4 OPERATING COSTS AND EFFICIENCY OF CARGO AIRCRAFT

The cost for air cargo operations is relatively complex and fluid because of four factors:

- Aircraft technology,
- Route characteristics,
- Structure of operations,
- Sensitivity to energy prices.

Cost structure

The principal components of the cost for air cargo transport are: the aircraft's capital and direct operating costs, the airport and navigation fees,[25] the ground handling charges and the cost for airline administration. The capital costs include depreciation and amortization for purchased aircraft and rentals for leased aircraft. The direct operating costs are primarily for fuel, maintenance, crew and insurance. The crew and insurance costs are fixed. The maintenance costs, which include routine maintenance as well as major overhauls for the airframe and engines, are variable. The schedules for maintenance and replacement of parts is linked either to flight cycles or hours of operation. For aircraft that are obtained through wet leases or charters, the rental costs include crew and maintenance.[26] The airport fees are primarily landing and parking fees. The ground handling costs include handling charges for the aircraft and cargo. The costs for administration depend on whether the airline is all-cargo or combination and whether it provides a scheduler or charter service or both.

These costs can be divided between exogenous costs, over which the carriers have little or no influence, for example fuel prices and airport charges, and endogenous costs, which the carrier can control through its procurement and operating procedures, for example capital, labor, and maintenance.

There are some economies of scale associated operating an aircraft, specifically the labor and maintenance costs. For air freighters, the crew size does not vary significantly with the aircraft size and for passenger aircraft, the cargo capacity has no influence on crew size. For maintenance, the costs increase with the size of the aircraft but not linearly. The cost for engine maintenance varies as much with the number of engines as with their size. On the other hand, the capital cost for both the airframe and engines increases in proportion to capacity as measured in terms of maximum take-off weight (MTOW). The cost of the engines is roughly linear relative to thrust, which is generally proportional MTOW. The weight of the airframe has remained a relatively constant proportion of the aircraft's MTOW, 0.5–0.6, in part because most airframes continue to be fabricated from aluminum.

[25] These fees are based on aircraft weight and, in the case of navigation fees, the length of the overflight over the country levying the fee

[26] A typical aircraft lease is a wet lease. The lessor provides the aircraft, one or more complete crews (flight deck, cabin attendants and engineers) including their salaries but not their daily allowances, all maintenance for the aircraft and insurance, which usually includes hull and third party liability. The lessee provides fuel, navigation and airport fees as well in-flight services, cargo insurance and in some cases, coverage for War Risk. The lessee is charged per block hour with a minimum guaranteed block hours limit per month. The period is usually one to two years. A "dry lease" does not include insurances, crew, maintenance and so on. It is generally utilized by leasing companies and banks rather than operators. A charter is the provision of air transport in which the schedule and use of the aircraft are specified for one or more movements and the provider is responsible for all operating costs.

The most important cost, that for fuel, does not have significant economies of scale because fuel consumption per kilometer is roughly proportional to the loaded weight of the aircraft as discussed below. Fuel consumption per FTK varies more with load factor and distance traveled than with capacity.

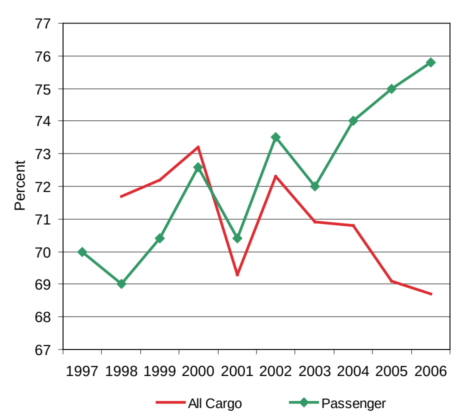
There is some variation in operating costs associated with the country of operation but this is relatively minor. The costs for crew and routine maintenance vary by country, but other costs are set through international competition. Because the number of crew on an air freighter is relatively small, the variation in labor costs for different regions has relatively little impact on total operating costs. The majority of the cost for aircraft maintenance is associated with major scheduled service including overhauls for both airframes and engines. These are performed by specially certified centers (MRO) located throughout the world. There is sufficient competition among these to minimize regional differences in cost. The costs for spares are set by the manufacturers and their licensed OEMs. The most important cost, fuel, is also relatively uniform throughout the world. There are some variations due to taxes and subsidizes (most notably in the Middle East) but these are generally short lived because aircraft operating on shorter hauls have a choice of where they obtain fuel. The more important variation is the change in jet fuel prices over time as discussed below.

