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Effects of cargo types and load efficiency on airline cargo revenues

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ABSTRACT

Numerous factors affect air cargo revenue management. Air cargo companies base their cargo charges on whichever is the greater of gross weight or volumetric weight. We developed a cargo consolidation model based on air cargo characteristics, and investigated the effect of cargo density, the Density Ratio of Heavy cargo to Light cargo (DRHL), and the percentage of small cargo on the chargeable weights and revenues of airlines. The empirical results show that a higher DRHL indicates greater chargeable weight, and that as the DRHL climbs to a certain level, the extent of chargeable cargo weights tends to stabilize gradually. The closer the cargo density approaches the most suitable loading density for a flight, the greater the chargeable weight is. A higher proportion of small cargo loaded on an aircraft means higher airline revenue. Our results can effectively combine types of air cargo to increase loading rates and revenues for airlines.

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1. Introduction

In the past decade, as global trading has matured, international air cargo transport has experienced tremendous growth under the closely linked global supply chain. Over the next two decades air cargo is expected to increase at a rate of 4.5%–5.0% per year (Airbus, 2014; Boeing, 2014). Air cargo industry will continue to flourish in the wake of air transport liberalization (Wang and Heinonen, 2015), prospective long-haul low-cost carriers (Poret et al., 2015), and the implementation of the open skies agreement (Alves and Forte, 2015).

Airline companies are the main operators of air cargo transport responsible for airport-to-airport services. The participants of air cargo include shippers, air freight forwarders, customs brokers, cargo terminals, ground handling services. After customs clearance procedures, the cargo is packed and placed in a container and loaded onto the aircraft. Most airlines provide both passenger and cargo transport and outsource part of their cargo operations to airfreight forwarders. Consequently, international air cargo, an operation-intensive industry, involves complex decision-making procedures and numerous players. How airline companies can

effectively combine types of air cargo to increase loading rates and revenues has become an important issue for operations management.

Unlike the fixed and known capacity of passenger seats, cargo space has greater uncertainty in terms of allocation and demand (Kasilingam, 1996; Morrell, 2011). Charges for airfreight are also complex and based on the gross weight or volume of the cargo, with the greater of the two as the chargeable unit. According to the IATA's list of airfreight rates, the greater the chargeable weight per shipment, the lower the unit price. Airfreight carriers consider both weight and volume when calculating their air cargo charges; thus, it is important to consider the relationship between the two when selling cargo space.

An aircraft loaded with excessively heavy cargo results in unused space because the aircraft has reached its maximum load, despite the cargo space not being fully used. In contrast, an aircraft carrying too much light cargo leads to wasted weight capacity because the total cargo weight is less than the aircraft's maximum load but its cargo space has reached full capacity. Therefore, accepting balanced quantities of heavy and light cargo ensures greater chargeable weights and increases revenues. As consignment weights increase, airline companies offer more favorable rates. This means that total revenues fluctuate depending on the percentage of large or small loads that aircrafts carry when the demand-supply-equilibrium game and the willingness to pay.

In summary, in terms of airfreight rates, it is necessary to

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consider multiple factors and limits because air cargo handling and freight charging are complex. Therefore, we created several mathematical models concerning flight charges, ULD weight limits, cargo weight, and balance to examine the effect of air cargo density, the Density Ratio of Heavy cargo to Light cargo (DRHL), and the percentage of small cargo on chargeable weights and revenues. We also provide operations management references for airline companies. The remainder of this paper is organized as follows: Section 2 presents a review of the relevant literature, Section 3 provides the model formulation details, while Section 4 presents its application. Finally, Section 5 offers concluding remarks and suggestions for future research.

2. Literature review

We mainly examined the characteristics of air cargo loading and factors affecting air cargo revenues. Because of aircraft restrictions, passenger planes can only carry cargo in the belly. In this case, fuel, the number of passengers, and quantity of baggage determine payloads and aircraft cargo space. The ULD used varies according to aircraft types, and different ULDs have specific weight and volume limits. Airline companies determine the number of pallets and containers allowed based on booking information from forwarders and cargo types, and the suitable types of ULD for aircrafts.

Over the past years, more attention has been paid to the problem that precedes airline container loading problem with pickup and delivery by considering how to optimize freight loading within ULDs ([Li et al., 2009](http://www.sciencedirect.com/science/article/pii/S0377221715001289), [Tang, 2011](http://www.sciencedirect.com/science/article/pii/S0377221715001289), and [Wu, 2010](http://www.sciencedirect.com/science/article/pii/S0377221715001289)) independently of aircrafts. [Vancroonenburg et al. \(2014\)](#) attempted to determine how to select the ULDs or items to be loaded in an aircraft or a fleet of aircraft, whereas others assumed that all ULDs must be loaded in the aircraft.

