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Determination of Air Cargo Performance: Analysis of Revenue Management, Terminal Operations, and Aircraft Loading (Air Cargo Management Literature Review)

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Abstract: Previous research or relevant research is very important in a research or scientific article. Previous research or relevant research serves to strengthen the theory and phenomena of the relationship or influence between variables. This article reviews three issues, namely: revenue management, terminal operations, and aircraft loading which affect the performance of air cargo. The results of this literature review article are: 1) There are revenue management problems that can affect air cargo performance; 2) There are problems with terminal operations that can affect the performance of air cargo; and 3) There are problems with aircraft loading which can affect the performance of air cargo.

Keywords: Revenue Management, Terminal Operations, Aircraft Loading, Air Cargo

INTRODUCTION

Airports are one of the most important infrastructures for international trade, as 35% of global trade, in terms of value, and around 90% of business-to-consumer e-commerce is transported by air (IATA, 2018). The air cargo industry is increasingly functioning as a major facilitator of world trade and has doubled in volume every 10 years since 1970 (Chang et al., 2007). The industry experienced an increase in demand of 10.4%, as measured in Freight Tonne Kilometers (FTK), in the first half of 2017 compared to the same period in the previous year. This growth was the strongest increase since the collapse that followed the 2010 Global Economic Crisis (Turkish Cargo, 2017). More than doubling growth is expected with 4.2% annually in world air cargo traffic and a more than 75% increase in world cargo fleet between 2018 and 2037 (Boeing, 2018). The number of shipments will triple and grow at an annual rate of 5.9% over the next 20 years. Among these, the top five areas with high growth rates are Domestic China (9.2%), Intra-Asia (7.9%), Asia–North America (6.7%), Europe–Asia (6.6%), and Southern Europe (6.5%). The results above show that the Asian region can become the focus of developing air transport in the future (Boeing, 2012).

Air cargo is a mode of air transportation that can be a good substitute for other modes of transportation such as sea or rail (Kupfer et al., 2016). Air cargo is used for the transport of urgent goods over medium to long distances. Its selling points are speed and reliability. Air cargo is a global means of transport and is generally produced on intercontinental wide-body flights (Lange, 2019). Air cargo transportation involves a series of services from origin to destination to move cargo through shippers, shippers, road carriers (or truck drivers), airlines (or carriers), and consignees (Derigs et al., 2009). Shippers need commodities to be delivered anywhere in the world at a low cost and the required level of service. The forwarder acts as an "intermediary" between the shipper and the airline. Road carriers provide ground transportation services before and after air transportation. Airlines receive, store, transfer, track, load, and unload cargo, and assign and manage capacity. The consignee receives the shipment (Kasilingam, 1997).

Air cargo transport is more complex than passenger transport because the former involves more players, more sophisticated processes, weight, and volume combinations, a variety of priority services, integration and consolidation strategies, and multiple network itineraries than the latter. the complexity of air cargo operations causes various problems that are still not resolved satisfactorily (Feng et al., 2015). Airlines are challenged to manage their air cargo operations efficiently by developing strategic operating plans that enable these airlines to quickly adapt and respond to changes in the global competitive environment. (Ferguson et al., 2013). So, it is necessary to carry out an analysis related to four types of problems: revenue management, terminal operations, and aircraft loading which affect air cargo.

The phenomena that have been stated provide the formulation of the problem to be discussed in this article as follows:

1. Does revenue management affect air cargo?
2. Does terminal operations affect air cargo?
3. Does aircraft loading affect air cargo?

LITERATURE REVIEW

Air Cargo Performance

Air cargo carriers aim to maximize their profits by capitalizing on current demand and using their limited capacities in the right places. Two types of airlines are involved in the supply chain of these services: integrated express carriers and combination passenger and freight carriers. Combination carriers may carry air freight, express parcels, and mail in the bowels of passenger aircraft and operate dedicated cargo aircraft (Li et al., 2012). The airline (or carrier) provides services to freight forwarders and shippers, including consulting, booking capacity, picking, receiving, packaging, sorting, loading, transportation, shipping, and tracking and tracing of cargo (Feng et al., 2015). Air cargo services are classified into several levels according to the level of priority (eg, speed and reliability) required by the shipper. Fares vary based on the priority of service and type of cargo, such as dangerous goods, live animals, perishable food, and goods of high value (Nobert & Roy, 1998).