The average unit cost per ton-kilometer for freight transport depends on the type of operation, the route and load factor. All cargo carriers offering scheduled and charter operations include both the capital and direct operating costs in their calculation of the costs for cargo transport whereas for passenger airlines, the transport costs for cargo carried as belly cargo is generally limited to the incremental cost for ground handling and fuel.

The length of the route affects the unit cost. Because of the time required for loading and unloading, air freighters generally perform only one or at most two flights per day. For shorter domestic and intraregional routes, this limits annual aircraft operating hours to 2000 hours or less, whereas for intercontinental routes the annual aircraft operating hours are typically 4000 hours or more. The result is variation in the unit costs per freight ton-km for capital and crew costs. There is also a variation in the fuel costs per kilometer, because of the fuel consumed per trip for taxiing, climbing, descending and waiting in holding patterns.

Load factor is important in determining average unit cost not only because there is a significant portion of fixed costs but more importantly because fuel consumption varies with the total weight of the aircraft. Since charter flights have higher load factors than scheduled air cargo services, they tend to have lower average unit costs for a similar number of operating hours. In the last few decades, the all-cargo airlines have provided both scheduled and charter services in order to maximize their fleet's load factor. During low periods on specific routes, the airlines reallocate aircraft between routes and between scheduled and charger services. They also employ a mix of owned and leased aircraft. Average load factors are typically between 68—73 percent but have been declining over the last decade (Figure 4-1) with the increase in proportion of scheduled services.

Figure 4-1. Load factor for international scheduled services



Source: IATA World Air Transport Statistics

Aircraft operating costs

Information on operating costs is available in different forms. The manufacturers provide data on operating costs but these do not reflect the costs incurred in actual operations. The U.S. DOT collects data actual operating costs from each of the airlines operating in the United States using Form 41. IATA, ATA and ICAO also collect data from member airlines. The U.S. data are compiled annually whereas the other organizations collect data when preparing special reports. The Form 41 reports the airline costs by function including direct operating costs, ground handling, passenger-related services (in-flight, sales and reservations, airport processing), administration and marketing. The data is reported quarterly as shown in Table 16. However, most of the information is reported by the larger airlines that are involved primarily in passenger transport. As a result, significant portions of the costs refer to passenger services both on the ground and in flight. There is also the larger administrative overhead associated with passenger operations. As a result the direct operating cost account for only about half of the total airline costs (Figure 4-2).

Table 4-1. Information on aircraft operating costs from two sources

ICAO accounting	DOT Form 41
• Flight Operations • Flight Crew Salaries, Expenses and Training • Aircraft Fuel & Oil • Insurance & Uninsured losses • Lease/Rental of aircraft • Maintenance & Overhaul • Depreciation & Amortization • User Charges & Station Expenses • Landing & Airport Charges • Route facility charges • Station Expenses • Passenger Services • Ticketing, Sales & Promotion • General & Administration	• Operating Expenses – quarterly by fleet type – quarterly by function incl. Direct Operating Cost, Servicing costs, and so on. – by objective • Other Finance Related Data • Traffic Statistics • Employment • General Profit & Loss • Balance Sheet

Figure 4-2. U.S. airlines costs, 2006

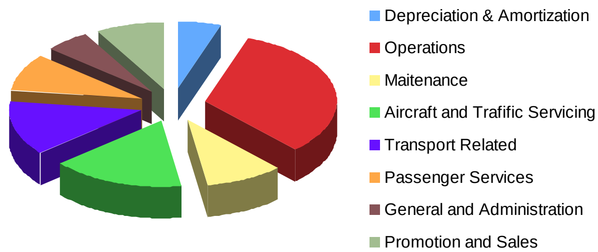
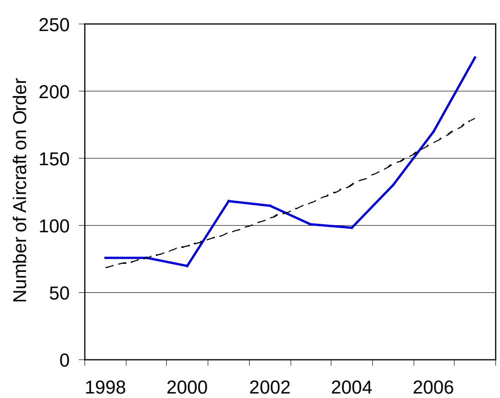


Figure 4-3. Airfreighter backlog



Source: Ascend, Inc

The operating costs are also reported by aircraft in terms of fleet operating costs per hour along with the utilization in terms of hours per day and average flight distance. Again, the majority of this information refers to passenger operations for which the direct operating costs, including crew, fuel, maintenance and capital costs account for only about half of the total airline costs. Ground operations account for approximately 30 percent and general management and in-flight services accounting for the remainder.

