STANDARD METHOD OF ESTIMATING COMPARATIVE DIRECT
OPERATING COSTS OF TURBINE POWERED TRANSPORT AIRPLANES

December 1967
PREAMBLE

The following data represents a modification to the 1960 revision of the Air Transport Association Standard Method of Estimating Comparative Direct Operating Costs of Transport Airplanes.

Since it is doubtful that new transport airplanes will be powered by reciprocating engines and the overwhelming majority of the passenger miles are now being flown with turbine powered airplanes, this revision is confined to the turbine powered airplanes. It is considered that, with proper adjustment to the crew costs and the maintenance labor rates to account for the changing economic situation from 1960 to 1967, the 1960 revision is still valid for airplanes powered by reciprocating engines.

In addition to new methods of determining costs and new values for many of the basic parameters, the formula has been extrapolated to include the Supersonic Transport. The formula is not considered to be applicable to rotary wing or V/STOL aircraft.

December 1967
The first universally recognized method for estimating direct operating costs of airplanes was published by the Air Transport Association of America in 1944. The method was developed from a paper, "Some Economic Aspects of Transport Airplanes," presented by Messrs. Mentzer and Nourse of United Air Lines, which appeared in the Journal of Aeronautical Sciences in April and May of 1940. The basis of this method was taken from statistical data obtained from airline operation of DC-3 airplanes and was extrapolated to encompass the direct operating costs of larger airplanes which were then coming into the air transport picture.

In 1948 it was determined that the 1944 method of estimating direct operating costs fell short of its goal due to rising costs of labor, material, crew, and fuel and oil. Consequently, the Air Transport Association reviewed the statistical data which were then available, including four-engined as well as twin-engined airplane data, and in July 1949 published a revision to the 1944 method.

The ATA method was again revised in 1955 for the same reasons as above and also to introduce the turboprop and turbojet airplanes. The 1960 revision revised the predictions on turbine powered airplanes based on experience gained to that date.

The formula has again been revised to bring it up to date and an effort has been made to make it easier to use, yet at the same time more meaningful to its basic purpose - comparing airplanes. The formula has been extrapolated to include the Supersonic Transport.

This revision has been prepared with the assistance of an ATA working group consisting of representatives of the ATA member airlines and prime airframe and engine manufacturers. The assistance of this group is gratefully acknowledged.

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INTRODUCTION

The objectives of a standardized method for the estimation of operating costs of an airplane are to provide a ready means for comparing the operating economics of competitive airplanes under a standard set of conditions, and to assist an airline operator and airplane manufacturer in assessing the economic suitability of an airplane for operation on a given route.

Any system evolved for these purposes must essentially be general in scope, and for simplicity will preferably employ standard formulae into which the values appropriate to the airplane under study are substituted. Clearly these formulae, seeking to give mathematical precision to complex economic problems, by their very nature can never attain this aim completely, but it can be closely approached by ensuring that the method quotes realistic universal averages.

Data derived from this report is intended to forecast a more or less airplane "lifetime average" cost and cannot necessarily be compared directly to actual cost data for an individual airline. These individual airline costs are dependent upon many things which the formula does not take into account. These would include, but not be limited to, fleet size, route structure, accounting procedures, etc. Particular care must be taken in comparing airline short term operating cost statistics to data derived from this report. Airline maintenance scheduling is such that heavy maintenance costs (overhaul) may not be included for a particular fleet during a short term period such as one year. In comparing data derived from this formula with actual reported data it should be noted that some carriers may capitalize certain costs. The capitalized cost would then be reported in depreciation or amortization cost figures. The formula is further based on the assumption that the carrier does its own work. Actual reported data may include work by outside agencies.

These formulae are designed to provide a basis of comparison between differing types of airplanes and should not be considered a reliable assessment of actual true value of the operating costs experienced on a given airplane. Where data are lacking, the user of this method should resort to the best information obtainable.

