation in whole Africa was the same. Severe blood shortages were faced by many areas in Africa which majorly affected the women and children of the countries in Africa.

Of the 20 countries with the highest maternal death rates, 19 are in sub-Saharan Africa where the risk of maternal death is 1 in 16, compared with 1 in 2800 in rich countries. Severe bleeding during delivery or after childbirth contributes to upto 44% of maternal deaths. (6) In Africa, the maternal mortality rate is the worst in the world. Hospitals are so poor that they cannot afford electricity for a refrigerated blood bank. (5) Also, the World Health Organization statistics reveal that in Africa, at least 285,000 children under the age of 5 years died of severe anemia caused by malaria and malnutrition. (4) Apart from the inadequate supply of blood, Africa also has other issues like; dependability on unsafe donors due to lack of supply at the right time and place; increased pressure to issue the un-tested blood which increases the risk of HIV and hepatitis; lack of proper infrastructure, in fact, only one-third of Africans live within 2 kilometers of a road that functions year-round (8); delays in delivery by regular mode of transport and uncertain whether conditions; all adds up to the inefficient and delayed delivery of medical supplies. In Rwanda, small hospitals store a small quantity of blood and when they are out of stocks, they refer big hospitals to the patients. Otherwise, they have to bring the stock from one of the Regional Centres for Blood Transfusion which would take a huge number of hours. Above all of that, Rwanda has poor drainage system and the roads get blocked during the rainy season as only 25% of the roads are paved. (9)

After looking at a never ending spreadsheet of dying patients, Keller with his old roommate Will, decided to make an effective delivery system which would ensure that the doctors have access to the right blood type at the exact time required. (5) Hence, to improve the condition of medical supply chain majorly in disconnected areas, Keller, Keenan and William, in contract with the Government of Rwanda, launched a healthcare logistics startup named Zipline.

Zipline is headquartered in California, USA started in 2014. The company uses autonomous electric drones to deliver medicines to the hospitals, clinics and health centers as and when demanded. This helped them to become the world's first automated blood delivery system operating at nation-wide scale in partnership with UPS foundation and Gavi. The supply chain functions, like, procurement, warehousing, distribution, etc., performed by Zipline plays a crucial role in its success. The just-in-time delivery of medical supplies by the firm has helped the country to improve its medical supply chain.

III. OPERATIONS OF ZIPLINE

In very simple terms, here is how they work. A doctor places an order for blood or vaccines to Zipline distribution center through message, email or call. After receiving the order, workers at Zipline takes the blood from the refrigerator, wraps it with insulated paper and packs it in an insulated cardboard box. The box is loaded in the drone and the drone is kept on the launcher. Then the wings are attached to the drone followed by the battery and finally, the drone is launched to the destination. Their route is tracked and can be changed with a tablet app. (18) Upon reaching the destination, it drops the supplies with the help of a parachute and then it returns to the distribution center.

The company follows a series of activities and steps apart from its basic operation process, before the blood or the vaccines are delivered at the venue. It is very crucial for the company to follow each step efficiently and effectively, in order to respond to the urgent needs faster, increase the chances of survival of the patients and reduce the number of deaths due to lack of blood. The faster the drones respond to the demand, the chances of survival of a patient increases to 80% as compared to only 8% if traditional modes of transportation are used for delivery. (7) The further sections of the paper talks about the supply chain functions performed by the company to manage all the operations and deliver the supplies just-in-time. Not only Zipline, any company's success is substantially dependent on the performance of the supply chain functions.

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IV. SUPPLY CHAIN FUNCTIONS OF ZIPLINE

Before Zipline, hospitals used paper forms to maintain the records of orders placed, usage, outcomes of transfusion, etc. The blood was distributed in the hospitals based upon the instincts of the staff using the data of current supply, previous demands by hospitals and wastage of blood. The staff were expected to maintain online records but due to lack of computers, internet and poor connectivity in major areas, they were unable to do so, because of which, they faced difficulty in forecasting the demands.

Only because of Zipline's digitized supply chain system, the company became more responsive to the individual's demand and could satisfy real-time needs of the patients. After Zipline, the orders could be placed using a single WhatsApp message, SMS and even a toll-free phone call. It is working with the Ministry of Health of Rwanda to determine the order size for each hospital. It uses a tracking software which ensure cent percent visibility and blood distribution based on the need. The government also has access to the electronic database developed by the company to track the demand, supply and real-time usage of the blood. (9)

4.1 Procurement

Overall, Rwanda collects 60,000-80,000 units of blood every year which is stored in National Center for Blood Transfusion. More than 65% of the blood supply is delivered outside Kigali by Zipline. (17). Zipline sources all the blood supplies from National Center for Blood Transfusion. (12) Also, every part of Zipline's drone is manufactured in-house. Their manufacturing unit for drone is established in California and manufacturing unit of the batteries is in Rwanda. (16) This gives employment to local population of Rwanda.

