**English 210**

**Semester: Spring 2020**

**Problem Statement**

# Transfuron


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**"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work"**

## Introduction:

The total population in Qatar witnessed a dramatic increase from 1.78 million in 2010 to 2.77 million in 2020 [22]. With this dramatic increase came the big problem of traffic, which can delay medical care and blood transport. Many different problems occur during the process of transporting blood from one hospital to another. First of all, comes the problem of the time it takes to transport the blood. Most regular means of transportation often report unexpected delays which can cause serious problems to the patients that are in need of the blood. Unexpected delays could be caused by car accidents that lead to traffic.Therefore this project will focus on the problem of delay in delivering medical care, and more specifically, the transport of blood.

## Problem Statement:

The transportation of blood is the most complicated process out of the whole blood transfusion process [10]. Transfusion is the process of transferring blood from one person (donor) to the receiver (accepter) where the blood is taken through a narrow tube placed within a vein in your arm. Most medical transportation services opt for cars, but in larger geographical areas, using cars is not very efficient. That is why, many would think that a better idea would be to use planes or helicopters. But even using planes is not the most ideal option. This is because this means of transportation heavily depends on the variability of flight schedules. Many flights have specific timings and getting a flight ready needs a lot of time and planning ahead. Sometimes, blood shortages means that transportation services are needed immediately. Not only that, but flights can be quite expensive because airlines have to pay a ton of money for jet fuel. That and fees for things like fuel surcharges can make the whole process very costly. One gallon of fuel costs around $5.18, but for a flight that lasts around 1 hour, 3,600 gallons of fuel are needed. This makes it around $18648 per flight. But even with planes, unexpected delays happen and sometimes blood bags are forgotten or left behind. When blood is left for a long period of time (about 42 days if it's stored correctly or a few days if it's not) the viability of the blood can be poor and unacceptable for a transfusion patient. Blood usually had to be stored at temperatures between 2-6 degrees celsius in blood bank refrigerators, so keeping the same temperature and conditions while it is being carried by the drone should keep the blood usable.

Regarding the condition of the blood bags, the blood bags should be stored after collection between ±4°C ± 2°C [14]. So, the carrying box would be filled with ice packs and blood bags[18] Regular ice packs with gel are used in the transportation process. However, considering the usage of dry ice is possible because both types of ice can last up to 24 hours in a cooler [11]. But, dry ice goes straight from solid to gas, while regular ice dissolves into water depending on the flying time, and the climate conditions which may cause the temperature inside the container to increase This issue can be solved by using a container that is insulated and keeps the ice in its original state of matter as long as possible. But, this type of container might cause additional weight. Therefore, it affects the speed. Also, when ice melts into water it can affect the condition of the blood bags as the surrounding temperature would rise up due to that. Another thing to consider is the ice temperature, the dry ice temperature can drop

below 0°C to -78.5°C [15]. While the regular ice also drops below 0°C and reaches almost -20 °C where we can see a difference between dry and regular ice [5]. That is why the dry ice is not used for blood transportation, where a temperature this low will spoil the blood bags.

Blood bags vary in size and quantity, there are the single, double, triple, quadruple and the penta blood bag at which the size of each bag ranges from 100 ml to 450 ml [23]. Which can be converted to almost 0.5 kg minimum [19]. Not every patient needs the whole blood bag; some patients need certain blood components such as red cells, platelets, and plasma. The blood bag must be labeled with detailed information about the donor, time of donation, and the expiry date [23]. According to WHO (World Health Organization) there is a minimum performance specification for blood transport boxes. For example for a container carrying 1-4 litres (2 bags) the maximum weight is 6 Kg [12]. These information should help us in designing our blood delivery drone.

The drawbacks of not delivering blood on time, might increase the chance of throwing it away [29]. Delivering blood is a very risky and fragile process that needs to be done with the utmost care as the blood has to be kept in their special bags and at precise temperatures to keep the blood usable. This is the reason why it is important to find a better solution to deliver blood bags safely. Therefore, in this project we are aiming to improve the current blood delivering system and provide a better service for hospitals.

