

AE 452 Aeronautical Engineering Design II

Cost of an Airplane

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Difficulties when estimating cost

- Number of parameters involved (technical, financial, political).
- Type of money to be used:
 - **Then year dollars:** actual dollars spent in each year of the program; past, present and future. For future program costs an estimation of the inflation rate must be made.
 - **Constant year dollars:** actual dollars spent normalized by inflation factors for some selected year.

Problems when estimating cost

- Aircraft **production quantity** and **rate**.
- The more aircraft **produced**, the more manufacturer **learns** and aircraft can be produced **cheaper** (learning curve effect).
- Each time the production quantity is **doubled**, the **labor cost per aircraft** goes down by ~20 %.

Production learning curve

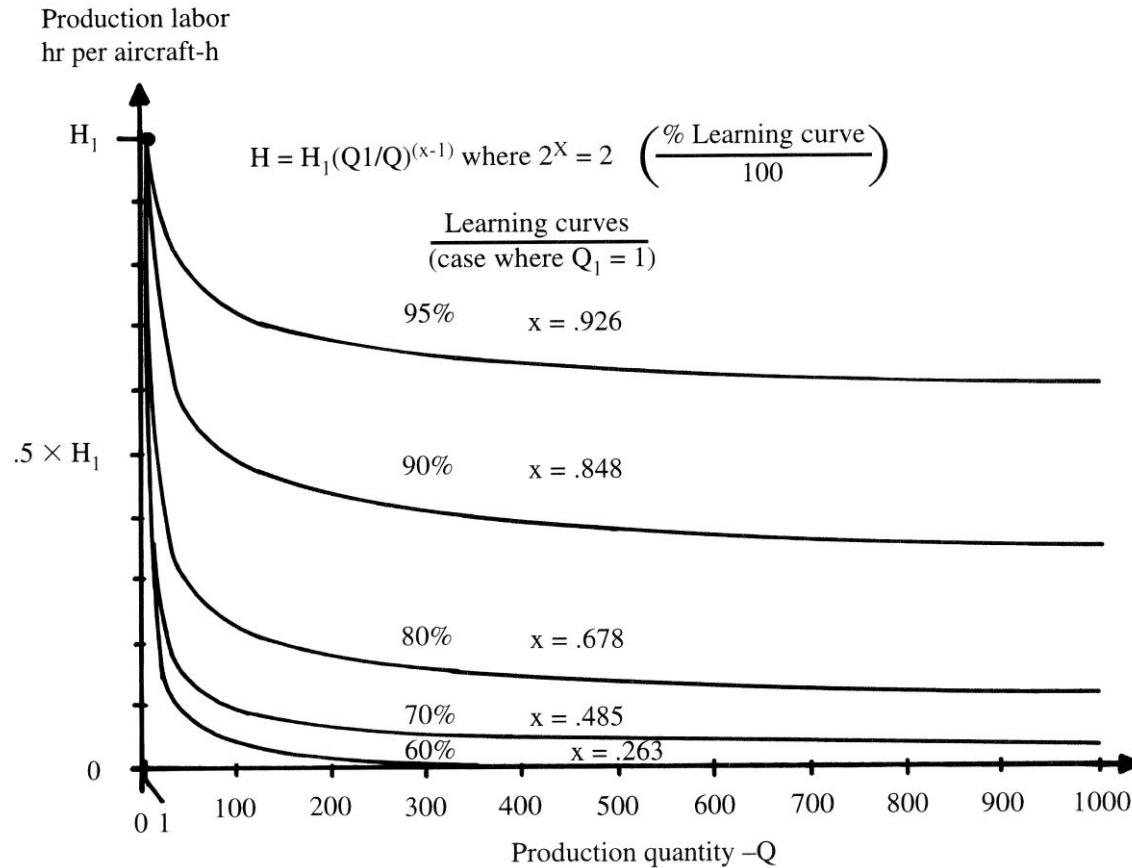


Fig. 18.1 Production learning curve.

