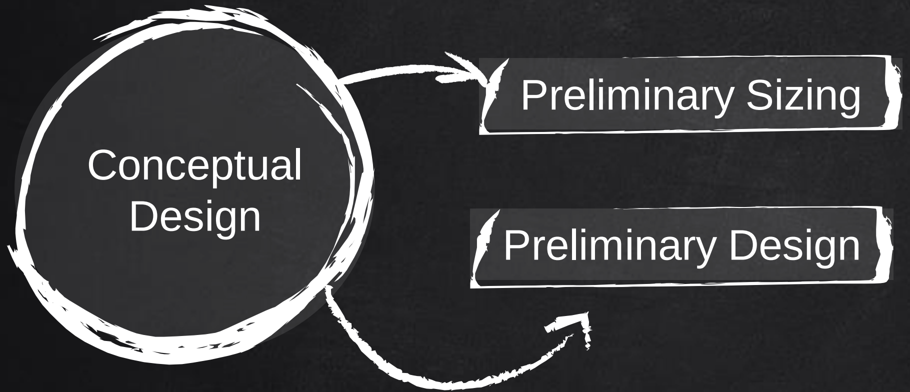
Design Book 2

Preliminary Weight Estimation

Preliminary Sizing



Gross T.O. Weight ($W_{T.O}$)
Empty Weight (W_e)
Mission Fuel Weight (W_f)
Max. Req. T.O. Thrust ($T_{T.O}$)
Wing Area & Aspect Ratio
Max Req. Lift coef. (clean) C_{Lmax}
Max Req. Lift coef. (T.O.) $C_{Lmax_{T.O}}$
Max Req. Lift coef. (landing) C_{Lmax_L}

Roskam method applies to 12 types of airplanes

1. Homebuilt Propeller Driven Airplanes
2. Single Engine Propeller Driven Airplanes
3. Twin Engine Propeller Driven Airplanes
4. Agricultural Airplanes
5. Business Jets
6. Regional Turbopropeller Driven Airplanes
7. Transport Jets
8. Military Trainers
9. Fighters
10. Military Patrol, Bomb and Transport Airplanes
11. Flying Boats, Amphibious and Float Airplanes
12. Supersonic Cruise Airplanes

Weight components

$$W_0 = W_{g,max} = W_{T.O.} = W_{OE} + W_F + W_{PL}$$

W_{OE}: operating empty weight

$$W_{OE} = W_e + W_{Crew} + W_{tfo}$$

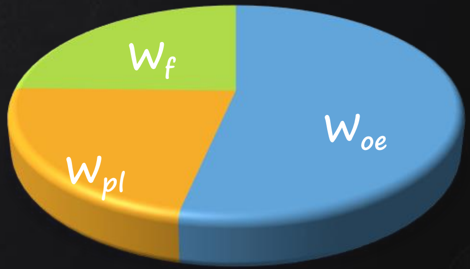
W_{tfo}: Trapped fuel & oil

$$W_e = W_{ME} + W_{FEQ}$$

W_{ME}: Manufactures empty weight

W_{FEQ}: Fixed equipment (Wvendors)

آنچه برای هواپیما خریداری می‌شود اعم از صندلی، مبلمان داخلی، سیستم اویونیک، تهویه مطبوع، هیدرولیک، ...



فرآیند محاسبات

گام اول: تعیین ومحاسبه W_{PL}

گام دوم: حدس با $W_{T.O.}$ بررسی بازار هواپیماهای مشابه $W_{T.O.guess}$

گام سوم: محاسبهٔ W_F مأموریت

گام چهارم: محاسبهٔ مقدار W_{OE} از

$W_{OE,Tent}=W_{T.O.guess} - W_F - W_{PL}$ Eq. (2.4) Roskam

گام پنجم: محاسبهٔ مقدار W_e

$W_{e,Tent}=W_{OE,Tent} - W_{tfo} - W_{Crew}$ Eq. (2.5) Roskam

گام ششم: پیدا کردن مقدارمجاز W_e از نمودار لگاریتمی

گام هفتم: مقایسهٔ مقدار $W_{e,Tent}$ و W_e بدست آمده از گام ۶ و تعدیل $W_{T.O.guess}$ برگشت به مراحل ۳ تا ۶ تا تلرانس $W_{T.O.}$ حدس زده شده و محاسبه شده کمتر از نیم درصد شود

Step I: Payload & Crew Weight

Sforza

Roskam: 175 lbs + 30 lbs baggage for short to medium distance 40 lbs for long

Table 2.2 Standard Average Passenger Weights from USDOT (2004)

Standard Average Passenger Weight	Weight per Passenger (lb)
Summer weights	
Average adult passenger weight	190
Average adult male	200
Average adult female	179
Average child (2–13 years old)	82
Winter weights	
Average adult passenger	195
Average adult male	205
Average adult female	184
Average child (2–13 years old)	87

Table 2.3 Average Crew Member Weights from USDOT (2004)

Crew Member	Average Weight (lb)	Average Weight with Bags (lb)
Flight crew member	190	240
Flight attendant	170	220
Male flight attendant	180	220
Female flight attendant	160	200
Crew member roller bag	30	NA
Pilot flight bag	20	NA
Flight attendant kit	10	NA

include a 16-pound allowance for personal items and carry-on bags

(a) 1/3 of passengers carry one personal item and one carry-on bag.
(b) 1/3 of passengers carry one personal item or carry-on bag.
(c) 1/3 of passengers carry neither a personal item nor a carry-on bag.
(d) The average weight allowance of a personal item or a carry-on bag is 16 pounds.
checked bags: 30 pounds

Number of pilots:
2 pilots < 8 hours flight duration
8 hours < 3 pilots < 12 hours
4 pilots > 12 hours