Table 4-2. Aircraft capital cost

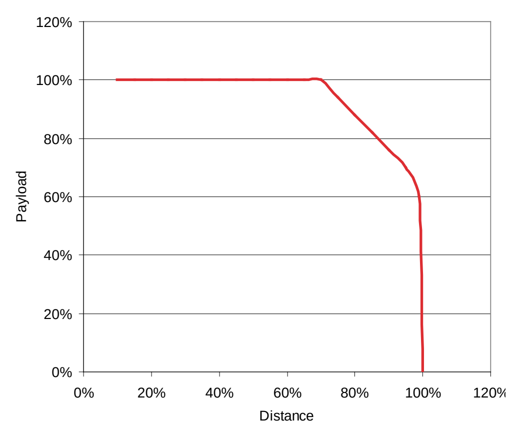
	New*	Used Aircraft	
Aircraft	$mn	$mn	Age
B737-200		0.45-2.25	17-37
737-400	40,0	10.0-23.5	5-17
320-200	50-60	14.0-40.0	0-17
A300B4-200F		7.0-10.7	20-30
A300B4-600RF		37.0-68.0	1-12
B767-200F	50-60	7.0-10.5	19-22
B767-300F	110-120	50.0-80.0	0-10
DC8-70F		5.50-8.50	33-38
B757-200F		18.5-35.0	6-22
DC10-40F		4.0-5.5	22-33
MD-11F		40.0-63.0	4-14
B747-400F	180-200	76.0-145.0	0-12

** Source: Air Finance Journal, July 2007, Manufacturer's website, Avmark Inc. Report 2005 Author's estimates*

The capital costs for air freighters are a relatively small part of total operating costs because of their age. The common practice of all-cargo airlines and combined carriers is to purchase used passenger aircraft and convert them by adding loading ramps. After 10 years of operation, the price of an aircraft will have decreased by at least 50 percent and after 15 years by 65—70 percent (Table 17). The integrators that offer express services prefer newer aircraft because they use them more intensively and can benefit from improved fuel efficiency. The current volume of new orders for air freighters is only about 200 compared with a fleet of 1,700. However, this number has been increasing. Since the majority of air freighters are 10 years or older, the fuel consumption and maintenance costs tend to be high relative to the capital costs as compared with passenger aircraft.

The average operating cost of an aircraft in flight is computed by dividing the direct operating costs plus capital costs by the number of hours of aircraft operation. The latter is computed in terms of block hours (the time from when the blocks or chocks are removed from the wheels of the aircraft prior to takeoff to when the blocks are placed on the wheels following landing). These costs include those incurred during taxiing, climbing, descending, and cruising at final altitude. Since there is a significant amount of fuel consumed while climbing and descending, the average fuel consumed per kilometer declines as the trip distance increases reaching an asymptote somewhere around 4-6 thousand kilometers. Trip distance also affects average block speed and therefore the fixed costs per kilometer. For short hops, block speeds average 500 kph; while for longer trips, they average 800 kph. For the extended range aircraft operating on the long international routes, the daily block hours can average 11-16 hours whereas for the short-haul market, daily block hours rarely exceed eight hours. As a result, aircraft employed on short routes have a relatively high cost per block hour with ground maneuvering, climbing and descending accounting for as much as ¼ - $^{1}/_{3}$ of the direct operating costs. For longer flights, this proportion drops to $^{1}/_{10}$ -$^{1}/_{7}$.

