



Transportation Engineering Notebook

Done By :

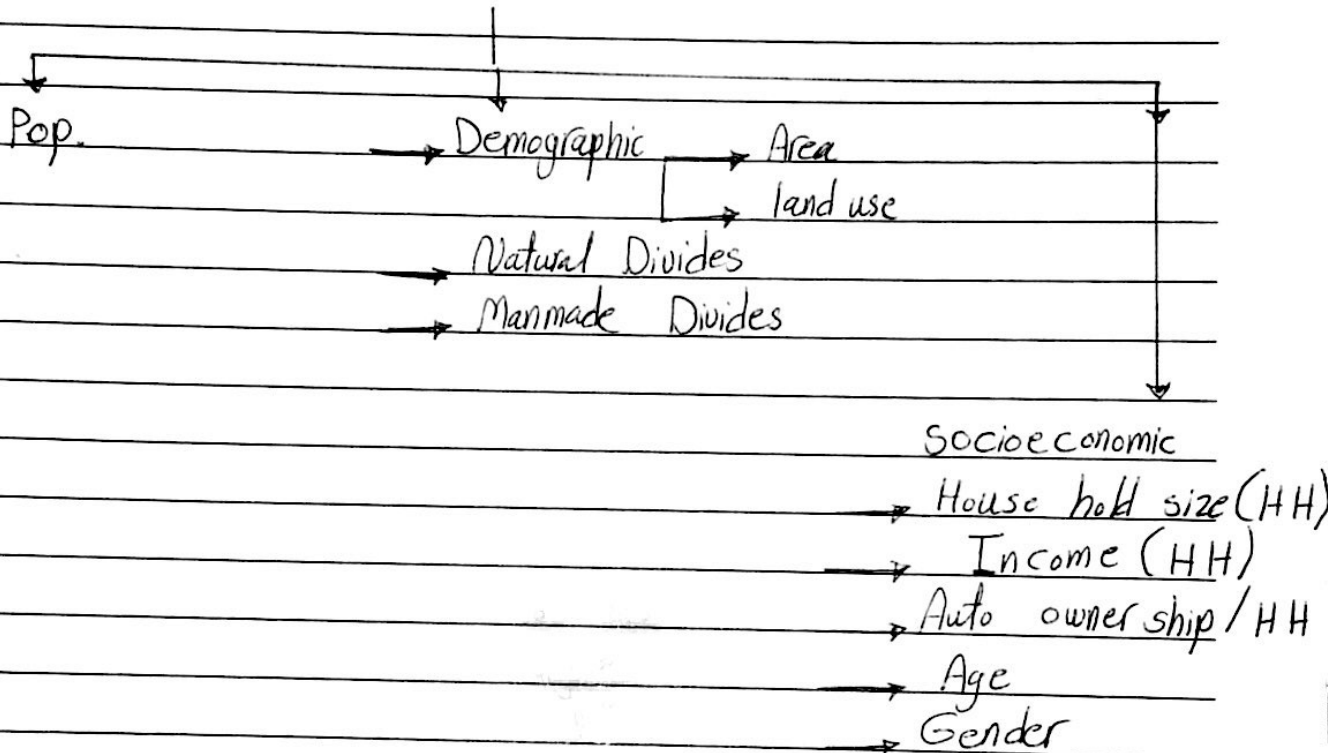
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4/2/2016

Urban Transportation Planning Process (UTP)

① Study Area (SA)

② Divide (SA) into smaller Units → Zones (TAZ)



③ O-D survey:

trip length

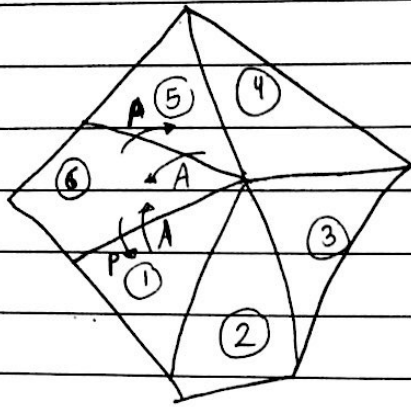
links used

Modes of transportation used

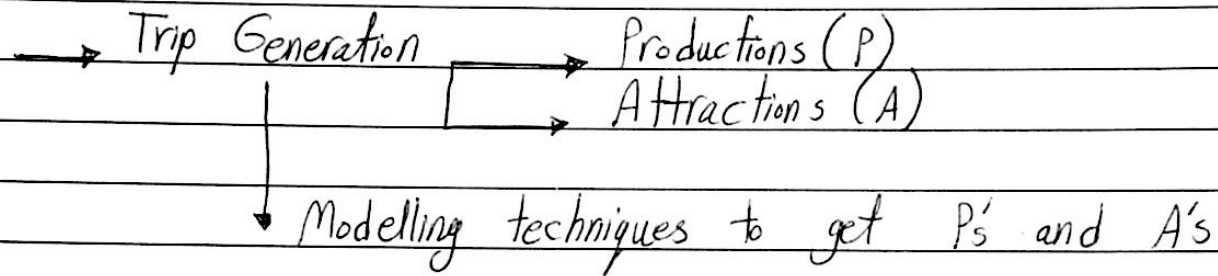
travel time (min)

cost

etc....



Internal- Internal trips



O-D survey

(7/2/2016)

HH size:

Age

Gender:

Employment:

Auto ownership / HH

income / Avg. Annually

origin

Destination

Cost

travel time

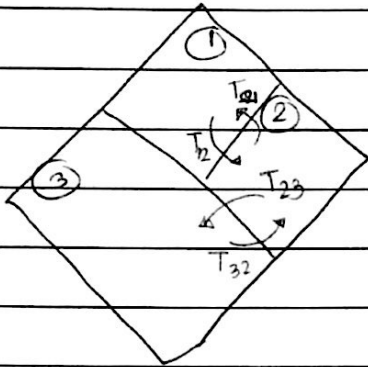
Modes of transport

4-step Demand Modelling,

Trip generation

Productions (P)

Attractions (A)



Study Area.

T_{12} : Produced from 1
Attracted to 2

T_{23} : Produced from 2
Attracted to 3

Zone	P	A
1	T_{12}	T_{21}
2	T_{23}	T_{32}
3	T_{32}	T_{23}

For the same study Area

$$\sum_{i=1}^n P_i$$

$$\sum_{j=1}^n A_j$$

=

• Trip purposes normally defined:

1. Home-Based-work (HBW)
2. Home-Based-other (HBO)

الدولة

Shopping

visit

Dr.

entert

tourism

3. Non-Home-Based (NHB)

أي، حالة ليس أن أظن أن هذا في أي دولة

Ex 12.2

Computing trips Generated in a Suburban Zone
Consider a zone that is located in a suburban area of a city. The population income data for the zone are as follows.

Number of dwelling units: 60 (house hold)

Average income per dwelling unit, \$ 44000

Determine the number of trips per day generated in this zone for each trip purpose assuming that the characteristics depicted in Fig. 12.2 through 12.5 apply in this situation. The problem is solved in four basic steps.

$$HH = (60)$$

Low (L)

Medium (M)

High (H)

Income
Fig 12.2

$$\frac{60 \times 9}{100}$$

$$\frac{60 \times 40}{100}$$

$$\frac{60 \times 51}{100}$$

Automobile
figure 12.3

0

1

+2

$$\frac{60 \times 9 \times 54}{100 \times 100}$$

$$\frac{60 \times 9 \times 4}{100 \times 100}$$

$$\frac{60 \times 51 \times 2}{100 \times 100}$$

$$\frac{60 \times 51 \times 68}{100 \times 100}$$

$$\frac{60 \times 9 \times 42}{100 \times 100}$$

$$\frac{60 \times 40 \times 4}{100 \times 100}$$

$$\frac{60 \times 17 \times 38}{100 \times 100}$$

$$\frac{60 \times 29 \times 58}{100 \times 100}$$

$$\frac{60 \times 51 \times 30}{100 \times 100}$$

(Avg. daily trips) 12.4

1

6

7

2

8

13

3

11

15

$$\Sigma \text{Trips (L)} = 19$$

$$\Sigma \text{Trip (M)} = 232$$

$$\Sigma \text{Trip (H)} = 415$$

by Purpose Fig 12.5

↓

↓

↓

↓

↓

↓

↓

↓

↓

HBW

HBO

NHB

HBW

HBO

NHB

HBW

HBO

NHB

$$19 \times 15\%$$

$$19 \times 55\%$$

$$19 \times 30\%$$

$$17\%$$

$$51\%$$

$$32\%$$

$$18\%$$

$$48\%$$

$$34\%$$

3

10

6

90

118

74

75

199

141

$$\Sigma \text{HBW} = 118$$

$$\Sigma \text{HBO} = 327$$

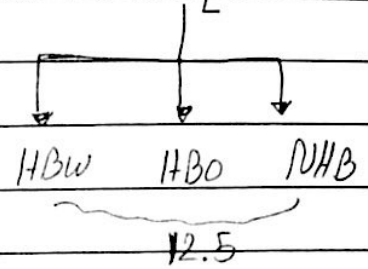
$$\Sigma \text{NHB} = 221$$

Five Apple

Scanned by CamScanner

$$L: 0: HH * \%HH(L) * (\%HH(L)/0) * (Trip(L)(0)) = \sum T_L$$

: 1



: 2

$$M: 0: HH * (\%HH(M))$$

1:

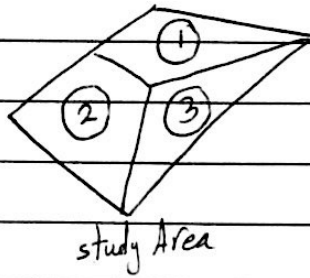
2:

$$H: 0: HH * (\%HH(M))$$

1:

2:

