

Original Paper

Models for Drone Go Aerial Disaster Relief Response System

Yin Chen Shen^{1*}

¹ Mathematics Department in Mathematics, College of Sichuan University, Chengdu, Sichuan Province, China

* Yin Chen Shen, Mathematics Department in Mathematics College of Sichuan University Chengdu Sichuan, China

Received: February 6, 2019

Accepted: March 18, 2019

Online Published: March 20, 2019

doi:10.22158/ibes.v1n1p33

URL: <http://dx.doi.org/10.22158/ibes.v1n1p33>

Abstract

According to the requirement, we established a non-linear programming model and a three-dimensional packing model and designed a Drone Go disaster response system meeting the demand of medical supplement and road video reconnaissance. We also determine the optimal location selection, container assembly schemes, as well as the UAV flight routes and flight plans.

First of all, we established a coordinate system to fit the topographic map of Puerto Rico through the digital image processing method and collect the road pixels in the topographic map. Then compared it with the detection range of the UAVs to analyze the exploration area and reconnaissance rate of different flight plans.

Second, we establish a nonlinear programming model with the constraint of the distance between the hospitals and the distribution of the medicine. Using time and exploration area as the target function to determine the optimal location and make a best decision by weighing both factors.

Third, we establish a model of three-dimensional packaging and using the heuristic algorithm to determine the best package solution of two iso container respectively. The constraint is to take enough medicine and drone to make the two highest utilization rates of the volume of the container, trying to reduce the use of buffer material.

Finally, the optimal flight plan is determined with the consideration of the highest flight safety and detection efficiency of UAV. In the stability analysis of our model, we prove the reliability of our model from different perspectives. Then we analyzed the advantages and disadvantages of our model.

Keywords

non-linear programming, Linear programming, 3D packing problem, digital image processing, heuristic algorithm

1. Introduction

1.1 Background

Recently, with the maturity of the UAV technology, UAV-transportation technology has been widely used in series fields of life, such as electric power, military, rescue and so on. In particular, when serious natural disasters occur, like hurricanes, earthquakes, tsunamis and other serious natural disasters, which are usually destructive and possess a wide range of impact, the disasters will cause long term damage to local communities and transportation. As a consequence, it will make it difficult to implement traditional rescue methods. The UAV-transportation technology can greatly reduce the difficulty of disaster relief supplies transportation and road traffic detection in the affected areas because it can transport disaster relief materials to accurate places timely and transmit the real-time disaster situation video to the command center, so as the damaged roads.

1.2 The Restatement of Problem

Problem A. Select a Drone Go disaster response system with A fleet of drones and A medical packages to meet the requirement of Puerto Rico's hurricane. Design a solution to package up to three iso containers with the cargo to Puerto Rico.

Problem B. determine the optimal location of those up to three cargo containers for the Drone Go disaster response system in Puerto Rico. The places should ensure that the system can supply the medical road network and video reconnaissance simultaneously.

Problem C. Decide a drone delivery routes and schedules to meet emergency medical requirements in Puerto Rico's hurricane scenario with a drone flight plan for each type of UAV included in the Drone Go disaster response system to enable the Drone Go fleet to supervise major highways and roads.

2. Assumptions

- **UAVs are not affected by weather:** UAVs are not affected by weather and secondary disaster, as these conditions are impossible to predict.
- **Excluding the drone or medicine loss in the secondary disaster:** Ignoring the extra power loss when the drone takes off and lands because it is tiny comparing with the whole power using in the flight.
- **Ignoring the extra power loss when the drone takes off and lands:** Assume that the power supply of the hospital and the container site is stable enough to ensure the charging demand of the drone or the drone will not be a good way to the delivery.
- **Assume that the power supply of the hospital and the container site is stable enough to ensure the charging demand of the drone:** Assume that the plane must return to iso container every day, and it is too risky and useless to fly at night cause the drone cannot detect at that time.
- **Assume that the plane must return to iso container every day, and it is too risky and useless to fly at night cause the drone cannot detect:** Ignore the influence of air resistance and other factors about air because they are tiny

- **Ignore the influence of air resistance and other factors about air:** Drones have the same probability of destruction and it can be assumed to obeys the exponential distribution.
- **Drones have the same probability of destruction and it can be assumed to obeys the exponential distribution:** UAVs are not affected by terrain as the maximum height of drones is higher than most of the mountains.

2.1 The Primary Notations Used in This Paper Are Listed in Figure 1.

H_i	The number of hospitals
A_i	The position of container A
B_i	The position of container B
D_{ij}	The distance between hospital i and hospital j
D_{Aij}	The distance between A_i and hospital j
D_{Bij}	The distance between B_i and hospital j
$d_i^{(j)}$	The flight distance of i model drone with the load j
$v_i^{(j)}$	The flight speed of i model drone with the load j
n	The days of rescue
T	The distance between hospital i and hospital j
T_i	The days of the MED in container i can supply
M	The expected life of drones
t	The average daily flight time of drones
PI_x	The road pixels contained in scheme x
V_A	The volume of MED in container A
V_B	The volume of MED in container B
$V_{A,j}$	The volume of MED j in container A
$V_{B,j}$	The volume of MED j in container B
V_0	The volume of container
Q_G	The number of drones in container
Q_{G0}	The number of demanding drones
Q_m	The total number of MED
Q_d	The demand of daily MED