Elements of life cycle cost

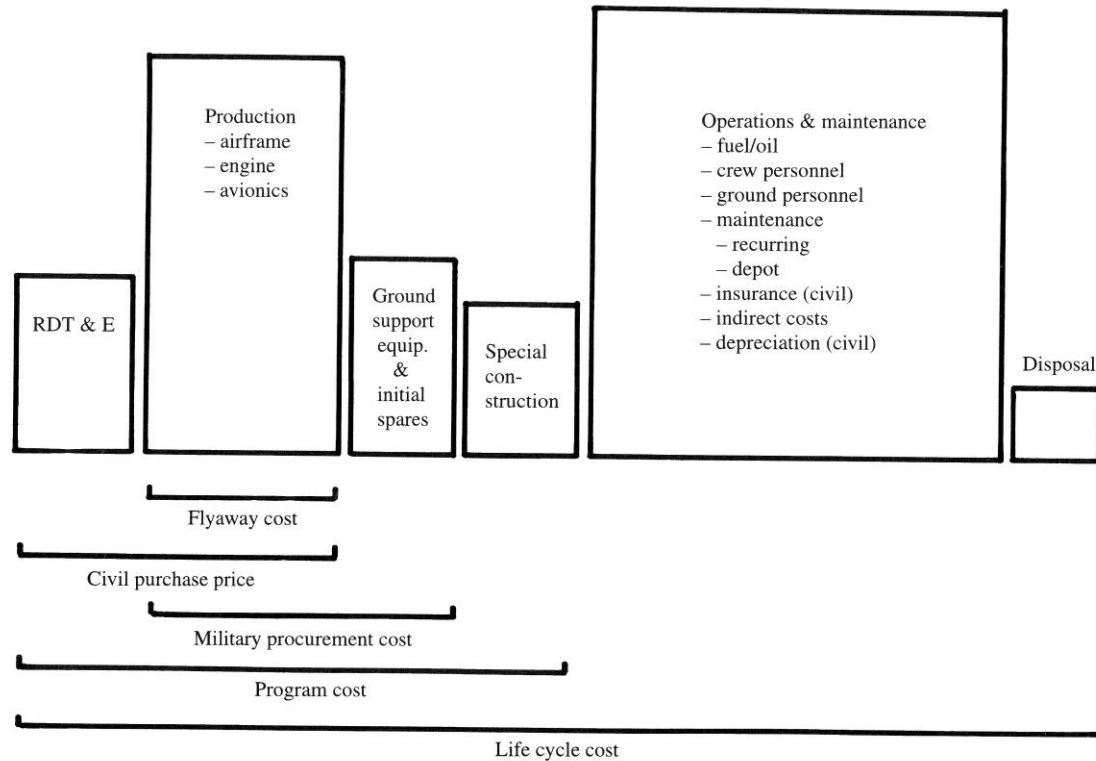


Fig. 18.2 Elements of life cycle cost.

Elements of life cycle cost

- **RDT&E (Research, Development, Test and Evaluation):** technology research, design engineering, prototype fabrication, flight and ground testing and evaluations for operational suitability.
- RDT&E costs are **fixed costs** (non-recurring costs).

Elements of life cycle cost

- **Flyaway (production) costs:** labor and material costs to manufacture the airplane including the airframe, engines and avionics.
- Includes production tooling (jigs, fasteners, molds, etc.), manufacturer's overhead and administrative expenses.
- Production costs are **recurring**.

Elements of life cycle cost

- **Program cost:** the total cost to develop and deploy a new airplane into the inventory (mostly military).
- Some aircraft require special ground facilities for operational deployment.

Elements of life cycle cost

- **Operations and maintenance:** covers fuel, oil, aircrew costs, maintenance, insurance and depreciation.
- **Disposal:** getting rid of the airplane after its useful life has ended (recycling, etc.).

RDT&E and Production Costs (DAPCA IV model)

Development and Procurement Costs of Aircraft Model

- is a **cost estimation relationship model** and it estimates the **hours** required for RDT&E and production by the engineering, tooling, manufacturing and quality control groups.
- These are multiplied by **hourly rates** to yield costs.

RDT&E and Production Costs (DAPCA IV model)

- **Engineering hours:** include airframe design and analysis, test engineering, configuration control and systems engineering.
- **Tooling hours:** includes preparation for production. Design and fabrication of tools and fixtures, production of molds, programming CAD/CAM tools, development and fabrication of production test apparatus.

RDT&E and Production Costs (DAPCA IV model)

- **Manufacturing hours:** direct labor to fabricate the aircraft; forming, machining, fastening, subassembly fabrication, final assembly, routing (hydraulic, electric and pneumatic lines) and purchased part installation (engines, avionics, sub-systems, etc.)
- **Quality control:** includes receiving inspection, production inspection and final inspection.

RDT&E and Production Costs (DAPCA IV model)

- **Flight test costs:** all costs to demonstrate airworthiness and/or compliance with military standards except for the costs of the flight test airplanes themselves.
- **Manufacturing materials:** raw materials and purchased hardware and equipment from which the airplane is built (aluminum, composites, electric, hydraulic, pneumatic systems, fasteners, etc.)

DAPCA IV Cost Model

(cost in constant 2012 Dollars)

- Engineering hours: $H_e = 4.86 W_e^{0.777} V^{0.894} Q^{0.163}$
- Tooling hours: $H_t = 5.99 W_e^{0.777} V^{0.696} Q^{0.263}$
- Manufacturing hours: $H_m = 7.37 W_e^{0.82} V^{0.484} Q^{0.641}$
- Quality control hours: $H_q = 0.076 H_m$ (cargo airplanes)
 $H_q = 0.133 H_m$ (all others)

DAPCA IV Cost Model

(cost in constant 2012 Dollars)

- **Development support costs:** $C_D = 91.3 W_e^{0.630} V^{1.3}$,
Include fabrication of mockups, subsystem simulators, structural and other test items.
- **Flight test costs:** $C_F = 2498 W_e^{0.325} V^{0.282} FTA^{1.21}$
Q: smaller of production quantity or number to be produced in 5 years,
FTA: number of flight test airplanes.

