

# Transport collectif

## Capacités, opérations, vitesses

CIV6708

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Référence principale: VUCHIC, Vukan R. *Urban Transit: Operations, Planning, and Economics*, 2005

Chapitre 1

POLYTECHNIQUE  
MONTRÉAL





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- Capacité de ligne
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- Arrêts et types d'arrêts
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- Voies uniques, lignes circulaires, tronç/branches

### Capacité de ligne

vitesse, fiabilité, confort ↑ quand  $\frac{\text{volume}}{\text{capacité}} \downarrow$   $\frac{\text{Volume}}{\text{capacité}} = \alpha_c$

Si  $\alpha_c \rightarrow 1.0$  :

- délais
- incertitude
- $t_w \uparrow$
- frustrations

Capacité de ligne  $C_L = C_u f_{\text{peak}} = \frac{P_d}{\alpha_c} \left[ \frac{\text{places}}{h} \right]$  : nb de places pouvant se déplacer en passant par un point par direction/h

Capacité de station  $C_s$   
 noeud  $C_q$  : nb de places pouvant s'arrêter par heure (toutes lignes et directions)  
 arrêt  $C_s$

Capacité théorique calculée avec  $h_{\text{min}}$  → difficile en catégorie C (congestion, régularité, volume)  
 Le plus pénalisant souvent :  $C_{s,q,s}$

Trains, métros (SRR) : intervalle minimum  $h_{s,\text{min}}$  : l'élément le plus complexe qui influence la capacité de ligne → fig.2.1 (souvent le plus pénalisant)

$$h_{s,\text{min}} = \underbrace{\Delta t_s}_{\text{temps d'arrêt}} + \underbrace{\Delta t_r}_{\text{temps de réaction}} + \sqrt{\frac{2n_y \cdot l_y}{a_p} + \frac{n_y \cdot l_y}{v_p} + \frac{v_p(K+1)}{2b_p}}$$

↑
↑
↑  
accélération programmée
vitesse programmée
décélération programmée  


facteur de sécurité

$\frac{h_{s,\text{min}}}{s}$	$\frac{\Delta t_s, \Delta t_r}{s}$	$\frac{l_y}{m}$	$\frac{a_p, b_p}{m/s^2}$	$\frac{v_p}{m/s}$	$\frac{K, n_y}{-}$
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mode autonome :  $K \downarrow \Delta t_r \downarrow$

Capacité des unités et véhicules  
 → capacité de véhicule  
 $C_u = n_y C_y$   
 ↳ nombre de véhicules/unité

$n_y$  dépend du mode, catégorie de passage et technologie

sur rue: bus  $n_y = 1, 2, \text{max } 3$   
 sur rail: trains  $n_y = [1, 10]$  voire plus (rare)

- ↳ dépend de :
- longueur des stations/quais/platformes
  - catégorie A, B ou C
  - volume

$l_y$  : longueur de véhicule  
 $l_u = n_y l_y$  : longueur d'unité

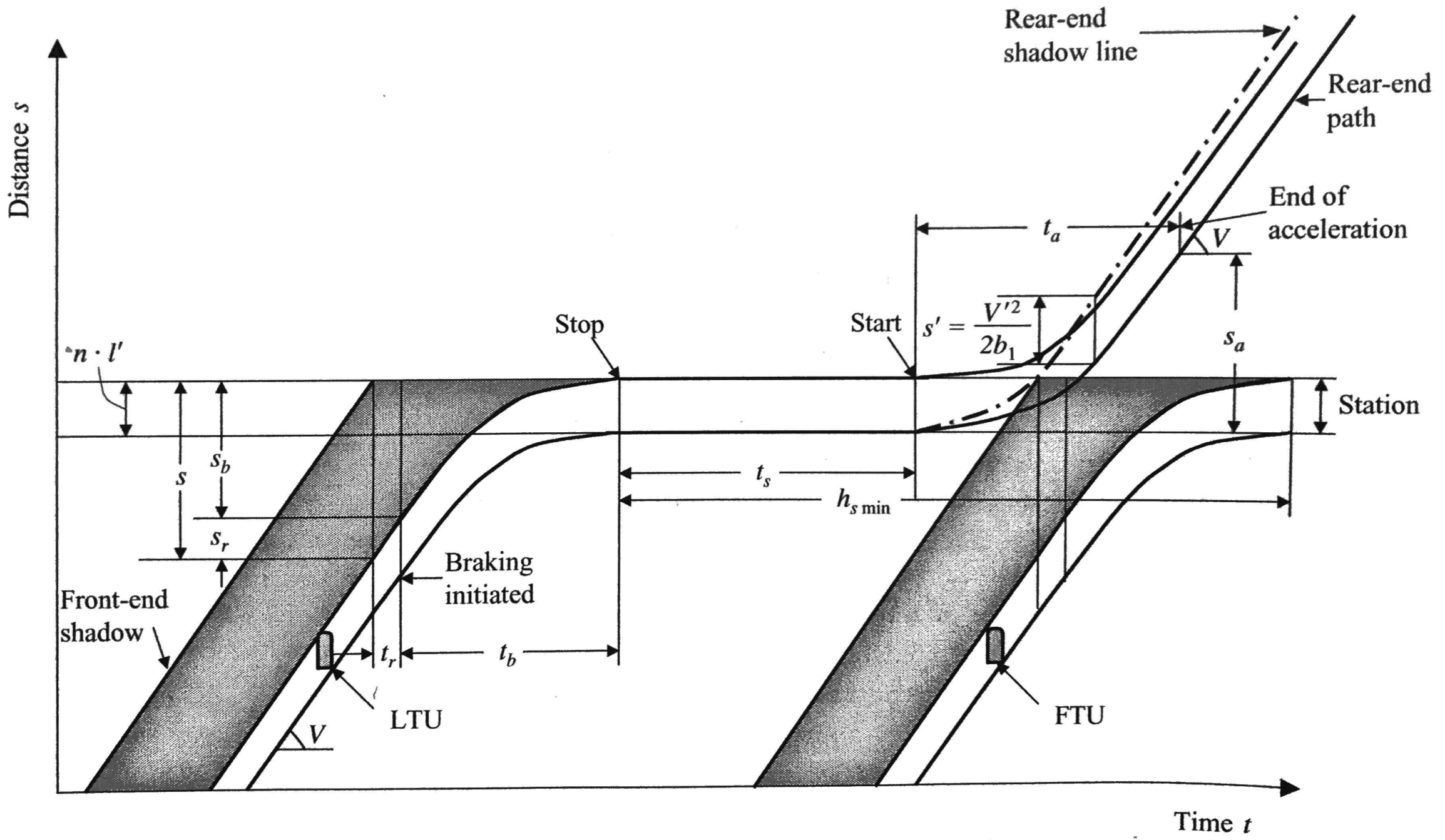


Figure 2.1 Time-distance elements of departure/arrival sequence and headway between consecutive TUs at a station.



- **Exercice: Dessiner le diagramme de la figure 2.1 pour le métro de Montréal**
  - ***Règle de sécurité: un train ne peut quitter la station tant que la station suivante n'est pas entièrement libérée par le train précédent***



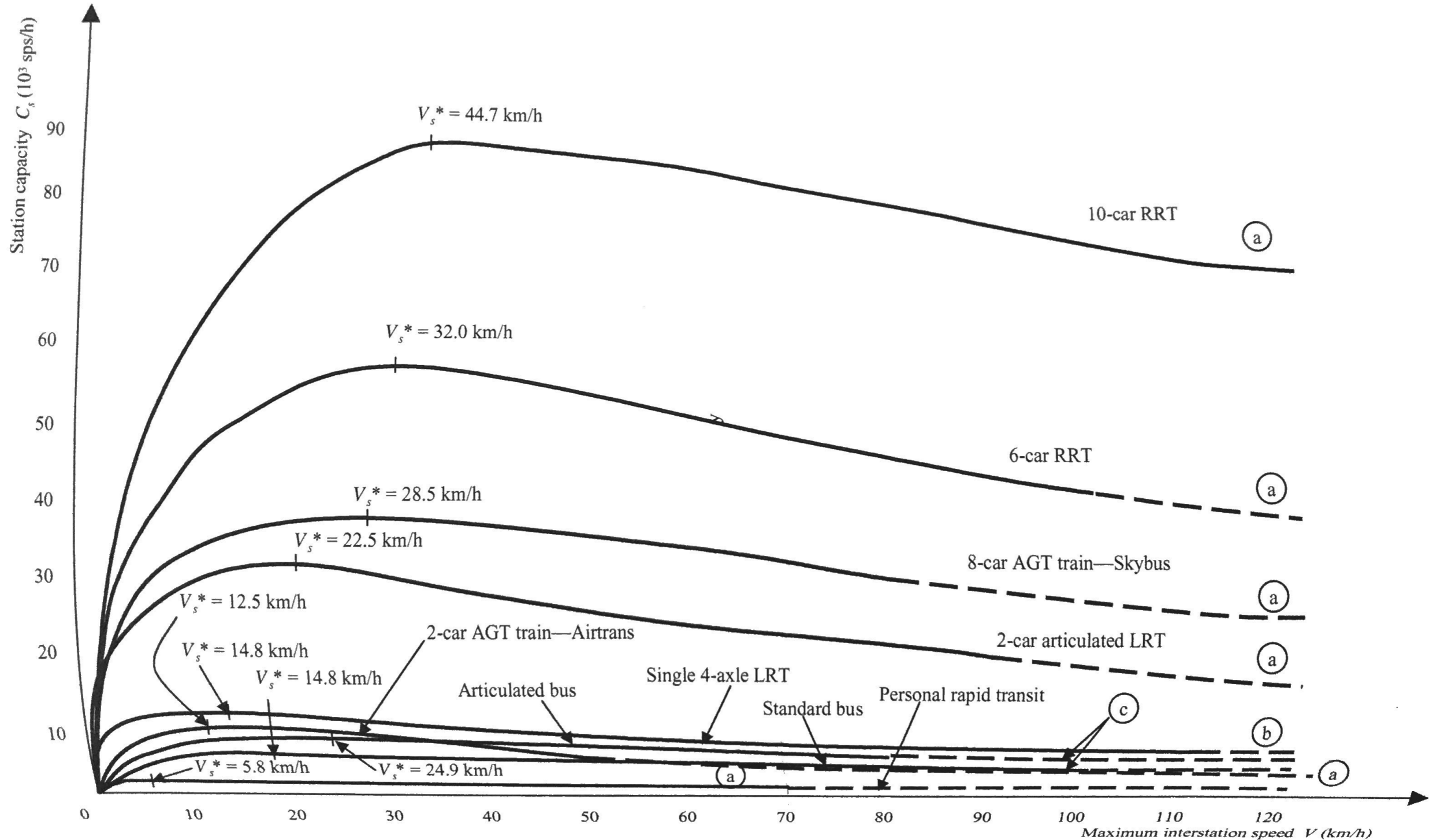


Figure 2.2 Station capacities of different modes with their typical safety regimes.



**Table 2.1** Theoretical and practical capacities of typical transit modes

Item	Symbol (dimension)	Standard bus $h=1\text{min}$	Light rail $h=1.5\text{min}$	Rapid transit $h=2\text{min}$
Vehicles/TU	$n$ (veh/TU)	1	2	10
Vehicle length	$\ell'$ (m)	12	24	21
Vehicle capacity	$C_v$ (sps/veh)	53	189	175
Safety distance	$s_o$ (m)	1	2	2
Reaction time	$t_r$ (s)	1	1	0
Normal braking rate	$b_n$ (m/s <sup>2</sup> )	1.4	1.2	1.1
Emergency braking rate	$b_e$ (m/s <sup>2</sup> )	4.0	3.0	1.8
Maximum speed	$V_{\max}$ (km/h)	90	90	120
Operating safety regime	—	c	a	a
Speed for maximum way capacity	$V_w^*$ (km/h)	37	39	78
Maximum way capacity	$C_{vw}^*$ (sps/h)	53,754	134,350	320,888
Speed for maximum station capacity	$V_s^*$ (km/h)	29.7	22.5	44.7
Maximum station capacity	$C_{vs}^*$ (sps/h)	6373	30,758	89,950
Practical capacity (see note below)	$C$ (sps/h)	3180	15,120	52,500

Note: The values shown assume average  $h_{s\text{ min}}$  of 1, 1.5, and 2.0 minutes for the three modes, respectively. They are realistic, except that at busy stops buses often have two lanes, allowing overtaking, thus averaging  $h_{s\text{ min}} < 1\text{ min}$  and  $C$  up to 6,000 sps/h and in special cases much higher.



# Calcul de l'intervalle

$h_{peak}$  dépend habituellement de  $h_{smin}$ , donc du temps d'arrêt à l'arrêt le plus achalandé ( $\Delta t_s$ )

$$\Delta t_s = \Delta t_{do} + \Delta t_{dc} + \max(n_B \bar{\Delta t}_B, n_A \bar{\Delta t}_A)$$

$\Delta t_{do}$  : temps d'ouverture/fermeture des portes  
 $\Delta t_{dc}$  : à la porte la plus achalandée  
 si une seule voie d'accès :  $n_B \bar{\Delta t}_B + n_A \bar{\Delta t}_A$   
 ou débarquements avant embarquements

Le nombre de voie d'accès et  $\alpha_c$  ont une influence considérable sur  $\Delta t_s$ , donc l'intervalle  $h_{smin}$

$n_B$  : nb d'embarquements (à un arrêt) [pass.]  
 $n_A$  : nb de débarquements (à un arrêt) [pass.]  
 $\bar{\Delta t}_B$  : temps moyen par embarquement [s/pass.]  
 $\bar{\Delta t}_A$  : temps moyen par débarquement [s/pass.]

En pratique :

bus :  $\bar{\Delta t}_B = [3.0, 5.0] s$   
 $\bar{\Delta t}_A = [1.5, 3.0] s$

métro :  $\bar{\Delta t}_B = [0.6, 1.4] s$   
 $\bar{\Delta t}_A = [0.5, 1.2] s$

$n_{Bchu}$  : nb de voies d'accès d'embarquement par unité  
 $n_{Achu}$  : nb de voies d'accès de débarquement par unité

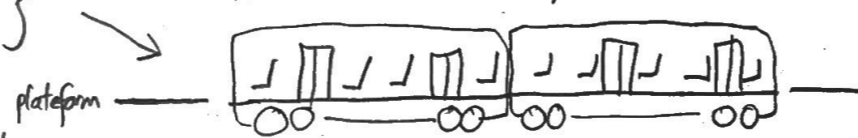
$n_{Bmax}$  : nb d'emb. } à la voie d'accès la plus  
 $n_{Amax}$  : nb de déb. } achalandée

$\bar{n}_B$  : nb d'emb. } moyen par =  $\frac{n_B}{n_{Bchu}}$   
 $\bar{n}_A$  : nb de déb. } voie d'accès =  $\frac{n_A}{n_{Achu}}$

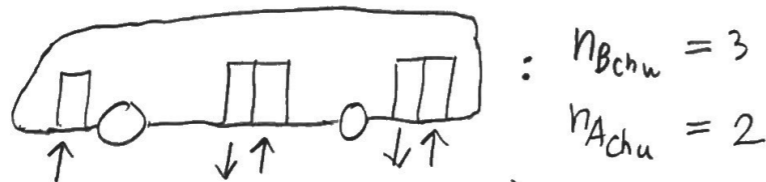
$\epsilon_{B/A}$  : coefficient de distribution des embarquements/débarquements  
 $= \frac{n_{B/Amax}}{\bar{n}_{B/A}}$

Facteurs influençant  $\Delta t_s$ :

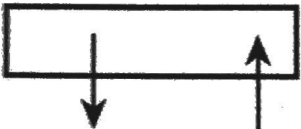
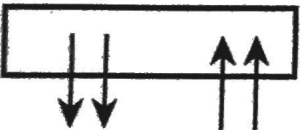
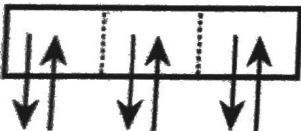
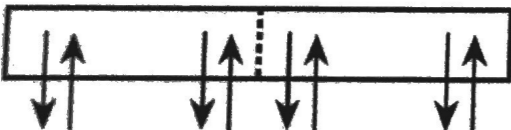
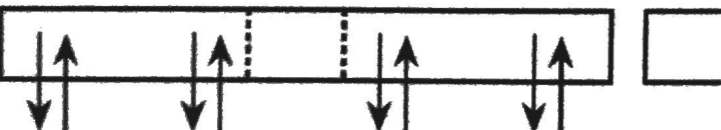
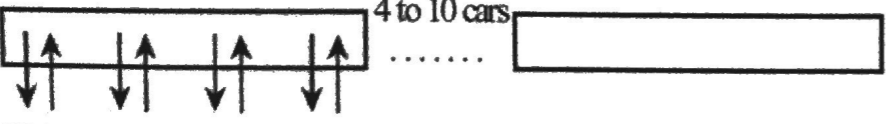
- hauteur du plancher des véhicules } idéal : hauteur plancher = hauteur plateforme (métro)
- hauteur de la plateforme
- nb de voies d'accès
- tarification et méthodes de perception
- nb de véhicules par unité
- obstacles à la circulation (roues des bus) +  $\alpha_c$



Voies d'accès:



**Table 2.2** Physical and operating elements affecting TU standing times

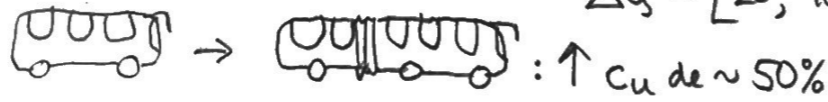
Transit mode and TU sketch	Vehicle floor/ platform height	Cars × doors × channels = TU total (board + alight)	Fare type/ collection	Boarding		Alighting time $\tau_a$ (s/prs)	Difference from preceding cases
				$t_o$ (s)	$\tau_b$ (s/prs)		
i. Bus 	H/L	$1 \times 2 \times 1 = 2$ (1 + 1)	Graduated/at boarding	1.0	3.0–5.0	1.5–3.0	—
ii. Bus/streetcar 	H/L	$1 \times 2 \times 2 = 4$ (2 + 2)	Flat, passes, validation	1.0	2.0–3.0	1.5–3.0	More channels, faster fare collection
iii. Bus/streetcar 	L/L	$1 \times 2 \times 2 = 4$ $1 \times 3 \times 2 = 6$	Self-service, validation	2.0	1.2–2.2	1.0–1.6	Low floor, faster fare control
iv. Articulated bus, single LRV 	H/L	$1 \times 4 \times 2 = 8$	Self-service, validation	2.0	1.6–2.6	1.5–3.0	More channels but high floor
v. LRT train 	L/L H/H	$2 \times 4 \times 2 = 16$ $3 \times 4 \times 2 = 24$	Any type, prepaid	3.0	0.8–1.6	0.6–1.4	More channels, low floor; no fare collection
vi. Metro 	H/H	$4 \times 3 \times 2 = 24$ $10 \times 4 \times 2 = 80$	Any type, prepaid	3.0	0.6–1.4	0.5–1.2	More channels

Note: Bus includes trolleybus.