Two factors were identified as differentiating the air cargo transportation network when compared to its passenger counterparts, namely: First, cargo operations are more concentrated than passenger operations, rely more on a hub-and-spoke structure, and involve fewer airports. While passengers generally select airports within a 1-hour radius of their origin or destination, the catchment area for air cargo transport extends to a 12-hour radius as it relies on Road Feeder Services (RFS) for the ground leg. This means that a small number of airports can be used to cover the same delivery area.

In addition, cargo handling and consolidation require an additional layer of logistics, consisting of dedicated warehouses and ground handlers, special temperature control rooms for perishable products, etc., which not all airports have. Second, the number of connections with other airports is not the best proxy for assessing the relevance of an airport in the air cargo transportation network. Despite the correlation between the two factors, the cargo business is characterized by a large imbalance in the number of goods that can be transported. This demand imbalance is especially relevant for passenger airlines, which use a combination of full cargo and belly capacity. Rather than the number of joints, what should be assessed is the overall cargo capacity that the joints can provide (Bombelli et al., 2020). The main differences between cargo and passenger operations according to (Feng et al., 2015), are as follows:

1. Uncertainty

   Air cargo transportation is subject to higher uncertainty than passenger transportation in terms of capacity availability. In passenger transportation, passengers may cancel reservations, and a small number of passengers may not show up. However, in booking capacity for air cargo, the freight forwarder must promise the use of the cargo capacity on certain flights before twelve (or six) months (Amaruchkul et al., 2011). The quantity of goods to be shipped is not the order ordered, so this creates high fluctuations in capacity management. Usually, freight forwarders don't have to pay for unused capacity. Without penalty fees for unused capacity, shippers can order more than is needed to cut risk or compete unscrupulously with others. Meanwhile, many air cargo orders were canceled, rebooked, and canceled again because airlines usually do not charge fees for booking changes. Therefore, the order process is subject to considerable volatility (Petersen, 2007).

2. Complexity

   Forecasting cargo capacity is significantly more complex than forecasting passenger aircraft capacity. While passenger aircraft capacity is determined based on the number of seats, cargo capacity depends on the type of container used, called unit load devices (ULD), which is further determined by various dimensions, such as pivot weight, pivot volume, type, and center of gravity (Leung et al., 2009). For example, the capacity may be sufficient in terms of volume but not in terms of weight when heavy cargo arrives. Multiple dimensions are a key feature of freight, leading to the complexity and uncertainty of air cargo capacity management.

3. Flexibility

   Transshipment itineraries between origin and destination (OD) for cargo transportation benefit airlines more than passenger transportation. In general, all major airlines operate what is called hub-and-spoke networks. Passengers and cargo are transported from various origins to a small number of hubs, where the passengers and cargo are combined and then transported to other hubs using wide-body aircraft. For passenger transportation, too many transits are not acceptable, while air cargo can be moved through several intermediary airports from origin to destination to meet delivery times (Amaruchkul et al., 2011). The airline only needs to notify the airport of the origin, transit, and destination to the forwarder and can make a transshipment itinerary plan to optimize the use of network capacity.

The factors influencing the choice of airlines for cargo transportation are constantly evolving. Cost of carriage is an important factor in air cargo services, but consistent transportability and reliability to minimize risk are even more important (Lille & Sparks, 1992). Space availability for the Americas route, as well as freight costs and schedules for the Europe and Southeast Asia routes, were considered the most important variables (Lee, 2003). The most important service factors provided by airlines are convenient schedules, flight frequency, space, convenient use of telephones, and consistent sales policies, rather than fares. Judging from each route, the airline that offers lower fares for routes to Southeast Asia, enough space for routes to America, and convenient schedules for routes to Europe, is the most preferred (S. W. Moon, 2006).

Factors that can influence the selection of airlines for cargo transportation are summarized from several previous studies by (Yoon & Park, 2015), namely: freight rates and flight frequency appear as the most important factors when choosing an airline (Kim, 2008). The factors that affect a forwarder when choosing an airline are low rates, reliable delivery schedules, and fast cargo transportation times (Moon, 2010). The weight and size of the goods are also important variables (Bae, 2011). Accuracy and speed are more important factors than other factors from a professional perspective (Park et al., 2009).