9/2/2015



$$P_1 = 100$$

$$P_2 = 200$$

$$P_3 = 300$$

$$\sum_{i=1}^3 P_i = 600$$

$$\sum_{j=1}^3 A_j = 800$$

HBW or HBO:

In order to adjust the ΣP to be equal ΣA :

- ① Multiply each attraction zone with a factor $\left(\frac{\sum P_i}{\sum A_j} \right)$

NHB:

- ② Delete all unbalanced Production and replace each production with the respective balanced (1) attraction for each zone in (SA)

trip Distribution

(O-D matrix)

O(i) \ D(j)	1	2	3	
1	$\emptyset$ T_{11}	T_{21}	T_{31}	A_1
2	T_{12}	T_{22}	T_{32}	A_2
3	T_{13}	T_{23}	T_{33}	A_3
	P_1	P_2	P_3	

$$\text{Total } P = \text{Total } A$$

Attr. given as values for

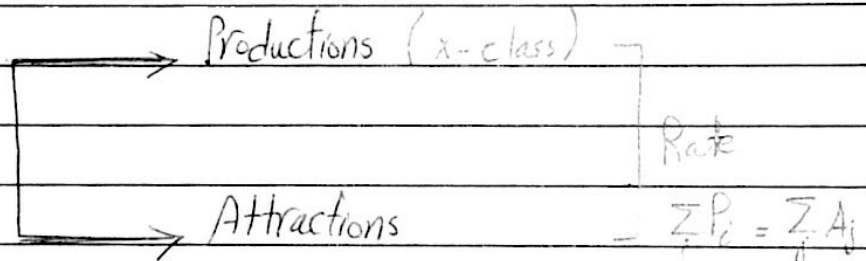
$$T_{ij} = \frac{P_i \times A_j \times FF_{ij} \times K_{ij}}{\sum (A_j \times FF_{ij} \times K_{ij})}$$

$$T_{12} = \frac{P_1 \times A_2 \times FF_{12} \times K_{12}}{(A_1 \times FF_{11} \times K_{11}) + (A_2 \times FF_{12} \times K_{12}) + (A_3 \times FF_{13} \times K_{13})}$$

14/2/2016

4- Step Demand Modeling:

1: trip generation



→ 2: trip Distribution : (Gravity model)

$$T_{ij} = P_i \frac{A_j \times FF_{ij} \times K_{ij}}{\sum (A_j \times FF_{ij} \times K_{ij})}$$

Ex 12.4

O-D table from 1st iteration (Singly constrained):

$D_j \backslash O_i$	1	2	3	calculated (A)	Given desired (A)
1	T_{11}	T_{21}	T_{31}	$A_1 = 379$ ($> 5\%$)	300
2	T_{12}	T_{22}	T_{32}	$A_2 = 210$ ($> 5\%$)	270
3	T_{13}	T_{23}	T_{33}	$A_3 = 161$ ($> 5\%$)	180
calculated (P) Given	$P_1 = 140$	$P_2 = 330$	$P_3 = 280$		

→ Another iteration

Note: T_{11} when Production (1) - 1st
 T_{22} when Attraction (2) - 2nd

Note: $\sum P_i = \sum A_j$ (value of $\sum P_i$ & $\sum A_j$ should be equal)

A_j can be adjusted another iteration if: (for each A_j)

$$\left(\frac{A_{\text{Desired}} - A_{\text{cal}}}{A_{\text{Desired}}} \right) \times 100\% > 5\%$$

Zone 1:

$$T_{11} = P_1 \left(\frac{A_1 FF_{11} K_{11}}{(300)(39)} + \frac{A_2 FF_{12} K_{12}}{(270)(52)} + \frac{A_3 FF_{13} K_{13}}{(180)(50)} \right)$$

$$= 47$$

$$T_{12} = P_1 \left(\frac{(270) A_2 FF_{12} (52) K_{12}}{(140)} \right)$$

$$= 57$$

$$T_{13} = P_1 \left(\frac{A_3 FF_{13} K_{13}}{(36)} \right)$$

Adjusted attraction for zone (j) in iteration (K)
from trip generation

$$= \frac{\text{Desired Attraction for zone (j)}}{\text{computed Attraction for zone (j) from previous iteration}}$$

* Adjusted Attraction for zone (j) in iteration (K-1)

for 2nd iteration only $A_j = A_j^{(K-1)}$

Adjusted Attraction for 2nd iteration (Doubly constrained)

$$\text{Zone 1: } A_{12}^{jk} = \frac{A_1^{(300)} A_{1(2-1)}^{(300)}}{C_{1(2-1)}^{(379)}} = 237$$

$$\text{Zone 2: } A_{22} = \frac{A_2^{270} A_{2(2-1)}^{270}}{C_{2(2-1)}^{210}} = 347$$

$$\text{Zone 3: } A_{32} = \frac{A_3^{180} A_{3(2-1)}^{180}}{C_{3(2-1)}^{161}} = 201$$

Note →

(Computed & Given) $\frac{A_{ij}}{C_{ij}}$

نصف (1.5) $\frac{A_{ij}}{C_{ij}}$

نصف من اجل ذلك

for 2nd iteration O-D matrix

$$T_{11} = P_1^{140} \left(\frac{A_{12}^{237} * FF_{11}}{\frac{A_{12}}{237} + \frac{A_{22}}{347} + \frac{A_{32}}{201}} \right)$$

$$= 34$$

Assume that a 3rd iteration is needed:

$$\text{Zone 1: } A_{13} = \frac{A_1^{300}}{C_1(3-1)} \frac{A_1^{237}}{A_1(3-1)} = 234.6$$

$$\text{zone 2: } A_{23} = \frac{A_2^{270}}{C_2(3-1)} \frac{A_2^{347}}{A_2(3-1)} = 349.58$$

$$\text{zone 3: } A_{33} = \frac{A_3^{180}}{C_3(3-1)} \frac{A_3^{20}}{A_3(3-1)} = 202.12$$

3rd iteration:

$$T_{11} = 34.22$$

$$T_{21} = 151.676$$

$$T_{31} = 114.43$$

$$\sum 300.316 = A_1$$

16/2/2016

c) Modal Split

3. Trip Interchange Models

$$T_{ij} = IVTT + \underbrace{25}_{\text{walking}} \times \text{excess time} + 3 \left(\frac{\text{cost/income/min.}}{\text{walking}} \right)$$

$$\left(\frac{60}{24000} \times \left(\frac{8}{20} \times 250 \right) + \left(\frac{10}{30} \right) + \left(\frac{260}{24000} \right) + \left(\frac{104}{20000} \right) \right) \times 365 = 120000 \text{ min}$$

$$M_{ijSD} = \frac{I_{ija}^b}{I_{ija}^b + I_{ijt}^b} \times 100$$

Ex 12.9

$$I_{SDa} = \left(\frac{10}{30} \right) 60 + \left(\frac{2.5}{24000} \times 5 \right) + 3 \left(\frac{5.15 \times 10 + 0.75}{24000} \right) = 66.25 \text{ exp. min}$$

$$I_{SDt} = \left(\frac{8}{20} \right) 60 + \left(\frac{2.5}{24000} \times 8 \right) + 3 \left(\frac{0.10 \times 8}{20000} \right) = 56 \text{ exp. min}$$

$$M_{SDa} = \frac{I_{SDt}^b}{I_{SDt}^b + I_{SDa}^b} \times 100 = \frac{56^2}{56^2 + 66.25^2} \times 100 = 41.6\%$$

Logit Models :

Utility - Attractiveness of a specific of transportation
مقياس
من الكمية
والعيار

$$U = B_0 + B_1 x_1 + \dots + B_n x_n$$

$$P(A) = \frac{e^{U_A}}{e^{U_A} + e^{U_T}}$$

$$P(T) = 100\% - P(A)$$

or $= \frac{e^{U_T}}{e^{U_A} + e^{U_T}}$

4 analysis of performance

4 step Demand Modelling

① Trip generation

$\sum P_i$ → x-class
 $\sum A_i$ → rate

② Trip Distribution

Gravity
O-D matrix

③ Modal split

Trip End

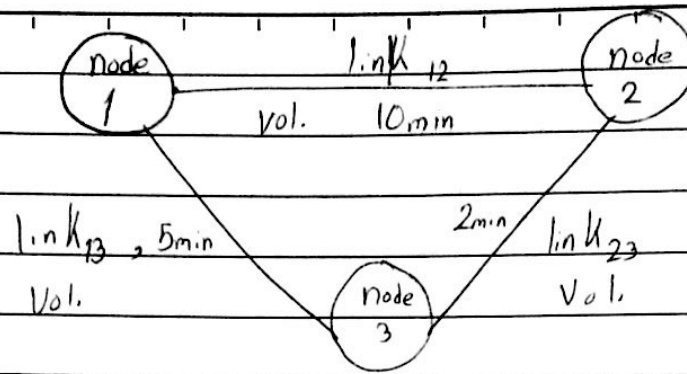
Trip interchange

QRS

logit

④ traffic Assignment (Route choice)

18/2/2016



Network → skim tree

Other Models used to Model Demand Trip Generation

2 Trip generation with count data models

$$P(T_i = 4) = \frac{e^{-\lambda} \lambda^4}{4!}$$

$$P(T_i \leq 3) = P(T_i = 0) + P(T_i = 1) + P(T_i = 2) + P(T_i = 3)$$

$$= \frac{e^{-\lambda} \lambda^0}{0!} + \frac{e^{-\lambda} \lambda^1}{1!} + \frac{e^{-\lambda} \lambda^2}{2!} + \frac{e^{-\lambda} \lambda^3}{3!}$$

$$P(T_i > 3) = 1 - P(T_i \leq 3)$$

23/2/2016

2 Trip Generation with count data models

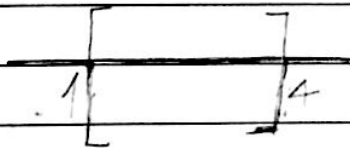
$$P(T_i=2) = \frac{e^{-\lambda} \lambda^2}{2!}$$

