The development of operational concept and Design Requirements and Objectives (DRO) of medical transport drone in Liukang Tangaya Archipelago

I Safi’i, A Fariz, M F Rahman, O Arifianto, R A Sasonko and Y I Jenie

Faculty of Mechanical and Aerospace Engineering, Bandung Institute of Technology, Bandung 40132

Abstract. In this paper we proposed a concept of operation and developed a design requirements and objectives for a medical transport drone. The drone will be used to transport medical supplies between small islands in Indonesia. Liukang Tangaya Archipelago is chosen as study case since it represents similar archipelago in rural part of Indonesia. Limited infrastructure and man power skill are the main challenge of the operation of drone in the area. Thus, simplicity of operation and minimum support are major consideration in the requirements. A hybrid type is considered to be the best suited type for the area and mission. A hub and spoke concept is chosen with Sapuka Island as the center. A set of design requirements and objectives are defined based on the chosen drone type and mission.

1. Introduction

Based on [1], it is stated that health services are the rights of people, and the provision of the supporting facilities become the nation responsibilities. This statement is reinforced by [2], in which it is said that one of the described resources is the availability of pharmaceutical preparations and medical equipment. Pharmaceutical preparations and medical equipments may be available if those resources can be properly distributed by the stakeholders.

Unfortunately, not all regions in Indonesia receive a guaranteed distribution. For example, the condition that happened in Liukang Tangaya Archipelago/Sub-district. The difficulties of medicines distribution are filmed as-it-is in [3]. In this film, a story of a paramedic assigned to give services in Liukang Tangaya Archipelago is presented. The documentary shows the difficulty in the distribution of supplies to support health services.

To overcome this problem, an idea was proposed in the form of drone for transporting medical supplies around Liukang Tangaya Archipelago. This paper will discuss about the development of operational concept, and the design requirements and objectives (DRO) of transport drone for medical supplies around Liukang Tangaya Archipelago.

In the DRO derivation process, some data and information about Liukang Tangaya Archipelago, including geographical, human resources, and infrastructure data are collected and presented in the second chapter. A study of various companies that use drones for goods delivery will be described in the third chapter. Appropriate operational concepts and drone type are discussed in the fourth chapter. The DRO, as the result of the study, will be presented in the fifth chapter. The last chapter would be the conclusions of this paper and insights for the future works.
2. Study of Liukang Tangaya sub-district

Liukang Tangaya Archipelago, also called Liukang Tangaya Sub-district, is located in Pangkajene dan Kepulauan (Pangkep) Regency, South Sulawesi Province. This sub-district consists of small islands which are separated far enough from Pangkajene, the Capital of Pangkep Regency [4]. The areas of Pangkep Regency are the red-edged area in figure 1, with the Liukang Tangaya Sub-district being small islands enclircled within the blue-line circle.

The territory of the sub-district can be divided into three major regions. The first is the western region, consists of Tampaang, Poleonro, Satanger, Kapoposang Bali, and Sailus Islands. The second is the central region which consists only of Sapuka Islands, the capital of the sub-district. The third is the eastern region, consists of Balobaloang, Sabalana, and Sabaru Islands [5].

Each region has some big islands, such as Tampaang and Sailus Besar Island in the western region, Sapuka Island in the central region, and Sabaru and Sabalana Islands in the eastern region. The distances between Sapuka Island and the outer islands are shown in table 1.

The majority of residents in the sub-district used to travel by boat [5]. It is also true for the delivery of medical supplies. From [3], it is shown that the delivery of the medical supplies from Pangkajene to Sapuka is done by using a boat. Also, it is shown that there is a port to facilitate the boats keeping.

In the sub-district, there are only 2 “puskesmas” or Community Health Center, 8 “pustu” or Community Health Sub-center, and 31 “posyandu” or Integrated Service Post [6]. Since only a few medical personnel work in Liukang Tangaya, it is shown from [3] that the paramedic often travel from island-to-island by boat in order to treat her patients who are away from the health facilities.
There are only 2 doctors and 23 paramedics in the entire sub-district [6]. The number of highly educated human resource in the sub-district is also low. The majority of population in the sub-district, about 10%, only goes to elementary school [5]. About 80% of the Liukang Tangaya population are not in school. So, it can be concluded that the number of health facility and human resource in Liukang Tangaya is limited.

| Islands       | Distance (km) |
|---------------|---------------|
| Sapuka – Sabaru | 106           |
| Sapuka – Sailus Besar | 96           |

From [3], it can be seen there are wires from house-to-house, that it is assumed to be the supply of electricity. However, the National Electricity Company, PLN, said that until 2009 there is no customer from Liukang Tangaya Sub-district [7]. Another reference reported that fuel is hard to find in Liukang Tangaya [8]. So, it can be inferred that both electrical and fuel facility is quite difficult to find in Liukang Tangaya Islands, whereas those facilities are one of the major support for drone operation.

