

# Fast delivery of life saving medical supplies in rural areas of Ethiopia

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## Technical advance

**Keywords:** Maternal mortality, UAV, PPH, Thermoelectric cooler, Blood, Vaccines

**Posted Date:** March 25th, 2020

**DOI:** <https://doi.org/10.21203/rs.3.rs-18834/v1>

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3 **in rural areas of Ethiopia**

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14

15 **Abstract**

16 **Background:** Ethiopia’s maternal mortality rate is among the highest in the world with 470  
17 deaths per 100,000 live births. Every year post-partum hemorrhage (PPH) remains the leading  
18 cause of maternal mortality in Ethiopia. The problem is worse in the rural setting where there are  
19 not proper facilities and trained health workers to administer injectable medicine. Currently, the  
20 methods used by health centers in rural areas include referring the patient to the nearest hospital  
21 within a short period of time even though most of patients die in the ambulances without  
22 reaching the hospitals in nearby.

23 **Method:** In this project, the design of rotary-wing unmanned aerial vehicle (UAV) with  
24 thermoelectric cold-box system is proposed. The temperature of blood bag is controlled by a  
25 thermoelectric cooler working based on the Pieter effect. The blood is transported to rural health  
26 centers through UAV, and the blood containing box will release it from higher altitudes using  
27 servo dropping mechanism.

28 **Results:** The prototype was built and undergone through different iteration process. The  
29 proposed device was tested for safety, delivery time, bioavailability, range of operation, weight  
30 of the package and durability. For this design, the drone was flown a distance of 10km with less  
31 than 15 minutes while 100 meters above the ground.

32 **Conclusion:** The proposed project has a clinical significance such as saving the lives of mothers  
33 and the child. Through the design of a UAV, the transportation of medical and biological  
34 component is feasible. The use of UAVs for medical supply delivery will considerably reduce  
35 the number of people admitting to the hospital and, therefore, minimizes the cost of medical  
36 services that comes with hospitalization.

37 **Keywords:** Maternal mortality    UAV    PPH    Thermoelectric cooler    Blood    Vaccines  
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## Background

39  
40 In Sub-Saharan Africa, more than 250,000 women die each year due to complications related to  
41 pregnancy or child birth [1,2]. According to WHO (world health organization) report, Ethiopian's  
42 maternal mortality rate is recorded as one of the highest in the world with 470 deaths with 100,000  
43 live births [ 3]. Direct and indirect causes can contribute to the maternal death. Hemorrhage,  
44 infection, hypertensive disorders and obstructed labour are considered as direct causes while the  
45 indirect one includes concurrent diseases that are complicated during pregnancy [1]. Postpartum  
46 hemorrhage (PPH) is defined as the loss of more than 500 ml blood after delivery [4,5,8]. However,  
47 for the clinical purpose any amount of blood loss that could potentially result in hemodynamic  
48 instability should be considered PPH [5]. It remains to be the leading cause of maternal mortality  
49 in developing countries like Ethiopia [3]. The problem is worse in resource poor setting where  
50 there are not proper facilities, such as refrigerator, and skilled healthcare givers to administer  
51 injectable uterotonics, which are the standard treatment for PPH [3,6,7]. Blood transfusion can be  
52 a life-saving medical intervention [10,11], and a vital reason for improving blood transfusion is to  
53 reduce maternal mortality rate. However, it is the least available service in district hospital,  
54 Ethiopia [3]. In African countries, one of the reasons identified is the challenge to provide access  
55 to blood due to infrastructure limitation [3.9]. Insufficient and unreliable cold storage capacity to  
56 accommodate the different types of blood and other medications required has been reported as a  
57 challenges [12].

58 To treat mother's suffered from postpartum hemorrhage and patient with a severe anemia, several  
59 techniques have been used. Of these oxytocin is a standard medical therapy that is routinely  
60 administered for prevention and treatment of PPH [3,6,7,13,14]. However, the cost and the need  
61 for a skilled person to inject could compromise its acceptability [3]. Misoprostol has also been