Operating costs fall into two categories - Direct and Indirect Cost, the latter dependent upon the particular service the operator is offering although in certain particulars, the Indirect Costs may also be dependent upon and be related to the airplane's characteristics. This method deals with only the direct operating costs with one exception. As maintenance burden is required to be reported to CAB as a Direct Cost, it is included in this formula. For data relating to estimation of Indirect Cost the following reference is provided:

The following pages present the detailed Direct Operating Cost Equation. The costs are calculated as a cost per airplane statute mile \( (C_{am}) \); however, can be converted as follows:

**Block Hour Cost**: \[ \text{Cost/Mile} \times V_b = C_{am} \times V_b \]

**Flight Hour Cost**: \[ \text{Cost/Mile} \times V_b \times \frac{t_b}{t_f} = C_{am} \times V_b \times \frac{t_b}{t_f} \]

Where:
- \( t_b \) = Block time - hours
- \( t_f \) = Flight time = \( t_b - T_{gm} \) - hours
- \( V_b \) = Block speed - MPH

**Block Speed**

For uniformity of computation of block speed, the following formula based upon a zero wind component shall be used:

\[ V_b = \frac{D}{T_{gm} + T_{cl} + T_d + T_{cr} + T_{am}} \]

Where:
- \( V_b \) = Block speed in mph
- \( D \) = CAB trip distance in statute miles
- \( T_{gm} \) = Ground Maneuver time in hours including one minute for takeoff
  - \( = .25 \) for all airplanes
- \( T_{cl} \) = Time to climb including acceleration from takeoff speed to climb speed
- \( T_d \) = Time to descend including deceleration to normal approach speed
- \( T_{am} \) = Time for air maneuver shall be six minutes (No credit for distance)
  - \( = .10 \) for all airplanes
- \( T_{cr} \) = Time at cruise altitude (including traffic allowance)
  \[ = \left( \frac{D + K_a + 20}{V_{cr}} \right) - \left( \frac{D_c + D_d}{V_{cr}} \right) \]
\[ D_c \] = Distance to climb (statute miles) including distance to accelerate from takeoff speed to climb speed.

\[ D_d \] = Distance to descend (statute miles) including distance to decelerate to normal approach speed.

\[ v_{cr} \] = Average true airspeed in cruise (mph)

\[ K_a \] = Airway distance increment = (7 + 0.015D) up to \( D = 1400 \) statute miles

\[ 0.02D \] for \( D > 1400 \) statute miles

**NOTES:**

1. Climb and descent rates shall be such that 300 FPM cabin pressurization rate of change is not exceeded. In the transition from cruise to descent, the cabin floor angle shall not change by more than 4° nose down.

2. The true airspeed used should be the average speed attained during the cruising portion of the flight including the effect of step climbs, if used.

3. Zero wind and standard temperature shall be used for all performance.

**RESERVE FUEL**

Fuel reserve shall be the amount of fuel required to do the following:

(These are in excess of minimum Federal Aviation Regulations and are representative of airline operational practices. This excess is not related to safety requirements).

**Subsonic Airplanes**

**Domestic**

(1) Fly for 1:00 hour at normal cruise altitude at a fuel flow for end of cruise weight at the speed for 99% maximum range.

(2) Exercise a missed approach and climbout at the destination airport, fly to and land at an alternate airport 200 nautical miles distant.

**International**

(1) Fly for 10% of trip air time at normal cruise altitude at a fuel flow for end of cruise weight at the speed for 99% maximum range.
(2) Exercise a missed approach and climbout at the destination airport, fly to an alternate airport 200 nautical miles distant.

(3) Hold for 30 minutes at the alternate airport at 1,500 feet altitude.

(4) Descend and land at the alternate airport.

**Supersonic Airplanes**

**Domestic and International**

(1) Fly 5% of trip air time at cruise altitude at supersonic cruise speed at a fuel flow for end of cruise weight.

(2) Exercise a missed approach and climbout at the destination airport and fly to the alternate airport 200 nautical miles distant.

(3) Hold 20 minutes at 15,000 feet over the alternate airport.

(4) Descend and land at the alternate airport.

**Flight to Alternate Airport (All airplanes)**

(1) Power or thrust setting shall be 99% of maximum subsonic range.

(2) Power setting for holding shall be for maximum endurance or the minimum speed for comfortable handling, whichever is greater.

(3) Cruise altitude shall be the optimum for best range except that it shall not exceed the altitude where cruise distance equals climb plus descent distance.

