



Università degli Studi di Trieste

Dipartimento di Ingegneria e Architettura

Laurea Magistrale: Ingegneria Civile

Corso : Strade Ferrovie ed Aeroporti (284MI-2)



Lezione 09: Geometria Aeroporti

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Argomenti

Le superfici di limitazione degli ostacoli

Orientamento delle piste

Dati di riferimento di un aerodromo

Manovre di decollo e atterraggio e Lunghezza pista

Caratteristiche geometriche delle runway (planimetriche e altimetriche)

Distanze di separazione nella circolazione a terra

Caratteristiche geometriche delle uscite dalle runway e delle holding bay

Caratteristiche geometriche delle taxiway e manovre di taxing

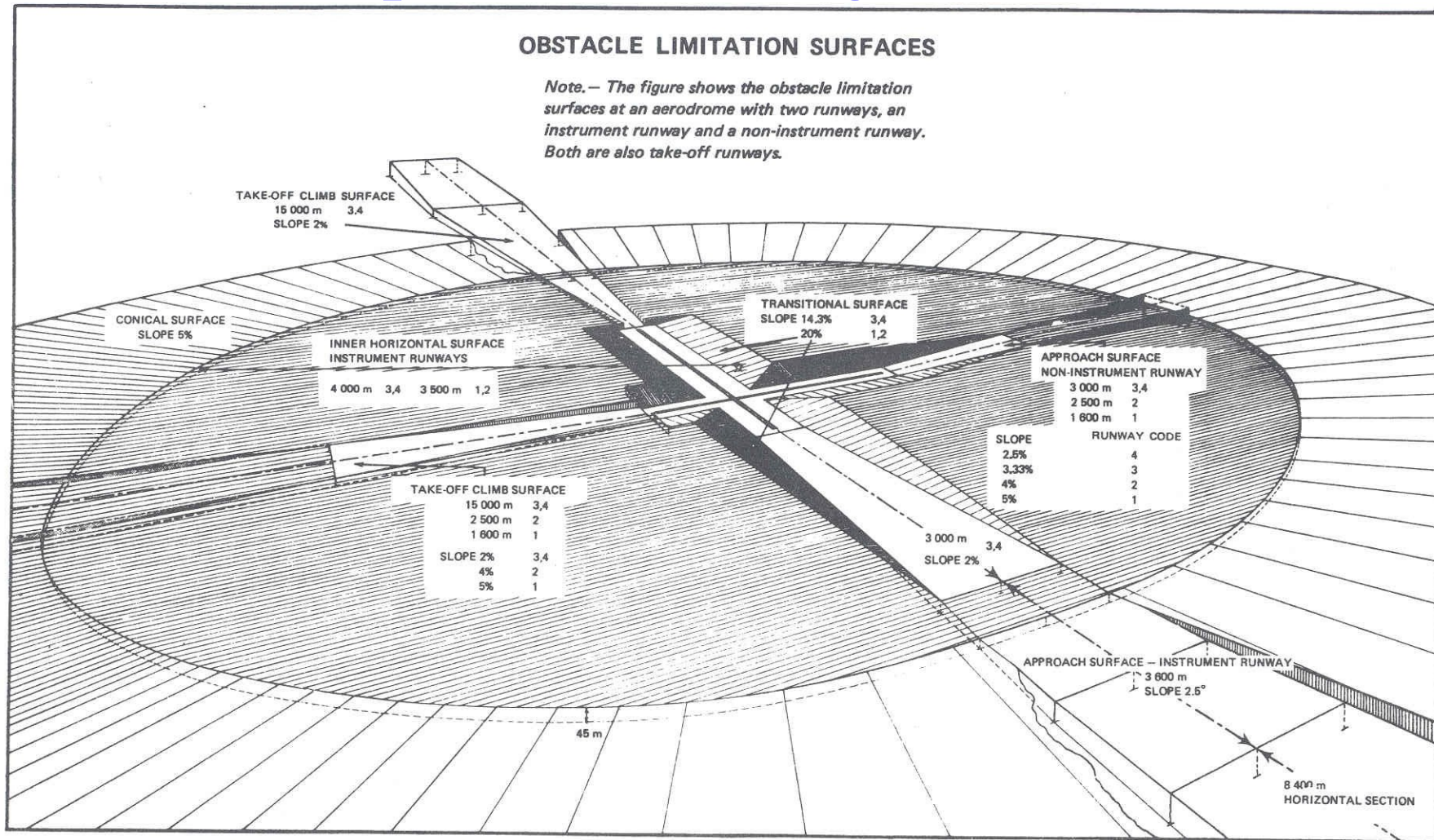
Esercizio sulle piste di volo

Area terminale

Superfici limiti degli ostacoli

OBSTACLE LIMITATION SURFACES

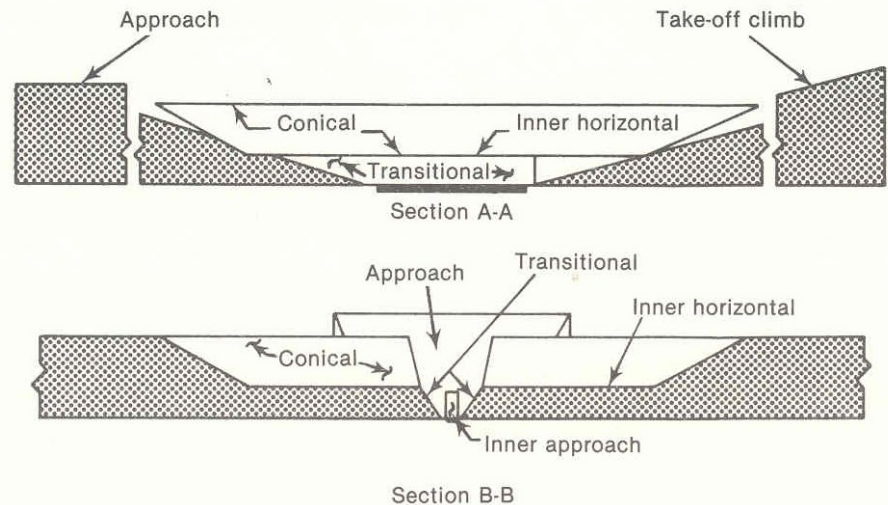
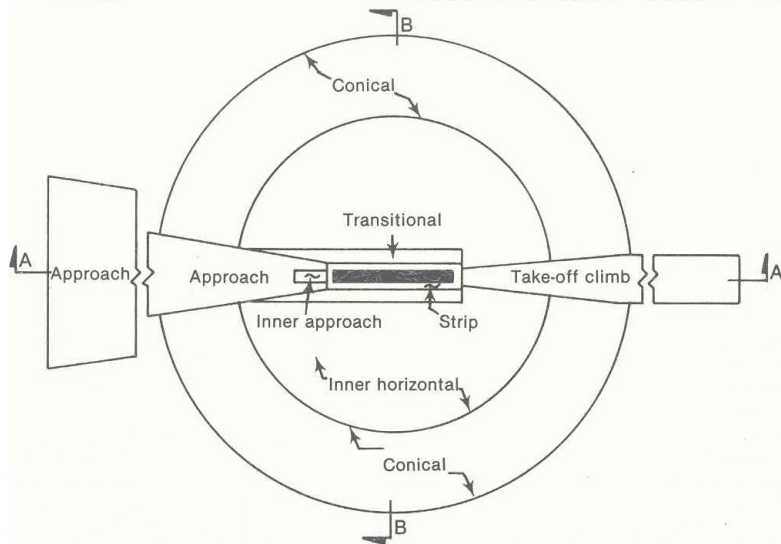
Note.— The figure shows the obstacle limitation surfaces at an aerodrome with two runways, an instrument runway and a non-instrument runway. Both are also take-off runways.



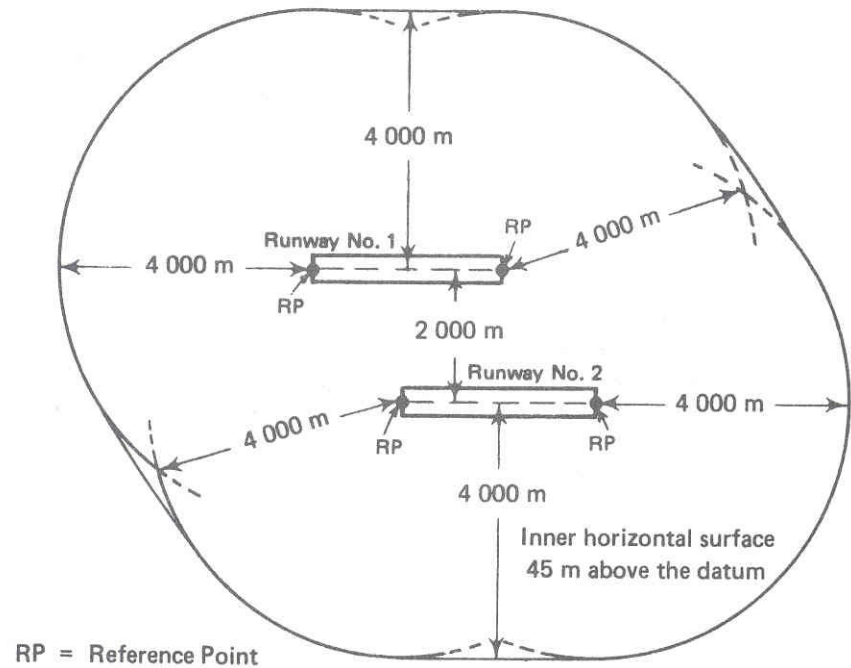
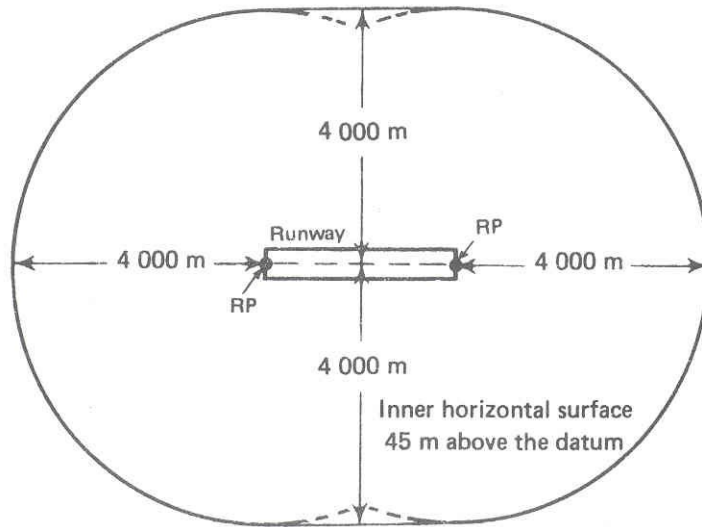
Superficie orizzontale e conica

RUNWAY CLASSIFICATION

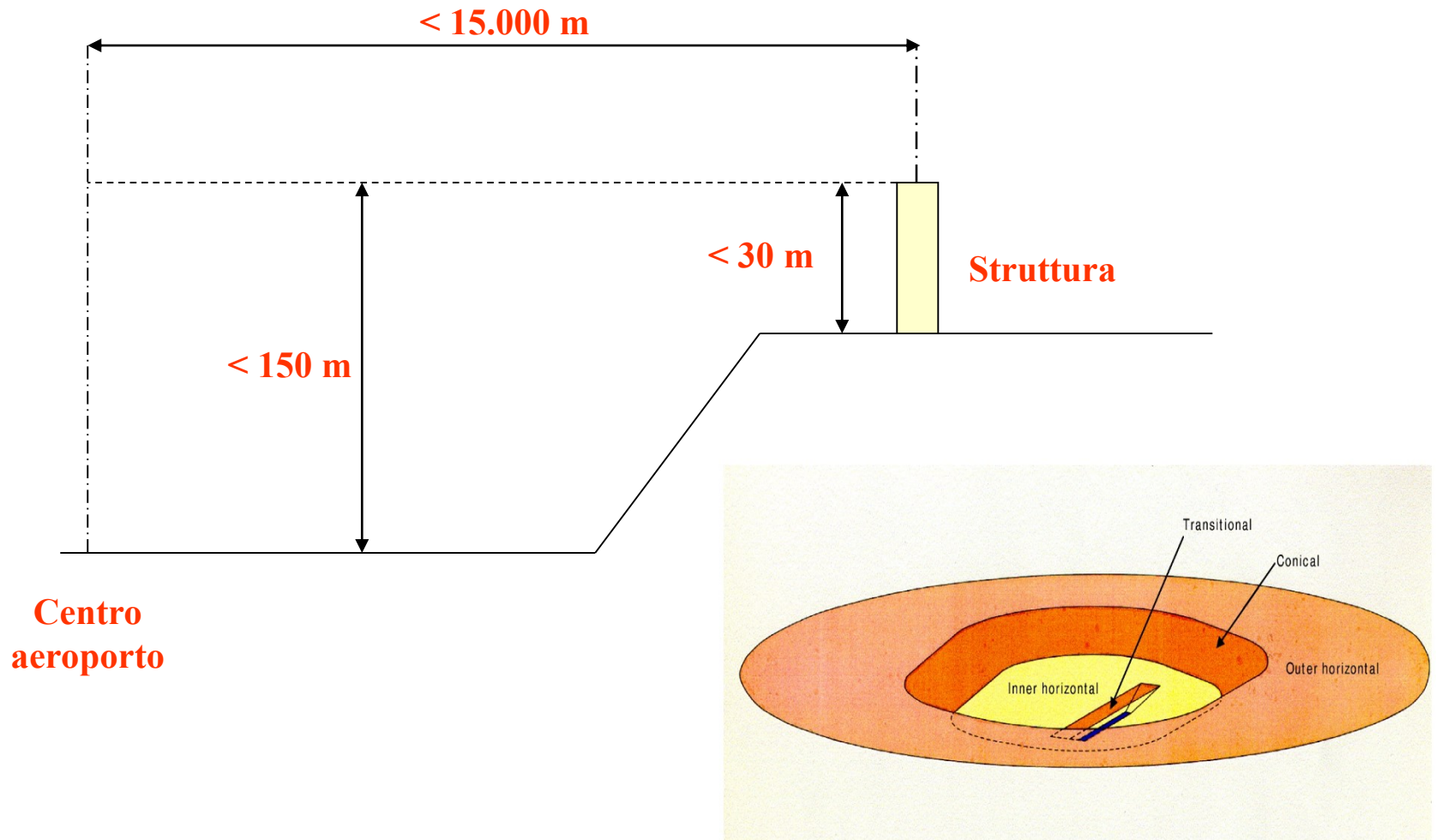
Surface and dimensions ^a (1)	Non-instrument				Non-precision approach			Precision approach category		
	Code number				Code number			I	II or III	
	1	2	3	4	1,2	3	4	Code number	Code number	Code number
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	
CONICAL										
Slope	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Height	35 m	55 m	75 m	100 m	60 m	75 m	100 m	60 m	100 m	100 m
INNER HORIZONTAL										
Height	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m
Radius	2 000 m	2 500 m	4 000 m	4 000 m	3 500 m	4 000 m	4 000 m	3 500 m	4 000 m	4 000 m



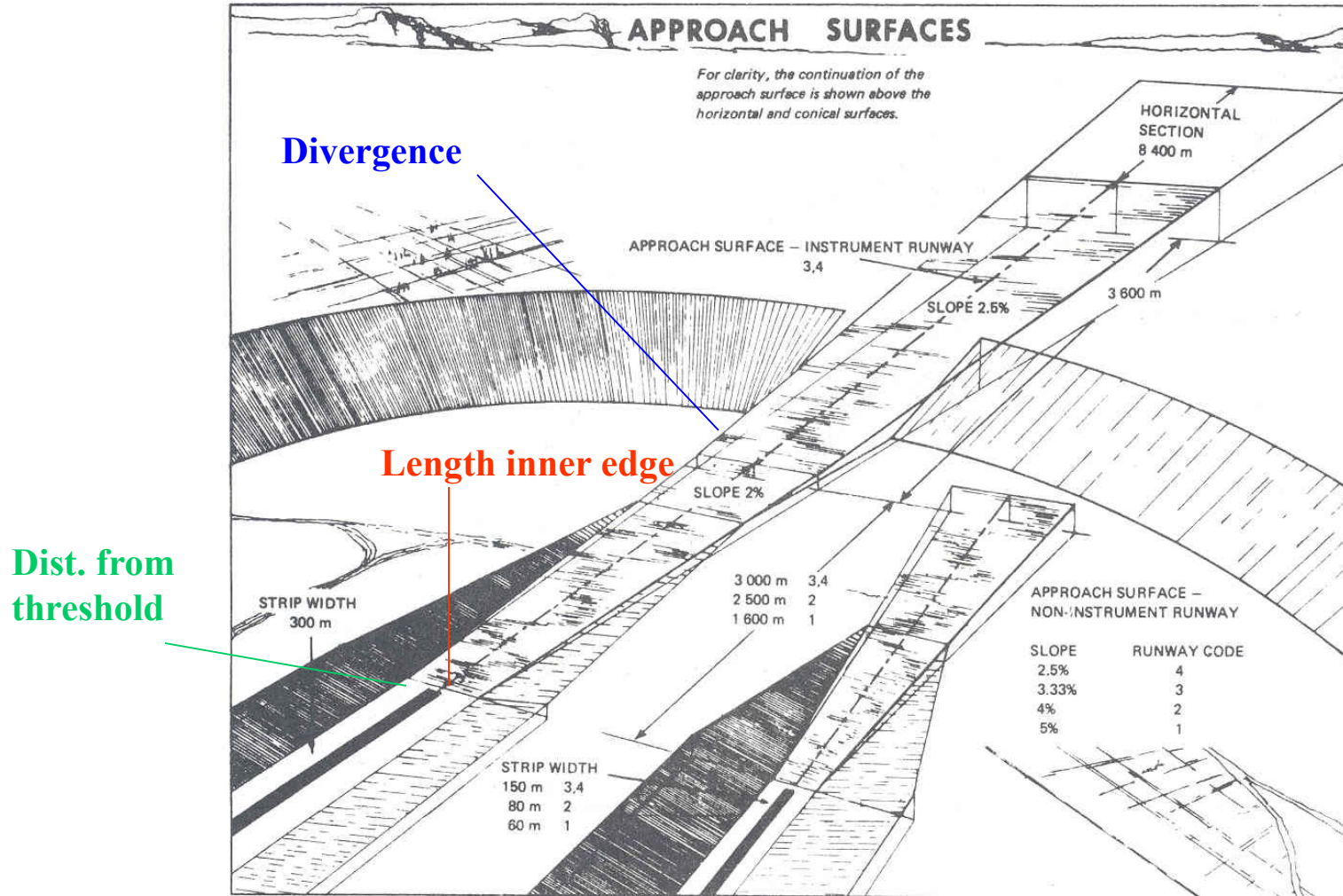
Superfici orizzontali composte



Superficie orizzontale esterna



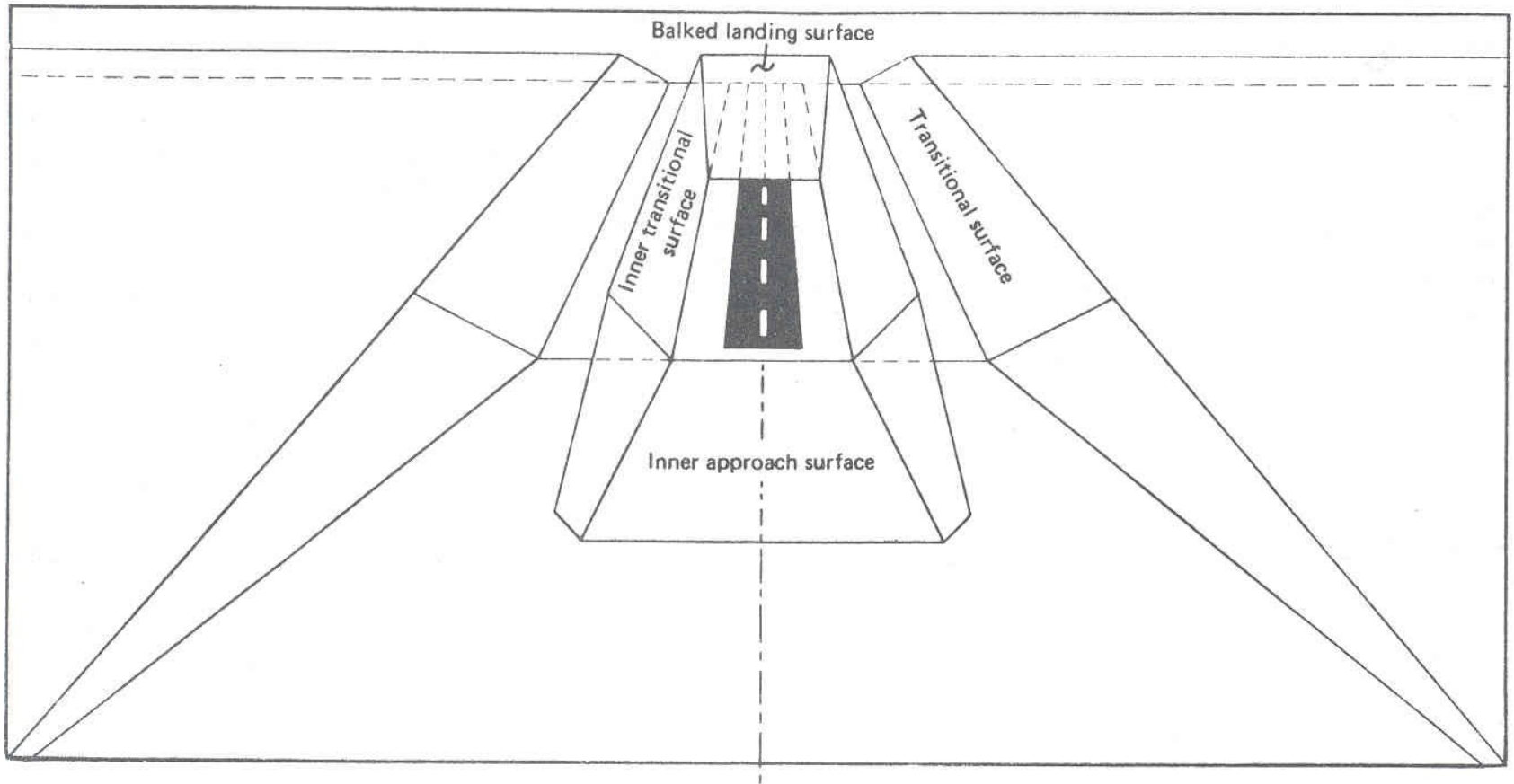
Superficie di transizione e avvicinamento (1)



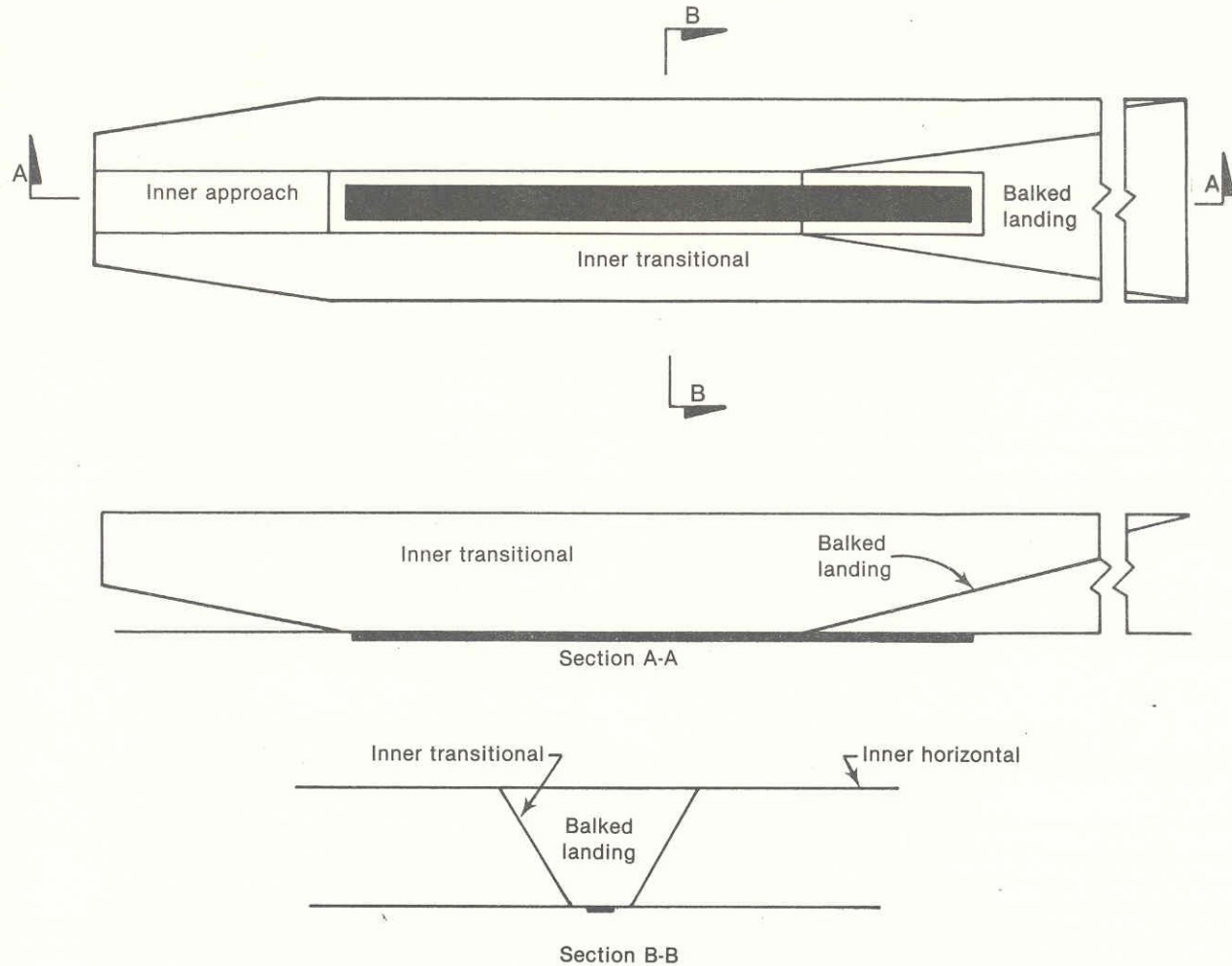
Superficie di transizione e avvicinamento (2)

Surface and dimensions ^a	RUNWAY CLASSIFICATION									
	1	Non-instrument			Non-precision approach			Precision approach category		
		Code number			Code number			I	II or III	
		2	3	4	1,2	3	4	Code number 1,2 3,4	Code number 3,4	
APPROACH										
Length of inner edge	60 m	80 m	150 m	150 m	150 m	300 m	300 m	150 m	300 m	300 m
Distance from threshold	30 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m
Divergence (each side)	10%	10%	10%	10%	15%	15%	15%	15%	15%	15%
First section										
Length	1 600 m	2 500 m	3 000 m	3 000 m	2 500 m	3 000 m	3 000 m	3 000 m	3 000 m	3 000 m
Slope	5%	4%	3.33%	2.5%	3.33%	2%	2%	2.5%	2%	2%
Second section										
Length	—	—	—	—	—	3 600 m ^b	3 600 m ^b	12 000 m	3 600 m ^b	3 600 m ^b
Slope	—	—	—	—	—	2.5%	2.5%	3%	2.5%	2.5%
Horizontal section										
Length	—	—	—	—	—	8 400 m ^b	8 400 m ^b	—	8 400 m ^b	8 400 m ^b
Total length	—	—	—	—	—	15 000 m	15 000 m	15 000 m	15 000 m	15 000 m
TRANSITIONAL										
Slope	20%	20%	14.3%	14.3%	20%	14.3%	14.3%	14.3%	14.3%	14.3%

Superfici interne (1)



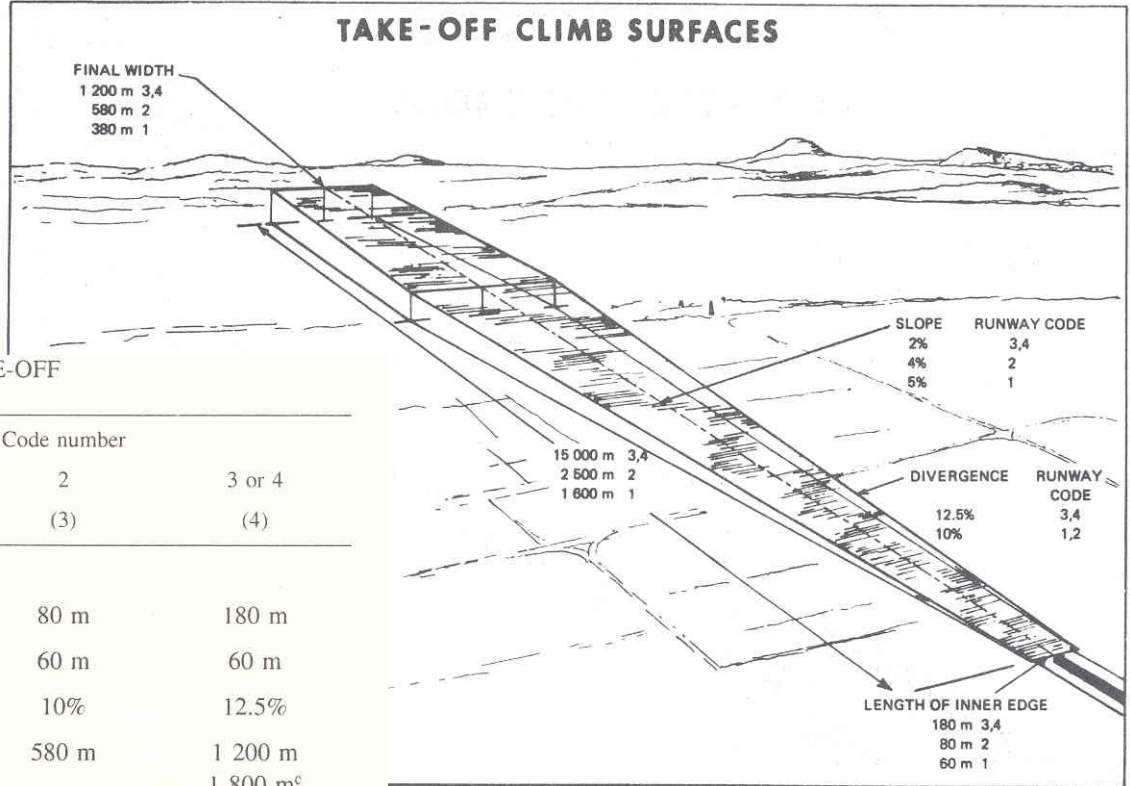
Superficie interne (2)



Superfici interne (3)

Surface and dimensions ^a	RUNWAY CLASSIFICATION									
	1	Non-instrument			Non-precision approach			Precision approach category		
		Code number		4	Code number		I		II or III	
		2	3		1,2	3	1,2	3,4	3,4	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
INNER APPROACH										
Width	—	—	—	—	—	—	—	90 m	120 m	120 m
Distance from threshold	—	—	—	—	—	—	—	60 m	60 m	60 m
Length	—	—	—	—	—	—	—	900 m	900 m	900 m
Slope								2.5%	2%	2%
INNER TRANSITIONAL										
Slope	—	—	—	—	—	—	—	40%	33.3%	33.3%
BALKED LANDING SURFACE										
Length of inner edge	—	—	—	—	—	—	—	90 m	120 m	120 m
Distance from threshold	—	—	—	—	—	—	—	^c	1 800 m ^d	1 800 m ^d
Divergence (each side)	—	—	—	—	—	—	—	10%	10%	10%
Slope	—	—	—	—	—	—	—	4%	3.33%	3.33%

Superficie di decollo

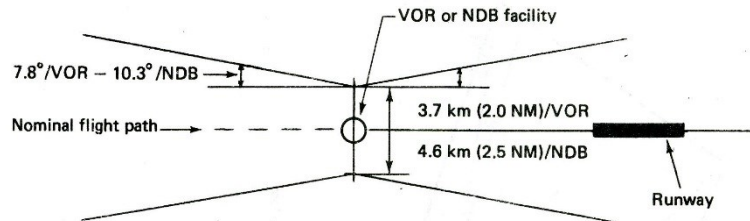
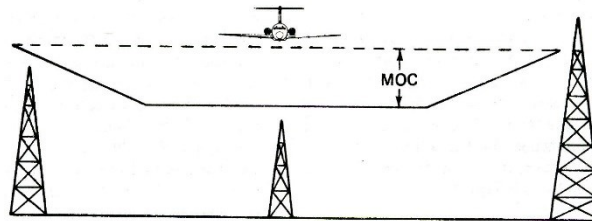
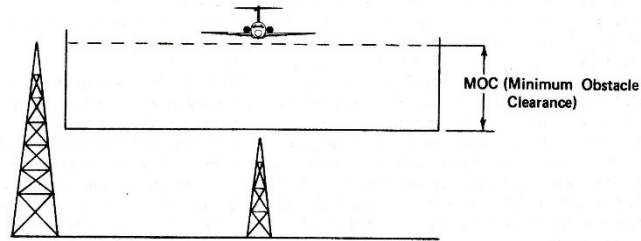


RUNWAYS MEANT FOR TAKE-OFF

Surface and dimensions ^a	Code number		
	1	2	3 or 4
(1)	(2)	(3)	(4)
TAKE-OFF CLIMB			
Length of inner edge	60 m	80 m	180 m
Distance from runway end ^b	30 m	60 m	60 m
Divergence (each side)	10%	10%	12.5%
Final width	380 m	580 m	1 200 m 1 800 m ^c
Length	1 600 m	2 500 m	15 000 m
Slope	5%	4%	2% ^d

- a. All dimensions are measured horizontally unless specified otherwise.
 b. The take-off climb surface starts at the end of the clearway if the clearway length exceeds the specified distance.
 c. 1 800 m when the intended track includes changes of heading greater than 15° for operations conducted in IMC, VMC by night.
 d. See 4.2.24 and 4.2.26.