**Needs Analysis of Potential Users and Stakeholders:**

In Qatar, the main public hospital is Hamad General Hospital. Blood donations are only available at the blood center, which is part of Hamad General Hospital. Therefore, when any other private hospitals request additional blood, they have to get in contact with the blood center at Hamad. Hence, the blood bags can be distributed and become available in every certified hospital and clinic. In case, they ordered it from the blood center and have the correct storage equipment for it. In fact, the Blood Center is asking individuals to donate blood to help maintain a sufficient supply of blood for use. Consequently, an inadequate amount of blood could lead to distribution problems, and might cause shortage in certain blood types in some hospitals [24]. Most large hospitals, such as Hamad General Hospital, Women's Wellness and Research Center, Rumailah hospital, and the blood center, are located very close to each other. According to Google Maps, the distance between the Blood Center and Al-Emadi Hospital is around 15 minutes' drive in regular traffic, and it might take longer depending on the traffic. The same delivery would take a typical drone 6 minutes, regardless of the traffic. Therefore, a drone carrying a container could ease the way of transporting blood bags between the Bank Center and any other hospital in normal or urgent situations.

**Interview with Hamda Al-Naimi**

To get a better idea of the project that we will be working with, we decided to interview a member of a group that did their senior design project about something similar to what we are trying to do. Unfortunately, we were only able to interview one of the members as the other members were unavailable. The person who we interviewed is Hamda Al-Naimi, an Electrical and Computer Engineering graduate, class 2018. We asked her the following questions:

1) What inspired you to make the drone?
2) What went wrong/ obstacles and difficulties and how did you handle them ?
3) How was your experience?
4) We know that you were contacted by the Ministry of Transportation and communications regarding your medical drone. How will that help the drone delivery services in Qatar?
5) Future recommendations.

She told us that what inspired them the most to do this project was the fact that ambulances were way too slow and would take about 30 minutes to reach people sometimes. They might be a little faster in some areas but slower to reach others like, for example, Al-Khor and other places that are far from the city whereas a drone would only take about 2-3 minutes.

One of the problems that Hamda's group faced was the issue of the IP addresses of the Ooredoo modem that they were using not being the same as the drone's IP address. Because of this, they needed to obtain a static IP, but that process itself took them about 4 months, as she stated. But in the end, they still got it. Another complication that took place was obtaining a regulation so that their drone was registered and was allowed to be used as a medical drone.

After asking about their experience, we learned more about where they got their idea from. They got the idea after visiting QITCOM and looking at all the different drones that were available by Ooredoo. There were many different innovative types of drones including drones that even went underwater. This was what inspired the group to try working with something that includes drones and that was how they got the idea of using drones for medical uses. Hamda also says that this project was a great opportunity to meet people from different majors as she is an Electrical Engineering student but had three Mechanical Engineering students working with her on the project. Not only that, but Hamda's group won many awards for this project as it is the first of its kind here in Qatar and was even contacted by the Ministry of Transportation and Communications, MOI, Ministry of Defense, Hamad Hospital, Sidra Hospital, and many other places regarding this project. It was even on the news.

We also asked Hamda about future recommendations so that we can learn from her group's experience. She told us that a good idea would be to have charging stations for the drone, both for its modem and for the drone itself. She also suggested working with the 5G network rather than 4G since it is available with Ooredoo now and would reduce the chances of internet lagging when trying to track the location of the drone, and communicating with the user.

From this interview, we learned that

- Ambulances in Qatar can take up to 30 minutes to arrive at the scene of a medical incident.
- Using the new 5G network on the drone would be better than using the 4G one since the 4G one lost connectivity a few times
- Making sure to get permission to use the drone as early as possible by obtaining a regulation
- Making sure the I.P addresses of the modem and the drone are the same from the beginning and if not then obtaining a static I.P early because it took them about four months to get it.

**Interview with Dr. Yasser Al-Hamidi**

This was a more general interview concerning the drones to be used in this project. About which type of drone would offer more stability to keep the contents being transported undamaged: The multi-rotor design offers the best stability, it offers six degrees of freedom. The shape of the container being transported has to be aerodynamic and not a cuboid with sharp edges for better overall aerodynamics and therefore higher top speed, fuel efficiency ...etc.

Depending on the ranges, for something like organ transport electrical drones may not be enough. We need to take into consideration the weight of the organs and the container and the extra energy needed to carry the container. It seems that most drones can only carry very light loads of around a couple kilograms. Now we are using specialized drones but it seems that very few drones can carry loads of around 12.5kg ( see 'packaging safety' section) and even then their flight times will be cut in half and the range even more so as the top speed would decrease as well.

Modern battery technology does not provide satisfactory flight times for electrical drones carrying heavy loads. We may have to look at using other fuel such as petrol or maybe a hybrid ( e.g., petrol + battery).

