Aircraft Design

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The complete step-by-step guide for development of most of the existing types of aircraft

Workbook

2021

-This book is designed specifically for the Aircraft Design course-

Contents

1. Preparation for statistical analysis

Having all aircraft design requirements, an extensive research for similar aircrafts can be completed. It is a common practice that engineers research from 3 to 5 aircrafts that have number of passengers, mission and range close to the one you design. You can search those parameters on the web or in the aircraft design books.

All parameters and characteristics of the machines included in the research is recorded in the table below. This table is later used to derive the first order parameters of the aircraft you are designing.

№	Parameters and Characteristics	Aircraft 1 (country)	Aircraft 2 (country)	Aircraft 3 (country)	Your Aircraft Name
	Mass				
1	Take Off Mass, kg				
2	Number of Passengers				
3	Mass of the Empty Aircraft, kg (Approximate mass*)				
4	Fuel Mass, kg (Approximate mass*)				
5	Wing loading, daN/m2				
	Geometry				
6	Wingspan, m				
7	Wing Area, m2				
8	Aspect Ratio				
9	Aircraft Length, m				
10	Fuselage Diameter, m				
	Flying Capabilities				
11	Minimum Speed, km/h				
12	Maximum Speed, km/h				
13	Range, km				
14	Max Flight Height, km				
15	Take Off Distance, m				
16	Landing Distance, m				
	Powerplant				
17	Engine Make				
18	Number of Engines				
19	Thrust, daN				
20	Take Off Relative Thrust, kW/daN)				
21	Specific Fuel Consumption, kg/kNh				

Table 1: Statistical Parameters and Characteristics

2. Types of flight missions

The flight mission of the aircraft predefines its future project. The flight missions can be categorized based on the tactical use of the Aircraft. This distinguishes the missions to Civil, Surveillance, Bombing and Combat. You can choose your flight mission based on your aircraft design project. It is important to remember all components of your flight. For instance, the components of the Civil Flight are: Take Off, Climb, Cruise, Descent and Lending.