The last thing to be considered is the availability of spaces for the operation of drone. From [3] it is known that there are pavement roads in some districts, but there are more scenes that show Liukang Tangaya residents walk on a dirt road. The width of the roads are just about 2 m. Other infrastructure that can be used for drone operation, which are observed at a glance in [4], is an open field.

3. Transport drone in the world
Recently, drones have been widely used in many applications, i.e. commercial, scientific, agricultural, etc. In case of the use of drones for goods delivery purpose, there are some companies that have offered such service. The review of some companies that use drones to transport goods and medical supplies are presented in this section.

3.1. DHL
DHL is a German delivery firm. It has developed a delivery drone since 2013. The first model of DHL’s drone, Parcelfcopter 1.0, was a quadcopter with dimension of about 1.03 m. The quadcopter could fly crossing a river within the distance of about 1 km. It could carry payloads of 1.2 kg. In 2013, Parcelfcopter 1.0 was still flown manually. In the fourth quarter of 2014, DHL announced its
Parcelcopter 2.0. It was an autonomous quadcopter that can flown over an open sea within the distance of about 12 km. Just like the previous generation, the second generation could only carry 1.2 kg of payloads.

In the early of 2016 [9], DHL has successfully concluded a three-month test of its third Parcelcopter generation in the Bavarian community of Reit in Winkl. Parcelcopter 3.0 is an autonomous tiltwing drone that can fly over mountainous region in the distance of about 8.3 km. It can carry 2.2 kg of payloads. Figure 3 shows the Packstation of DHL, while figure 4 shows the drone flying in VTOL mode.

3.2. Zipline
Zipline’s drone, called Zips, has started to deliver blood in Kabgayi, Rwanda, since 2016. The first generation of Zipline’s drone is a fixed-wing drone that can carry up to 1.5 kg of payloads. The 12-kg drone can fly autonomously in the distance of about 150 km, delivering blood in almost half of the Rwanda’s territory from a single launch site. Payload brought by Zips will be dropped from a height of about 100 ft. The payload is equipped with a small parachute, so it can land safely.

In 2018, Zipline announced its new drone callep Zip 2, as shown in figure 5. It can fly up to 128 km per hour and carry 1.75 kg of payloads. Its service area is about 160 km. Since 2016, Zipline has performed more than 4000 times blood delivery [10]. The known population in Rwanda by 2015 is about 11 million people [11].
If it is considered that Zipline’s drone has flight as much as 4000 times within the past two years, thus the average flight of Zipline drone is about 5.5 times in a single day. If the drone carried about 1.75 kg of payloads for every flight, thus the need for blood in Rwanda within a day is about 10 kg. The dropped payload example is shown in figure 6.

![Figure 6. Dropped payload example.](image)

**Figure 6.** Dropped payload example.

3.3. CargoCopter

CargoCopter is a product from KU Leuven. The 4th prototype is a tail-sitter UAV concept that combine fixed-wing and multi rotor capabilities. It can fly about 60 km, carrying 5 kg of payload with size equal to men shoes. It can fly autonomously and reach 100 km per hour of speed. Since the UAV using hybrid concept, it can take off and land vertically. In addition, the UAV is able to fly at high speed efficiently during the cruising mode, so it can reach a long distance [12]. The CargoCopter is depicted in figure 7.

![Figure 7. CargoCopter 4th prototype.](image)

**Figure 7.** CargoCopter 4th prototype [12].

4. Conceptual study of operation

In this section, a study to develop an operational concept for medical transport drone in Liukang Tangaya is discussed. The study began with some assumptions used. Then, the operational concept chosen is discussed. At the end, a discussion about the chosen drone type which is appropriate to the concept is presented.

4.1. Assumptions

The main community health center in Liukang Tangaya is located in Sapuka Island [13]. Also, from [3], it is known that the medical supplies are delivered from Pangkajene to Sapuka Island. Thus, it is assumed that the medical supplies warehouse is placed at Sapuka Island.

