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A Feasibility Assessment of the Optimal Use of Hydrogen Drones in Fashion Item Replenishment Logistics

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Extended Abstract

What should be considered in optimising the delivery routes for stock replenishment in a retail textile company? Traditional land-based truck delivery makes prompt returned or new products replenishments in small batches from one location to another impractical due to the high shipping costs incurred. Drones, which serve as digitized delivery equipment especially in western countries nowadays, realise last-mile and door-to-door deliveries. Breaking geographical barriers, drones raise operational efficiency and lower human- and equipment-related costs. Nonetheless, drone delivery regulations set legal boundaries. Added to this are the teething issues arisen in the drone deliveries across regulatory borders. As a consequence, retail replenishment performance and stock holding cost are rendered sub-optimal. In a fashion company's setting, how do the small-batch deliveries using drones demonstrate their multifaceted advantages on the existing replenishment operation and the environment? A feasibility assessment able to show the logistics and environmental benefits of drone delivery with reference to the relevant regulations is yet to be in place to push boundaries.

Objective

This paper was to assess the feasibility of using hydrogen drones to improve fashion retail logistics distribution and replenishment operations with reference to relevant legal requirements. It also aimed at identifying the differences in the delivery efficiency and environmental impact between the existing truck and the optimised drone logistics replenishment models of a fashion brand.

Data/Methodology

The findings of this paper are based on empirical but masked operational data of an Asian clothing brand, which has multiple fashion stores in both Hong Kong and Macau. The potential benefits of adopting hydrogen drone delivery to achieve transportation efficiency and environmental protection were first explored by understanding locational and cross-locational drone regulations. The existing fashion item truck replenishment model of the company was identified. Assuming certain drone specifications good for the delivery purposes, a drone replenishment model for the delivery of requested or returned items among stores was then developed. In the end, the two models were compared in terms of their travel distance, delivery time, and carbon emission impact during peak and slack seasons.

Results

Findings on the existing regulations reflect room for drone delivery of fashion items within Hong Kong, and between Macau and the city, all depending on the careful selection of the types of unmanned aviation vehicles (UAV) with respect to the power such as hydrogen fuel cell, gasoline and hybrid engine; wingspan; maximum payload; maximum take-off weight; maximum speed; altitude of operation; flight duration, time, area; and the communications with and approvals of relevant authorities and parties.

In the fashion item truck replenishment operation, number of trucks, requesting and responding stores, delivery lines (with stops at different stores) of trucks, delivery weekdays, delivery costs per clothing unit and distance, and storage cost of trucks are system parameters for the model. The drone version of replenishment model requires additional inputs: regulation-banned locations and daily delivery costs. Important decision variables and system parameters in the truck replenishment model are shown in Figures 1 and 2, respectively. The map of the shortest delivery lines with all replenishments completed, and the route arrangements in one delivery line are illustrated in Figures 3 and 4, respectively. The existing truck and the optimised drone's travel distances, delivery times and carbon emission impacts are compared in Table 1.

Fashion Item (Unit)	Respondent										
Requester	Store05	Store10	Store17	Store27	Store38	Store39	Store41	Store44	Store45	Store46	Tota
Store05		1			1		1				3
Store10			1	1		1		1	1	1	6
Store17									1		1
Store27			1							1	2
Store38											0
Store39											0
Store41	1				1					1	3
Store44			1	1		1					3
Store45		1	1		1		1	1			5
Store46					1						1
Total	1	2	4	2	4	2	2	2	2	3	24