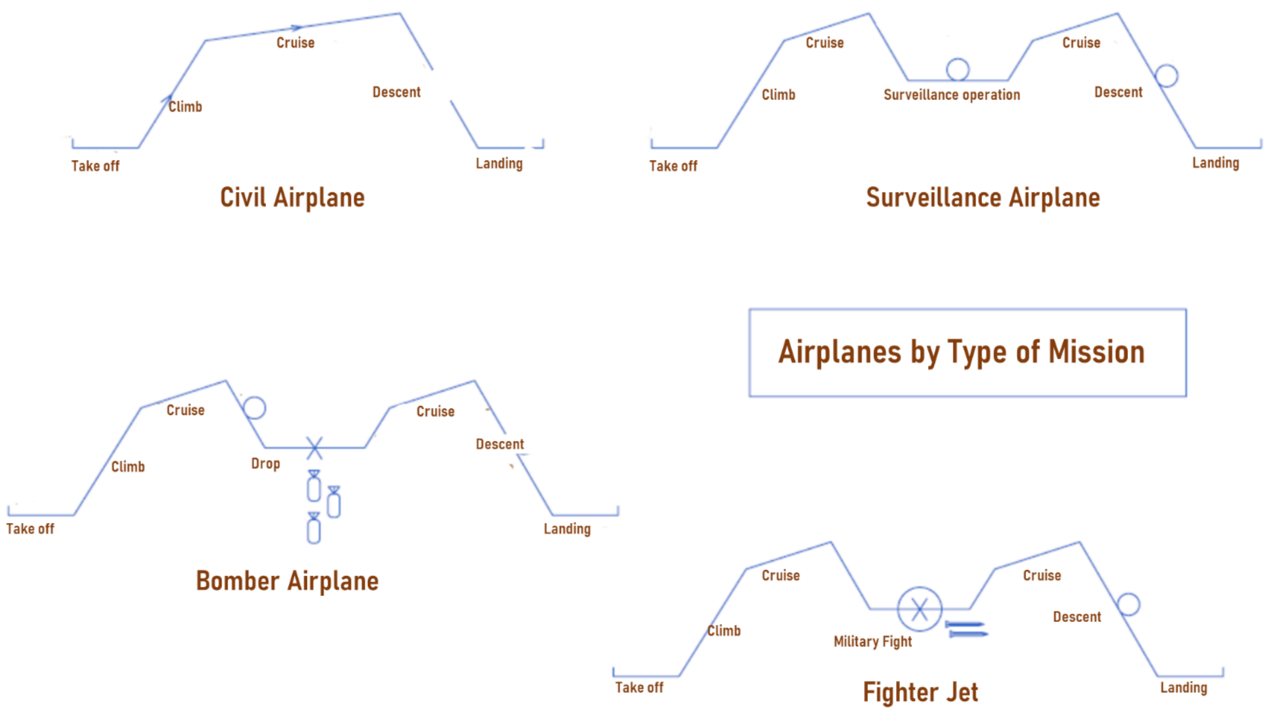

Figure 1: Airplanes by Type of Mission

As you can see every element of the flight can be classified, so it makes sense that you will have different characteristics and variables for each stage of the flight. Once you decide what is the mission that suits to your aircraft and explored the stages of your mission, you can find the parameters specific to each stage in the table below.

№	Segment Name	Characteristics
1	Take Off	L_{toff}, V_{toff}
2	Climb	H_{cl}, V_{cl}, $tg\theta$
3	Cruise Flight	V_{cr}, H_{cr}, L
4	Descending	V_{des}, δH
5	Landing	V_{des}, l_{des}
6	Maneuvering	H_m, t_m, n_y

Table 2: Segment Variables

3. Determination of the main aircraft parameters

The determination of the main aircraft parameters includes the estimation of those key relative and absolute characteristics:

- Take off mass - m_0
- Take off wing loading p_0
- Take off traction – $\overline{P}_0$
- Estimated wing span – S
- Take off thrust – P_0

The choice for the main aircraft parameters is conducted in terms of the data obtained during the statistic research of similar aircraft types. It is worth mentioning that later in the project those parameters may change due to the advanced calculations performed throughout the project. But at this stage they are your starting point from which you can continue with the mass estimation with continuously increasing level of accuracy throughout the project.

3.1. Initial estimations of the aircraft mass

The take-off mass is the mass with which the aircraft starts its mission. This is not necessary the maximum possible pass for the aircraft. Some aircrafts include military equipment and could be overloaded, this reduces their manoeuvrability. At this stage you shouldn't aim for accuracy, but to include the main components of the mass:

$$m_0 = m_{cw} + m_{ld} + m_{fl} + m_{ey} \qquad (1)$$

- Crew mass- m_{cw}
- Loading mass (passengers, luggage, armoury, etc.) - m_{ld}
- Fuel mass - m_{fl}
- Empty mass - m_{ey}
- Take off mass – m_0

The mass of the crew can be easily calculated. To determine the fuel mass and the mass of the empty aircraft, you need to modify their parameters in *Equation 1*.

$$m_0 = m_{cw} + m_{ld} + (m_{fl}/m_0)m_0 + (m_{ey}/m_0)m_0 \qquad (2)$$

We can take the values of $m_{ey}^* = m_{ey}/m_0$ and $m_{fl}^* = m_{fl}/m_0$ as a relative empty and fuel masses, respectively.

The final equation for the initial aircraft mass estimation is:

$$m_0 = (m_{cw}+m_{ld})/(1-m_{lf}^* - m_{ey}^*) \qquad (3)$$

3.1.1. Estimating the mass of the empty aircraft.

At that stage the empty mass can be calculated based on the statistical analysis. It is usually from 0.3 to 0.7 of the whole mass, depending on the aircraft size and mission. The Figure 2 shows the relative empty mass depending on the type and the take off mass of the aircraft. Table 3 shows summarized statistical analysis to determine m^*_{ey}.

$$m_{ey}^* = A(2.2m_0)^C K_p \tag{4}$$

- A, C – Coefficients;
- m_0 – Take-off mass (from the statistics), kg;
- K_p – Coefficient of the propeller type.