Another thing is the range from Pangkajene to Sapuka Island is 292 km [4]. To overcome this problem of range, a limitation may be specified in the medical supplies delivery concept. The medical supplies boxes from Pangkajene to Liukang Tangaya Archipelago should be transported by using a boat, not by drone.

4.2. Operational concept

This sub-chapter discusses 5 main things, which are (1) flight profile, (2) route system, (3) communication, (4) man power, and (5) environmental aspect. An appropriate route system for medical supplies distribution in Liukang Tangaya will be discussed in route system section. Every flight phase of drone, from take-off to landing, is discussed in flight profile section. Data transfer between drone and ground control station is discussed in communication section. Man power section discusses the required number of drone operator and its consideration. The last section emphasizes on the challenge caused by unique operation area.
4.2.1 Flight profile
A medical transport drone is expected to deliver medical supplies within specific range. The delivery process should consider that the takeoff point in the islands is not a wide are, therefore a vertical take-off and landing method should be fulfilled. The other consideration is the dropping point may not have any facility to support the drone operation since it could be in a rural area within the islands. Therefore, the drone should fly towards the dropping point, drop the supplies, and directly fly back to the takeoff point. The flight profile is illustrated in figure 8.

![Flight profile diagram]

Figure 8. The designed flight profile.

4.2.2. Route system
There are several route systems that are commonly used by airlines, they are hub-and-spoke, point-to-point, or the combination of the two systems which are illustrated in figure 9. All passengers/cargos in a pure point-to-point system are boarding at flight origin and deplane at the destination. In the hub-and-spoke system, by contrast, all passengers/cargos, except those whose origin or destination is the hub, transfer at the hub for a second flight to their destination [14]. Each route system has its advantages and disadvantages that best suited for a certain condition which make an eventual predominance of one system unlikely.

In the case of medical supplies distribution using a drone in Liukang Tangaya, the hub-and-spoke system is proposed to be applied. This network system is the best option since the community main health center is only placed in an island, that is in Sapuka Island. Hence, Sapuka Island will be the hub, while other islands will be the spokes. The map of hub-and-spoke system is depicted in figure 10.

As a hub for the whole medical supply operation, Sapuka Island should be equipped with a standard infrastructure to operate the drone. Ground control system (GCS), refuelling/recharging station, maintenance based, and man power is among the list. As the flight profile proposed in previous section, the other island does not require any of those infrastructures. Therefore, the operational of this drone use the minimum resources.
4.2.3. Communication

The drone is expected to fly in fully autonomous mode. Thus, it means the communication between drone and ground control station should always be connected. Nowadays, the data transfer between these things is done using radio frequency. The ground antenna will be bigger as the distance increase.

Another consideration is the long distance means the radial shape of earth will block the line of sight (LOS) of the radio frequency. Thus, the drone need to fly high enough so the LOS is not blocked. Assuming that the earth is round, a simple Pythagorean can be used to calculate the minimum flight altitude. Figure 11 shows the illustration, where R is the radius of earth, d is the distance, and h is the flight altitude.

**Figure 9.** Point-topoint and hub-and-spoke route system [16].

**Figure 10.** Hub-and-spoke route system for medical supplies distribution in Liukang Tangaya.
Based on Pythagorean theorem, then:

\[ d^2 = (R + h)^2 - R^2 = 2R h + h^2 \]  

(1)

Since \( h \ll R \), therefore,

\[ d \approx \sqrt{2Rh} \]

Assuming that the earth radius is \( 6.371 \times 10^6 \) m,

\[ d \approx 3570 \sqrt{h}, \]

Therefore,

\[ h = d^2 / (1.27 \times 10^7) \]  

(2)

The farthest distance to the destination is around 120 km, thus a simple calculation in equation (2) result the minimum flight altitude is about 1130 m or around 3700 ft.

4.2.4. *Man power*

One of the biggest challenges in the medical transport drone operation in Liukang Tangaya is the limited number of experienced human resources. Therefore, the operation should be designed using the smallest possible number of man power. In the previous section, both flight profile and route system has been proposed and discussed. In order to minimize the number of people involved in the operation, the drone should be designed to be fully autonomous.

The drone will be only operated and monitored from a single GCS in Sapuka. Once the drone is flown, an operator should monitor the path. All drone’s routes should be pre-programmed. During the operation, health facilitators in the islands of destination should be involved. The operator must provide information when the medical supplies have arrived, so the health facilitator can take it immediately. In order to perform maintenance and to ensure that the drone can operate properly, some engineers got to work in the GCS.