Superfici PANS – OPS (1)



Superfici PANS – OPS (2)

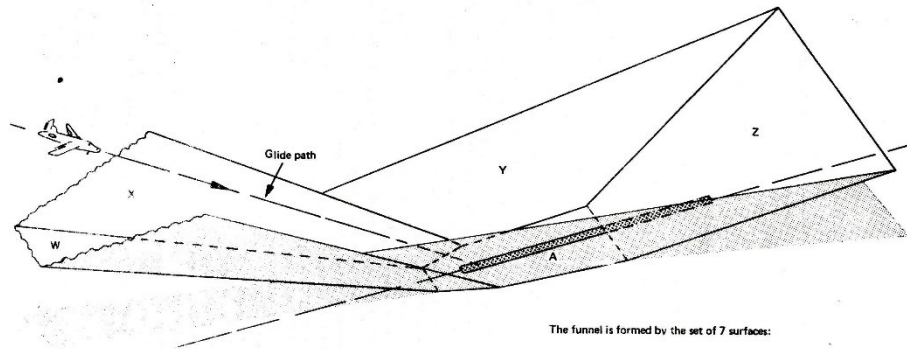


Figure 1-7. The approach funnel (OAS)

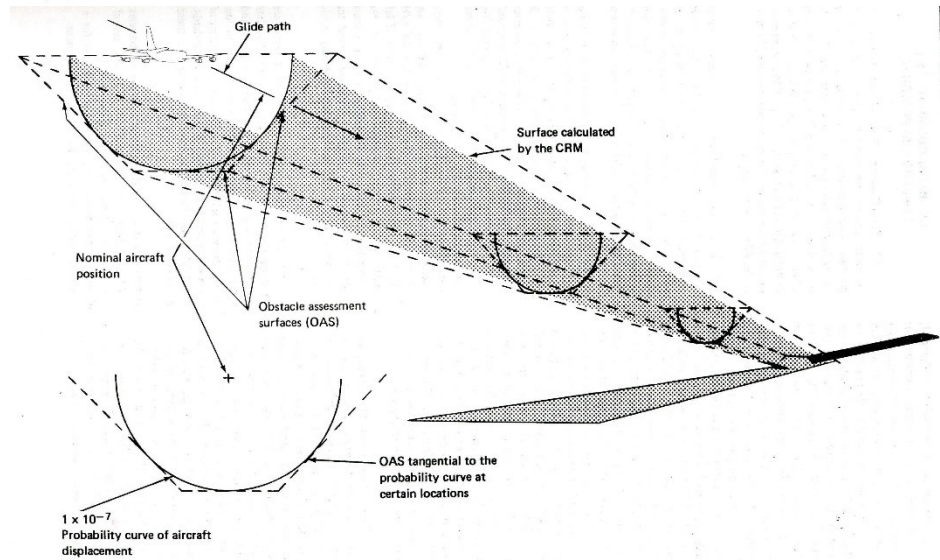


Figure 1-8. The approach funnel (CRM)

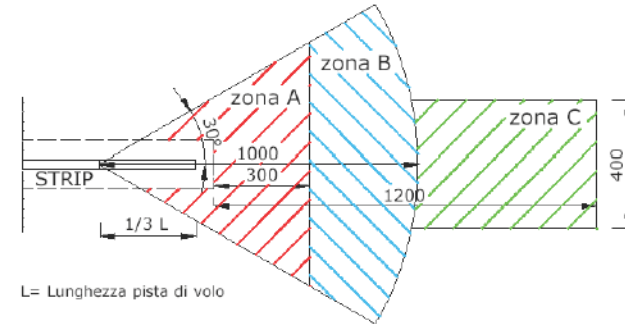
Normativa italiana

Tabella 4.2 - Dimensioni e pendenze delle superfici di separazione dagli ostacoli

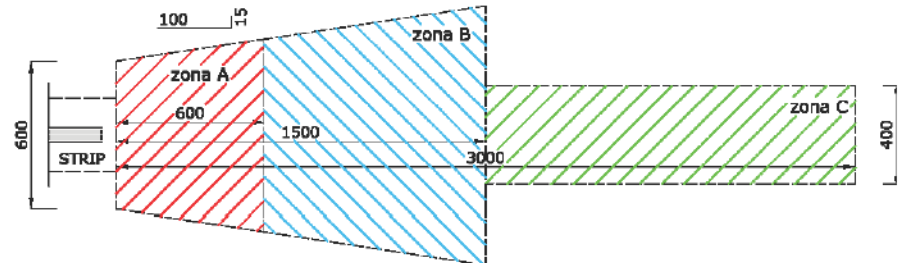
Superficie e dimensioni ^a	CLASSIFICAZIONE DELLE PISTE									
	Non strumentali				Avvicinamenti non di precisione				Avvicinamenti di precisione di categoria	
	Numero di codice				Numero di codice				N° di codice	
(1)	1 (2)	2 (3)	3 (4)	4 (5)	1,2 (6)	3 (7)	4 (8)	1,2 (9)	3,4 (10)	3,4 (11)
Conica										
Pendenza	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Altezza	35 m	55 m	75 m	100 m	60 m	75 m	100 m	60 m	100 m	100 m
Orizzontale										
interna										
Altezza	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m
Raggio	2000 m	2500 m	4000 m	4000 m	3500 m	4000 m	4000 m	3500 m	4000 m	4000 m
Interna										
Avvicinamento										
Larghezza	---	---	---	---	---	---	---	90 m	120 m [*]	120 m [*]
Distanza dalla soglia	---	---	---	---	---	---	---	60 m	60 m	60 m
Lunghezza	---	---	---	---	---	---	---	900 m	900 m	900 m
Pendenza	---	---	---	---	---	---	---	2.5%	2%	2%
Avvicinamento										
Lunghezza bordo interno	60 m	80 m	150 m	150 m	150 m	300 m	300 m	150 m	300 m	300 m
Distanza dalla soglia	30 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m
Divergenza (su entrambi i lati)	10%	10%	10%	10%	15%	15%	15%	15%	15%	15%
Prima sezione										
Lunghezza	1600 m	2500 m	3000 m	3000 m	2500 m	3000 m	3000 m	3000 m	3000 m	3000 m
Pendenza	5%	4%	3.33%	2.5%	3.33%	2%	2%	2.5%	2%	2%
Seconda sezione										
Lunghezza	---	---	---	---	---	3600 m ^b	3600 m ^b	12000 m	3600 m ^b	3600 m ^b
Pendenza	---	---	---	---	---	2.5%	2.5%	3%	2.5%	2.5%
Sezione orizzontale										
Lunghezza	---	---	---	---	---	8400 m ^b	8400 m ^b	---	8400 m ^b	8400 m ^b
Lunghezza totale	---	---	---	---	---	15000 m	15000 m	15000 m	15000 m	15000 m
Transizione										
Pendenza	20%	20%	14.3%	14.3%	20%	14.3%	14.3%	14.3%	14.3%	14.3%
Transizione interna										
Pendenza	---	---	---	---	---	---	---	40%	33.3%	33.3%
Atterraggio interrotto										
Lunghezza bordo interno	---	---	---	---	---	---	---	90 m	120 m [*]	120 m [*]
Distanza dalla soglia	---	---	---	---	---	---	---	---	1800 m ^d	1800 m ^d
Divergenza (su entrambi i lati)	---	---	---	---	---	---	---	10%	10%	10%
Pendenza	---	---	---	---	---	---	---	4%	3.33%	3.33%

(a) Tutte le dimensioni sono misurate in orizzontale, ove non sia specificato altrimenti
 (b) Lunghezza variabile
 (c) Distanza fino alla fine delle strisce di sicurezza
 (d) O fine della pista, quale fra le due risulti inferiore
 (e) Per piste di codice F la larghezza è aumentata a 155 m

Per piste di volo di codice 1 e piste di volo di codice 2:



Per piste di volo di codice 3 e piste di volo di codice 4:

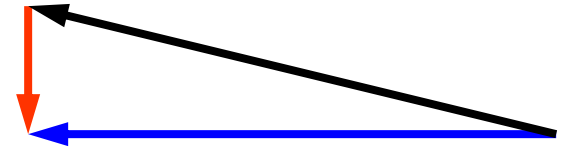
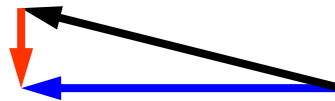
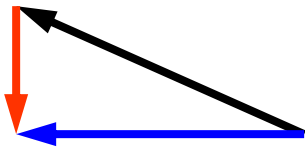
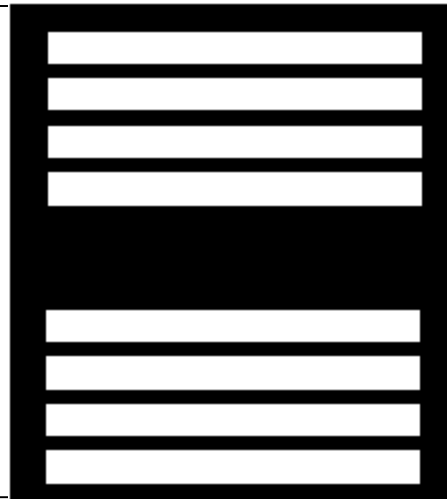


Zone di tutela (PSZ Public Safety Zones)

Orientamento delle piste e regime dei venti

SOGLIA

RUNWAY



Norme ICAO e FAA

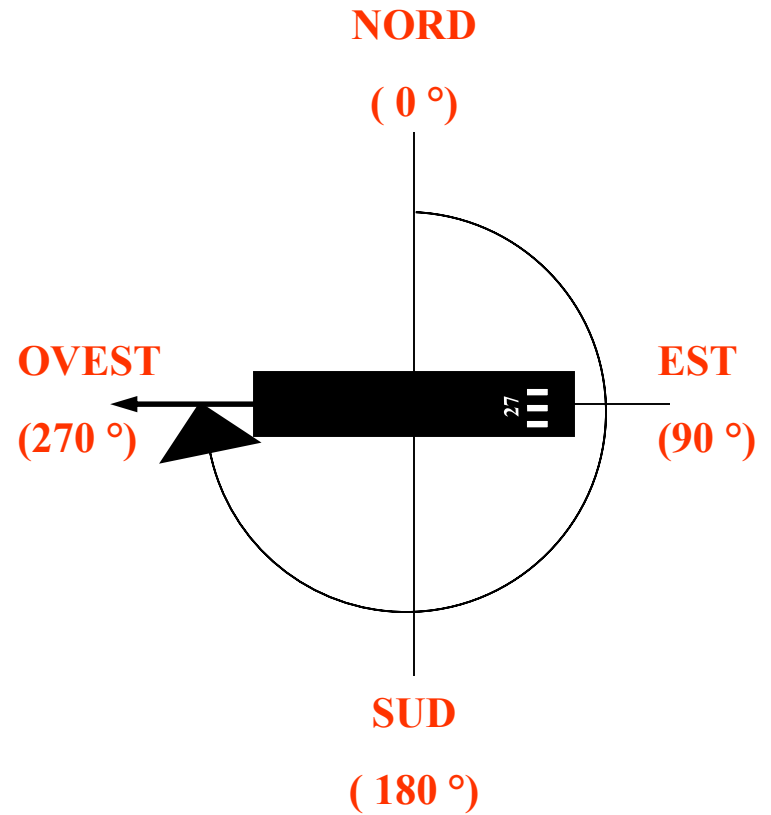
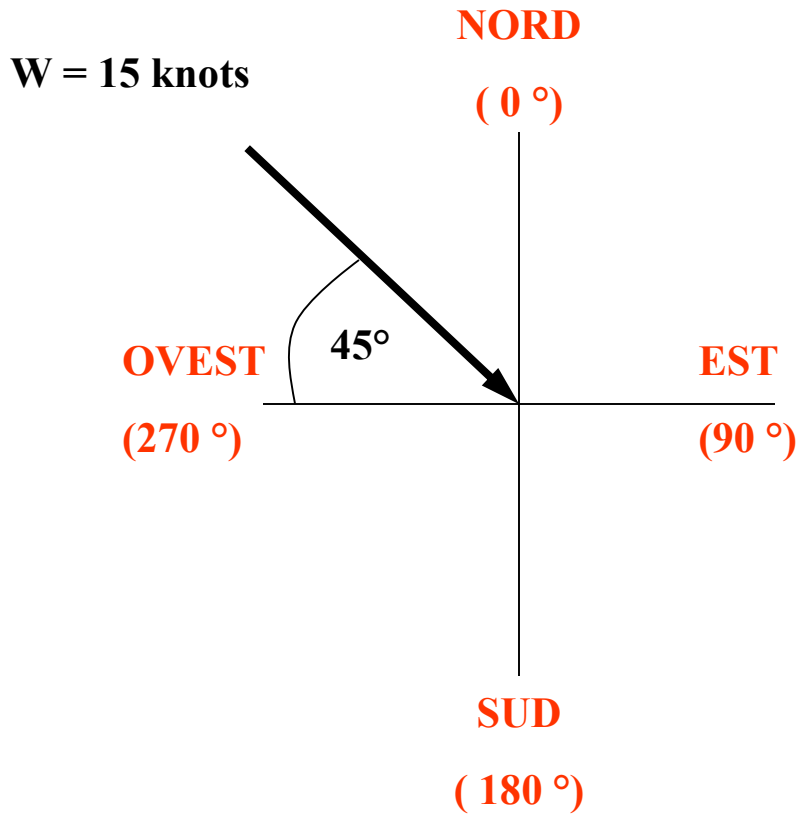
Lunghezza di campo Aereo [m]	Vento trasversale max [km/h (nodi)]
< 1200	19 (10)
1200 - 1500	24 (13)
> 1500	37 (20)

NORMA ICAO

Codice Aeroporto	Vento trasversale max [km/h (nodi)]
AI - BI	10,5
AII - BII	13,0
AIII, BIII e da CI a DIII	16,0
Da AIV a DIV	20,0

NORMA FAA

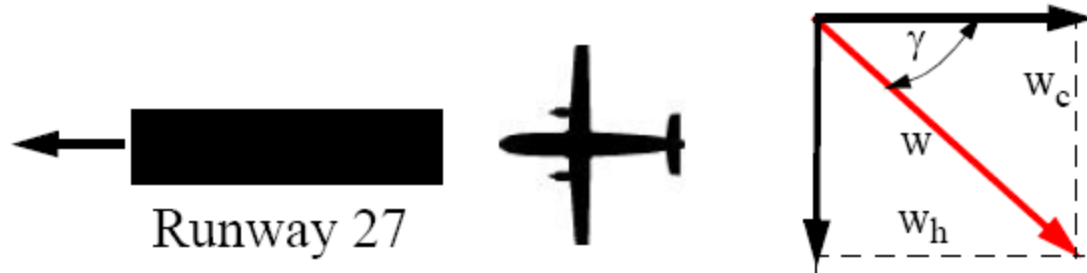
Regime dei venti (1)



VENTO DA 315 ° A 15 KNOTS

PISTA 27

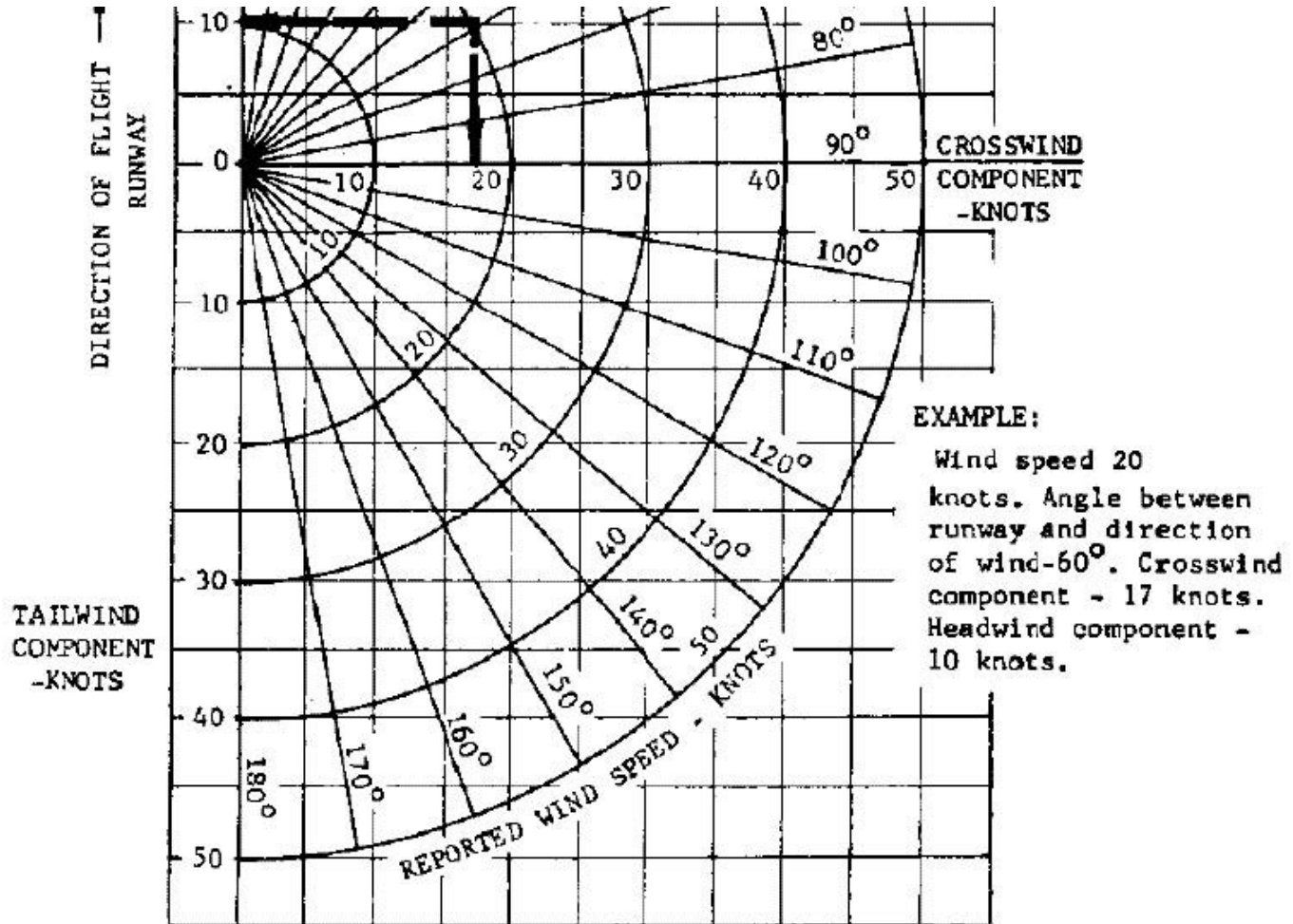
Regime dei venti (2)



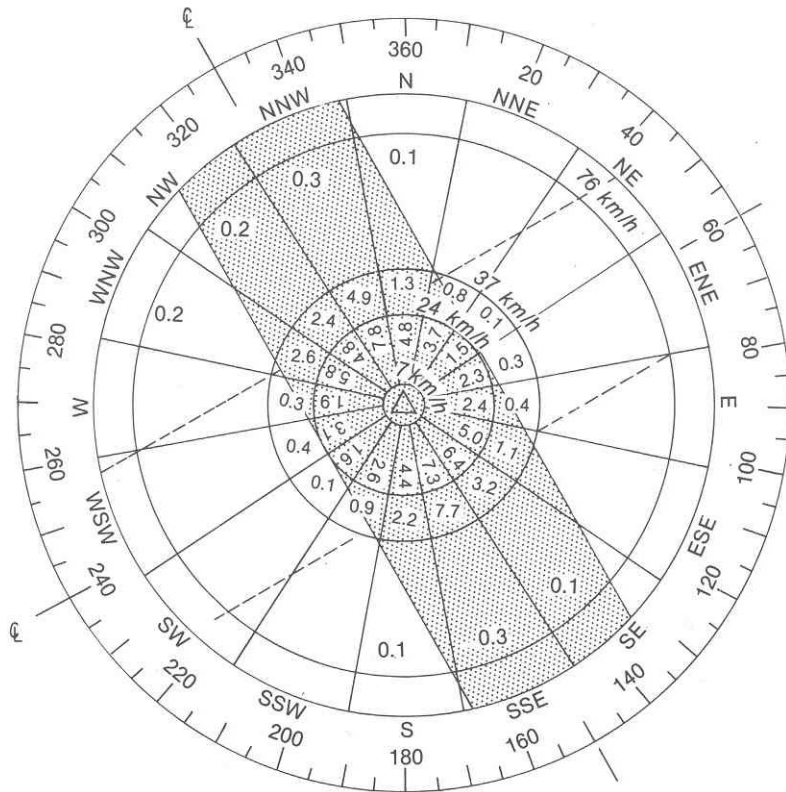
$$W_c = W * \sin (\gamma)$$

$$W_h = W * \cos (\gamma)$$

Regime dei venti (3)



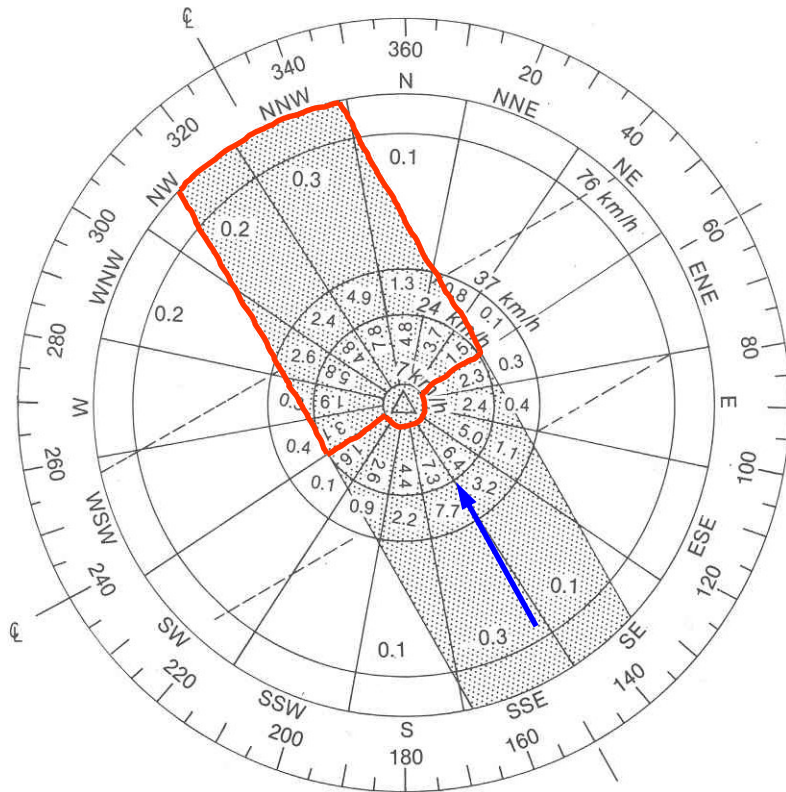
Calcolo del coefficiente anemometrico (1)



△ 4.6% calms, 0~6 km/h

Wind direction	Percentage of winds			Total
	7~24 km/h (4~13 kt)	26~37 km/h (14~20 kt)	39~76 km/h (21~41 kt)	
N	4.8	1.3	0.1	6.2
NNE	3.7	0.8	---	4.5
NE	1.5	0.1	---	1.6
ENE	2.3	0.3	---	2.6
E	2.4	0.4	---	2.8
ESE	5.0	1.1	---	6.1
SE	6.4	3.2	0.1	9.7
SSE	7.3	7.7	0.3	15.3
S	4.4	2.2	0.1	6.7
SSW	2.6	0.9	---	3.5
SW	1.6	0.1	---	1.7
WSW	3.1	0.4	---	3.5
W	1.9	0.3	---	2.2
WNW	5.8	2.6	0.2	8.6
NW	4.8	2.4	0.2	7.4
NNW	7.8	4.9	0.3	13.0
Calms — (0~6 km/hr (0~3 kt))				4.6
Total				100.0

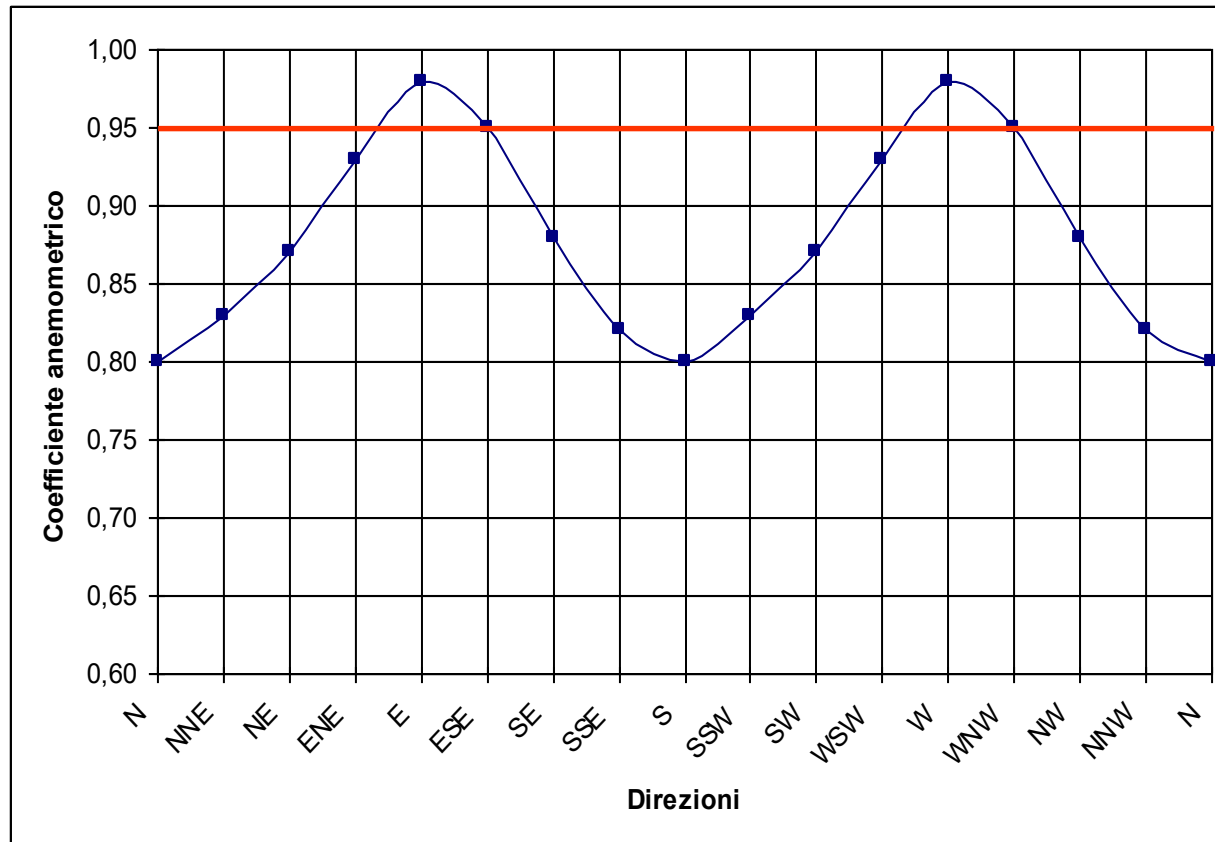
Calcolo del coefficiente anemometrico (2)



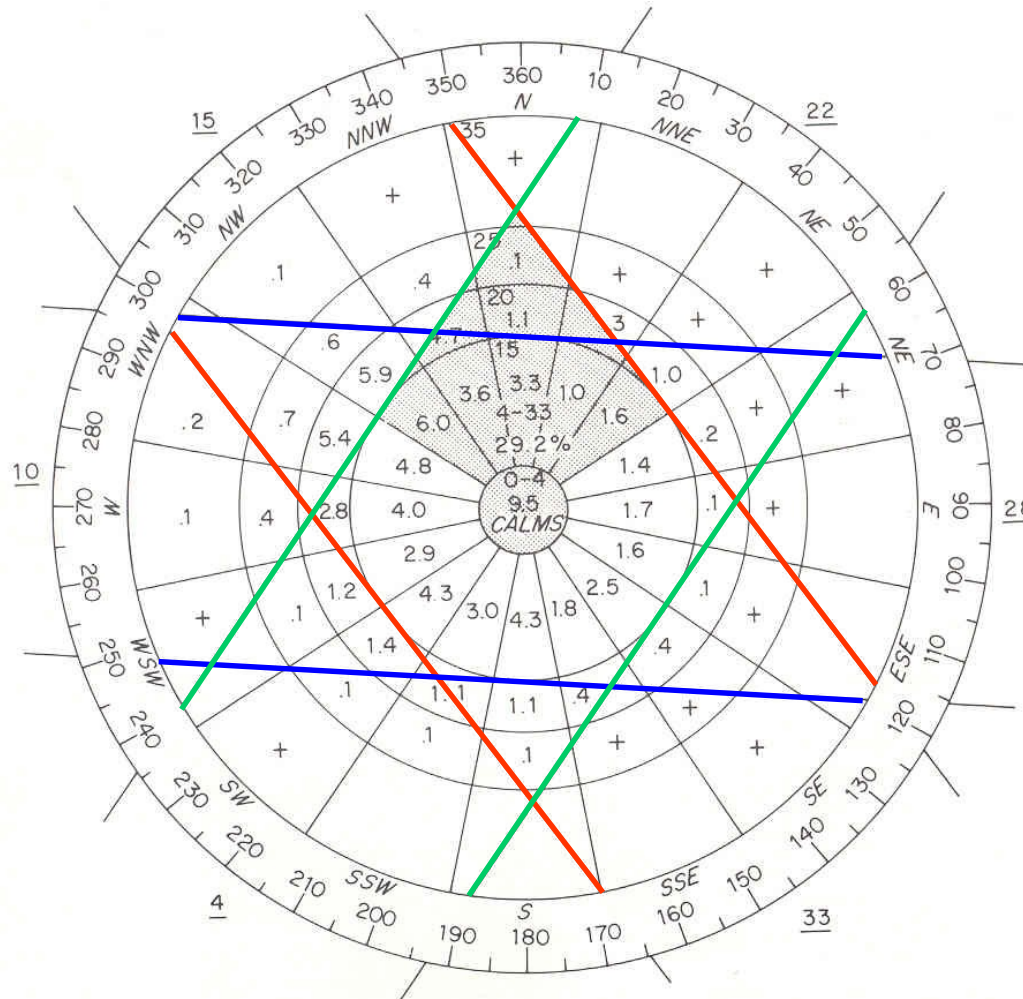
△ 4.6% calms, 0~6 km/h

Wind direction	Percentage of winds			Total
	7~24 km/h (4~13 kt)	26~37 km/h (14~20 kt)	39~76 km/h (21~41 kt)	
N	4.8	1.3	0.1	6.2
NNE	3.7	0.8	---	4.5
NE	1.5	0.1	---	1.6
ENE	2.3	0.3	---	2.6
E	2.4	0.4	---	2.8
ESE	5.0	1.1	---	6.1
SE	6.4	3.2	0.1	9.7
SSE	7.3	7.7	0.3	15.3
S	4.4	2.2	0.1	6.7
SSW	2.6	0.9	---	3.5
SW	1.6	0.1	---	1.7
WSW	3.1	0.4	---	3.5
W	1.9	0.3	---	2.2
WNW	5.8	2.6	0.2	8.6
NW	4.8	2.4	0.2	7.4
NNW	7.8	4.9	0.3	13.0
Calms — (0~6 km/hr (0~3 kt))				4.6
Total				100.0

