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DRONE DELIVERY SCHEDULING SIMULATIONS FOCUSING ON CHARGING SPEED, WEIGHT AND BATTERY CAPACITY: CASE OF REMOTE ISLANDS IN SOUTH KOREA

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ABSTRACT

Most countries usually have a logistical dead-zone problem which the delivery demand cannot be fully fulfilled on time via conventional transportation vehicles (i.e. trucks) due to the intrinsic geographical conditions. Demand in either small islands or mountainous regions might be hard to fulfill by logistics providers in comparison with other delivery areas. In this work, we proposed a drone delivery scheduling model and conducted various simulations using it to check the effect of various factors such as recharging speed, drone weight, and battery capacity on the simulation results. To show the feasibility of the proposed model and simulations, we analyzed a real case of remote islands in South Korea.

1 INTRODUCTION

During the past few years, drones have gained favor as an efficient delivery vehicle to replace traditional vehicle for logistics. Since a drone moves in the air, it does not disturb the ground obstacles such as traffic congestion and buildings. Therefore, it has excellent accessibility to customer on last-mile delivery. Thus, more companies have preliminarily tested drones for parcel delivery and are continuing technical experiments to use on actual areas.

Currently, delivery drones are usually limited to carrying one package of goods to a single destination. The available moving distance is only about 10~15 km when there are weak winds and clear sight. The weight of the loadable item is limited to approximately 5 lbs. Due to the short flight times due to the limited battery capacity, it is difficult to do route delivery with multiple items within the current level of technology. In addition, one of the most important concerns is the safety of the drone based delivery. In many countries, commercial drones are prohibited from flying in the city to prevent accidents which could occur during delivery or taking items.

Therefore, it is more likely that the drones will be used outside the city (plane area, mountainous area, island) rather than putting the drones into the crowded city. Furthermore, the drones could be a good alternative to deliver parcels to the remote islands or the mountainous areas. Demand in either small islands or mountainous regions might be hard to fulfill using the conventional carriers.

In South Korea, there are many inhabited islands throughout the west and south coast. In general, the delivery lead time for the remote islands is one to three more days than other areas. It is inconvenient that the island residents must move to the near larger islands or main land to claim their ordered items. In this study, we propose a drone delivery scheduling model for effectively delivering the parcels to the remote islands. The proposed model is based on a hub and spoke network and a mixed integer programming model used for our various simulations.

Figure 1: Remote islands in South Korea

2 MODEL CONSIDERATIONS

The assumptions and characteristics of the proposed model and simulations are as follows.

- The battery capacity is limited to an hour approximately, and recharging is required when the battery is fully exhausted.
- Several drones are used together for the parcel delivery to any remote islands.
- A drone can load and carry only one item at a time due to the fixed payload. The scheduling model generates various optimal objective values and schedules according to various purposes (maximizing delivery volume, balancing delivery volume), and suggesting delivery and charging timing of each drone.

3 SIMULATION RESULTS AND CONCLUSIONS

The simulations using the proposed model and two data sets (real data and virtual data) were carried out to check the followings:

- Checking the feasibility of the model by running the model in accordance with the various distances from the depot to the destination (remote islands) and the delivery amounts.
- Checking the increase of the delivery amounts by changing the recharging speed, the body weight and the battery capacity.

The real data was used for checking the feasibility while the virtual data was used for better understanding the effect of changing various factors (i.e. recharging speed, body weight, and battery capacity). After the simulations, we found that the fast speed of the drone derives better results (increasing the maximum number of the parcels) when the distance variance among destinations (the remote islands) is small. Also, the simulation results showed that the recharging speed plays an important role to increase the delivery amount in comparison with the other two factors. Thus, when trying to improve the drone specifications, we need to focus on reducing the recharging speed of the battery which directly increase the delivery amounts. To verify our simulation results, we are now conducting the extensive experiments using various scenarios and experiment designs, and they will be published as a journal article in the near future.

Table 1: Simulation results.

1) Using real data (the figures indicate the maximum number of parcels delivered by the drones)										
RS	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%
Results	18	18	19	19	20	20	21	21	22	23
W	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%
Results	18	18	19	19	20	20	21	21	22	22
BC	110%	120%	130%	140%	150%	160%	170%	180%	190%	200%
Results	18	19	19	20	20	21	21	21	22	22
2) Using virtual data (the figures indicate the maximum number of parcels delivered by the drones)										
RS	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%
Results	59	60	61	62	64	65	66	67	69	70
W	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%
Results	59	60	61	62	64	65	66	67	68	70
BC	110%	120%	130%	140%	150%	160%	170%	180%	190%	200%
Results	60	61	63	64	65	66	66	67	68	68

RS: Recharging speed, W: Weight, BC: Battery capacity

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