Revenue Management (RM)

Air Cargo Revenue Management (CRM) deals with the integrated management of available cargo and cargo space, and cargo rates after accommodating passengers and their bags. CRM differs from Passenger Yield Management (PYM) in several ways due to the specific characteristics of cargo inventory, cargo business, and cargo ordering behavior (Kasilingam, 1997). Air cargo revenue management is the integrated management of specific cargo and passenger aircraft capacity forecasting, network capacity planning and allocation, pricing, overbooking, reject-or-accept policies, and capacity contracts, to maximize overall profitability. Air cargo revenue management differs from passenger yield management in several aspects due to the different characteristics of different cargo types in terms of available capacity estimation, network capacity allocation, and capacity ordering behavior (Feng et al., 2015).

The characteristics of an air cargo RM differ from an air passenger RM in many ways. One fundamental difference is the nature of the product. For air passenger RM, seats are a well-defined product in terms of demand initiated by the customer and capacity provided by the supplier. However, air cargo shipments are categorized by weight and volume, which can be stochastic in practice. In addition, with the hub-and-spoke operation of most airlines today, RM's research focus has shifted from the traditional one-leg version to the network version. However, no substantial research work was found to confirm the applicability of real-world problems to air cargo RM (K. Huang & Lu, 2015). Cargo yield management differs from passenger yield management in many ways. The four important differences are as follows:

1. Uncertain capacity

   Passenger yield management controls a fixed and known number of seats. In managing cargo revenue, the weight and volume/position available for sale are not fixed. It depends on payload, stomach space, and the expected number of passengers on board and their bags. In addition to the variability of the expected number of passengers, the load is also a variable. It depends on several factors like a runway, weather, fuel weight, ramp weight, etc. This introduces the need to develop a model to estimate the available capacity for cargo sales. This in turn makes one of the main inputs of the overbooking model, capacity, and stochastic properties. In the PYM overbooking model, the capacity is assumed to be known and deterministic.

2. Three-dimensional capacity

   Cargo capacity is 3 dimensions, namely weight, volume, and the number of container positions. For example, when ordering low-density shipments, capacity may be available in terms of weight but not in terms of volume. Sometimes, weights and volumes may be available to accommodate a shipment, but may not fit in the container due to their different shape. This results in what is known as a suck loss. The 3-dimensional nature of capacity necessitates the need to work with weight and volume/position capacity estimates. This can sometimes be overcome by using standard weight-volume relationships or density values established using historical data.

3. Itinerary control

   Passengers prefer to follow their itinerary without being bumped or diverted. On the other hand, cargo can be sent by any route as long as it is available at the destination within the specified or agreed delivery date and time. Therefore, several routes may be available to deliver cargo from origin to destination. This adds one more dimension to PYM's traditional capacity/bucket allocation model used to allocate space to different tariff or service classes.

4. Allotments

   The main differences above warrant a special type of yield management system with a more complex model than the traditional passenger yield management system. For example, mathematically, the overbooking model must be able to handle the stochastic nature of cargo capacity. The allocation model needs to address some routing between the origin and destination. Additional models are required to prepare rations. In addition, the relationship between weight and volume is another important issue that must be considered in all yield management models.

Terminal Operations

Before cargo is transferred to the aircraft, it is delivered to the airport terminal by truck and then unloaded for inspection, information verification, sorting, and packing. This process involves decision issues regarding workforce planning and scheduling, cargo processing, truck arrivals, and stevedoring management for air cargo terminal operations, all of which are interdependent. Airlines sometimes require the services of third-party terminal operators, such as the Hong Kong Air Cargo Terminal and the Singapore Airport Terminal Services Terminal, particularly for international cargo transportation (Feng et al., 2015). Air cargo terminals are an integral part of the air cargo supply chain operations.

Air cargo terminal performance contributes to the overall performance of the air cargo supply chain. In response, air cargo supply chain actors are eager to find the best air cargo terminal that can provide the best service at a reasonable cost. Airport fees and cost minimization are indeed important considerations for air cargo carriers in choosing a terminal (Wasesa et al., 2015). Air cargo terminals can be seen as an important link in the global supply chain network. The incredible speed of aircraft combined with the high frequency of scheduled flights to cities around the world has greatly reduced transit times (Rong & Grunow, 2009).

Aircraft Loading

Aircraft loading is mostly in the form of loading ULDs into aircraft with multi-dimensional constraints, such as weight, volume, container position, the center of gravity, type of container, and random passenger baggage. As a modeling problem, plane loading is defined as the 3D bin packing problem (BPP), which is one of the basic problems in combinational optimization and is characterized as an NP-hard problem (Feng et al., 2015). Broadly speaking, the air cargo loading (ACL) problem aims to assign cargo containers to specific loading positions within the aircraft.