λ = expected value of trips = e^{β_1} ← linear regression

$$\begin{aligned} P(T_i \leq 2) &= P(T_i=0) + P(T_i=1) + P(T_i=2) \\ &= \frac{e^{-\lambda} \cdot \lambda^0}{0!} + \frac{e^{-\lambda} \cdot \lambda}{1!} + \frac{e^{-\lambda} \cdot \lambda^2}{2!} \end{aligned}$$

$$P(T_i > 2) = 1 - P(T_i \leq 2)$$

$$P(1 < T_i < 4)$$



TRip Distribution

2. Growth Factor Models

Factor: $T_{ij} = (t_i G_i) = \frac{t_{ij} G_j}{\sum_x t_{ix} G_x}$

Ex 12.6

1st iteration (600) (1.2) (400) (1.1)

$$T_{AB} = t_{AB} G_A = t_{AB} G_B = 446$$

$$\frac{t_{AB} G_B}{(400) (1.1)} + \frac{t_{AC} G_C}{(100) (1.4)} + \frac{t_{AD} G_D}{(100) (1.3)}$$

$$T_{BA} = t_{BA} G_B = t_{BA} G_A = 411$$

$$\frac{t_{BA} G_A}{(400) (1.2)} + \frac{t_{BC} G_C}{(300) (1.4)} + \frac{t_{BD} G_D}{0}$$

$$T_{AB} = \frac{T_{AB} + T_{BA}}{2} = \frac{446 + 411}{2} = 428$$

	A	B	C	D
A	~	428	141	124
B	428	~	372	~
C	141	372	~	430
D	124	~	430	~
Σ	693	800	943	554

2nd iteration

$$G_A = 720/693 = 1.04$$

$$\frac{L_i}{693}$$

$$G_B = 770/800 = 0.96$$

$$800$$

$$G_C = 980/943 = 1.04$$

$$943$$

$$G_D = 520/554 = 0.94$$

$$554$$

(1 = G_f) $\Rightarrow$ $\frac{L_i}{L_j}$ $\Rightarrow$ $\frac{L_i}{L_j}$

2-D iteration O-D

$$T_{AB} = \frac{693 \times 1.04 \times 428 \times 0.96}{428 \times 0.96 + 141 \times 1.04 + 124 \times 0.94} = 439.31$$

$$T_{BA} = \frac{800 \times 0.96 \times 428 \times 1.04}{428 \times 1.04 + \cancel{141 \times 1.04} + \cancel{124 \times 0.94}} = 410.88$$

$\rightarrow 372(1.04)$

$$\bar{T}_{AB} = \frac{410.88 + 439.31}{2} = 425.095$$
$$= 425.095 \approx 425$$

2nd iteration O-D table

	A	B	C	D
A	~	425	158	121
B	425	~	371	~
C	158	371	~	420
D	121	~	420	~
Σ	704	796	949	541
Diff.	2%	3.4%	3%	4%

stop. solution

28/2/2016

Average growth factor Model

$$T'_{ij} = T_{ij} \left(\frac{G_i + G_j}{2} \right)$$

T'_{ij} : # of estimated trips between zones i and j

T_{ij} : Present no. of trips between zones i and j

Example

1st iteration

$$T'_{AB} = 25 \times \left(\frac{3+4}{2} \right) = 87.5$$

Not used T_{AB} here

2nd iteration

$$G_A = 1.143$$

$$G_B = 1.379$$

$$G_C = 0.917$$

$$G_D = 0.558$$

$$T'_{AB} = 87.5 \left(\frac{1.143 + 1.379}{2} \right) = 110.34$$

$$T_A = 281.43$$

$$T'_{AC} = 128.56$$

$$T_B = 807.86$$

$$T'_{AD} = 42.53$$

$$T_C = 865.29$$

$$T'_{BC} = 515.93$$

$$T'_{BD} = 181.59$$

$$T_D = 444.92$$

$$T'_{CD} = 220.8$$

12th iteration

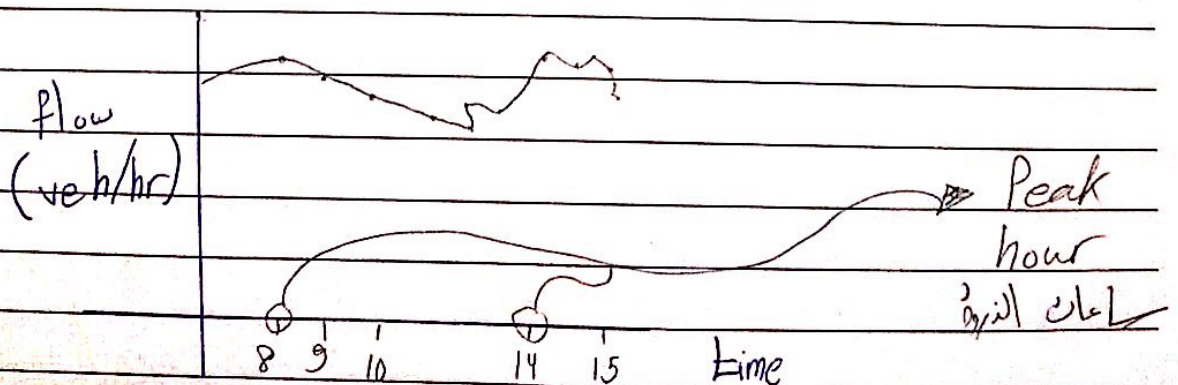
	A	B	C	D
A	~	87.5	125	50
B	87.5	~	420	187.5
C	125	450	~	300
D	50	187.5	300	~

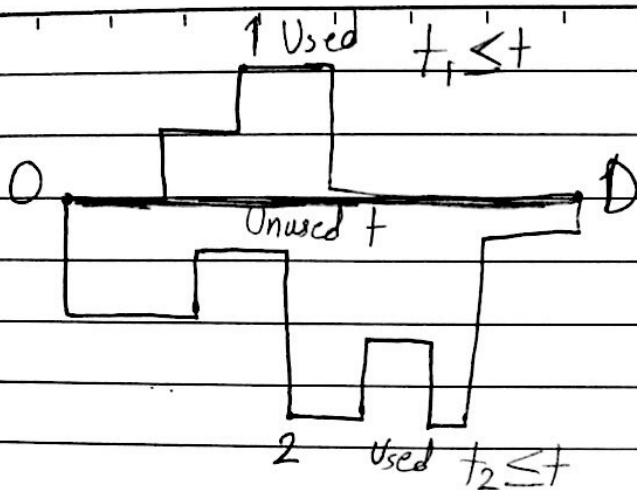
Route choice

Traffic flow = traffic Demand
= Equivalent hourly volume

Equivalent hourly volume : no. of vehicles traversing a segment of a road during one hour (veh/hr.)

Capacity: max. traffic flow that could be accommodated by a specific segment of road. (veh/hr.)





According to UE:

in order to use both routes, travel time 1
= travel time 2

• Performance Function: $T_1 = \overset{B_0}{\underbrace{T_0}} + B_1 \frac{X_1}{C_1}$

T_1 : travel time on Route 1 (min)

$T_0(B_0)$: All or nothing travel time
(Based on speed and distance) (min)

B_1 : coefficient of correlation

X_1 : traffic flow on route 1 (veh/hr) in (1000 s')

C_1 : Capacity on route 1 (veh/hr) in (1000 s')

UE:

$$t_1 = t_2$$

reduction of the capacity:

(Bottle-neck) when capacity of road is reduced.

Example 1

$$X_1 + X_2 = 3.5 \rightarrow ?$$

initially $\rightarrow$ route 1: $t_1 = 2 + 3 \left(\frac{X_1}{C_1} \right)$, $C_1 = 2500$

route 2: $t_2 = 2 + 2 \left(\frac{X_2}{C_2} \right)$, $C_2 = 4000$

1000 = change in TTT

During reconstruction:

$$t_1 = 2 + \frac{3}{2.5} X_1$$

$$t_2 = 4 + \frac{2}{2} X_2$$

total travel time (TTT) = $X_1 t_1 + X_2 t_2$
(veh-hr)

$$(TTT)_{\text{before}} = (TTT)_{\text{after}}$$

$$I_{\text{before}} \neq I_{\text{after}}$$

$$X_1 + X_2 = 3.5 \quad \text{--- (1)}$$

let assume:

$$t_1(3.5) = 2 + 3 \left(\frac{3.5}{2.5} \right) = 6.2 \text{ min}$$

$$t_2(0) = 4 \text{ min}$$

$$6.2 > 4 \rightsquigarrow$$

والسبب ان (Route 1) volume β أصغر من Route 2

$$t_1(0) = 2 \text{ min}$$

$$t_2(3.5) = (5.75 \text{ min})$$

$$2 < 5.75$$

$$4 \text{ min} \text{ \& } 5.75 \text{ min}$$

UE applies

• Using UE;