For aircraft structural safety, weight limits exist for every position and area inside the aircraft cargo holds (see operation manuals for different aircraft types). Forwarders can also choose between more containers or more pallets depending on whether the plane carries more cargo in small cardboard boxes, irregular voluminous light cargo, or larger cargo. [Chan et al. \(2006\)](#) presented a two-phase intelligent decision support system for the air cargo loading problem. They developed a new approach for the air cargo 3D loading plan on differently shaped and sized pallets.

Previous studies of airline cargo management has focused mainly on cost analysis ([Chao and Hsu, 2014](#); [Lakew, 2014](#); [Mayer and Scholz, 2012](#)). [Yan et al. \(2008\)](#) developed a stochastic demand cargo container-loading plan model to minimize total operating cost, subject to the related operating constraints. The results show the model and the solution method to be useful for air express carriers. For the air cargo revenue management problem, [Huang and Chang \(2010\)](#) developed a solution algorithm based on approximating the expected revenue function in the dynamic programming (DP) model while accounting for the stochastic volume and shipment weight. [Han et al. \(2010\)](#) considered booking acceptance and rejection options for airline companies. They assumed that each booking request is endowed with a random weight and volume, and proposed a Markovian model for calculating and deciding whether to accept booking requests as a reference for airline companies in allocating aircraft cargo capacities.

3. Model formulation

Airfreight charging characteristics necessitate considering both

weight and volume. Therefore, chargeable weight is greater when the aircraft cargo has a higher ratio of low-volume heavy cargo to high-volume light cargo. This section provides an airfreight charging model, a description of a mathematical model involving the factors affecting air cargo revenues, and limits of ULD loading onto the aircraft.

3.1. Airfreight charging model

Charges for airfreight account for both cargo weight and volume, and the greater of the two is the chargeable weight. The conversion from cargo volume to volumetric weight, according to IATA criteria, is that the volume (in cubic centimeters) divided by 6000 (5000 for express carriers). According to the IATA list of airfreight rates, airline companies charge different unit prices based on chargeable weights by cargo types. As chargeable weights increase, airline companies offer more favorable rates. [Table 1](#) lists the air cargo delivery rates from Taipei (TPE) to Dallas Fort Worth International Airport (DFW) in the United States in 2013. If the chargeable weight is less than 44 kg, the unit price is US\$12.66/kg. However, the minimum charge is US\$70, which means that the freight remains US\$70 for all chargeable weights less than 5 kg. If the chargeable weight is between 35 and 45 kg, the charges are calculated using US\$438.3/(9.74*45). [Fig. 1](#) shows a summary of the relationships between chargeable-weight class intervals and total prices in 2013. In this study, small cargo refers to cargo whose freight rate is not the lowest. Take the TPE-DFW delivery route for example, small cargo on this route refers to cargo whose chargeable weight is less than 1000 kg (i.e., whose freight rate is higher than US\$5.44).

According to the pricing characteristics, let σ^f represent airline revenue from the flight of an f -type aircraft on route t . σ^f can be formulated as

$$\sigma^f = \sum_b \text{Max} \left\{ \sum_i \text{Min} \left(B_{bi}^f \cdot \hat{w}_b^f \cdot P_i^f(\hat{w}_b^f), W_{i+1} \cdot P_{i+1}^f \right), M^t \right\} \forall f, t \quad (1)$$

$$\hat{w}_b^f = \text{Max} \left\{ W_b^f, \frac{V_b^f}{\gamma} \right\} \quad \forall f, t, b \quad (2)$$

$$B_{bi}^f = \begin{cases} 1 & \text{if } \hat{w}_b^f \in (W_i, W_{i+1}] \\ 0 & \text{otherwise} \end{cases} \quad \forall f, t, b, \quad (3)$$

where $\hat{w}_b^f$, $P_i^f(\hat{w}_b^f)$, W_b^f , and V_b^f are the chargeable weight, unit price, gross weight, and volume on the master airway bill b of an f -type aircraft on route t , respectively; γ represents the IATA criteria for the volume to volumetric weight conversion for air cargo. Depending on whether the volume is in cubic centimeters or cubic feet, the constant is 6000 (5000 for express carriers) or 0.2119¹ (0.1765 for express carriers). The chargeable weight of a master airway bill can be calculated using Equation (2). W_i are the weight boundaries of rate class interval i , and M^t is the minimum charge for route t . The symbol definitions in this study are shown at [Appendix A](#).

3.1.1. How the DRHL affects chargeable weights

Airline companies base their charges on weight for heavy cargo and volume for light cargo. The higher the DRHL on a flight, the

¹ 1 foot = 12 × 2.54 cm; 6000 cubic centimeters = 0.2119 (6000 ÷ 12³ ÷ 2.54³) cubic feet.

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