**BLOCK FUEL**

Block fuel shall be computed from the following formula:

\[ F_b = F_{gm} + F_{am} + F_{cl} + F_{cr} + F_d \]

Where

- \( F_b \) = Block fuel
- \( F_{gm} \) = Ground maneuver fuel based on fuel required to taxi at ground idle for the ground maneuver time of 14 minutes plus one minute at takeoff thrust or power.
- \( F_{cl} \) = Fuel to climb to cruise altitude including that required for acceleration to climb speed.
\[ F_{cr} \] - Fuel consumed at cruise altitude (including fuel consumed in 20 statute mile traffic allowance and allowance for airway distance increment \( K_0 \)). Cruise altitude shall be optimum for minimum cost with the following limitations:

- (a) Cruise distance shall not be less than climb plus descent distance.
- (b) Cruise climb procedures shall not be used.
- (c) A maximum of two step-climbs may be used.

\[ F_{am} \] - Six minutes at best cruise procedure consistent with airline practice (no credit for distance).

\[ F_d \] - Fuel required to descend including deceleration to normal approach speed.

1. FLYING OPERATIONS

a. Flight Crew Costs (Figure 1)

These costs were derived from a review of several representative crew contracts. Based on this review, yearly rates of pay were arrived at which were used with welfare, training, travel expense, and crew utilization factors to produce the crew cost equations herein.

**Domestic Subsonic Airplane with Two-man Crew**

- **Turboprop**
  \[ C_{am} = \left[ 0.05 \left( \frac{TOG_{max}}{1000} \right) + 63.0 \right] \frac{1}{V_b} \]

- **Turbojet**
  \[ C_{am} = \left[ 0.05 \left( \frac{TOG_{max}}{1000} \right) + 100.0 \right] \frac{1}{V_b} \]

**Domestic Subsonic Airplane with Three-man Crew**

- **Turboprop**
  \[ C_{am} = \left[ 0.05 \left( \frac{TOG_{max}}{1000} \right) + 98.0 \right] \frac{1}{V_b} \]
Domestic Supersonic Airplane with Three-man Crew

\[ C_{am} = \left[ 0.05 \left( \frac{TOGW_{max}}{1000} \right) + 135.0 \right] \frac{1}{V_b} \]

International Subsonic and Supersonic Airplane with Three-man Crew

Add 20.00 to term in brackets [ ] for domestic operation with three-man crew

Additional Crew Members (All Operations)

\[ C_{am} = [35.00] \frac{1}{V_b} \]

Where: \( TOGW_{max} = \) Maximum Certificated takeoff gross weight

b. Fuel and Oil - (Including 2% non-revenue flying)

It is assumed that the rate of consumption of oil will be \( 0.135 \text{ lbs/hr/eng} \).

Fuel and oil densities have been assumed as follows:

- JP-4 grade of fuel: 6.4 lbs/gal
- Kerosene grade of fuel: 6.7 lbs/gal
- Synthetic jet oil: 8.1 lbs/gal

NOTE: Turbine fuel standard BTU content of 18400 BTU/LB. is used in this report.

\[ C_{am} = 1.02 \left[ \frac{F_b \times C_{ft} + N_e \times 0.135 \times C_{ot} \times t_b}{D} \right] \]

Where: \( F_b = \) Block fuel in pounds (See page 4)

- \( C_{ft} = \) Cost of Fuel
  - \( \text{Domestic} = \$0.01493/\text{lb} \) ($0.10/U.S. Gallon - Kerosene)
  - \( \text{International} = \$0.01642/\text{lb} \) ($0.11/U.S. Gallon - Kerosene)

- \( C_{ot} = \) Cost of oil for turbine engines
  - \( \text{Domestic} = \$0.926/\text{lb} \) ($7.50/U.S. Gallon)

- \( N_e = \) Number of engines installed
D = CAB trip distance - statute miles

c. Hull Insurance Costs

During the initial introduction of a new type airplane such as the subsonic jets when first introduced and now the supersonic transport, the insurance rates are understandably high, but over the useful life of the airplane will average 2% per year.