Figure 4-4. Trade-off of distance and payload

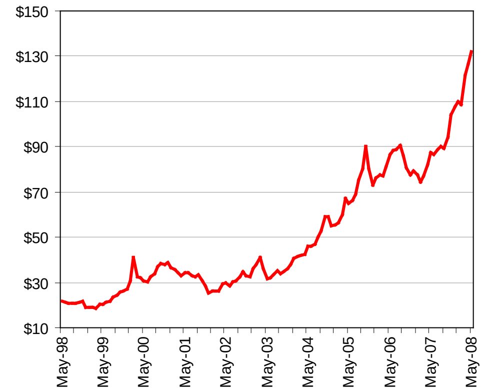


Source: ref. Peeters P.M.1, Middel J., and Hoolhorst A.

For the longer flights, the aircraft must carry additional fuel over longer distances, thereby reducing the payload and creating a tradeoff between payload and maximum range (Figure 4-4). There are also external factors affecting block hour costs such as airport congestion, which introduces delays during taking off and landing, and weather en route, which can require detours thereby increasing route distance

An analysis conducted by ICAO in 2000 indicated operating costs per block hour for air freighters of $4,000–6,500 for larger wide-bodied aircraft, $2,500–3,500 for the smaller wide-bodied aircraft and $1,600–2,800 for the narrow bodied aircraft. The fuel costs accounted for 33–44 percent for the wide-bodied aircraft and 24–33 percent for the narrow-bodied aircraft. Since that time the fuel costs have increased by 150 percent as shown in Figure 4-5. At the same time, there has been a gradual increase in fuel efficiency, which has offset about 30 percent of this increase.

Figure 4-5. Average prices for jet fuel ($/barrel)



Source: ATA

An analysis of the 2006 operating costs was made using the U.S. DOT database for U.S. carriers. The costs included crew, fuel, maintenance and capital costs. After certain adjustments were made (Annex), the operating costs per block hour for different types of aircraft were as shown in Table 18. These indicate that the hourly rate is $11,000–12,500 for the larger wide-bodied aircraft versus $7,000–10,000 for the medium wide-bodied aircraft and $3,000–4,250 for the narrow bodied aircraft. The proportion of costs accounted for by fuel is 48–71 percent for wide-bodied aircraft and 32–47 percent for narrow-bodied aircraft.

Table 4-3. Estimated aircraft operating costs per block hour

	Fuel	Total Direct Op. Costs	% Fuel Cost	Operating Hours
B727-200/231A	4,086	12,095	34%	4,420
B737-200C	2,424	5,061	48%	913
B757-200	3,525	9,181	38%	5,602
B767-300/300ERr	4,747	8,815	54%	7,477
DC-9-40	5,045	11,484	44%	1,702
DC-10-30CF	7,526	14,086	53%	4,007
A300-600/R/CF/RCF	5,252	12,111	43%	5,604
A310-200C/F	5,108	14,848	34%	4,079
MD-11	7,343	15,139	49%	6,607
B747-100	10,983	16,406	67%	1,457
B747-200/300	10,076	15,295	66%	2,424
B747-400	8,899	13,838	64%	3,488
B747F	11,181	16,583	67%	5,726

Source: US DOT 41 - 2006

Adjustments: Fuel $0.75/liter, 5% increase in other costs

Fuel efficiency

As mentioned previously and discussed further in Annex 4, the fuel consumption of an aircraft is proportional to its loaded weight. Thus the consumption per additional ton of cargo is roughly constant. The fuel consumption per kilometer varies, because the aircraft must carry more fuel.[27] There have been significant improvements in fuel efficiency over the last thirty years due to improvements in aircraft technology, specifically airframe design and engine efficiency. Another round of efficiency improvements is in the process with the introduction of composite materials. However, the latter will have little impact on air cargo in the short run since most air freighters are older. Over the medium term, there will be a change in the composition of the air freighter fleet that will result in the larger, more economical, aircraft. However, without a dramatic increase in demand to spur acquisition of new capacity, the change will be slow.

Improvements in engine technology have reduced the consumption per unit of thrust. Most of these gains were been a result of the development of high-bypass ratio engines in the early 1970's. These reduce the fuel consumption per unit of thrust by allowing engines to be configured for long hauls with greater efficiency during cruising or for short hauls with greater efficiency during take-off and climb. Initially this was used to improve the propulsive efficiency for long haul, wide-body aircraft, resulting a noticeable drop in fuel consumption (Figure 4-6). Subsequently, in the 1980s, these types of engines were installed on smaller aircraft.