Figure 1. Notations

3. The Problem Analysis

Since the dynamic performance of the UAV are not given in the question, it can be approximately considered that the weight of the UAV itself is equal to the maximum carrying weight. Moreover, it is assumed that the output power of the UAV is constant, that is, the flight time of the UAV is constant. According to the power theorem:

$$P = F \cdot V$$

When the output power P is constant, the flight speed is inversely proportional to the traction F , then the conclusion comes out:

$$v = \frac{m}{\dots}$$

So, the distance L is:

$$L = v \cdot t$$

According to the information given in the problem, the key to the problem can be listed as follows: under the condition of meeting the medical transportation requirements of Puerto Rico hurricane, the transportation time need to be shortened as much as possible and the road detection area should be wild. The plan is to use as many type B or F UAVs as possible when considering shorter transport times as the speed is fast, and more type B UAVs when considering a larger road detection area. These two requirements will also be the primary issues to be considered in the establishment of the models to ensure the selection of the best location. When thinking about the number of the containers, the distances can be calculated by the altitudes and longitudes as the first factor. Distance between Hospitals are listed in Figure 2.

Sequences Of Hospitals	H1	H2	H3	H4	H5
H1	0				
H2	41.93km	0			
H3	45.96km	24.82km	0		
H4	54.3725	24.26km	10.48km	0	
H5	114.99km	78.93km	69.98km	60.62km	0

Figure 2. Distance between Hospitals

It is known from the Figure 2 that the maximum distance between the two hospitals is 114.99km, which is more than twice the maximum no-load flight distance of any UAV in the selection. Therefore, it is obvious that one container cannot meet the rescue requirements. According to the data, it can be estimated that the time T of the affection lasted for hurricane 2017 in Puerto Rico is 360 days. Adding up the daily demand of five hospitals and V_{di} of different types of medicine packages, the total volume V_s of boxed drugs can be calculated as:

$$V_S = V_d * T$$

Assuming that the volume of a iso container for V_0 , it shows that $3V_i \gg V_S$, because requirements asked to minimize any unused space which needs buffer material, therefore three iso containers can only stuffed by a large number of UAVs to reduce the cost of container, but in too many planes will lead to higher costs and waste by the low use rate, so the solution is using two iso containers to meet the requirements of transport conditions, shorten the transport time and expand road detection area as much as possible.

In order to meet the requirements of minimizing unused space, we consider using the Three-dimensional Packing Model and the algorithm to reduce the spare area of iso containers, both guarantee the daily supplements, and take as many numbers of UAVs as possible, to ensure that the exploration efficiency and improve the system stability and reliability.

In the model, we combine the low risk (the lowest flight time) with high return (the wildest exploration area) to make the final decision. First, we work out the optimal solution under two targets Respectively through the nonlinear programming model. Then giving weight to each result to make the final decision

of location. When arranging the flight plan, we need to meet the supply schedule first and then increase the efficiency of the detection.

We can draw the following conclusions from the analysis of the problems:

- 1) The location of the two iso containers enables the Drone Go disaster response system to meet the requirements
- 2) Establish TDP model and algorithm to minimize the empty space in iso containers in order to reduce the volume of buffer materials
- 3) Establish the nonlinear programming model, work the solution out with the shortest flight time and the widest detection area respectively, and finally determine the optimal location of two iso containers by weighing the flight time and the exploration area.

4. Model

4.1 Drone Model

4.1.1 Usage Time and Backups

The probabilities of all the drones to get destroyed obey the exponential distribution. The mathematical expectation value means the usage time. We use the central limit theorem:

$$\lim_{n \rightarrow \infty} F_n(x) = \lim_{n \rightarrow \infty} \left\{ \frac{\sum_{i=1}^n X_i - n\mu}{\sqrt{n\sigma^2}} \leq x \right\} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{t^2}{2}} dt$$

M, when alpha is 0.95, the minimum amounts of the drones is $N \geq \left(\frac{mnT}{1.645M} \right)^2$. So, there is a positive correlation between the amounts of everyday running drones and the backup drones.

4.1.2 Best Location Problem

We found the less time the drones run, the less possibly they get destroyed. So the locations must satisfy the following demands:

- 1) Increasing the reconnaissance area
- 2) Declining the whole everyday running time of all the drones.

4.1.3 Drone Selection

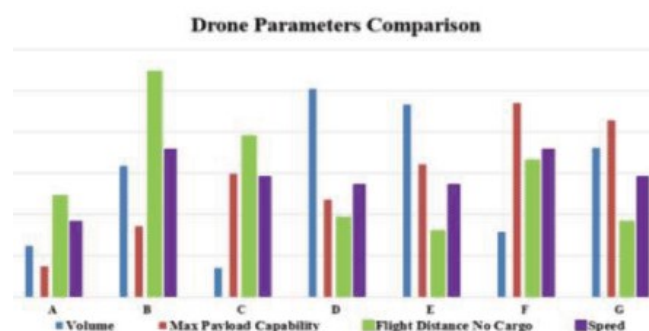


Figure 3. Drone Parameters Comparison

Also, the selection of the drones must obey the rules. In Figure 3 compared those drones with the four parts. The results show that Drone B run fastest and can cover a very long distance without cargo, which means it can cover a large reconnaissance area. So we choose Drone B.