Before:

$$t_1 = t_2$$

$$2 + \frac{3}{2.5} x_1 = 4 + \frac{2}{4} x_2 \quad \text{--- (2)}$$

using eq. (1)

$$x_2 = 3.5 - x_1$$

$$x_1 = 2.206 \text{ (2206 veh/hr)}$$

$$x_2 = 1.294 \text{ (1294 veh/hr)}$$

substituting in PF's to get t_1 or t_2 :

$$t_1 = 2 + \frac{3}{2.5} (2.206) = 4.647 \text{ min}$$

$$t_2 = 4 + \frac{2}{4} (1.294) = 4.647 \text{ min}$$

$$TTT = x_1 t_1 + x_2 t_2$$

$$= \frac{1}{4} (x_1 + x_2) = 4.647 (3500) = 16264.5 \text{ veh-min}$$

1/3/2016

TTT initially = 16264.5 veh-min
during reconstruction :-

$$t_1 = 2 + 1.2 X_1$$

$$t_2 = 4 + X_2$$

$$q = X_1 + X_2 \dots (3)$$

$$TTT_{\text{initial}} = TTT_{\text{during}}$$

$$= X_1 t_1 + X_2 t_2$$

$$16264.5 = t_2 (X_1 + X_2) = t_2 q$$

$$(4 + X_2) q = 16264.5$$

$$q = \frac{16264.5}{(4 + X_2)} \dots (4)$$

but $t_1 = t_2$

$$2 + 1.2 X_1 = 4 + X_2$$

$$2 + 1.2 (q - X_2) = 4 + X_2 \dots (5)$$

substitute for equ. (4) in (5)

$$X_2 = 0.901 \text{ (901 Veh/hr)}$$

$$q = 3.319 \text{ (3319 veh/hr)}$$

$$X_1 = 2.418 \text{ (2418 veh/hr)}$$

A reduction of

$$3500 - 3319 = 181 \text{ veh/hr}$$

due to reduced capacity on Route 2

TTT $\rightarrow$ دالة التكلفة
التأخر

Ex 2 $q = 6000 \text{ veh/hr}$ (fixed) $x_1 + x_2 = 6 \dots (1)$

initially :

$$C_1 = 4400 \text{ veh/hr}$$

$$C_2 = 5200 \text{ veh/hr}$$

during reconstruction:

$$C_1 = 4400 \text{ veh/hr}$$

$$C_2 = 2200 \text{ veh/hr}$$

initially:

check:

$$t_1(6) = 10.82 \text{ min}$$

$$t_2(0) = 3 \text{ min}$$

$$t_1(0) = 4 \text{ min}$$

$$t_2(6) = 11.08 \text{ min}$$

both routes are used

$$t_1 = t_2$$

$$\frac{4}{4.4} x_1 = 3 + \frac{7}{5.2} x_2 \dots (2)$$

sut. for $x_2 = 6 - x_1$ in equ. (2)

$$x_1 = 2.85 \text{ (2850 veh/hr)}$$

$$x_2 = 3.15 \text{ (3150 veh/hr)}$$

$$TTT = \frac{t_1 x_1}{60} + \frac{t_2 x_2}{60}$$

$$= \left(\frac{4 + 5(2.85)}{4.4} \right) \frac{2850}{60} + \left(\frac{3 + 7(3.15)}{5.5} \right) \frac{3150}{60}$$

$$= 723.88 \text{ veh/hr}$$

under reconst

check

$$t_1(6) = 10.82 \text{ min}$$

$$t_2(0) = 3 \text{ min}$$

$$t_1(0) = 9 \text{ min}$$

$$t_2(6) = 22.09 \text{ min}$$

both routes are used

under reconst

$$t_1 = t_2$$

$$4 + \frac{5}{4.4} x_1 = 3 + \frac{7}{2.2} x_2 \quad \text{--- (3)}$$

sub. for $x_2 = 6 - x_1$ in (3)

$$x_1 = 4.19 \text{ (4190 veh/hr)}$$

$$x_2 = 1.81 \text{ (1810 veh/hr)}$$

$$TTT = \frac{t_1 x_1 + t_2 x_2}{60}$$

$$= 875.95 \text{ veh/hr}$$

$$\text{Added veh-hr} = 875.95 - 723.88$$

$$= 152 \text{ veh-hr are added}$$

Ex 3 two routes connect an O-D,
and the flow 15000 veh/hr

route 1: $t_1 = 4 + 3x_1$

route 2: $t_2 = 6 + 6x_2$

مقدار الوقت الذي سيستغرق
منه لو خرج في الصباح الباكر
قبل الازدحام

Assume UE applies:

if UE flow on route 1 = 9780 veh/hr

$$x_1 + x_2 = 15$$

$$9.78 + x_2 = 15 \Rightarrow x_2 = 5.22$$

$$t_1 = t_2$$

$$4 + 3x_1 = 6 + 6x_2$$

$$4 + 3(9.78) = 6 + 6(5.22)$$

$$b = 2.02 \text{ min}$$

free flow
travel time

Ex 4) three routes connect an O-D with the following PF's:

$$t_1 = 8 + 0.5x_1$$

$$t_2 = 1 + 2x_2$$

$$t_3 = 3 + 0.75x_3$$

if the peak-hr traffic demanded = 3000 veh/hr
Determine UE traffic flows?

$$x_1 + x_2 + x_3 = 3 \dots \textcircled{1}$$

$$t_1(3) = 9.5$$

$$t_2(0) = 1$$

$$t_3(0) = 3$$

$$t_1(0) = 8$$

$$t_2(3) = 7$$

$$t_3(0) = 3$$

$$t_3(3) = 5.25$$

$$t_1(0) = 8$$

$$t_2(0) = 1$$

$$t_1(3) > t_3(0) > t_2(0)$$

$$t_1(0) > t_2(3) > t_3(0)$$

$$t_1(0) > t_3(3) > t_2(0)$$

$\therefore$ route 1 will never be used
the the eqn. (1) not be used
we used $x_2 + x_3 = 3 \dots \textcircled{2}$

$$t_2 = t_3 \rightsquigarrow \text{get } x_2, x_3$$

Ex 5 Three routes connect a (O-D),
and the PF's :-

$$t_1 = 2 + 0.5 X_1$$

$$t_2 = 1 + X_2$$

$$t_3 = 4 + 0.2 X_3$$

Determine UE flows if :

(a) 10000 veh/hr

(b) 5000 veh/hr

(a) Check if all routes are used :

$$t_1(0) = 2 \quad \left\{ \begin{array}{l} t_2(0) = 1 \\ t_3(0) = 4 \end{array} \right. \quad \left\{ \begin{array}{l} t_1(10) = 6 \\ t_2(10) = 2 \\ t_3(10) = 1 \end{array} \right.$$

$$t_2(0) = 1 \quad \left\{ \begin{array}{l} t_1(0) = 2 \\ t_3(0) = 4 \end{array} \right. \quad \left\{ \begin{array}{l} t_1(0) = 2 \\ t_2(0) = 1 \\ t_3(0) = 4 \end{array} \right.$$

$$t_3(0) = 4 \quad \left\{ \begin{array}{l} t_1(0) = 2 \\ t_2(0) = 1 \end{array} \right. \quad \left\{ \begin{array}{l} t_1(0) = 2 \\ t_2(0) = 1 \\ t_3(0) = 4 \end{array} \right.$$

$$t_1(0) > t_2(0) > t_3(0) \quad t_2(0) > t_3(0) > t_1(0) \quad t_3(0) > t_1(0) > t_2(0)$$

all 3 routes are used

$$X_1 + X_2 + X_3 = 10 \quad \text{--- (1)}$$

$$t_1 = t_2$$

$$2 + 0.5 X_1 = 1 + X_2$$

$$X_2 = 1 + 0.5 X_1 \quad \text{--- (2)}$$

$$t_1 = t_3$$

$$2 + 0.5 X_1 = 4 + 0.2 X_3$$

$$X_3 = -10 + 2.5 X_1 \quad \text{--- (3)}$$

substituting (2); (3) in (1):

$$10 = x_1 + (1 + 0.5 x_1) + (-10 + 2.5 x_1)$$

$$x_1 = 4.75 \text{ (4750 veh/hr)}$$

$$x_2 = 3375 \text{ veh/hr}$$

$$x_3 = 1875 \text{ veh/hr}$$

$$t_{UE} = 4.375 \text{ min}$$

Mathematical Programming Approach to User Equilibrium

Mathematical Programming Approach to UE:

→ when many alternative routes are involved solving the equation (travel time) becomes difficult. UE^o route flows can be obtained by minimizing the following:

$$\min S(x) = \sum_n \int_0^{x_n} t_n(w) \cdot dw$$

- n : a specific route

$t_n(w)$: PF corresponding to route (n)

w : denotes flow, x_n 's

flow on all route ≥ 0

$$x_n \geq 0$$

$$q = \sum_n x_n$$

Ex two routes connect an (O-D) with the following PF's:

$$t_1 = 4 + 3x_1 \quad ; \quad t_2 = 2.02 + 6x_2$$

$$q = 15000$$

$$x_1 + x_2 = 15$$

solve using math. Prog.

$$\min S(x) = \int_0^{x_1} (4 + 3w) dw + \int_0^{x_2} (2.02 + 6w) dw$$

$$\min S(x) = \int_0^{15-x_2} (4 + 3w) dw + \int_0^{x_2} (2.02 + 6w) dw$$

$$\min S(x) = \left[4w + \frac{3w^2}{2} \right]_0^{15-x_2} + \left[2.02w + \frac{6w^2}{2} \right]_0^{x_2}$$

$$= x_2^2 - 10.44x_2 + 88.34$$

$$\frac{dS(x)}{dx_2} = 2x_2 - 10.44 = 0$$

$$x_2 = 5.22 \text{ (5220 veh/hr)}$$

$$x_1 = 9.78 \text{ (9780 veh/hr)}$$

$$t_1 = t_2 = 33.34 \text{ min}$$

3. System Optimization :

Preferred routes are those, which minimize total syst. travel time.

- no traveler ^{دست} Can switch to a different Route without increasing total system travel time.
- travelers can switch to routes decreasing their total travel time but only if system optimal flows are maintained.
- Realistically, travelers will likely switch to non-sys-opt. routes to improve their own travel times.

$$S(x) = \sum_n x_n t_n(x_n)$$

n : route between O-D

$t_n(x_n)$: travel time for a specific route

x_n : flow on a specific route.