The insured value rate is assumed to cover 100% of the initial price of the complete airplane

\[ C_{am} = \frac{\text{Rate}/\text{Dollar Value}}{(\text{Utilization})} \times \frac{\text{Airplane Cost}}{V_b} \]

\[ C_{am} = \frac{(I_{RA}) \times (C_t)}{U \times V_b} \]

Where: \( I_{RA} = 2\% \)

\( C_t \) = Total airplane cost including engines (dollars)

\( U \) = Annual utilization - Block hours/year (Figure 4)

2. DIRECT MAINTENANCE - FLIGHT EQUIPMENT

The term "maintenance" as presented in this method includes labor and material costs for inspection, servicing, and overhaul of the airframe and its accessories, engines, propellers, instruments, radio, etc. The formulae further include a 2% non-revenue flying factor.

There are two well established procedures being used for the maintenance of airplanes, namely periodic and progressive. The use of either of these procedures is dependent on the policy set forth by the individual airline, and in general, the costs will be approximately the same.

Close study of operating statistics shows that the average cost of maintenance may be fairly represented as functions of weight, thrust, price and/or flight cycles. Maintenance burden will also be included in this section.

a. Labor - Airplane (Excluding engines only) (Figure 2)

\[ C_{am} = \frac{K_{FH}a \times t_f + K_{FC}a}{V_b} \times \frac{V_b}{t_b} \times (R_L)^{1/2} \]

Where: \( K_{FC}a = 0.05 \times \frac{W}{1000} + 6 - \left[ \frac{630}{W} \right] + 120 \) = Labor manhours per flight cycle
\[ K_{FH_a} = 0.59 \frac{C_{FC_a}}{t_f + \frac{C_{FC_a}}{t_b}} \]

Labor manhours per flight hour

\[ R_L = \text{Labor Rate} - \$/hr - \$4.00 \]

C

\[ M = \text{Cruise Mach Number (assume 1 for subsonic airplanes)} \]

\[ W_a = \text{Basic Empty Weight of the Airplane Less Engines} - \text{Lbs.} \]

b. Material - Airplane (Excluding engines only)

\[ C_{am} = \frac{C_{FH_a} \cdot t_f + C_{FC_a}}{V_b \cdot t_b} \]

Where:

\[ C_{FH_a} = 3.08 \frac{C_a}{10^6} = \text{Material cost} - \$ / \text{flight hour} \]

\[ C_{FC_a} = 6.24 \frac{C_a}{10^6} = \text{Material Cost} - \$ / \text{flight cycle} \]

\[ C_a = \text{Cost of complete airplane less engines (dollars)} \]

c. Labor - Engine (includes bare engine, engine fuel control, thrust reverser, exhaust nozzle systems, and augmentor systems) (includes gear box, but does not include propeller on turboprop engines) (Figure 3)

\[ C_{am} = \frac{K_{FH_e} \cdot x \cdot t_f + K_{FC_e}}{V_b \cdot x \cdot t_b} (R_L) \]

Where:

\[ K_{FH_e} = (0.6 + 0.027 \frac{T}{10^3}) \cdot N_e = \text{Labor manhours per flight hour} \]

(turbojet)

\[ K_{FH_e} = (0.65 + 0.03 \frac{T}{10^3}) \cdot N_e = \text{Labor manhours per flight hour} \]

(turbojet)

\[ K_{FC_e} = (0.3 + 0.03 \frac{T}{10^3}) \cdot N_e = \text{Labor manhours per flight cycle} \]

(jets and turboprop)

\[ T = \text{Maximum certificated takeoff thrust, including augmentation where applicable and at sea level, static, standard day conditions (Maximum takeoff equivalent shaft horsepower at sea level, static, standard day conditions for turboprop).} \]

\[ R_L = \text{Labor rate per man-hour} - \$4.00 \]

\[ N_e = \text{Number of engines} \]
Material - Engine (Includes bare engine, engine fuel control, thrust reverser, exhaust nozzle systems and augmentor systems) (Includes gear box, but does not include propeller on turboprop engines)

\[
C_{am} = \frac{C_{FH_e} x t_f + C_{FC_e}}{V_b x t_b}
\]