Number of flight attendants:
FAA regulations: 1 attendant for every 50 seats

Step I (continue)

$$W_{plc} = W_{PL} + W_{Crew}$$

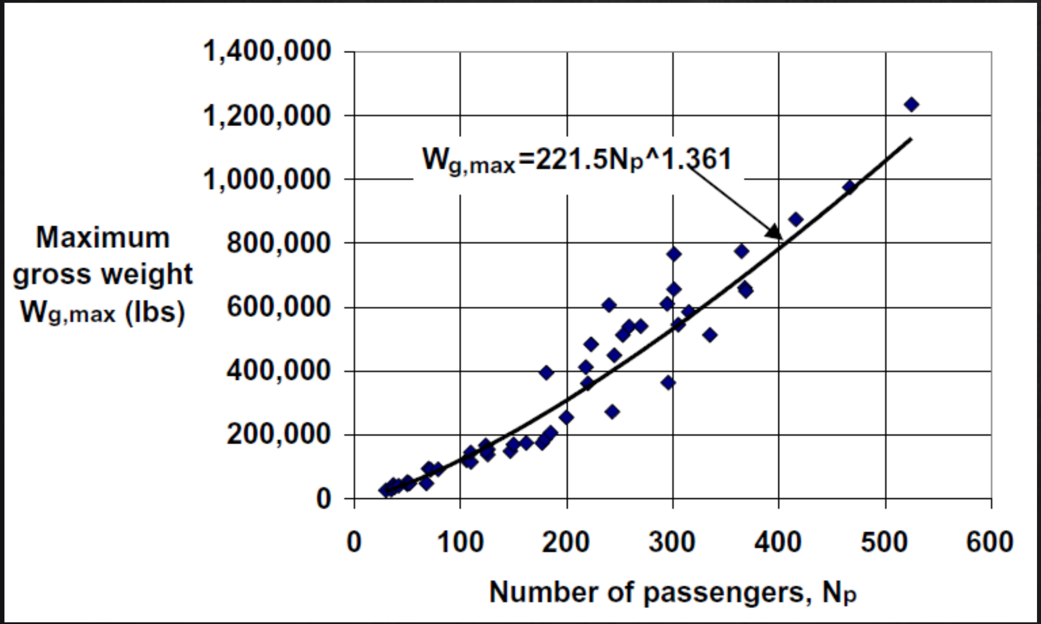
$$W_{PL}=170*(190+30)=\boxed{37400\ lbs}$$

$$W_{crew}=2*(190+50)+4*(170+50)=\boxed{1360\ lbs}$$

$$W_{plc} = 38760\ lbs$$

وزن بار غیرمسافر (**cargo**) در این فاز
محاسبه نمی‌شود بعد از طراحی برنده و
استخراج حجم در دسترس بار فضای
اضافی برای حمل بار استفاده خواهد شد.

Step II: Take off Weight



Sforza: Fig. 1.12 Take-off weights versus number of passenger seats for 46 operational commercial jet transports.

حدس اولیه وزن برخاست از هواپیماهای مشابه

یا

استفاده از نمودارهای وزن بر حسب تعداد مسافر

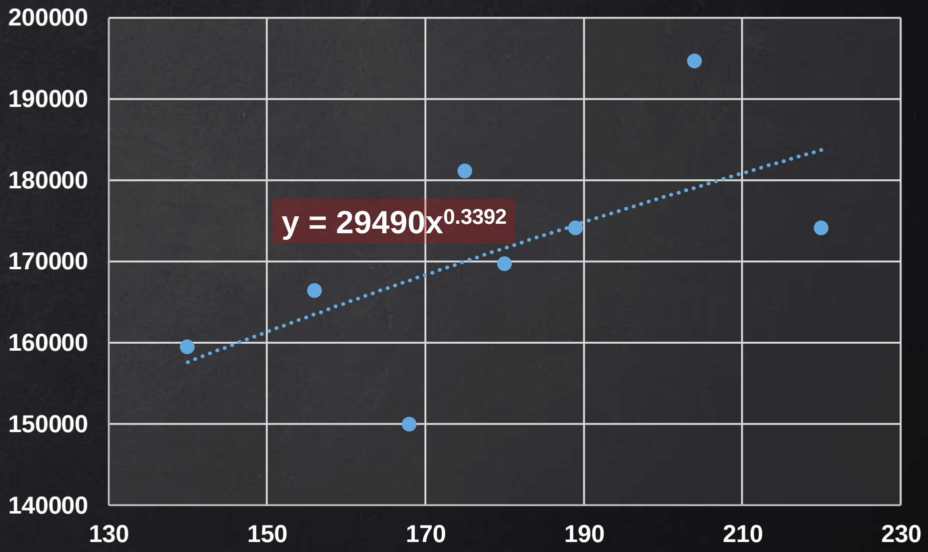
↓

تولید نمودار اختصاصی بر اساس هواپیماهای مشابه

Step II (continue)

	NP (2 Class)	NP max	WTO	We
B737-400	147	168	150000	76760
B737-800	162	189	174200	92190
B737-900	177	220	174200	94740
B737 Max 7	126	140	159500	?
B737 Max 8	162	175	181200	?
B737 Max 9	180	204	194700	?
A319-100	124	156	166500	89500
A320-200	150	180	169800	92800

$W_{T.O.guess} = 170000\ lbs$



Step III: Fuel Weight Estimation

$W_F = W_{Fused} + W_{Fres}$

Roskam

Fuel-Fraction Method

The fuel-fraction for each phase is defined as the ratio of end weight to begin weight

as a fraction of W_{Fused}
or
as a requirement for additional range so that an alternate airport can be reached
or
as a requirement for (additional) loiter time

Fuel Reserve

Step III (continue)

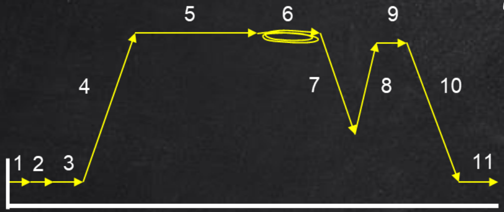


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Table 2.1 Suggested Fuel-Fractions For Several Mission Phases