Ex Two routes connect an O-D with PFs:
 $t_1 = 5 + 3x_1$; $t_2 = 7 + x_2$

$$x_1 + x_2 = 7 \text{ --- (1)}$$

- What are the syst. opt. flows
- What are the UE flows

$$TTT_{\text{syst. opt}} - TTT_{\text{UE}}$$

• At Syst. opt.

$$S(x) = x_1(5 + 3x_1) + x_2(7 + x_2) \text{ --- (2)}$$

sub. for $x_2 = 7 - x_1$ in (2)

$$S(x) = x_1(5 + 3x_1) + (7 - x_1)(7 + 7 - x_1)$$

$$\frac{dS(x)}{dx_1} = 8x_1 - 16 = 0$$

$$x_1 = 2 \quad . \quad x_2 = 5$$

$$t_1 = 5 + 3x_1 = 11 \text{ min}$$

$$t_2 = 7 + x_2 = 12 \text{ min}$$

A decrease of
0.25 veh-min
was obtained
using syst. opt.

$$TTT_{\text{syst. opt}} = x_1 t_1 + x_2 t_2 = 82 \text{ veh-min}$$

at U.E :

$$t_1 = t_2$$

$$5 + 3x_1 = 7 + (7 - x_1)$$

$$x_1 = 2.25$$

$$x_2 = 4.75$$

$$t_1 = t_2 = 11.75$$

$$TTT_{\text{UE}} = 82.25 \text{ veh-min}$$

6/3/2016

Basics of Engineering Economics

Budget.

Multiple project → hierarchy

construct new highway (III)

Improve safety (I)

Improve operation (II)

one project → Multiple Alternative

Alt.1 Alt.2 Alt.3

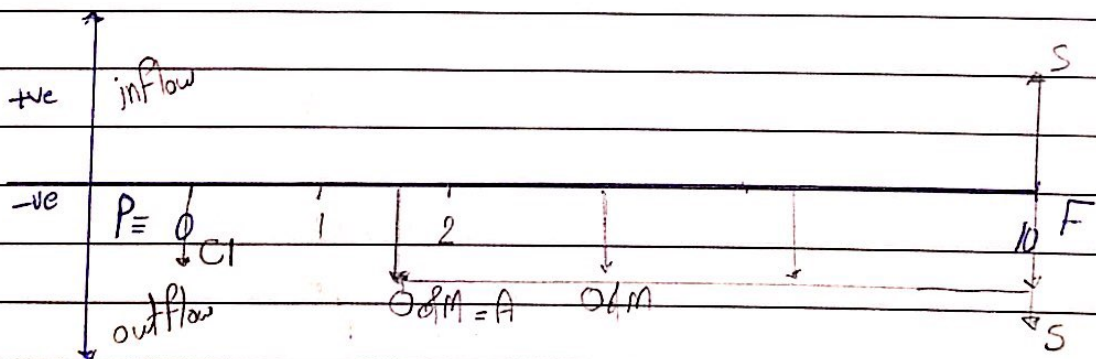
Evaluation:

→ Money, JD

→ other → Environmental

→ social impact

etc.



n : no. of time period CFD

(مبلغ سنوي)
(Annual Amount) Any amount of money paid or gained annually = Annuity (A)

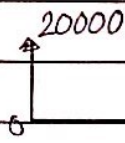
Annuity

أي مبلغ من المال يدفع أو يُكسب سنوياً
وإذا كان كل سنة يدفع مبلغاً معيناً أو يكسب مبلغاً معيناً

10/3/2016

①

Example



$$P = +20000$$

$$n = 1 \text{ yr.}$$

$$i = 9\%$$

$$\Rightarrow I_1 = 20000 \times 0.09 = 1800$$

$$F = P + I_1 = 21800$$

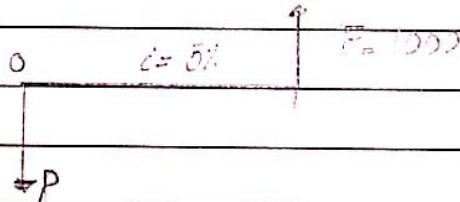
$$\begin{aligned} \text{Amount due,} &= 1800 + 20000 \\ &= 21800 \end{aligned}$$

$$\begin{aligned} F &= P(1+i) \\ &= 2000(1+0.09) \end{aligned}$$

②

Example

$$P = ? , n = 1 , F = 1000 , i = 5\%$$



$$\begin{aligned} \text{Total accrued (F)} &= P + P \times i \\ 1000 &= P(1 + 0.05) \end{aligned}$$

$$P = \frac{1000}{1.05} = 952.38$$

$$\begin{aligned} I_1 &= 1000 - 952.38 \\ &= 47.62 \text{ JD} \end{aligned}$$

(4)

Example

$$P = 1000, n = 3, i = 10\%$$

$$I_1 = 100$$

$$\text{@ end of } n=1, P=1000, \text{ Amount owed } (F_1) = 1000 + 1000 \times 0.10 = 1100$$

$$I_2 = 110$$

$$\text{@ end of } n=2, P=1100, \text{ Amount owed } (F_2) = 1100 + 1100 \times 10\% = 1210$$

$$I_3 = 121$$

$$\text{@ end of } n=3, P=1210, \text{ Amount owed } (F_3) = 1210 + 1210 \times 10\% = 1331$$

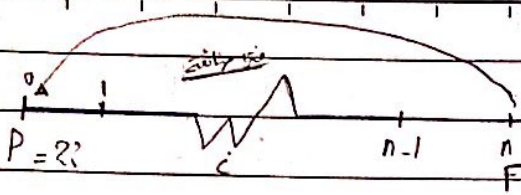
for simple $\rightarrow$

$$\text{@ end of } n=1, P=1000, \text{ Amount owed} = 1100$$

$$\text{@ end of } n=2, P=1000, \text{ Amount owed} = 1100 + 1000 \times 10\% = 1200$$

$$\text{@ end of } n=3, P=1000, \text{ Amount owed} = 1300$$

13/3/2016



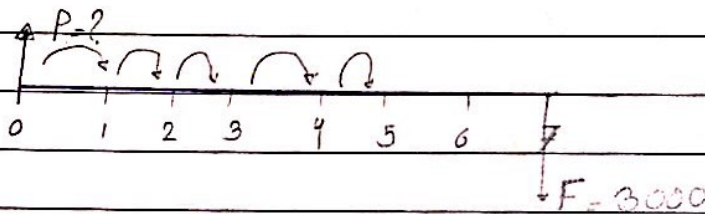
$$F = P(F/P, c, n)$$

$$(1+c)^n$$

$$P = F(P/F, c, n)$$

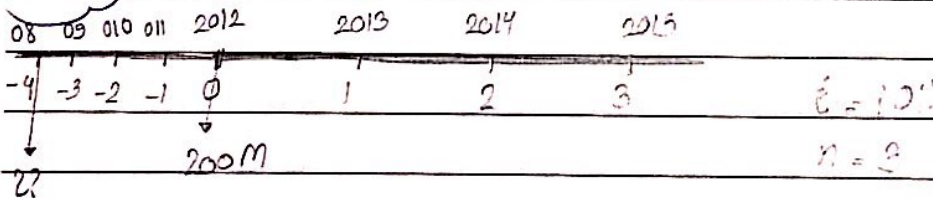
$$P = F \frac{1}{(1+c)^n} \rightarrow P = F(1+c)^{-n}$$

Ex:



$$P = F(P/F, c, n) = 3000(1+0.06)^{-7} = 1995$$

Ex



$$F = P(F/P, 10\%, 9) = 200 * (1+0.10)^9 = 266200000$$

$$P = F(P/F, 10\%, 9) = 200 \left(\frac{1}{(1+0.1)^9} \right) = 136,600,000$$

Uniform Series

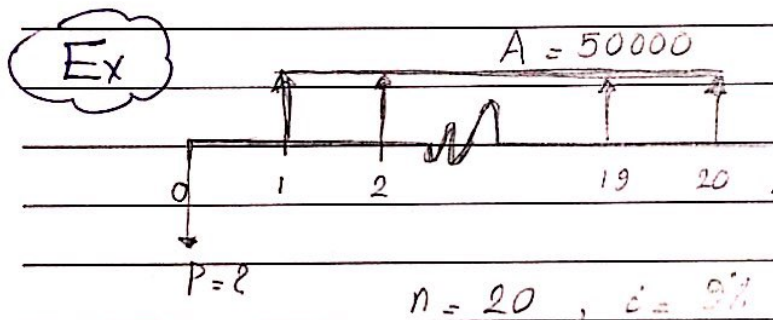
Present worth factor
and Capital Recovery
factor

$$P = A \left(\frac{(1+i)^n - 1}{i(1+i)^n} \right)$$

$$P = A (P/A, i, n)$$

$$A = P \left(\frac{(1+i)^n \cdot i}{(1+i)^n - 1} \right)$$

$$A = P (A/P, i, n)$$



$$\begin{aligned} P &= A (P/A, 9\%, 20) \\ &= 5000 \left(\frac{(1+0.09)^{20} - 1}{0.09(1+0.09)^{20}} \right) \\ &= 456,427 \end{aligned}$$

(Future & Annuity & $\frac{F}{A}$)

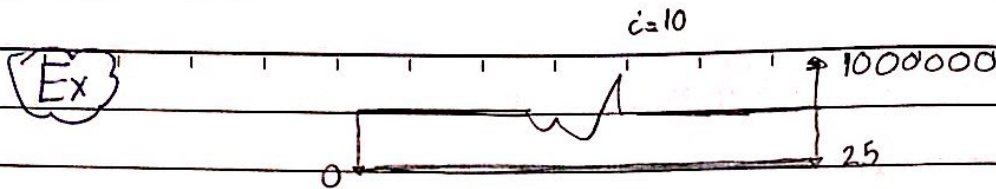
$$\frac{F}{(1+i)^n} = A \left(\frac{(1+i)^n - 1}{i(1+i)^n} \right) \rightarrow F = A \left(\frac{(1+i)^n - 1}{i} \right)$$

$$F = A (F/A, i, n)$$

$$A = F \left(\frac{i}{(1+i)^n - 1} \right)$$

$$A = F (A/F, i, n)$$

15/3/2015



$$A = F(A/F, 10\%, 25)$$

$$A = 1000000 \left(\frac{10\%}{(1.10)^{25} - 1} \right) = 10,200$$

Basic Analysis Tools

Mutually Exclusive Proposals

e.g. constructing a new highway

Alt.1 Alt.2 Alt.3

select = only one Alt

Independent Projects:

Proj. 1 → BRT

Proj. 2 → Building new schools

Proj. 3 → Buying new vehicles for the Ministers

you may select all of them

Budget

1. Present Worth Analysis (PW):

a. Equal life alternatives

→ Mutually Exclusive :

one proposal → if $PW \geq 0$ → Alternative is justified

more than one proposal → Select the alternative with the largest

cost PW Revenue

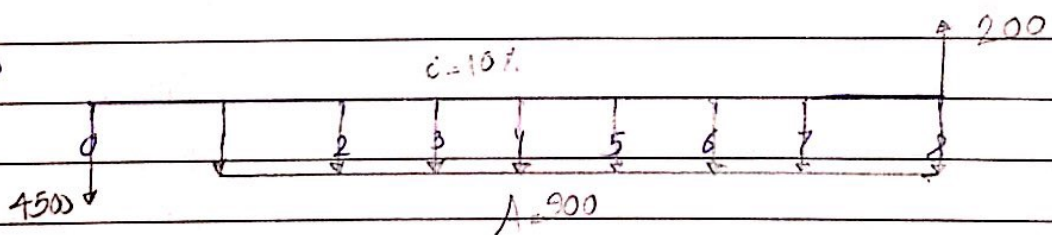
least negative most positive

Independent Projects:

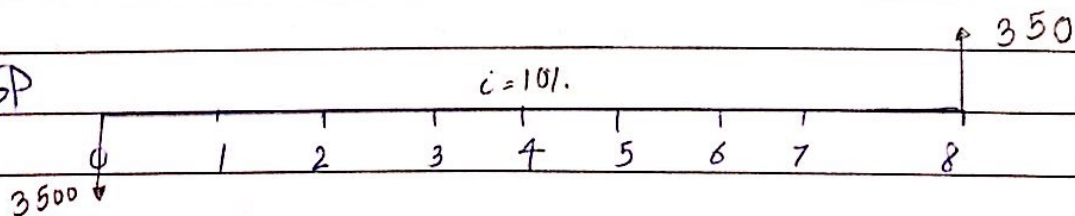
Select all projects with $PW \geq 0$ at MARR

Ex

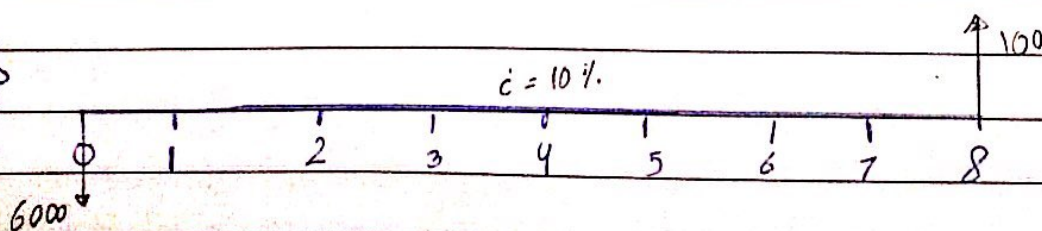
EP



GP



SP



17/3/2016

(P/A, 10%, 8)

0.467

$$PW_{EP} = -4500 - 900 \left(\frac{(1.10)^8 - 1}{0.1 (1.10)^8} \right) + 200 (1.10)^{-8}$$

$$(P/F, i, n) = (1+i)^{-n}$$

$$= \$ - 9208$$

$$(P/F, 10\%, 8)$$

$$PW_{GP} = -3500 - 700 (P/A, 10\%, 8) + 350 (P/F, 10\%, 8) = \$ - 7071$$

$$PW_{SP} = -6000 - 50 (P/A, 10\%, 8) + 100 (P/F, 10\%, 8) = \$ - 6220$$

• solar powered Machine is justified or selected.

b. Present Worth Analysis of Different-Life Alternatives
Mutually exclusive proposals:

→ equal service requirement must be met:

using one of those approaches:

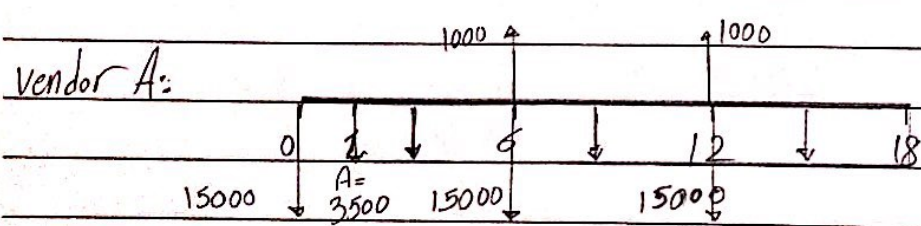
1- Least common Multiple (LCM)

2- Study period : compare alternatives using Study period of (n) years.

depending on planning horizon, and ignoring alternatives not within the study period

Ex: MARR = 15%, Mutually Exclusive

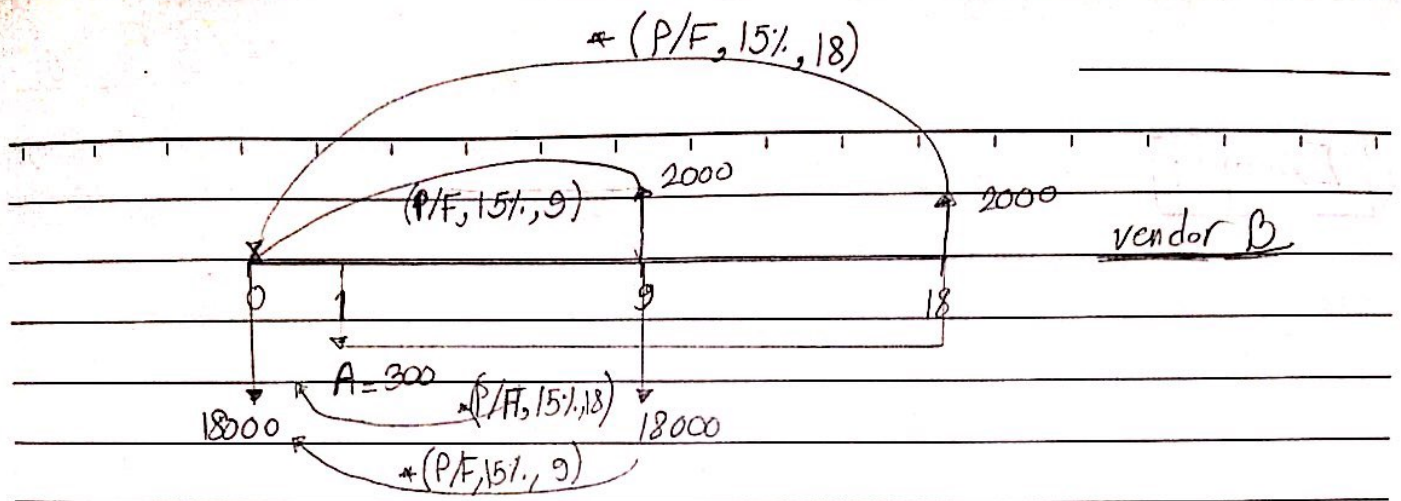
a. Using LCM : vendor A : 6, 12, 18
Vendor B : 9, 18



4.2

Five Apple

Scanned by CamScanner



$$\begin{aligned}
 PW_A = & -15000 - 15000 (P/F, 15\%, 6) - 15000 (P/F, 15\%, 12) \\
 & + 1000 (P/F, 15\%, 6) + 1000 (P/F, 15\%, 12) + 1000 (P/F, 15\%, 18) \\
 & - 3500 (P/A, 15\%, 18) = \$ - 45,036
 \end{aligned}$$

$\xrightarrow{0.43}$ $\xrightarrow{0.19}$
 $\xleftarrow{6.13}$ $\xleftarrow{0.081}$

$$\begin{aligned}
 PW_B = & -18000 - 18000 (P/F, 15\%, 9) + 2000 (P/F, 15\%, 9) \\
 & + 2000 (P/F, 15\%, 18) - 3000 (P/A, 15\%, 18) = \$ - 41,384
 \end{aligned}$$

$\xrightarrow{0.23}$

alternative B is justified

Independent project

Do Not use LCM nor study Period

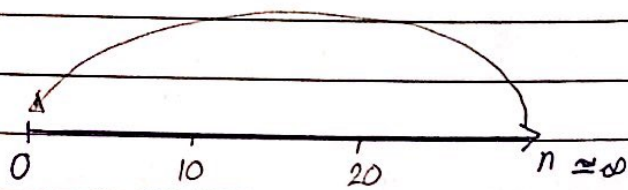
Select all projects whose $PW \geq 0$

• @ MARR

→ Proj 1 $n=5$ (PW on 5yrs)
 Proj 2 $n=10$ (PW on 10yrs)