4.1.4 Reconnaissance Shape

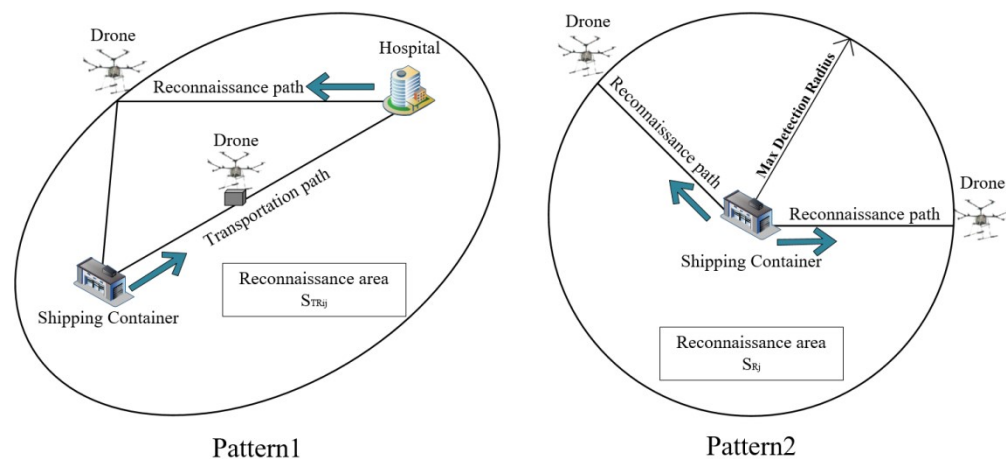


Figure 4. Drone B

The drones with cameras can conduct detection tasks in two situations:

1) On the way to hospitals

Because the hospitals and the locations are stationary, so we found the flight path of drones is oval in shape showed in Figure 4. The focal points are the hospitals and the locations.

2) Definite detection tasks

Also we found the flight path of drones which conduct a detection task is circle in shape showed in Figure 4.

4.1.5 Digital Image Processing

According to the coordinates of the hospitals and the container locations and the reconnaissance shapes, we use Matlab to extract the area of the reconnaissance and the road on the image (1). Showing in Figure 5.

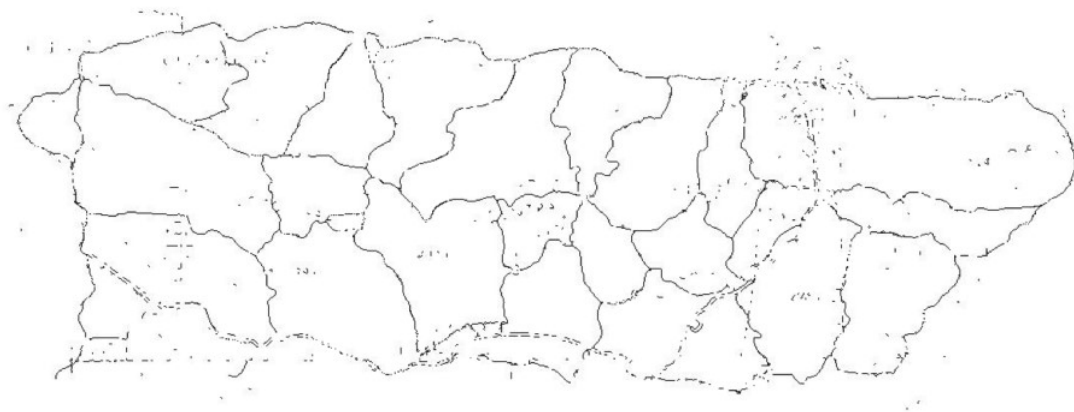


Figure 5. Extracted Highways

4.1.6 Drone Model

Figure 5 Extracted highways. According all the above conditions, we establish the following equations to find the best location where n_{ij} means whether distribute cargo from container location j to hospital i , 1, if yes; 0, if not and define $c_0 \leq 0.1$:

$$\left\{ \begin{array}{l} d_{5,A} \leq D_2^{(3)} \\ d_{4,A} \leq D_2^{(5)} \text{ or } d_{4,B} \leq D_2^{(5)} \\ d_{1,B} \leq D_2^{(5)} \\ d_{2,B} \leq D_2^{(5)} \\ d_{3,B} \leq D_2^{(2)} \text{ or } d_{3,A} \leq D_2^{(2)} \\ d_{5,A} + d_{4,A} \geq d_{4,5} \\ \frac{|V_A - V_B|}{V_A + V_B} \leq c_0 \\ \sum n_{ij} \geq 1 \end{array} \right.$$