Mission Phase No. (See Fig.2.1) / Airplane Type:	Engine Start, Warm-up 1	Taxi 2	Take-off 3	Climb 4	Descent 7	Landing Taxi, Shutdown 8
1. Homebuilt	0.998	0.998	0.998	0.995	0.995	0.995
2. Single Engine	0.995	0.997	0.998	0.992	0.993	0.993
3. Twin Engine	0.992	0.996	0.996	0.990	0.992	0.992
4. Agricultural	0.996	0.995	0.996	0.998	0.999	0.998
5. Business Jets	0.990	0.995	0.995	0.980	0.990	0.992
6. Regional TBP's	0.990	0.995	0.995	0.985	0.985	0.995
7. Transport Jets	0.990	0.990	0.995	0.980	0.990	0.992
8. Military Trainers	0.990	0.990	0.990	0.980	0.990	0.995
9. Fighters	0.990	0.990	0.990	0.96-0.90	0.990	0.995
10. Mil.Patrol, Bomb, Transport	0.990	0.990	0.995	0.980	0.990	0.992
11. Flying Boats, Amphibious, Float Airplanes	0.992	0.990	0.996	0.985	0.990	0.990
12. Supersonic Cruise	0.990	0.995	0.995	0.92-0.87	0.985	0.992

Notes: 1. The numbers in this table are based on experience or on judgment.
2. There is no substitute for common sense! If and when common sense so dictates, the reader should substitute other values for the fractions suggested in this table.

$$\frac{W_1}{W_{T.O.}} = 0.99$$

$$\frac{W_2}{W_1} = 0.99$$

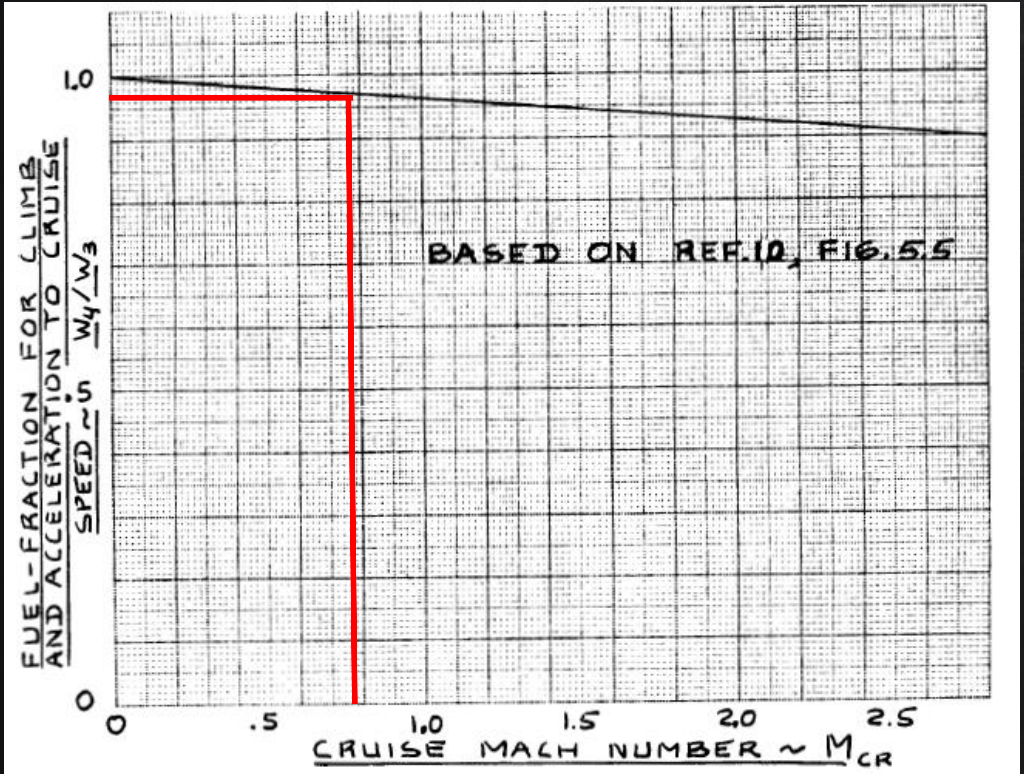
$$\frac{W_3}{W_2} = 0.995$$

$$\frac{W_4}{W_3} = 0.98$$

or
Fig. 2.2 Roskam
or
Breguet's Eq.

Step III (continue)

Roskam Vol. I Fig. 2.2



$$\frac{W_4}{W_3} = 0.98$$

Step III (continue)

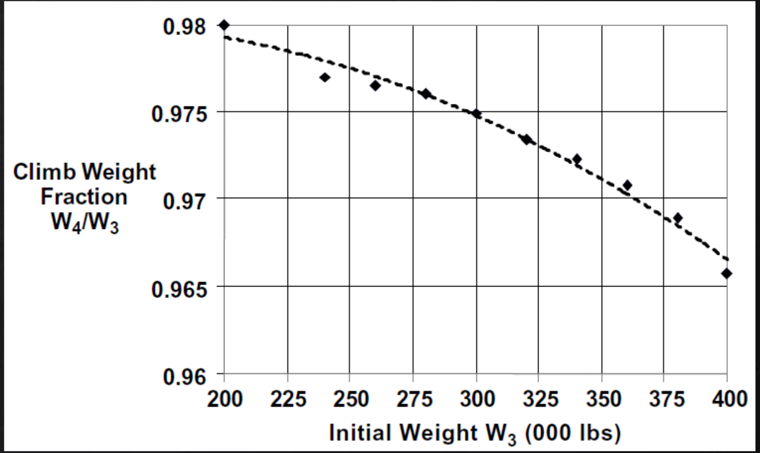
Sforza

Table 2.4 Weight Fractions for the Mission Segments for Turbofan Aircraft (R in nm, V in kts, and C_j in hr^{-1})

Stage	Description	W_i/W_{i-1}
1	Engine start and warm-up	0.990
2	Taxi	0.990
3	Takeoff	0.995
4	Climb	0.980
5	Cruise to full range	$\exp[-RC_j/V(L/D)]$
6[a]	One hour additional flight at cruise conditions	$\exp[-C_j/(L/D)]$
6[b]	Ten percent nominal flight time additional	$\exp[-RC_j/10V(L/D)]$
7[a]	Descent to destination and refused landing	0.990
8[a]	Climb	0.980
9[a]	Diversion to alternate airport 200 nm distant	$\exp[-200C_j/V(L/D)$
9[b]	Diversion to alternate airport 200 nm distant plus 0.5 h hold at 15,000 ft altitude at alternate airport	$\exp[-200C_j/V(L/D)$ $+\exp[0.5Cj/V(L/D)]$
10	Descent	0.990
11	Landing	0.992

[a] *Flight diversion for domestic flights.*
[b] *Flight diversion for international flights.*

Sforza Fig. 2.4



The weight fraction *W4/W3* for the Douglas DC-10-10 airliner in a climb to 35,000 ft as given by Shevell (1989). Dotted line is added to indicate the trend.