DAPCA IV Cost Model

(cost in constant 2012 Dollars)

- **Engine production cost:**

$$C_{\text{ENG}} = 3112(0.043T_{\text{max}} + 243.25M_{\text{max}} + 0.969T_{\text{turbine inlet}} - 2228)$$

Increase by 15-20% for a turbofan engine.

- **Manufacturing materials cost:**

$$C_{\text{M}} = 22.1 W_e^{0.921} V^{0.621} Q^{0.799}$$

DAPCA IV Cost Model

(cost in constant 2012 Dollars)

- Recommended fudge factors:
 - Aluminum: 1.0,
 - Graphite-epoxy: 1.1-1.8,
 - Fiberglass: 1.1-1.2,
 - Steel: 1.5-2.0,
 - Titanium: 2.0.

DAPCA IV Cost Model

(cost in constant 2012 Dollars)

- Average wrap rates (employee salary+employee benefits+overhead+administrative costs):

$$R_e = \$ 115 / h,$$

$$R_t = \$ 118 / h,$$

$$R_m = \$ 108 / h,$$

$$R_q = \$ 98 / h.$$

DAPCA IV Cost Model

(cost in constant 2012 Dollars)

- **Avionics costs:** $C_{\text{avionics}} = 5\text{-}25\%$ of flyaway cost or \$4000–8000/lb,
- Investment cost factor = 1.1-1.4 * predicted flyaway cost,
- Initial spares = 10-15% purchase price.

DAPCA IV Cost Model

(cost in constant 2012 Dollars)

- RDT&E + production costs

$$= H_e R_e + H_t R_t + H_m R_m + H_q R_q + C_D + C_F + C_M + C_{eng} N_{eng} + C_{avionics}$$

Operations and maintenance costs (O&M)

- Military aircraft:
 - Fuel costs 15 %,
 - Crew salaries 35 %,
 - Maintenance 50 %.
- Civil aircraft:
 - Fuel costs 38 %,
 - Crew salaries 24 %,
 - Maintenance 25 %,
 - Depreciation 12 %,
 - Insurance 1 %.

Fuel and oil costs

Table 18.1 LCC parameter approximations

Aircraft class	FH/YR/AC	Crew ratio	MMH/FH
Light aircraft	500–1000	–	1/4–1
Business jet	500–2000	–	3–6
Jet trainer	300–500	–	6–10
Fighter (modern)	300–500	1.1	15–20
Bomber	300–500	1.5	25–50
Military transport	700–1400	1.5 if FH/YR < 1200 2.5 if 1200 < FH/YR < 2400 3.5 if 2400 < FH/YR	20–40
Civil transport	2500–4500	–	5–15

Crew salaries - civil

- **Block hours:** the total time the aircraft is in use, from when the blocks are removed from the wheels at the departure airport to when they are placed on the wheels at destination.
- **Block speed:** trip distance/block time $\ll V_{\text{cruise}}$,
- Additional distance between two airports:
 - = 2 % if $D > 1400$ miles,
 - = $(0.015 + 7/D)$ if $D < 1400$ miles.

Crew salaries - civil

- Crew cost/block hour (2012 prices):
 - Two man crew = $70.4(V_c W_o / 10^5)^{0.3} + 168.8$,
 - Three man crew = $94.5(V_c W_o / 10^5)^{0.3} + 237.2$.

Crew salaries – military

- Crew ratio: # of aircrews/aircraft:
 - Fighters: 1.1,
 - Transports: 3.5.
- Crew cost/year = 2080*engineering hourly wrap rate

Maintenance expenses

- MMH/FH: maintenance man hours/flight hour.
- Labor costs:
 - \approx MMH/FH*FH*manufacturing wrap rate,
- Materials, parts and supplies costs:
 - Military aircraft \approx labor costs,
 - Civil aircraft:

$$\frac{\text{material cost}}{\text{flight hour}} = 3.3 \left(\frac{C_a}{10^6} \right) + 14.2 + \left[58 \left(\frac{C_e}{10^6} \right) - 26.1 \right] N_e$$

C_a : aircraft cost less engine

C_e : cost per engine

N_e : number of engines

Depreciation and insurance

- Allocation of the purchase price over the operating life of the aircraft,
- If the resale value is 10% of the purchase price and the depreciation period is 12 years:
 - Yearly depreciation = $\text{airframe cost} \times 0.9 / 12$.
- Insurance = 1% cost of operations.