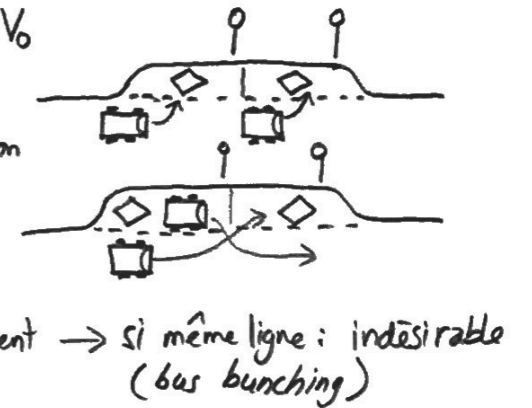
Pour ↑ capacité

- ↑  $c_u$  ou  $n_y$  Le plus efficace: trains de 10 wagons ( $n_y=10$ ), 3.2m de large, 200 à 250m de long au total  
 $\Delta t_s = [25, 40]$  sec, 80 pass/s embarquement



- ↓  $h_{min}$ , ↓  $\Delta t_s$  : ↑  $n_{Bchu}$ ,  $n_{Achu}$ , ↓ temps de perception

- configuration / optimisation des arrêts et stations :
  - arrêts multiples / simultaneous stopping : ↓  $\Delta t_s$ , mais ↓  $V_0$
  - dépassements / leapfrogging : meilleure répartition du volume
  - convois / platooning : bus de plusieurs lignes qui se suivent → si même ligne: indésirable (bus bunching)



Description d'une ligne: indiquer tous ces indicateurs. capacité seulement = trop simpliste.

- Capacité offerte  $C_L$  [places/h/direction]
- Vitesse d'opération  $V_0$  [km/h]
- Niveau de confort  $e$  [ $m^2$ /places]
- Fiabilité  $R$  [%]
  - idéalement: [0, 3min] de retard
  - en pratique: [-3, 5min] de retard/avance
- Coefficient d'utilisation de la capacité/confort  $\alpha_c$  [ $\frac{pass}{place}$ ]

→ tableaux 2.3 et 2.4

**Table 2.3** Comparison of capacities and related performance elements on a transit line\*

Performance Elements		Transit Systems	i. 1920s Streetcar— Typical	ii. 2000s LRT— Typical	iii. 2000s LRT— Maximum Performance
Comfort standard	$\sigma$ (m <sup>2</sup> /sps)		0.15	0.25	0.15
TU capacity	$C_{TU} = C_v \times n$ (sps)		$120 \times 2 = 240$	$190 \times 3 = 570$	$271 \times 3 = 810$
Offered line capacity	$C = C_{TU} \times f_{\max}$ (sps/h)		$240 \times 100 = 24,000$	$570 \times 45 = 25,650$	$810 \times 45 = 36,450$
Load factor	$\alpha$ (prs/h)		0.92	0.86	0.90
Utilized capacity	$C_p = \alpha \times C$ (prs/h)		22,080	22,059	32,802
Reliability	R (%)		80	94	90
Operating speed	$V_o$ (km/h)		12	24	20
Utilized productive capacity	$P_c = C_p \times V_o$ (prs-km/h <sup>2</sup> )		264,960	529,416	656,100

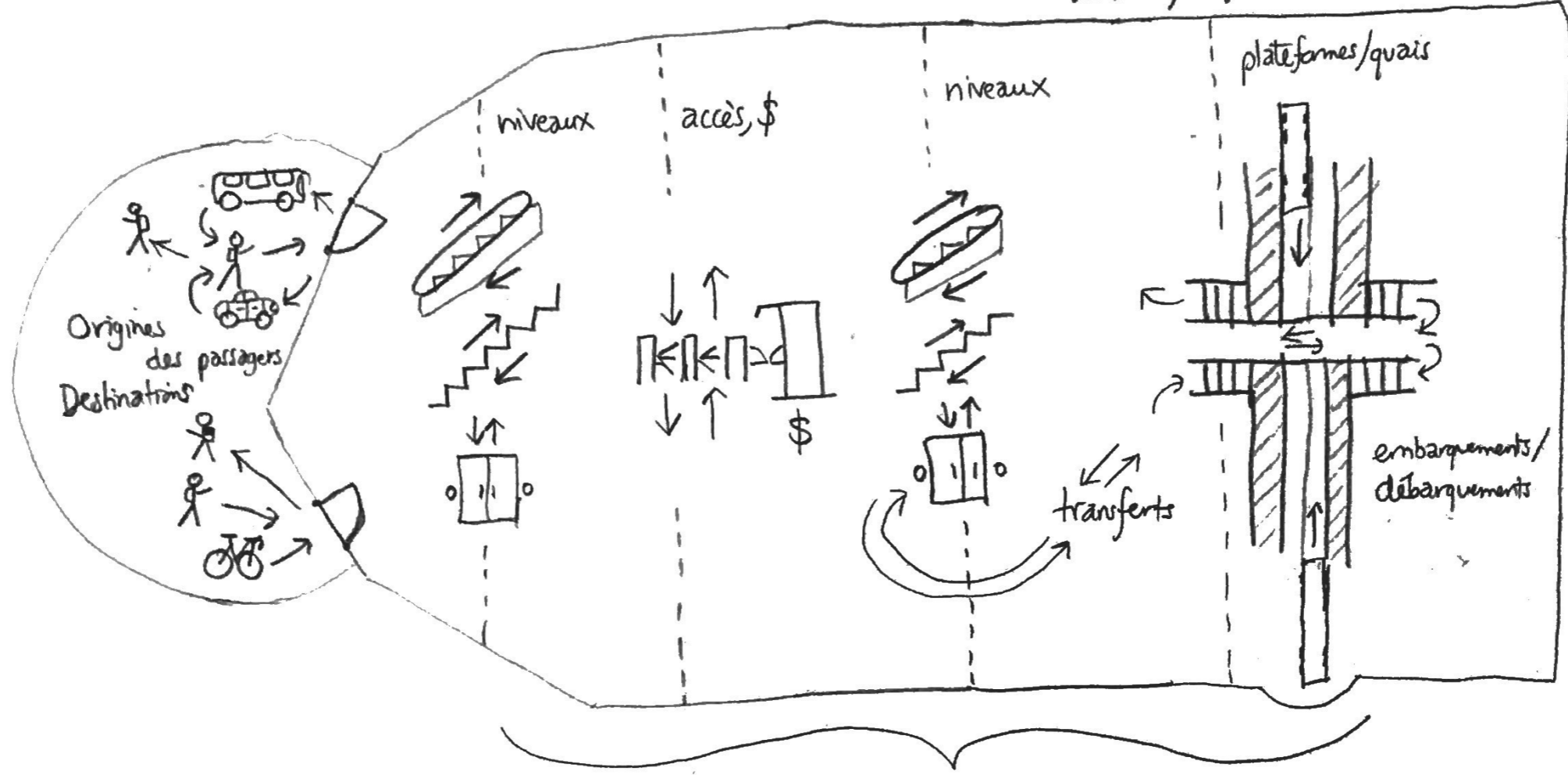
\*Values in this table are typical for the first two cases (1920s and 2000s); the third case is estimated through extrapolation of conditions for the preceding two cases.



**Table 2.4** Maximum offered line capacities of transit modes

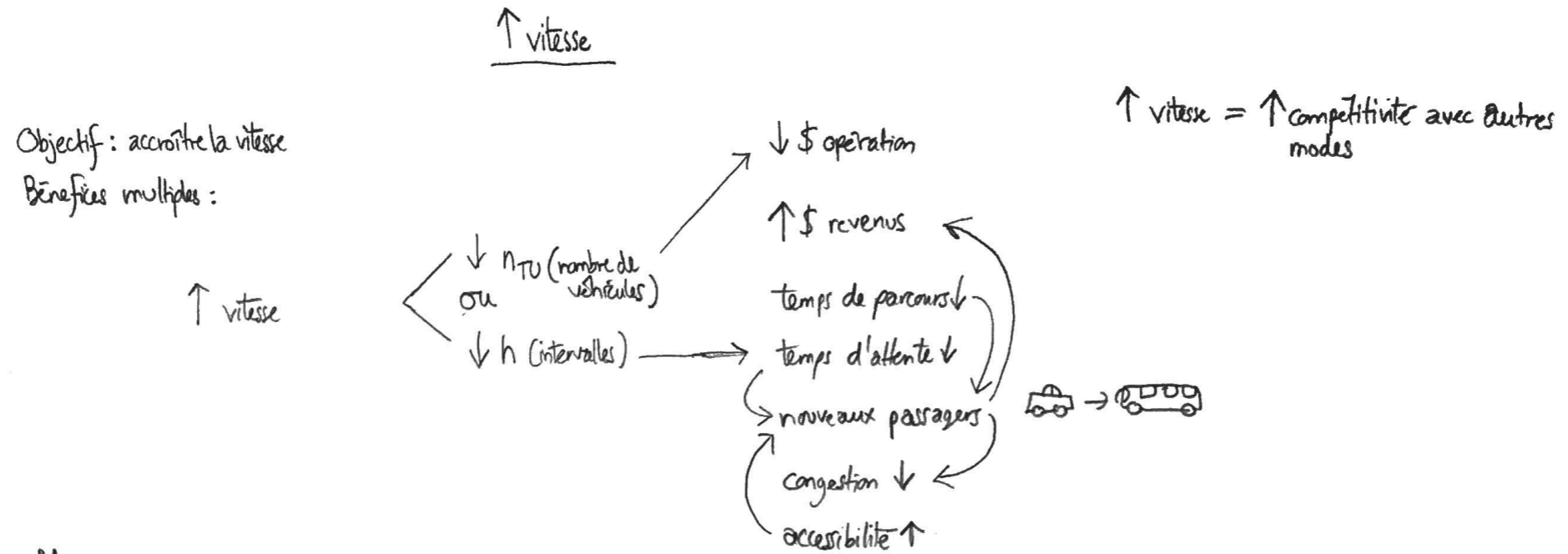
Mode	Vehicle dimensions $L \times W$ (m)	TU capacity $n C_v = C_{TU}$ (sps)	Minimum headway $h_{min}$ (s)	Maximum frequency $f_{max}$ (TU/h)	Max offered line capacity $C$ (sps/h)	Ratio to basic bus capacity $C_{av}/C_{av}^{bus}$	Operating speed at capacity $V_o$ (km/h)	Offered productive capacity $P_c$ ( $10^3$ sp-km/h <sup>2</sup> )	Ratio to basic bus productive capacity $P_c/P_c^{bus}$
1. Standard bus, single stops	12.00 × 2.50	1 × 75 = 75	70–50	51–72	3800–5400	1.0	8–12	36–52	1.0
2. Articulated bus, single stops	18.00 × 2.50	1 × 120 = 120	80–60	45–60	5400–7200	1.4	7–11	45–63	1.2
3. 50% standard, 50% articulated bus multiple stops	12.00 × 2.50 18.00 × 2.50	1 × 75 = 75 1 × 120 = 120	40–20	90–180	8800–17,500	2.9	10–16	105–225	3.7
4. High-capacity bus	12.00 × 2.50 22.00 × 2.50	1 × 75 = 75 1 × 160 = 160	30–12	120–300	9000–30,000	4.2	16–20	173–360	6.1
5. Streetcar ROW C, multiple stops	14.00 × 2.20	2 × 110 = 220	60–30	60–120	13,200–26,400	4.3	8–14	158–296	5.2
6. Light rail transit, ROW B, multiple stops	24.00 × 2.65	3 × 170 = 510 2 × 280 = 560	150–75	24–48	12,200–26,900	4.2	18–30	280–622	10.2
7. AGT—VAL, Westinghouse	12.50 × 2.05	4 × 86 = 344	90–75	40–48	13,800–16,500	3.3	20–36	330–475	9.1
8. AGT—rail	12.70 × 2.50	6 × 100 = 600	100–90	36–40	21,600–24,000	4.9	20–36	518–690	13.7
9. Rapid transit	18.00 × 2.90	8 × 180 = 1440	100–90	36–40	51,800–57,600	8.6	22–36	988–1200	24.9
10. Rapid transit	21.00 × 3.15	10 × 240 = 2400	150–120	24–30	67,200–72,000	15.1	24–40	1935–2304	48.2
11. Regional rail, diesel	26.00 × 3.20	10 × 200 = 2000	240–200	15–18	30,000–36,000	7.2	30–40	1080–1152	25.4
12. Regional rail, electric	26.00 × 3.20	10 × 200 = 2000	180–120	20–30	40,000–60,000	10.9	35–55	1680–2640	49.1

Capacité de station → la station la plus achalandée, avec le plus de transferts, est souvent le maillon faible



influencent  $C_p$ ,  $t_s$ ,  $h_{min}$  ...





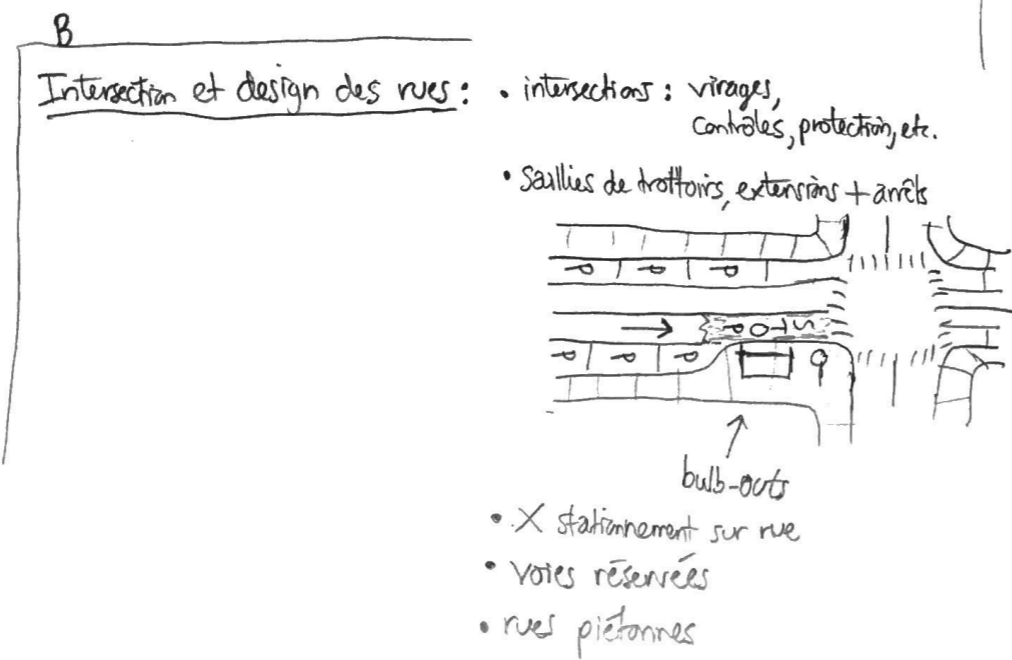
Moyens: Cat. C → B → A (↑  $V_r$ )  
Mesures préférentielles (↑  $V_r$ )  
• ↑  $n'$  (voies d'accès) (↓  $t_s$ )  
reconfiguration des arrêts (↓  $t_s$ )  
reconfiguration des stations (↓  $t_s$ )

Design des véhicules:

- ↑ circulation intérieure: ↓ nb de sièges, surtout entre les portes
- portes à 2 voies d'accès:
  - ⊗
  - ⊙
- plancher bas (bus, SLR)
- caractéristiques dynamiques: électrique: plus confortable, ↓ bruit

bus accélérations:  $[0.8, 1.6] m/s^2$   
freinage:  $[1.2, 2.0] m/s^2$

↑ performance arrêt-départ  
accélérations fréquentes



C

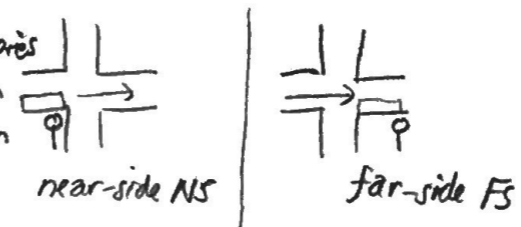
Priorités aux feux :

- ↑ vert
- phases de virages
- priorités de virages pour TC
- feux chandelle (avant vert après vert)
- Changement de phase à l'approche d'un TU
- priorité absolue → devient vert dès l'arrivée du TU

D

Configuration des arrêts :

- ↑ distance inter-arrêts → bus minimum : 300m
- alternance avant/après intersection avec synchronisation des feux



Attention : Synchronisation ≠ Synchronisation

→ fig. 2.6

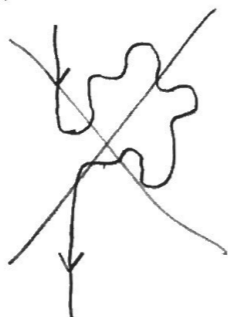
E

Opérations :

- ↑ vitesse de paiement (↓ paiement manuel, ↑ cartes à puce, cartes de crédit... paiement sur l'honneur, paiement en station)

- ↻ changement de parcours

↓ virages (X)



- parcours express, arrêts limités, service zonal

→ TRANSIT STREET DESIGN GUIDE (NACTO)

Sensibilité de la vitesse d'opération par rapport à :

- nombre d'arrêts
- accélérations
- distance inter-arrêts

→ fig. 2.7 + 2.8



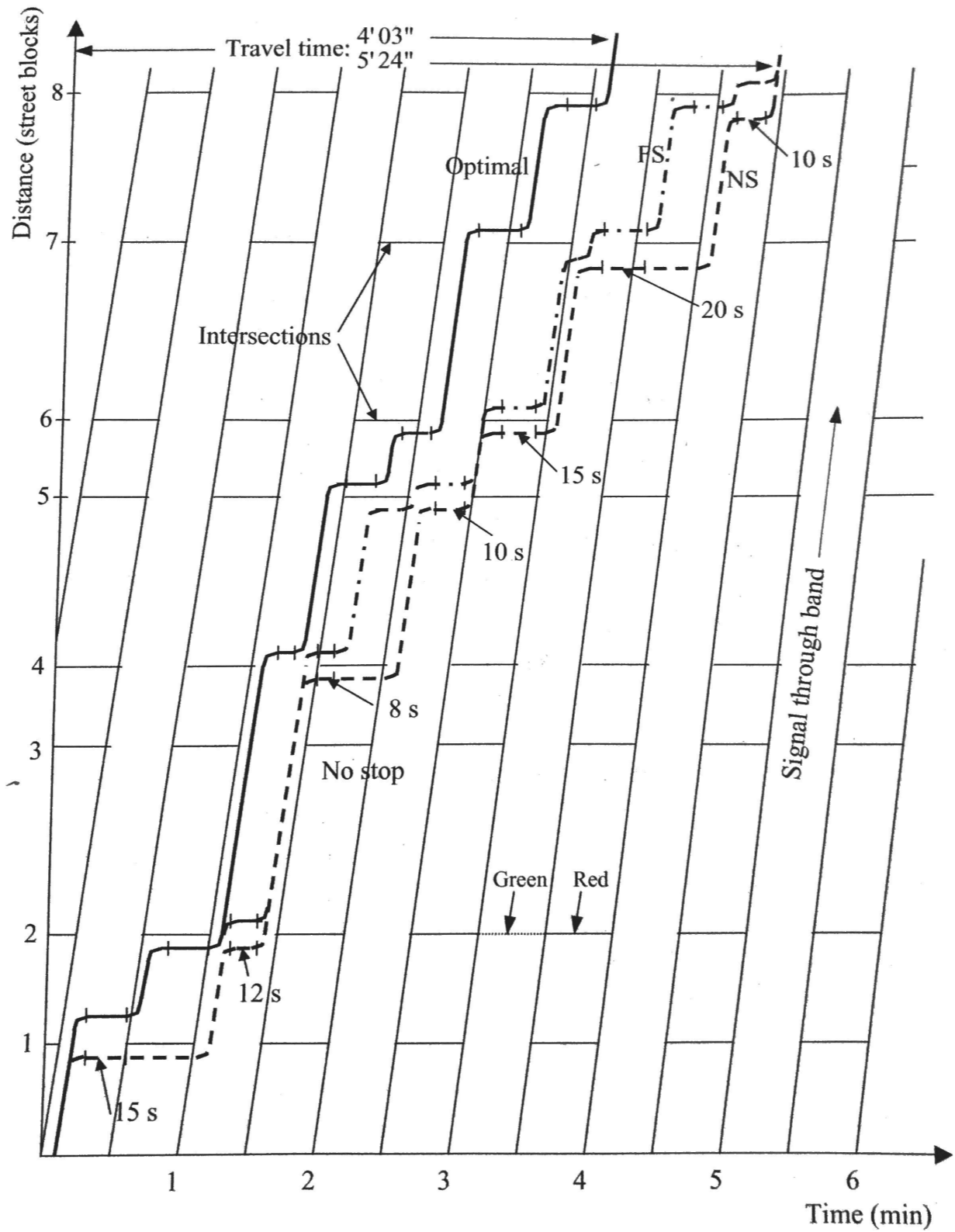


Figure 2.6 Transit unit travel time for all-NS, all-FS, and alternative stop locations.

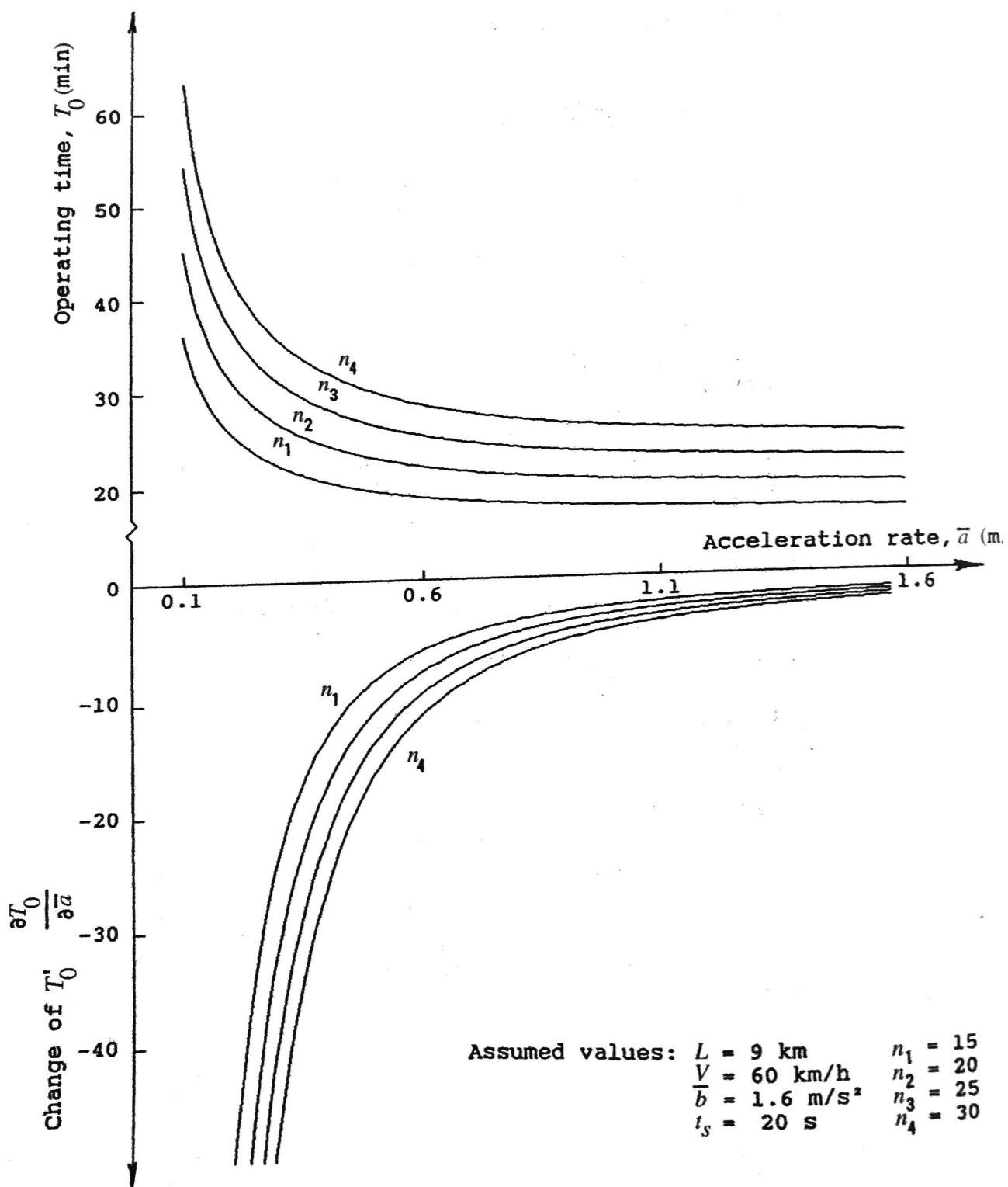


Figure 2.7 Operating time as a function of acceleration rate  $a$  for different number of stations  $n$ .

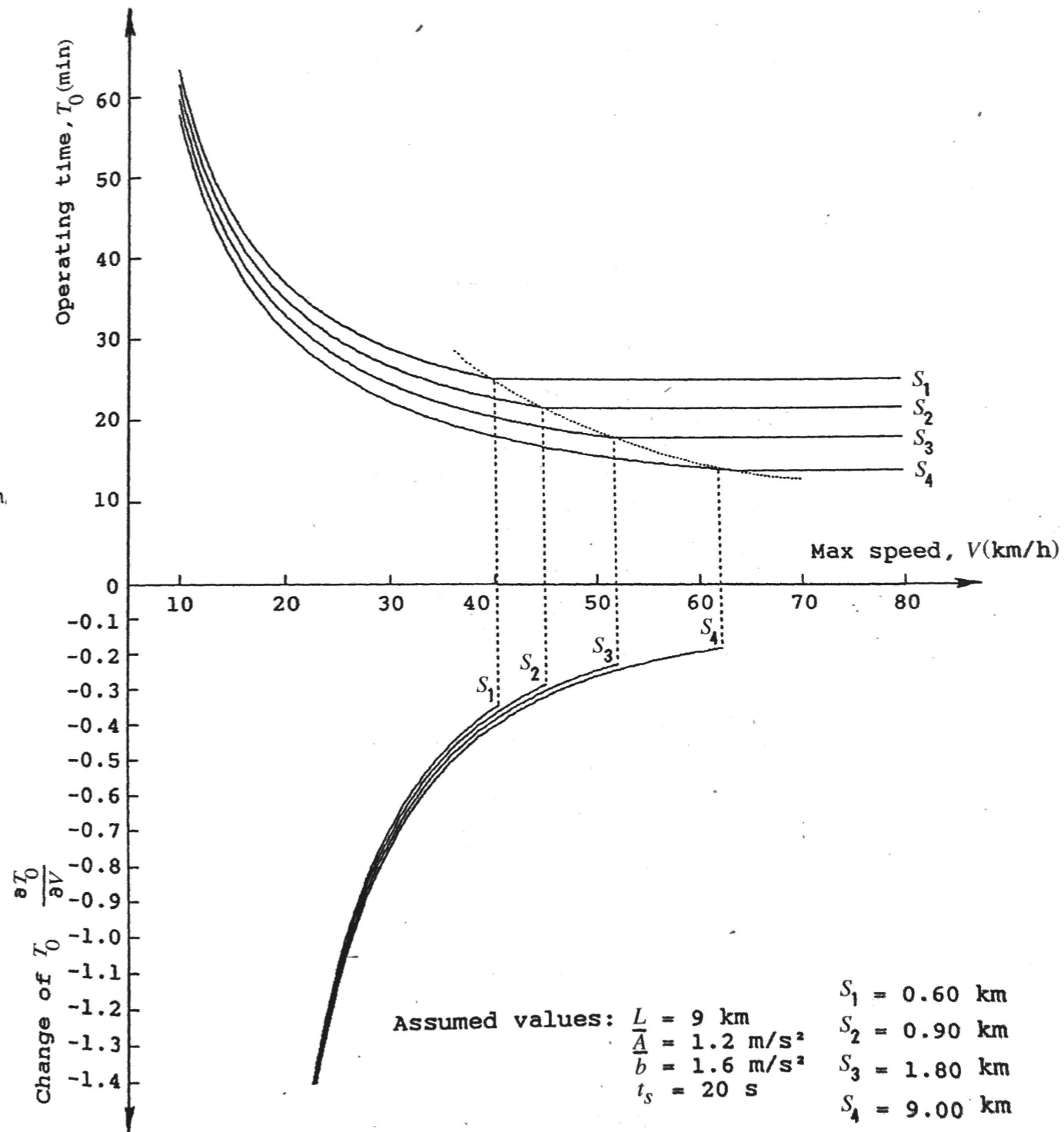


Figure 2.8 Operating time as a function of maximum speed  $v$  for different station spacings  $s$ .



Arrêts et types d'arrêts

Arrêts sur demande  $N_d$

- arrêts n'importe où  
à la limite : 2 arrêts par passager  
(↓ + ↑)

Arrêts fixes sur demande  $N_o$

- arrêts aux panneaux, selon demande

Arrêts fixes  $N_f$

- arrêts aux panneaux en tout temps  
peu importe la demande

$N_d = \infty$   
 $N_f < N_o$

fig. 2.12  
+ 2.13

Distances inter-arrêts

Vieille habitude (arrêts à pratiquement chaque intersection)  
↳ 160m vs 320m

Avantages de ↑ 320m :

- $V_o$  ↑
- confort ↑
- ↓  $N_{TU}$
- ↓ énergie consommée
- ↓ usure des véhicules
- ↓ mobilier (panneaux, bancs, ...)
- ↓ espace utilisé pour arrêts
- ↓ congestion causée par les bus
- ↓ pollution air + bruit

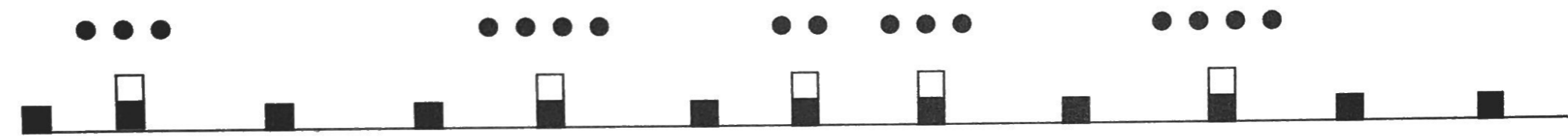
Désavantage de ↑ 320m

- distance d'accès ↑ en moyenne de 80m (≈ 1min)