Calcolo del coefficiente anemometrico (3)

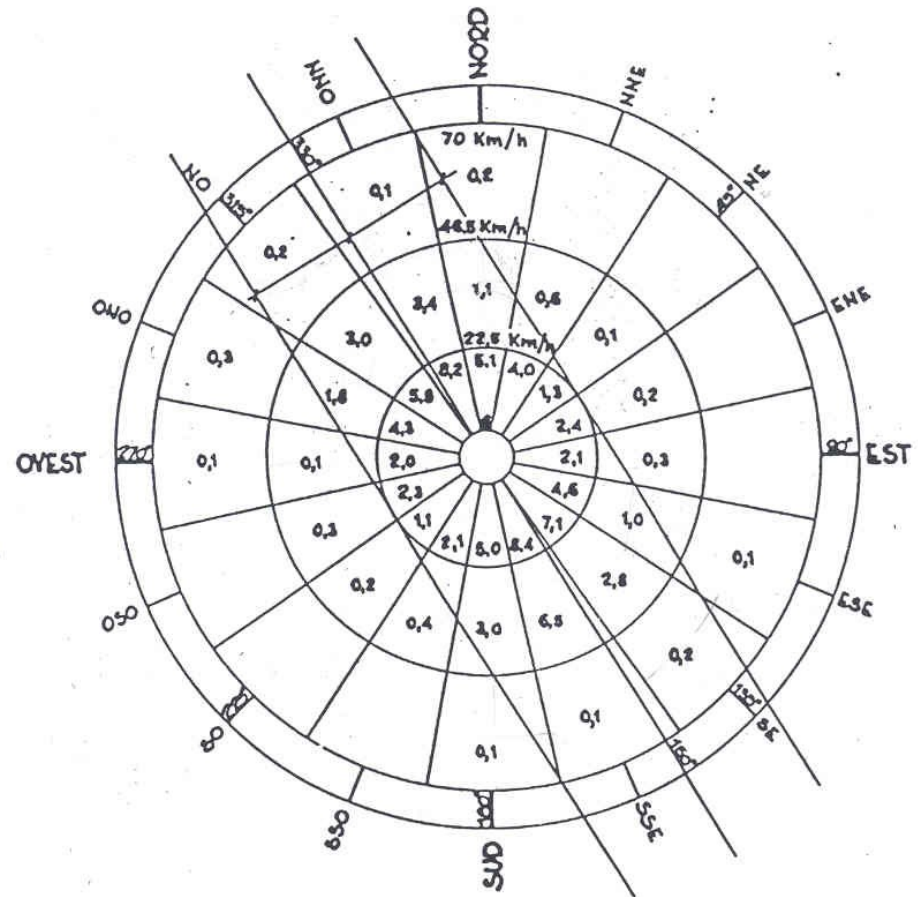


Coefficiente per più piste



Esempio di calcolo

Direzione del vento	Frequenza			Totale
	Da 6 a 22,5 km/h	Da 22,5 a 46,5 km/h	Da 46,5 a 70 km/h	
N	5,1	1,1 6/8	0,2 1/4	6,4
NNE	4,0	0,6 1/4	-	4,6
NE	1,3	0,1	-	1,4
ENE	2,4	0,2	-	2,6
E	2,1	0,3 1/4	-	2,4
ESE	4,6	1,0 2/3	0,1	5,7
SE	7,1	2,8	0,2 7/8	10,1
SSE	8,4	6,5	0,1	15,0
S	5,0	3,0 6/8	0,1 1/4	8,1
SSO	2,1	0,4 1/4	-	2,5
SO	1,1	0,2	-	1,3
OSO	2,3	0,3	-	2,6
O	2,0	0,1 1/4	0,1	2,2
ONO	4,3	1,8 2/3	0,3	6,4
NO	5,9	3,0	0,2 7/8	9,1
NNO	8,2	3,4	0,1	11,7
Calma	Da 0 a 6 km/h			7,9
Totale				100,0t



Dati aeroporto di Ronchi

direzione	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
Intensità Vento																
0 - 4 nodi	81,768															
4 - 10	0,787	0,513	1,267	1,917	4,863	1,095	1,232	0,924	0,958	0	0	0	0	0	0	0
10 - 13	0	0,102	0,376	0,41	1,13	0,102	0,205	0	0	0,136	0	0	0	0	0	0
13 - 20	0,068	0,102	0,136	0,205	1,061	0,064	0,034	0,068	0,068	0	0	0	0	0	0	0
> 20	0	0	0	0,136	0,171	0,034	0,034	0	0,034	0	0	0	0	0	0	0

Dati di riferimento di un aerodromo

Punto di riferimento

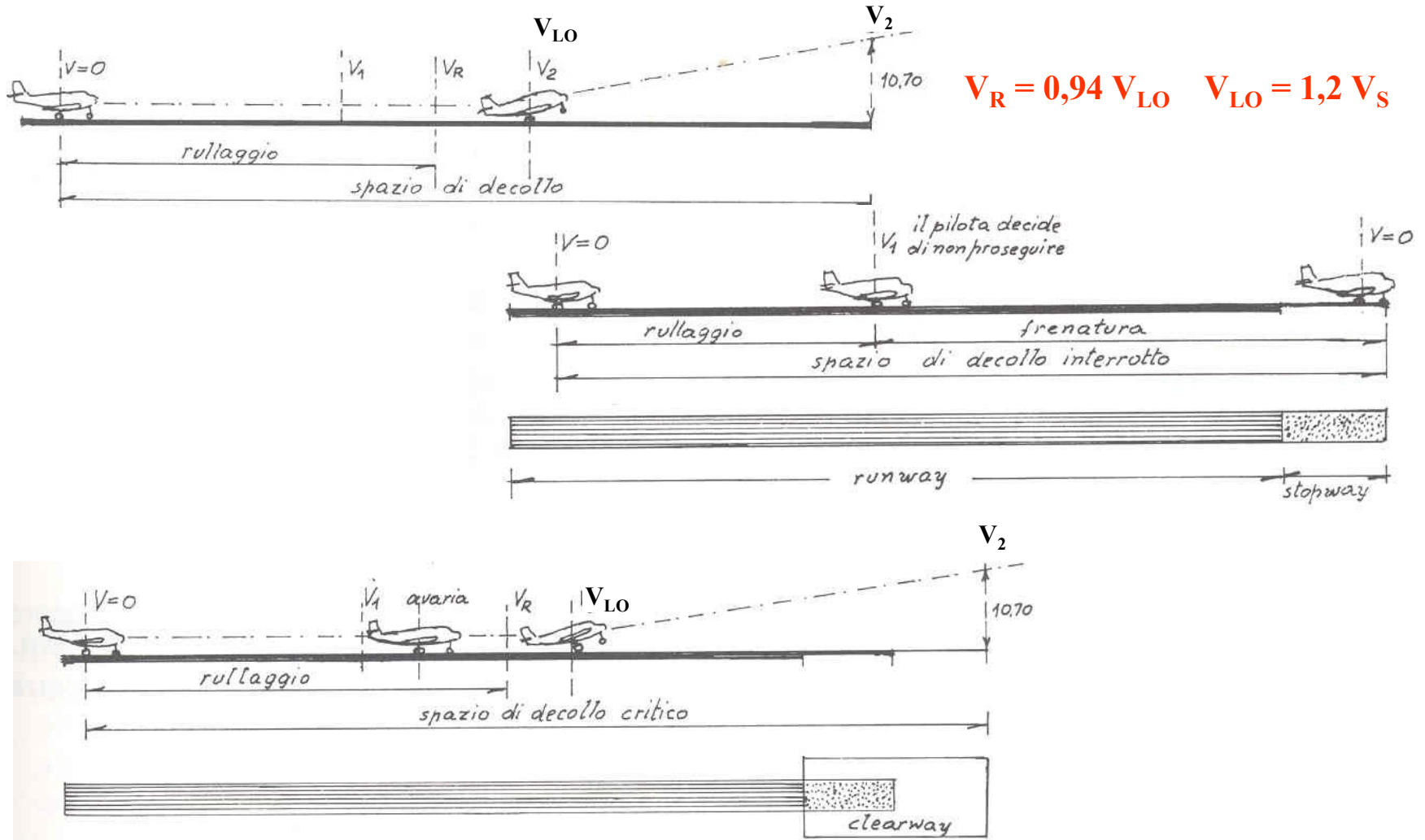
Altitudine aerodromo e piste

Temperatura di riferimento

Dimensioni e informazioni aerodromo

Distanze dichiarate

Le manovre di decollo (1)



Le manovre di decollo (2)

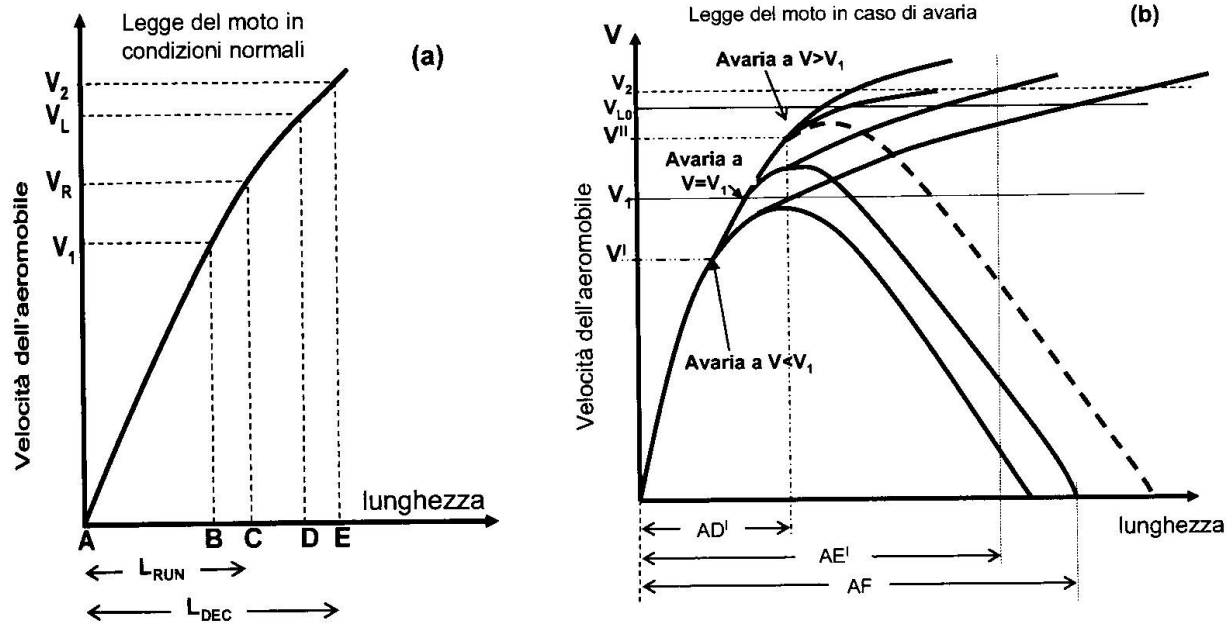
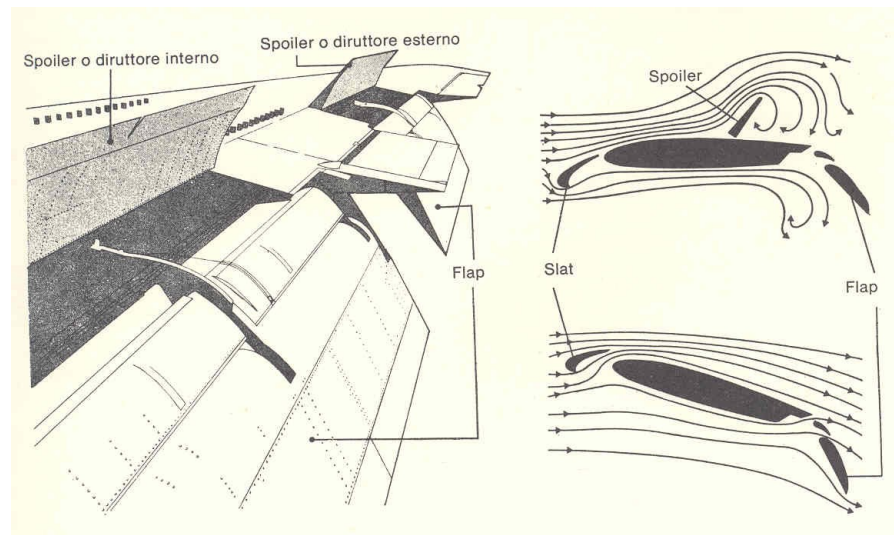
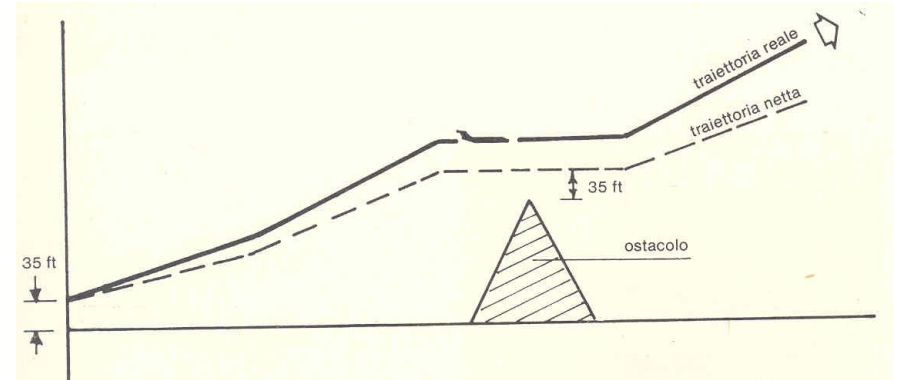
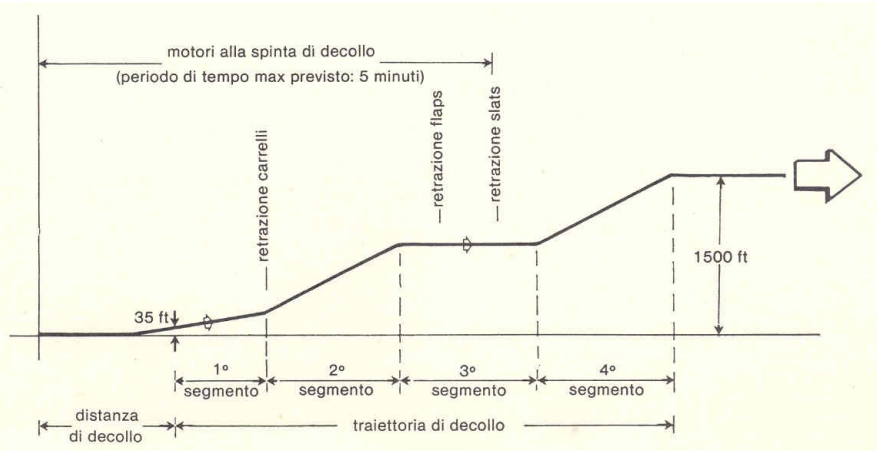
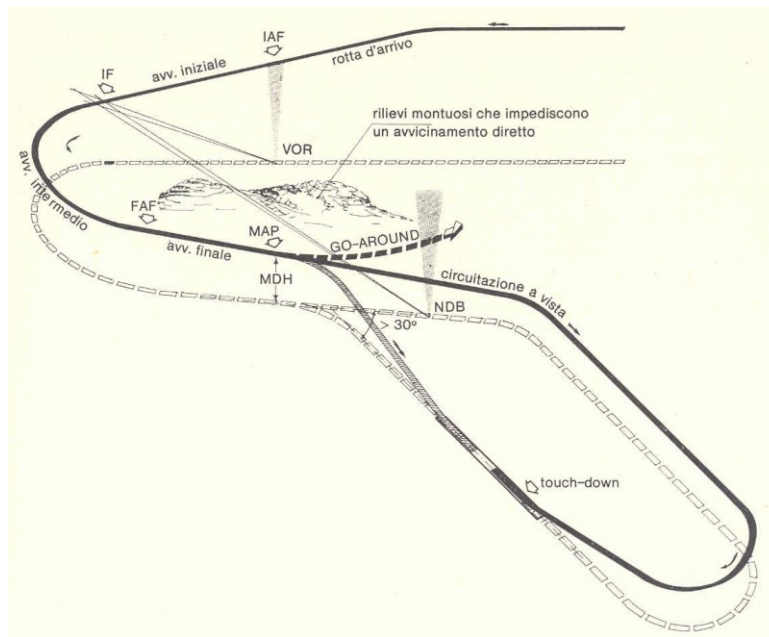
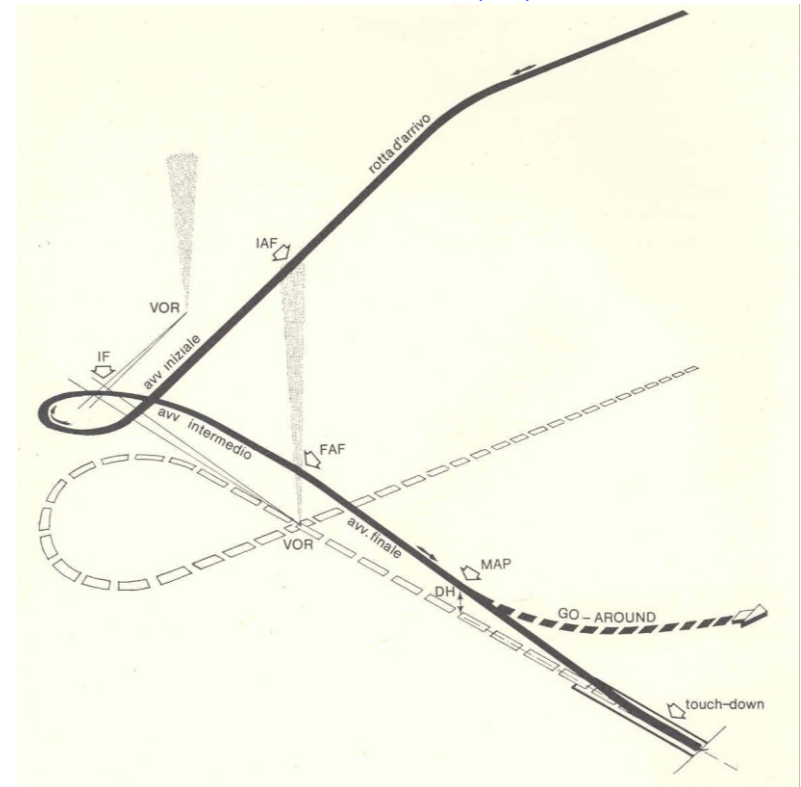
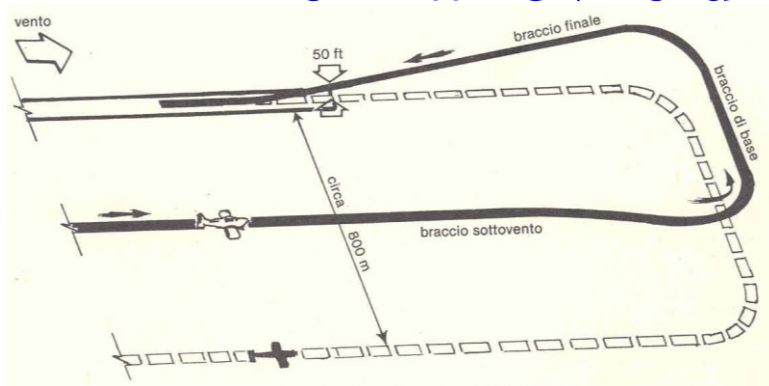


Figura 10. 6: Legge del moto dell'aeromobile in fase di decollo in condizioni normali (a) ed in caso di avaria ad un motore (b).

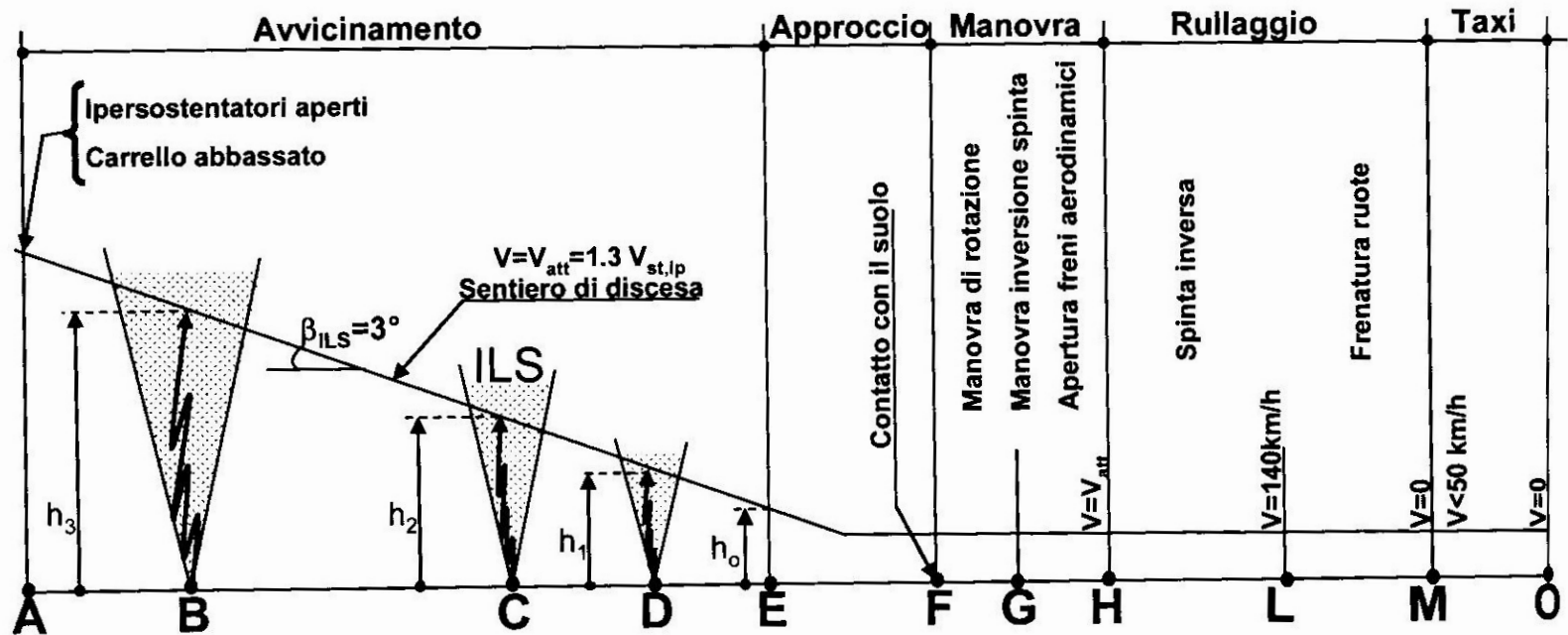
La salita di decollo



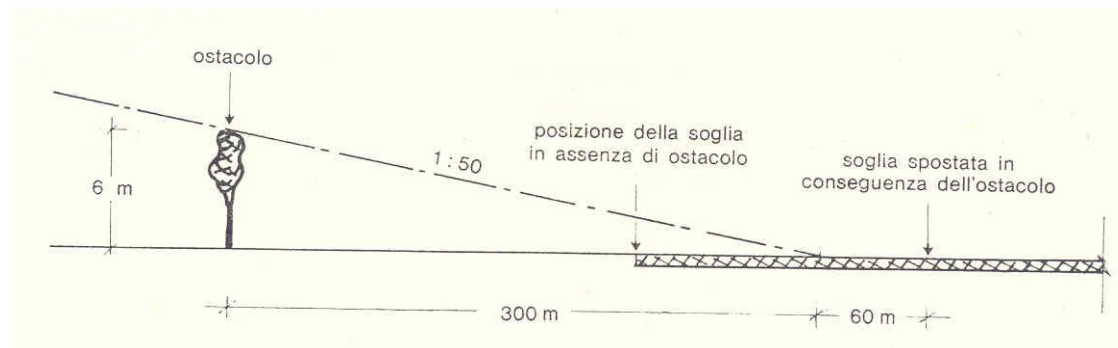
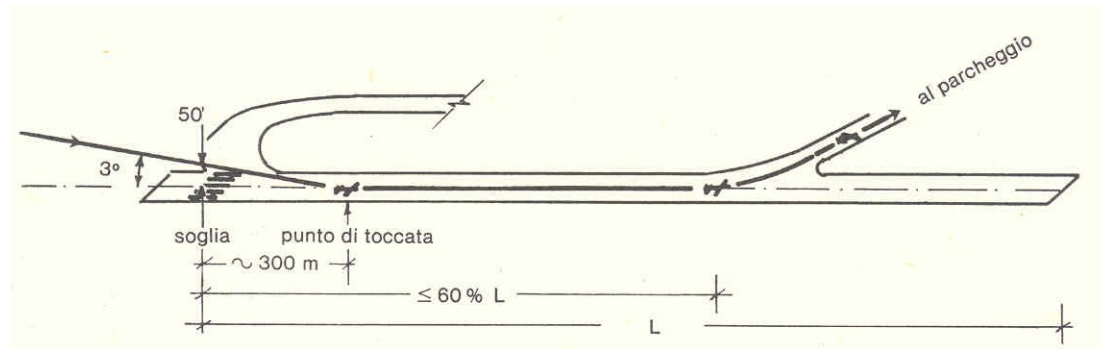
Le manovre di avvicinamento (1)



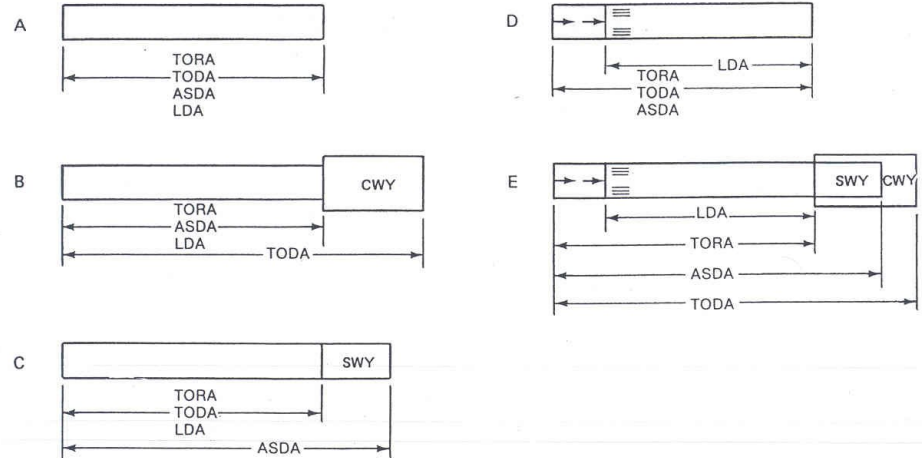
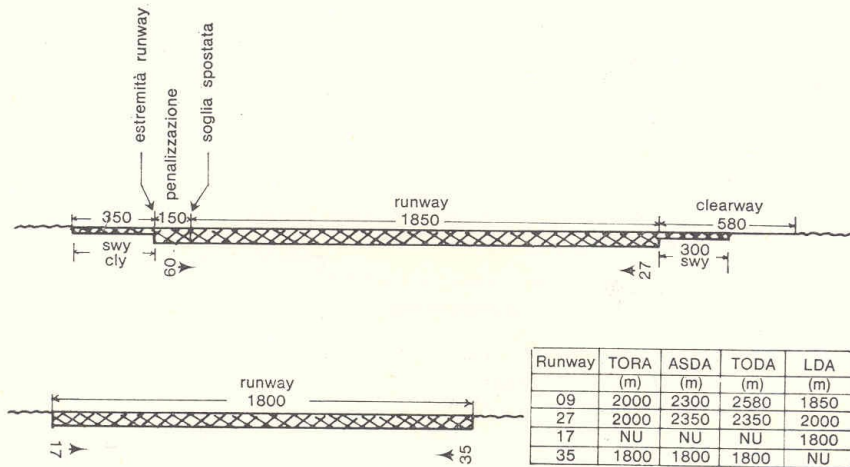
Le manovre di avvicinamento (2)



Le manovre di atterraggio



Le distanze dichiarate



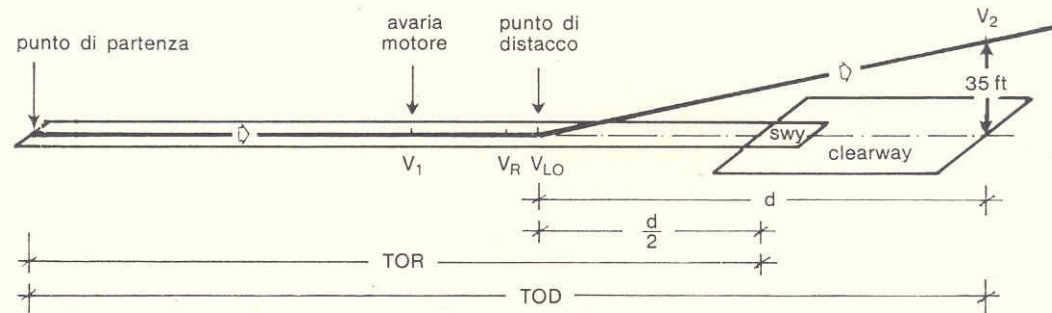
TORA (Take-Off Run Available, corsa di decollo disponibile) lunghezza di pista dichiarata disponibile e adatta alla corsa a terra di un aereo che decolla;

TODA (Take-Off Distance Available, distanza di decollo disponibile) TORA + clearway se esistente;

ASDA (Accelerate Stop Distance Available, distanza di accelerazione ed arresto disponibile) TORA + stopway se esistente;

LDA (Landing Distance Available, distanza di atterraggio disponibile) lunghezza di pista dichiarata disponibile e adatta per un aereo in fase di atterraggio;

Le distanze richieste (1)



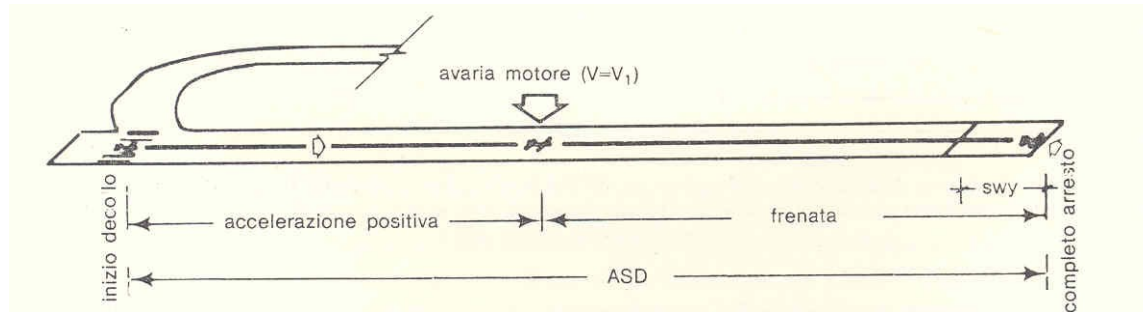
TOD (Take-Off Distance) è la maggiore delle seguenti distanze:

- Distanza orizzontale compresa fra il punto di partenza per il decollo ed il punto in cui un aeromobile con il motore critico inoperativo alla V_1 raggiunge con la sua parte più bassa la quota di 35 piedi (10,7 m);**
- La stessa distanza del punto “a”, con tutti i motori operativi, incrementata del 15 %.**

TOR (Take-Off Run) è la maggiore delle seguenti distanze:

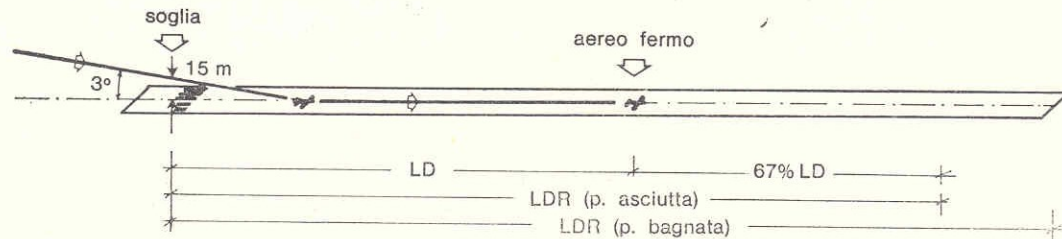
- Distanza orizzontale compresa fra il punto di partenza ed il punto intermedio fra il punto di distacco (V_{LO} Velocità di Lift-Off) ed il punto finale di decollo (quota di 35 piedi), nel caso di avaria al motore critico in corrispondenza di V_1 ;**
- La stessa distanza del punto “a” con tutti i motori operativi, incrementata del 15%.**

Le distanze richieste (2)



ASD (Accelerate-Stop Distance) è la distanza compresa tra il punto di inizio decollo ed il punto di completo arresto del veivolo, nel caso di avaria al raggiungimento della velocità V_1 .