62 used as both prevention and treatment of PPH. Although the delivery of misoprostol reduces  
63 maternal mortality rate and could have advantages as it is easy to use and relatively cheap, it has  
64 been reported relatively less effective than oxytocin [3, 15-18]. The methods, currently, used by  
65 health centers in rural Ethiopia includes referring the patient to the nearest hospital within a short  
66 period of time [19,27]. However, these solutions create a problem most of the time because, the  
67 roads from rural areas to urban hospitals are not always as stable physically and provide a speedy  
68 transportation to patient as the result of this patient's die in the ambulances without reaching the  
69 hospitals in nearby. The other problem with the existing solution is mothers who delivered child  
70 safely by using medication have a high risk of developing severe anemia which requires immediate  
71 blood transfusion. Although the medications provide short-term solutions blood transfusion is  
72 must to solve the problem reliably. In Ethiopia, blood is not stored at rural health center because  
73 of inadequate blood, unavailability of material for the proper storage and unavailability of 24-hour  
74 electricity [3]. Also transporting blood and medical supplies by road is often a long and difficult  
75 process in Ethiopia because of limitation of infrastructure such as road, and number of ambulances  
76 [20]. These all limitation makes any health center in Ethiopia not to make any blood transfusion  
77 for birth giving mothers. In this project unmanned aerial vehicle with its own cooling system is  
78 proposed. Using a modified drone to implement a medical supply delivery system which carries  
79 blood first-aid equipment, medicine and other medical supplies, Ethiopian's health care system  
80 can eliminate the unnecessary burdens that families face and at the same time play a vital role in  
81 the development of technology in the medical arena.

## 82 **Methods**

### 83 **Proposed Design**

84 The design can be classified into two major parts based on the functions it provides. The first part  
85 is the unmanned aerial vehicle part which is designed to carry a payload to remote areas with  
86 automated navigation. The second design is the design of storage system called the cold-box for  
87 the safety of the blood transported the system contains a cooling unit and automatic temperature  
88 controlling system to carry bloods, vaccines and other medical supplies at the required  
89 temperature. The unmanned aerial vehicle consists of both software and hardware parts. The most  
90 common hardware components involved in prototyping include GPS (Global positioning system)  
91 and compass, flight control unit, data transmission module, data receiving module, remote  
92 controller, DC (direct current) motors and on screen display. Using these components, the UAV's  
93 body design was developed to allow for an appropriate implementation of each component while  
94 carefully considering the weight, the balance, and the drone's overall center of mass. The most  
95 important electrical component used for prototyping is flight controller. It is essentially the brains  
96 of UAV, which allows the drone to maintain balance, and it does this by gathering data through  
97 sensors and computing for the necessary changes for the motors. **Figure 1** show functional block  
98 diagram of the rotary-wing unmanned aerial vehicle and with thermoelectric cooler. The list of  
99 components used for designing cold box includes thermoelectric cooling system, LM35  
100 temperature sensor, 12V battery and Arduino Uno microcontroller. **Figure 2** shows the flow chart  
101 of the cold-box design. The thermoelectric cooler designed operates with LM35 temperature  
102 sensor and DC fan to control the storage temperature of the cold-box. The blood during  
103 transportation needs to be maintained at standard temperature range to maintain at a normal  
104 condition. The LM35 senses the temperature of the cold box and compares with the standard  
105 temperature stored by the UAV. The thermoelectric cooler then reduces the temperature of the  
106 cold-box based on the temperature range measured by the LM35 temperature sensor.

## 107 **Results**

### 108 **Final design**

109 The design of the UAV and the cold box prototype has gone through different iteration processes  
110 to come up with the final working design of our project. In addition to this changes have been  
111 made to the design of our project. The design team modified the first proposed initial design until  
112 designing the final design. **Figure 3** shows parts of the final design (from left to right: from top to  
113 bottom). The following components has been used in the final design: S500 Multi-Rotor Air-  
114 Frame, Pixhawk Flight controller, X8R Receiver, GPS, Taranis transmitter, propeller, safety  
115 switch, Arduino UNO, Brushless DC motor, Lipo Battery, Lightweight material to make the  
116 package, servo motor, servo controller, DC fan, and LCD (liquid crystal display). **Figure 4** shows  
117 the final design of cold box and constitute in the quadcopter drone. Functional testing, electrical  
118 safety and performance testing have been done in order to verify whether the design criteria and  
119 specification were fulfilled. **Table 1** shows the test results (see at the end of the conclusion part)

### 120 **Discussion**

121 In Ethiopia, mothers who live in rural areas suffering from bleeding related complications even  
122 though the government has taken serious measurements. Medications, oxytocin and misoprostol,  
123 have been used for the management and prevention purpose [13-18]. However, they might bring  
124 severe anemia which requires immediate blood transfusion. This indicates that a fast and simple  
125 blood delivery mechanism is needed. In this study a device can deliver blood and other critical  
126 medical supplies to rural areas of Ethiopia is designed with appropriate controlling temperature  
127 mechanism. Drone technology is increasingly being used for medical purposes such as transporting  
128 blood, vaccines and organs in some countries [24]. In Rwanda, the collaboration of the government