The problem of loading new air cargo is subject to four types of constraints, namely: assignment constraints; maximum position weight limit and consideration of zero fuel weight limit; center of gravity (CG) envelope restriction condition, which is based on the weight of the aircraft and CG which fluctuates during the refueling process; respecting panel weight limits (legacy limitations of passenger aircraft structures), which are related to CG sheathing; and finally, lateral unbalance limits for a two-row cargo configuration (Desai et al., 2023).

Table 1. Literature Review Findings

No.	Author (years)	Research Title	Research result
1	Jitamitra Desai, Sandeep Srivathsan, Woen Yon Lai, Liqun Li, Chuhang Yu (2023)	An optimization-based decision support tool for air cargo loading	The air cargo loading problem is formulated as a mixed integer nonlinear programming model 0–1, which is then linearized, and four types of plane configurations are used to test our formulation. The results show that significant improvements can be achieved compared to the more traditional methods used in the freight forwarding industry
2	Bo Feng, Yanzhi Li, Zuo-Jun Max Shen (2015)	Air cargo operations: Literature review and comparison with practices	This study reviews the literature on air cargo operations and compares theoretical studies with the practical problems of airlines, freight forwarders, and terminal service providers. We then highlight in-depth findings from industry interviews and present the gaps between previous research and practical reality. We finally discussed the new research opportunities for air cargo operations according to the gaps
3	Alessandro Bombellia, Bruno F. Santosa, Lóránt Tavasszy (2020)	Analysis of the air cargo transport network using a complex network theory perspective	To our knowledge, this is the first work in which a global cargo network consisting of passenger airlines, full cargo airlines, and capacity integrators is studied. We use the estimated annual cargo capacity between the airport pairs as the model input. After assessing the network characteristics of the sub-networks representing different carrier types, the full network is obtained as a superimposition of each sub-network. The resulting network has the characteristics of a small world and is scale-free. Its topological properties result in higher flow unbalance and concentration concerning its counterpart passengers, with smaller characteristic path lengths and diameters. These results are consistent with the larger catchment areas of cargo airports, which rely heavily on road feeder services for the ground leg
4	Iordanis Tseremoglou, Alessandro Bombelli, Bruno F. Santos (2022)	A combined forecasting and packing model for air cargo loading: A risk-averse framework	Packing problems are sequentially solved after a new order request is received, predicting the shipping dimensions, if necessary, and taking into account the uncertainty of those predictions. An order is accepted if it results in a feasible loading configuration where no previously received orders were unloaded. When applied in a deterministic context, our packaging methods outperform those used by partner airlines, increasing cargo volumes by up to 20%
5	R.G. Kasilingam (1997)	Air cargo revenue management: Characteristics and complexities	Air Cargo Revenue Management (CRM) deals with the integrated management of available cargo and cargo space, and cargo rates after accommodating passengers and their bags. CRM differs from Passenger Yield Management (PYM) in several ways due to the specific characteristics of cargo inventory, cargo business, and cargo ordering behavior. This adds to the complexity of some of the traditional yield management models and requires the development of certain additional models. There is a difference between CRM and PYM
6	Anne Lange (2019)	Does cargo matter? The impact of air cargo operations on departure on-time performance for combination carriers	This study uses an econometric model to investigate how air cargo operations impact the quality of service perceived by passengers. Based on empirical data from the U.S., this shows that air cargo operations increase departure delays

7	Ching-Cheng Chao, Ko-Ting Kao (2015)	Selection of strategic cargo alliance by airlines	This study explores how airlines select strategic cargo alliances to become members. Ordered by weight, the dimensions in descending order are business benefits, resource complementarity, cost-effectiveness, and brand image. The three criteria considered most important by airlines were 'improving flight routes and frequency,' 'increasing revenue,' and 'improving load factor
8	Baozhuang Niua, Zhipeng Daia, Xiaopo Zhuo (2019)	Co-opetition effect of promised-delivery-time sensitive demand on air cargo carriers' big data investment and demand signal sharing decisions	RM proved to be very effective in generating additional revenue for diverse and uncertain demand, given the fixed perishable inventory capacity. By most estimates, the revenue gain from implementing RM is around 4%-5%, which is comparable to the total profitability of many airlines in a good year. However, unlike air passenger operations supported by well-developed RM systems with advanced decision models, the process of selling air cargo space to forwarders or freight forwarders is usually not very automated
9	Dongsheng Xu, Cai Wen Zhang, Zhaowei Miao, Raymond K. Cheung (2014)	A flow allocation strategy for routing over multiple flow classes with an application to air cargo terminals	Major cargo terminals are now installing increasingly integrated automated shipping handling systems to increase their operational efficiency which can be measured by the average delivery time or facility throughput, for example. Routing is an important decision category that has a significant impact on operational efficiency. In this paper, motivated by a project with one of the world's busiest air cargo terminals, we investigate the route optimization problem for several flow classes with different priority levels