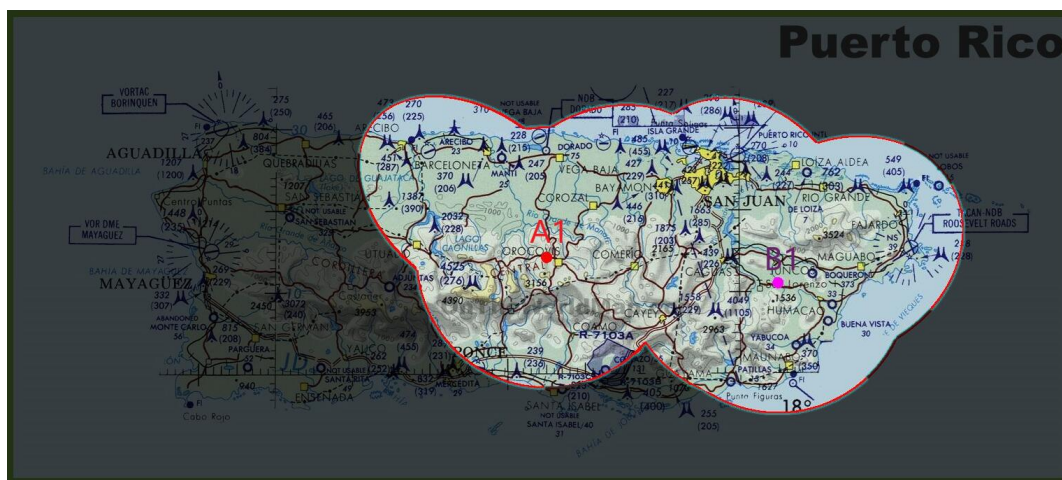


Figure 6. The Reconnaissance Area of A1B1

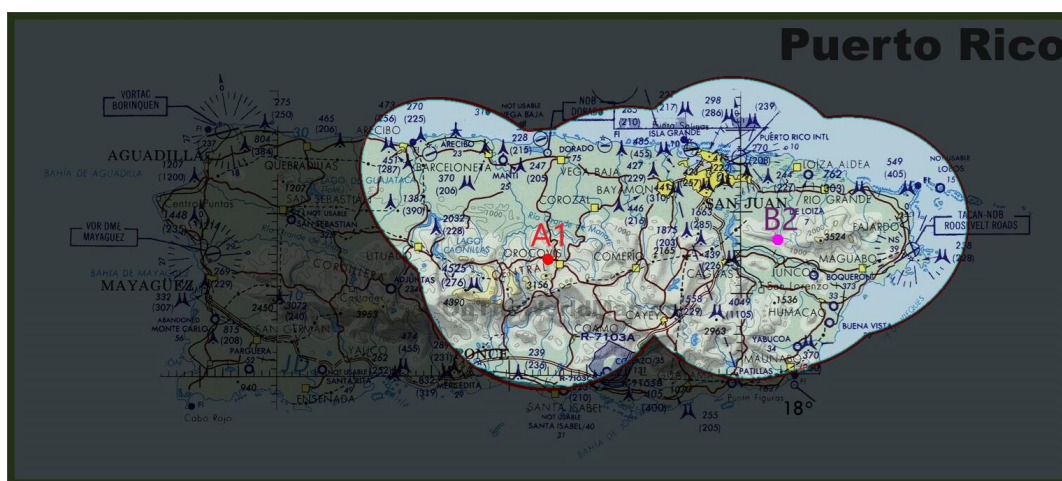


Figure 7. The Reconnaissance Area of A1B2

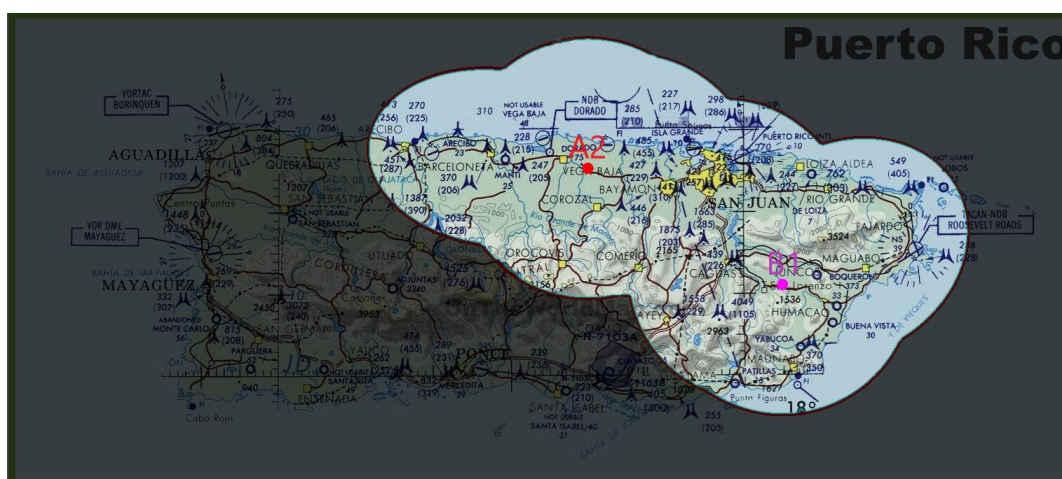


Figure 8. The Reconnaissance Area of A2B1

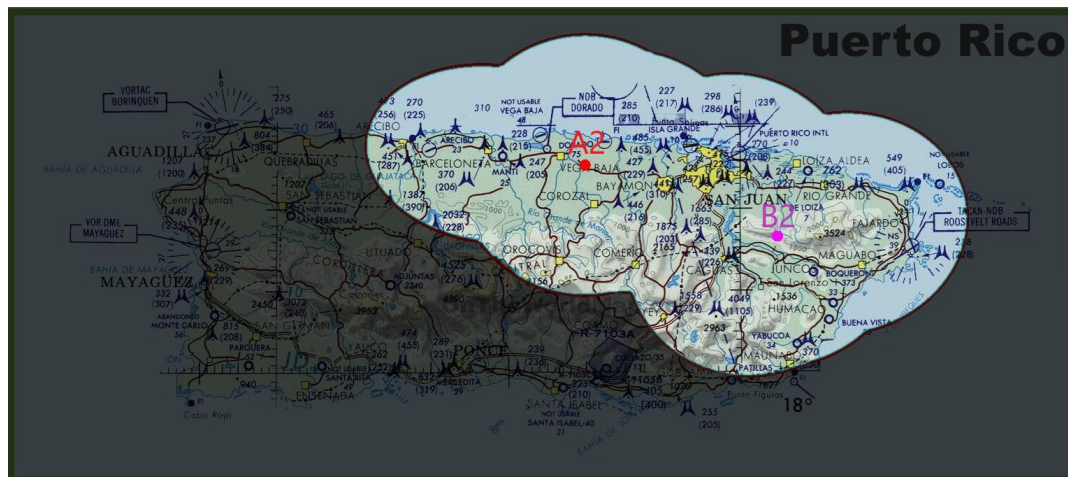


Figure 9. The Reconnaissance Area of A2B2

The result is plan 2 is the best scheme. The plan that using container A as the producer of H5, H3 or H5 only cannot meet the restraint of c_0 . and the distance between H1 and H5 and the distance between H2 and H5 is too long, so these pairs of hospitals cannot share one containers. The distance between H3 and H4 is too much shorter than the flight distance of drone b, so we consider them the same position. As a result, the scheme we need to discuss is A for H5, H4 or for H5,H4 and half of H3, and B supplies others. Then take the minimum time and maximum area into account, we draw a conclusion that scheme 2 is the best.

4.1.7 Model Optimization

When considering the emergency, we optimize our model. The demand of medicine differs from hospitals to hospitals, we define the center of gravity is (x, y) (where $x_0 = \frac{\sum Qx_i}{\sum Q}$, $y_0 = \frac{\sum Qy_i}{\sum Q}$ means the cargo distributed from j to i, d means the distance). We calculate the equations (2) using penalty function, the results are listed in Figure 10. We use SPSS for data normalization and calculate the weighted average:

$$G = c \cdot O_1 + (1-c) \cdot O_2$$

The destruction rate and the reconnaissance have connections with the recovery after disasters. On the analogy of the rate between disaster-relief funding and post-disaster reconstruction funding, c is 0.4.

Plan	Total Flight Time(min)	Plan	Reconnaissance Rate(%)
A1B1	574.5352153	A1B1	65.53%
A1B2	562.6260965	A1B2	62.76%
A2B1	527.6075096	A2B1	48.66%
A2B2	515.6983908	A2B2	45.24%
A3B3	552.3139495	A3B3	59.23%
A3B4	543.7889951	A3B4	54.12%
A4B3	532.8885272	A4B3	50.93%
A4B4	524.3635727	A4B4	44.54%