4.2 Warehousing

Zipline has distribution centers from where the drones are launched. These centers also perform the function of storage and warehousing of blood and the drones. Previously, the hospitals used to store blood and other related products with them for emergency. As blood plasma and platelets have a short shelf life they get wasted in hospitals and health centers around the world. This was an expensive waste of medical supplies and taxpayers money. Because of centralized warehousing of blood all around the country and with the help of just-in-time delivery of blood and related products, Rwanda became the first country to not waste even a single unit of blood in the year 2017 (12). Zipline has 15 drones in each distribution facility. Zipline currently owns 6 distribution centers in Africa. 2 of the centers are located in Rwanda and 4 in Ghana. (15).

4.3 Delivery

When we think of drones, we think of quad copters. Zipline uses planes instead of quad copters as quad copters uses far more energy to fly and just can't manage the range from batteries necessary to travel longer distances and also, they are relatively slow. On an average, one delivery is completed in 15-45 minutes and it takes 5-7 minutes to launch the drone after receiving the order and there are approx. 500 deliveries per day. As of now, These planes cruise at 100 kmph with a range of over 160 km allowing the drone an 80 km zone around the location. When the drone reaches the delivery location, it descends to 30 feet to deliver the packet. The weight capacity per flight is 1.8 kg. The drones are designed uniquely in order to reduce the weight of the plane and increase the distance travelled per flight. Zipline communicates directly with Rwanda Central Air Traffic Control in the nation's capital, Kigali airport. The company charges between \$15 and \$45 (£11.60 to £34.85) per delivery, from the government, depending on product weight, urgency and distance. (27)

V. INNOVATIONS TO COUNTER CHALLENGES FACED BY ZIPLINE

The company implemented some innovations and changes in order to be more efficient and reduce the time taken for delivery. To manage and operate the drones, one has to take a lot of measures in order to ensure safety. As a result of this focus of Zipline on safety, it had no accidents which caused any injury since they started their service in October

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2016. The first simple thing that Zipline did, in order to ensure safety, was to keep two pieces of some of the parts of the drone. It has two motors while it uses only one during flight and two of every actuator. If somehow, both the pieces of any parts gets damaged, the plane will automatically deploy a parachute allowing it to softly touch down back to earth. This procedure can also be initiated by the control tower if a command from the airspace authority is received. There are many more innovations and changes did by Zipline which helped the company to grow and become successful. (13)

Firstly, it removed the GPS circuit and replaced it with the detachable battery which itself contained GPS, because the GPS took time to connect to the satellite and this process caused a delay in the delivery of supplies This step reduced the time taken to launch the drone from 10-15 minutes. Not only GPS, the battery also stores the data from all the sensors onboard like speed of the drone, altitude, directions, etc. The moment the battery is hooked up to charge at the charging station, the data begins to pour into Zipline servers which serves as a great asset to the company.

Secondly, the pre-flight check is done with a mobile app that connects to the launcher system. The launch technicians simply point the phone at the QR codes at each control surface, which sends a message to the plane to actuate the control surface. The phone then use Liza's computer vision algorithm to make a pass or a fail judgment for each control surface. Once the plane is ready and assembled on the launcher, it accelerates the plane to 100 kmph cruising speed in just 0.3 second and the drone is launched.

Thirdly, in order to avoid having to land at the destination, the plane simply drops the supplies in an insulated cardboard box, with a simple parachute which after taking the supplies can be disposed. Or, in other words, the clinics do not require any additional infrastructure to sign up as a client of the distribution center. And after the delivery of the supplies, the drone returns to the distribution center.

Next, the procedure to land the drone with no pilot is even more incredible. There is a small hook at the end of the tail which will grab the wire strung between the two actuated arms on either side of the capture system. Arms are raised up at the last moment to catch the hook. The plane constantly communicates its location in 3-D space. The radio receivers next to the platform, allows the wire to stay out of the way until the last moment minimizing any risk of collision with the wire. The capture system misses about 10% of the time but the plane is programmed to immediately detect a miss and throttle up its engines to gain altitude and make another pass.

The separable components of the drone helps the staff to lift it easily and also, if any problem is found with the wings or any other part during the pre-flightcheck, they are simply swapped out without having to start the entire assembly process over again.

The inner skeleton is entirely made of lightweight carbon fiber composites which is then covered in a light weight foam shell which is easy to replace if it gets damaged. As a result, the entire fuselage weighs just 6.4 kg, the wings weigh 2 kg with the wingspan of 3 meters. Batteries (lithium ion batteries with a total capacity of 1.2 kilowatt hours) are the heaviest part of the aircraft making up half of the total weight of the aircraft, weighing a total of 10 kg.