Source: Data of Research

RESEARCH

This scientific article writing method uses a literature review with a systematic type of literature review (systematic literature review). The systematic literature review is a research method undertaken to identify, evaluate and interpret all research relevant to a particular research question, topic area, or phenomenon of interest. There are three main processes in a systematic literature review, namely planning the review, conducting the review, and reporting the review (Bela et al., 2021). Journal searches were carried out using search engines such as ScienceDirect, Mendeley, and Scholar Google.

RESULT AND DISCUSSION

Revenue Management Affects Air Cargo Performance

Not much literature discusses the effect of RM on air cargo, but RM problems will affect the air cargo work process. Air cargo revenue management issues relate to matters such as special cargo and passenger aircraft capacity, network capacity planning and allocation, pricing, overbooking, reject-or-accept policies, and capacity contracts (Feng et al., 2015). Overbooking, which is one of the critical issues in yield management, is handled. RM must make the right decision to accept or reject incoming booking requests. Incoming order requests may consist of one or more shipments, which may or may not differ in size. Two nested problems that RM analysts have to resolve when receiving a new order request. Outside issues consist of forecasting the dimensions of the shipment (if not provided) and available aircraft capacity (Tseremoglou et al., 2022). After estimating the available capacity in an overbooking situation, the airline decides to accept or reject booking requests from freight forwarders to optimize expected revenue. Concerning this issue, (Amaruchkul et al., 2007) proposed a single-flight Markov decision model to help airlines decide whether requests from freight forwarders should be accepted or rejected.

A refinement of the model (Amaruchkul et al., 2011) addresses the issue of capacity allocation in the management of one leg of air cargo revenue with additional consideration of the level of profit for each type of cargo. They assume that each cargo order request has a random weight, volume, cargo type, and profit rate, and they propose a Markovian model for handling order requests. Meanwhile, (K. C. Huang & Chang, 2010) also modeled the same decision problem by using dynamic programming, and they proposed a joint approximation algorithm to solve high-dimensional state space problems to improve the de-coupling heuristic, which is one of the six algorithms with the highest performance.

In addition to the ad hoc sales issues mentioned above, air cargo revenue management includes medium to long-term contract issues. For example, studying the problem of incomplete carrier-shipper contracts, in which the carrier's level of effort determines the size of the request (Gupta, 2008). Studying contracts with three parameters, namely allotment, lump-sum payment, and refund rate, between carrier and forwarder in the principal-agent framework (Amaruchkul et al., 2011). An option contract that considers forwarder transfer. Numerical studies further provide an analysis of the impact of overbooking on contract parameters and profitability (Hellermann, R., Huchzermeier & Spinler, 2013).

Terminal Operations Affect Air Cargo Performance

Cargo processing issues include routing cargo between crews and multi-type facilities (e.g., self-driving vehicles, stacker cranes, cargo hoists, and conveyors), and scheduling cargo, to minimize waiting times and maximize resource utilization. There is not much literature that discusses the effect of terminal operations on air cargo, but these problems can affect the work process of air cargo. Using time-colored Petri nets to model air cargo processing from handling equipment at the terminal (C. Lee et al., 2006). Develop approaches to troubleshoot different types of material handling equipment in automated air cargo terminals by considering the interaction between the equipment (Lau & Zhao, 2006). Flow allocation routing strategy, in which a set of allocation ratios is derived from a multi-commodity network flow model with congestion considerations (Xu et al., 2014).

In local municipal air cargo transportation, the management of arrival and unloading of air cargo terminal trucks determines the time intervals for cargo delivery, intending to minimize waiting times, subject to limited service capabilities. This process influences the decision on the number of pickups and deliveries and truck routes for the freight forwarder. Problems scheduling trucks at airport terminals and modeling the terminals as a single service queuing system with random mass arrivals (Hall, 2001). Develop a truck arrival scheduling model at an air cargo terminal by coordinating shipments that are directly transferred to departure flights and other shipments that must be stored in terminal storage facilities (Ou et al., 2010).