4.2.5. *Operational challenge*

The drone used for the operation of medical supplies distribution will be flown over sea. Weather factors possibly exist in the sea environment that can endanger the safety of the flight, for example
temperature, humidity, wind, etc. Sea surface temperature anomaly is common. Both hot and cold environments can reduce the flight performance of the drone. In the sea, a large amount of water vapor present in air. Long-term use in humid and salty environments will affect the drone’s equipments.

Other weather factors that can cause much problem than humidity is water precipitation. Due to the presence of a large amount of water vapor, rain can come down at any time. Obviously, drones can not hold up well in rain, sometimes even slightly. Other weather factor that is not less important is the wind. Wind sometimes can cause a bad impact for the flight. It can blow fast and strong across the open sea. Higher wind speeds will make the drone more difficult to hold its positioning, which result in shorter flight times. Therefore, the drone should be designed for the need to fly over sea.

4.3. Consideration of drone type
Lately, there are so many types of drone with their own function and advantages. Reference [15] classifies drone or unmanned aerial vehicle (UAV) into several types depending on its flying principle, as shown in figure 12. However, there are still many types of drone that have not been mentioned. From all of drone types listed there, four type of drones are selected for preliminary consideration, they are fixed-wing, quadrotor, single rotor, and fixed-wing hybrid.

![Figure 12. Common UAV types [15].](image)

As discussed in the previous chapter, the availability of facilities and human resources still become the major consideration. In addition to the limited number of public facilities in Liukang Tangaya, most of its area is still in the form of a forest. In this condition, it will be quite difficult to use a fixed-wing drone type to distribute the medical supplies, either to find a place that can be a runway or build launcher and net as landing facilities in islands.

Even if it is possible to use a fixed-wing type, a lot of human resources will be needed to operate the drone in the entire sub-district. Therefore, a type of drone that can take off and land vertically would be more appropriate in such condition. In addition, the drone must be designed to fly autonomously in order to reduce the number of operators.

The operation requires the drone to travel in a long distance, flying over sea. For this requirements, fixed-wing and fixed-wing hybrid types are better than quadrotor and single rotor ones, since they can carry large payloads, travel in a long distance, and withstand in an extreme weather, better than quadrotor and single rotor types.

Based on the obtained data and information, comparison presented in table 2 is used to determine our tendencies to find which of four drone types is the most appropriate type for the mission. It can be inferred that the fixed-wing hybrid type is the most appropriate drone type for the mission.
5. Design requirements and objectives of the transport drone

Based on the review and the operational concept discussed in the previous chapter, DRO for medical transport drone can be derived. The DRO consist of three parts, each part has several points of requirements or objectives. First, the general part describes the general requirements of the transport drone and its supporting facilities. Second, the internal arrangement part describes the requirements of drone payload and its baggage. The last, the drone performance part describes the drone performance during its operation.

5.1. General requirements

The drone should be designed to be fully autonomous, flown from a single Ground Control Station (GCS). GCS is located only in Sapuka Island. The drone must be designed to fly over the sea. It must be ensured that GCS is able to communicate with the drone in real-time without any disconnection during the operation. It is recommended that the drone can be packed in such a way, so it can be brought by aircraft’s cargo.

5.2. Internal arrangement

The drone should be able to carry at least 2 kg of payloads. The baggage dimension or the payload space of the drone should not be less than 21.5 cm x 29 cm x 20 cm, equivalent to the volume of 4 fully-loaded bloodbags and 5 cm thick of cooler. The medical supplies carried by the drone must be delivered safely.

5.3. Drone performance

The drone should be able to take off and land vertically (VTOL) at its maximum take off weight (MTOW). The distance of the drone can be flown must not be less than twice of 110 km so that the drone can deliver the payload and come back to the GCS in one take-off and one landing. The flying altitude is 1130 m or around 3700 ft above the sea level.

6. Conclusion and future work

The concept of operation and design requirements and objectives (DRO) for developing a medical transport drone has been presented in this paper. The concept of operation adopts hub-spoke system with the hub is Sapuka Island and the spokes are the other islands in Liukang Tangaya. The DRO has been derived based on chosen. These objectives and requirements are divided into three parts, which are general requirements, internal arrangement, and drone performances. The future development of the medical transport drone will refer to the results in this paper.

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