Where:

\[
C_{FH_e} = 2.5 N_e (C e/10^5) = \text{Material Cost - $/Flight Hour (For Subsonic Airplanes)}
\]

\[
C_{FC_e} = 2.0 N_e (C e/10^5) = \text{Material Cost - $/Flight Cycle (For Subsonic Airplanes)}
\]

\[
C_{FH_e} = 4.2 N_e (C e/10^5) = \text{Material Cost - $/Flight Hour (For Supersonic Airplanes)}
\]

\[
C_{FC_e} = 2.9 N_e (C e/10^5) = \text{Material Cost - $/Flight Cycle (For Supersonic Airplanes)}
\]

\[N_e = \text{Number of engines}\]

\[C_e = \text{Cost of one engine}\]

e. Maintenance Burden

This may be calculated at 1.8 times the direct airplane and engine labor cost.

3. DEPRECIATION - FLIGHT EQUIPMENT

The depreciation of the capital value of an airplane is dependent to a large degree on the individual airline and the world economic and competitive conditions as the airplane is maintained in a fully airworthy condition throughout its life. For the purposes of this formula, the depreciation periods in years (D_a) and the residual value for the airplane and its components is as follows:

<table>
<thead>
<tr>
<th>Complete Airplane Including Engines and All Surros</th>
<th>Depreciation Period (D_a)</th>
<th>Residual Value</th>
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<tr>
<td>Subsonic Turbine Engine Airplane</td>
<td>12</td>
<td>0%</td>
</tr>
<tr>
<td>Supersonic Airplane</td>
<td>15</td>
<td>0%</td>
</tr>
</tbody>
</table>

NOTE: Financial accounting practice normally recognizes a residual value, however, the dollar amount is usually nominal.
a. Depreciation (Total Aircraft Including Spares)

\[ C_{am} = \frac{1}{V_b} \left[ \frac{C_t}{D_a U} + 10 \left( \frac{C_t - N_e C_e}{D_a U} \right) + 40 \frac{N_e C_e}{D_a U} \right] \]

Where:
- \( C_t \) = Total airplane cost including engines (dollars)
- \( C_e \) = Cost of one engine (dollars)
- \( N_e \) = Number of engines
- \( D_a \) = Depreciation period (years)
- \( U \) = Annual utilization - block hours/year (See Figure 4)
FIG. 1 FLIGHT CREW COST—DOMESTIC
$/$ BLOCK HOUR or T/OG-W/MAH/1000

1. FOR INTERNATIONAL SUBSONIC AND SUPERSONIC AIRCRAFT
   OPERATION ADD $20,000

2. FOR ADDITIONAL CREW MEMBER
   ALL OPERATIONS ADD $35,000

- SST - 3 MAN CREW
- SUBSONIC TURBOJET
  - 2 MAN CREW
- SUBSONIC TURBOJET
  - 1 MAN CREW
- TURBOPROP
  - 2 MAN CREW
- TURBOPROP
  - 1 MAN CREW
**Fig. 2** *Airplane (excluding engines only) Maintenance Labor*

Labor manhours vs. $W_o$ (Basic Empty Weight of Airplane less engines)

$K_{FCC} = \text{Labor manhours per flight cycle}$

$K_{FHH} = 0.59 K_{FCC}$

$= \text{Labor manhours per flight hour}$
Fig. 3 ENGINE MAINTENANCE LABOR
MANHOURS AS MAX. TAKEOFF THRUST

$K_{FH}$ = MAN HOURS PER FLIGHT HOUR
$K_{FC}$ = MAN HOURS PER FLIGHT CYCLE

$T = \text{MAX. CERTIFIED TAKEOFF THRUST,}
\text{INCLUDING PULLENTION WHERE APPLICABLE}
\text{AND AT SEA LEVEL, STATIC, STANDARD DAY}
\text{CONDITIONS. (MAXIMUM TAKEOFF EQUIVALENT}
\text{SPEED HORSEPOWER AT SEA LEVEL, STATIC,}
\text{STANDARD DAY CONDITIONS FOR TURBO PROP)}$
Fig. 4 Annual Utilization

Block Hours/Year vs Block Time Hours

SST

Subsonic Airplanes

Note: 1 day week cargo with daytime operations will have the same utilization.