Figure 10. Comparisons between 8 Schemes

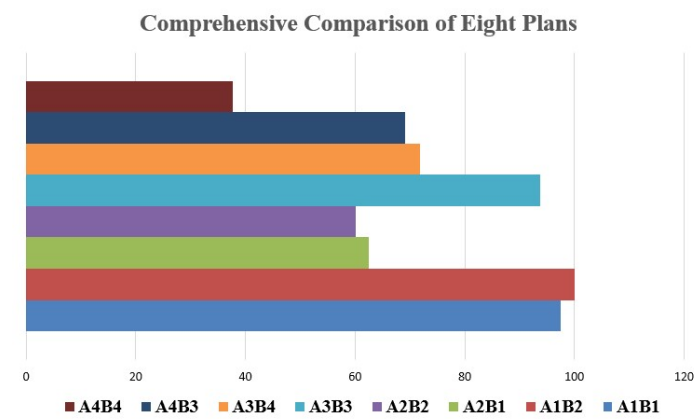


Figure 11. Comprehensive Comparison of Eight Plans

The results showed in Figure 11 show plan 2 is the best, and plan1 and plan 5 can be considered as a backup plans when c changes.

Shipping Container Location Coordinate	A1 (18.239,-66.416)	B2 (18.279,-65.921)
Distance To The Hospitals	H4-32.4km H5-41.99km	H1-29.18km H2-13.24km H3-23.09km
Reconnaissance Rate(%)	62.76%	
Total Flight Time(min)	562.63min	
Number of Drone Transported Daily	8	

Figure 12. The Index of Best Location

4.2 Schedule Model

During the delivery and return of drones, the schedule should conform to the following reality constraints:

- 1) Each aircraft should minimum the detecting time.
- 2) Detection aircrafts cannot take off at the same time.
- 3) Each aircraft can fly most three times a day, because of the charging time. We establish the following 0-1 equations:

Using Lingo, we can find sets of optimal solutions, and consider the shortest usage time:

Number	Drone Flight Plan(First Day Of The Period)											
Drone 1	To H1(M1+3)	Charging In The H1	Back To B	Charging At ContainerB	Reconnaissance	Charging At ContainerA						
Drone 2	To H2(M1+3)	Charging In The H2	Back To B	Charging At ContainerB		Stand By						
Drone 3	Stand By	To H2(M1)	Charging In The H2	Back To B	Charging At ContainerB	Reconnaissance	Charging					
Drone 4	To H3(M1+2)	Charging In The H3	Back To B	Charging At ContainerB		Stand By	Reconnaissance					
Drone 5	To H5(M1)	Charging In The H5	Back To A	Charging At ContainerA	Reconnaissance	Charging At ContainerA						
Drone 6	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA		Stand By	Reconnaissance					
Drone 7	Stand By	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA	Reconnaissance	Stand By					
Drone 8	Stand By	To H4(M2)	Charging In The H4	Back To A	Charging At ContainerA		Stand By					
Time	7:00-8:00	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	