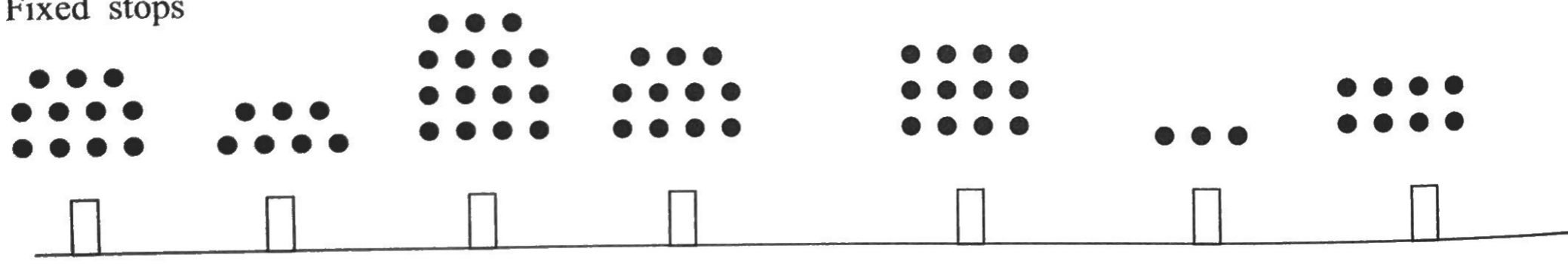
1. Demand stopping



2. On-call stopping



3. Fixed stops



Potential stopping location     
  Actual stopping     
  Passengers

*Figure 2.12 The concept of the three stopping regimes along a transit line.*



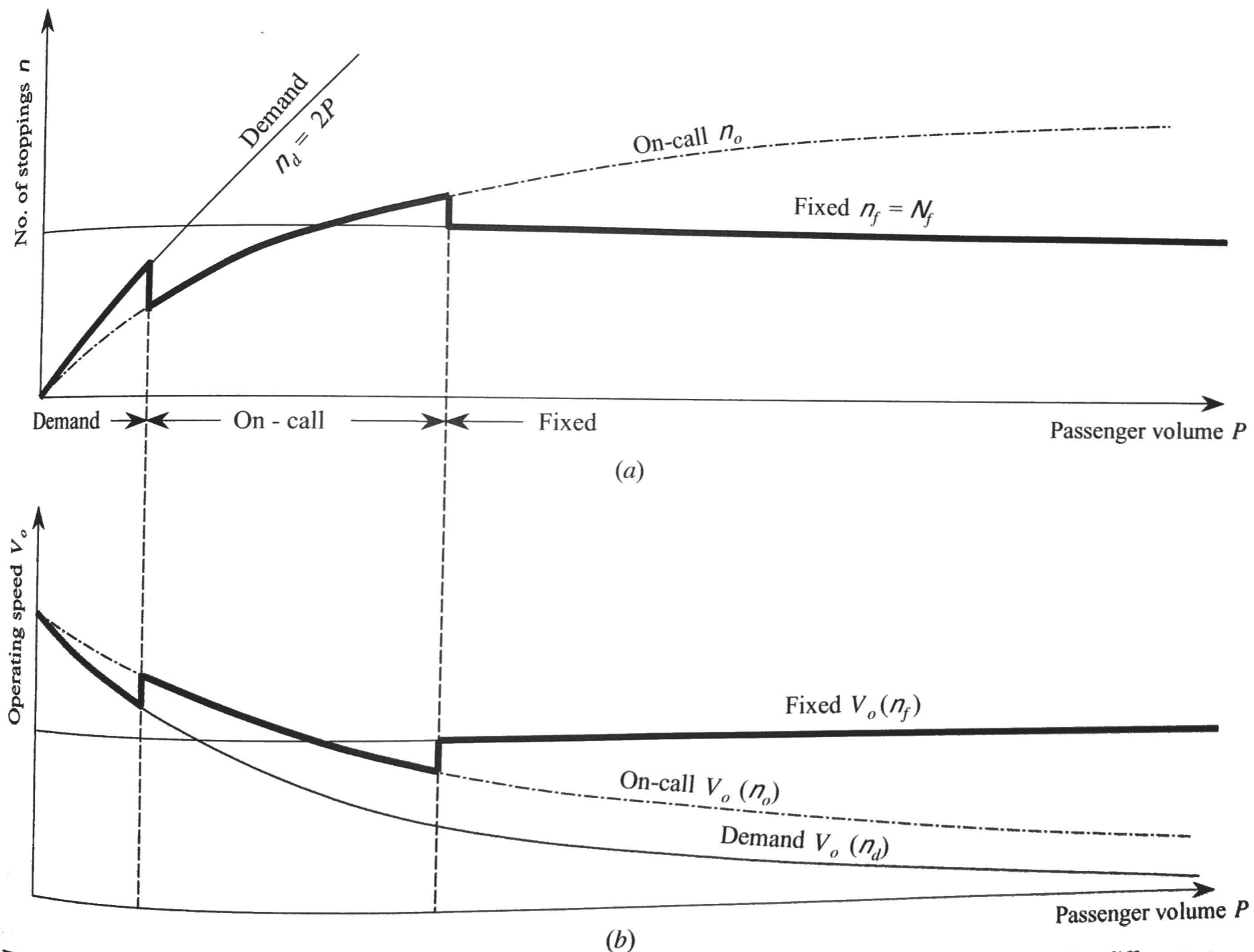
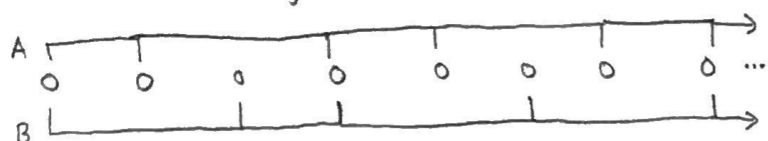


Figure 2.13 Stopping regime domains as functions of passenger volume: (a) number of stoppings for different stopping regimes; (b) operating speeds for different stopping regimes.

Services accélérés (rail) → se font aussi en bus

Deserte alternée  
Skip-stop  
fig. 2.14 (Haut) + 2.15 + 2.16



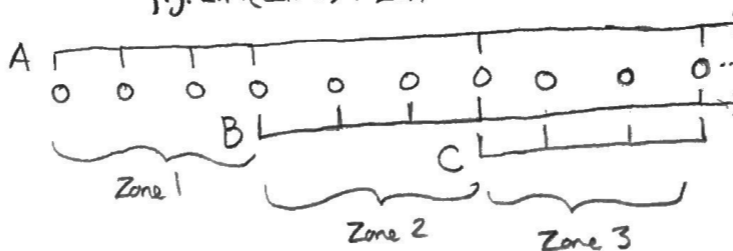
↳ peut être opéré avec voies doubles (1/direction)

$V_0 \uparrow$ , productivité  $\uparrow$ ,  $C_L =$ , confusion  $\uparrow$ ,

$t_{wz}$  aux stations alternées  $\uparrow$ , confort  $\uparrow$ ,  $\$_{opération} \downarrow$   
↳ attente • waiting

Montréal: potentiel pour le métro. → exercice: gain de  $V_0$ ?

Service Zonal  
Zonal operation  
fig. 2.14 (centre) + 2.17



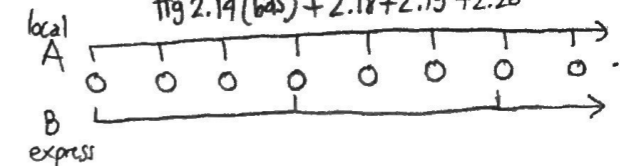
↳ plusieurs types de services

peut être opéré avec voies doubles (1/direction)  
mais ajout d'aiguillages en X + mieux avec 3<sup>e</sup> voie.

$C_L \downarrow$ ,  $V_0 \uparrow$ ,  $N_{TU} \uparrow$ ,  $C_V \downarrow$ ,  $\$_{opération} = / \downarrow$

$\uparrow$  transferts,  $h$  irrégulier, confort  $\uparrow$

Service local/express  
Express/local operation  
fig 2.14 (bas) + 2.18 + 2.19 + 2.20



Configurations: fig. 2.18

• si 2 voies seulement (1/direction):

$V_0 \uparrow$  (express), confort  $\uparrow$  (express)

$v_{eh-km} \uparrow$ , + complexe

$t_w \uparrow$  (local)

• si 4 voies à certaines stations:

$h \downarrow$   $t_a \downarrow$  (local),  $\$_{investissement} \uparrow$

• si 3/4 voies partout:

$\$ \uparrow$   $\$ \uparrow$   $\$ \uparrow$  investissement,  $h \downarrow$ ,  $t_w \downarrow$ ,  $V_0 \uparrow$ ,  
confort  $\uparrow$ , fiabilité  $\uparrow$

Comparaisons: fig. 2.21 à 2.24 + tableau 2.11 + tableau 2.12  
(Utilisation de la capacité)

Méthodologie:

• nb de station  $\uparrow$ : service accéléré à considérer  
nb de station  $\downarrow$ : X

• nb de déplacement vers grands générateurs:  
Zonal, express, alterné

• utilisation/capacité  $\downarrow$ : service accéléré à considérer

• utilisation/capacité  $\uparrow$ : alterné seulement

•  $h \downarrow$ : service accéléré à considérer

•  $h \uparrow$ : X ( $t_w \uparrow$ )



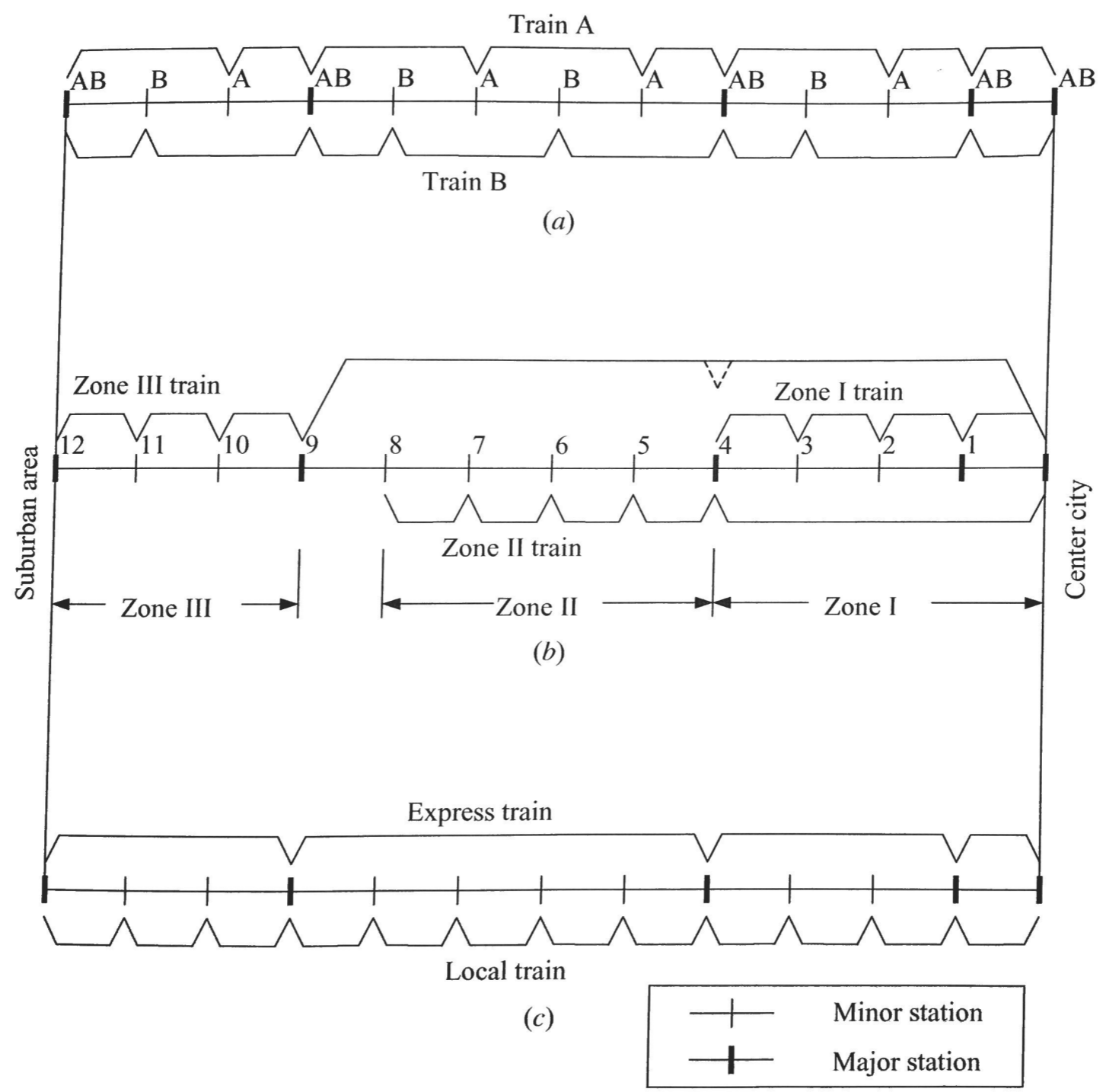


Figure 2.14 Types of accelerated transit operations: (a) skip-stop operation; (b) zonal operation; (c) express/local operation.

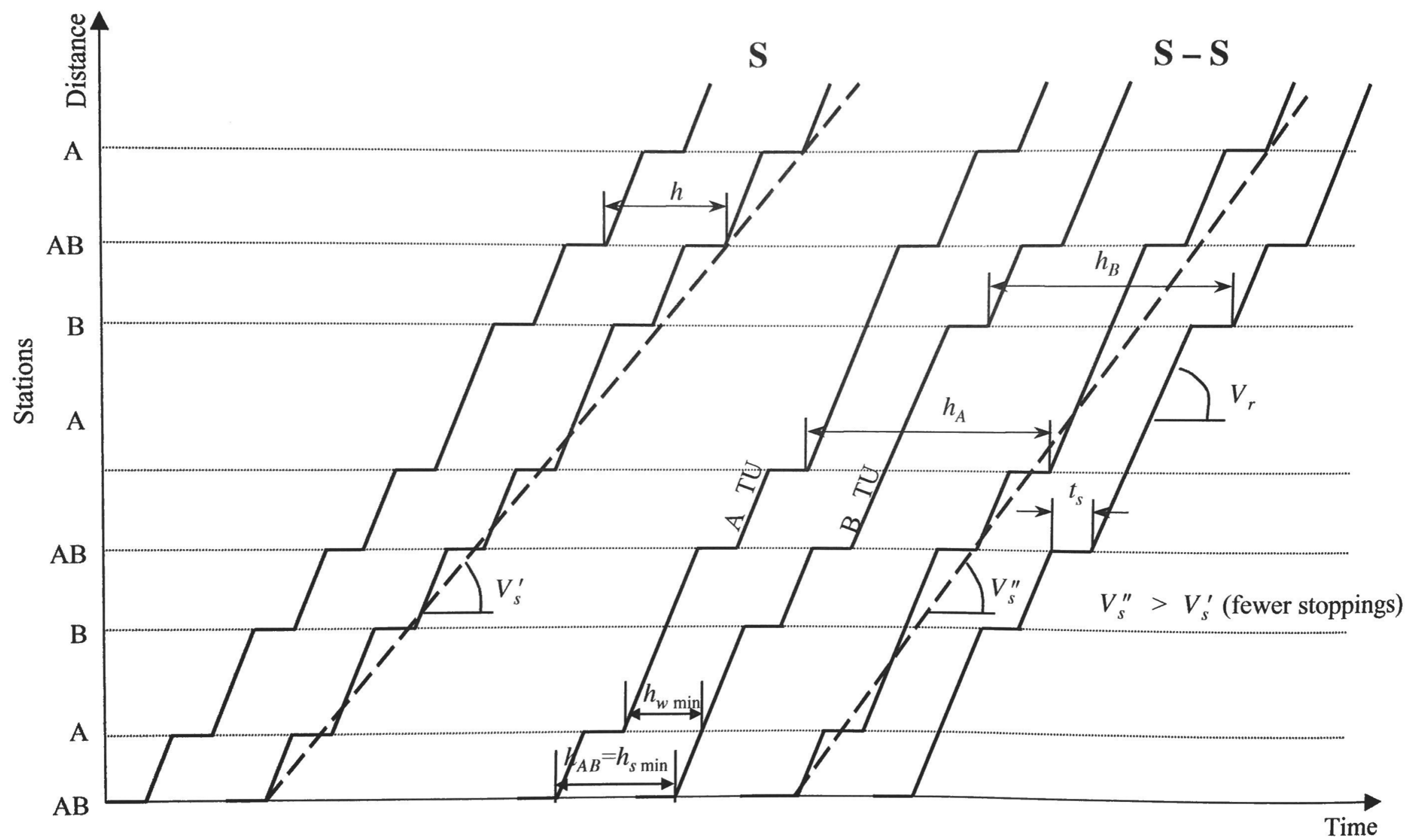


Figure 2.15 Time-distance diagram for standard (S) and skip-stop (S-S) operations.