The changes in airframes included refinements in aerodynamics and improved trim, which reduced drag. The aerodynamic efficiencies of large aircraft have improved approximately 15 percent over the last quarter century through improved wing design and better integration of propulsion and airframe. These improvements reduced the coefficients for drag[28] as shown in Figure 4-7. The impact of these two improvements can be seen in the 20 percent reduction in fuel consumption for subsequent versions of the Boeing 747 (Table 4-4).

Improvements in fuel efficiency through reduction in the weight of the airframe are only now being introduced through the use of advanced materials. Lighter airframes reduce the required thrust and fuel consumption per unit of cargo capacity. It is estimated that a 1 percent reduction in the gross weight of an empty aircraft can reduce fuel consumption between 0.25–0.75 percent. So far, the use of advanced materials such as improved aluminum alloys and composites has been limited to control surfaces, flaps, and slats and the savings in weight have been more than offset by the added weight for improvements in aerodynamics and engines. More extensive use of composites is appearing in the newest aircraft as the increased cost for fuel offsets the higher cost for these materials. While this will have some effect on the integrators, which utilize newer aircraft, this will not have an impact on the all cargo airlines for another decade.

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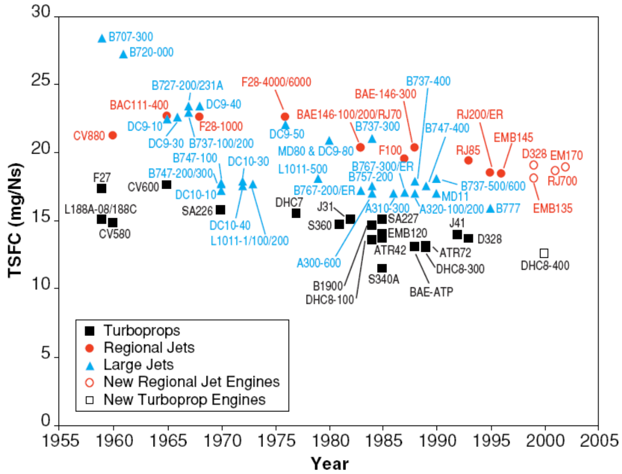
[27] Similarly, the more cargo that is carried, the more fuel that must be transported but this is a secondary effect.

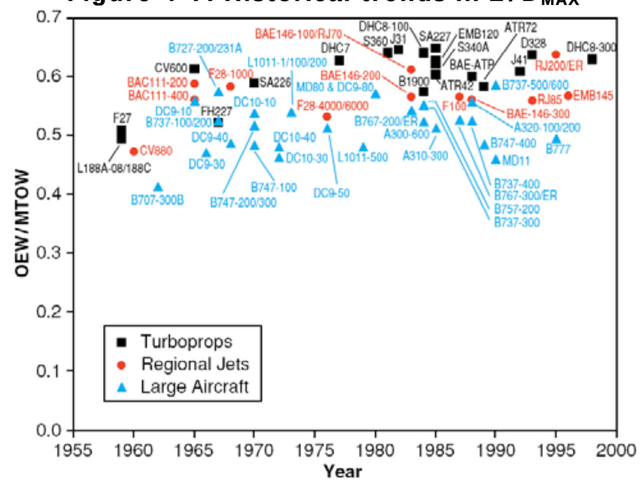
[28] Aircraft drag is the sum of zero-lift drag and induced drag due to lift. The former is the sum of drag due to skin friction and pressure. The skin friction occurs at the boundary layer as a result of the viscosity of the air and depends on whether the flow is laminar or turbulent. This drag depends on the shape of the airframe and the speed of travel. Pressure drag depends on the thickness of the boundary layer and its affects pressure recovery at the trailing edge. This is relatively small in subsonic flight. Drag due to lift has two components induced and viscous. The former is vortex drag depended on the distribution of lift across the span of an aircraft. The latter is due to the increase in the boundary layer with the angle of attack. At a given speed, the impact of aircraft weight on drag will occur because of the change in the wing to generate sufficient lift and the angle of attack of the aircraft. The marginal impact of cargo weight on drag is much less than the impact on lift. Thus for our purposes, the increase in thrust and thus increase in fuel required can be treated as a function of total aircraft weight.