Managing many UAVs in one airspace, who don't have any way to communicate among themselves is a challenge faced by every drone operator. Zipline has developed and patented the software solution which allows multiple UAVs, to detect other UAVs in an airspace. (Patent Number 9997080). There are several patents assigned to Zipline (8 in total). (14)

VI. REASONS FOR SELECTING RWANDA

Out of all the countries present in the world, what was the reason behind starting the operations in a country like Rwanda which is one among the smallest countries in Africa. First of all, being a small country, it has small focused government and along with that, the different ministries are really investing heavily in technology and education. Also, countries with urgent healthcare needs, such as Rwanda, are more likely to quickly overcome regulatory hurdles.

Second, unique set of challenges in terms of blood and other medical products exists in Rwanda. Rwanda is called a land of 1000 hills. Therefore, it is a hard place to access medical products immediately when urgently required. The

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drones can deliver the supplies irrespective of the time, traffic or weather of the day. There is a lack of investment in infrastructure in Rwanda. The maintenance costs of the country's roads is very high as the roads get destroyed due to heavy rainfalls and landslides. Even if they try to maintain the roads, their budget does not allow them to do so. (23)

They have simple air space in Rwanda. They have a small team of Civil Aviation Authority who can make decisions quickly. They have clear communication protocol with the Civil Aviation, they can track the drones in real time. They can command Zipline if they need to shift or remove the drone from the airspace. Lastly, every citizen in Rwanda is only 15 minutes away from Zipline if they need any essential medical products and because Rwanda has a small land area and is densely populated, a single drone launch site can serve a large number of its people.(21)

VII. IMPACTS OF ZIPLINE

The first person in the world to receive a blood transfusion through blood delivered by drone was a two year old, Ghislane Ihimbazwe, which saved her life. Zipline impacted the Rwandan economy positively which is proved by the facts listed in this section. Zipline's drones have flown more than 1 million km across Rwanda and has made over 13,000 deliveries of red blood cells, platelets and plasma, a third of which have been emergencies, to more than 12 hospitals in Rwanda. (26) Zipline now delivers more than 170 different vaccines, blood products and medications to 2,500 health facilities. Its reach now serves nearly 22 million people. Through Zipline, the amount of medical waste generated was reduced significantly as Rwanda has been able to dramatically decrease inventory at hospitals (24)

VIII. CHALLENGES FACED BY ZIPLINE

In spite of the success of the company in Rwanda, it still faces many challenges and critiques. Some argue that, if the amount invested by the government in Zipline, was instead invested for the upgradation of the country's infrastructure, it would have been better. Better roads would not only increase the efficiency of transportation but also, create jobs and combat the growing epidemic of youth unemployment across the continent.(10)

Also, sometimes the company faces difficulty in the delivery of supplies in Rwanda, it being a hilly area. Due to this, it sometimes become difficult to determine the exact drop location.

The drones can only carry a limited amount of weight in one flight which restricts the company to smaller and lighter items. Hence, heavy or large items still cannot be delivered by the drones. (25)

Apart from this, the company also faces some general challenges like, there is a difficulty in predicting the demand, which sometimes may lead to less supply of medical supplies than required by the people. There could be some fraudulent activities and people could shoot the drones which would lead to increased costs and failure to deliver the supply within limited time-frame as promised.

IX. FUTURE PLANS OF ZIPLINE

Backed by a number of investors, Zipline is planning to expand its services in Ghana, Tanzania and the US. The Zipline Ghana deal is worth 12 million dollars and it is working with North Carolina as a part of FAA's UAS Integration Pilot Program. (20) In Ghana, the company will make on-demand, emergency deliveries of 148 different vaccines, blood products and medications and will operate 24 hours a day, seven days a week from four distribution centers. Each center will be equipped with 30 drones and deliver to 2,000 health facilities, serving 12 million people across the country. Each Zipline distribution center has the capacity to make up to 500 flights each day. (26) Because that country is far bigger, Zipline plans to set up five drone-launching bases that will reach 20% of the population (21)

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X. CONCLUSION

Africa is one of the developing nations of the world. Most of the countries in Africa are densely populated and lack basic infrastructure facilities. Because of lack of infrastructure facilities and lack of funds to develop the same, they face huge problems in transportation. One major problem faced by the countries in Africa was the number of women and children deaths due to inaccessibility of blood and other vaccines. Looking to this problem, Zipline, in partnership with the government of Rwanda, launched its operations in Rwanda and are planning to expand in Ghana and Tanzania. It is a US based autonomous drone delivery startup, launched in 2014 and aims to provide instant access to vital medical supplies to every human on earth. They are providing 13 Million people with urgent medicines.

Zipline uses drones to deliver blood and other vaccines to many parts of Rwanda. It saves lives of the people of the country who do not have immediate access to the medications by delivery in almost 30 minutes. In order to deliver the supplies more efficiently and with less time, it implemented many innovative technologies and methods in its operations and also in the supply chain activities. These innovations positively impacted a large number of people in the country by saving their lives and Zipline contributed in reducing the mortality rates in Rwanda.

Further studies can be conducted on how Zipline's model can be adopted by different countries in order to improve their healthcare supply chain.

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