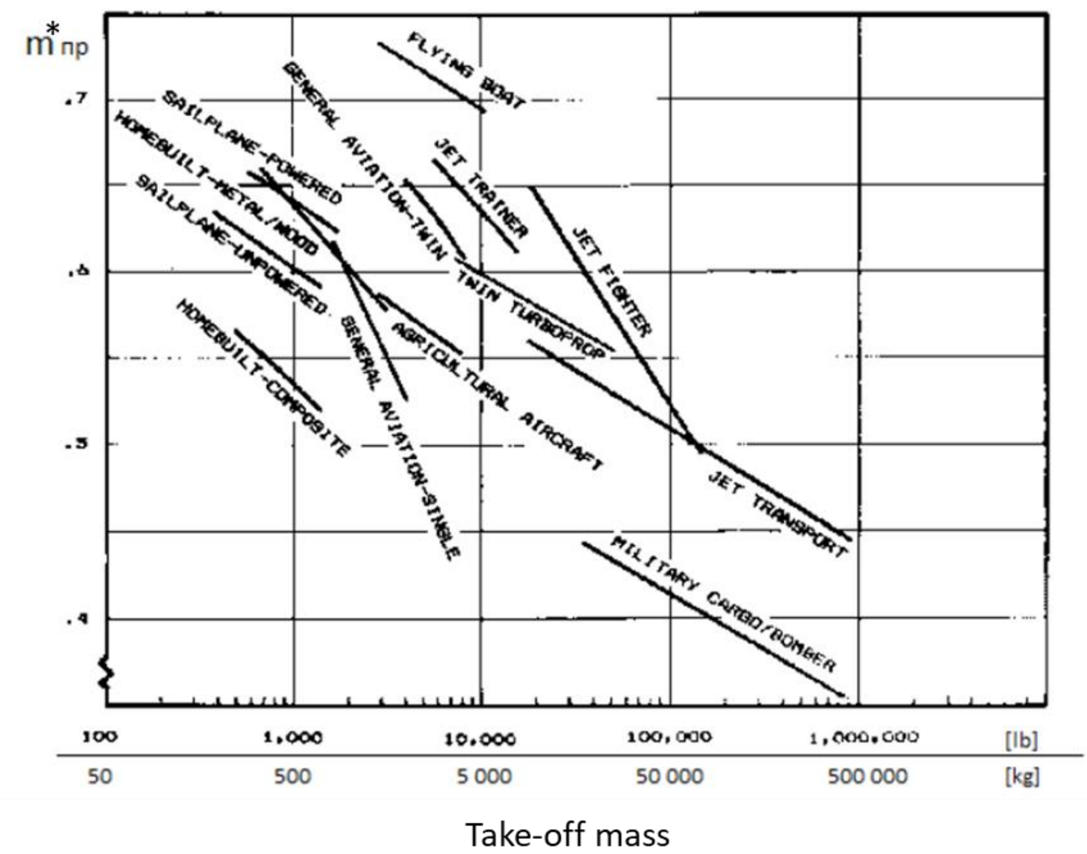

Figure 2: Relative empty aircraft mass

Aircraft Type	A	C
Glider	0.86	-0.5
Monoplane	0.91	-0.5
Single Engine	2.36	-0.18
Two Engine	1.51	-0.1
Agricultural	0.74	-0.03
Turbofan	0.96	-0.05
Jet Engine	1.59	-0.1
Fighter Jet	2.34	-0.13
Bomber	0.93	-0.07
Heavy Transport	1.02	-0.06
K_p = 1.00 for fixed propellers		

Table 3: Empty Plane Coefficients

3.1.2. Estimating the fuel mass

The fuel needed and basically its mass can be estimated from all segments of the flight that require significant fuel consumption: take-off, climbing, cruise flight, descending, landing, manoeuvring. Once you determine the segments of your flight by choosing its mission, the sum of the fuel used in each segment will give you the final fuel volume and mass for the mission.

If you the number of segments is denoted with i then the fuel in the end of this segment will be m_i. So the difference between the starting point and the final point is due to the fuel burn. To determine the change in the mass due to fuel burn depending on the number of segments, you can use the following equation:

$$m_{fl}^* = m_{fl}/m_0 = 1.06(1-(m_2/m_1)(m_3/m_2)\ \ldots m_n/m_{n-1}) \qquad (5)$$

, where n is the number of segments.

When determining the fuel mass change during flight it is important to take into account the aerodynamic qualities of the aircraft, which are determined from the quality coefficient K_{max}.

- Take-off fuel segment:

$$m_i/m_{i-1} = 0.970 \qquad (6)$$

- Climbing segment:

$$m_i/m_{i-1} = (1-0.009\ \delta H)/(1-0.0045\ \delta H) \qquad (7)$$

, where δH is the required climbing altitude.

- Cruise flight segment:

$$m_i/m_{i-1} = \exp((-Lc)/(V_{cr}K_{cr})) \qquad (8)$$

, where: L – Flight range

c – Specific fuel consumption, kg/daNh

V_{cr} - Cruise speed, km/h

K_{cr} - Aerodynamic quality coefficient

- Aeronavigation reserve is required in case of emergency. It is usually 3 to 5 % of the total fuel mass: $m_i/m_{i-1} = 0.95\ldots0.97$

3.1.3. Estimating the mass of the cabin crew

The mass of the cabin crew is usually approximated taking for each bomber of the cabin crew a weight of 90kg.

$$m_{cr} = 90n_{cr} \qquad (9)$$

, where n_{cr} is the number of the cabin crew members.