129 with drone company (Zipline) makes it possible to deliver blood from the center to its rural areas.  
130 However, the designed device has no any cooling system which maintains the blood at optimum  
131 temperature, it has been used for a short trip [21, 22]. In the united states, manned aircraft was also  
132 proposed to reduce maternal mortality rate by delivering blood to critical access hospitals.  
133 However, risks to the flight crews travelling in remote areas was a great concern [23]. In 2016,  
134 pilot drone project was conducted and successfully delivered drugs and laboratory samples to rural  
135 places in Madagascar. Although it was a promising innovation, limited flight range, due to lack of  
136 cooling system placed inside the drone, was reported as a limitation [25]. The major challenges in  
137 the use of medical drone is the legal permission from Aviation Authorities in some countries like  
138 India [24]. Mostly bloods being delivered by the drone was jeopardize due to temperature  
139 difference during the flight [26]. So there must be appropriate temperature management in drone  
140 payload compartments. Our method provides reliable blood delivery mechanism with temperature  
141 controlled device. While the designed device meets desired objectives, it delivers medical supplies  
142 to a short distance. This is only due to low battery capacity which can be replaced by another  
143 powered battery that makes it possible to long distance travel with longer periods. On the other  
144 hand, unmanned aerial vehicle implemented in both Rwanda and Madagascar couldn't travel  
145 longer distance with keeping medical products at desired temperature for safety [21,22,25]. The  
146 proposed design provides high level of safety. It can also be used for transporting organs for  
147 transplantation.

## 148 **Conclusion**

149 In conclusion, this project provided insight on the feasibility of the objectives set out to be  
150 achieved. The design team successfully designed and built a drone with an arm attachment (for the  
151 cold box) to enhance the successful transportation of blood and other critical medical supplies.

152 Thus, the design and testing of the drone successfully demonstrated the concept feasibility of  
 153 implementing blood and other critical medical supplies delivery drones in the health care system  
 154 of Ethiopia.

155 **Table 1:** design objectives and their test results

No	Feature to be tested	Input	Method	Design specification	Result
1.	Delivery Time	Enumerating the time	Measuring the time using timer	Maximum of 10±5 delivery time	The time is in the range
2.	Safety	The storage temperature	Sensor, the LM35 temperature sensor	2°C-8 °C	The cooling of the thermoelectric cooler
3.	Weight of the package	The package loaded to the drone	Measuring the weight of the drone	The weight of the payload should be < 2.4Kg	The weight < 2.4Kg
4.	Range of operation	The distance traveled by the drone	Measuring the speed and time of flight	Up to 10Km	Operating range is below 10Km
5.	Bioavailability	The storage temperature of the UAV	The measurement of the temperature sensor	The material from which the cold box is manufactured	The reduced environmental effect on the cold box
6.	Durability	Physical analysis of the drone	Analyzing and calculating the service life of the drone	The strength of the different components	The components are good quality and light weight

156  
 157 **Abbreviations**

158 UAV: Unmanned aerial vehicle; GPS: Global positioning system; PPH: postpartum hemorrhage;  
 159 WHO: World Health Organization; DC: Direct current; LCD: Liquid crystal display

160 **Acknowledgments**

161 We would like to acknowledge Dr. Timothy Kwa and Mr. Mohammed Aliy for their valuable  
162 advises and guidance

### 163 **Authors' contribution**

164 BF, AA, LG, ST, DO are investigators of this study and they conceptualized, designed, and  
165 implemented. All authors contributed to the preliminary study, the design, prototyping and  
166 testing. This study was initiated by LG. The article was drafted by BF, taking into account the  
167 comments and suggestions of the coauthors. All authors read and approved the final manuscript.

### 168 **Funding**

169 All the authors dedicated their additional working hour to develop this paper with no specific  
170 grant from any funding agency