20/3/2015

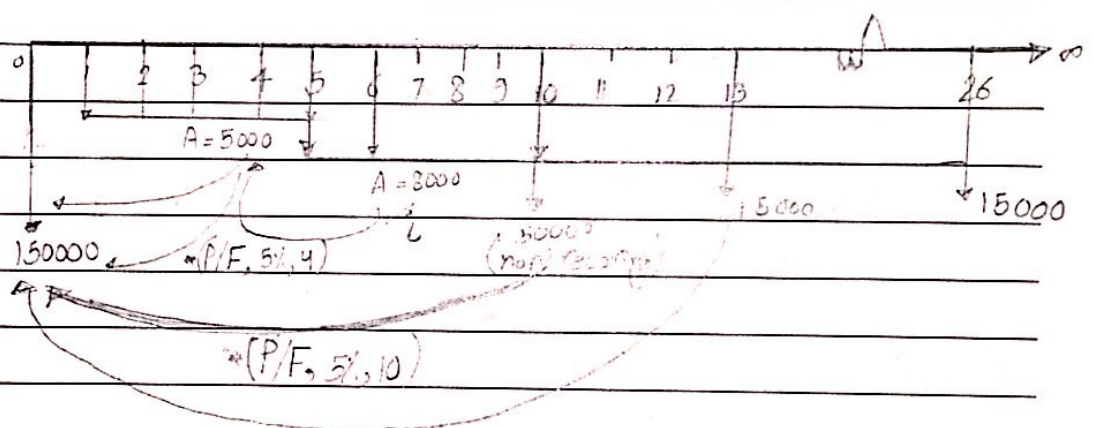
C. Capitalized Cost Analysis



$$CC = \frac{A}{i}$$

$$CC = \frac{AW}{i}$$

Ex



① for IC and non recurring cost:

$$CC_1 = -150000 - 50000 (P/F, 5\%, 10)$$

$$= \$ -180695$$

② Convert all recurring costs to Annuities; then to CC:

$$A = -15000 (A/F, 5\%, 13) = \$ -847$$

$$CC_2 = \frac{A}{i} = \frac{-847}{0.05} = \$ -16,940$$

③ Consider $A=5000$ to continue to ∞ , and reduce it to P :

$$CC_3 = \frac{-5000}{i} = \$-100000$$

④ Consider $(A=8000-5000)$ to start at yr. 5; reduce it to its CC at yr. 4, and then reduce it to $n=0.0$ using $(P/F, i, 4)$

$$CC_{\text{at yr. 4}} = \frac{-3000}{0.05} = \$-60000$$

$$CC_{\text{at yr. 0.0}} = -60000 (P/F, 5\%, 4) \\ = \$-42,362$$

$$\text{a) } CC_{\text{total}} = CC_1 + CC_2 + CC_3 + CC_4 \\ = \$-346,997$$

$$\text{b) } AW = CC_{\text{total}} \times i \\ = -346,997 \times 0.05 \\ = \$-17,350$$

2. Annual Worth Analysis

Example

- ① Calculate AW for vendor A. Using the previously calculated PW, which was calculated using LCM $n = 18$ yrs.

$$AW = PW(A/P, 15\%, 8)$$

$$= -45030(0.1632) = \$ -7349$$

- ② Calculate AW without using PW, with the given life, $n = 6$ yrs.

$$AW_A = -15000 (A/P, 15\%, 6) - 3500 + 10000 \overset{\uparrow}{\underset{0.1142}{(A/F, 15\%, 6)}}$$
$$= \$ -7349$$

for either of Mutually Exclusive Projects or Independent Projects; when Computing AW

→ no need to Use LCM or Study Period

22/3/2016

Evaluating Alternatives by Annual Worth Analysis

Example

2 Mutual Exclusive proposal are being compared on the basis of (AW) with a MARR = 8% / yr.

$$AW_H = -15000 (A/P, 8\%, 4) - 6000 + \frac{20}{100} (15000) (A/F, 8\%, 4)$$

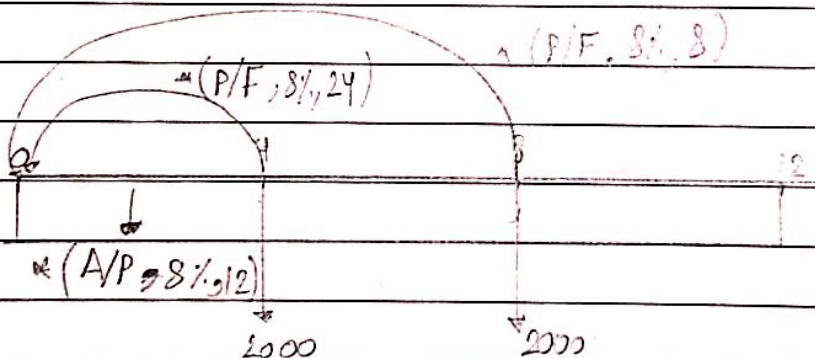
10.222

$$= \$ -9864$$

$$AW_{IC} = -20000 (A/P, 8\%, 12) - 9000$$

$$- (2000 (P/F, 8\%, 4) + 2000 (P/F, 8\%, 8)) (A/P, 8\%, 12)$$

$$+ \frac{40}{100} (20000) (A/F, 8\%, 12) = \$ -11571$$



AW of permanent investment

Example

$$AW_A = -650000 (A/P, 5\%, 10) - 170000 + 17000 (A/F, 5\%, 10)$$

$$AW_B = -4000000 * 5\% - 5000 - 30000 (A/F, 5\%, 5)$$
$$= \$ -210429$$

$$AW_C = -6000000 * 5\% - 3000 = \$ -297000$$

Evaluating Transportation Alternatives

Ex. 13.2

Criteria

	Rank	W _i	W _i
1 ROR	1	$n-3=2$	$5/11 * 100\% = 30$
2 Rider	2	$n-3=2$	$4/11 * 100\% = 24$
3 Seated	3	$n-3=2$	$3/11 * 100\% = 17$
4 length	3	$n-3=2$	$3/17 * 100\% = 17$
5 diverted	4	$n-3=2$	$2/17 * 100 = 12$

$$n = 5$$

24/3/2016

Ex. 13.3

Plan A, DN

Plan B, All rail

Plan C, All highway

D: Highway + Rail

E: Express Bus + highway

< 1

> 1

< 1

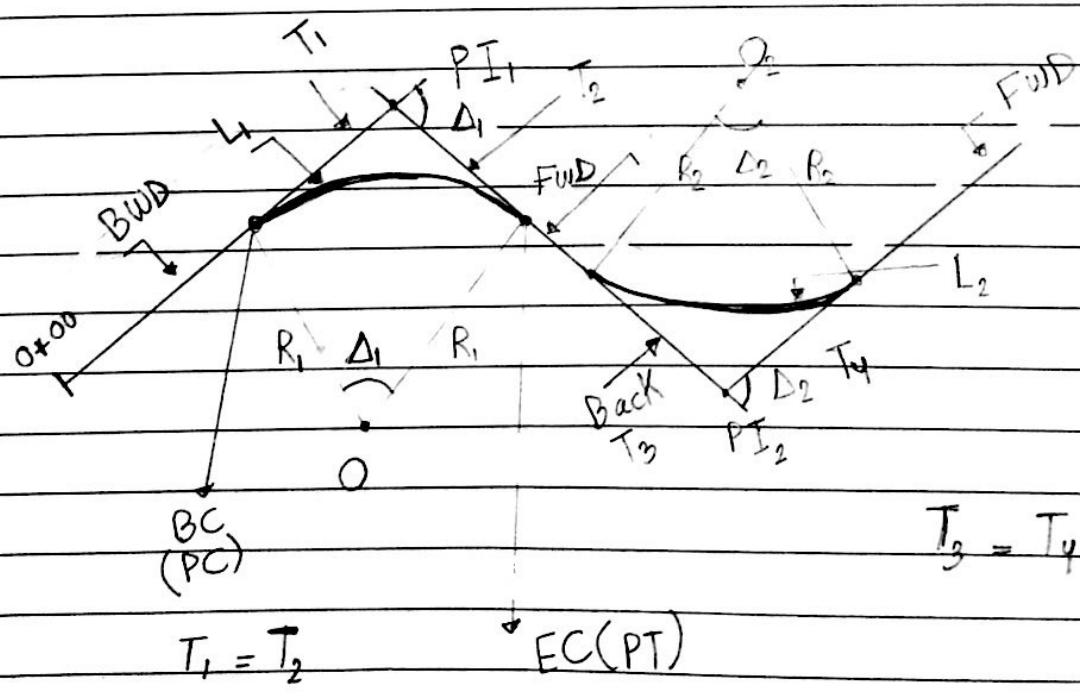
> 1

Horizontal Alignment of Highway and Railway

Circular Curves

Topographic Map:

Open Traverse O-D:



EC: End of curve (PT: Point of tangency)

BC: Beginning of curve (PC: Point of curvature)
is the tangent length (PI - BC)
OR (EC - PI)

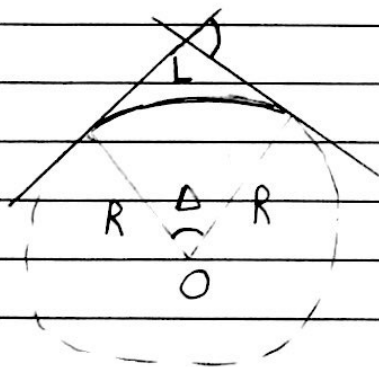
R: Radius of the circular curve

L: Length of the circular curve

PI: Point of intersection between
back & forward tangents.

Δ : The deflection angle

Simple circular curve:

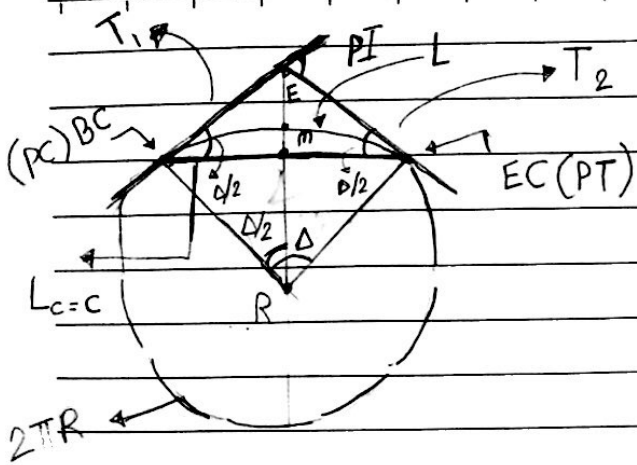


$$\frac{2\pi R}{360} = \frac{L}{\Delta}$$

$$L = \frac{2\pi R \Delta}{360} = \frac{\pi R \Delta}{180}$$

29/3/2016

Circular Curves



Layout of Simple Horizontal curve

$$R + E = R \sec(\Delta/2)$$

Back
tangent

Forward
tangent

L : Length of SCC

Lc : long chord

T : tangent length

E : External distance (PI - curve)

M : Middle ordinate (curve corr.)