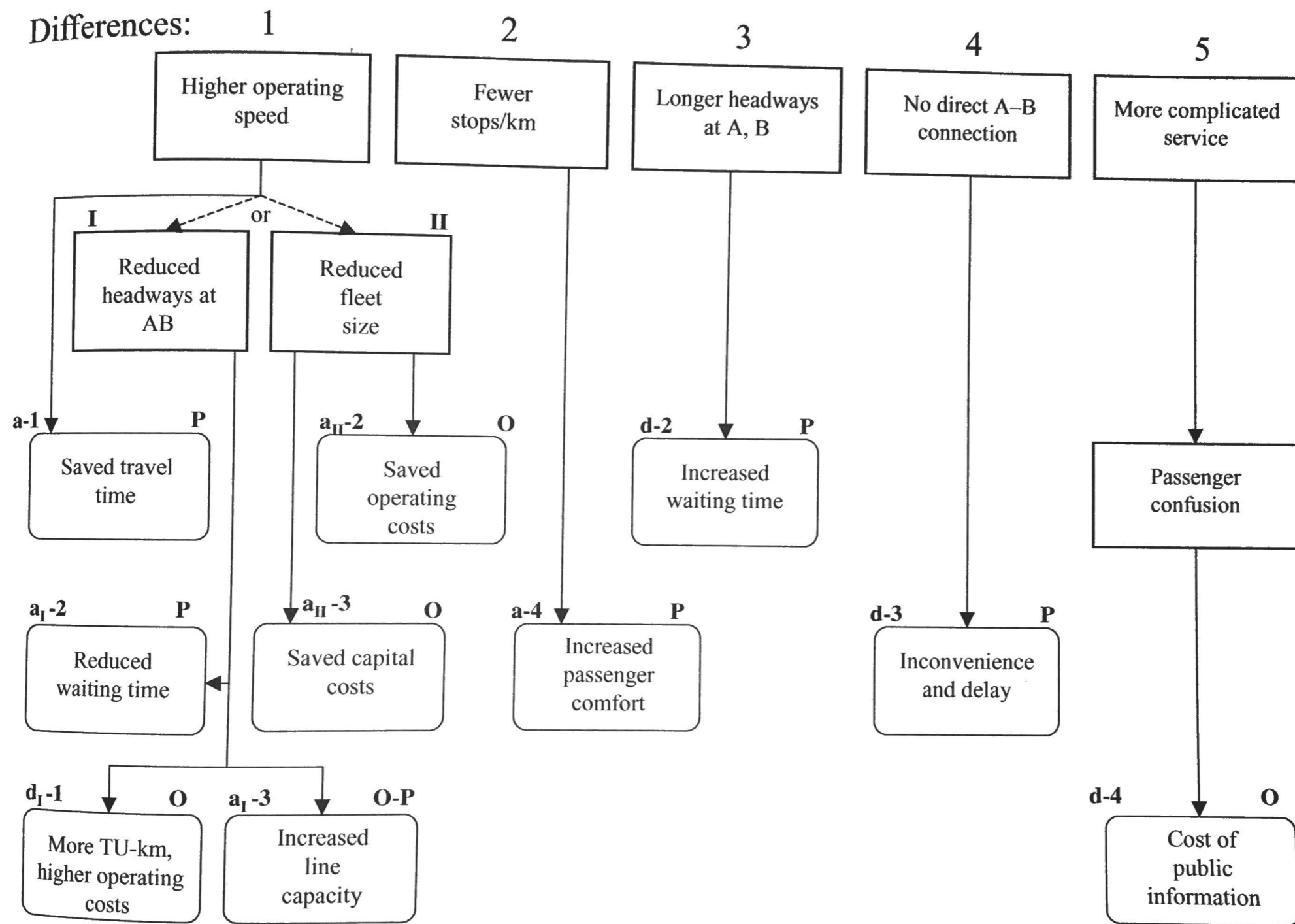
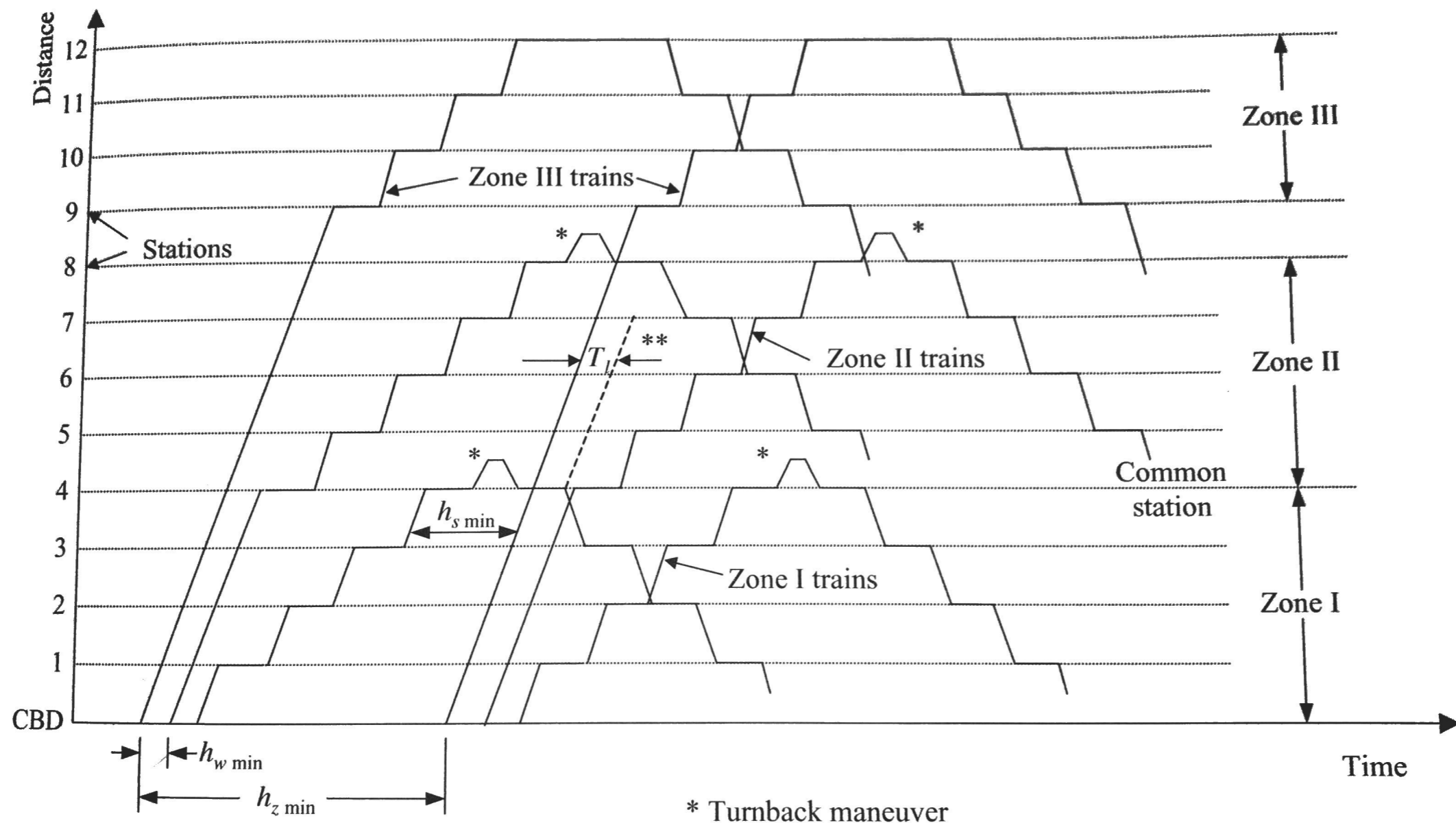


Figure 2.16 Skip-stop compared with standard operation.

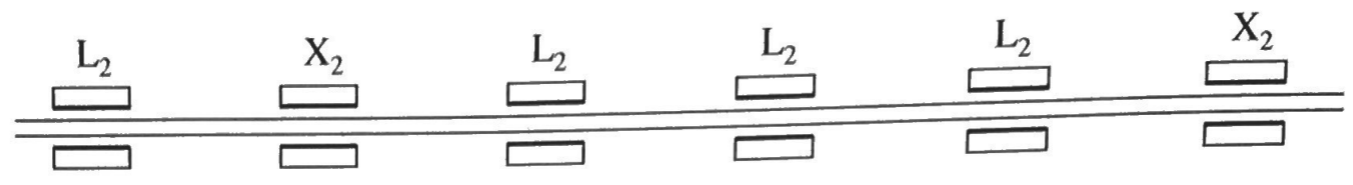




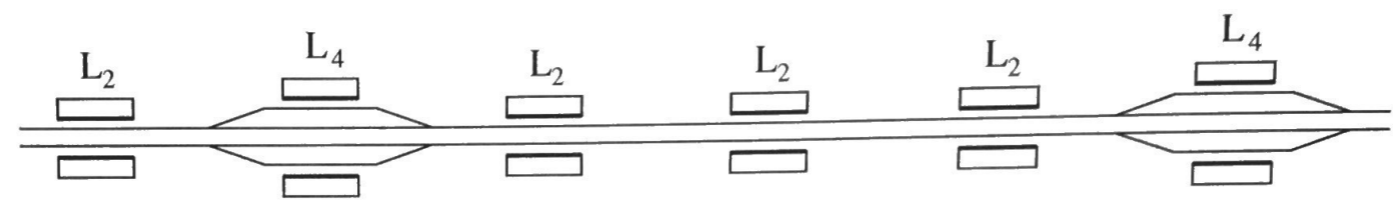
\* Turnback maneuver

\*\* Option with Zone III train stopping at station 4: zone II and zone I trains would have to be delayed by  $T_l$

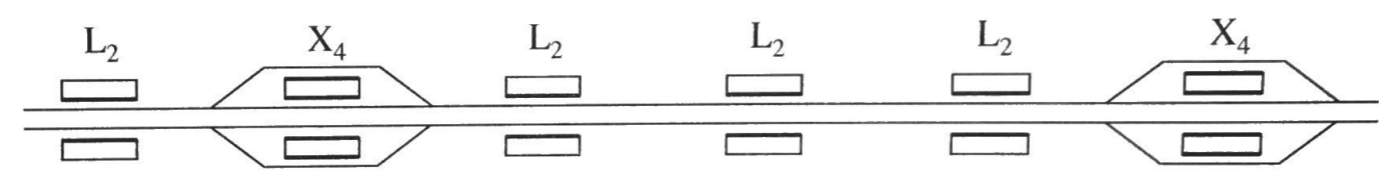
Figure 2.17 Time-distance diagram for zonal operation.



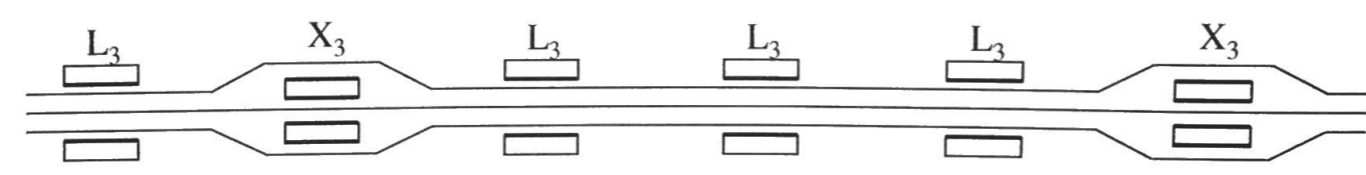
Case 2a. Two-track line without passing



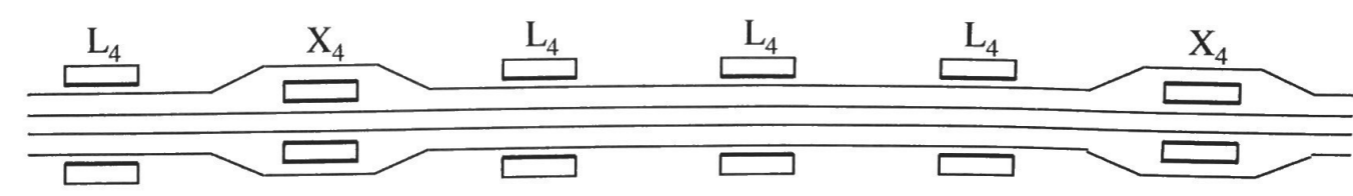
Case 2b. Two-track line with passing at local stations



Case 2c. Two-track line with passing at express stations



Case 3. Three-track line



Case 4. Four-track line

**Figure 2.18** Line and station design for different types of express/local operations.

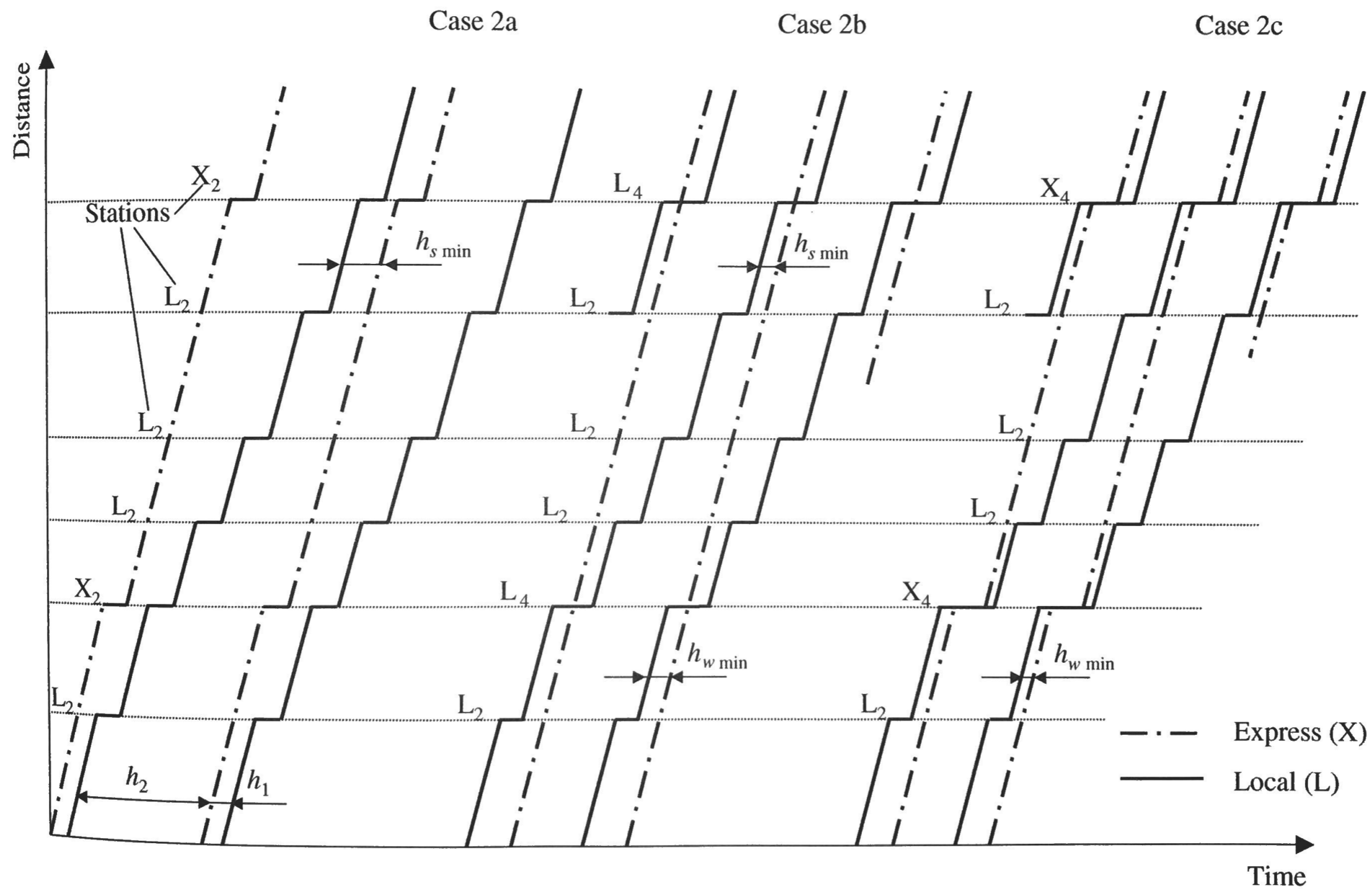
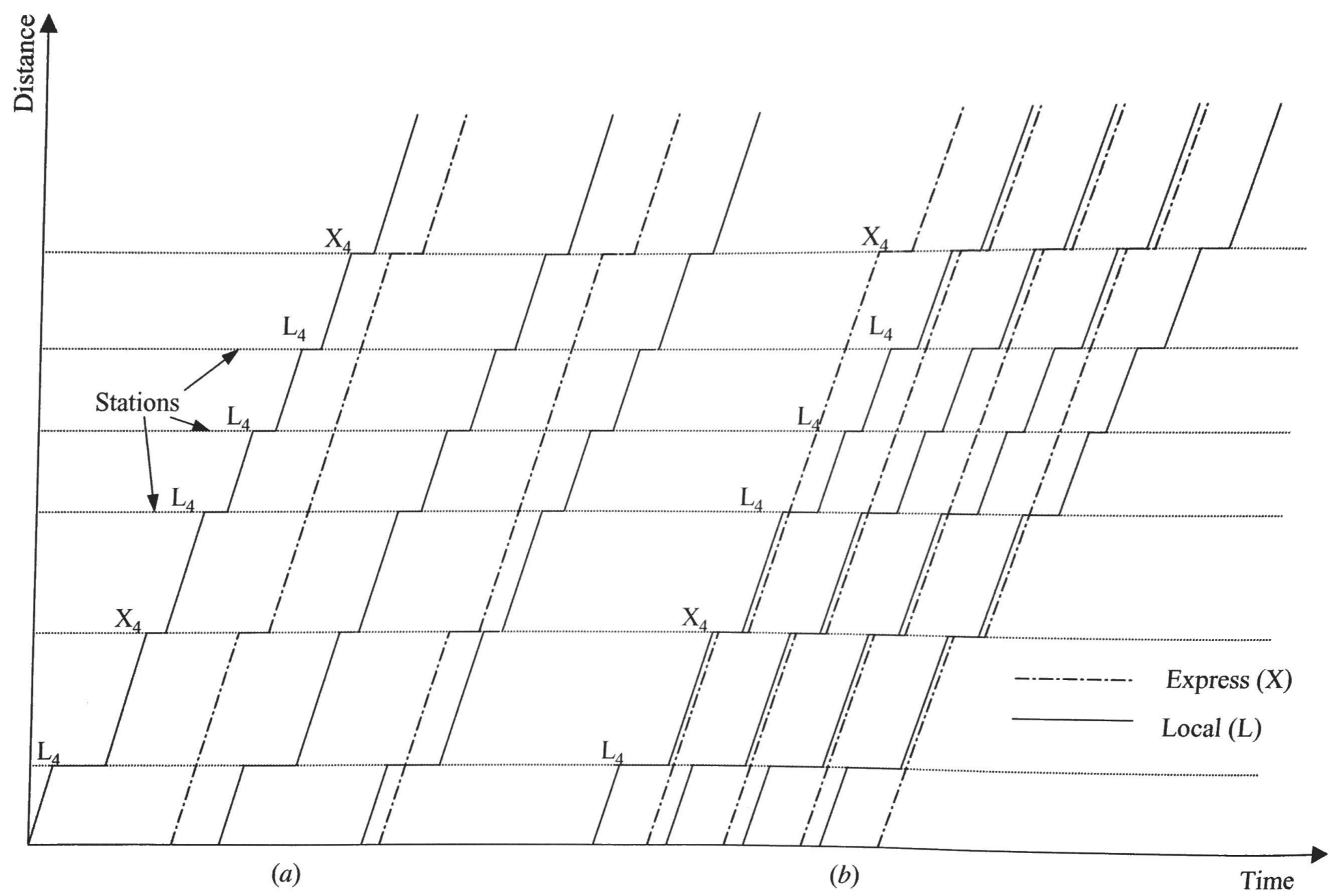


Figure 2.19 Time-distance diagrams for express/local operations on two-track lines.