3.1.4. Estimating the mass of the aircraft loading

The mass of the aircraft load includes the passengers and their luggage.

$$m_{ld}=90n_{pas}+180V_l \qquad (10)$$

, where n_{pas} – number of passengers

V_l – volume of the baggage aera, m^3.

3.2. Determination of the wing loading

The wing loading p = G/S is determined from one of three estimation cases: from the landing conditions, from the conditions for maintaining the cruise flight and from the maneuvering conditions. From the three cases you have to choose the minimum wing loading.

- Landing conditions

$$P_0^I = (c^{land}_{ymax}\ V^2_{min})/(30{,}2(1-m_{fl.hf}),\ daN/m^2 \qquad (11)$$

where: c^{land}_{max} = 2.5…3.2 –max lift coefficient when landing for effective wing mechanization

V_{min} – landing velocity

$m^*_{fl.hf}$ – relative horizontal flight fuel mass ($m^*_{fl.hf} = 1 - m_i/m_{i-1}$)

- Cruise flight conditions

$$P_0^{II} = (c_{ycr}\rho_{cr}V^2_{cr})/(20(1\text{-}0.6m^*_{fl.hf}) \text{ , daN/m}^2 \quad (12)$$

where: c_{ycr} - lift coefficient for cruise flight

ρ_{cr} - air density at flight altitude

V_{cr} – cruise flight velocity

- Manoeuvring conditions

$$P^{III}_0 = 0.1(c_{yman}/n_{ymax})q_{max}\text{, daN/m}^2 \quad (13)$$

where: c_{yman} - lift coefficient for manoeuvring

ρ_{max} – maximal structure loading coefficient

q_{max} – dynamic pressure, Pa

Once the estimation of the above coefficients is completed, you can take the once having the minimum value.

3.3. Aircraft traction and qualities

There are certain factors that ensure the aircraft has enough thrust and lift to overtake climb, descend, flying with one engine out of order and so on. Here you will consider again three cases: from the conditions for climbing with failed engine, from the condition for a cruise flight and from the condition for take off distance condition.

- climbing with one failed engine

$$P^{*I}_0 = k_v(n_{eg}/(n_{eg}\text{-}1)(1/K_{cb}+tg\theta), \quad (14)$$

where: k_v - coefficient

K_{cb} – aerodynamic quality when climbing

n_{eg} – number of engines

$tg\theta$ – climbing gradient

- horizontal flight

$$P^{*II}_0 = 1/(K_{cr}\,\delta^{0.85}\phi), \quad (15)$$

where: $\varphi = 0.8$ – throttling coefficient

δ – relative density at cruise altitude

- take-off condition

$$P^{*III}_{0} = 1.05[(520/(C_{ymaxto}l_{to}) + 0.5(3f_{to} + 1/K_{to})], \quad (16)$$

where: C_{ymaxto} =1,7…2.3 – Lift coefficient for take-off

f_{to} – friction coefficient of the landing gear (*Table 4*)

No	Airport Surface	f_{to}
1	Snow and ice	0.02
2	Dry concrete	0.02
3	Wet concrete	0.03
4	Solid primer	0.07
5	Wet grass	0.06
6	Grass	0.08

Table 4: Friction coefficient values

Once the estimation of the above coefficients is completed, you can take the once having the maximum value.

4. Aerodynamic scheme

The term "Aerodynamic Scheme" describes some scheme that includes all surfaces on the aircraft, regardless whether they are control surfaces or static. This scheme determines the shape, position and dimensions of those surfaces. A typical aircraft scheme consists of main surfaces, such as wing, that provide most of the total lift and supporting surfaces such as horizontal and vertical surfaces that help for the stabilization and control of the aircraft.

Depending the position of the supporting surfaces to the wing, we can divide the aerodynamic schemes to the following:

- Standard Scheme: Horizontal surfaces are positioned behind the wing
- Foreplane: Horizontal surfaces are positioned in from of the wing
- Flying wing: There is only a single surface

4.1. Choosing the aerodynamic scheme

When designing a new aircraft there has always been the problem for designing its general scheme. The general scheme is something more than the typical aerodynamic scheme and depends on the applications for which the machine will be used for. Once we know the tasks that the aircraft will perform, we can determine the components of the general aircraft scheme as:

- Positioning the crew and the load

- Choosing the take off and landing mechanization and the aerodynamic scheme
- Choosing the powerplant scheme, such as number, type of the engines and their position on the aircraft.
- Aircraft sections and armoury

We can organize all elements from the general scheme in a table for simplicity. We can use the values in that table later on, when determining the dimensions of each component in the aerodynamic scheme. The table is called features matrix and is provided on *Table 5*.