He said that using drones to transport organs might not be feasible. Although it is possible it may be very inefficient and not necessarily solve any problems. As organs need to be in very specific conditions and drone technology may not be good enough. We might have to focus on transporting blood bags.

That is why we urgently need to research the distances between the hospitals required of the drones to fly. As that is the main factor determining what kind of drones we can use right now and if it is feasible to transport organs.

He suggested we figure out some type of system where the container and its contents are cooled passively as it flies. So, for example, the propellers might be used somehow to cool the container while the drone is flying.

He recommended that we research passive cooling and evaporative cooling(aka desert cooling). It's an energy-efficient cooling system. IT works by having air blow at a wet fabric-like material. This can be used to cool the contents of the container without spending any extra energy. The air resistance while flying will be used to cool the container.

Main points learned from this interview:

- General information about different potential drone types to consider and that the multi rotor design may be the most practical choice.
- It would be better for the flight efficiency of the drone to have the container be aerodynamic.

- Due to modern battery limitations relatively small electrical drones may not be able to practically transport organs. This led us to narrowing our scope to only transporting blood bags.
- He introduced us to a potential solution that would allow us to stay with our original idea by keeping the load relatively light. That would involve passive cooling to preserve the organs rather than relying on a large quantity of heavy cooling materials, but implementing this method was deemed to require a lot of work and we decided to narrow our scope and project rather than expanding it.

**Interview with medical students in weil cornell.**

This interview was conducted during the circumstances of the current quarantine that causes changes in our original plans of the team, having an interview with a medical professor, the interview was made with a medical (med classified) student to understand the medical standards of the transportation of blood. The following questions were asked.

1) What is the viability of blood?
2) What are the Conditions for the transportation of blood?

The most Conventional way of storing blood is when it is being put in a 4 degrees C environment, but that might result in rapid loss of viability for platelets if contained for a long period of time. An opposite relationship occurs, almost logarithmically, between the storage period and the efficiency of the blood, though this process is considered better than other existing techniques. While another procedure of blood storage is glycerol-freezing, that will result in a significant reduction of platelet survival. Within 3 hours of collection of the blood it is advised to infuse platelet transfusions inside the container.

At the present time there is no way to get to know which blood storage leads to the highest platelet survival rate, although all the forms are similar when compared at a short period of time. Although it should be noted that the platelet loss is higher when in a medium of no plasma, than if plasma was present.

<u>Most important points learned by the interview:</u>

1. Blood has two ways of storage:
    a) Glycerol-freezing method
    b) Storing at 4 degrees celsius medium
2. All methods of storage don't vary when occurring at a short period of time. This aids our idea of having the drone delivery faster and at a short time
3. It is advised for the best platelet survival to have the platelets in a plasma medium.

We believe that the success rate of this project should be fairly high due to the fact that something similar has been done before in Rwanda, East of Africa. Where people living in Muhanga which is a small town and they are in need of blood would drive 50 kilometer. Considering the condition of the roads it would take them almost an hour in order to reach Rwanda. So, a company called Zipline specialized in delivering medical supplies in areas with poor infrastructures decided to try using a drone for blood delivery. They have tested this method and they were able to reduce the trip time to 14 minutes [9].

## Design Constraints

From our primary and secondary research, we determined that the drone system must meet the following constraints.

- The drone must be able to travel from Hamad to any private hospital inside Qatar in less than 30 minutes.
- The drone must fly under 400 feet, and should be less than 25 Kg.

- **Potential model comparison** [3]-[4]-[6]-[7]-[8]

This table shows the different characteristics of each drone and its uses. The most important characteristics are the speed, flight time, and uses. Taking all these into consideration should help us find the right drone.

| Types | Pros | Cons | Uses | Price | Speed/ Payload | Flight Time (At full charge) |
|---|---|---|---|---|---|---|
| Multirotor (Figure.1) | -Easily accessible<br>-Ease of use<br>-Good camera control<br>-Can operate in a closed area | -Short flight<br>-Small payload capacity | -Aerial photography and video aerial inspection | 5k-65k | 50 km/h / Up to 4kg | ~25-30 min |
| Fixed Wing (Figure.2) | -Long endurance<br>-Large area coverage<br>-Fast flight speed | -Launch and recovery needs a lot of space.<br>-No VTOL<br>-Harder to fly<br>-Expensive | -Used for commercial purposes such as aerial mapping | 25k-120k | 80 km/h / 2.3kg | ~30-40 min |
| Single Rotor (Figure.3) | -Long endurance<br>-Large payload capability<br>-VTOL | -More dangerous<br>-Harder to fly<br>-Expensive | -Research, surveying | 25k-300k | 200 km/h / NA | ~30-50 min |
| Fixed-Wing Hybrid (Figure.4) | -VTOL and long endurance flight | -Not perfect at either hovering or forward flight<br>-Still in development | -Drone delivery | 5k-25k | 50 km/h / ~6kg | ~30-40 min |