### 171 **Availability of data and materials**

172 Not applicable

### 173 **Ethics approval and consent to participate**

174 Not applicable

### 175 **Consent for publication**

176 Not applicable

### 177 **Competing interests**

178 The authors declare that they have no competing interests.

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# Figures

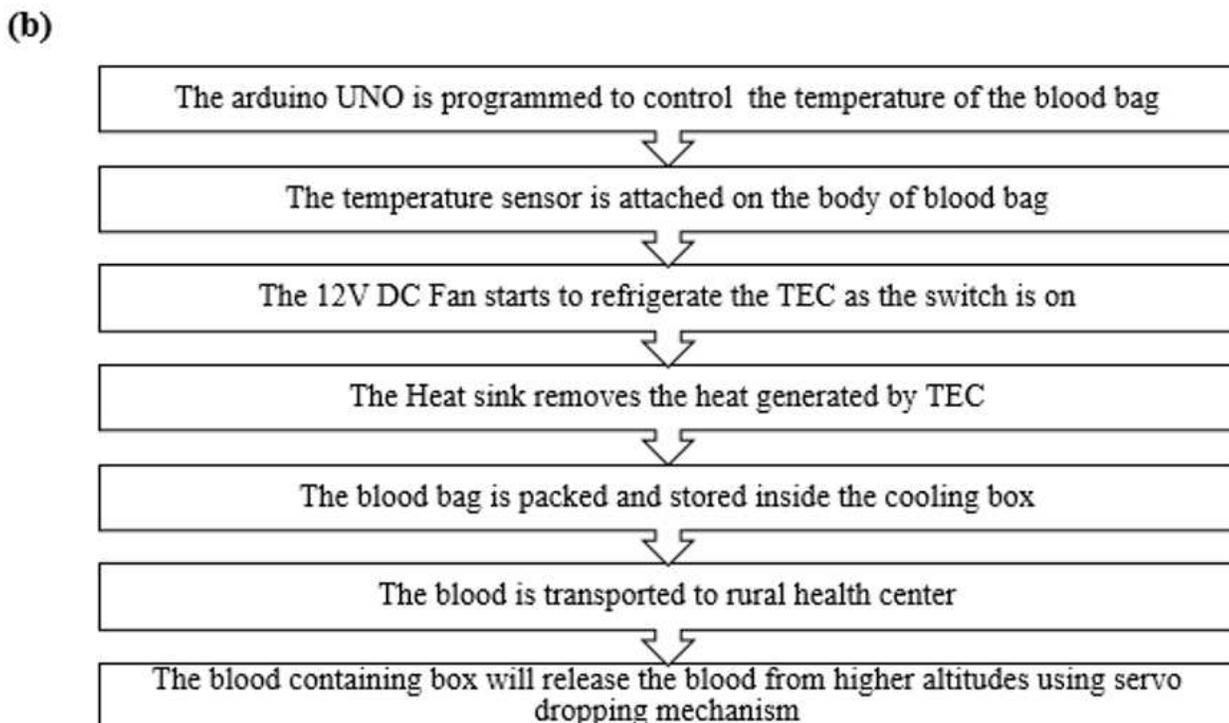
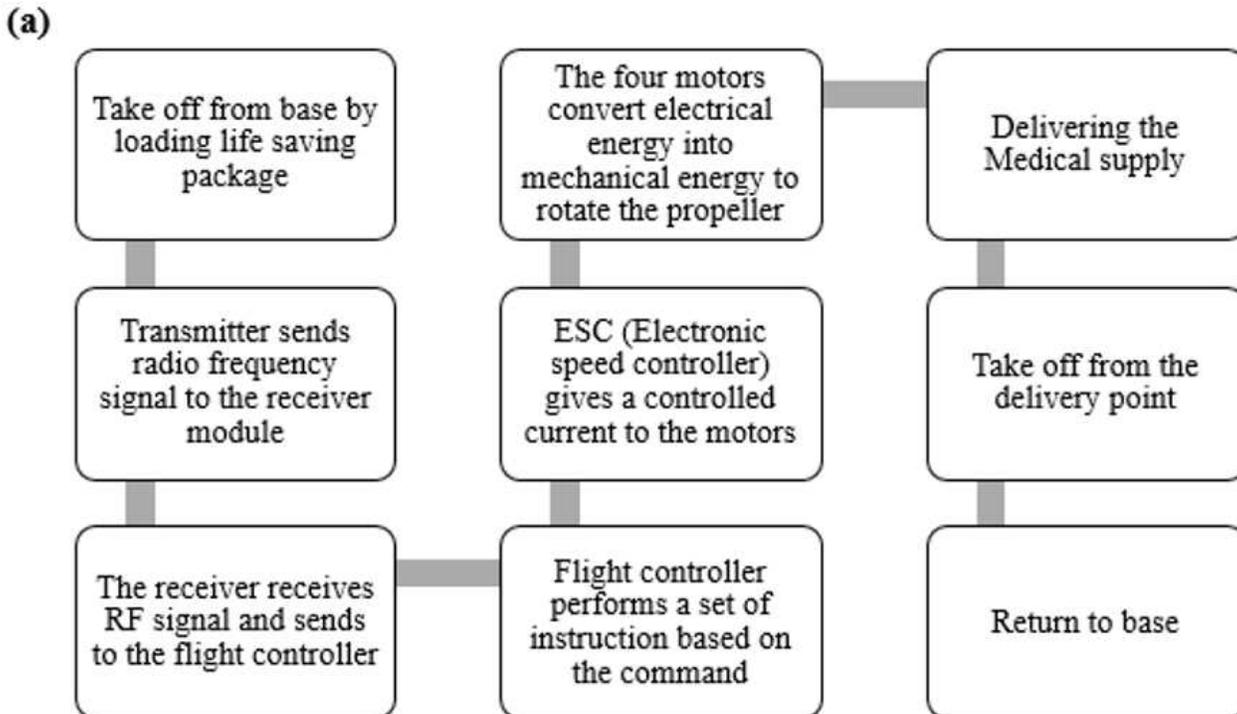