Aerodynamic scheme	standard	foreplane	flying wing	
Wing position	low wing	mid wing	high wing	
Wing shape	rectangle	tapered	triangle	trapezoidal
Wing sweep	straight	standard	reversed	convertible
Control surfaces	standard	T-shaped	V-shaped	H-shaped
Cabin shape	circular	rectangle	elliptical	
Lending gear	front wheel	tail wheel		
Engine type	turboprop	turbofan	piston	
Number of engines	1	2	3	4
Engines position	front	tail	wing	mixed

Table 5: Features Matrix

4.2. Wing airfoil and geometry

Based on the loading and traction coefficients, we can estimate the wing area (S) and re-estimate the required thrust produced by the engines:

$$S = \frac{0.1 m_0^l g}{P_0}$$

$$T_0 = 0.1 P_0^* m_o^l g$$

With the date from the previous section, we can find the wing span (l):

- S – wing area, m^2
- λ - aspect ratio (from the statistics and the scheme)

$$l = \sqrt{S\lambda} \tag{17}$$

Then based on the statistical analysis we can now choose the inner and outer chords of the whing and find the taper ratio.

$$\eta = \frac{b_0}{b_r}, \tag{18}$$

where η - the taper ration, b_0 – inner chord, b_r – outer chord.

We can now estimate the geometric and the aerodynamic chords of the wing:

$$b_m = \frac{b_0 b_r}{2} = \frac{S}{l}, \text{ where } b_m \text{ is the median geometric chord} \quad (19)$$

$$b_A = \frac{2}{3} b_0 \frac{1+\eta+\eta^2}{\eta(1+\eta)}, \text{ where } b_A \text{ is the median aerodynamic chord} \quad (20)$$

Once we choose the front wing sweep X_{fe}, we can now estimate:

$$X_{re} = arctg\left[\frac{2}{l}(b_r - b_0 + \frac{l}{2} tgX_{fe}\right], \text{ rear sweep} \quad (21)$$

$$X_{0.25} = arctg\left[\frac{2}{l}(\frac{b_r - b_0}{4} + \frac{l}{2} tgX_{fe}\right], \text{ crank sweep at 0.25 from the inner chord} \quad (22)$$

We can finally choose dihedral angle (Ψ)

4.3. Horizontal surface geometry

The following parameters related to the geometry of the horizontal pane have to be chosen:

- A_{hs} = [0.8…1.1] – static moment
- L_{hs}/b_A = [2.0…3.0], L_{hs} – distance from the center of gravity to the aerodynamic center of the horizontal surface
- λ_{hs} = [3.4…4.5] – HS aspect ratio
- η_{hs} = [2.0…3.5] – HS taper ratio
- X_{hs} – HS sweep angle
- Ψ_{hs} – HS dihedral angle

We can find A_{hs} with the following equation:

$$A_{hs} = \frac{S_{hs} L_{hs}}{S b_A} \quad (23)$$

The rest of the parameters for the horizontal surface (L_{hs}, S_{hs}, l_{hs}, b_{0hs}, b_{rhs}, b_{Ahs}, X_{rehs}) are estimated with the equations from the wing geometry section (17) – (22).

4.4. Vertical surface geometry

The following parameters related to the geometry of the vertical pane have to be chosen:

- A_{vs} = [0.05…0.08] – static moment
- L_{vs}/b_A = [2.0…3.0], L_{vs} – distance from the center of gravity to the aerodynamic center of the vertical surface
- λ_{vs} = [0.8…1.2] – VS aspect ratio
- η_{vs} = [2.0…3.5] – VS taper ratio
- X_{vs} – VS sweep angle

We can find A_{vs} with the following equation:

$$A_{vs} = \frac{S_{vs}L_{vs}}{Sl} \tag{24}$$

The rest of the parameters for the vertical surface (L_{vs}, S_{vs}, l_{vs}, b_{0vs}, b_{kvs}, $b_{avs,}$ X_{revs}) are estimated with the equations from the wing geometry section (17) – (22).