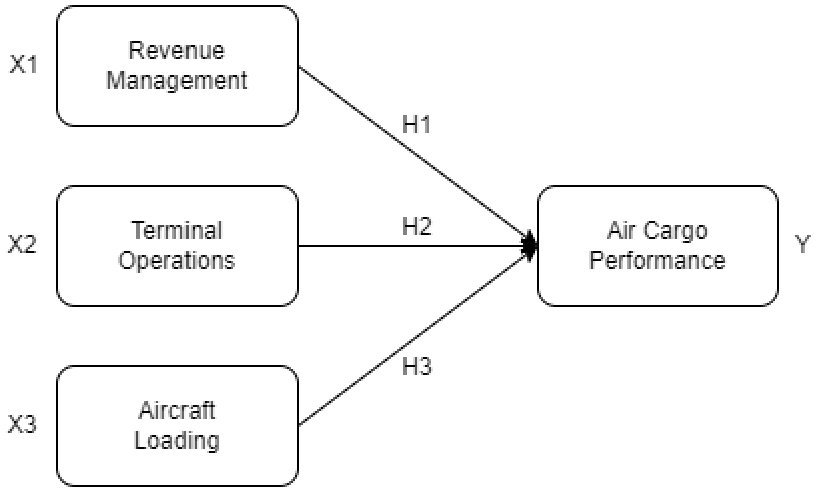
Aircraft Loading Affects Air Cargo Performance

There is not much literature that discusses the effect of aircraft loading on air cargo, but problems in aircraft loading will affect the air cargo work process. Bin Packing Problem (BPP) balance. Aircraft loading issues were identified as BPP issues. The loading rate of the aircraft depends on the passenger's baggage, weather conditions, loading duration, and even the placement of the passenger's seat (eg first wing or first tail). In load balancing, for example, ground-loading crew members were found to have little time to achieve optimal loading for the combination or passenger aircraft. A myriad of problems had to be addressed. Key decision issues include how to allocate different types of containers, pallets, and non-certified pallets with nets to different aircraft cabins and how to combine heavy and light cargo on board to maximize loading rates and minimize fuel costs under different conditions. The aircraft loading problem needs to extend the traditional BPP model to a balanced BPP model by incorporating mechanical problems. Policies that can be applied realistically instead of optimal solutions desired by airlines (Feng et al., 2015).

Discussion of the issue of how to load the maximum number of containers onto an aircraft, with a compromise between minimizing fuel consumption and meeting safety requirements (Mongeau & Bès, 2003). Cargo container loading plan model and check this model with FedEx operation made by (Yan et al., 2006). Then, the model is extended to the problem of loading aircraft into a stochastic environment and constructs a mixed integer non-linear model for container loading of cargo taking into account the stochastic perturbation of daily cargo transport demand. (Yan & Chen, 2008). A new problem was identified, in which airlines seek optimal baggage allowance policies when cargo is carried in the remaining abdominal space of the aircraft along with passenger baggage (Wong et al., 2009).

Conceptual Framework

Based on the description that has been explained previously, the following framework is obtained:



Source: Data of Research

Picture 1. Conceptual Framework

Based on the conceptual framework image that has been presented, the following results are obtained:

1. H_1 : Revenue Management Affects Air Cargo Performance
2. H_2 : Terminal Operations Affect Air Cargo Performance
3. H_3 : Aircraft Loading Affects Air Cargo Performance

In addition to the results stated above, variable Y can still be influenced by variables other than those listed, such as overbooking (X_4), service supply chains (X_5), capacity management (X_6).

CONCLUSIONS

Based on the research result and discussion that have been described, conclusions can be drawn to answer research questions:

1. Revenue Management Affects Air Cargo Performance;
2. Terminal Operations Affect Air Cargo Performance;
3. Aircraft Loading Affects Air Cargo Performance.

RECOMMENDATIONS

Based on the theory, relevant articles, and discussion, hypotheses can be formulated for further research:

1. Fleet routing affects air cargo performance;
2. Flight scheduling affects air cargo performance;
3. Service supply chains affect air cargo performance;
4. Capacity management affects air cargo performance;
5. Overbooking affects air cargo performance;
6. Bin Packing Problem (BPP) affects air cargo performance;
7. Service outsourcing affects air cargo performance;
8. Dynamic outsourcing affects air cargo performance.

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