Le distanze richieste (3)



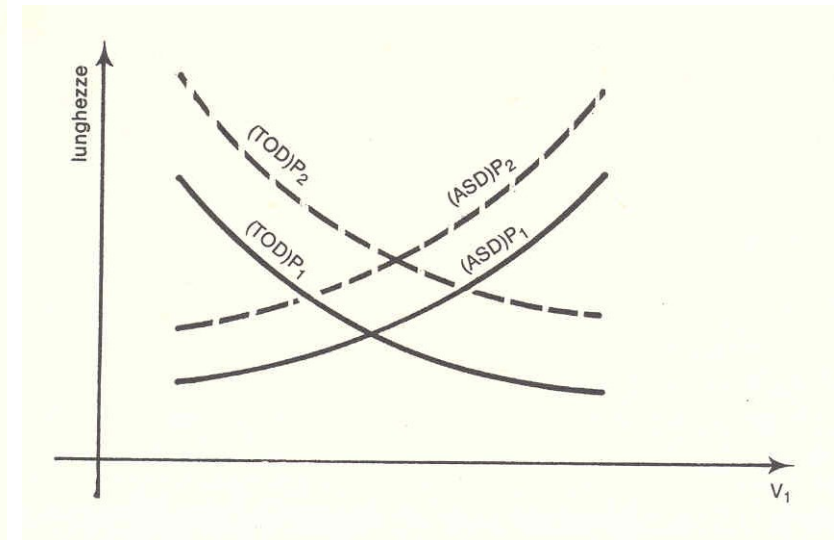
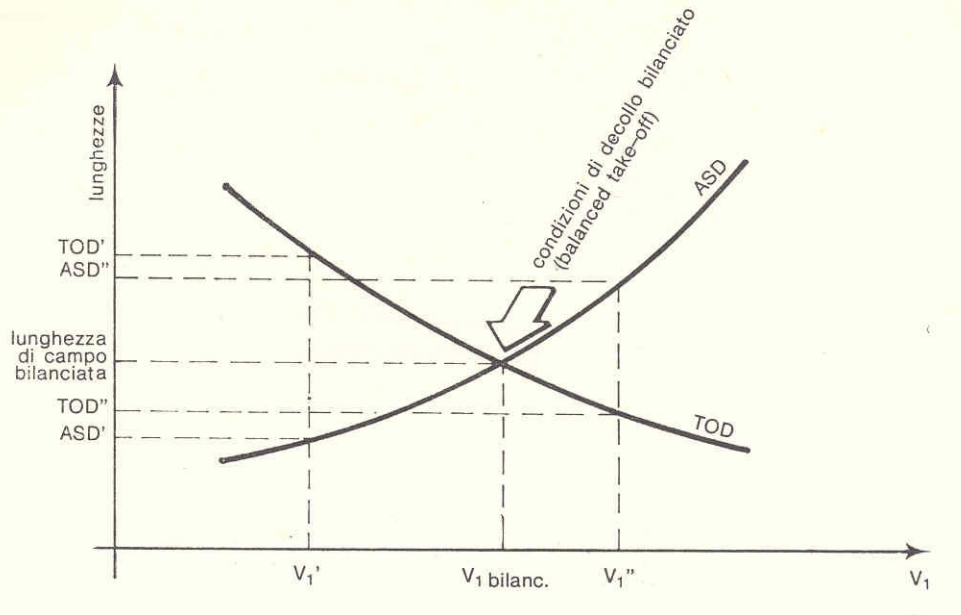
LDR (Landing Distance Required) Metodo A: è la maggiore delle seguenti distanze:

- distanza orizzontale necessaria in configurazione di atterraggio, con angolo di discesa 3° e con tutti i motori operativi per fermarsi su pista bagnata a partire da un punto alto 10,7 m sulla superficie di atterraggio, incrementata del 15 %;
- La stessa distanza del punto "a" ipotizzando il motore critico inoperativo, incrementata del 10 %.

LDR (Landing Distance Required) Metodo B:

- Su pista asciutta è costituita dalla distanza orizzontale necessaria per atterrare e fermarsi a partire da 15 metri in corrispondenza della soglia, incrementata del 67 %.
- Su pista bagnata si ottiene la LDR incrementando del 15% il valore su pista asciutta precedente

Compatibilità tra distanze richieste e dichiarate (1)



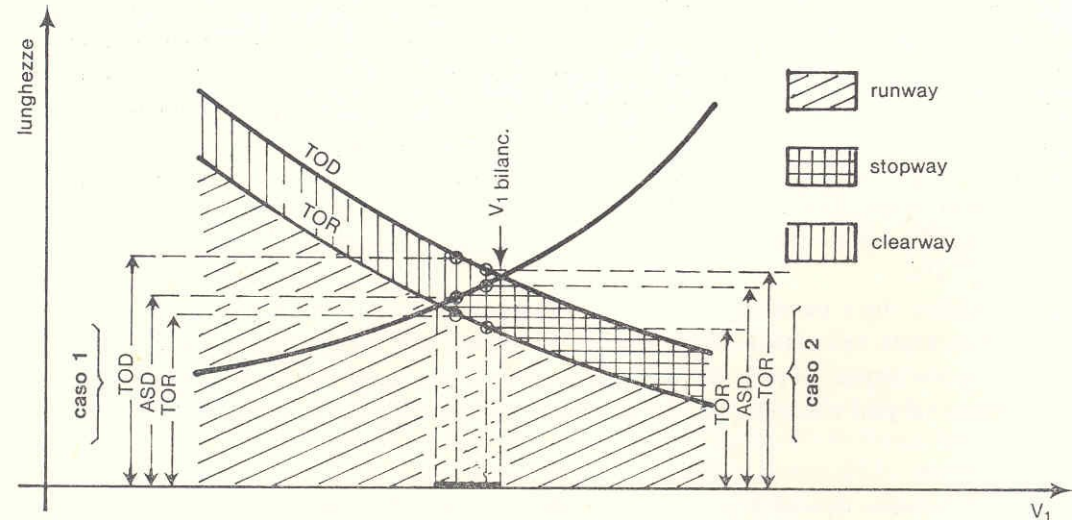
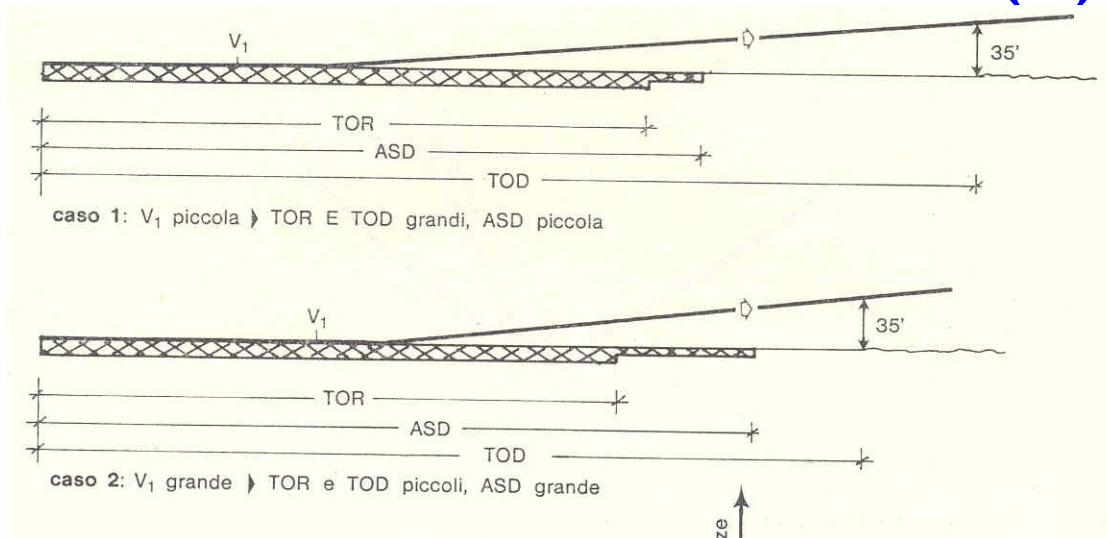
TOR < TORA

TOD < TODA

ASD < ASDA

LDR < LDA

Compatibilità tra distanze richieste e dichiarate (2)



Lo spazio di decollo (1)

$$R_{\text{aer.}} = \frac{1}{2} \cdot C_r \cdot \rho \cdot S_m \cdot v^2$$

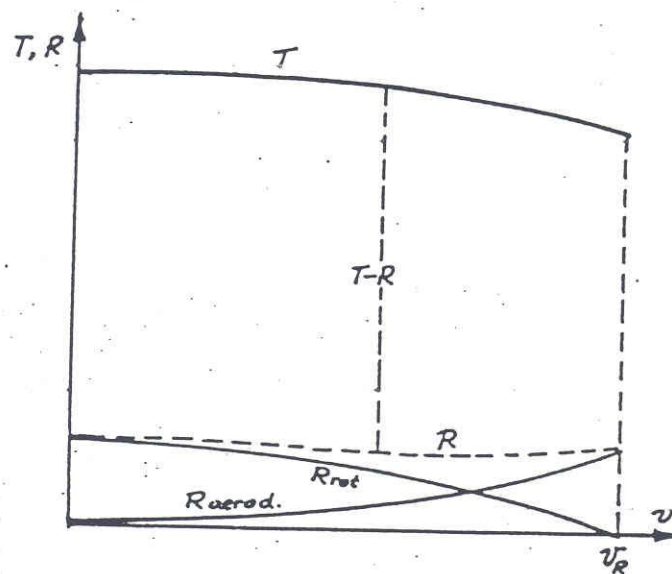
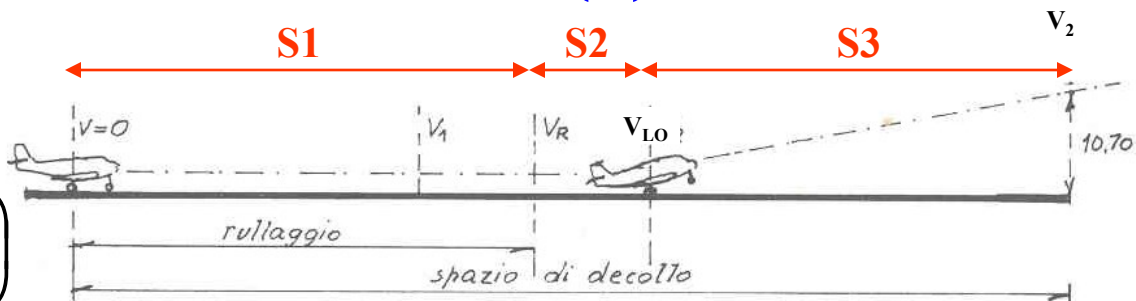
$$R_{\text{rot.}} = f_{\text{rot.}} \cdot \left(Q - \frac{1}{2} \cdot C_p \cdot \rho \cdot S_a \cdot v^2 \right)$$

$$R = R_{\text{aer.}} + R_{\text{rot.}}$$

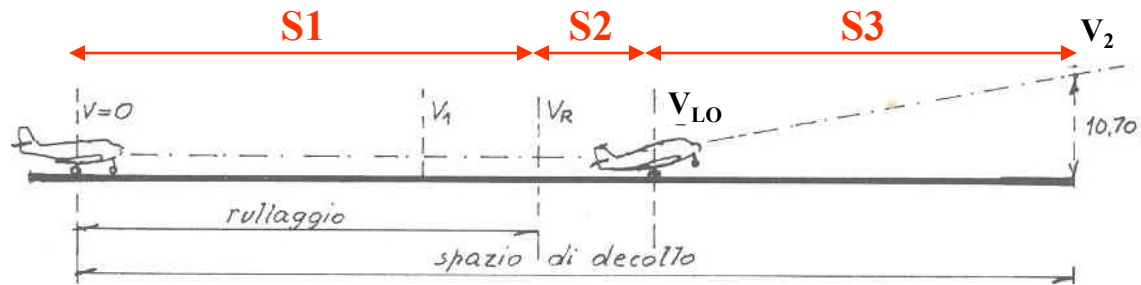
$$T - R = \frac{Q}{g} \cdot a$$

$$ds = v \cdot dt = v \cdot \frac{dv}{a}$$

$$S_1 = \int_{v=0}^{v_R} \frac{v}{a} \cdot dv$$



Lo spazio di decollo (2)



$$S_1 = \int_{v=0}^{v_R} \frac{v}{a} \cdot dv$$

$$S_2 = v_m \cdot t_m$$

$$S_3 = 10,7 / \text{tg}(3^\circ)$$

$$v_m = \frac{v_R + v_2}{2}$$

$$t_m \cong 3 \text{ [s]}$$

Fattori che influenzano lo spazio di decollo

$$Q = P = \frac{1}{2} \cdot C_p \cdot \rho_0 \cdot S_a \cdot v_0^2 = \frac{1}{2} \cdot C_p \cdot \rho_h \cdot S_a \cdot v_h^2$$

$$v_h = \frac{v_0}{\sqrt{\frac{\rho_h}{\rho_0}}} = \frac{v_0}{\sqrt{\delta}}$$

TABELLA V.1 - Aria tipo internazionale (unità tecniche)

Quota campo m	Temperatura media °C	Pressione mm (Hg)	Peso specifico γ kg _p /m ³	Densità ρ kg _p /m ³	Densità relativa $\delta = \rho/\rho_0$
0	15	760	1,2250	0,1249	1
500	11,75	715,9	1,1673	0,1190	0,9528
1000	8,50	674,1	1,1117	0,1133	0,9075
1500	5,25	634,2	1,0581	0,1079	0,8638
2000	2,00	596,2	1,0064	0,1026	0,8216
2500	-1,25	560,1	0,9569	0,0975	0,7810
3000	-4,50	525,8	0,9091	0,0927	0,7421

$$L_{\text{real.}} = L_{\text{base}} K1 * K2 * K3$$

$$K1 = 1 + 0,07 * (H/300)$$

$$K2 = 1 + 0,01 * (T_R - T_S)$$

$$K3 = 1 + 0,1 * (i)$$

$$T_S = 15 - 0,0065 * H$$

Esempio di calcolo

$L_{\text{base}} = 1700 \text{ m};$ **Quota aeroporto: $H = 150 \text{ m};$**

Temperatura di riferimento $T_R = 24 \text{ }^\circ$ **Pendenza media pista $i = 0,5 \text{ } \%$**

$T_S = 15 - 0,0065 * H = 14,025 \text{ }^\circ$

$L_{\text{real.}} = L_{\text{base}} * K1 * K2 * K3 = 1700 * 1,035 * 1,100 * 1,050 \cong 2033$

$K1 = 1 + 0,07 * (H/300) = 1 + 0,07 * (150/300) = 1,035$

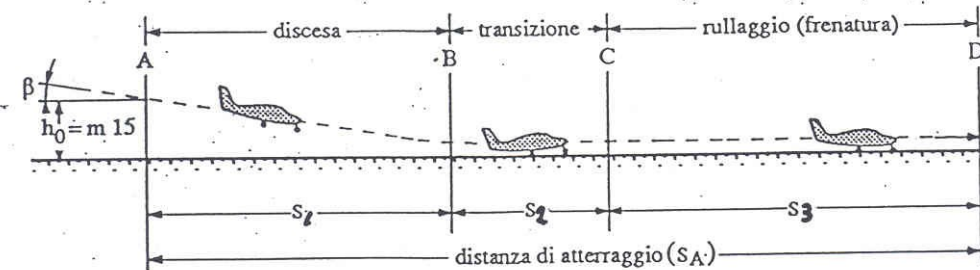
$K2 = 1 + 0,01 * (T_R - T_S) = 1 + 0,01 * (24 - 14,025) = 1,100$

$K3 = 1 + 0,1 * (i) = 1 + 0,1 (0,5) = 1,050$

Lo spazio di atterraggio

$$S_1 = 15/\text{tg}(3^\circ)$$

$$S_2 = v_m \cdot t_m$$



$$Q = m \cdot g = \frac{1}{2} \cdot C_p \cdot \rho \cdot S_a \cdot v_a^2$$

$$\frac{Q}{g} \cdot \frac{dv}{dt} = - \left[f \cdot Q + \frac{1}{2} (C_r - f \cdot C_p) \cdot \rho \cdot S_a \cdot v^2 \right]$$

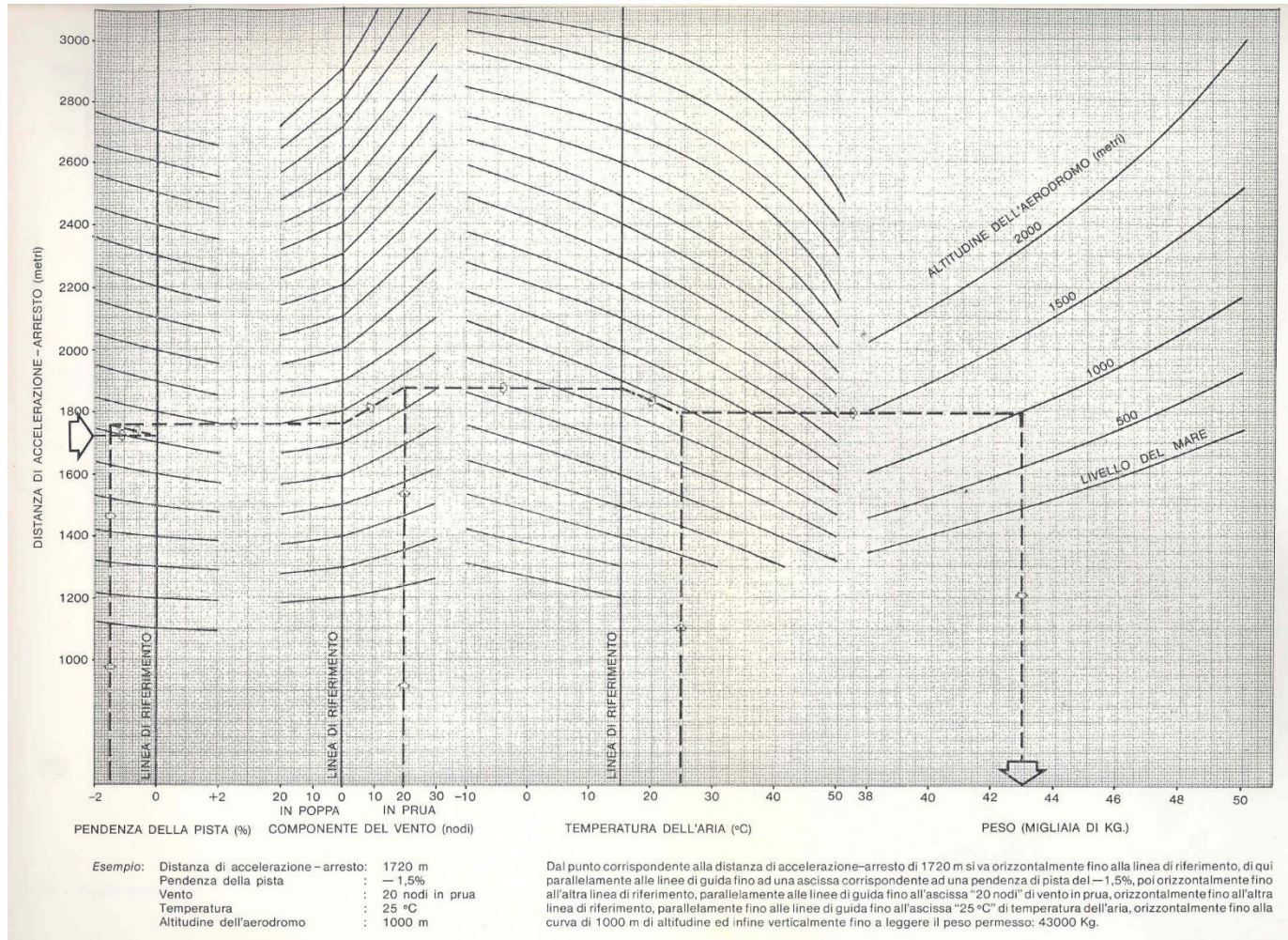
$$ds = v \cdot dt = v \cdot \frac{dv}{a}$$

$$\frac{v}{g} \cdot \frac{dv}{ds} = - \left[f + \left(\frac{C_r}{C_p} - f \right) \cdot \frac{v^2}{v_a^2} \right]$$

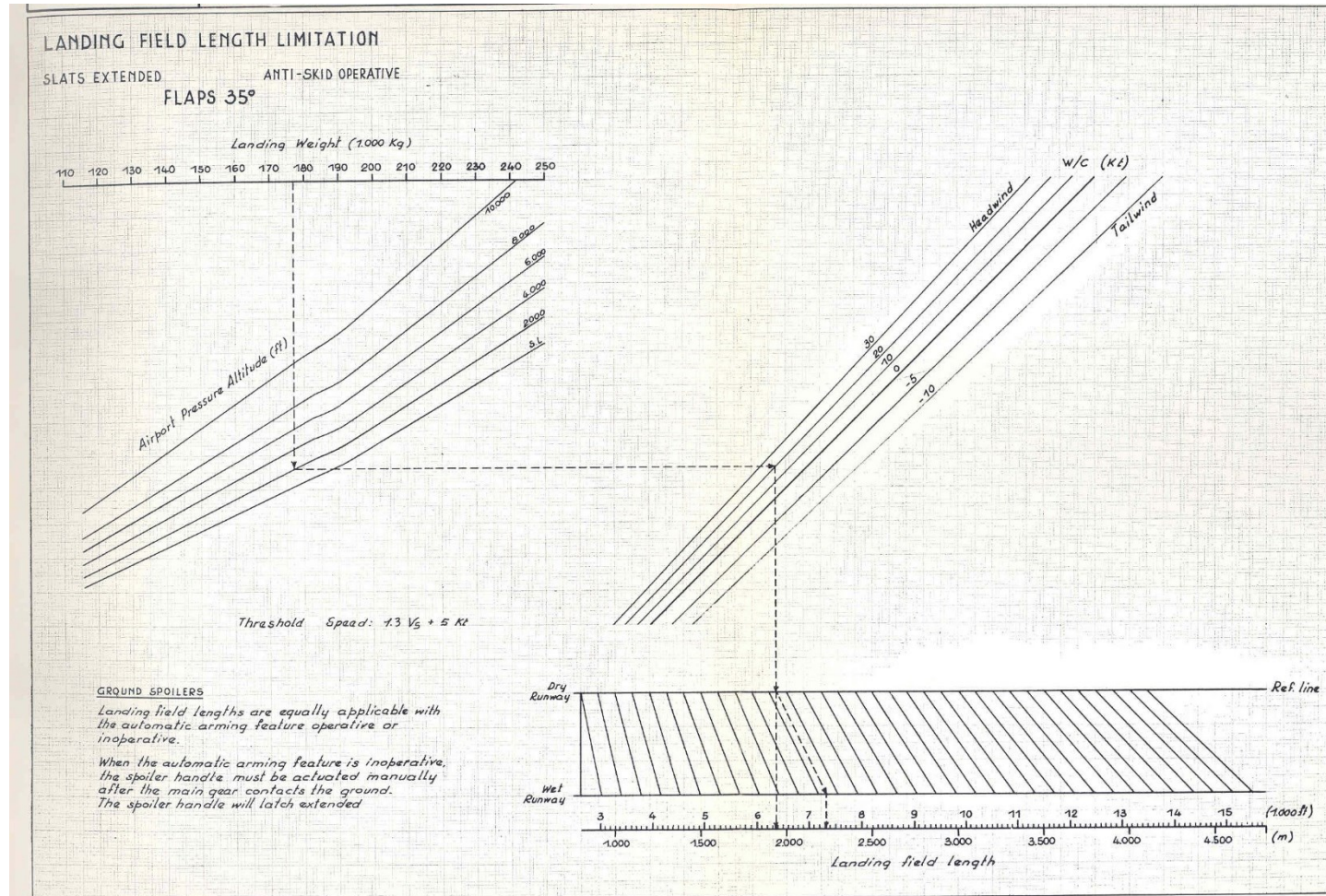
$$\mu = \frac{C_r}{C_p}$$

$$S_3 = \frac{\ln \frac{f}{\mu}}{2 \cdot (f - \mu) \cdot g} \cdot v_a^2$$

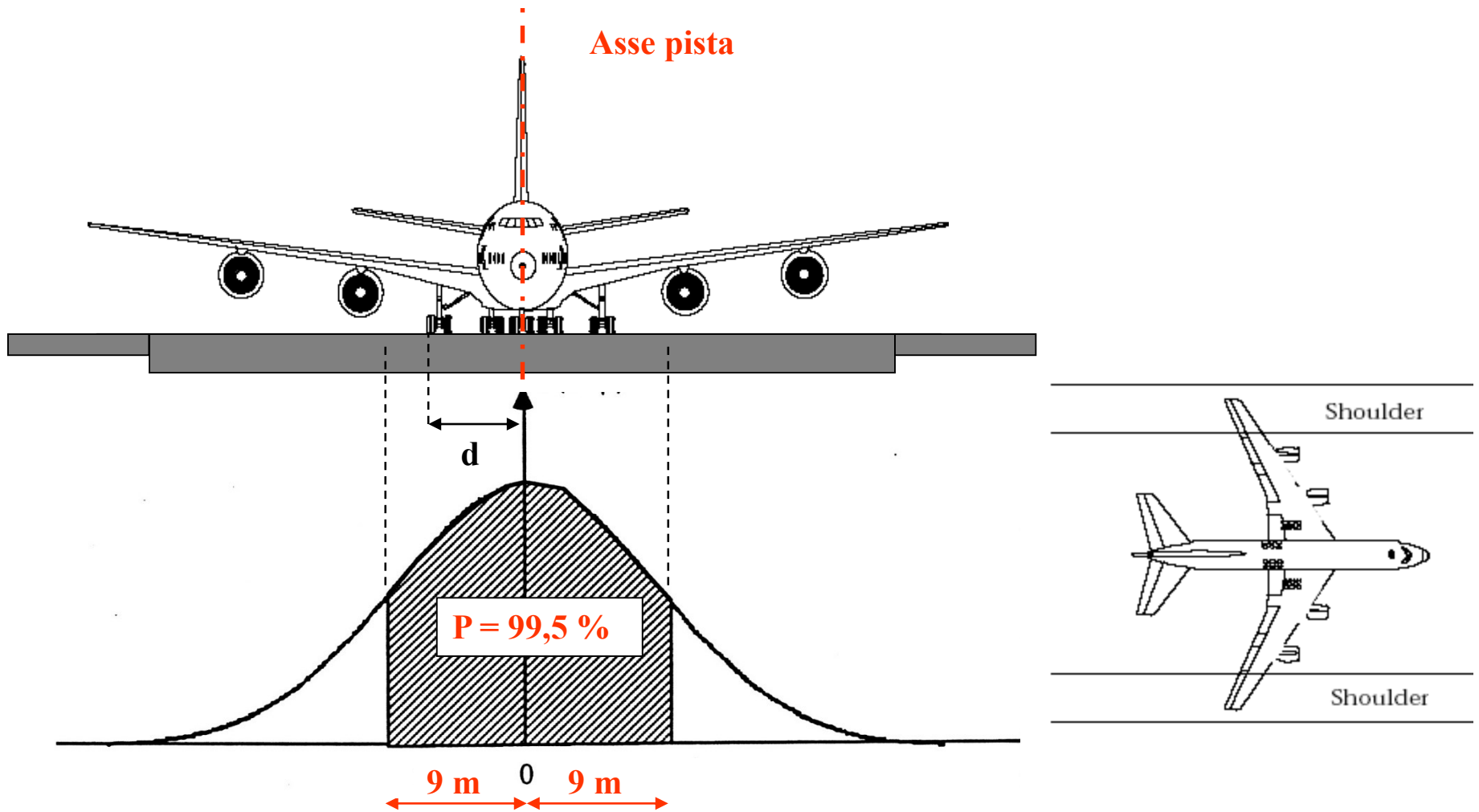
I diagrammi di prestazione (1)



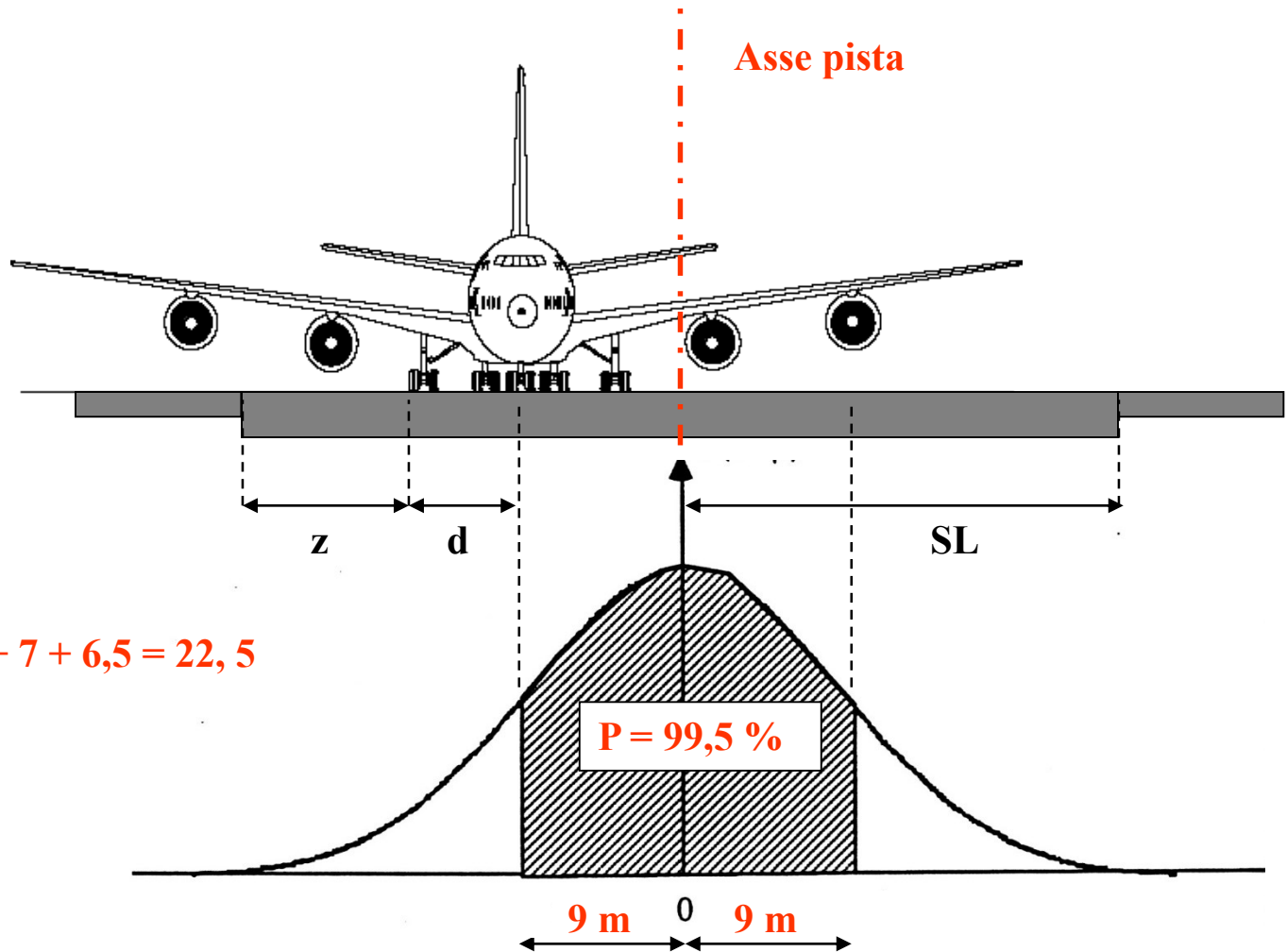
I diagrammi di prestazione (2)