4.5. Elevator and rudder design

The parameters typically used for the design of the control surfaces are:

- Elevator area S_{el}, m^2 – S_{el}/S_{hs} = [0.3…0.4]
- Rudder area S_{rd}, m^2 – S_{rd}/S_{vs} = [0.35..0.45]
- Aileron area S_{ai}, m^2 – S_{ai}/S = [0.05…0.07]
- Aileron span l_{ai}, m – l_{ai}/l = [0.3…0.4]
- Aileron chord b_{ai}, m b_{ai}/b = [0.20..0.25]

5. Cabin design

5.1. Estimating the fuselage width

The width of the fuselage can be estimated based on the design of the passenger cabin. In this case the width of the body shall be about 635..650 mm above the cabin floor and can be estimated using the following equation:

$$B_m = B_2n_2 + B_3n_3 + c_nn_n + 2\delta_1 + 2\delta_2, \tag{25}$$

where:

B_2 and n_2, B_3 and n_3 – width and quantity of the double and triple blocks of seats respectively. They are shown on *Figure 3.*

c_n and n_n – width of the cabin corridors (c_n *>509mm*)

δ_1 = 30…50mm – distance between the seats and the inner wall of the cabin

δ_2 = 120…130mm – cabin wall thickness

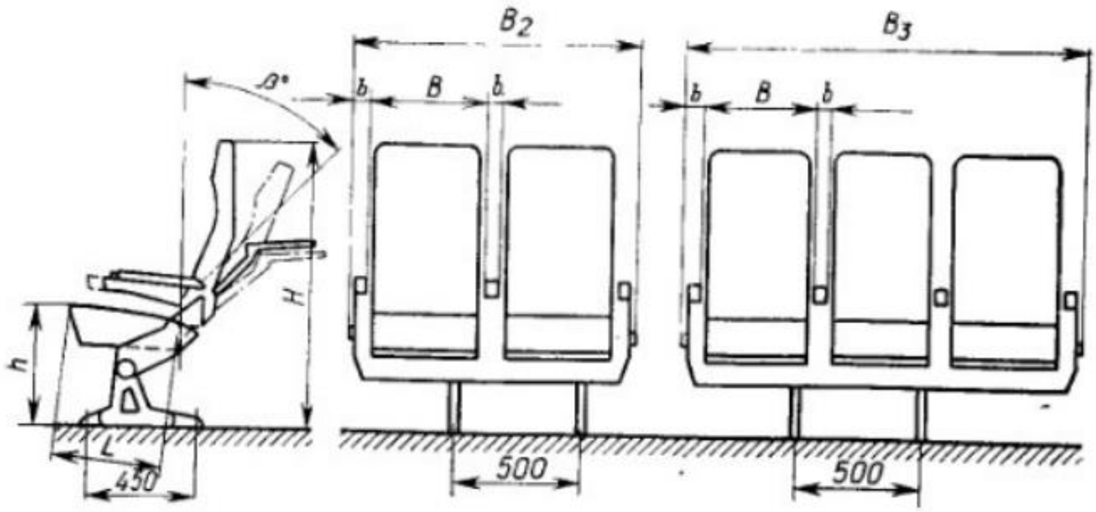

Figure 3: Transport aircraft seat dimensions

We can use *Table 6* to determine each of the cabin dimensions.

Class	Forearm distance B, mm	Forearm size b, mm	Seat length L, mm	Seat height, h	Seat and backrest height H, mm	Backrest shift angle, deg	Seat block width	
							B2	B3
I	500	70	500	445	1140	45	1260	-
II	440	50	470	445	1120	36	1030	1520

Figure 4: Transport aircraft cabin dimensions

5.2. Estimating cabin length

The cabin length can be determined with the following equation:

$$L_c = l_1 + (i_r - 1)t + l_2, \tag{26}$$

where:

l_1 – minimum distance between the front compartment to the front row *(Figure 4)*. Ist class = 630mm, IInd class = 615mm, IIIrd class = 585mm;

l_2 – minimum distance between the rear compartment to the back row *(Figure 4)*. Ist class = 1000mm, IInd class = 800mm, IIIrd class = 750mm;

i_r – number of rows;

t – distance between two seat blocks. Ist class = 980…1080mm, IInd class = 840…870mm, IIIrd class = 780…810mm;

5.3. Estimating cabin height

The height of the cabin H_{cab} shall be between 1900mm and 2500mm. The ratio between the cabin width and cabin length is represented by the coefficient k_φ = 0.2…0.5.