Step III (continue)

Sforza

Table 2.7 Weight Fractions for the Mission Segments for Turboprop Aircraft (R in nm, V in kts, and C_{tp} in lb/hp-hr)

Stage	Description	W_i/W_{i-1}
1	Engine start and warm-up	0.990
2	Taxi	0.995
3	Takeoff	0.995
4	Climb	0.985
5	Cruise to full range	$\exp\{-RC_{tp}/[326\eta_p(L/D)]\}$
6	One hour added flight at cruise conditions	$\exp\{-(1\text{hr})(V)C_{tp}/[326\eta_p(L/D)]\}$
7	Descent to destination and refused landing	0.985
8	Climb	0.985
9	Diversion to alternate airport 200 nm distant	$\exp[-200C_p/326\eta_p(L/D)]$
10	Descent	0.990
11	Landing	0.995

The best time advantage for a turbofan compared to a turboprop may be assumed to be in the ratio of the cruise speeds, that is, about 500 mph/350 mph = 1.43, so that a 60-min flight in a turbofan would be about an 80–90-min flight in a turboprop. Of course, a transcontinental flight would be quite different, with a 6-h flight in a turbofan becoming a 9-h flight in a turboprop.

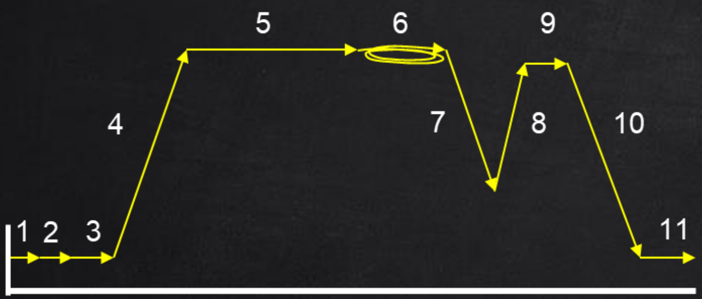
Step III (continue)

Fuel consumption in cruise for jet airplanes:

$\frac{W_5}{W_4} = ?$ → Breguet's range Eq.

$$R = \frac{V}{C_j}\left(\frac{L}{D}\right) ln\left(\frac{W_4}{W_5}\right)$$

R in nm, V in kts & Cj in lb/lb-hr



Note that the quantity V/C_j must have the same units as does the range *R*

می توان برای افزایش دقت محاسبات مسافت طی
شده در صعود نیز محاسبه گردد و از برد کسر گردد.

Step III (continue)

Sforza

Table 2.5 Some Units in Use for Range, Speed, and Specific Fuel Consumption

Property	Airline Operations	English Units	Common US Units	Metric Units	Common Metric Units
Horizontal distance	1 nm	6076 ft	1.151 mi	1852 m	1.852 km
Horizontal speed	1 kt	1.688 ft/s	1.151 mph	0.5144 m/s	1.852 kph
Specific fuel consumption	1 lb/lb-hr	1 hr^{-1}	1 hr^{-1}	28.33×10^{-6} kg/N-s	28.33 mg/N-s

Step III (continue)

Selection of cruise performance characteristics

$\frac{V}{a} = M$ → From mission specification

a → In 35000 to 36000 ft speed of sound, is approximately constant (at 574 kts or 660 mph)

$\frac{L}{D}$

Sfc or C_j

Table 2.2 Suggested Values For L/D, c_j, η_p, And For c_p For Several Mission Phases

Mission Phase No. (See Fig. 2.1)	Cruise (5) L/D	Cruise c_j lbs/lbs/hr	Cruise c_p lbs/hp/hr	Cruise η_p	Loiter (6) L/D	Loiter c_j lbs/lbs/hr	Loiter c_p lbs/hp/hr	Loiter η_p
Airplane Type								
1. Homebuilt	8-10*		0.6-0.8	0.7	10-12		0.5-0.7	0.6
2. Single Engine	8-10		0.5-0.7	0.8	10-12		0.5-0.7	0.7
3. Twin Engine	8-10		0.5-0.7	0.82	9-11		0.5-0.7	0.72
4. Agricultural	5-7		0.5-0.7	0.82	8-10		0.5-0.7	0.72
5. Business Jets	10-12	0.5-0.9			12-14	0.4-0.6		
6. Regional TBP's	11-13		0.4-0.6	0.85	14-16		0.5-0.7	0.77
7. Transport Jets	13-15	0.5-0.9			14-18	0.4-0.6		
8. Military Trainers	8-10	0.5-1.0	0.4-0.6	0.82	10-14	0.4-0.6	0.5-0.7	0.77
9. Fighters	4-7	0.6-1.4	0.5-0.7	0.82	6-9	0.6-0.8	0.5-0.7	0.77
10. Mil.Patrol, Bomb, Transport	13-15	0.5-0.9	0.4-0.7	0.82	14-18	0.4-0.6	0.5-0.7	0.77
11. Flying Boats, Amphibious, Float Airplanes	10-12	0.5-0.9	0.5-0.7	0.82	13-15	0.4-0.6	0.5-0.7	0.77
12. Supersonic Cruise	4-6	0.7-1.5			7-9	0.6-0.8		

Notes: 1. The numbers in this table represent ranges based on existing engines.
2. There is no substitute for common sense! If and when actual data are available, these should be used.
3. A good estimate for L/D can be made with the drag polar method of Sub-section 3.4.1.
* Homebuilts with smooth exteriors and/or high wing loadings can have L/D values which are considerably higher.