**Figure 2.20** Express/local operations on a four-track line (case 4): (a) independent running of X and L trains; (b) synchronized running of X and L trains for simultaneous transfers.

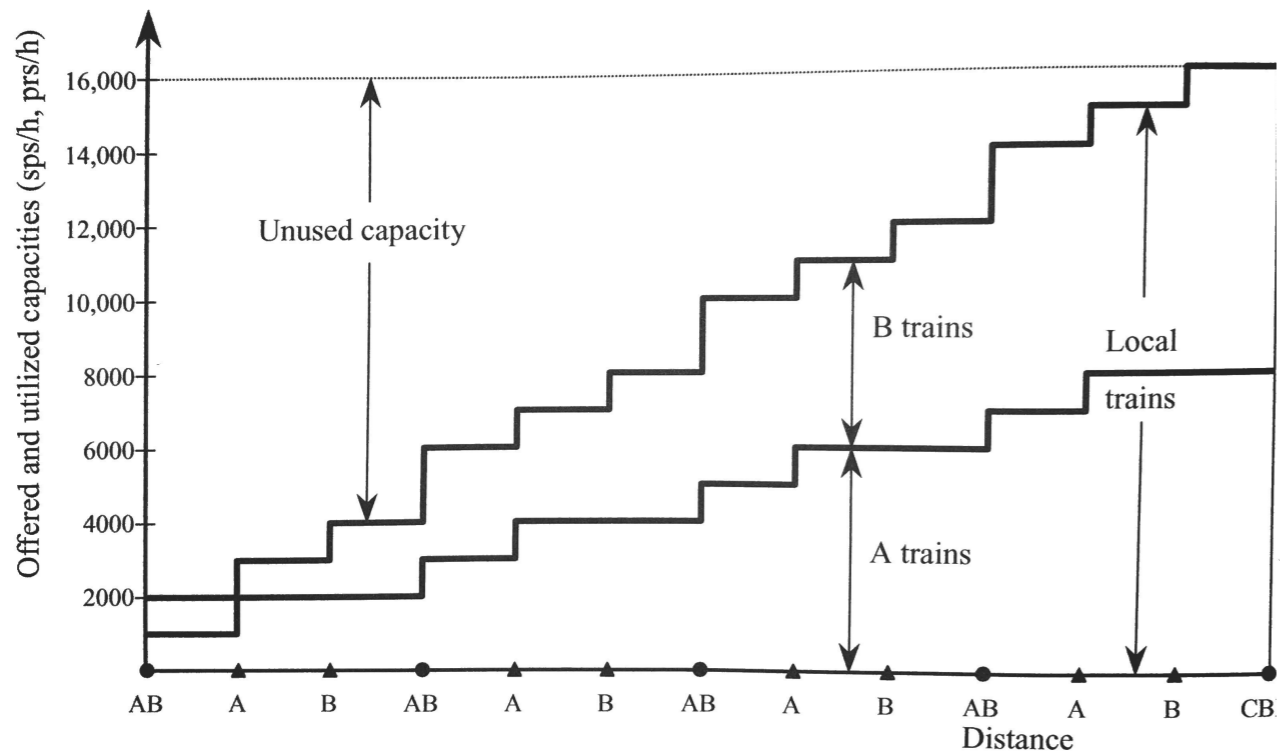


Figure 2.21 Offered and utilized capacities for local and skip-stop operations.

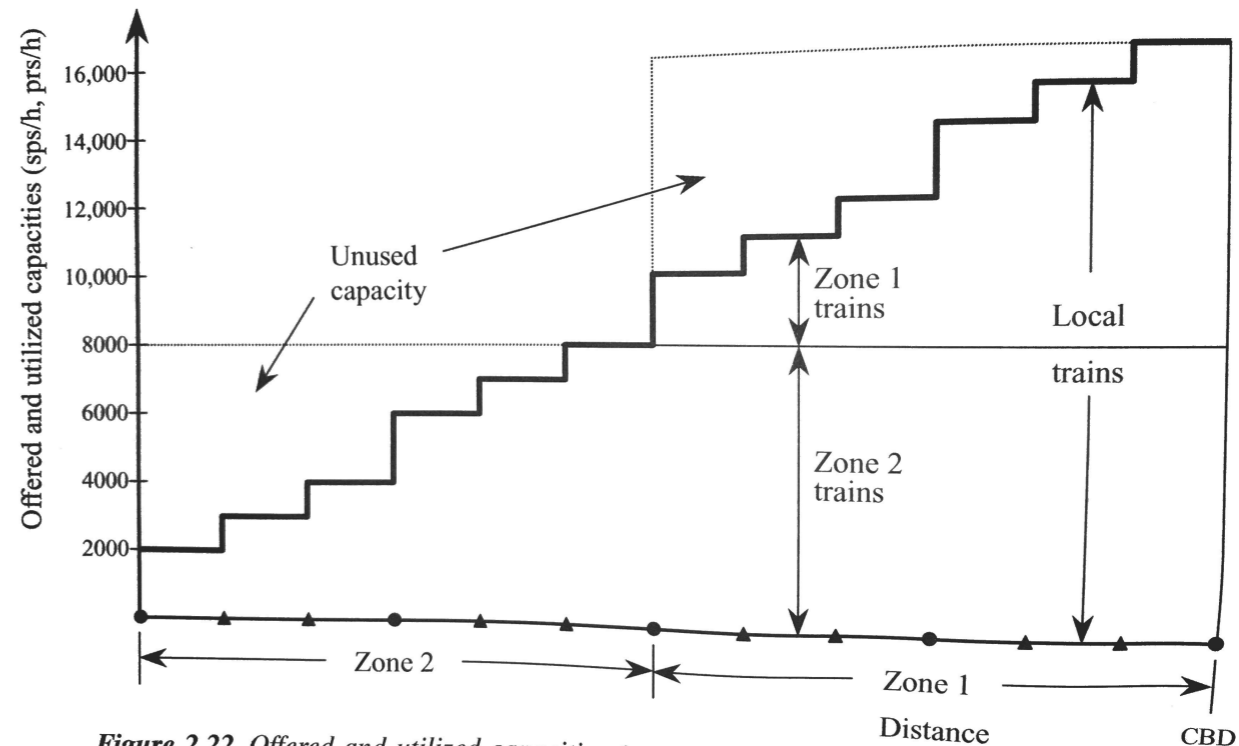


Figure 2.22 Offered and utilized capacities for local and zonal (two-zone) operations.

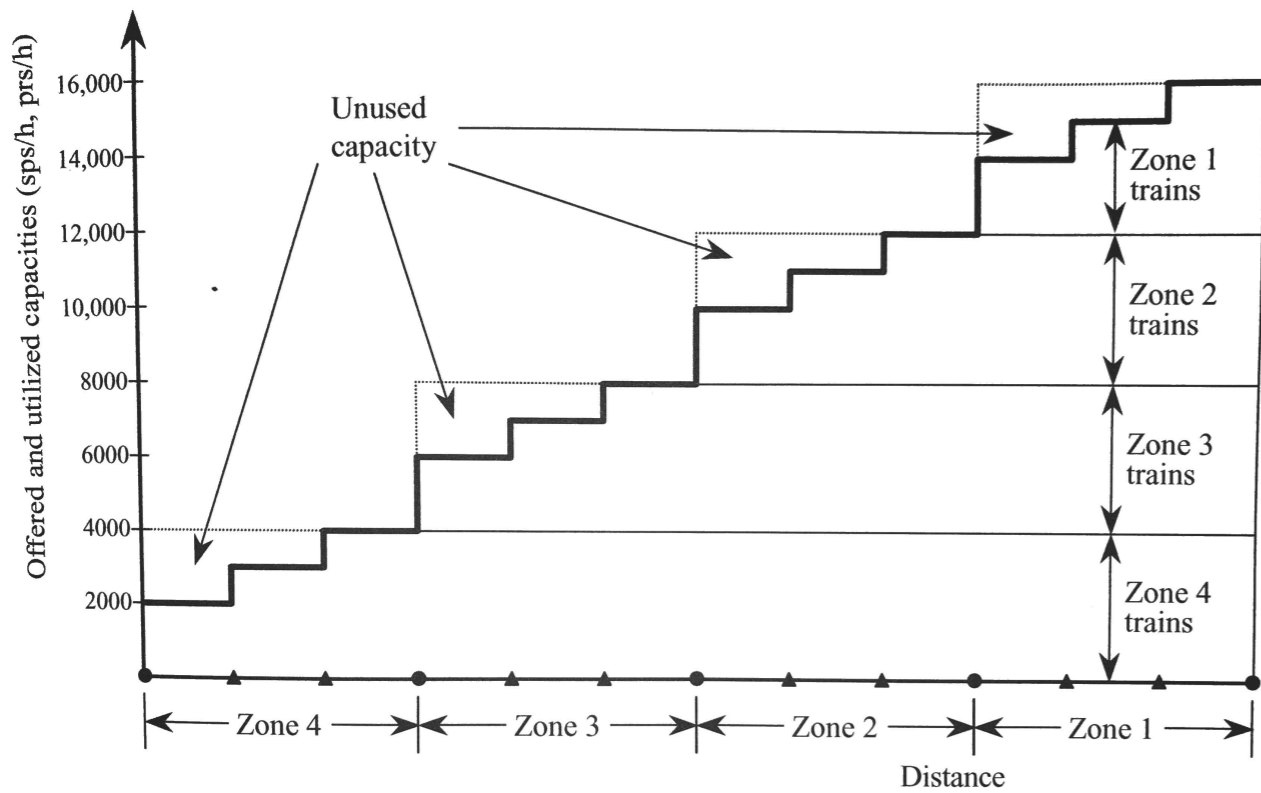


Figure 2.23 Offered and utilized capacities for local and zonal (four-zone) operations.

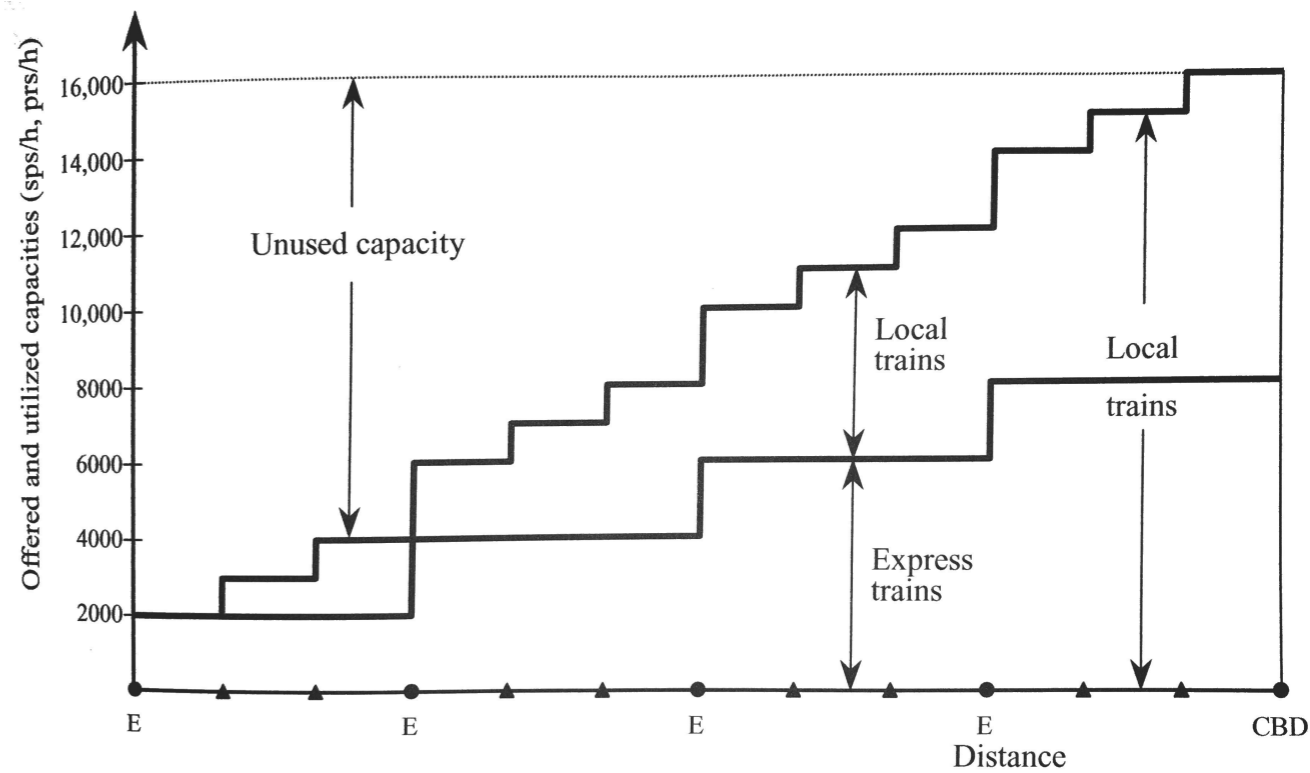


Figure 2.24 Offered and utilized capacities for local and express operations.

**Table 2.11** Comparison of operating data for different types of service

Regime	Train Type	$L$	$T_o$	$V_o$	$P_{max}$	$f$	$n$	$h$	$T$	$V_c$	$N_t$	$\Sigma N_t$	$N_f$	$\Sigma N_f$	$\bar{\alpha}$	$\bar{\alpha}_{serv}$
Local (all stop)		12	24	30	16,000	20	8	3	54	27	18	18	144	144	0.56	0.56
Skip-stop	A	12	20	36	8000	10	8	6/3	48	30	8	16	64	128	0.54	0.56
	B		20	36	8000	10	8	6/3	48	30	8		64			
Zonal—2	I	6	12	30	8000	10	8	6	30	24	5	12	40	96	0.63	0.75
	II	12	18	40	8000	10	8	6	42	34	7		56			
Zonal—4	I	3	6	30	4000	10	4	6	18	20	3	18	12	72	0.75	0.90
	II	6	9	40	4000	10	4	6	24	30	4		16			
	III	9	12	45	4000	10	4	6	30	36	5		20			
	IV	12	15	48	4000	10	4	6	36	40	6		24			
Local/ express	L	12	24	30	8000	10	8	6/3	54	27	9	16	72	128	0.50	0.56
	X	12	16	45	8000	10	8	6/3	42	34	7		56			

Assumed values:  $\alpha C_v = 100$  prs/TU;  $T_r = 1$  min/km;  $T = 1$  min;  $\min \Sigma t_r = 6$  min.

**Table 2.12** Transit line characteristics for different types of local and accelerated services

Characteristics	Type of Service	Local	Skip-stop	Zonal	Express/local
Stations	Many	+	+	+	+
	Few	+	—	—	—
Travel pattern	Many-to-one	+	+	+	+
	Many-to-many	+	+	—	—
Passenger volume	Moderate	+	+	+	+
	At capacity	+	+	—	—
Headways	Short	+	+	+	+
	Long	+	—	—	—

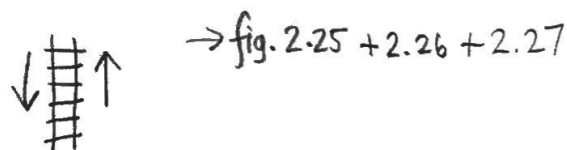
+ Condition allowing respective service.

— Condition not conducive to respective service.