Larghezza della runway (1)



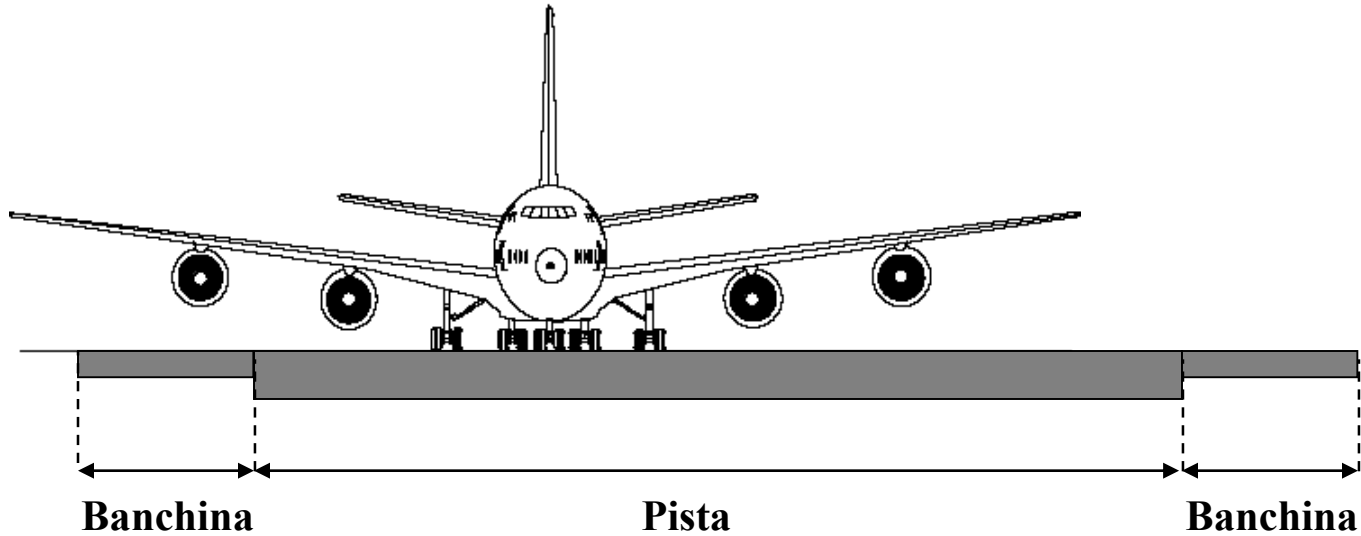
Larghezza della runway (2)



$$SL = 9 + d + z = 9 + 7 + 6,5 = 22,5$$

$$L = 2 * SL = 45\text{ m}$$

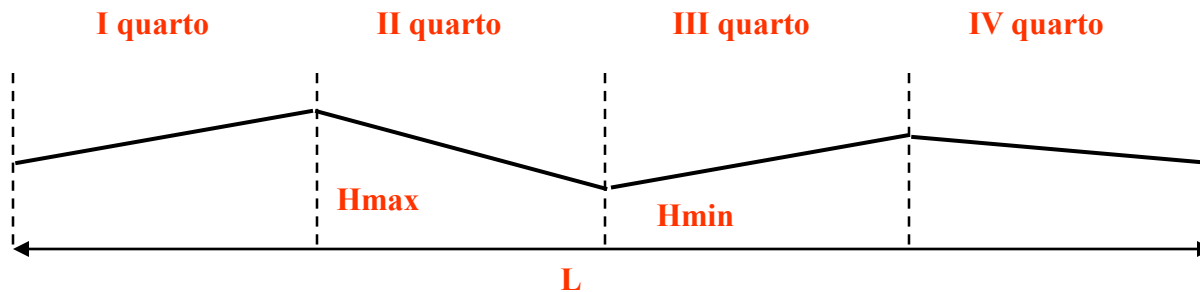
Larghezza della runway (3)



Cod. alfabetico	A	B	C	D	E	F
Cod. numerico	[m]	[m]	[m]	[m]	[m]	[m]
1	18	18	23			
2	23	23	30			
3	30	30	30	45		
4			45	45	45	60

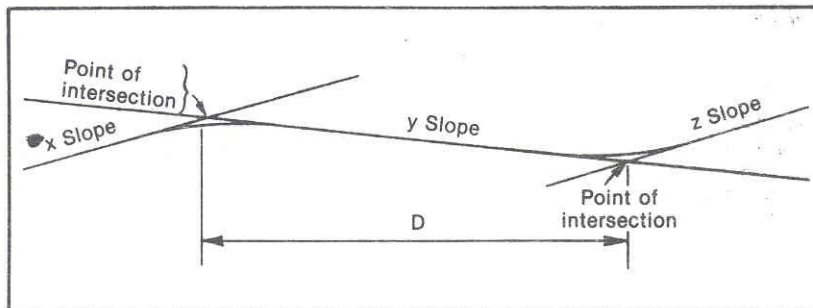
Pendenze longitudinali della runway (1)

Cod. numerico	1	2	3	4
Pendenza longitudinale media $(H_{max} - H_{min})/L$	$\leq 2 \%$	$\leq 2 \%$	$\leq 1 \%$	$\leq 1 \%$
Pendenza massima	$\leq 2 \%$	$\leq 2 \%$	$\leq 1,5 \%$	$\leq 1,25 \%$
Pendenza massima I e IV quarto	-	-	$\leq 0,8 \%$ *	$\leq 0,8 \%$
Variazione di pendenza	$\leq 2 \%$	$\leq 2 \%$	$\leq 1,5 \%$	$\leq 1,5 \%$
Raggio raccordi verticali	$\geq 7.500 \text{ m}$	$\geq 7.500 \text{ m}$	$\geq 15.000 \text{ m}$	$\geq 30.000 \text{ m}$



Pendenze longitudinali della runway (2)

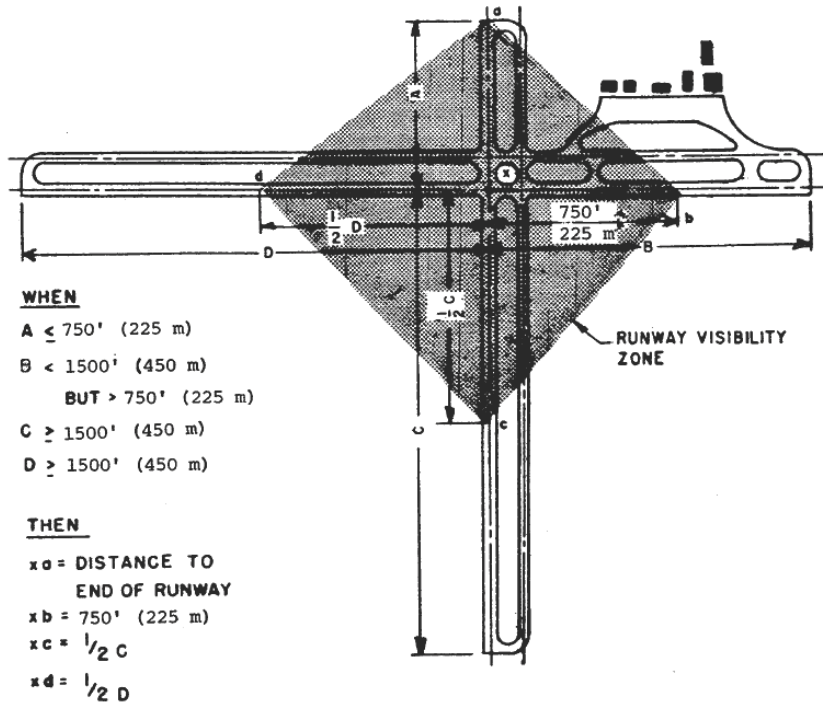
Cod. numerico	1	2	3	4
A	5.000 m	5.000 m	15.000 m	30.000 m
R	7.500 m	7.500 m	15.000 m	30.000 m



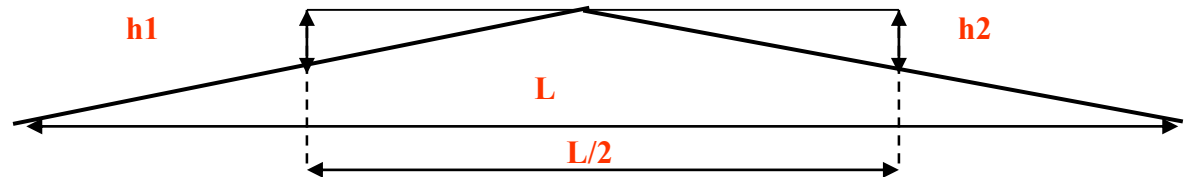
$$D \geq A * (|x - y| + |y - z|)$$

$$D \geq 45 \text{ m}$$

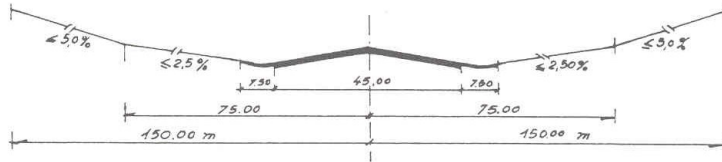
Distanze visibilità



Cod. alfabetico	A	B	C	D	E	F
	[m]	[m]	[m]	[m]	[m]	[m]
h1	1,5	2	3	3	3	3
h2	1,5	2	3	3	3	3
Distanza di vis.	L/2	L/2	L/2	L/2	L/2	L/2



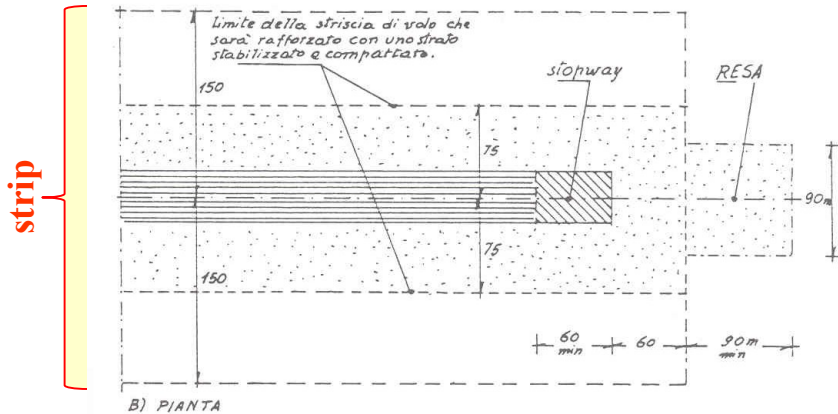
Sezione trasversale



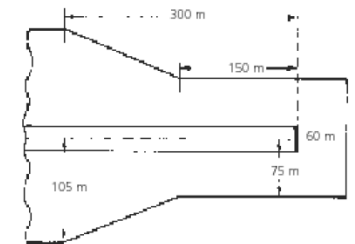
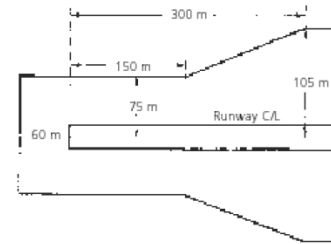
A) SEZIONE TRASVERSALE

Runway End Safety Area

CGA, Cleared and Graded Area)



B) PIANTA



Code number

1 2 3 4

Runway

maximum transverse slope

2% where the code letter is A or B; and 1.5% where the code letter is C, D, or E

Width of runway strip

precision and non-precision runway
non-instrument runway

150 m	150 m	300 m	300 m
60 m	80 m	150 m	150 m

Strip

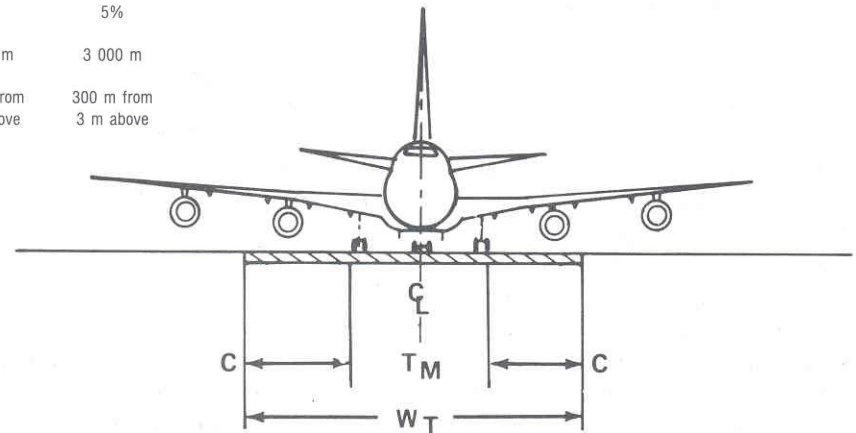
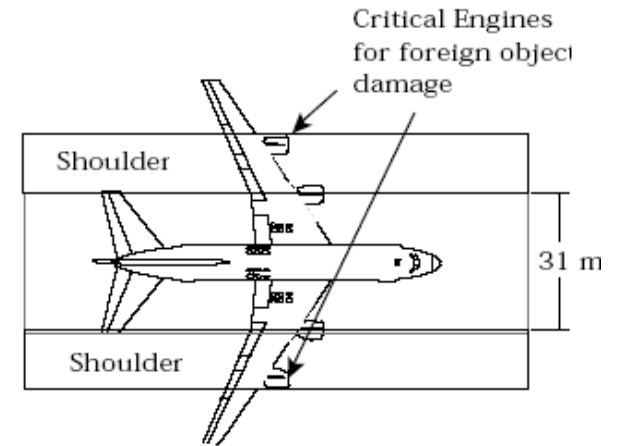
maximum longitudinal slope
maximum transverse slope

2%	2%	1.75%	1.5%
3%	3%	2.5%	2.5%

Larghezza piste di circolazione

Physical characteristics	Code letter				
	A	B	C	D	E
Minimum width of:					
taxiway pavement	7.5 m	10.5 m	18 m ^a 15 m ^b	23 m ^c 18 m ^d	23 m
taxiway pavement and shoulder	—	—	25 m	38 m	44 m
taxiway strip	27 m	39 m	57 m	85 m	93 m
graded portion of taxiway strip	22 m	25 m	25 m	38 m	44 m
Minimum clearance distance of outer main wheel to taxiway edge	1.5 m	2.25 m	4.5 m ^a 3 m ^b	4.5 m	4.5 m
Maximum longitudinal slope of taxiway:					
pavement	3%	3%	1.5%	1.5%	1.5%
change in slope	1% per 25 m	1% per 25 m	1% per 30 m	1% per 30 m	1% per 30 m
Maximum transverse slope of:					
taxiway pavement	2%	2%	1.5%	1.5%	1.5%
graded portion of taxiway strip upwards	3%	3%	2.5%	2.5%	2.5%
graded portion of taxiway strip downwards	5%	5%	5%	5%	5%
ungraded portion of strip upwards	5%	5%	5%	5%	5%
Minimum radius of longitudinal vertical curve	2 500 m	2 500 m	3 000 m	3 000 m	3 000 m
Minimum taxiway sight distance	150 m from 1.5 m above	200 m from 2 m above	300 m from 3 m above	300 m from 3 m above	300 m from 3 m above

F
30.5 m
55 m
115 m
60 m
6 m

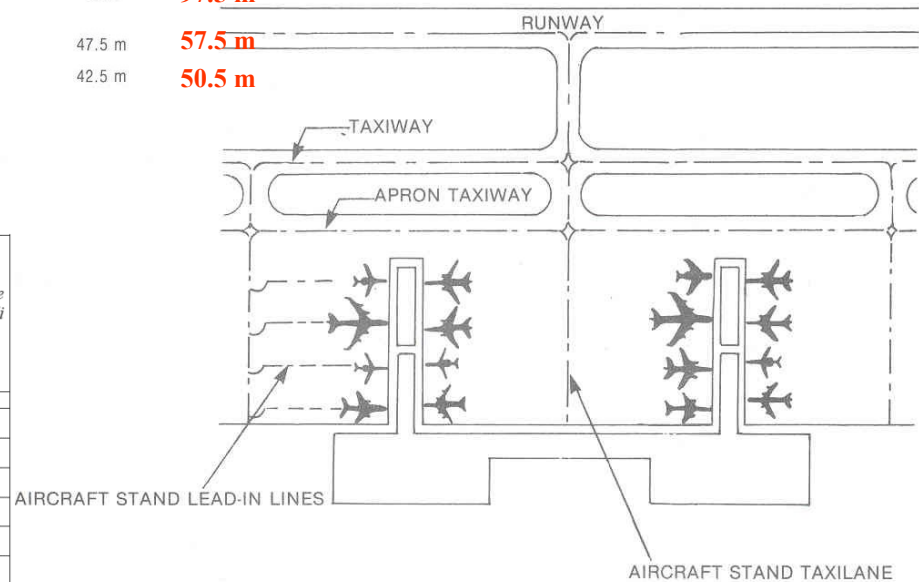


Le distanze di separazione (1)

Physical characteristics	Code letter					F
	A	B	C	D	E	
Minimum separation distance between taxiway centre line and:						
centre line of instrument runway code number 1	82.5 m	87 m	—	—	—	
2	82.5 m	87 m	—	—	—	
3	—	—	168 m	176 m	—	
4	—	—	—	176 m	182.5 m	190 m
centre line of non-instrument runway code number 1	37.5 m	42 m	—	—	—	
2	47.5 m	52 m	—	—	—	
3	—	—	93 m	101 m	—	
4	—	—	—	101 m	107.5 m	115 m
taxiway centre line	23.75 m	33.5 m	44 m	66.5 m	80 m	97.5 m
object						
taxiway ^e	16.25 m	21.5 m	26 m	40.5 m	47.5 m	57.5 m
aircraft stand taxilane	12 m	16.5 m	24.5 m	36 m	42.5 m	50.5 m

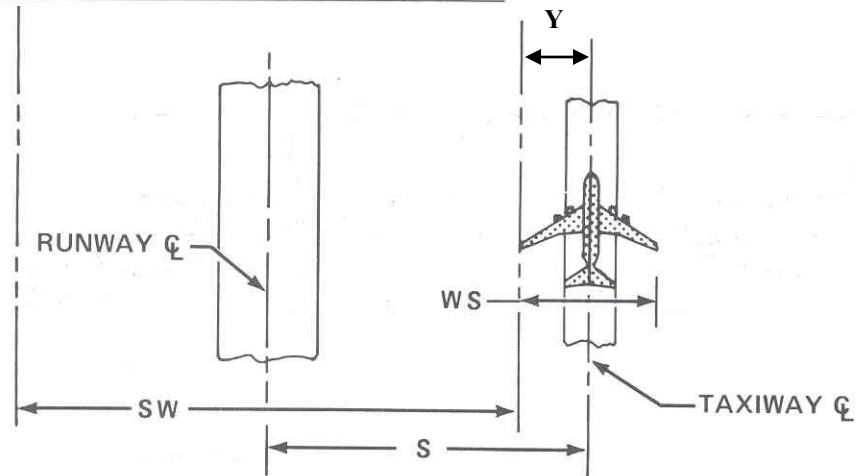
Tabella 3.4 - Distanze di separazione delle taxiway

Lettera di codice	Distanze tra asse pista e asse delle taxiway								Distanza interasse taxiway	Distanza tra asse taxiway e manufatti, escluse vie d'accesso alle piazzole	Distanza tra manufatti e asse vie di accesso alle piazzole
	Piste strumentali				Piste non strumentali						
	Numero di codice										
	1	2	3	4	1	2	3	4			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
A	82,5	82,5			37,5	47,5			23,75	16,25	12
B	87	87			42	52			33,5	21,5	16,5
C			168				93		44	26	24,5
D			176	176			101	101	66,5	40,5	36
E				182,5					80	47,5	42,5
F				190					97,5	57,5	50,5



Le distanze di separazione (2)

Code number	1		2		3				4			
Code letter	A	B	A	B	A	B	C	D	C	D	E	F
1/2 wing span (Y) + 1/2 strip width (non-instrument approach runway)	7.5	12	7.5	12	7.5	12	18	26	18	26	32.5	
	30.0	30	40.0	40	75.0	75	75	75	75	75	75.0	
Total	37.5	42	47.5	52	82.5	87	93	101	93	101	107.5	115
or												
1/2 wing span (Y) + 1/2 strip width (instrument approach runway)	7.5	12	7.5	12	7.5	12	18	26	18	26	32.5	
	75.0	75	75.0	75	150.0	150	150	150	150	150	150.0	
Total	82.5	87	82.5	87	157.5	162	168	176	168	176	182.5	190



Le distanze di separazione (3)

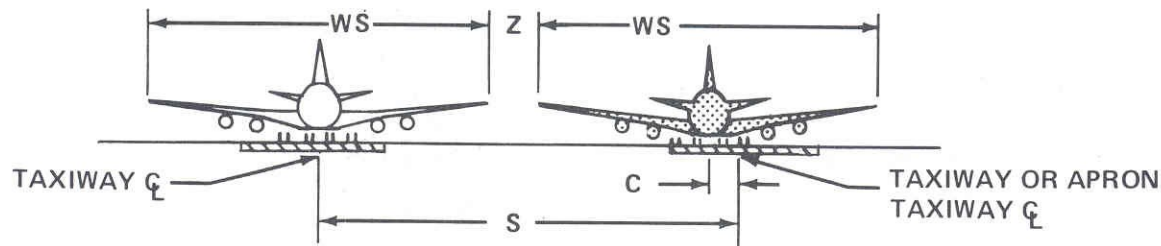
Code letter

Separation distances

A B C D E **F**

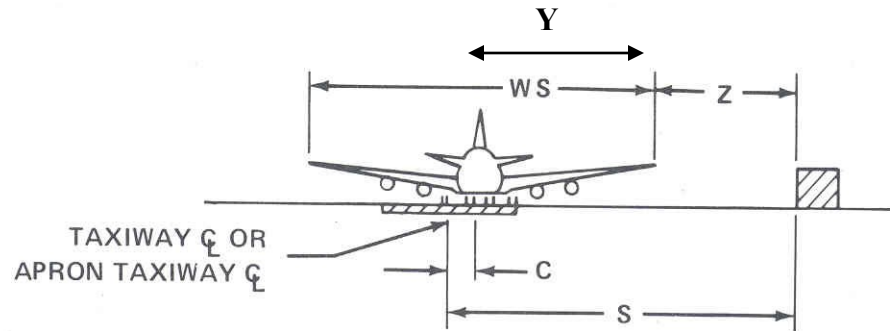
Between apron taxiway/taxiway centre line and taxiway centre line:

wing span (WS)	15.00	24.00	36	52.0	65.0	
+ maximum lateral deviation (C)	1.50	2.25	3	4.5	4.5	
+ increment (Z)	7.25	7.25	5	10.0	10.5	
Total separation distance (S)	23.75	33.50	44	66.5	80.0	97,5



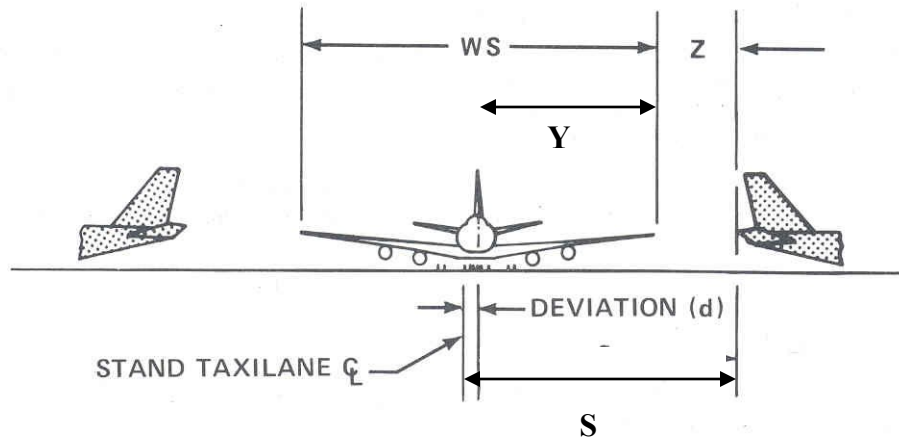
Le distanze di separazione (4)

Separation distances	Code letter					
	A	B	C	D	E	F
Between taxiway centre line and object:						
½ wing span (Y)	7.50	12.00	18	26.0	32.5	
+ maximum lateral deviation (C)	1.50	2.25	3	4.5	4.5	
+ increment (Z)	7.25	7.25	5	10.0	10.5	
Total separation distance (S)	16.25	21.50	26	40.5	47.5	57,5
Between apron taxiway centre line and object:						
½ wing span (Y)	7.50	12.00	18	26.0	32.5	
+ maximum lateral deviation (C)	1.50	2.25	3	4.5	4.5	
+ increment (Z)	7.25	7.25	5	10.0	10.5	
Total separation distance (S)	16.25	21.50	26	40.5	47.5	57,5



Le distanze di separazione (5)

Separation distances	Code letter					
	A	B	C	D	E	F
Between aircraft stand taxilane centre line and object:						
½ wing span (Y)	7.5	12.00	18.0	26.0	32.5	
+ gear deviation	1.5	1.50	2.0	2.5	2.5	
+ increment (Z)	3.0	3.00	4.5	7.5	7.5	
Total separation distance (V)	12.0	16.50	24.5	36.0	42.5	50,5

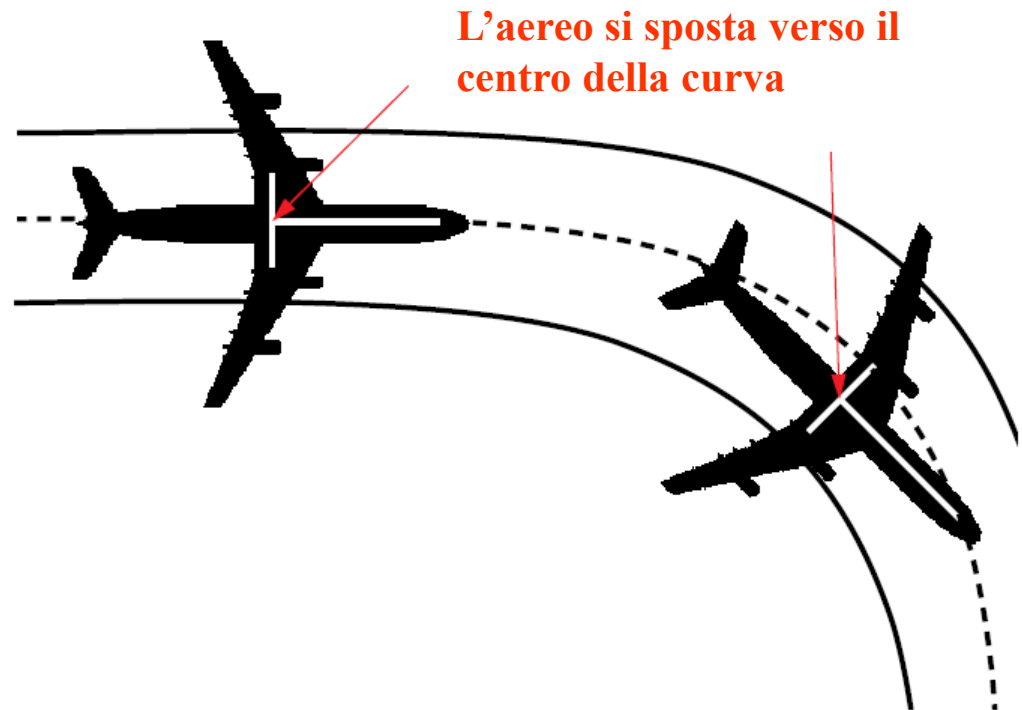


Le curve delle taxiway (1)

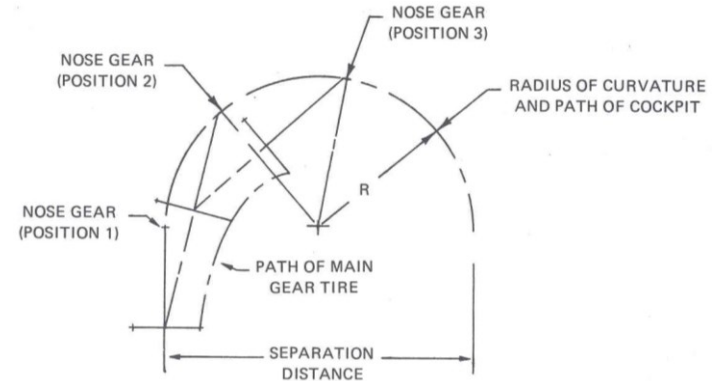
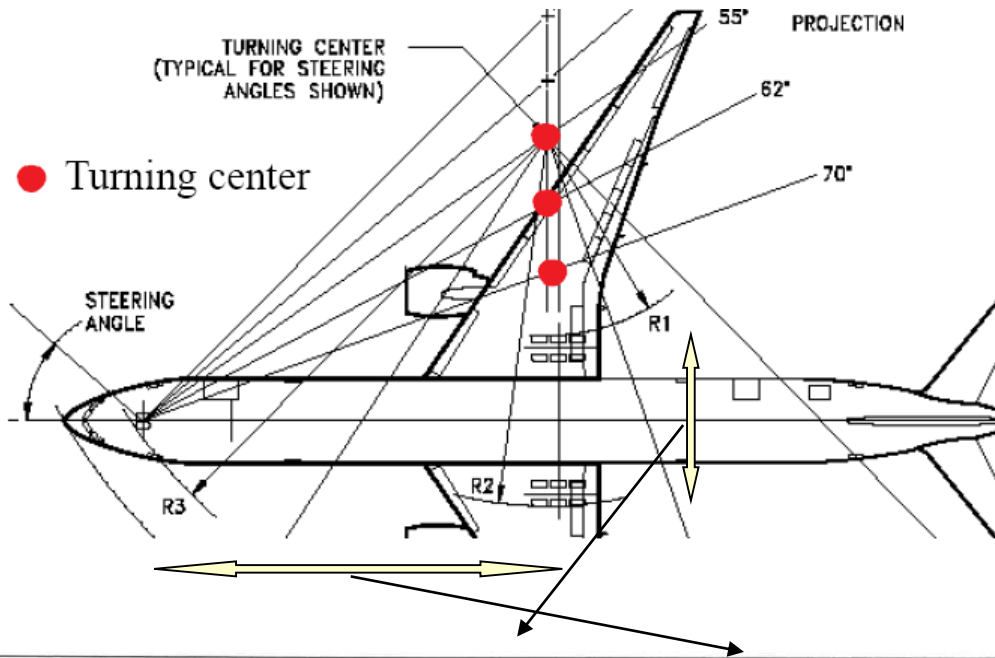
$$\frac{V^2}{R} = 127,133 \cdot [\cancel{\text{tg}(\alpha)} + f_T]$$

↑
0,133

Speed (km/h)	Radius of curve (m)
16	15
32	60
48	135
64	240
80	375
96	540



Le curve delle taxiway (2)