Figure 13. Schedule

Number	Drone Flight Plan(Second Day Of The Period)											
Drone 1	To H1(M1+3)	Charging In The H1	Back To B	Charging At ContainerB	Reconnaissance	Charging At ContainerA						
Drone 2	To H2(M1+3)	Charging In The H2	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging					
Drone 3	Stand By	To H2(M1)	Charging In The H2	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging				
Drone 4	To H3(M1+2)	Charging In The H3	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging					
Drone 5	To H5(M1)	Charging In The H5	Back To A	Charging At ContainerA	Reconnaissance	Charging At ContainerA						
Drone 6	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA	Stand By	Reconnaissance	Charging					
Drone 7	Stand By	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA	Reconnaissance	Charging					
Drone 8	Stand By	To H4(M2)	Charging In The H4	Back To A	Charging At ContainerA	Reconnaissance	Charging					
Time	7:00-8:00	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	

Figure 14. Schedule

Number	Drone Flight Plan(Third Day Of The Period)											
Drone 1	To H1(M1+3)	Charging In The H1	Back To B	Charging At ContainerB	Reconnaissance	Charging At ContainerA						
Drone 2	To H2(M1+3)	Charging In The H2	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging					
Drone 3	Stand By	To H2(M1)	Charging In The H2	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging				
Drone 4	To H3(M1+2)	Charging In The H3	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging					
Drone 5	To H5(M1)	Charging In The H5	Back To A	Charging At ContainerA	Reconnaissance	Charging At ContainerA						
Drone 6	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA	Stand By	Reconnaissance	Charging					
Drone 7	Stand By	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA	Reconnaissance	Charging					
Drone 8	Stand By	To H4(M2)	Charging In The H4	Back To A	Charging At ContainerA	Reconnaissance	Charging					
Time	7:00-8:00	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	

Figure 15. Schedule

Number	Drone Flight Plan(Fourth Day Of The Period)											
Drone 1	To H1(M1+3)	Charging In The H1	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging					
Drone 2	To H2(M1+3)	Charging In The H2	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging					
Drone 3	Stand By	To H2(M1)	Charging In The H2	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging				
Drone 4	To H3(M1+2)	Charging In The H3	Back To B	Charging At ContainerB	Stand By	Reconnaissance	Charging					
Drone 5	To H5(M1)	Charging In The H5	Back To A	Charging At ContainerA	Reconnaissance	Charging At ContainerA						
Drone 6	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA	Stand By	Reconnaissance	Charging					
Drone 7	Stand By	To H4(M1+3)	Charging In The H4	Back To A	Charging At ContainerA	Reconnaissance	Charging					
Drone 8	Stand By	To H4(M2)	Charging In The H4	Back To A	Charging At ContainerA	Reconnaissance	Charging					
Time	7:00-8:00	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	

Figure 16. Schedule

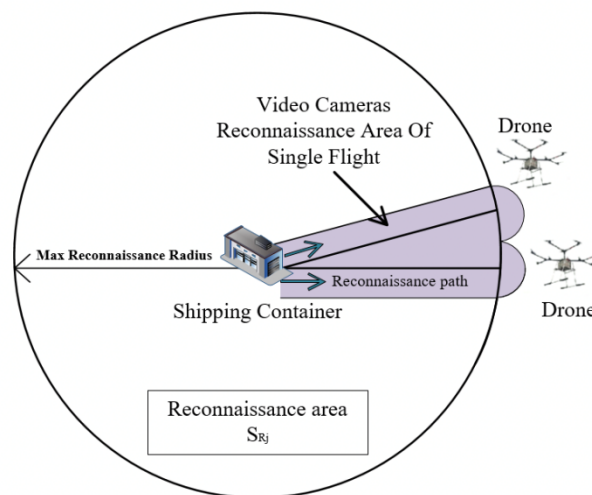


Figure 17. Plan of Road Reconnaissance

Each place should keep their path 2 km away from each other to minimum the detecting time. The result means the detection schedule and time Table is four days as a period with the Drone Go of 123 124 234 134 to permit every Drone Go is used as the same frequency.

We assumed that the detection radius is 1 km,

$$\frac{\left(\frac{y_2 - y_1}{x_2 - x_1}x - y + \frac{x_2 y_1 - x_1 y_2}{x_2 - x_1}\right)^2}{a^2} + \frac{\left(\left(\frac{x_2 - x_1}{y_1 - y_2}x - y + \frac{x_2 y_1 - x_1 y_2}{x_2 - x_1}\right)^2}{a^2 - (x_2 - x_1)^2}\right)}{a^2 - (x_2 - x_1)^2}$$

$$L = 4a \int_0^{\frac{\pi}{2}} \sqrt{1 - e^2 \sin^2 \theta} d\theta$$

The detection time is $C/(n * r)$, and the longest time to explore the full graphics is 84 days, which can meet the requirements, so the conclusion is reasonable. It also shows the Time Table and the test flight route:

Time	Container A	Container B
7:00-8:00	Drone B(MED1) To H5 Drone B(MED1+MED3) To H4	Drone B(MED1+MED3) To H1 Drone B(MED1+MED3) To H2 Drone B(MED1+MED2) To H3
8:00-9:00	Drone B(MED1+MED3) To H4	Drone B(MED1) To H2
9:00-10:00	Drone B(MED2) To H4	