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Step III (continue)

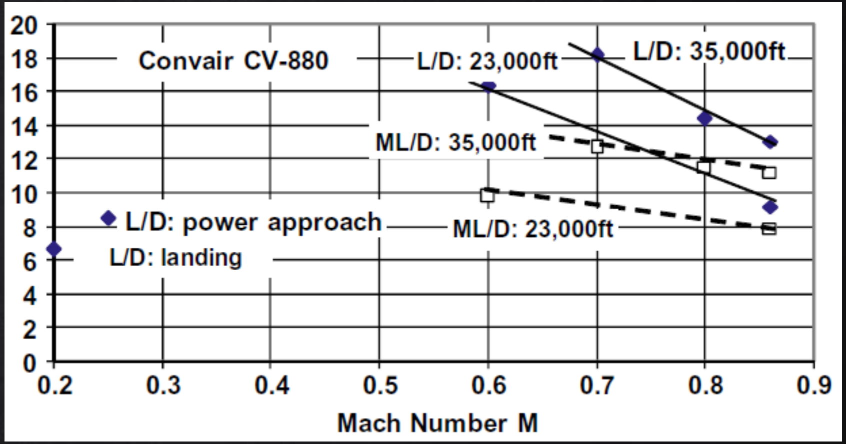
Selection of cruise performance characteristics

Loftin (1985)

Airplane	L/D
B707	19.5-19
DC-8	17.9
B767-200	18
B747	18
Lockheed L1011-200	17
MD 10-30	17.5

$$\frac{L}{D} = 14 \sim 19$$

$$\text{Sfc or } C_j = 0.5 \sim 0.6$$



Sforza, Fig. 2.5
Data from Heffley and Jewell (1972) show the variation of *L/D* and *ML/D* as a function of *M* for the Convair CV-880 jetliner at two altitudes. The *L/D* for typical power approach and landing at sea level are also shown.

Step III (continue)

Fuel consumption in cruise for turboprop airplanes:

$\frac{W_5}{W_4} = ?$ ⇒ Breguet's Eq.

$$R = 326\,\frac{\eta_P}{C_{tP}}\left(\frac{L}{D}\right) ln\left(\frac{W_4}{W_5}\right)$$

R in nm & Ctp in lbs/hr-hp

$V = 250 - 300$ kts

$$R = 375\,\frac{\eta_P}{C_{tP}}\left(\frac{L}{D}\right) ln\left(\frac{W_4}{W_5}\right)$$

R in miles & Ctp in lbs/hr-hp

$\eta_P = 82\% - 92\%$

$\frac{L}{D} = 14 - 18$

Sfc or $C_{tP} = 0.5–0.7$ lbs/hp-hr

Step III (continue)

Fuel consumption in loiter:

$\frac{W_6}{W_5} = ?$ Breguet's endurance Eq. For Jet

$$E = \frac{1}{c_j}\left(\frac{L}{D}\right) ln\left(\frac{W_5}{W_6}\right)$$

Table 2.2 Suggested Values For L/D, c_j, η_p, And For c_p For Several Mission Phases

Mission Phase No. (See Fig. 2.1) / Airplane Type	Cruise (5) L/D	Cruise c_j lbs/lbs/hr	Cruise c_p lbs/hp/hr	Cruise η_p	Loiter (6) L/D	Loiter c_j lbs/lbs/hr	Loiter c_p lbs/hp/hr	Loiter η_p
1. Homebuilt	8-10*		0.6-0.8	0.7	10-12		0.5-0.7	0.6
2. Single Engine	8-10		0.5-0.7	0.8	10-12		0.5-0.7	0.7
3. Twin Engine	8-10		0.5-0.7	0.82	9-11		0.5-0.7	0.72
4. Agricultural	5-7		0.5-0.7	0.82	8-10		0.5-0.7	0.72
5. Business Jets	10-12	0.5-0.9			12-14	0.4-0.6		
6. Regional TBP's	11-13		0.4-0.6	0.85	14-16		0.5-0.7	0.77
7. Transport Jets	13-15	0.5-0.9			14-18	0.4-0.6		
8. Military Trainers	8-10	0.5-1.0	0.4-0.6	0.82	10-14	0.4-0.6	0.5-0.7	0.77
9. Fighters	4-7	0.6-1.4	0.5-0.7	0.82	6-9	0.6-0.8	0.5-0.7	0.77
10. Mil.Patrol, Bomb, Transport	13-15	0.5-0.9	0.4-0.7	0.82	14-18	0.4-0.6	0.5-0.7	0.77
11. Flying Boats, Amphibious, Float Airplanes	10-12	0.5-0.9	0.5-0.7	0.82	13-15	0.4-0.6	0.5-0.7	0.77
12. Supersonic Cruise	4-6	0.7-1.5			7-9	0.6-0.8		

Notes: 1. The numbers in this table represent ranges based on existing engines.
2. There is no substitute for common sense! If and when actual data are available, these should be used.
3. A good estimate for L/D can be made with the drag polar method of Sub-section 3.4.1.
* Homebuilts with smooth exteriors and/or high wing loadings can have L/D values which are considerably higher.

Breguet's endurance Eq. For Turboprop

$$E = \frac{375}{V}\frac{\eta_P}{C_{tP}}\left(\frac{L}{D}\right) ln\left(\frac{W_5}{W_6}\right)$$

V → From mission specification

Step III (continue)

Sforza

Table 2.4 Weight Fractions for the Mission Segments for Turbofan Aircraft (R in nm, V in kts, and C_j in hr^{-1})

Stage	Description	W_i/W_{i-1}
1	Engine start and warm-up	0.990
2	Taxi	0.990
3	Takeoff	0.995
4	Climb	0.980
5	Cruise to full range	$\exp[-RC_j/V(L/D)]$
6[a]	One hour additional flight at cruise conditions	$\exp[-C_j/(L/D)]$
6[b]	Ten percent nominal flight time additional	$\exp[-RC_j/10V(L/D)]$
7[a]	Descent to destination and refused landing	0.990
8[a]	Climb	0.980
9[a]	Diversion to alternate airport 200 nm distant	$\exp[-200C_j/V(L/D)$
9[b]	Diversion to alternate airport 200 nm distant plus 0.5 h hold at 15,000 ft altitude at alternate airport	$\exp[-200C_j/V(L/D)$ $+\exp[0.5C_j/V(L/D)]$
10	Descent	0.990
11	Landing	0.992

[a] *Flight diversion for domestic flights.*
[b] *Flight diversion for international flights.*