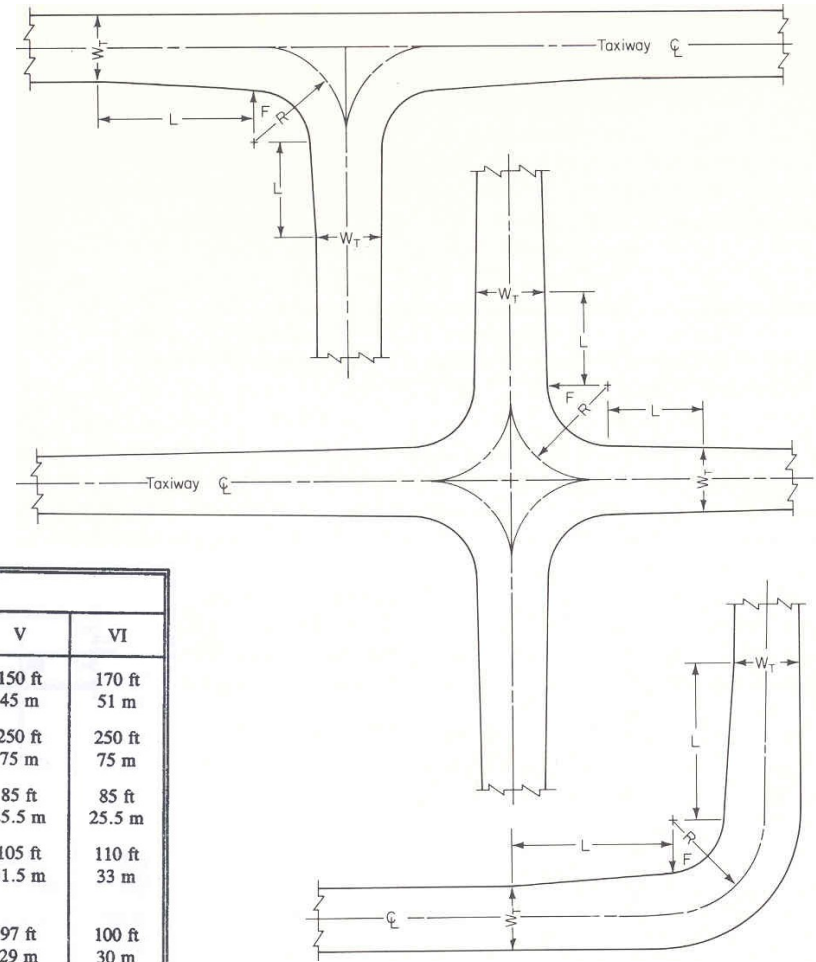
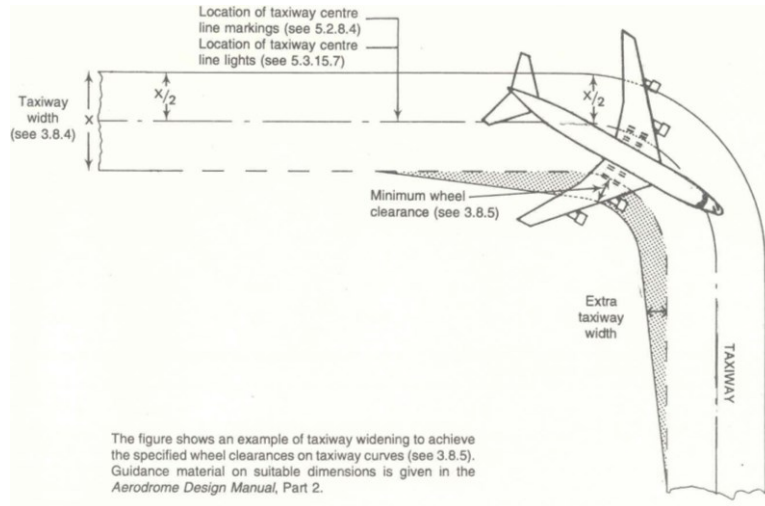


Aircraft model	Maximum steering angle	Approx. maximum steering angle during 180° turn
Lear 55	55°	40°
F28-2000	76°	45°
MD80	82°	65°
Concorde	60°	85°
MD11	70°	60°
B747	70°	50°

Code letter	Aircraft model	Outer main gear wheel span (m)	Main gear to cockpit (m)	Radius of curvature (m)
A	Lear 55	4.5	5.7	11.875
B	F28-2000	6.0	11.9	16.75
C	MD80	9.0	20.3	22.0
C	Concorde	9.0	29.6	22.0
D	MD11	14.0	31.0	33.25
E	B747	14.0	28.0	40.0

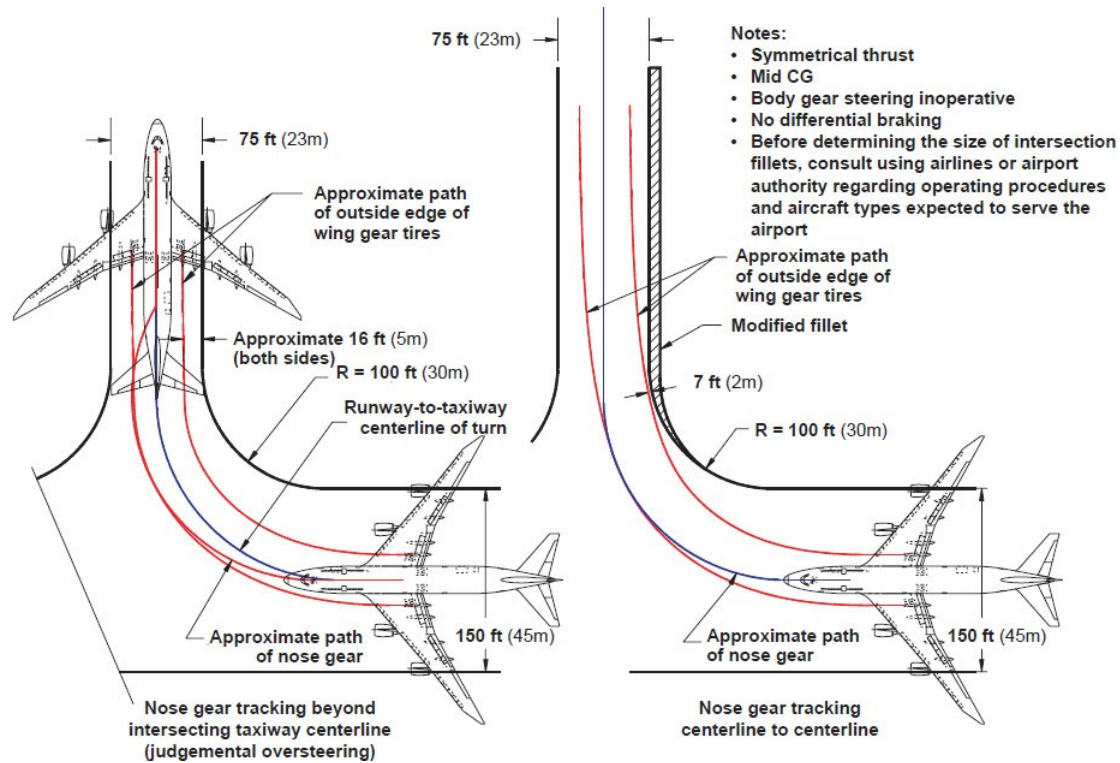
Code letter	Radius (m)	Velocity $V = 4.1120 (R^{1/2})$ (km/h)
A	11.875	14.17
B	16.75	16.83
C	22.0	19.29
D	33.25	23.71
E	40.0	26.01

I raccordi planimetrici nelle taxiway (1)

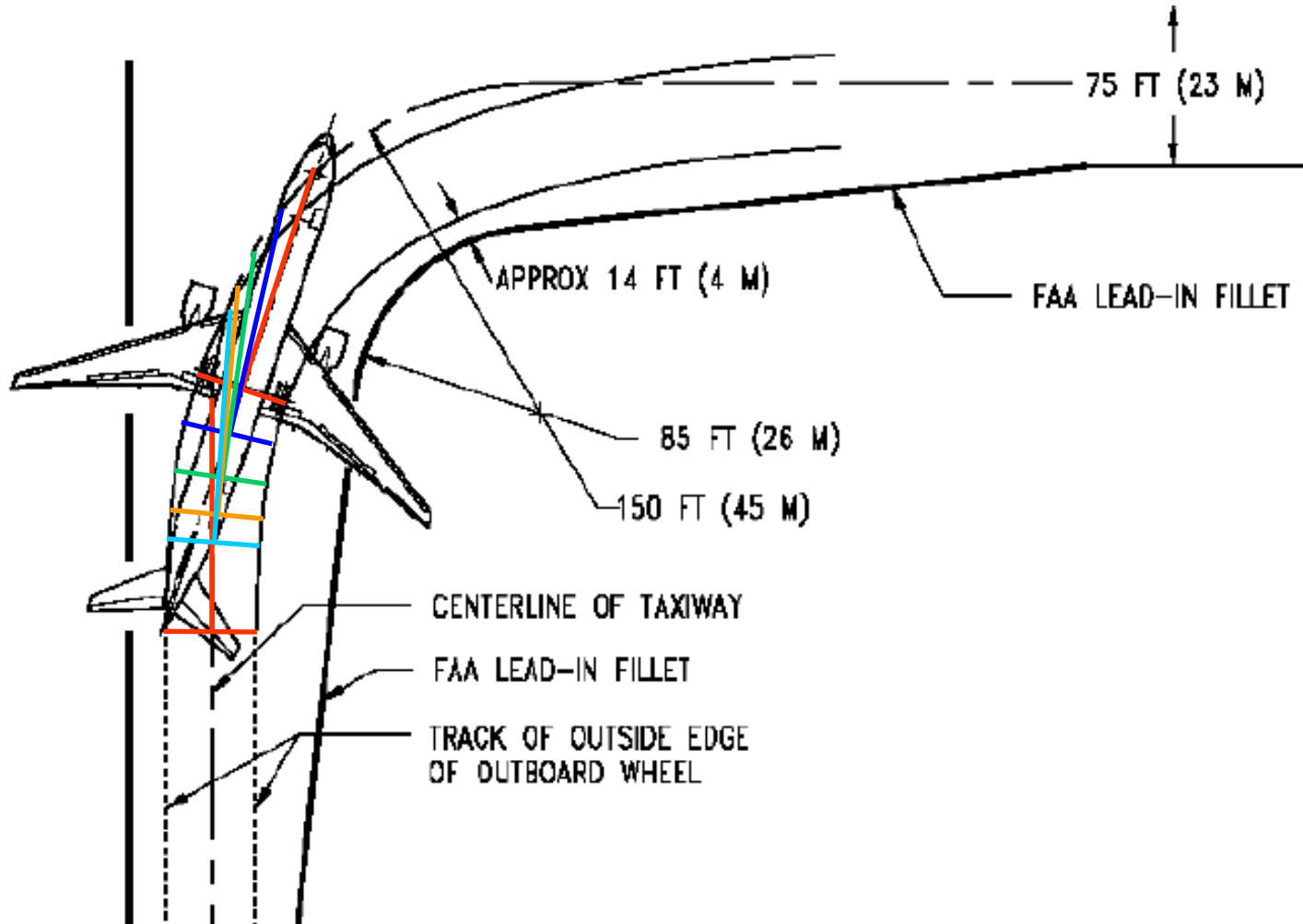


ITEM	DIM 1/	AIRPLANE DESIGN GROUP					
		I	II	III 2/	IV	V	VI
Radius of Taxiway Turn 3/	R	75 ft 22.5 m	75 ft 22.5 m	100 ft 30 m	150 ft 45 m	150 ft 45 m	170 ft 51 m
Length of Lead-in to Fillet	L	50 ft 15 m	50 ft 15 m	150 ft 45 m	250 ft 75 m	250 ft 75 m	250 ft 75 m
Fillet Radius for Tracking Centerline	F	60 ft 18 m	55 ft 16.5 m	55 ft 16.5 m	85 ft 25.5 m	85 ft 25.5 m	85 ft 25.5 m
Fillet Radius for Judgmental Oversteering Symmetrical Widening 4/	F	62.5 ft 18.75 m	57.5 ft 17.25 m	68 ft 20.4 m	105 ft 31.5 m	105 ft 31.5 m	110 ft 33 m
Fillet Radius for Judgmental Oversteering One Side Widening 5/	F	62.5 ft 18.75 m	57.5 ft 17.25 m	60 ft 18 m	97 ft 29 m	97 ft 29 m	100 ft 30 m

I raccordi planimetrici nelle taxiway (1)



I raccordi planimetrici nelle taxiway (2)



Le bretelle di uscita rapida (1)

Codice numerico	R [m]	V [km/h]
3, 4	550	93
1,2	275	65

$$\frac{V^2}{R} = 127,133 \cdot f_T$$

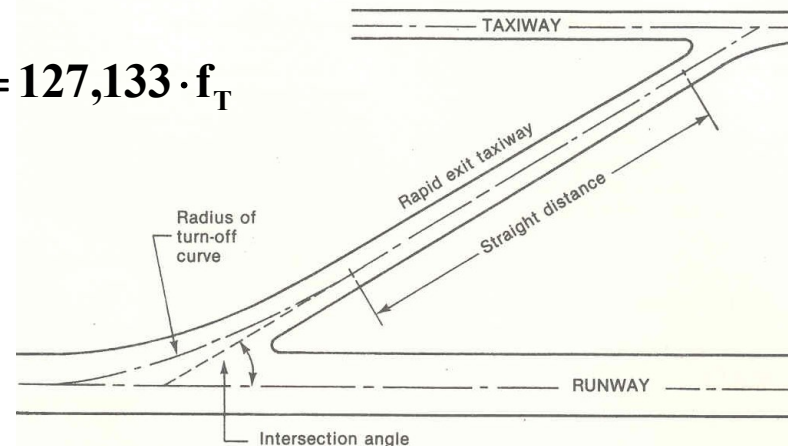
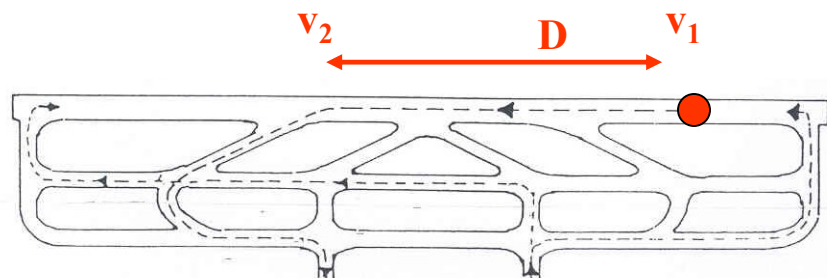


Table 1-11. Accumulated rapid exit usage by distance from threshold (metres)

Aircraft category	50%	60%	70%	80%	90%	95%	100%
A	1 170	1 320	1 440	1 600	1 950	2 200	2 900
B	1 370	1 480	1 590	1 770	2 070	2 300	3 000
C	1 740	1 850	1 970	2 150	2 340	2 670	3 100
D	2 040	2 190	2 290	2 480	2 750	2 950	4 000

$$D = \frac{v_1^2 - v_2^2}{2 \cdot d}$$

$$d = 1,52 \text{ m/s}^2$$

nei rettilinei

$$d = 0,76 \text{ m/s}^2$$

nelle curve

Le bretelle di uscita rapida (2)

Programma REDIM al sito www.atsl.cce.vt.edu/index.htm

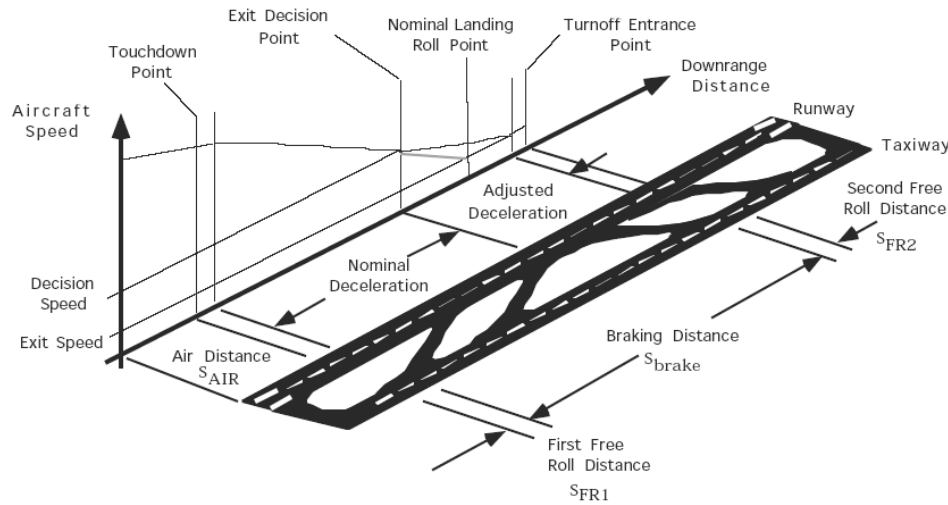
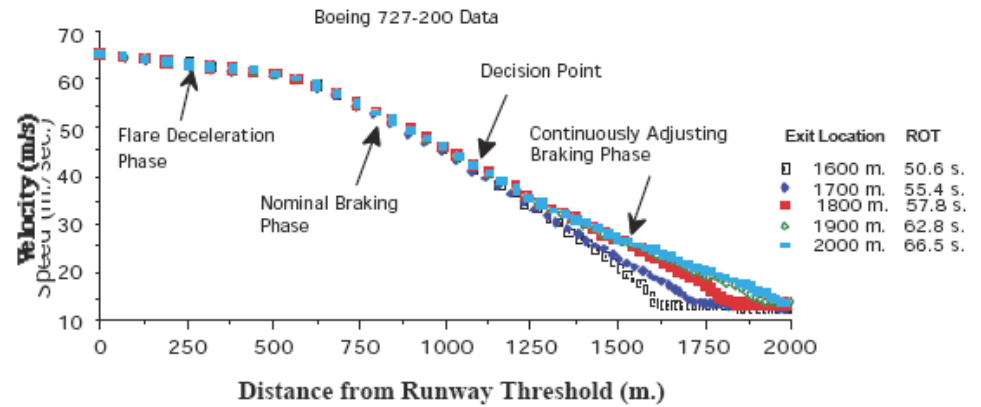


Figure 1.1 Aircraft Landing Segmentation.



Le bretelle di uscita rapida (3)

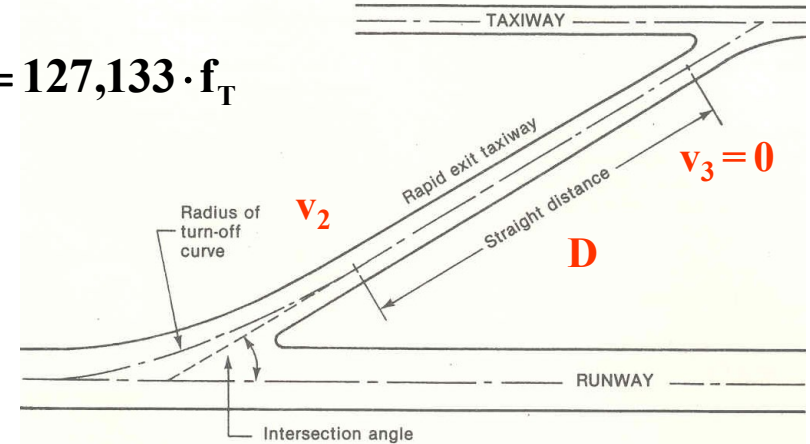
Codice numerico	R [m]	V [km/h]
3, 4	550	93
1,2	275	65

$$\frac{V^2}{R} = 127,133 \cdot f_T$$

$$D = \frac{v_1^2 - v_2^2}{2 \cdot d} \quad d = 1,52 \text{ m/s}^2$$

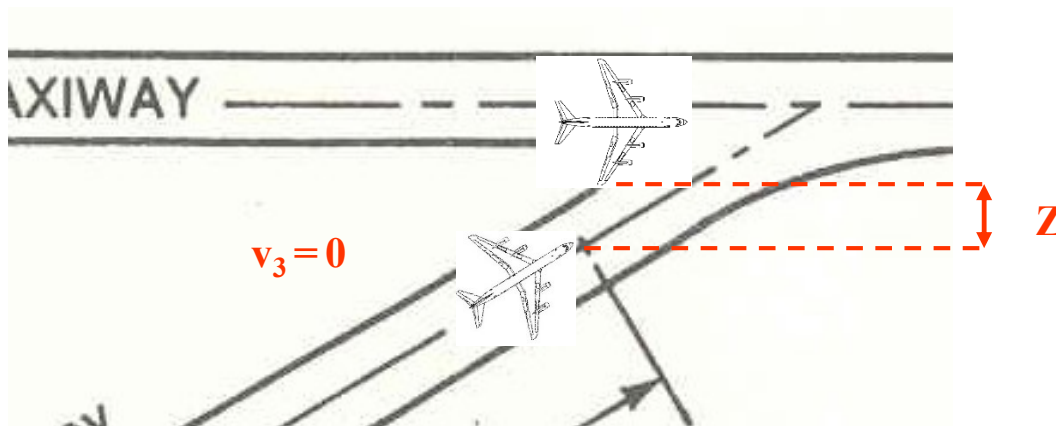
$$d = 0,76 \text{ m/s}^2$$

nei rettilinei
nelle curve



Dmin = 35 m per codici 1,2

Dmin = 75 m per codici 3,4



Le bretelle di uscita rapida (4)

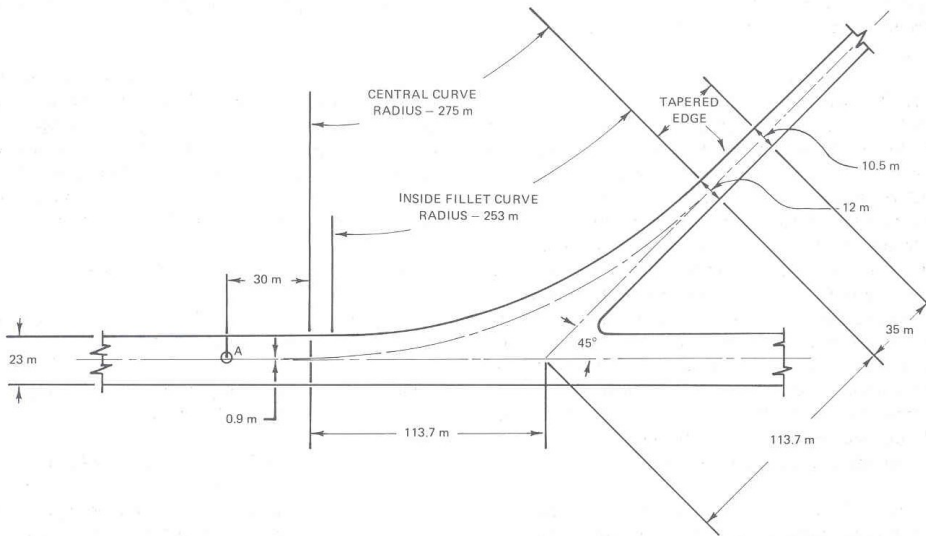


Figure 1-8. Design for rapid exit taxiways (code number 1 or 2)

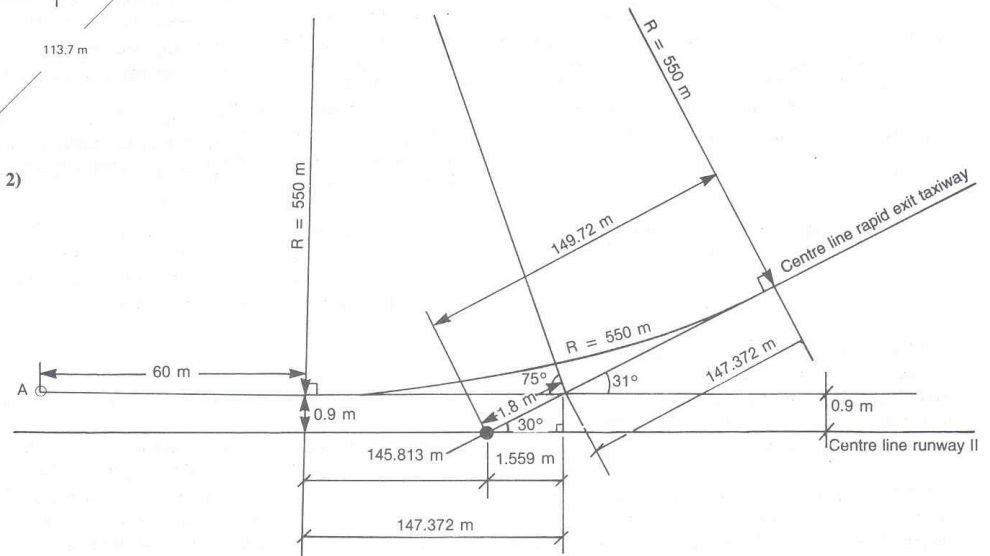
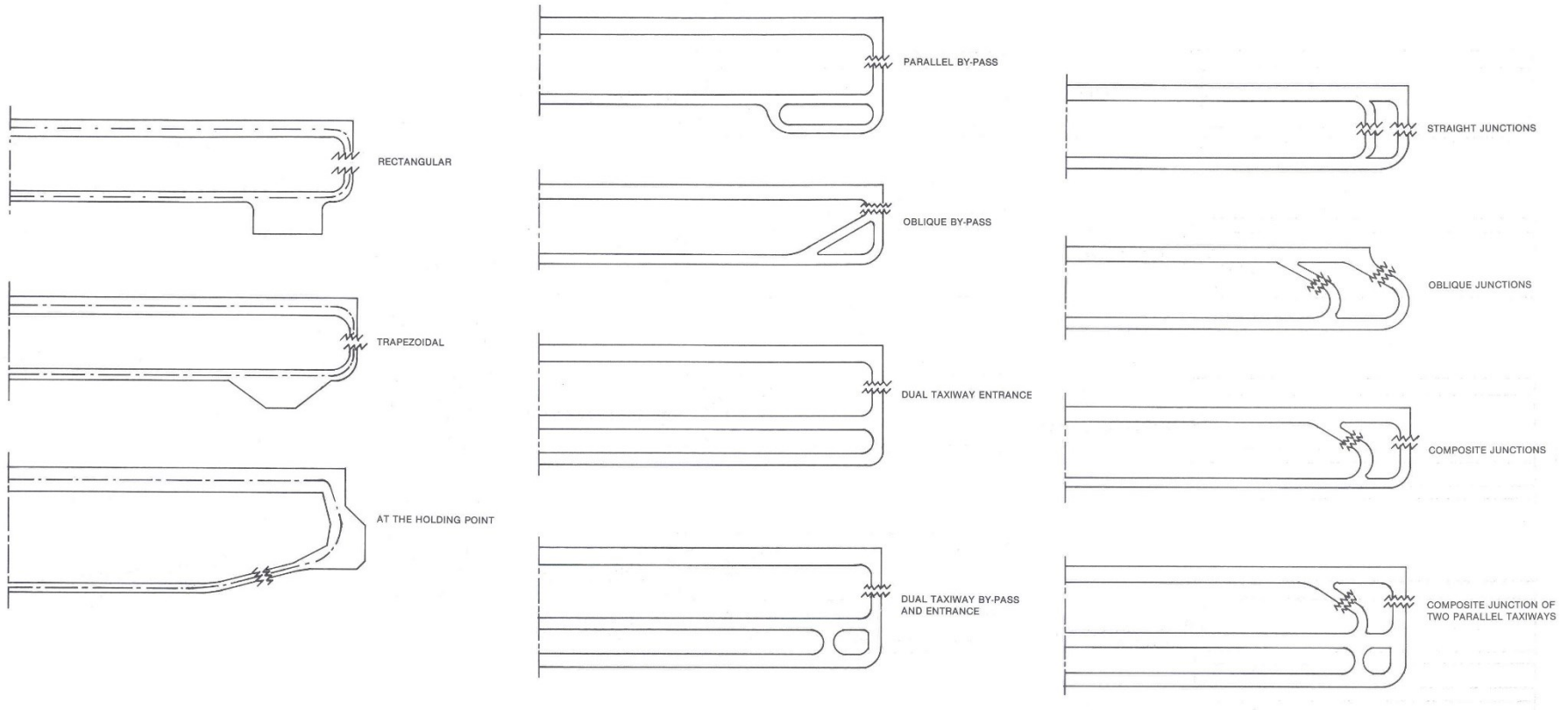


Figure 1-7. Design for rapid exit taxiways (code number 3 or 4)

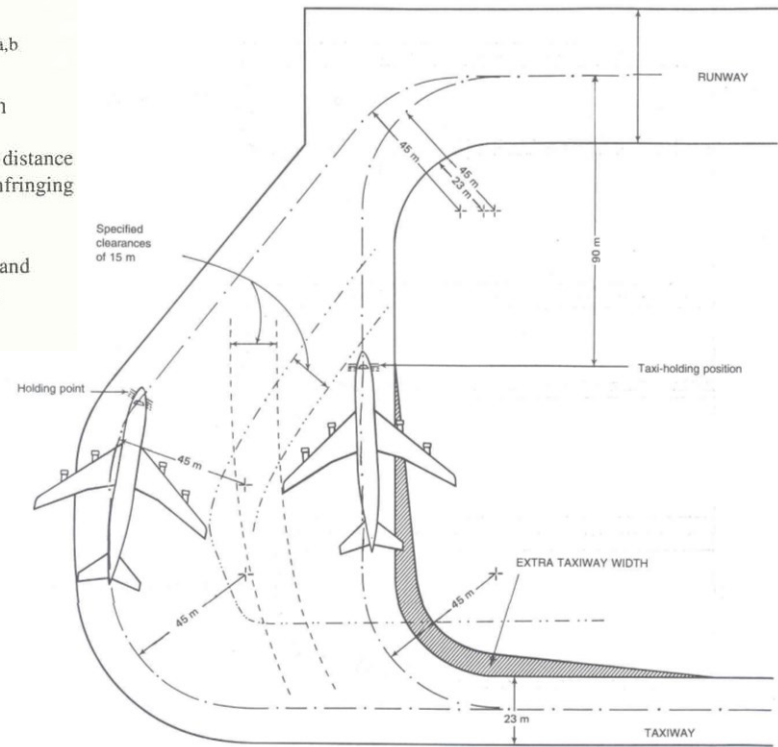
Le aeree di attesa (1)



Le aeree di attesa (2)

Type of runway	Code number			
	1	2	3	4
Non-instrument	30 m	40 m	75 m	75 m
Non-precision approach	40 m	40 m	75 m	75 m
Precision approach category I	60 m ^b	60 m ^b	90 m ^{a,b}	90 m ^{a,b}
Precision approach categories II and III	–	–	90 m ^{a,b}	90 m ^{a,b}
Take-off runway	30 m	40 m	75 m	75 m

- a. If a holding bay, taxi-holding position or road-holding position is at a lower elevation compared to the threshold, the distance may be decreased 5 m for every metre the bay or holding position is lower than the threshold, contingent upon not infringing the inner transitional surface.
- b. This distance may need to be increased to avoid interference with radio navigation aids, particularly the glide path and localizer facilities. Information on critical and sensitive areas of ILS and MLS is contained in Annex 10, Volume I, Attachments C and G to Part I, respectively (see also 3.11.5).