Figure 18. Time Table



Figure 19. The Best Flight Route

4.3 Three-Dimensional Packing Model

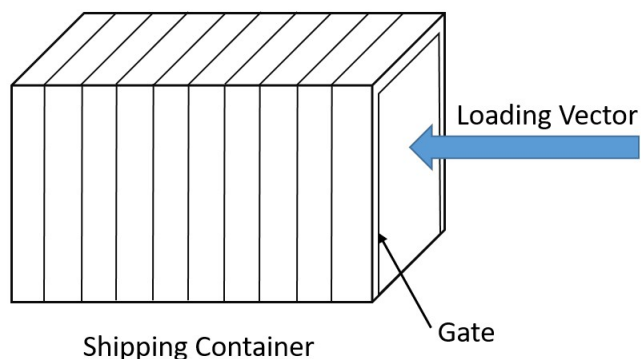


Figure 20. Loading Vector Schematic Diagram

We pack the container along the loading vector showed in Figure 20. Using the layer method and the packing rules in. We use the heuristic algorithm to calculate the filled space rate. The highest rate is 99.85%, and only 401 pieces of MED1 are loaded at this time. This result is meaningless. Therefore, considering the addition of new constraints which are as follows:

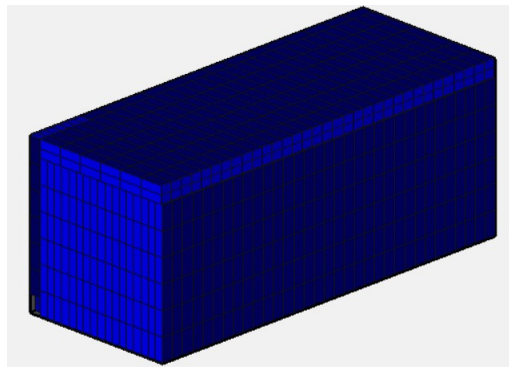


Figure 21. Packing Rate 99.85%

These equations conform to stability, fleet design, place of delivery and days of medication. The number of left-box aircraft is larger so the running time is longer, we can consider reducing B and adding medicine, that is, increasing the ratio c_0 to maximum the filled space. Then the left optimal solution is the volume ratio %. The excess drug can be used as an emergency, so it can still be considered that the condition is met, and finally the optimal solution for packing is considered as:

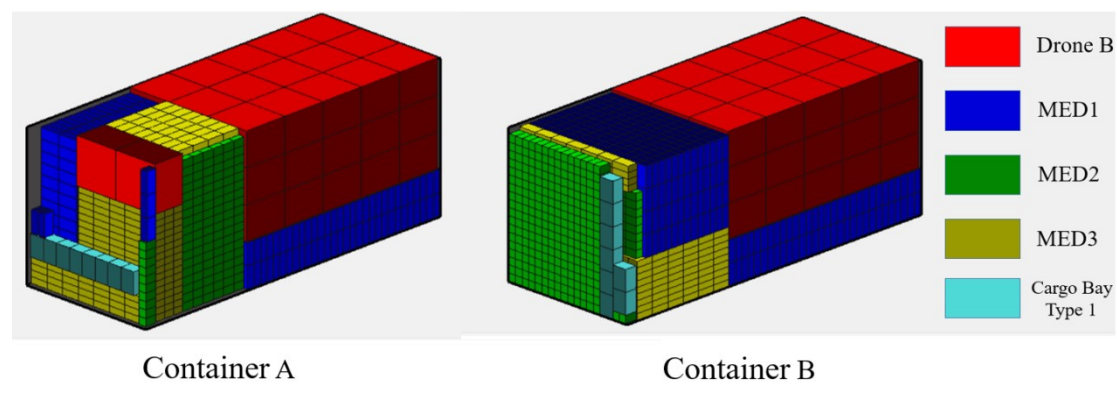


Figure 22. Optimal Solution for Packing

Shipping Container B-3D-P		Shipping Container B-emergency	
Cargo	Quantity	Cargo	Quantity
Grone B	45	Grone B	45
MED1	1456	MED1	1287
MED2	363	MED2	596
MED3	730	MED3	858
Cargo Bay Type1	8	Cargo Bay Type1	8
Packing Rate	92.48%	Packing Rate	97.01%

Figure 23. Packing Plan

Shipping Container A	
Cargo	Quantity
Grone B	48
MED1	1149
MED2	383
MED3	766
Cargo Bay Type1	8
Packing Rate	96.47%

Figure 24. Packing Plan

In Figure 24, Shipping Container B-3D-P is the solution to 3D-P and Shipping Container B-emergency is the solution to emergency, so the shipping container emergency has large packing rate.

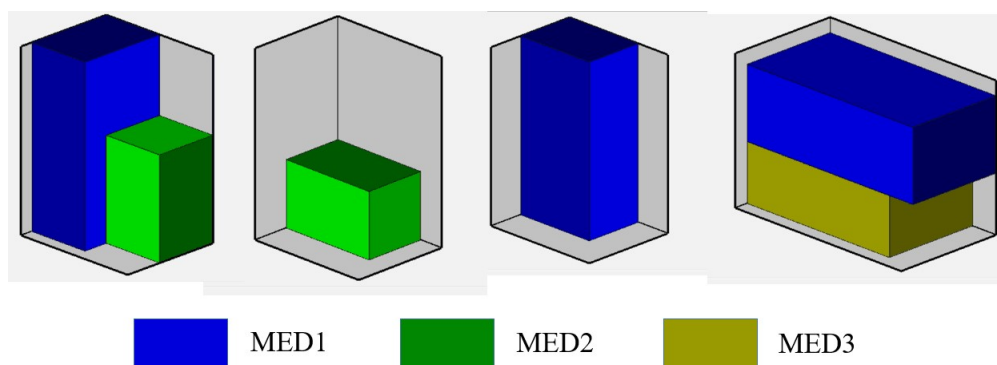


Figure 25. The Solution for Cargo Bay

4.4 Model Optimization

As the number of daily running aircraft is positively correlated with the number of aircraft backups, we come up with an optimized model on the basis of 2, comparing the max payload capability and flight distance we choose Drone F to distribute 4a which greatly reduces the whole daily delivery time and reduces the aircraft destruction. However, since there are no cameras on Drone F and the flight distance is shorter, the detection area will be reduced.