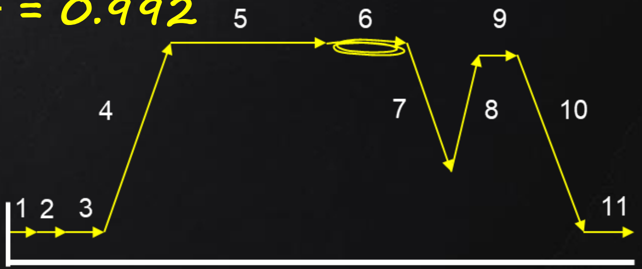
$$\frac{W_7}{W_6} = 0.99$$

$$\frac{W_8}{W_7} = 0.98$$

$$\frac{W_9}{W_8} = \text{Breguet Eq.}$$

$$\frac{W_{10}}{W_9} = 0.99$$

$$\frac{W_{10}}{W_9} = 0.992$$



Step III (continue)

$W_F = W_{Fused} + W_{fres} = M_f\ W_{T.O.} = (1 - M_{ff})\ W_{T.O.}$

$$M_{ff} = \frac{W_{11}}{W_0} = \prod_{1}^{n} \frac{W_i}{W_{i-1}} = \left(\frac{W_1}{W_{T.O.}}\right) \prod_{1}^{i=10} \frac{W_{i+1}}{W_i}$$

$$M_{ff} = \frac{W_1}{W_{T.O.}} \times \frac{W_2}{W_1} \times \frac{W_3}{W_2} \times \frac{W_4}{W_3} \times \frac{W_5}{W_4} \times \frac{W_6}{W_5} \times \frac{W_7}{W_6} \times \frac{W_8}{W_7} \times \frac{W_9}{W_8} \times \frac{W_{10}}{W_9} \times \frac{W_{11}}{W_{10}}$$

$M_{ff} = 0.7011$

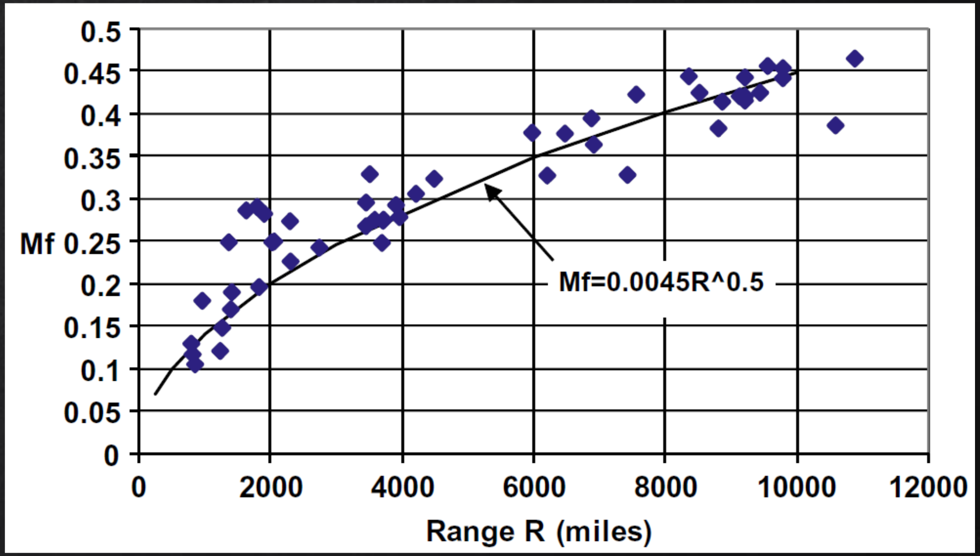
Step III (continue)

$M_{ff} = 0.7011$

$M_f = 0.2508$

$M_{ff} = 0.749$

از این نمودار می توان به عنوان یک چک پوینت جهت بررسی صحت محاسبات استفاده نمود. اما در این مرحله اصلاح و تغییری ایجاد نمی کنیم و پس از محاسبه وزن خالی و بررسی نتایج این بخش را به عنوان بخش قابل اصلاح در نظر می گیریم.



Sforza Fig. 2.3
The total fuel fraction *Mf* is shown as a function of range as estimated from available information on 50 airliners. The solid line is an approximate curve fit to the data shown.

Step IV & Step V

$$W_{OE,Tent} = W_{T.O.guess} - W_F - W_{PL}$$

$W_{OE,Tent}$ = 81790 lbs

$$W_{e,Tent} = W_{OE,Tent} - W_{tfo} - W_{Crew}$$

Roskam

M_{tfo}=0.005

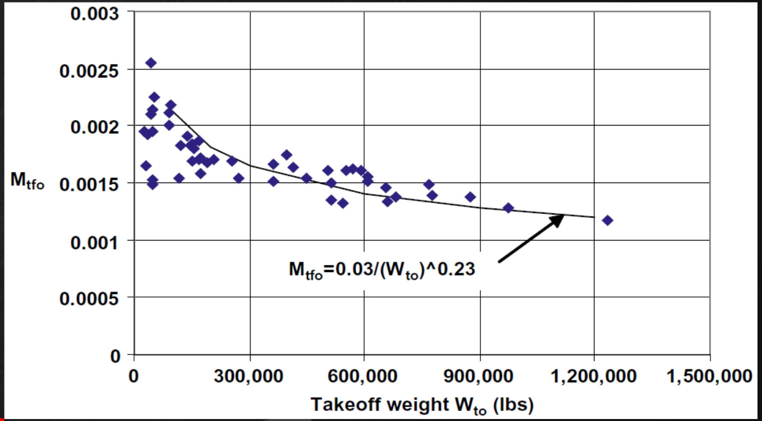
Torenbeek

$$M_{tfo} \approx 0.227\left(\frac{M_f^2}{W_{T.O}}\right)^{1/3}$$

تورنبیک براساس حجم تانک سوخت هواپیماها و چگالی سوخت رابطه‌ای پیشنهاد داد.

Sforza

Sforza Fig. 2.9



$$M_{tfo} = \frac{0.03}{\sqrt{(W_{T.O})^{0.23}}}$$

اسفرزا رابطه تورنبیک را برای ۵۰ هواپیمای تجاری خود به کار گرفت و رابطه ای جدید مختص هواپیماهای مسافربری ارائه داد.