Figure 1: Multirotor

Figure 2: Fixed Wing

Figure 3 Single Rotor



Figure 4: Fixed Wing Hybrid

- **Flying Authorization**

Several critical challenges stop in the way of developing the desired drone, those challenges are not only limited to the physical or the appearance of the drone that we usually see in the market. There are certain legal limitations in terms of the size, weight, speed and the altitude that it can fly. These criteria lie under the flying authorization. In Qatar, only Qatari citizens are allowed to fly their drones if they get a permit from the Civil Aviation Authority (CAA). The drone pilots can operate their drones to fly strictly under 400 feet. The weight of the drone should be less than 55 lbs, which is equivalent to 25 Kg [13]-[14]. Nonetheless, our project will focus on using the drone under governmental legalization. The design of the drone is different from the commercial well known drones, as it will be registered in the CAA system as a medical drone. In addition, a tracking system will be integrated to allow the authorized users to know the exact location of the drone, the remaining time for the blood to be delivered and the condition of it. The GPS installed in the drone will act like a mapping service such as Google Maps and hence it will notify the location and the time remaining to both ends.

## Other Risk Factors

- **Climate**

The range of most drones to be 30 mph is limited to conditions with wind speeds below 20 mph. Flying drones in fog, snow, or even drizzle is not advised. In addition to any physical effects on the aircraft, there is a danger that the electronics will be impaired and contact between the controller and the drone may be disrupted if any precipitation happens in the air.

The airplane can be reported from suppliers to be capable of communicating with the aircraft for up to 1 km, but the effective flying distance will be less than this because of a need for a line-of-view to the drone, because the maximum legal distances are lower. Cold temperatures reduce battery life and give shorter flying times. Altitude can be a factor: the thin air in the mountains means that special rotors are needed and battery life is reduced.

**How will it adapt to a different climate in Qatar? What about fog wind etc.**

The climate in Qatar can have severe effects on the operation of the drones, especially in the extreme weather of the summer months. Fog, haze, and glare are not of much concern as they do not harm the drone, but in extreme cases can affect the communication and the camera vision. On the other hand, in some cases wind, turbulence, humidity, solar storms, rain, and extreme heat can significantly affect the drone's flight. In extreme cases these weather conditions can even damage the drone's components (especially with exposure overtime). Lastly, it is highly advised to avoid severe weather such as lightning thunderstorms and hail. As these weather conditions can lead to severe damage or the drone crashing [21].

It is important to only deploy the drones when the weather permits to do so. Therefore, the Ground Control System will use weather measurements and information to determine if a drone can safely fly during the current weather conditions. In case it determines that it is not safe for the drone to take flight other forms of blood transportation would be used as back ups. So if strong winds or extreme heat prevent the drone from flying or preserving the blood then an ambulance may be used instead. Though the container is designed to be very insulated and should be able to preserve blood well. Ultimately, these decisions will be made on a case by case basis based on all the relevant external factors, the final specifications of the drone and container, and the contents of the container.

**Security**

Ensuring the security of the drones is crucial, as lives may depend on the drone's mission and the contents being transported should not get in the hands of someone with malicious intent. Qatar consistently ranks as one of the safest countries in the world [25]. The security focus would be mainly on the cybersecurity perspective, as the government fundamentally has less control over cybercrimes. In fact they may be carried out with the attacker(s) being relatively safe and not risking exposing their identity. Therefore, the attacker(s) may not even be in Qatar so the country's national medical care could be vulnerable to attacks from foreign nations. This is why it is important to secure drones against any type of potential attack.

