



# A mathematical programming model for aircraft leasing decisions

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## ABSTRACT

For the airline fleet planning problem, this paper formulates a mathematical programming model specifically also taking into account of the increasingly popular capital lease, which has some mixed features of the two traditional aircraft acquisition methods: operating lease and purchase. Given the aircraft requirements, budget, and debt-ratio limit, the objective is to minimize the total cost within the planning horizon. Numerical experiments were conducted to compare the optimal solutions for the airlines with different business models, scales, and experiences. This paper further simulates a scenario under the new standards which will be applied in 2019. The results of sensitivity analysis show that when the debt-ratio constraint is relaxed, capital leases would be helpful for reducing the cost of airlines.

## 1. Introduction

The high cost of aircraft burden airlines with immense financial pressure. Purchasing aircraft involves not only large down payments and loan repayments, but also depreciation costs during the aircraft's useful life. Therefore, apart from purchasing aircraft, airlines also lease aircraft to compose their fleets. Table 1 shows the percentage of leased aircraft in the world during the past five decades. The share has increased from 0.5% in 1970 to just over 40% in 2014. According to a forecast by Boeing Company, the share is likely to reach 50% in 2020 (Geffert, 2015). This trend means that aircraft lease planning is a critical strategic decision for airlines. Furthermore, the number of commercial aircraft in the world will increase as the global air transportation market grows. Boeing Company (2014) estimated that there will be 36,770 new aircraft from 2014 to 2033 at a cost of 5200 billion USD. These trends mean that aircraft leasing and purchasing decisions will increasingly affect the finances of airlines in the coming decades.

There are different types of aircraft leasing and new types are continuously being developed. The contents of some aircraft leasing alternatives influence not only airline expenses but their entire balance sheets. Thus, it is important for airline operators to consider the various types of aircraft leasing options, the financial condition of the airline, and fleet planning goals. In recognition of these challenges, this paper aims to formulate a model to optimize aircraft leasing and purchasing decisions, taking into account different types of leasing.

Although there are many aircraft leasing alternatives, most can be classified into one of the two most common types: operating leases or capital leases. In the air transport industry, many major airlines use

both operating and capital leases to compose their fleets. For example, American Airlines built its fleet with 516 operating leased aircraft, 33 capital leased aircraft, and 397 purchased aircraft (American Airlines, 2016). In the Middle East, the Emirates fleet includes 134 operating leased aircraft, 81 capital leased aircraft, and 16 purchased aircraft (Emirates Group, 2016). In Asia, Cathay Pacific has adopted operating leases, capital leases, and purchases simultaneously for many years. The current fleet of Cathay Pacific includes 60 operating leased aircraft, 50 capital leased aircraft, and 91 purchased aircraft (Cathay Pacific, 2016). These examples indicate that airlines have different strategies for aircraft leasing, taking into account their financial conditions, fleet planning goals, and alternatives provided by leasing companies.

A comparison between operating leases and capital leases is shown in Table 2. If the airline operator's goal was to satisfy the air transport demand for a relatively short period of time while avoiding depreciation costs and risks due to purchasing new aircraft, then operating leases would be appropriate. In this case, airlines lease aircraft that are owned by leasing companies. To provide operating leasing services, leasing companies usually order in large quantities different aircraft types that are in common use. Since one of the goals of operating leases is to provide additional fleet capacity for short periods of time, the terms of operating leases are flexible and may be several months or years. Vasigh et al. (2014) indicated that the terms of most aircraft operating leases are between 2 and 7 years. Currently, the Generally Accepted Accounting Principles (GAAP) published in the United States specify that the terms of operating leases should not exceed three-fourths of the estimated useful life of the leased assets; that is, the aircraft.

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**Table 1**  
The share of leased aircraft in the world's airline fleets.  
Source: Geffert (2015).

Years	1970	1980	1990	2000	2014	2020 (forecasted)
Percentage	0.5%	1.7%	14.7%	24.7%	40.7%	50%

Under the new standard that will be implemented in 2019, lease terms of operating leases cannot exceed 12 months (International Accounting Standards Board, 2016). During these periods, airlines pay rent to leasing companies, according to their contracts. In operating leases, rent is defined as an operational expense in the financial reports of airlines and has no influence on assets, debts, and depreciation costs. When the lease term ends, airlines can choose to renew or terminate the leases, but are not allowed to purchase leased aircraft. Since operating leases provide flexibility in lease terms, leasing companies need to cover the depreciation costs and the risk that aircraft are idle when the lease terms end. To cover costs and risks of leasing companies, rental costs for operating leases are high compared to other types of leases. Furthermore, Vasigh et al. (2012) indicated that, operating leases do not allow the benefit of writing off an aircraft to a zero tax basis, since the lease payments are accounted for as expenses.