W_{tfo} = 306 lbs

Step VI: Empty Weight

Roskam Fig. 2.9

$$log(W_e) = \frac{1}{B}(log(W_{T.O.}) - A\ )$$

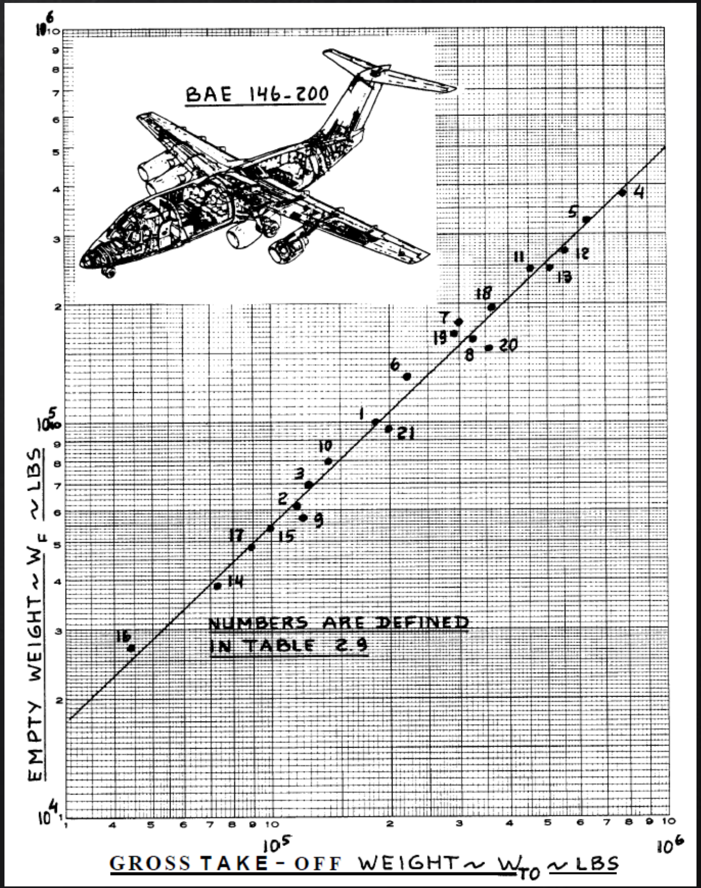
$W_e = 90633\ lbs$

Roskam

Table 2.15 Regression Line Constants A and B of Equation (2.16)

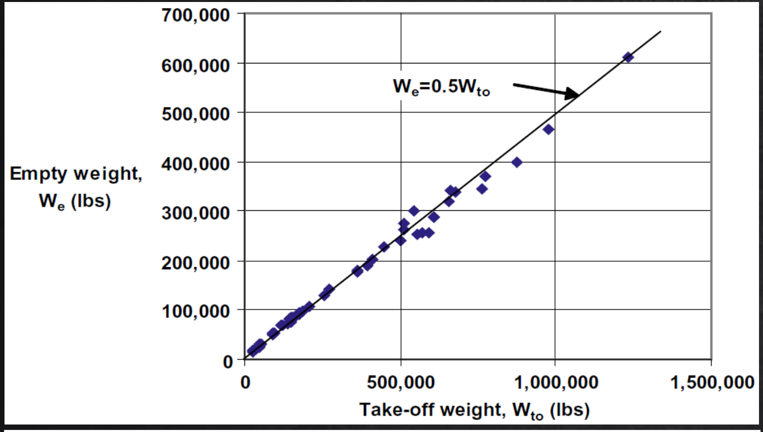
Airplane Type	A	B
1. Homebuilts		
Pers. fun and transportation	0.3411	0.9519
Scaled Fighters	0.5542	0. 8654
Composites	0.8222	0.8050
2. Single Engine Propeller Driven	-0.1440	1.1162
3. Twin Engine Propeller Driven	0.0966	1.0298
Composites	0.1130	1.0403
4. Agricultural	-0.4398	1.1946
5. Business Jets	0.2678	0.9979
6. Regional TBP	0.3774	0.9647
7. Transport Jets	0.0833	1.0383
8. Military Trainers		
Jets	0.6632	0.8640
Turboprops	-1.4041	1.4660
Turboprops without No.2	0.1677	0.9978
Piston/Props	0.5627	0.8761
9. Fighters		
Jets(+ ext.load)	0.5091	0.9505
Jets(clean)	0.1362	1.0116
Turboprops(+ ext. load)	0.2705	0.9 830
10. Mil. Patrol, Bomb and Transport		
Jets	-0.2009	1.1037
Turboprops	-0.4179	1.1446
11. Flying Boats, Amphibious and Float Airplanes	0.1703	1.0083
12. Supersonic Cruise	0.4221	0.9876

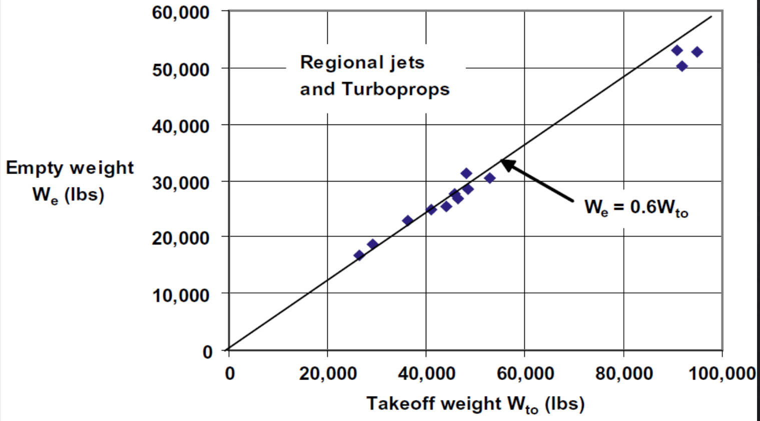
$$log(W_e) = \frac{1}{1.0383}(log(W_{T.O.}) - 0.0833\ )$$