The drones will communicate to the ground systems via radio frequencies. There is a wide selection of potential bands of frequencies that can be used. The decision of the frequencies used to communicate will be made based on the final design of the drone (the length of its antenna can limit the frequencies available)[20]. The signals sent between the drones and the ground system will be encrypted using symmetric key cryptography. It is highly preferred due to its efficiency and well-analyzed security [2]. So if someone intercepts the signals being sent between a drone and the ground system, they should not be able to decipher the messages. Each drone is equipped with a GPS tracker that would broadcast its location to the system controlling the drones. In case of an attack, the relevant authorities will be immediately alerted and will have access to the drone's live location. Thereby, the authorities will send an order to the device that is installed on the container to lock it and keep it relatively secure.

In other respects, the ground control systems, as well as the connected hospital systems, will have a firewall to ensure that there aren't any vulnerabilities from that perspective. A firewall monitors and regulates all data being sent and received from the hospital network. This increases the security of the hospital systems and ultimately helps prevent cyber attacks on the hospital system along with the ground control system. It is important to secure both as a vulnerability in one network could lead to another in the other network.

If hackers somehow manage to take control of a drone, a common and effective attack is to trick the drone by spoofing its GPS signals. Through this, they can make the drone travel and land at a specific location while the GPS readings on the drone show that it is going in the right direction [1]. Therefore no warnings will be sounded off and the ground system would not be alerted. Hence, it is wise to have a different way to measure the location of the drone. One of the uses of the camera installed on the drone is that it will be used to confirm the location of the drone and provide a second form of verification to help foil the attack.

There might be concerns that the individuals who are in control of the drones can spy on the public or steal what the drone transports. However, the drone system will be under the authority of the government and no other entities will have access to it. It will be controlled by the Ground Control System employees specialized for this task. Furthermore, no one will manually fly the drones as the flights would be automated. Instead, they work on the system

that monitors and commands the drones. Therefore, there should be no direct way to steal one of the drones or its contents when working on the ground control system as they are not manually controlled and any anomalies in the flight paths of the drones will set off alarms due to the security measures described earlier .

You will have to operate a high quality, multi frequency GNSS receiver on board to reach this absolute level of accuracy, in other words a flight that will take off, travel, and land safely with no complications in the accuracy of the travel path and connection with the drone. The L1 and L2 frequencies have to be controlled at least. For a more accurate position, we suggest post-processed kinematic (PPK). You also need a package with a large number of pixels so that your pictures are sufficiently good to cover a reasonable quantity of land while still having a lower (best) GSD rating. Absolute precision (less is better) will vary from 1 to 3x the GSD. How close you are to 1x defines the output of your drone camera lens and sensor.

**Bird Strikes**

Considering the risks that might be a constraint in dealing with medical drones, experts from the University of Dayton Research Institute worked on experimenting with the damage that a drone will cause if it hits an airplane. The results of their experiment were shocking as they found that the drone will be completely penetrated in the airplane's wing and could cause a considerable amount of damage [16]. However, bird strikes are the constraint to us. According to a paper published by Stanford University, most birds fly under 500 meters except during migration [17]. However, drones fly under 400 feet. As a result the drone will be operated with that range of altitude and this increases the chance of it being hit by birds. A possible solution would be installing a camera and a sound device that can detect and alert the drone to change its path.

**Design**

However, our main concern is the safety and the design of the package by not failing in midair or getting hijacked, and by keeping the delivered blood bags in their optimal conditions in order to deliver it successfully[2]. From a medical point of view, any delay in time when transporting the blood bags will decrease the chance of using the blood and can be considered as defected and unusable. According to Dr. Yasser, the best design is the multirotor since it has the highest stability compared to other models. Figure [A] shows the possible two ways that we can attach the container to the drone. The container itself should be thermally insulated and made of materials that withstand pressure, shocks and are sturdy enough to handle any issues that might arise while transporting the blood bags.

Figure [A]

## Conclusion

Providing the best healthcare services is not easy. There are many drones in Qatar, not many are used for medical purposes. The purpose of our project is to design a prototype for a drone that aims to transport blood bags from one hospital to another hospital. We aim to have the drone system connected to all hospital systems. If a doctor from any hospital requested a specific type of blood bags, the drone will be sent from the blood center to that hospital by using the built in GPS system with a tracker. The tracker will allow the doctors to track the current location of the drone. Also, we aim to develop a specialized container to maintain a suitable environment for the ordered package. All drones will be synchronized and monitored to avoid any service interruptions during the transportation by implementing a firewall security system. Starting such services is important since it will save more lives, time and money if done properly because every little second counts and could be the difference between life and death.

Figure B:

Figure B: Shows potential designs of the drone. This shows that our project is not completely out of reach and that it has been thought of before and we can use it for transporting blood.

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