Voies uniques, lignes circulaires, troncs/branches

Voies uniques • Single track



→ fig. 2.25 + 2.26 + 2.27

- La localisation des voies d'évitement/dépassement est critique
- besoin d'une grande précision + discipline pour conserver l'horaire et éviter les retards

passing sidings/turnouts

$t_{TO}$  → temps de parcours entre les évitements

$S_{TO}$  → distance entre les évitements

$$t_{TO} = \frac{60 S_{TO}}{V_0} = \frac{h}{2}$$

$Se', Se''$  → distance entre dernier/premier évitement et terminaux

$Se', Se'' < S_{TO}$  → tient compte de  $t_t$  et  $t_t$  (battement)

$$Se' = \frac{h - t_t}{120} \cdot V_0$$

Lignes circulaires • Loop, ring lines



fig. 2.28

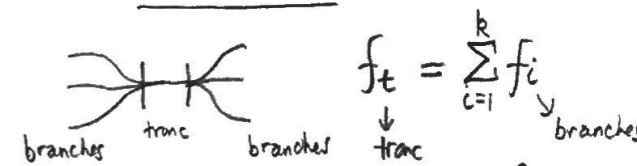
$t_t = 0$  (battement possible pour ↑ fiabilité)

$$T_0 = T_{cycle}$$

$$T_0 = h \cdot N \quad \rightarrow \text{nb de voyages}$$

$$V_0 = \frac{60L}{T_0} \left( = \frac{60L}{h \cdot N} \right) \rightarrow V_{0max} \text{ si } T_0 \text{ multiple de } h$$

Tronc/branches • Trunk with branches



$$f_t = \sum_{i=1}^k f_i$$

$$h_t = \frac{60}{f_t}$$

fig. 2.29a,b  
+ 2.30  
+ 2.31

$$C_t = \sum_{i=1}^k C_i = \sum_{i=1}^k f_i \cdot n_i \cdot C_{vi}$$

Idéal quand volumes des branches très semblables, sinon irrégulier → tableau 2.13

Possibilité de couplage/découplage des trains aux jonctions (délai à prévoir)

Si une des deux branches:  $P_B \gg 2P_A$ : mieux de coupler les lignes: ligne principale + 2 rabattements (+ transferts)

Synchronisation des horaires des branches: important! → fiabilité,  $t_{trk}$

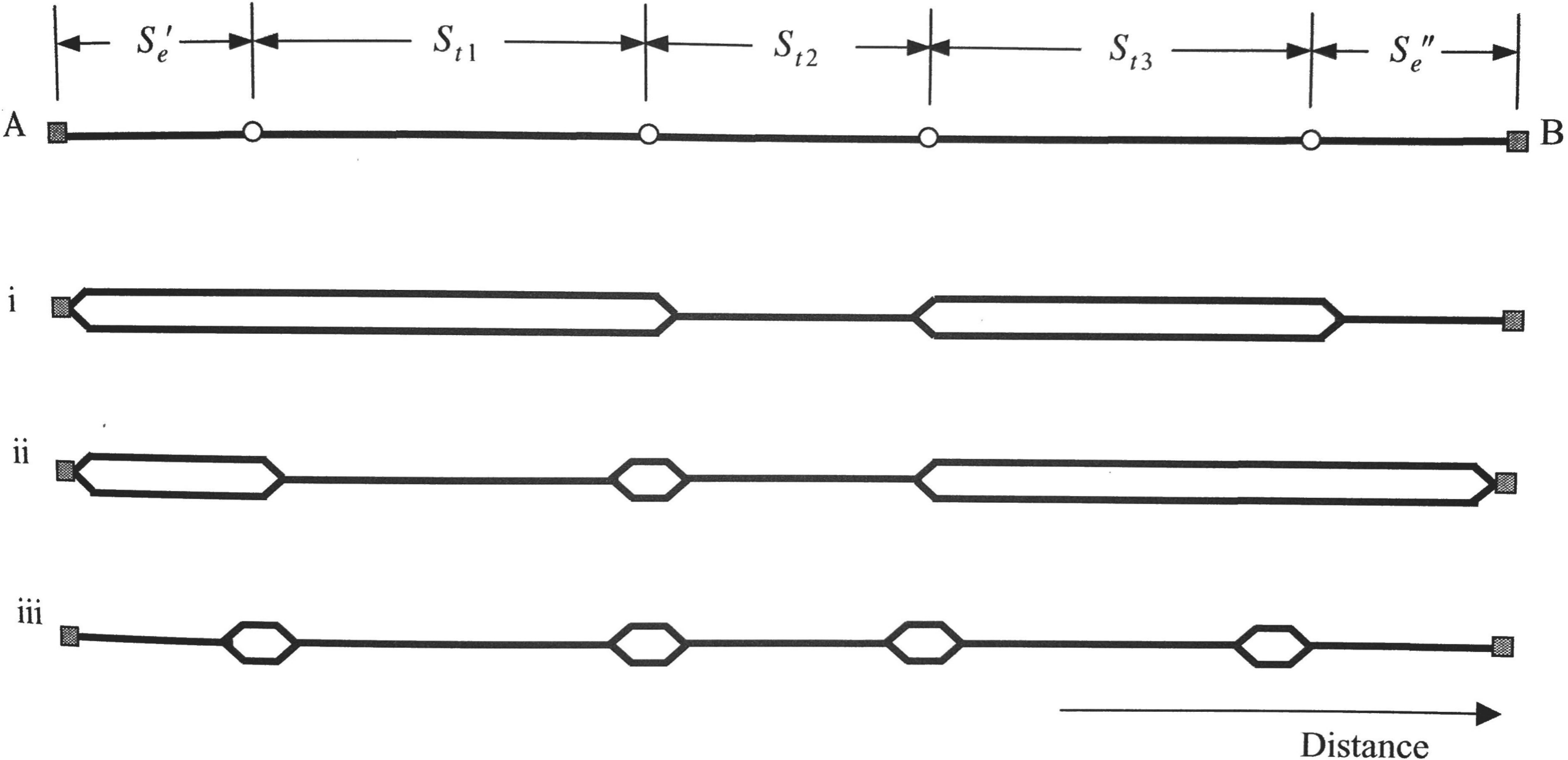


Figure 2.25 Line with single- and double-track sections and four meeting points.

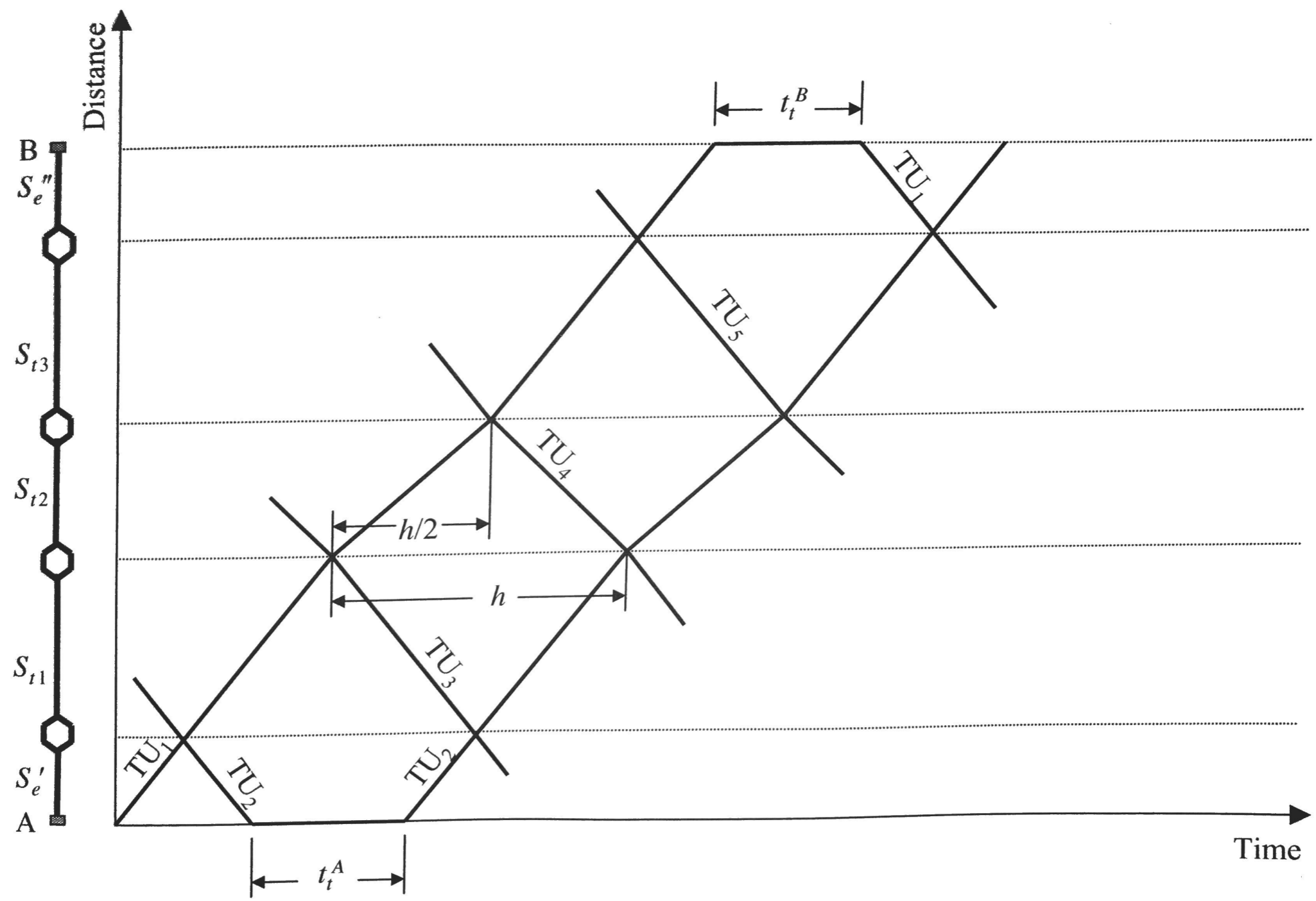


Figure 2.26 Time-distance diagram for the single track line iii from Figure 2.25 operating with minimum headway and five TUs.



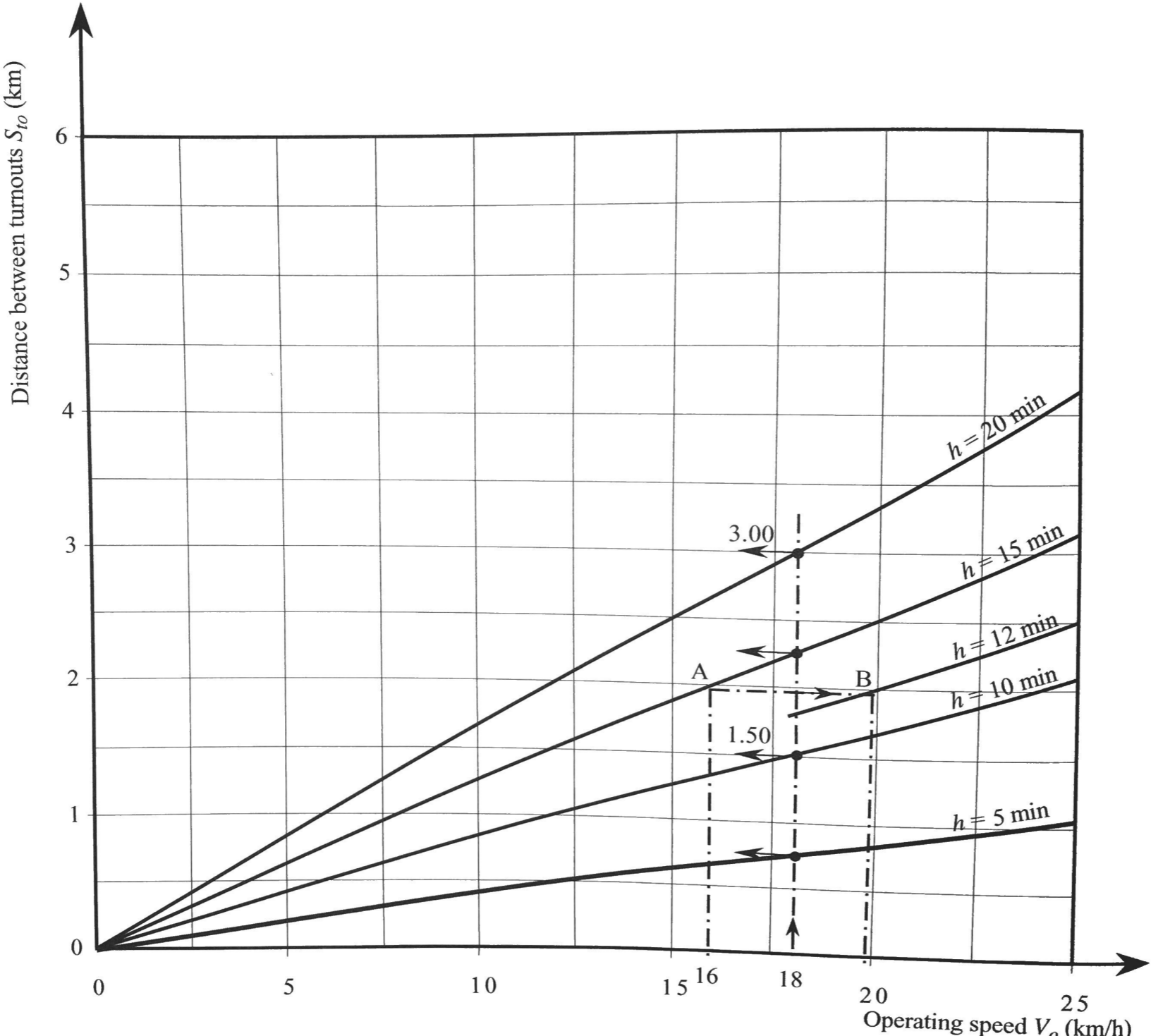


Figure 2.27 Relationships among operating speed, headway, and distance between passing sidings on single-track lines.

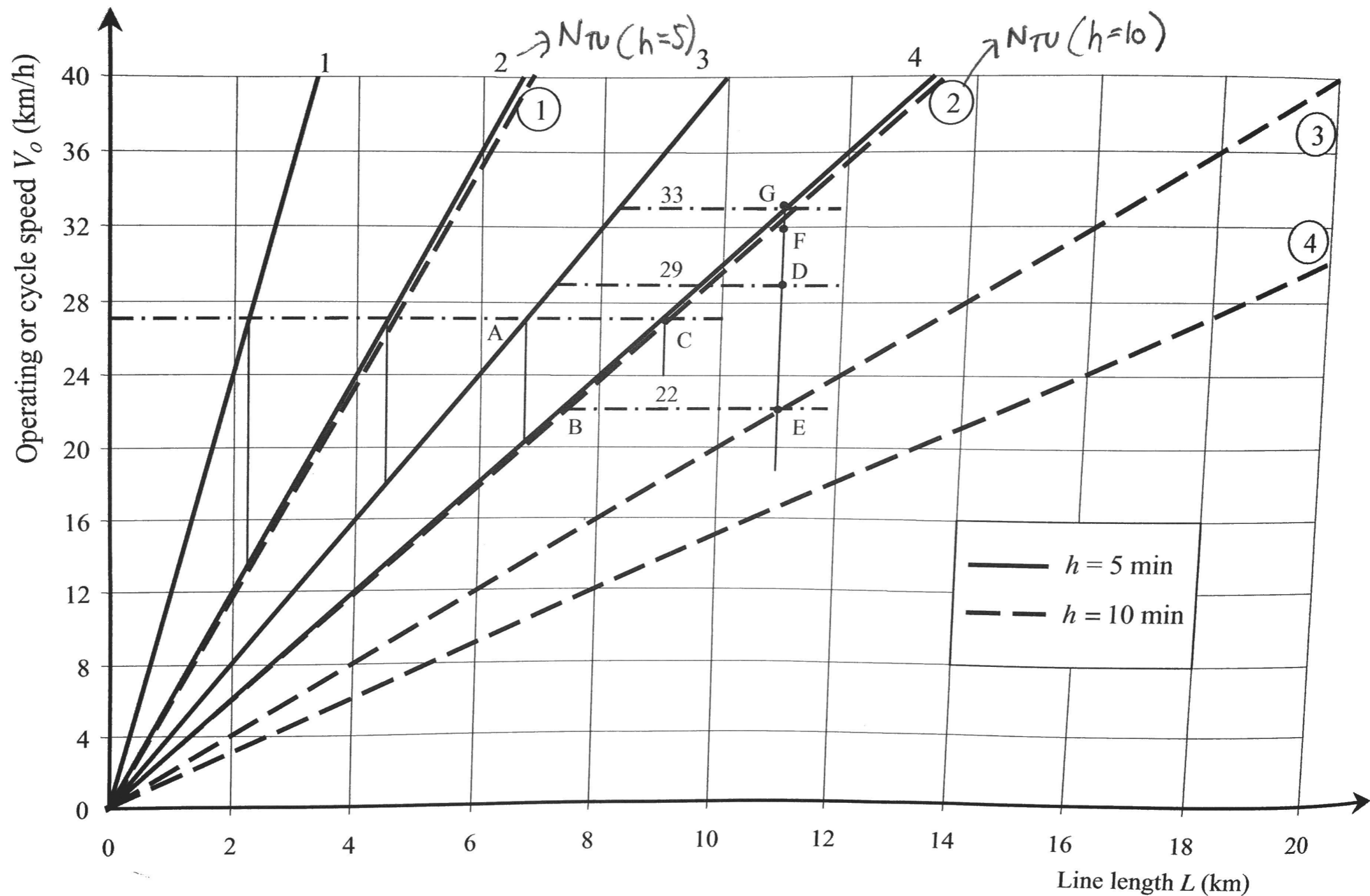
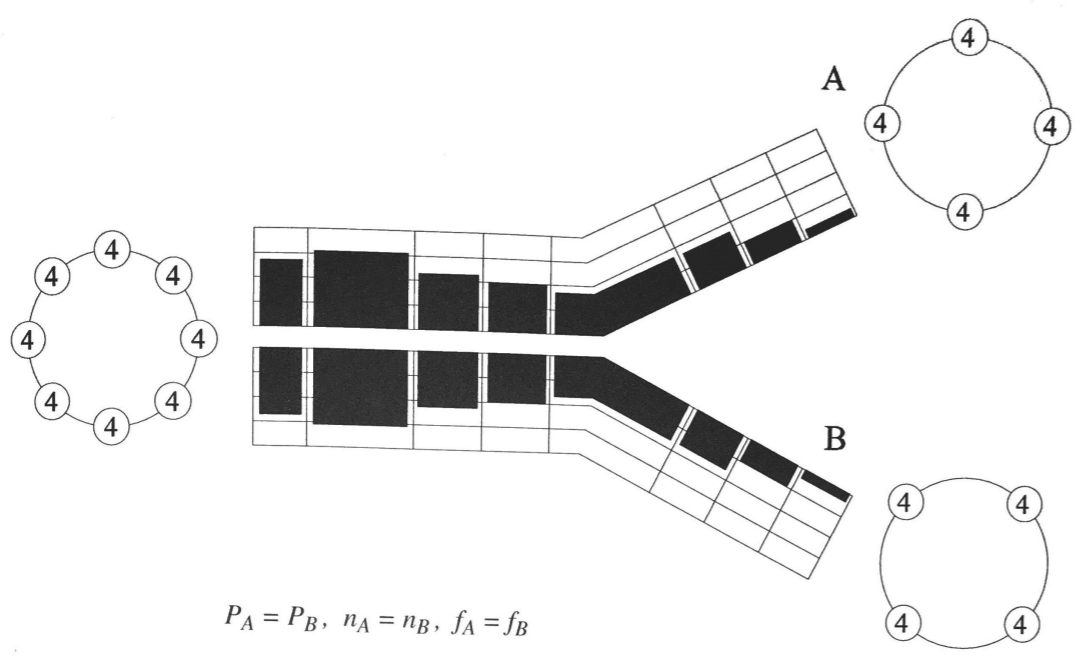


Figure 2.28 Relationships among line length, headway, number of TUs, and operating speed on circle lines.