Figure 1

Functional block diagram of the rotary-wing unmanned aerial vehicle and with thermoelectric cooler.

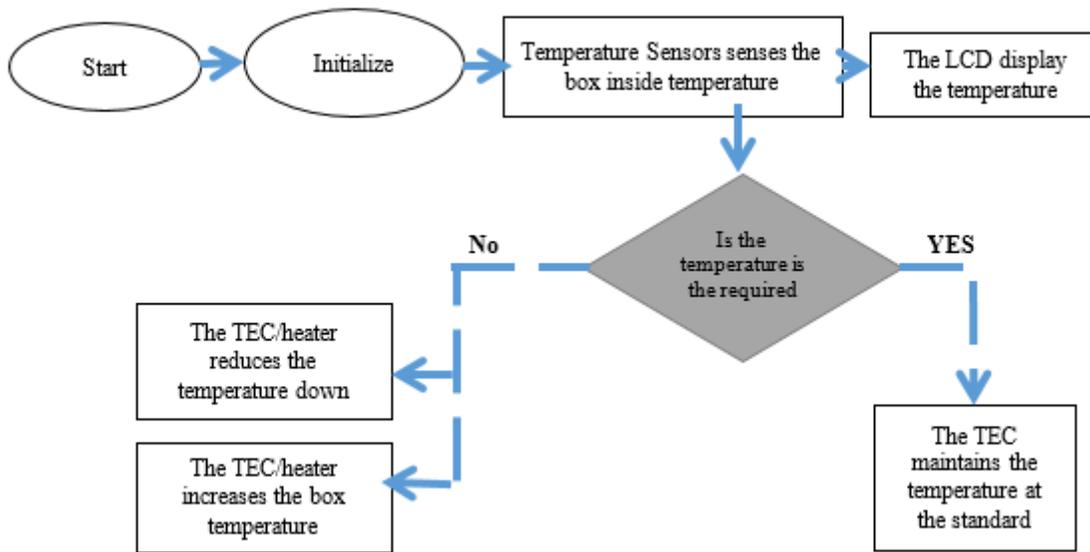
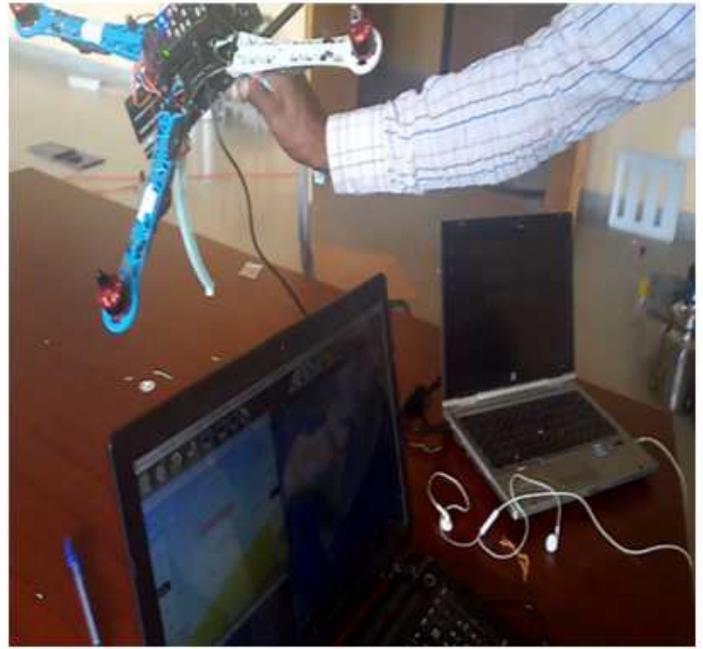


Figure 2

Flow chart of the cold-box design.



**Figure 3**

Parts of the final design (from left to right: from top to bottom).

**(a)**



**Cold-box**

**(b)**



**GPS**

**Lipo-battery**

**Flight Controller**

**Propeller**

**Cold box**

**Figure 4**

Final design of cold box and constitute in the quadcopter drone.