Esercitazione (1)

USO DEI DIAGRAMMI DI PRESTAZIONE PER IL CALCOLO DELLA LUNGHEZZA DI PISTA AL DECOLLO E ALL'ATTERRAGGIO

DATI:

Lunghezza pista: 3000 m

Quota di riferimento dell'aeroporto: 12,5 m s.l.m

Temperatura di riferimento dell'aeroporto: 28,6 ° C

Pendenza longitudinale della pista. Vedi profilo allegato

AEREI	Peso al decollo [kg]	Peso all'atterraggio [kg]	Velocità in soglia [km/h]
MD80	67.000	55.000	250
ATR42	14.500	-	200
BAE 146/300	44.000	38.000	200

DETERMINARE: Lunghezza base della pista; Classe ICAO dell'aeroporto; verificare il profilo in funzione della classe ICAO; Distanze dichiarate; distanze richieste per ogni aereo; verifica delle uscite per i vari aerei;

Le problematiche dell'area terminale

- Capacità, adeguata alla domanda **TERMINAL**
- Distanze pedonali limitate
- Ambiente piacevole e comodo
- Servizi disponibili e vicini
- Sicurezza

**PIAZZALI
(APRON)**



ACCESSI

Tipologie dei terminal

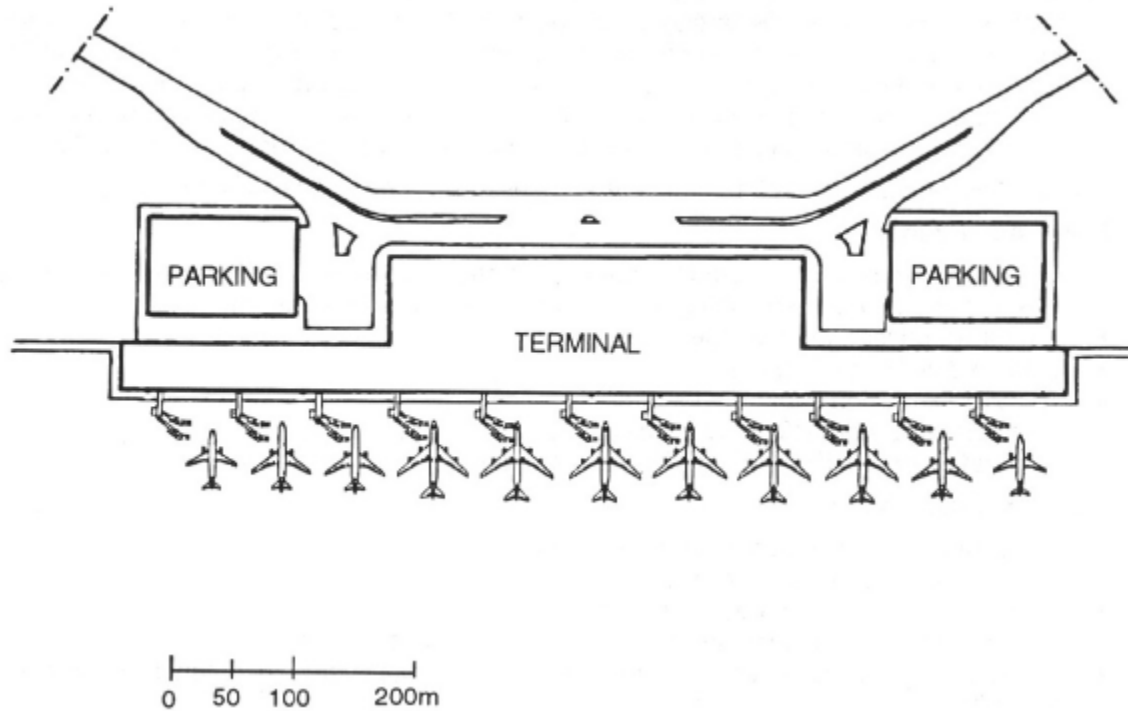
DISTRIBUZIONE ORIZZONTALE:

- **Lineare**
- **Moli**
- **Satellite**
- **Piazzale aperto (Transporter)**

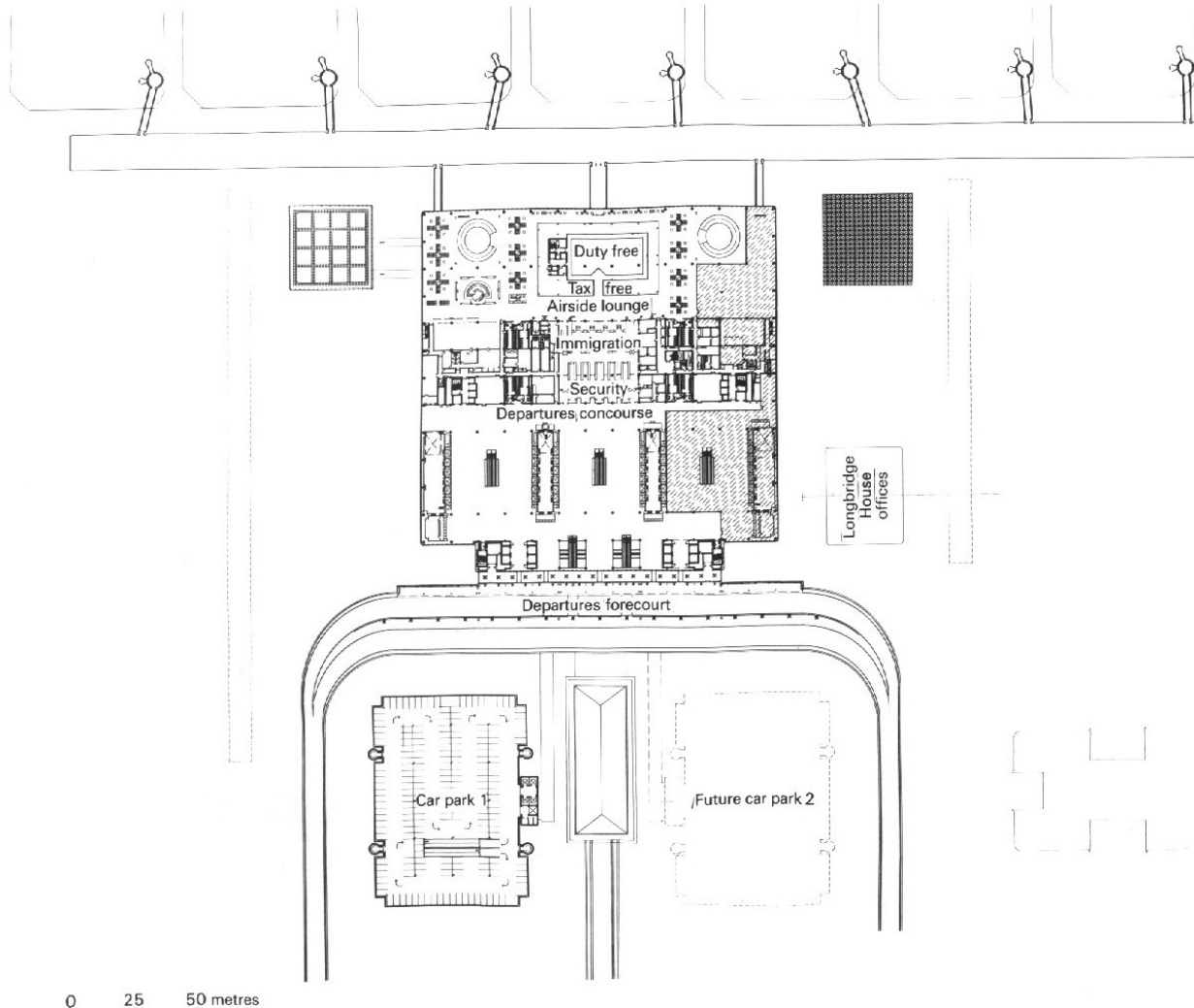
DISTRIBUZIONE VERTICALE

- **Piano singolo**
- **Un piano e mezzo**
- **Due piani**

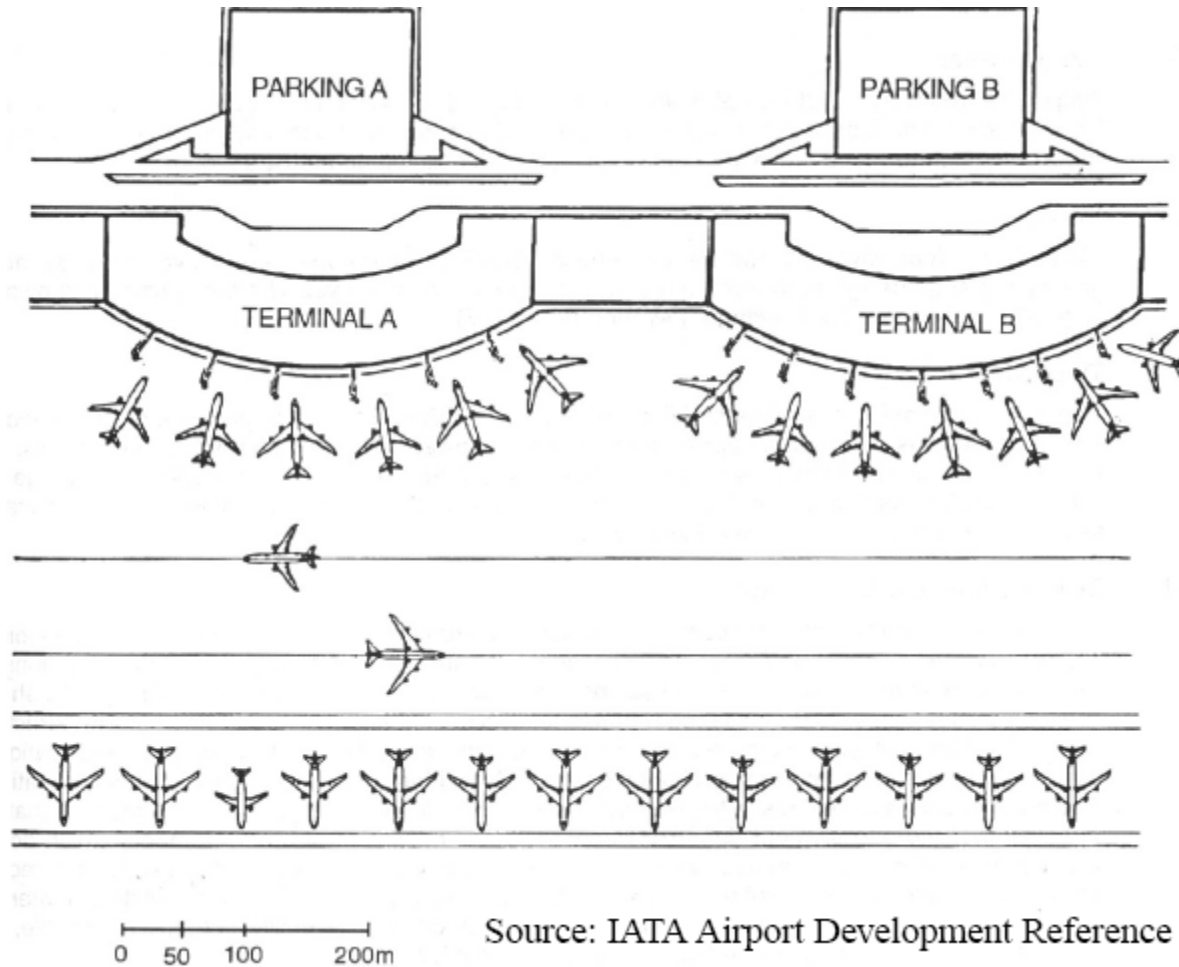
Terminal lineare centralizzato



Terminal lineare centralizzato

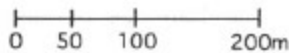
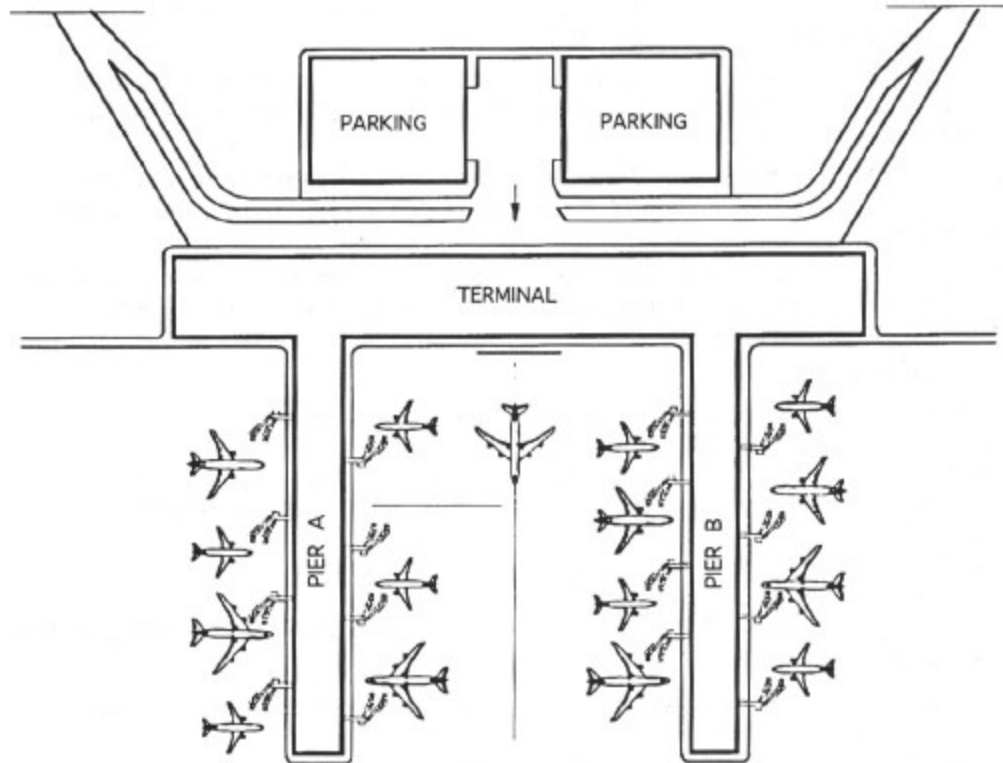


Terminal lineare semi-centralizzato



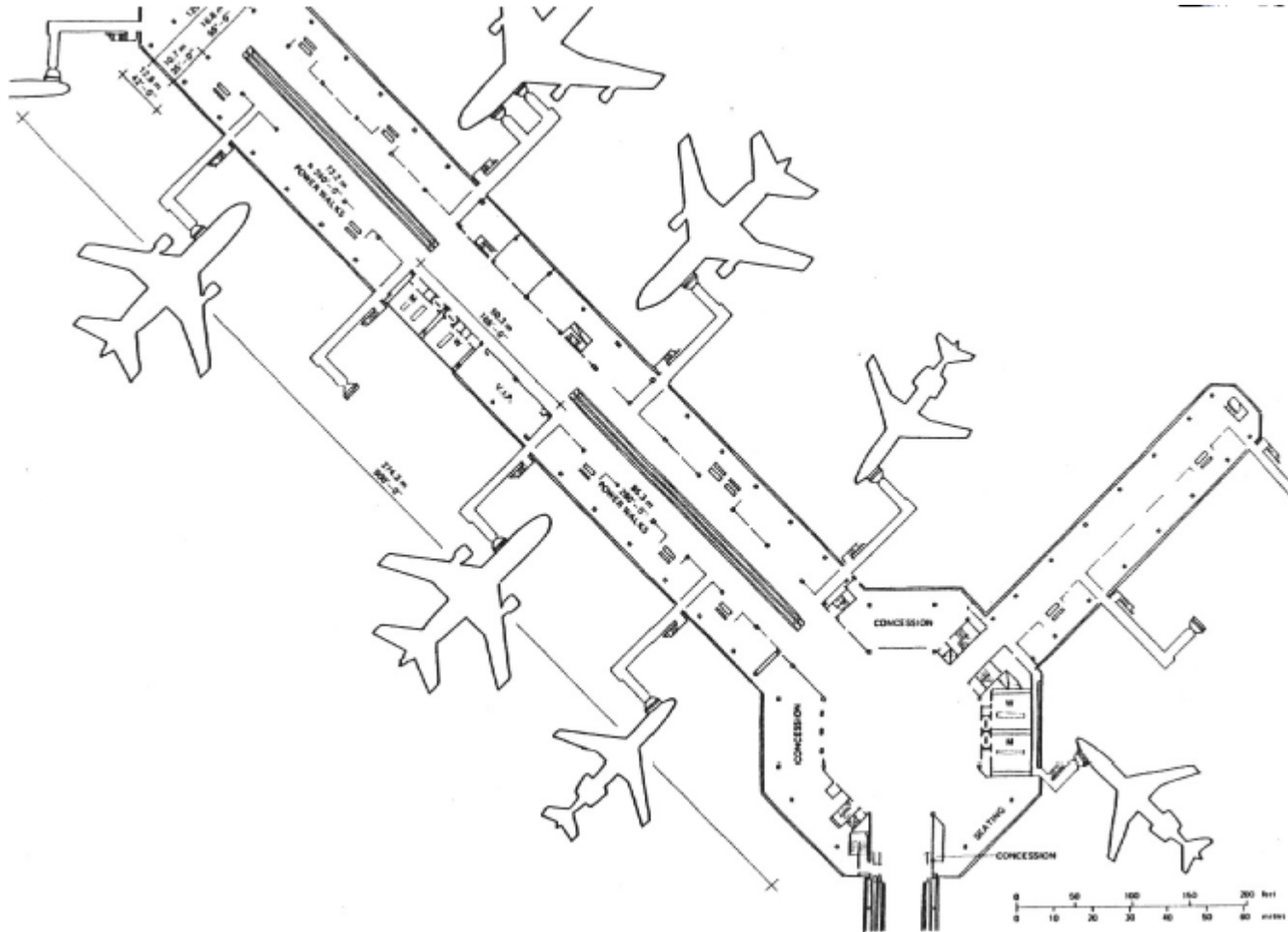
Source: IATA Airport Development Reference Manual

Terminal centralizzato con moli (1)

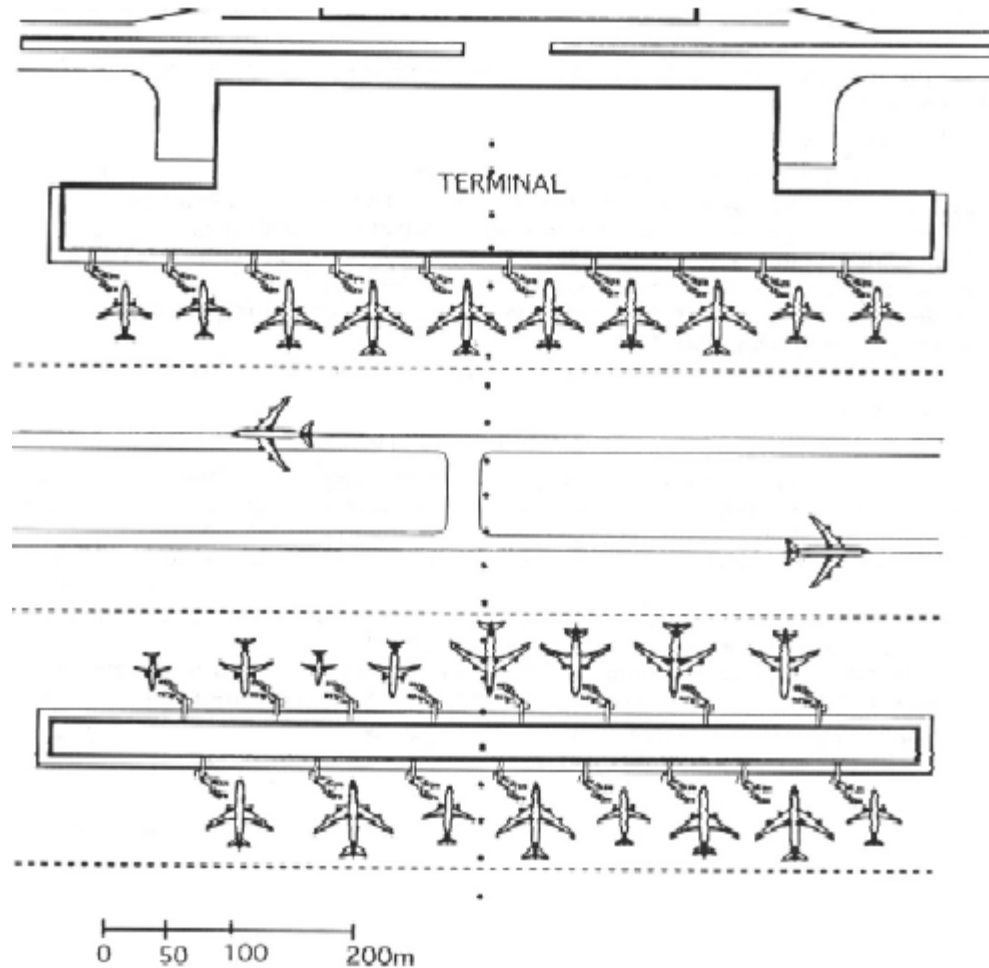


Source: IATA Airport Development Reference Manual

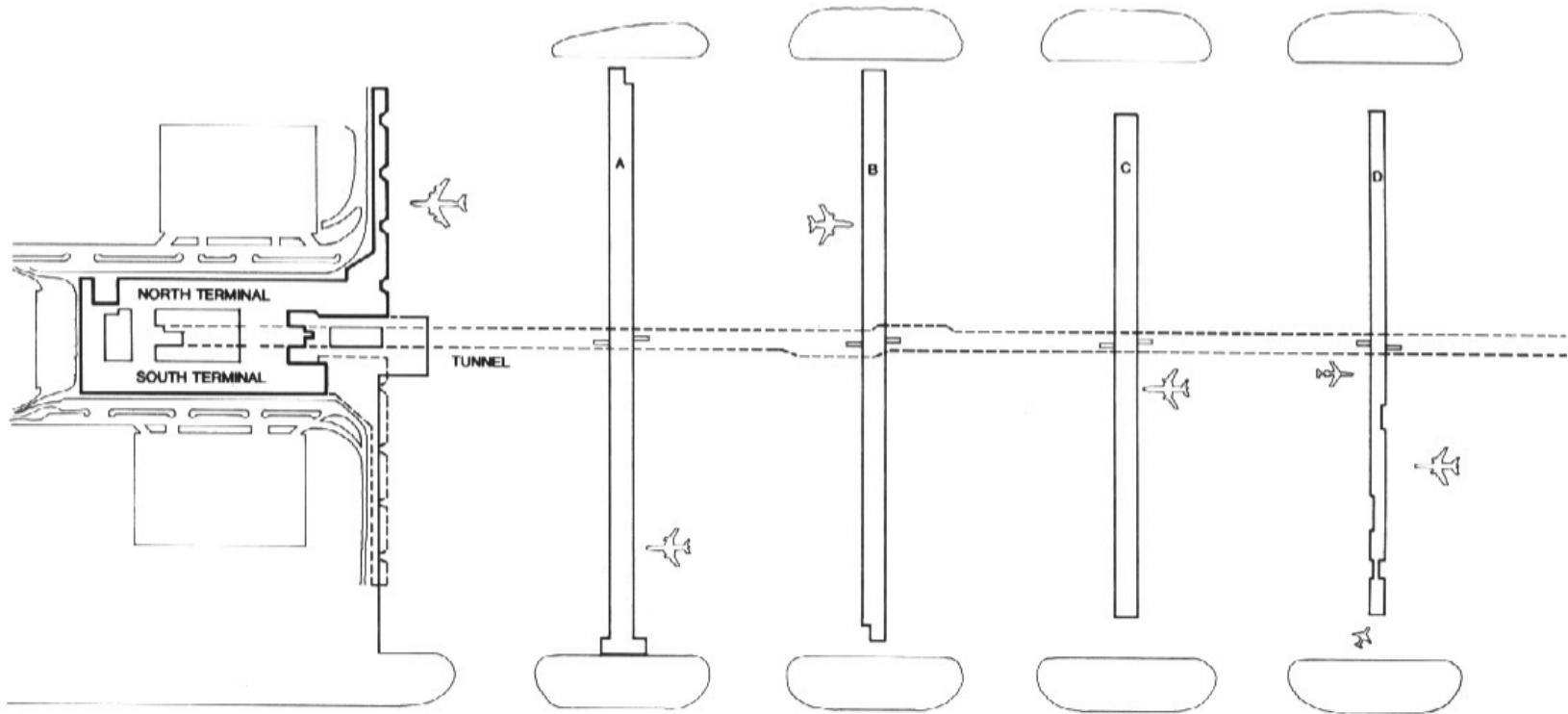
Terminal centralizzato con moli (2)



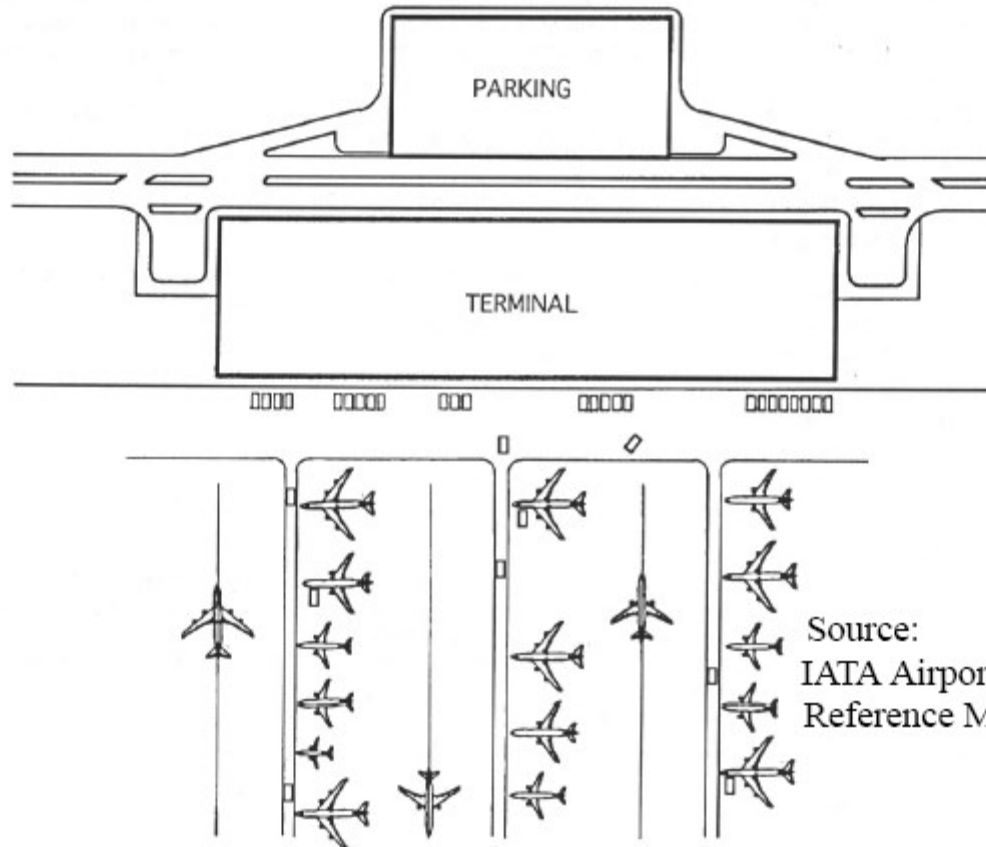
Terminal a satellite (1)



Terminal a satellite (2)

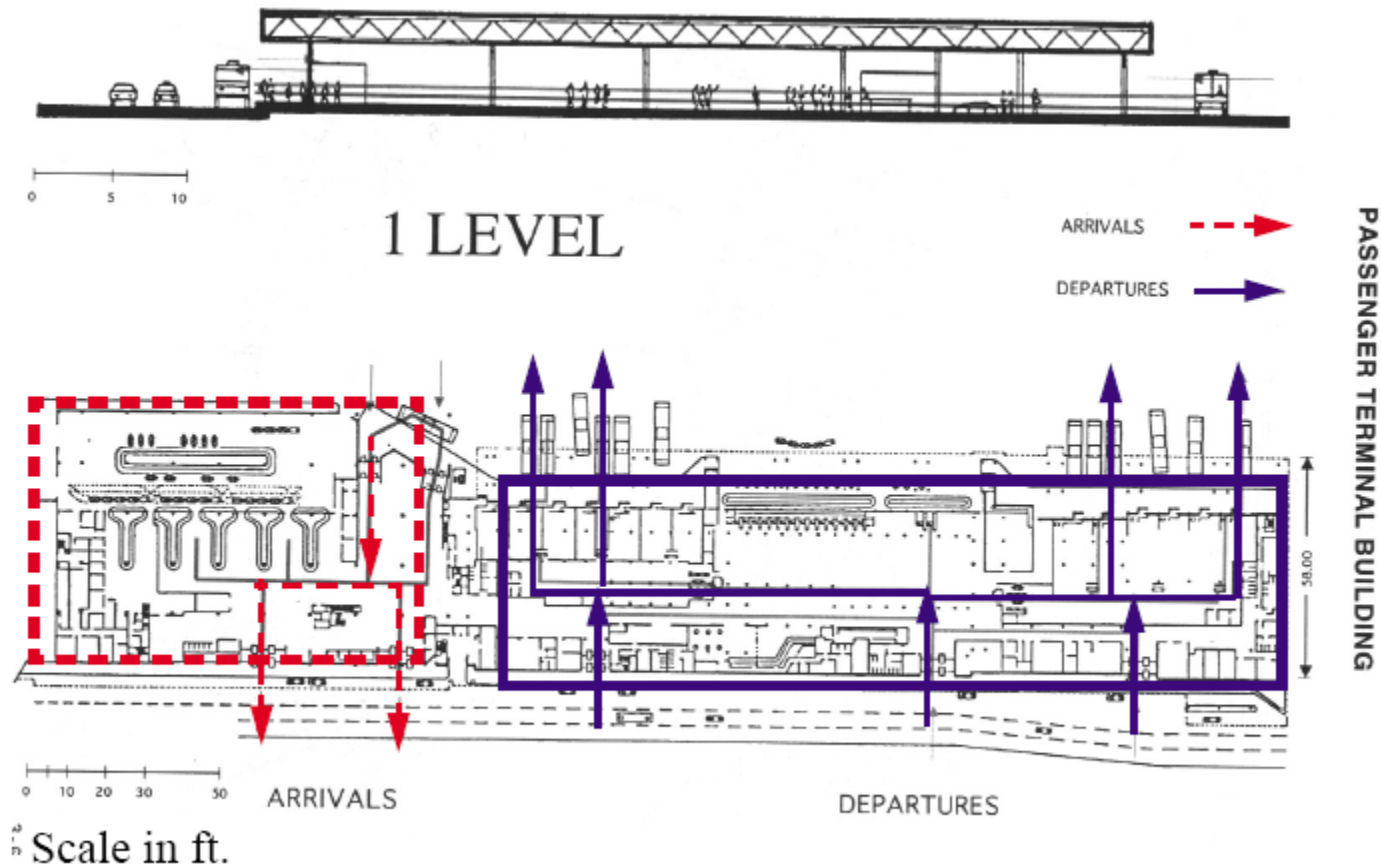


Transporter con terminal centrale



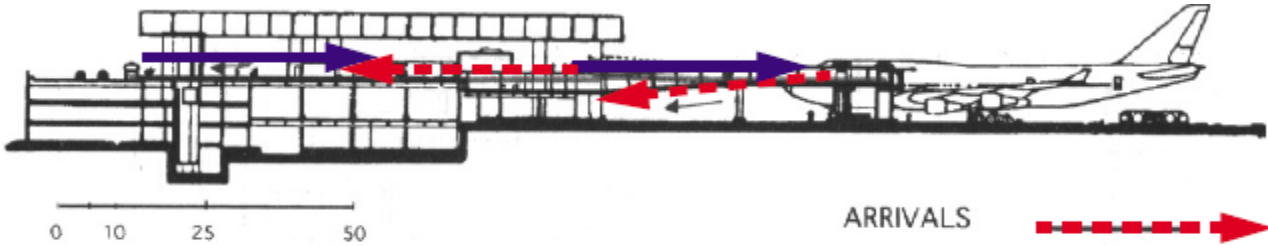
Source:
IATA Airport Development
Reference Manual

Terminal ad un piano

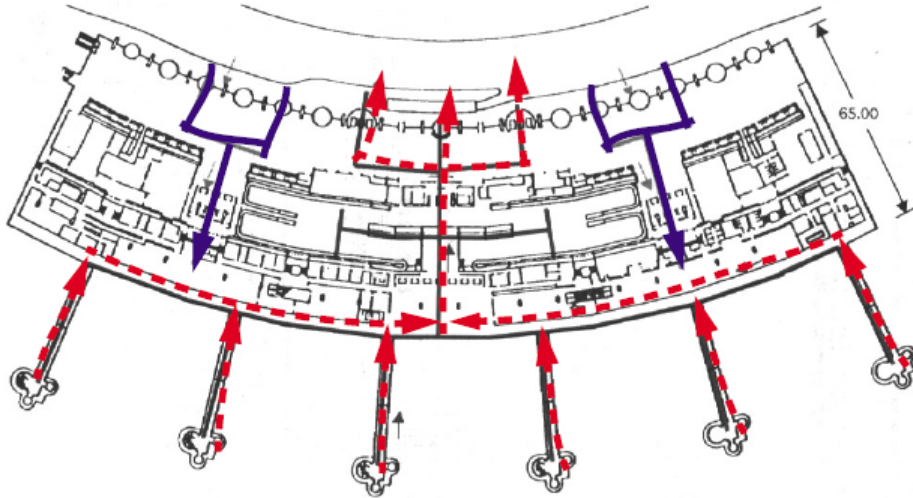


Source: IATA Airport Development Reference Manual

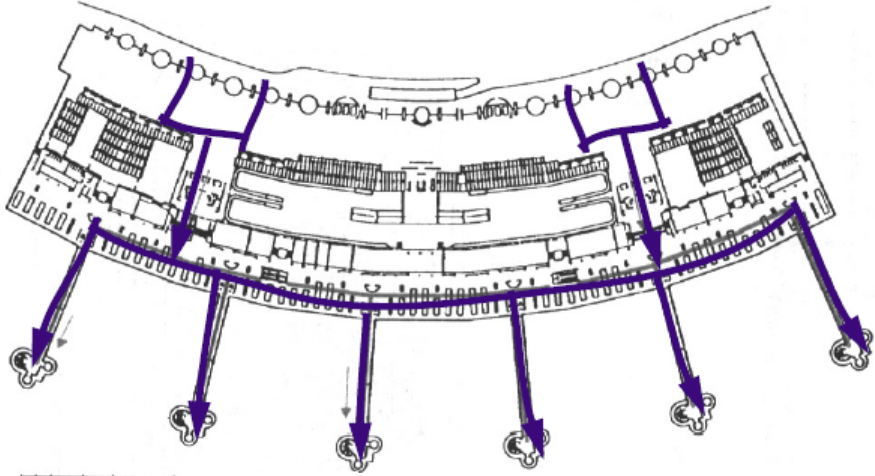
Terminal ad un piano e mezzo



ARRIVALS 
 DEPARTURES 



Arriving Passenger Flows 
 Departing Passenger Flows 



Scale in ft.