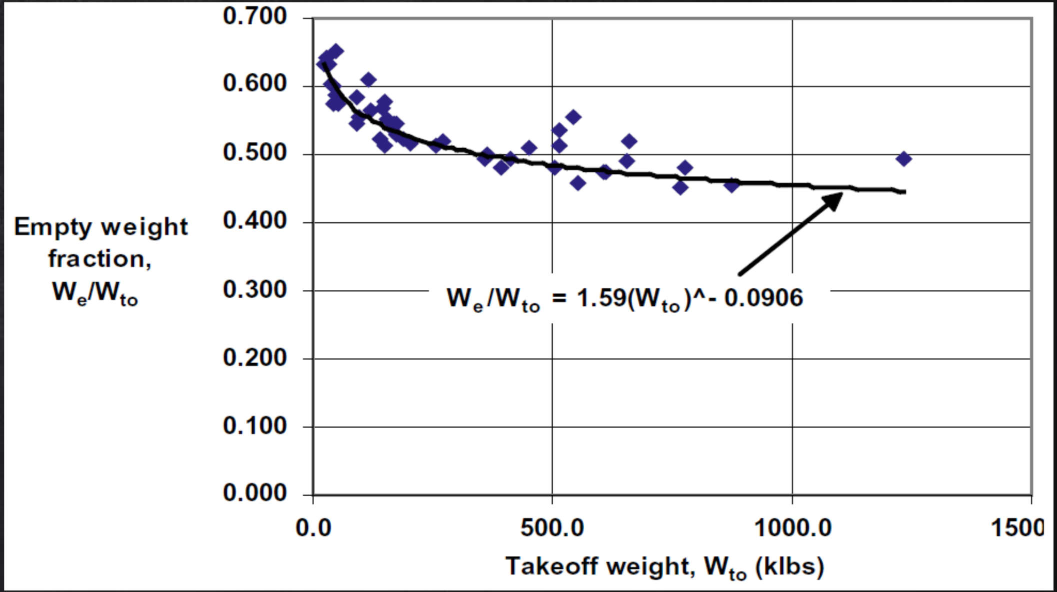


Step VI (continue)

Sforza Fig. 2.6, 2.7 & 2.11







W_e = 90775 lbs

Empty Weight

80,124 lbs

Tentative

90,633 lbs

Roskam Regression Line

90,775 lbs

Sforza Historical Correlation

Step VII

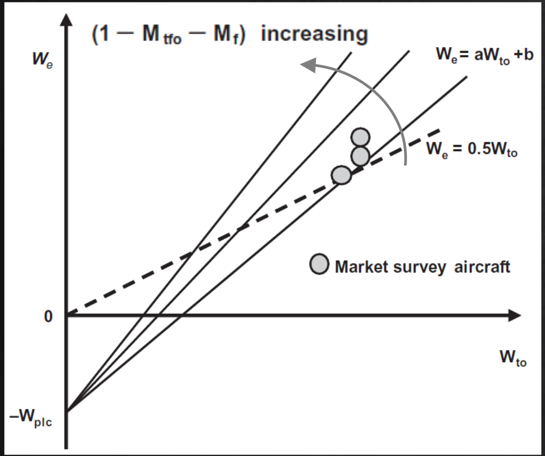
مقایسه وزن
خالی با نمودار
لگاریتمی

حدسی برای
وزن برخاست

Roskam Approach

محاسبه وزن
سوخت،
محموله و وزن
خالی

Step VII (sforza)



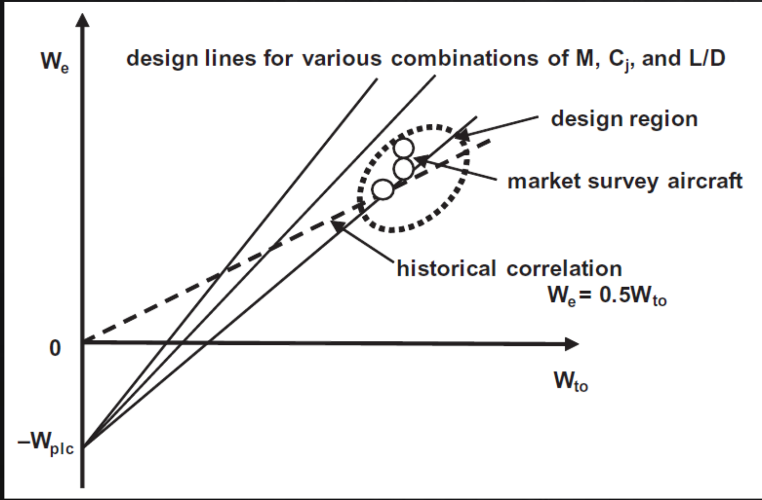
$$W_e = (1 - M_f - M_{tfo})W_{g,max} - W_{plc}$$

رابطه‌ای خطی

$$\boxed{W_e = aW_{g,max} + b}$$

$$a = 1 - (M_f + M_{tfo})$$

$$b = -W_{plc}$$



$$W_e = 0.6993W_{g,max} - 38760$$

$W_e = 0.7542 W_{T.o.} - 38760$
150000
130000
110000
90000
70000
50000
30000
10000
-10000
-30000
-50000
0
50000
100000
150000
200000
250000
Empthy Weight
Take Off Weight
Design line
Historical
log
B737-400
A320-200
B737-800
B737-900
Design Line new

Weight Reduction

Table 2.16 Weight Reduction Data for Composite

Structural Component	Construction W_{comp}/W_{metal}
Primary Structure	
Fuselage	0.85
Wing, Vertical Tail, Canard or Horizontal Tail	0.75
Landing Gear	0.88
Secondary Structure	
Flaps, Slats, Access Panels, Fairings	0.60
Interior Furnishings	0.50
Air Induction System	0.70 - 0.80

در استفاده از ضریب کاهش وزن باید دقت داشت.
درصدهای داده شده برای تغییر کامل و ۱۰۰ درصدی
آلیاژ آلمینیوم به مواد کامپوزیتی است.
استفاده از مواد کامپوزیتی مشکلاتی در خصوص عمر،
خستگی سازه و تعمیر و نگهداری آن ایجاد میکند.
برای استفاده از آلیاژهای لیتیم- آلمینبویم در سازه
برنه، بال و دم ضریب کاهش وزن لبن ۵ الی ۱۰
درصد است.

A380 25% composite
B787 50% composite
Bell-Boing v 22 75% airframe for composite
Eurofighter 75% airframe for composite
F/A-18 E/F 50 % to 60%
F-22 50% to 60%

thanks!

Any questions?