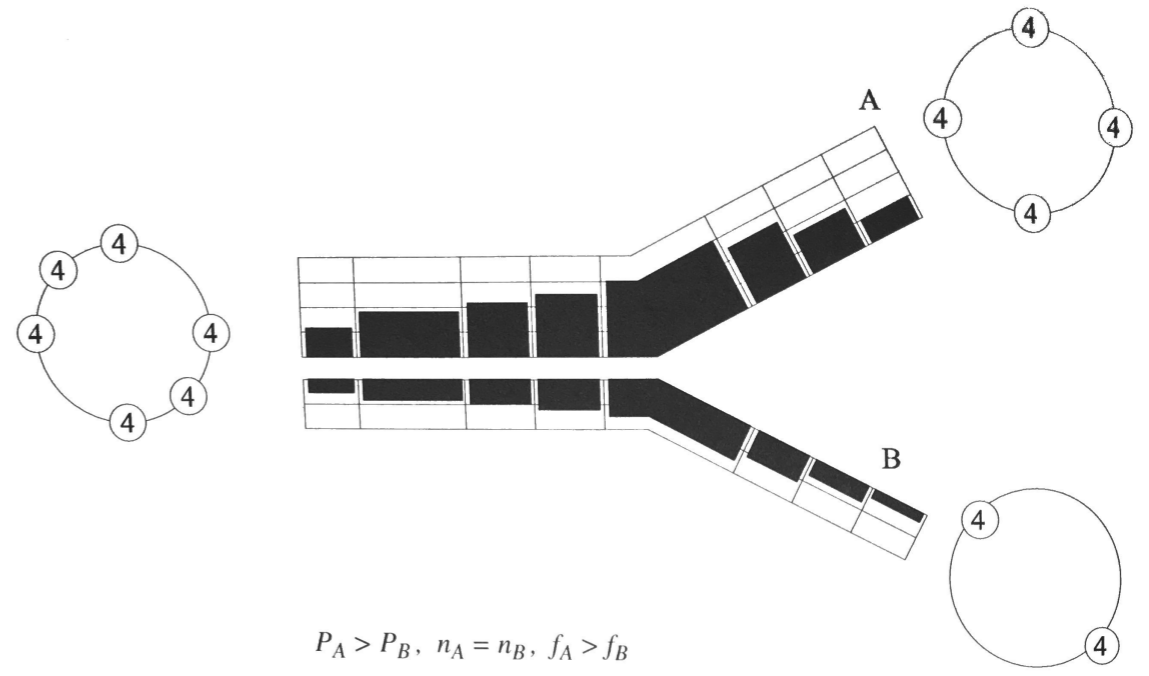
**Table 2.13** Different types of scheduling for trunk line T with branches A and B

Case	$P$	$n$	$f$	$h$	Regular section
i	$P_A \approx P_B$	$n_A = n_B$	$f_A = f_B$	$h_T = \frac{1}{2} h_A = \frac{1}{2} h_B$	T, A, B
ii	$P_A > P_B$	$n_A = n_B$	$f_A > f_B$	$h_T, h_B$ uniform $h_A$ irregular	T, B
iii	$P_A > P_B$	$n_A = n_B$	$f_A > f_B$	$h_T$ irregular $h_A, h_B$ uniform	A, B
iv	$P_A > P_B$	$n_A > n_B$	$f_A = f_B$	$h_T = \frac{1}{2} h_A = \frac{1}{2} h_B$	A, B
v	$P_A \gg P_B$	$n_A > n_B$	$f_A > f_B$	$h_T, h_B$ uniform $h_A$ irregular	B
vi	$P_A \gg P_B$	$n_A > n_B$	$f_A > f_B$	$h_T$ irregular $h_A, h_B$ uniform	A, B
With coupling of branch trains at the merging point, $n_T = n_A + n_B$					
vii	$P_A \approx P_B$	$n_A = n_B$	$f_A = f_B$	$h_T = h_A = h_B$	T, A, B
viii	$P_A > P_B$	$n_A > n_B$	$f_A = f_B$	$h_T = h_A = h_B$	T, A, B

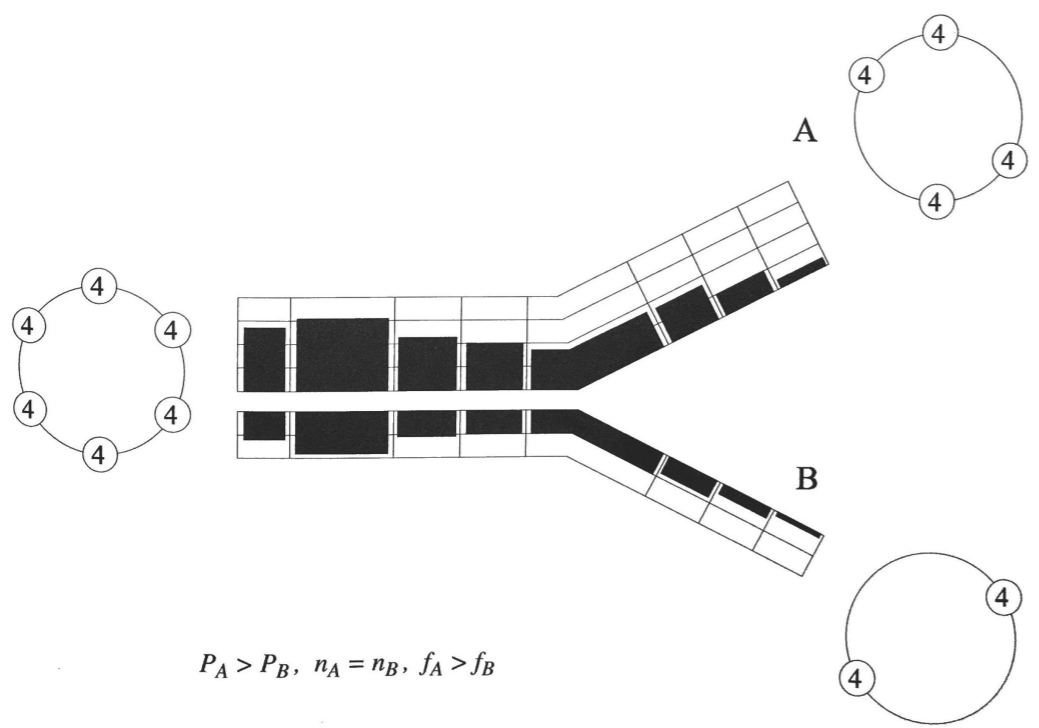




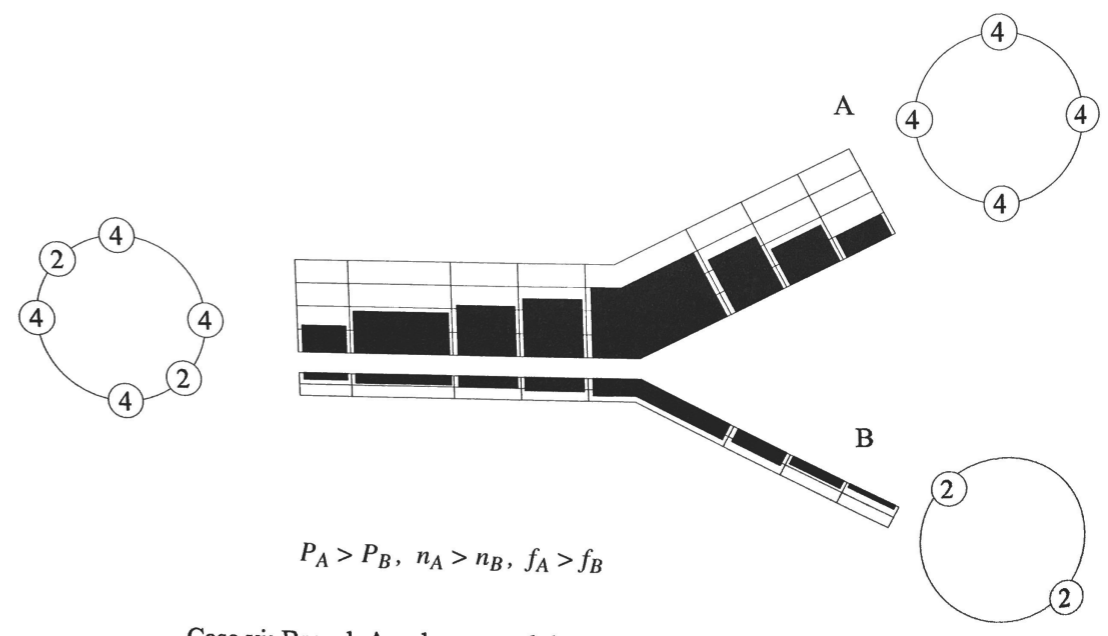
Case i: Branch volumes equal, 4-car train consists, equal headways



Case iii: Volumes the same as in case ii, but headways on branches uniform, on the trunk irregular



Case ii: Branch A volume heavier, 4-car train consists, uneven headways on A



Case vi: Branch A volume much heavier, different train consists and headways, trunk service irregular

Figure 2.29 Selected cases of different trunk-branch volumes, train consists, and headways.

Figure 2.29 (continued)

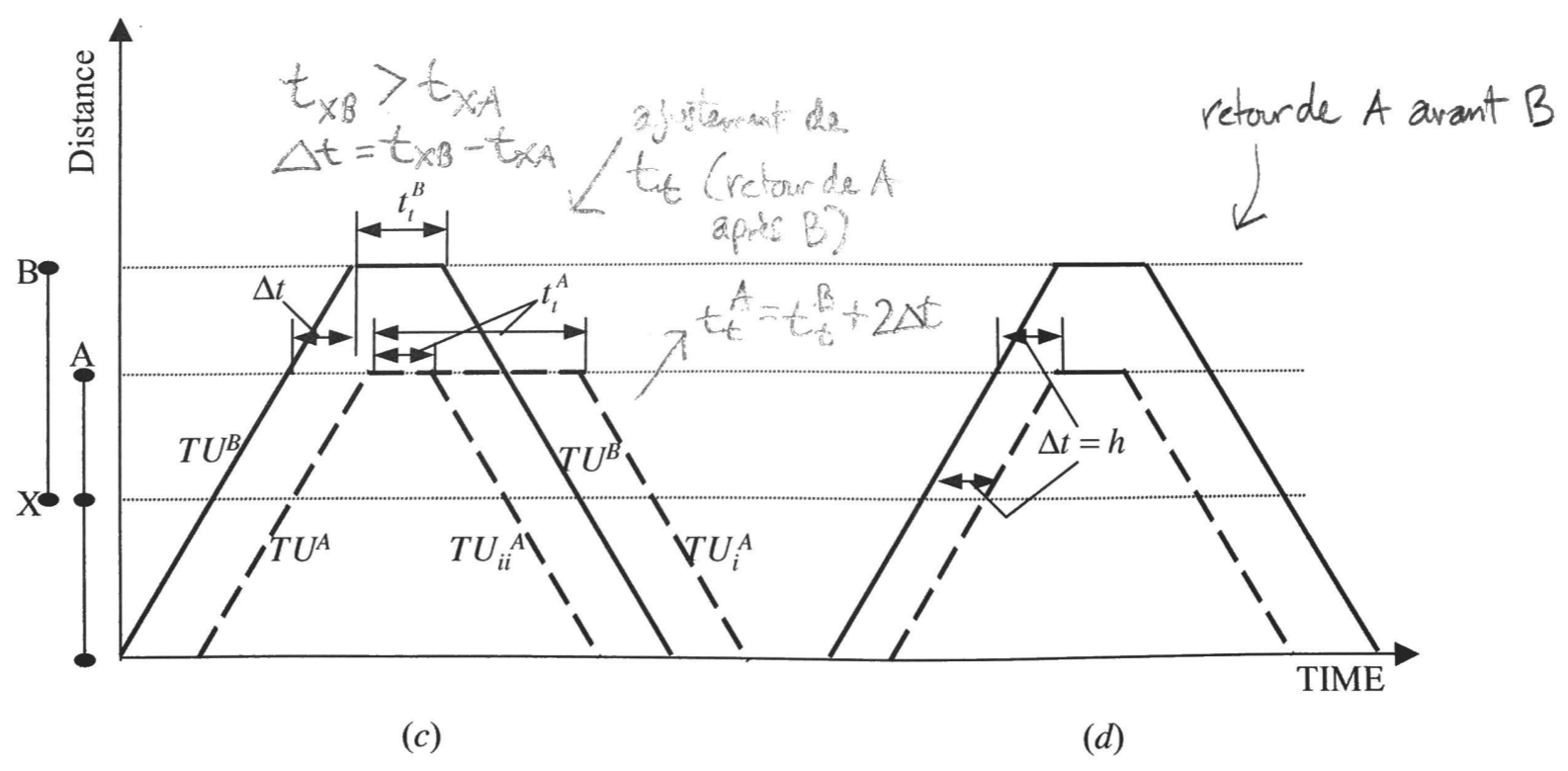
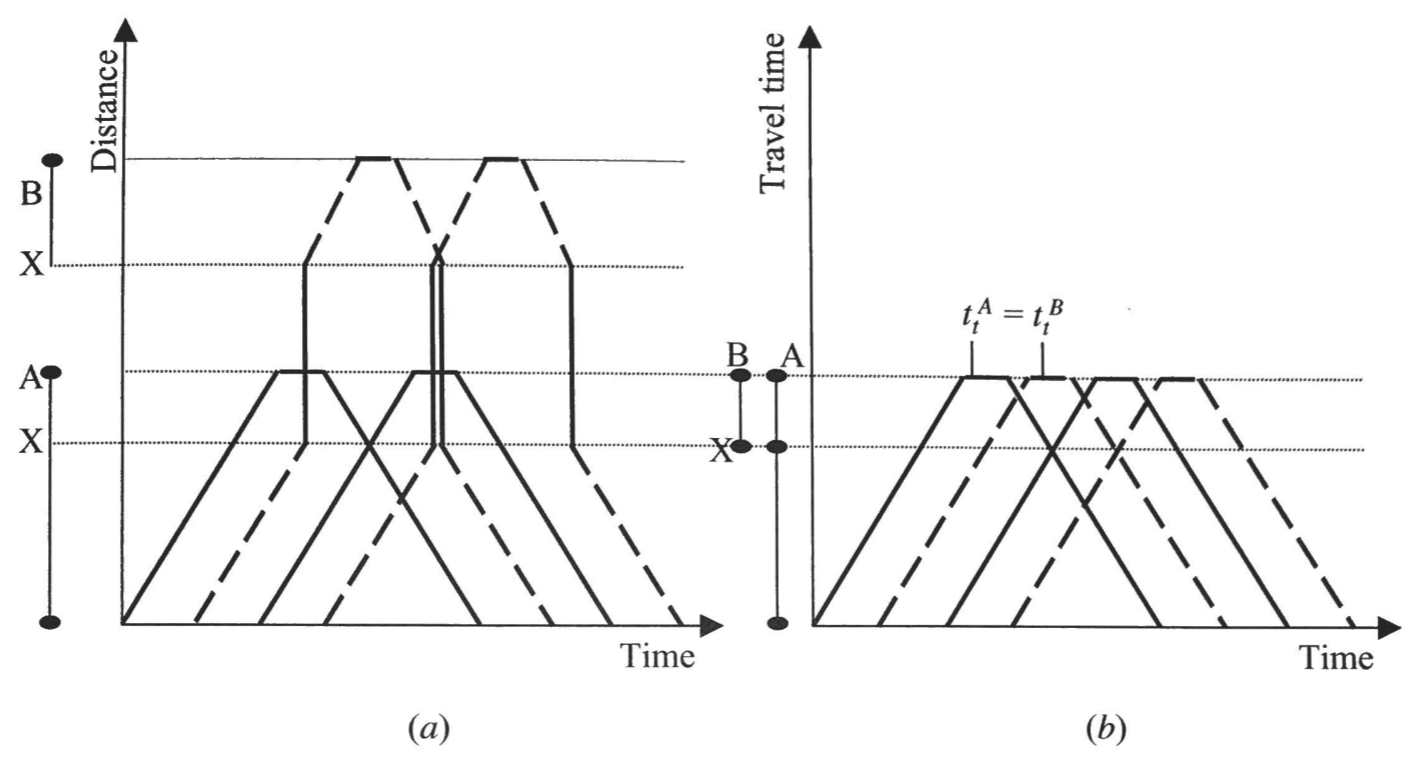


Figure 2.31 Trunk with branches line schedules: (a) separate presentation at branches; (b) joint diagram for branches; (c) operations with the same and inversed TU sequences; (d) case with  $\Delta t = h$ .