The relative volume in the cabin for each passenger shall be 0.84...1.2 m_3/passenger

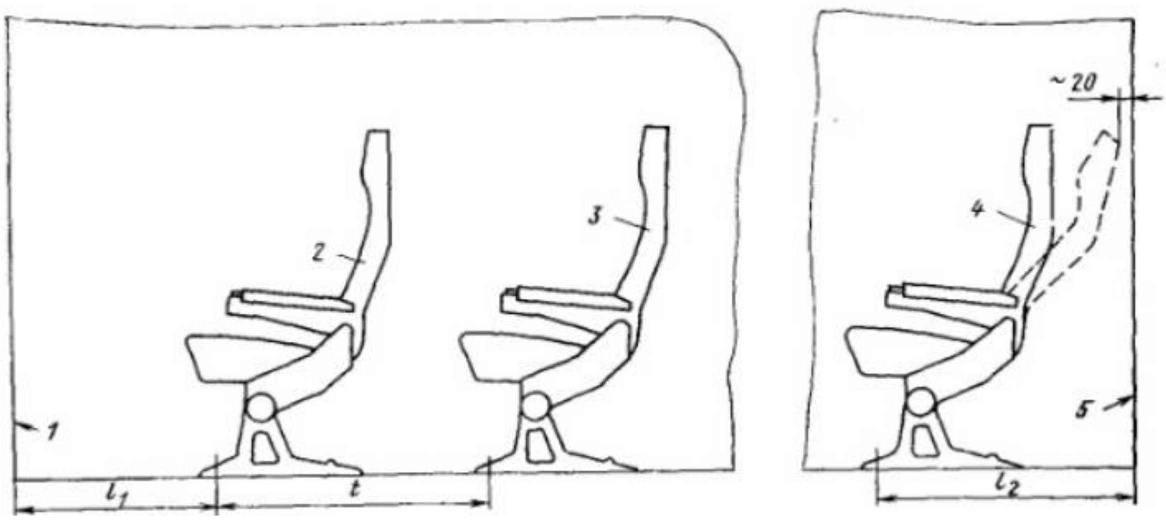

Figure 5: Scheme for mounting the passenger seats in the aircraft

5.4. Estimating the body length

The length of the aircraft body is estimated by choosing the extensions of the front and rear compartments of the body with the equation:

$$L_m = L_c + \lambda_f D_m + \lambda_b D_m, \tag{27}$$

where:

$\lambda_f = 1.2\ldots2$ and $\lambda_b = 2\ldots3$ – extensions of the front and rear compartment respectively.

D_μ – diameter of the median section estimated with $D_\mu = \sqrt{4S_\mu/\pi}$, where S_μ is section area.

6. Re-estimation of aircraft masses

6.1. Estimating the masses of aircraft construction

6.1.1. Estimating final relative wing mass

$$m_w^* = 1{,}15.10^{-4}.K_{mec}K_{con}K_{mat}\varphi\frac{n_e\sqrt{S}}{\sqrt{\theta c_0}cos^{1,5}X}\frac{\eta+4}{\eta+1}\left(1-\frac{\mu-1}{\eta+3}\right), \tag{29}$$

where:

- K_{con} – Coefficient related to the type of construction. K_{con} = 0.9 for wings with honey comb structure. K_{con} = 0.95 for riveted + glued wing. K_{con} = 1 for riveted wing.

- K_{mec} – Mechanization coefficient. K_{mec} = 0.9 for wing without mechanization. K_{mec} = 1 for wing with flaps. K_{mec} = 1.15 for full mechanization.
- K_{mat} – Wing material coefficient. K_{mat} = 1 for material D16, K_{mat} = 1.2 for material AMG6.
- Θ – coefficient determining the construction strength
- λ – Aspect ration
- η – Taper ration
- c_0 – Core wing thickness
- c_t – Tip wing thickness
- $\mu = c_0/c_k$ – thickness ratio
- φ = 0.68 – Unloading coefficient
- n_e = 5.5…6 – Overloading

6.1.2. Estimating final relative fuselage mass

$$m_m^* = 1{,}14 K_{ep}(1 - 0{,}4 p_{cab}^e) l_m^{1{,}5} m_{0,}^{-0.75}, \qquad (30)$$

where:

- K_{ep} =1.14 for engines mounted inside the fuselage. K_{ep} = 1 for engines mounted outside the fuselage.
- l_m - body length, m
- m_0 – take off mass, kg
- p_{cab} cabin pressure, atm

6.1.3. Estimating the final control surfaces mass

$$m_{tail}^* \frac{K_v K_m}{m_0}(4.4 + 0.8 * 10^{-3} m_0) S_{tail}, \qquad (31)$$

where:

- K_v - velocity coefficient, $Kv = 0.643 + 1{,}02.10^{-3} V_{cr}$
- K_m – 1 for low manoeuvrability aircrafts, K_m = 1.5 for hight manoeuvrability aircrafts
- V_{cr} – cruse speed, km/h
- $S_{tail} = S_{hs} + S_{vs}$, m^2