Figure 1. Quantities of fashion items

Distance (km)	Respondent									
Requester	Store05	Store10	Store17	Store27	Store38	Store39	Store41	Store44	Store45	Store46
Store05	0.0	2.3	4.2	2.6	10.6	0.7	7.2	1.8	2.5	7.5
Store10	2.3	0.0	2.6	1.0	9.0	2.7	5.6	3.8	0.7	5.9
Store17	4.2	2.6	0.0	1.6	6.3	4.8	3.0	4.7	1.9	3.3
Store27	2.6	1.0	1.6	0.0	8.0	3.2	4.6	3.8	0.3	4.9
Store38	10.6	9.0	6.3	8.0	0.0	11.2	3.4	11.1	8.3	3.7
Store39	0.7	2.7	4.8	3.2	11.2	0.0	7.8	1.9	3.0	8.1
Store41	7.2	5.6	3.0	4.6	3.4	7.8	0.0	7.7	4.9	0.3
Store44	1.8	3.8	4.7	3.8	11.1	1.9	7.7	0.0	3.8	8.1
Store45	2.5	0.7	1.9	0.3	8.3	3.0	4.9	3.8	0.0	5.2
Store46	7.5	5.9	3.3	4.9	3.7	8.1	0.3	8.1	5.2	0.0

Figure 2. Distances between clothing stores

requested and supplied among stores

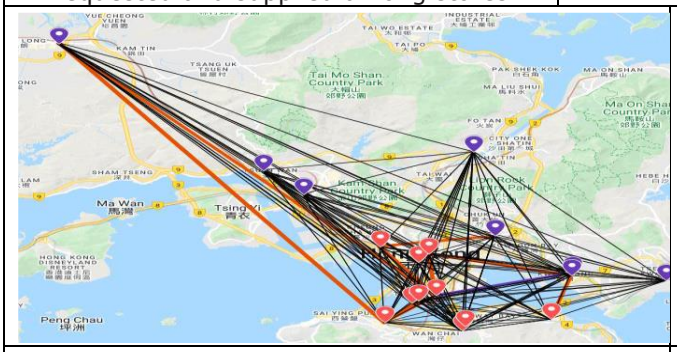

Figure 3. Optimised delivery lines of fashion items by drones using Excel Premium Solver

Peak season's line 1 shortest path	1st route	2nd route	3rd route
	Location		
	Store05	Store38	Store44
	Store44	Store46	Store23
	Store39	Store41	Store30
	Store10	Store17	Store36
	Store45	Store27	Store33
	Store27	Store45	
	Store17	Store10	
	Store41	Store05	
	Store46	Store44	
	Store38		
Distance (km)	16.0	13.7	35.8

Figure 4. Optimised routes in one drone delivery line in peak season

Table 1. Comparison of truck and drone replenishment models

	Peak Season		Slack Season	
	Existing Truck Model (weekly replenishment)	Optimised Drone Model (daily replenishment)	Existing Truck Model (weekly replenishment)	Optimised Drone Model (daily replenishment)
Travel distance	207.0 km	145.6 km	180 km	65.3 km
Delivery time	8 hours 41 minutes	1 hour 37 minutes	5 hours 57 minutes	43 minutes
Carbon emission	229.6 $kgCO_2$-e	0 $kgCO_2$-e (hydrogen drone assumed)	199.6 $kgCO_2$-e	0 $kgCO_2$-e (hydrogen drone assumed)

By formulating replenishment routing plans according to legal requirements, results in Table 1 reflects drone delivery is viable for the fashion brand's operations: stock arrival can be more punctual, and profit can be better promised by selling garment units more promptly. The benefit of its negligible carbon emission is incomparable.

Implications for Research

A feasibility assessment of using drones to replenish clothing items among locations was conducted. During COVID-19, there is a surge in the demand of delivery of items with more customised types and sizes. Delivery reducing human contact and operatable under various circumstances should be encouraged to convenience the market. Existing regulations on drone delivery can be reviewed regarding their flexibility to balance safety, privacy, and business vitality, in particular, in terms of drones' operational details. If the feasibility of drone delivery can be assessed systematically, its genuine benefits can be brought to the public squarely. In future, sensitivity analyses on the changes to drone delivery regulations can be conducted to identify its further benefits for the logistics industry. Systematic optimised route-based evaluations of drone delivery across regulatory borders can also be carried out.

Keywords: Drone delivery, replenishment operation, fashion, optimisation, regulations

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