Departing Passenger Flows 

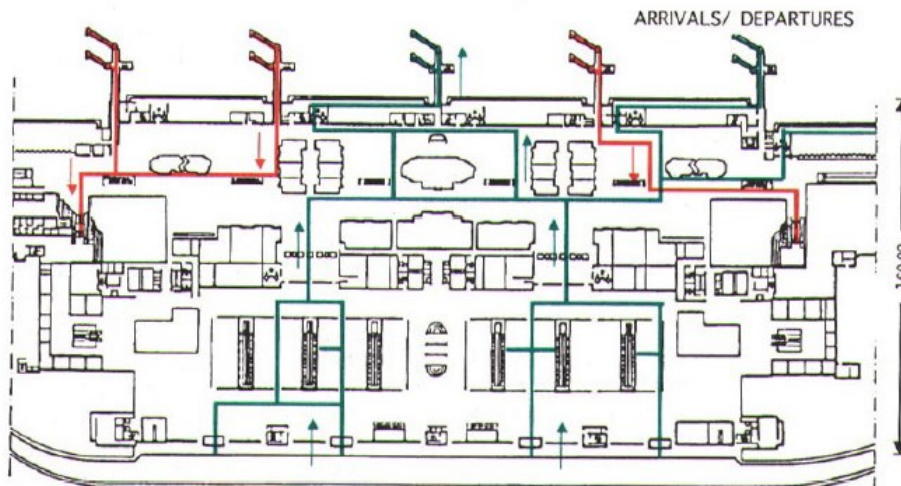
Terminal a due piani



0 10 25 50

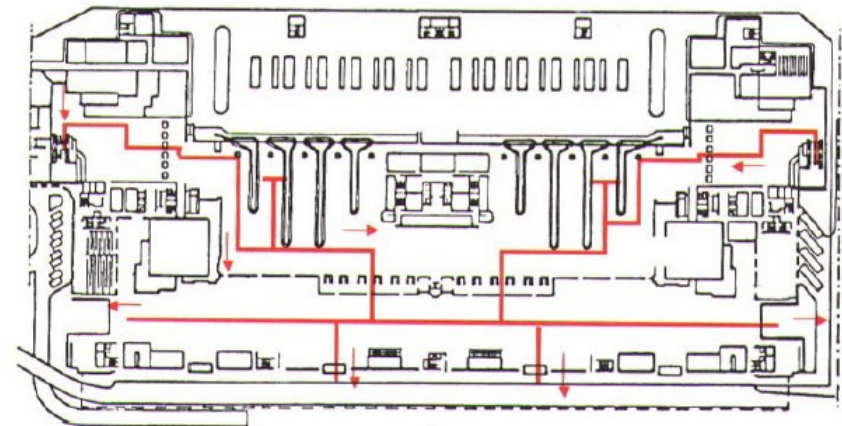
Scale in ft.

ARRIVALS ———
DEPARTURES ———



0 20 50

Departing Passenger Flows ———→
Arriving Passenger Flows ———→



0 20 50

ARRIVALS
Arriving Passenger Flows ———→

Numero di Stalli

u = fattore di utilizzazione (0 – 1)

N = numero stalli necessari

m_i = % di aerei del gruppo i che opera sull'aeroporto

T_i = tempo di servizio del gate per l'aereo di tipo i

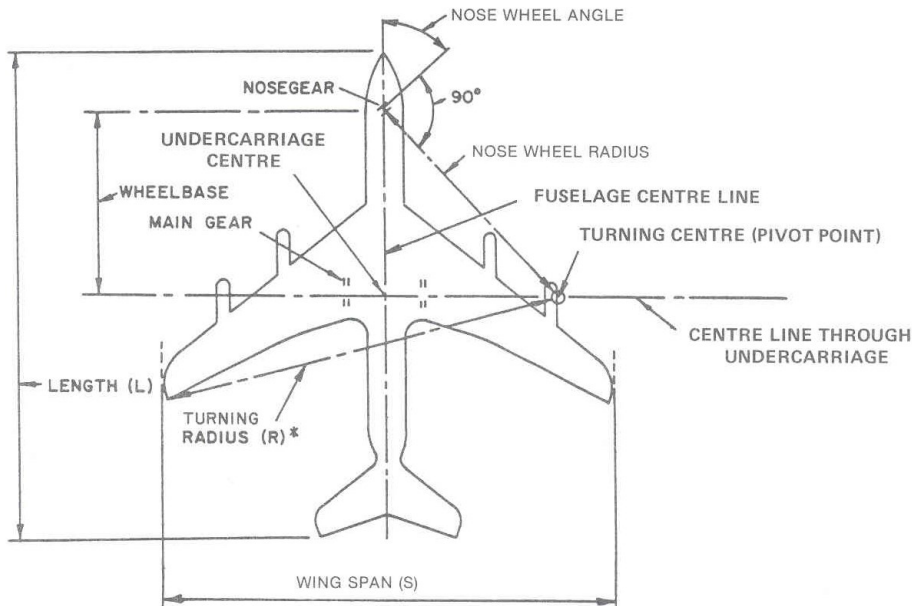
C = domanda richiesta all'aeroporto (Aerei/ora)

α = riserva

$$N = \left(\sum_i m_i \cdot \frac{T_i}{60 \cdot u} \right) \cdot C + \alpha$$

Aircraft	Through flight	Domestic		International Turnaround flight	Group	Aircraft
		Turnaround flight	Turnaround flight			
B-737, DC-9, F-28	25	45	—	—	S	F-28, B-737
B-707, B-757	45	50	60	60	M	B-707-320, A-300, L-1011, DC-10
A300, DC-10, L-1011	45-60	60	120	120	L	B-747 SP, B-747
B-747	—	60	120-180	120-180	LL	B-747 II (future aircraft)

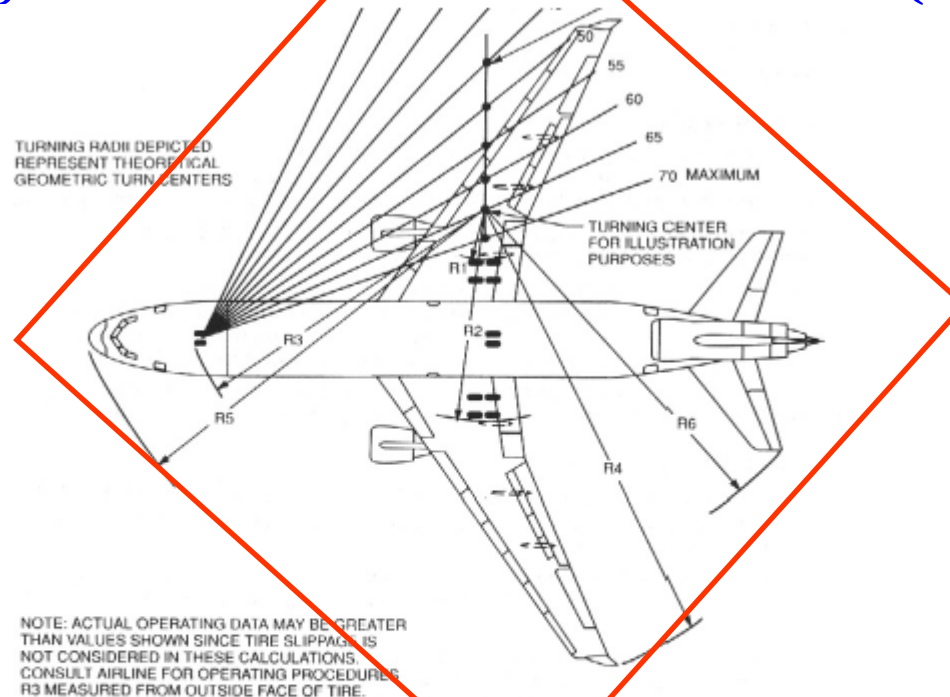
Ingombri statici e dinamici (1)



Aircraft type	Length (m)	Wing span (m)	Nose wheel angle	Turning radius (m)
A300B-B2	46.70	44.80	50°	38.80 ^a
B727-100	40.59	32.92	75°	21.90 ^c
B727-200	46.68	32.92	75°	25.00 ^c
B737-100	28.65	28.35	70°	18.40 ^a
B737-200	30.58	28.35	70°	18.70 ^a
B747	70.40	59.64	60°	60.20 ^a
B747-400	70.67	64.90		
B757	47.32	37.95	60°	27.90 ^a
B767	48.51	47.63	60°	36.00 ^a
BAC 111-400	28.50	27.00	65°	21.30 ^a
Caravelle	36.70	34.30	45°	29.00 ^a
Concorde	62.10	25.50	50°	30.10 ^c
DC8-40/50	45.95	43.41	70°	29.20 ^a
DC8-61/63	57.12	43.41/45.2	70°	32.70 ^c
DC9-10/20	31.82	27.25/28.5	75°	17.80 ^c
DC9-30	36.36	28.44	75°	20.40 ^c
DC9-40	38.28	28.44	75°	21.40 ^c
DC9-50	40.72	28.45	75°	22.50 ^c
DC9-80	45.02	32.85	75°	25.10 ^b
DC10-10	55.55	47.35	65°	35.60 ^a
DC10-30	55.35	50.39	65°	37.30 ^a
DC10-40	55.54	50.39	65°	36.00 ^a
L1011	54.15	47.34	60°	35.59 ^a
Vickers Viscount 800	26.10	28.60	50°	21.60 ^a

a To wing tip
b To nose
c To tail

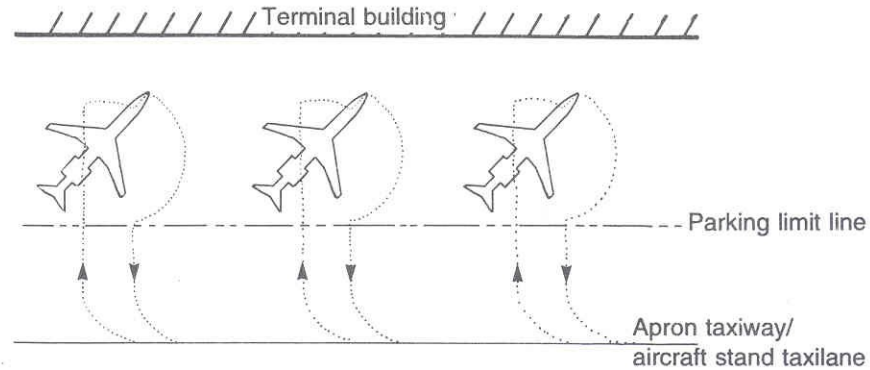
Ingombri statici e dinamici (2)



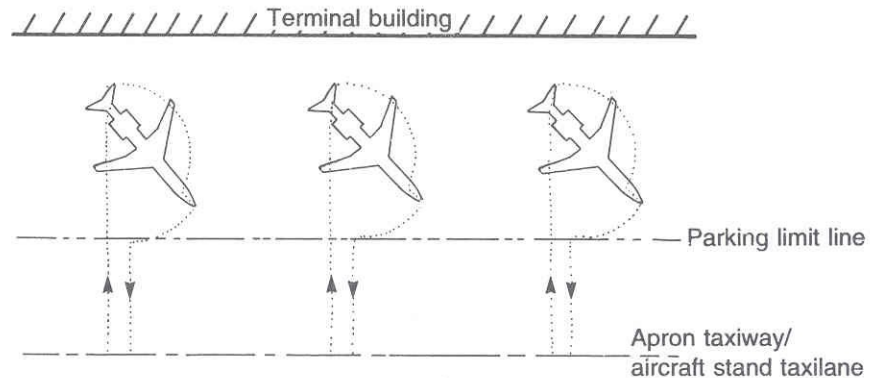
STEERING ANGLE (DEG)	R-1		R-2		R-3		R-4		R-5		R-6	
	FT	m	FT	m	FT	m	FT	m	FT	m	FT	m
25	153.7	46.8	194.9	59.4	194.0	59.1	222.8	80.0	205.7	62.7	220.2	67.1
30	120.2	36.6	161.4	49.2	164.3	50.1	229.5	69.9	178.2	54.0	189.5	57.8
35	95.5	29.1	136.7	41.7	143.5	43.7	205.2	62.5	159.4	48.6	167.7	51.2
40	76.3	23.2	117.5	35.8	120.2	39.1	186.4	56.8	145.9	44.5	151.3	46.1
45	60.7	18.5	101.9	31.1	116.8	35.6	171.2	52.2	136.1	41.5	136.5	42.2
50	47.6	14.5	88.8	27.1	107.8	32.9	158.5	48.3	128.7	39.2	128.3	39.1
55	36.3	11.1	77.5	23.6	100.9	30.8	147.6	45.0	123.1	37.5	119.9	36.6
60	26.3	8.0	67.6	20.6	95.6	29.1	138.0	42.0	118.8	36.2	112.9	34.4
65	17.3	5.3	58.5	17.8	91.4	27.9	129.4	39.4	115.8	35.2	107.0	32.6

Configurazione dei parcheggi (1)

a) Taxi-in/taxi-out
(angled nose-in parking)

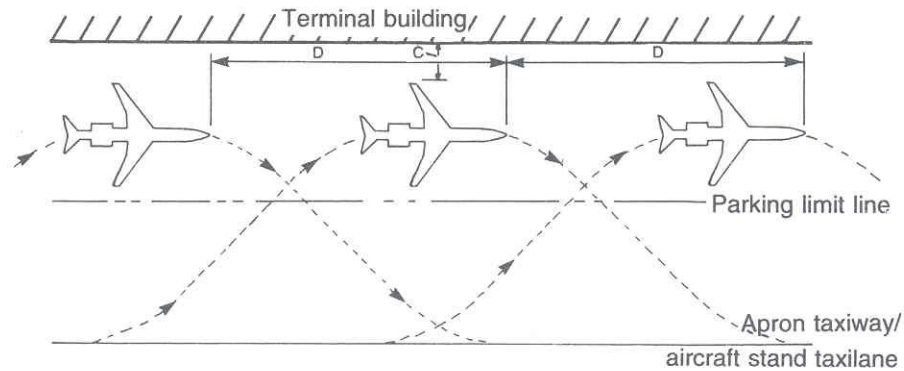


b) Taxi-in/taxi-out
(angled nose-out parking)

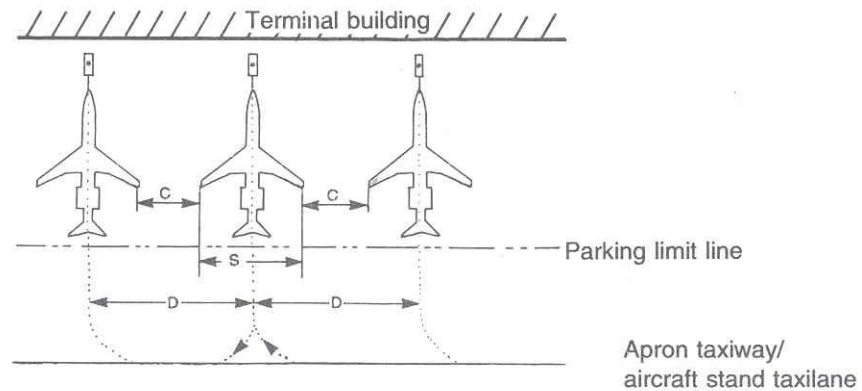


Configurazione dei parcheggi (2)

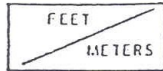
c) Taxi-in/taxi-out
(parallel parking)



d) Taxi-in/push-out

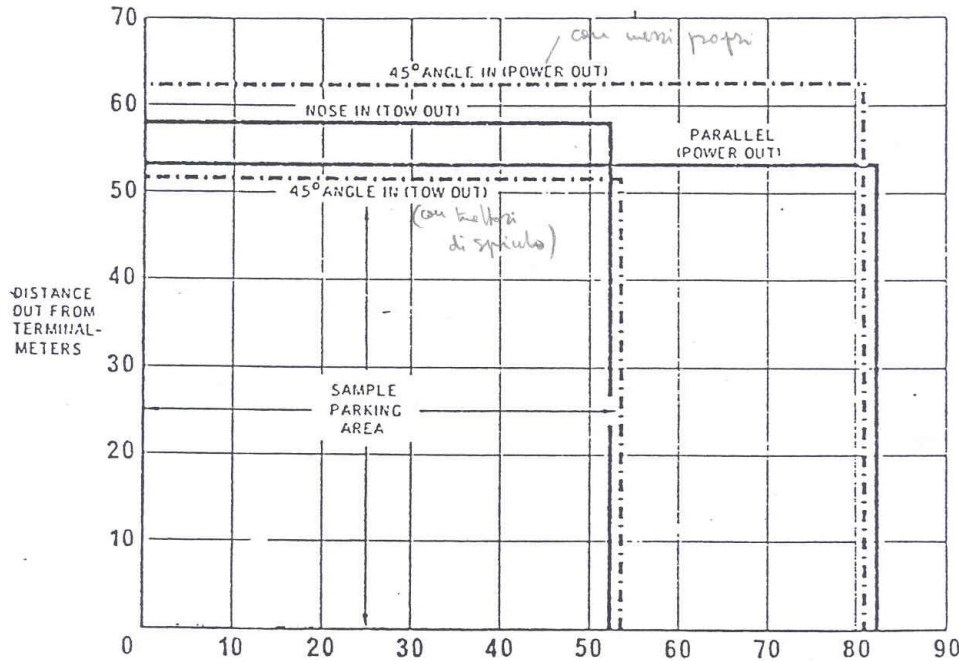


Dimensioni degli stalli e manovre (1)



EFFECTIVE TURN ANGLE	X	Y	A	R3	R4	R5	R6
63° 64'	1.35	33.11	122.26	69.71	109.27	89.29	111.15
	18.70	10.09	37.26	21.25	33.31	27.21	33.88

ed i diagrammi dei minimi spazi richiesti:
(ad es. per il AB 300)~



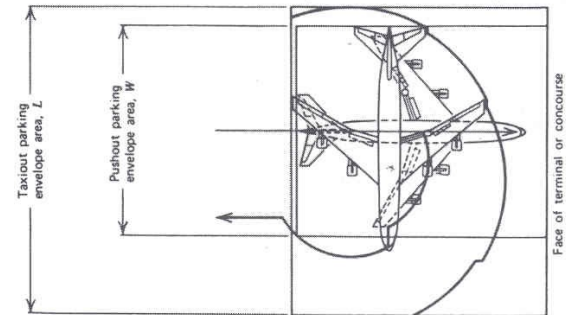
Aircraft Group	Push-out (ft., in.) ^f		Area (mq)	Taxi-out (ft., in.)		Area (mq)
	L ^d	W ^d		L ^d	W ^d	
A						
FH-227	103,1	115,2	1206	148,10	140,2	2119
YS-11B	106,3	124,11	1347	171,0	149,11	2606
BAC-111	123,6	113,6	1423	130,0	138,6	1829
DC-9-10	134,5	109,5	1494	149,2	134,5	2037
B						
DC-9-21,30	149,4	113,4	1719	149,0	138,4	2093
727 (all)	173,2	128,0	2252	194,0	153,0	3015
737 (all)	120,0	113,0	1378	145,4	138,0	2037
C						
B-707 (all)	172,11	165,9	2915	258,0	190,9	4999
B-720	156,9	150,10	2402	228,0	175,10	4072
DC-8-43,51	170,9	162,5	2817	211,10	187,5	4033
D						
DC-8-61,63	207,5	168,5	3549	252,4	193,5	4958
E						
L-1011	188,8	175,4	3361	263,6	200,4	5362
DC-10	192,3	185,4	3620	291,0	210,4	6218
F						
B-747	241,10	215,8	5298	328,0	240,8	8020

^fIncluding clearances of 20 ft wing tip to wing tip; nose to building: 30 ft, groups A and B; 20 ft, groups C and D; 10 ft, groups E and F.

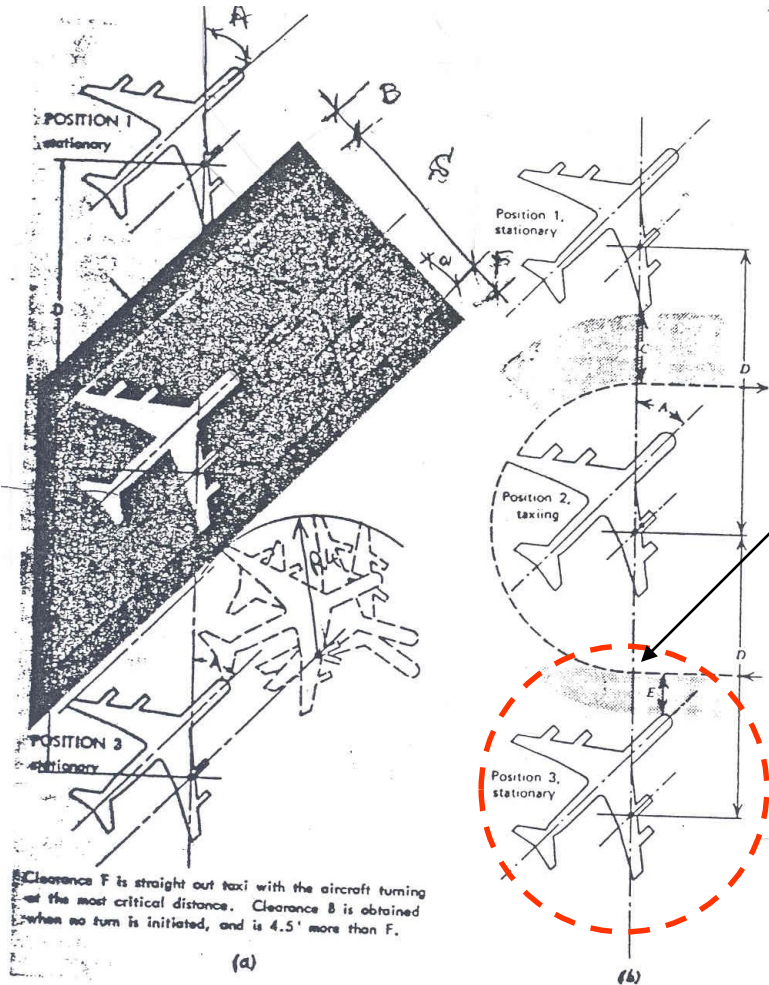
^gIncluding clearances of 20 ft to other aircraft and GSE, 45 ft.
^h1 ft = 0.3048 m.

^dLength and width are based on the largest dimension in the group of aircraft.

Source: *The Apron and Terminal Building Planning Report*, prepared for the FAA by Ralph M. Parsons Company, Report FAA-RD-75-191, July 1975 (rev. March 1976); and *Planning and Design Guidelines For Airport Terminal Facilities*, FAA Advisory Circular AC 150/5360-13, April 22, 1988.



Dimensioni degli stalli e manovre (2)

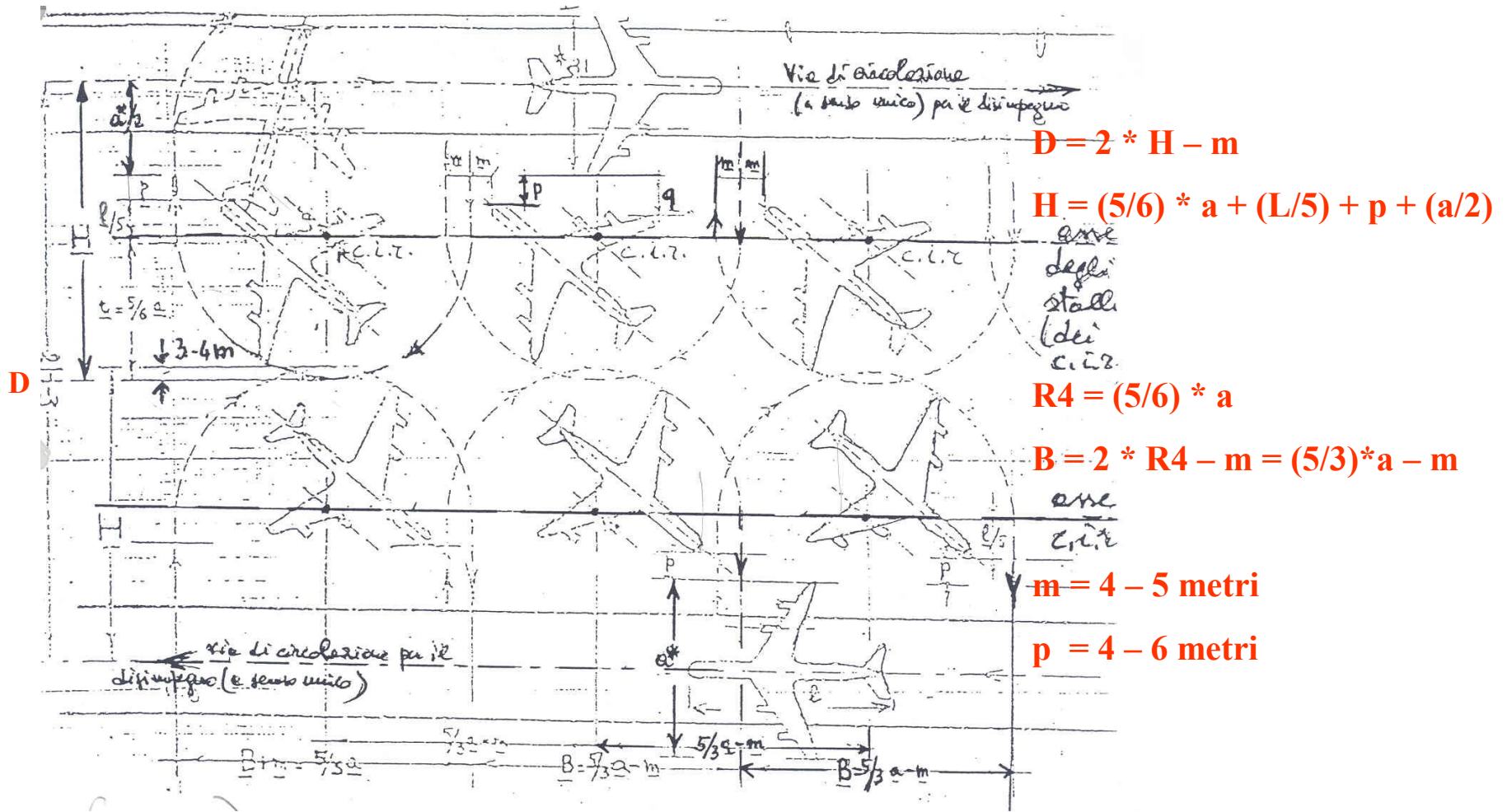


$$B = D * \text{sen}(A) - S$$

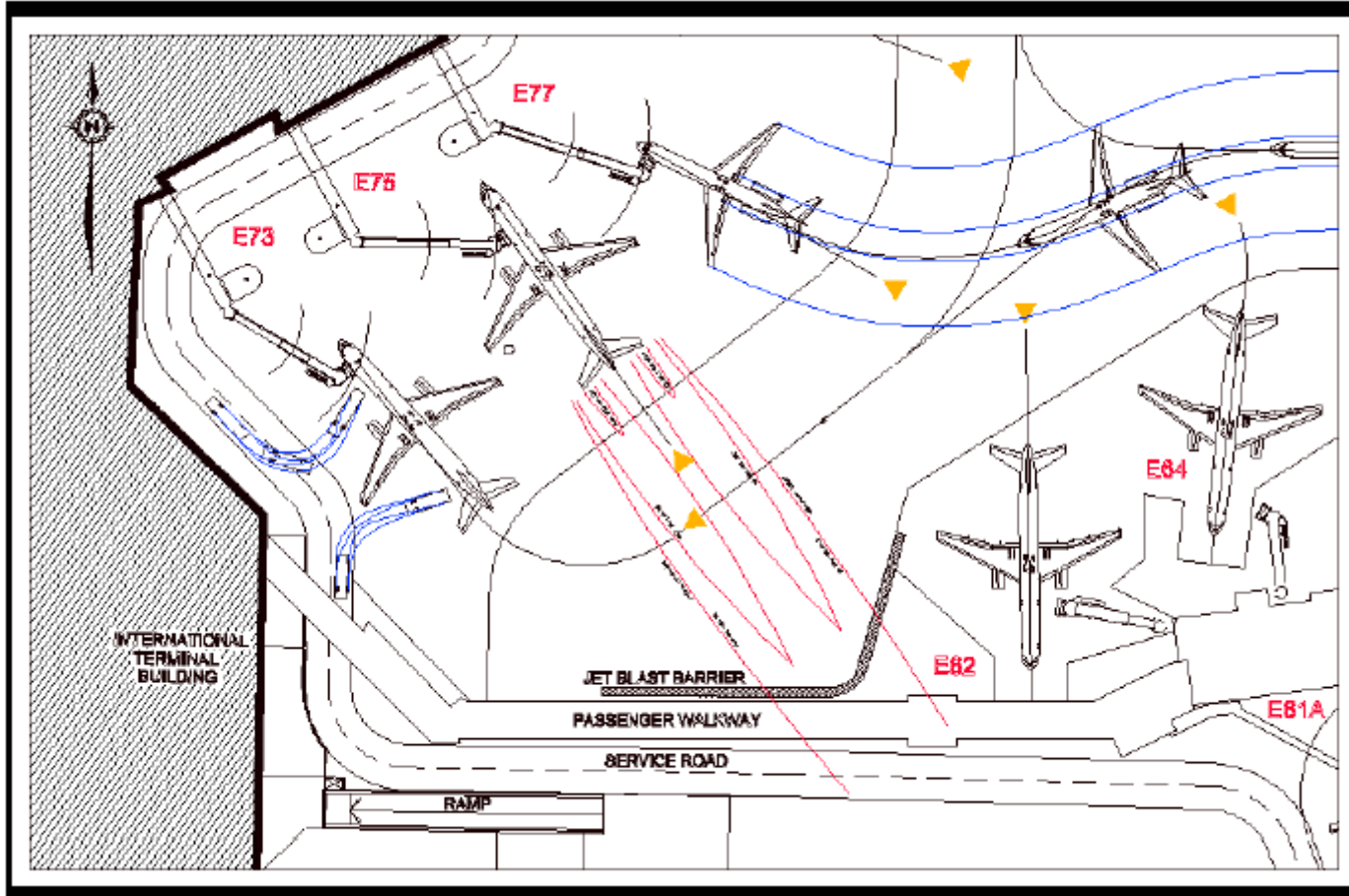
$$F = D * \text{sen}(A) - (a + R)$$

$$m = 2 * R - D$$

Dimensioni degli stalli e manovre (3)



Analisi dinamica negli apron



Approfondimenti e Riflessioni



“Un esperto è uno che conosce alcuni dei peggiori errori che può compiere nel suo campo, e sa come evitarli.”

WERNER KARL HEISENBERG



Le masse saranno sempre al di sotto della media. La maggiore età si abbasserà, la barriera del sesso cadrà, e la democrazia arriverà all'assurdo rimettendo la decisione intorno alle cose più grandi ai più incapaci. Sarà la punizione del suo principio astratto dell'uguaglianza, che dispensa l'ignorante di istruirsi, l'imbecille di giudicarsi, il bambino di essere uomo e il delinquente di correggersi. Il diritto pubblico fondato sulla uguaglianza andrà in pezzi a causa delle sue conseguenze. Perché non riconosce la disuguaglianza di valore, di merito, di esperienza, cioè la fatica individuale: culminerà nel trionfo della feccia e dell'appiattimento. L'adorazione delle apparenze si paga. »

Henri-Frédéric Amiel, “Frammenti di diario intimo”, 12 giugno 1871