6.1.4. Estimating the final landing gear mass

$$m_{ld}^{*} = K_{mt}K_{fl}(6.H_{hl} + 11.3)10^{-3} + 0,625K_{tr}\frac{\sqrt{p_{tr}}}{1+p_{tr}} + 0.005\,, \tag{32}$$

- K_{mt} = 0.65..0.7 – landing gear material coefficient
- K_{fl} – aerodynamic coefficient of the landing gear. K_{fl} = 1.2 aerodynamic shape, K_{fl} = 1 for unshaped landing gears
- K_{tr} = 1 for cambered tires, K_{tr} = 0.93 for uncambered tires
- H_{lh} – landing gear height, m
- P_{tr} – pressure in the tires, atm

6.1.5. Estimating the final landing gear mass

$$m_{c}^{*} = m_{w}^{*}m_{fs}^{*}m_{tl}^{*}m_{ld}^{*}, \tag{33}$$

6.2. Powerplant, fuel and equipment final relative mass

The powerplant mass denoted by $m^{*}_{pp} = 0.05\ldots0.1m_{0,}$ or between 0.5 and 1 % of the aircraft take off mass.

The equipment mass includes also the aircraft loading mass and can be found with the following equation:

$$m_{c}^{*} = \frac{200}{m_0} + 0.02m_{lm}^{*}(1 + 0.1\frac{L}{V_{cr}}) + 0.08\,, \tag{34}$$

where:

- $m^{*}_{ld} = m_{ld}/m_0$ – the relative loading mass
- L – range, km
- V_{cr} – cruise velocity, km/h

Finally the fuel relative mass is simply the ratio between the actual fuel mass and the take-off mass:

$$m_{fl}^{*} = \frac{m_{fl}}{m_0}, \tag{35}$$

7. Aircraft mass balance characteristics

The balancing characteristics are important for the relative positioning of the wing, tail, fuselage, passengers, engines etc.

One of the most important tasks of the engineers in determining the center of masses of the aircraft. The relative position of the center of masses and the median aerodynamic chord is of significant importance for its dynamic and balancing characteristics. The aircraft changes its mass during flight is this relative distance has to ensure that when the center of masses is moving back (tailwise), there is enough longitudinal stability. Also in case the center of masses moves forward, there is enough lever displacement to balance the aircraft for take-off and landing.

Here we are going to center the horizontal axis of the aircraft as since it is symmetric, the vertical axis moments can be neglected. The origin of the coordinate system can be either taken at the nose of the aircraft or at the tip of the coot wing chord.

We first need to estimate the sum of static horizontal moments with the equation:

$$x_m = \frac{\sum(mgx)i}{\sum(mg)i}, \tag{36}$$

where:

- x is the distance of the element from the chosen coordinate system origin.
- m is the mass of the element

Then we can estimate the balancing characteristics with the equation:

$$x_m^* = \frac{x_m x_A}{b_A}, \tag{37}$$

where:

- x_m – coordinates of the center of masses
- x^*_m longitudinal balancing
- x_A – coordinate of the tip of the median aerodynamic chord.

The coordinates of the elements are taken from a simplified aircraft blueprint, showing their relative positions.

The balancing characteristics of the aircraft have to be estimated in all of those cases:

- Maximum take-off mass
- Fully equipped aircraft without fuel.
- Full fuel tank without any load.
- Empty aircraft without fuel and load.

The moving masses such a passengers and cabin crew have to be positioned near the center of masses of the aircraft.

Aircraft Balancing			
Component	Moment	Distance	Force
	mgx, daNm	x, m	mg, daN
1.1 Wing			
1.2 Fuselage			
1.3 Main landing gear			
1.4 Front landing gear			
1.5 Horizontal surface			
1.6 Vertical surface			
2. Powerplant			
3. Equipment			
3.1 Front compartment			
3.2 Back compartment			

4. Cabin crew			
4.1 Pilots			
4.2 Flight attendants			
4.3 Crew luggage			
5. Fuel			
6. Load			
7. Passengers			
Σ(mgi x)		Σ(mg)i	

Standard positions of the aircraft components are:

- Wing center of mass position – 40…42% b_A
- Tail center of mass position – 45…50% b_{Ahot}
- Fuselage center of mass position – 50% of fuselage length
- Re-estimating passenger and cabin crew mass: 80kg for a pilot, 70kg for cabin crew, 75kg for passenger and 15kg for luggage per passenger.

The balance characteristic of the aircraft in each case shall be between x^*_m = 0.2…0.3.