Optimized address coordinate					
Candidate Location	Latitude	Longitude	Candidate Location	Latitude	Longitude
A5	18.365	-66.348	B2	18.279	-65.921

Figure 26. Optimized Address Coordinate

Plan	Total Flight Time(min)	Plan	Reconnaissance Rate(%)
A1B1	574.5352153	A1B1	65.53%
A1B2	562.6260965	A1B2	62.76%
A2B1	527.6075096	A2B1	48.66%
A2B2	515.6983908	A2B2	45.24%
A3B3	552.3139495	A3B3	59.23%
A3B4	543.7889951	A3B4	54.12%
A4B3	532.8885272	A4B3	50.93%
A4B4	524.3635727	A4B4	44.54%
A5B2	370.9736272	A5B2	51.74%

Figure 27. Comparisons between 9 Schemes

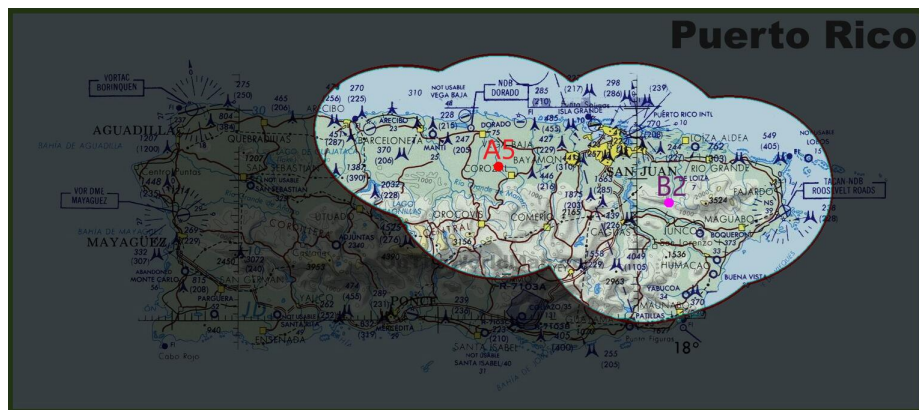


Figure 28. The Reconnaissance Area of A5B2

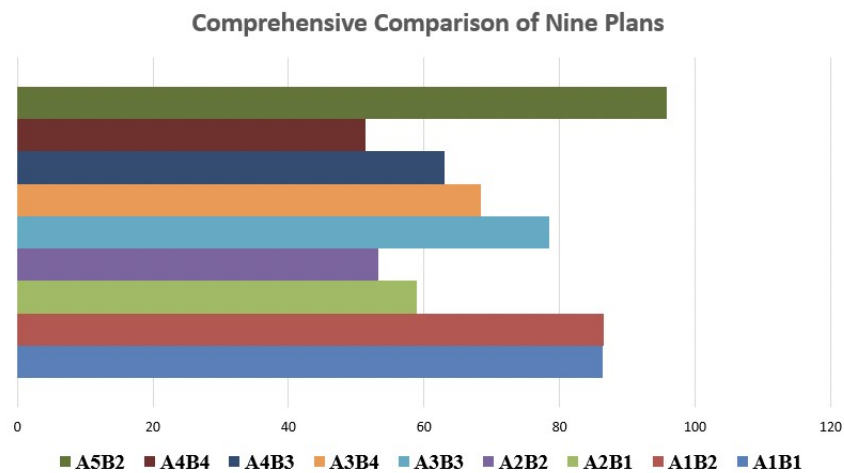


Figure 29. Comprehensive Comparison of Nine Plans

It can be seen in Figure 29 that this is a better solution in this situation. The reason is mainly because the flight time is greatly shortened, but the reconnaissance area is also reduced. Therefore, it can only

be used as an emergency solution, that is, an alternative solution when the amount of drone b is declined than the main option.

5. Strengths and Weaknesses

5.1 Strengths

- The model is stable even under emergency, which means the model fits the reality well;
- We consider that the distance back to the container is longer, so the reconnaissance area could be wilder;
- We think about the detection of road, because the wilder area of reconnaissance is not equal to the expansion to the area of roads;

5.2 Weaknesses

- We assume that the running time of drone is a constant which is not quite reasonable;
- The weight in the scoring is based on countries and disasters. So, it is changeable in different circumstance;

References

- Ho, Y. J., Lee, Seokcheon, & Song, B. D. (2019). Truck-Drone Hybrid Delivery Routing: Payload-Energy dependency and No-Fly Zones. *International Journal of Production Economics*.
- Li, Y. Z., Yuan, C. S., & Zhang, L. (2011). Analyze the C.G of a UAV Based on Load Task. *Science Technology and Engineering*. Retrieved from <http://ontheworldmap.com/puerto-rico/topographic-map-of-puerto-rico.html>
- <https://www.bbc.com/news/world-us-canada-45338080>
- Gao, L. N. (2017). *Lina. Optimal allocation model of disaster relief resources for material relief and financial appropriation*.
- Jens, E., & David, P. (2009). *Heuristic approaches for the two and three-dimensional knapsack packing problem*, *Computers Operations Research*, 36(4).