Figure 4-6. Improvements in TSFC



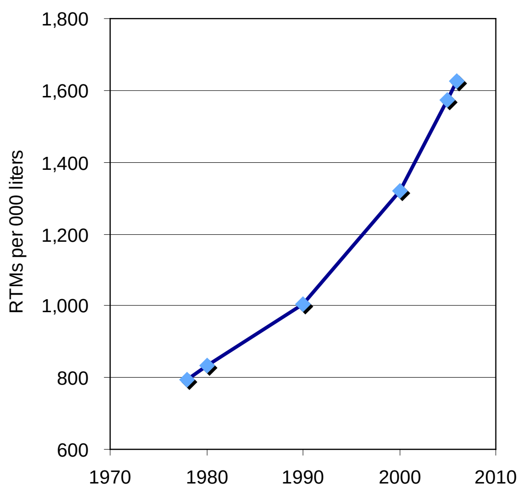
Source: Babikian, et al. MIT

Figure 4-7. Historical trends in L/D$_{MAX}$



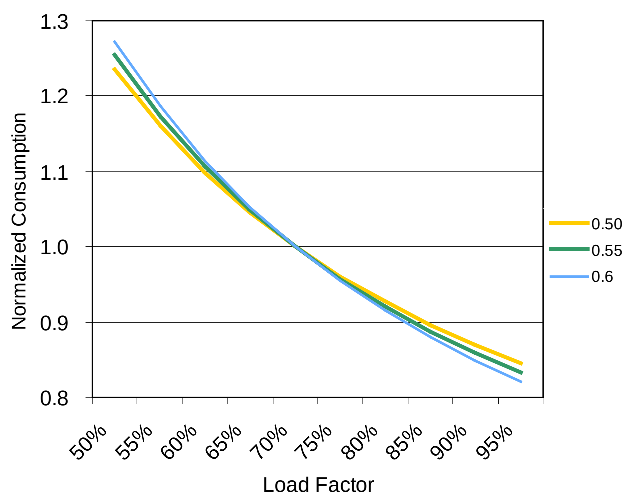
Source: Babikian, et al. MIT

Figure 4-8. Fuel efficiency



Source: ATA

Figure 4-9. Fuel efficiency vs. load factor



Source: Author's Estimates

In addition to improvements in aircraft, there have also been improvements in operations so as to reduce fuel consumption per unit of airfreight as measured in terms of revenue ton-kms. Over the last 30 years, these various factors have yielded a 50 percent reduction in fuel consumption as shown in Figure 4-8.

Table 4-4. Boeing 747 average fuel efficiency

	Liters/Hr
B747-100	14,645
B747-200/300	13,434
B747-400	11,865

Source: US DOT 2006

The cost of fuel is a significant part of the cost of airfreight. The fuel consumption at cruising speed is directly proportional to total aircraft weight for a given airframe and engine (Annex 4). For longer flights, it is also proportional to the distance. By implication, the fuel consumption per ton-kilometer is constant and thus for a specific flight, the marginal fuel consumed per ton is constant.

Since there are no significant economies of scale in fuel consumption associated with the size of air freighters, the principal technique for improving fuel efficiency is to increase the load factor. With an airframe weight equal to approximately 55 percent of maximum take-off weight, the increase in load factor from 60 to 90 percent will reduce fuel consumption per ton of cargo by about 20 percent. Figure 4-9 shows the relative change in fuel consumption versus load factor for different airframe weights (as a proportion of MTOW) assuming similar aircraft and engine design.

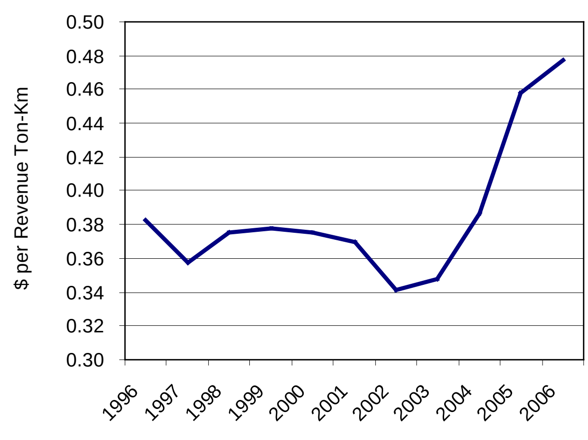
Pricing strategies

The pricing of air cargo is determined by market conditions. There are published guidelines, the Air Cargo Tariff or TACT, prepared by IATA based on regional meetings with its members. These are sometimes included in the bilateral air traffic agreements. However these rates are no longer enforced and apply only for small shipments or routes with relatively thin traffic. IATA members set their own rates often on a per shipment basis.