If the airline operator's goal was to finance aircraft, then capital leases—also called financial leases—would be appropriate. With this alternative, leasing companies make “loans of aircraft” to airlines. Airline operators designate aircraft types before leasing companies order them from manufacturers. Since aircraft types are determined by airline operators, in order to reduce the risk that an aircraft is idle when the lease term ends, the terms of capital leases are much longer than that of operating leases. The length of the lease terms of some capital leases are similar to the useful life of an aircraft. GAAP currently specifies that the terms of capital leasing contracts should be no shorter than three-fourths of the estimated useful life of the leased aircraft.

In January 2016, the International Accounting Standards Board (IASB) issued International Financial Reporting Standard (IFRS) 16-Leases, which will replace International Accounting Standard (IAS) 17-Leases. IFRS 16-Leases will be applied to annual reporting periods beginning on or after 1 January 2019 (IASB, 2016). Under IFRS 16, for all leases with terms greater than 12 months, lessees will be asked to recognize assets and liabilities, as requirements in existing capital leases. Rent for capital leases contain principal and interest, and airlines pay rent according to calculations in contracts. All the characteristics of capital leases mentioned above mean that a capital lease resembles a loan with a Loan-to-Value (LTV) of 100%. In the financial reports of airlines, the principal in capital leases is defined as debt, and capital leased aircraft are defined as assets. Moreover, depreciation costs for capital leased aircraft are covered by airlines. However, depreciation costs and expenses for interest can be deducted from the taxable income

of airlines. Vasigh et al. (2012) indicated that, for capital leases and purchases, having the aircraft as an asset on the balance sheet has long-term tax implications for the airline. That is, airlines can receive tax benefits for interest and depreciation expenses. Since lease terms are long and depreciation costs are covered by airlines, rent for capital leases is much lower than for operating leases.

Based on the above-mentioned characteristics, the pros and cons of the three alternatives (operating leases, capital leases, and purchases) can be summarized as the follows. First, for operating leases, the advantages include flexible lease terms and rentals that do not increase the debt ratios of airlines, and the disadvantage is high rental compared to other alternatives. Second, capital leases are similar to purchases, and airlines can determine aircraft types before ordering from manufacturers. The most important advantage of capital leases is that airline operators can avoid making down payments. In addition, the cost of rent in capital leases are lower than the cost of rent in operating leases. However, the disadvantages of capital leases include long lease terms, high interest rates compared to aircraft purchases, and the increase of rentals on airlines' debt ratios. Third, for aircraft purchases, in addition to the ability to determine the aircraft types to be purchased, the major advantage is the low acquisition cost per unit period compared to other alternatives. However, the disadvantages of purchases include the need to make down payments, the need to cover depreciation cost during the long useful life of an aircraft, and the increase of loans on airlines' debt ratios.

This paper proposes a mathematical model to explore aircraft leasing and purchasing decisions of airline operators. In this model, it is assumed that fleet planning has been completed, and the airline operator needs to determine the number of aircraft to be obtained via operating leases, capital leases, and purchases, and to make decisions about lease and/or loan terms. Costs including rent for aircraft leases and loans for purchases, and limits for terms of leases and loans for different alternatives were taken into account. Variations of the airline's assets and debts were also considered. The objective of the model is to minimize the airline's costs under constraints of fleet size, budget limits, and debt ratio. That is, the objective function in our model focuses on how much an airline pays when an aircraft is acquired. The changes in the IASB standard may affect some constraints (e.g. debt ratio) and parameters. While most fleet planning research has not considered the changes as a result of the new standard, the proposed model in this paper accounts for the new definition of capital leases (longer than 12 months) and operating leases (within 12 months). Regardless of changes to the classification of leases, airlines require various sources of aircraft—including long-term and short-term leases—and need to take into account flexibility and budget constraints.

Apart from the classification of leases into operating lease and capital lease, another classification of leases defines dry leases and wet leases. However, wet leases are rarely adopted by airline operators due to high rental costs. If an airline operator adopts wet leases, their

**Table 2**  
Comparison between operating leases and capital leases for aircraft.

	Operating Leases	Capital Leases
Airline's goal	Adjust fleet capacity in the short term.	Financing.
Aircraft type	Chosen and ordered by leasing company, with aircraft types in common use.	Assigned by airline but ordered by leasing company.
Lease term	Flexible and can be months or years, which are much shorter than the useful life of an aircraft.	Approximately equal to depreciation duration of an aircraft.
Airline's options at the end of lease term	Renew the lease or terminate the lease.	Renew the lease, terminate the lease, or purchase the aircraft.
Rent	High.	Low.
Depreciation cost	Covered by leasing companies.	Covered by airlines.
Influence on airline's balance sheet	No effect on assets or debt of the airline. Rent is part of the operation cost of the airline.	Leased aircrafts are assets of the airline. Rent is part of the debt of the airline.
Advantages for airline finance	Advantageous to reduce debt ratio of the airline because rent is not classified as debt.	Depreciation costs and interest expenses can be deducted from the airline's taxable income.

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