The structure of the pricing of air cargo services has changed as competition has increased. Freight All Kind (FAK) rates based on weight rather than commodity or cargo form began as an offering to large consolidators but have now become more commonplace as the market has grown more competitive. Volume discounts are used to attract business in general while specific commodity rates are used to develop specific markets. There are also class rates for commodities that require special handling, such as perishables and human remains.

Discriminatory pricing continues to be used to improve margins based not on the cargo but rather the level of service. Increasingly, price is differentiated according to guaranteed delivery time, for example next day, 2–4 day, or one week. Faster deliveries are duly compensated with a premium. In some cases this includes provision of value-added services (Table 4-5), but in general it refers to the value added from faster delivery times. Slower deliveries are offered a discount because they allow the airlines to route cargo in a

Figure 4-10. Average unit revenue for U.S. airline cargo



Source: ATA Annual Report 2006

Table 4-5. Differentiation of service levels, DHL

	Air First	Premium	Value
Time	fastest	3 days	economical
No weight or size restrictions	X	X	X
Clear transit time statement	X	X	X
Full shipment tracking visibility	X	X	X
E Quotation and e-Booking	X	X	X
Data transfer through EDIFACT	X	X	X
Express/ customs clearance	X		
Performance guarantee		X	
Freight unitized and sealed		X	X

Source: DHL Website

way that optimizes use of available capacity. Freight rates computed per kilometer taper off with distance in part because the block costs per kilometer decline and in part because the costs for cargo handling are fixed.

The pricing of air cargo has become contentious, as scheduled passenger flights often base their rates on the marginal cost of fuel whereas the all-cargo services base the price on the average unit operating cost of the aircraft. However, the lower price for belly cargo is offset by the uncertain availability of capacity, which varies with the quantity of passengers and luggage. All-cargo airlines compete by offering guaranteed capacity while integrators compete by offering faster, more predictable service.

The increase in operating costs has led to an increase in charges. This is reflected in the rapid rise in average unit rates charged for the U.S. airfreight business over the last two years, as shown in Figure 4-7. These relatively high unit rates reflect the dominance of higher rated express service for small shipments. The high unit revenues earned by FedEx contrast with normal intercontinental rates closer to $0.25 per ton-km for large shipment (Table 4-6).

Typical airfreight rates for major trade routes are shown in Table 4-7. These have increased with the fuel prices to the point that fuel surcharges sometimes exceed the base freight rate. In the short run, the rise in freight rates will be sustained by the increasing directional imbalances in international trade and an expected increase in the proportion of cargo transported on air freighters. The dominance of flows from Asia to North America and to Europe will continue to create/widen imbalances that will increase air transport costs. At the same time, an increasing share of Asian air export tonnage will flow through a limited number of Chinese gateway airports. This should create new opportunities for scheduled freight airlines to compete. The proportion of air cargo transported on widebody passenger aircraft is expected to decline, assuming passenger traffic continues to grow more slowly than airfreight.

The rising airfreight rates will encourage a modal shift for existing international cargo to sea and sea-air transport. This shift will be facilitated by improvements in supply chain management, which will continue to reduce overall delivery times, and the introduction of more express services by the large container shipping lines, which will reduce port-to-port transit times. In the medium term, increased fuel costs will be partially offset by the use of larger, more fuel-efficient aircraft. However, the market for airfreight will become more selective with air-cargo limited to the highest value and most time sensitive cargoes.

Table 4-6. U.S. airfreight carrier performance, 2006

	000's Departures	Traffic million RTK	Operating Revenues US$ mn	Rev/RTK US$
FedEx	377.0	16,964	22,068	1.30
UPS	153.4	10,088	4,571	0.45
ABX	55.7	919	1,260	1.37
Atlas/Polar		8,595	1,360	0.16
Evergreen Int'l		1,352	558	0.41
ASTAR		465	364	0.78

Source: ATA Annual Report 2007

Table 4-7. Typical freight rates

	$/kg
S. China- W. Europe	4.39
S. China-WCUS	4.62
S. China-Middle East	6.54
W. Europe-Middle East	2.01
ECUS-Middle East	2.00
W. Europe-E. Africa	3.45
W. Europe-W.Africa	6.44
China - C. Europe	8.85

Source: Freight Agents, excludes fuel surcharge which average $1.05 in May 2008