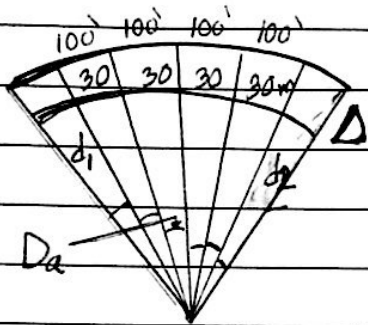
 Δ : map

R : calculated

$$\tan \frac{\Delta}{2} = \frac{T}{R} \Rightarrow T = R \tan \frac{\Delta}{2}$$

$$\frac{L}{\Delta} = \frac{2\pi R}{360} = \frac{\pi R \Delta}{180^\circ}$$

Arc definition:

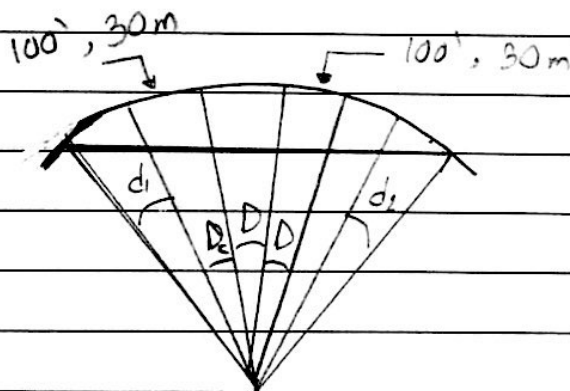


$$\Delta = d_1 + n D_a + d_2$$

$$\frac{2\pi R}{360^\circ} = \frac{180^\circ}{D_a} = \frac{30}{D_a}$$

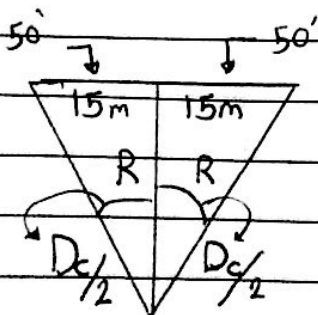
$$D_a = \frac{5729.59}{R} \text{ ft}, \quad D = \frac{1718.87}{R} \text{ m}$$

Chord definition:



D_c is the angle subtend by a chord with a length equal to 100' (30m)

$$\Delta = d_1 + n D_c + d_2$$



$$\sin \frac{D_c}{2} = \frac{50}{R}$$

$$= \frac{15}{R}$$

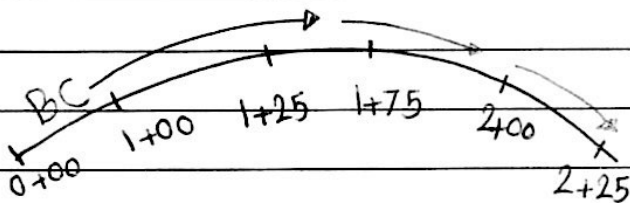
Used in Railway :

$$\sin \frac{\Delta}{2} = \frac{L_c/2}{R} \rightarrow L_c = 2R \sin \frac{\Delta}{2}$$

$$\cos \frac{\Delta}{2} = \frac{R-M}{R} \rightarrow M = R - R \cos \frac{\Delta}{2}$$

$$\cos \frac{\Delta}{2} = \frac{E+R}{R} \rightarrow E = \left(\frac{R}{\cos \frac{\Delta}{2}} \right) - R$$

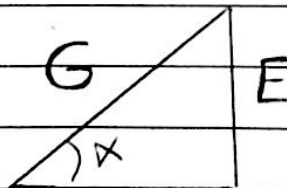
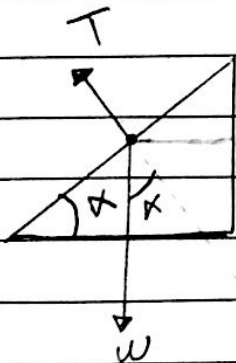
$$E = R \sec(\Delta/2) - R$$



$$\text{St. @ PC(BC)} = \text{St. @ PI} - T$$

$$\text{St. @ PT(EC)} = \text{St. @ PC} + L$$

Radial force & Design Speed :

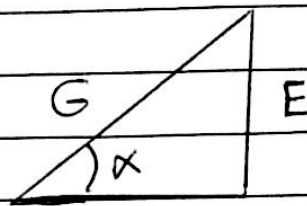
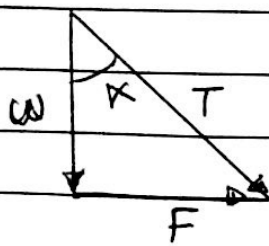


G: Gauge between inner & outer Rail

T: Normal force

F: centrifugal force (N, lb)

W: weight of the coach (car)



x : is a small angle , $\sin x \approx \tan x \approx \frac{F}{W}$

$$\frac{F}{W} = \frac{mv^2/R}{mg}$$

$$= \frac{mv^2/R}{mg} = \frac{v^2}{Rg}$$

m : mass of the coach

g : acceleration of gravity

(9.8 m/sec^2 , 32.2 ft/sec^2)

R : Radius of the curve (m, ft)

since , $\sin x = \tan x$

$$\frac{E}{G} = \frac{F}{T} = \frac{v^2}{gR}$$

$$\frac{5280}{3600}$$

$$E = \frac{G v^2}{g R} \quad U_3 = \frac{5.97 \cdot v^2 \cdot (1.47)^2 (\text{ft}^2/\text{sec}^2)}{32.2 (\text{ft}/\text{sec}^2) \cdot R}$$

$$= \frac{5.57 v^2}{R} \text{ inches}$$

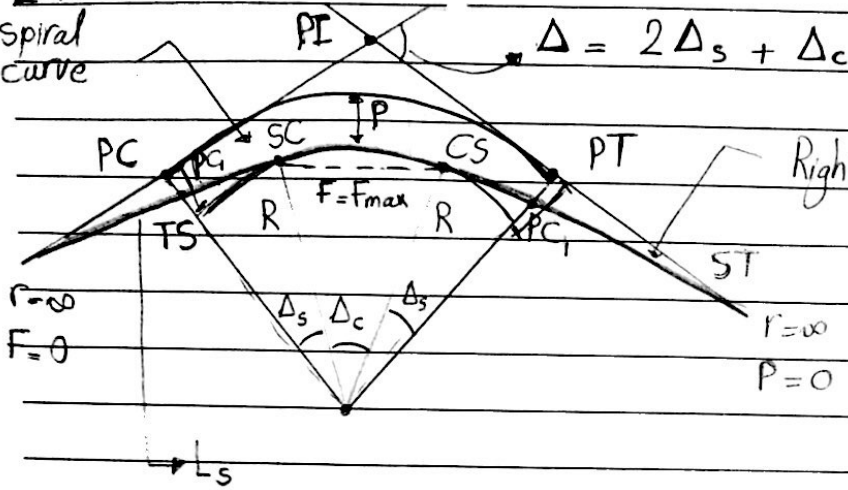
$$\text{Metric} = \frac{1511 \text{ mm} \cdot v^2 \left(\frac{1000}{3600} \right)^2 (\text{m}^2/\text{sec}^2)}{9.8 (\text{m}/\text{sec}^2) \cdot R}$$

$$= \frac{11.9 v^2 \text{ mm}}{R}$$

31/3/2016

Spiral Curve

Left spiral curve



Right spiral curve

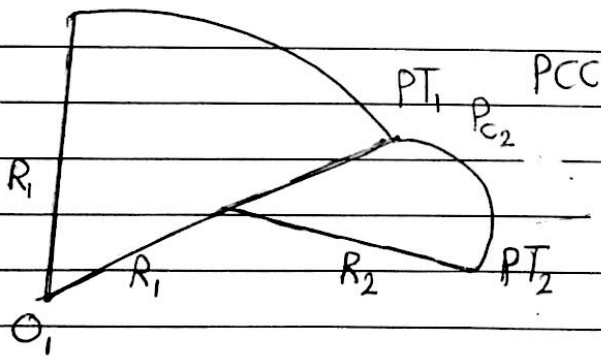
Simple curve:

P: Shift

$$\sin \frac{D_c}{2} = \frac{50'}{R} = \frac{15m}{R}$$

Δ_s : the deflection angle of the spiral curve

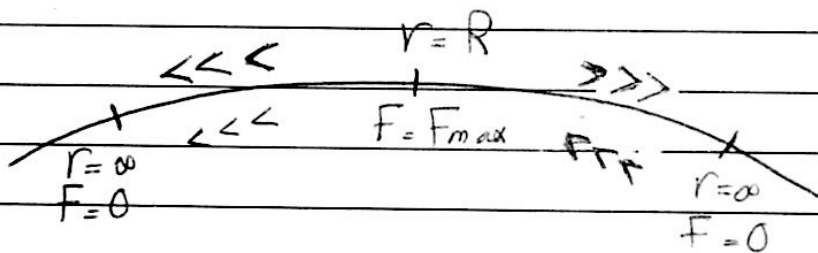
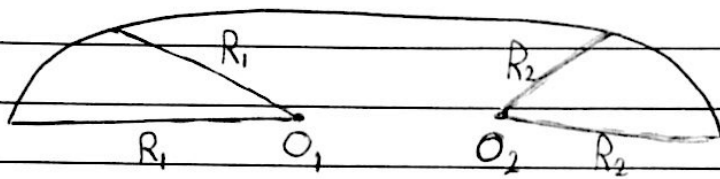
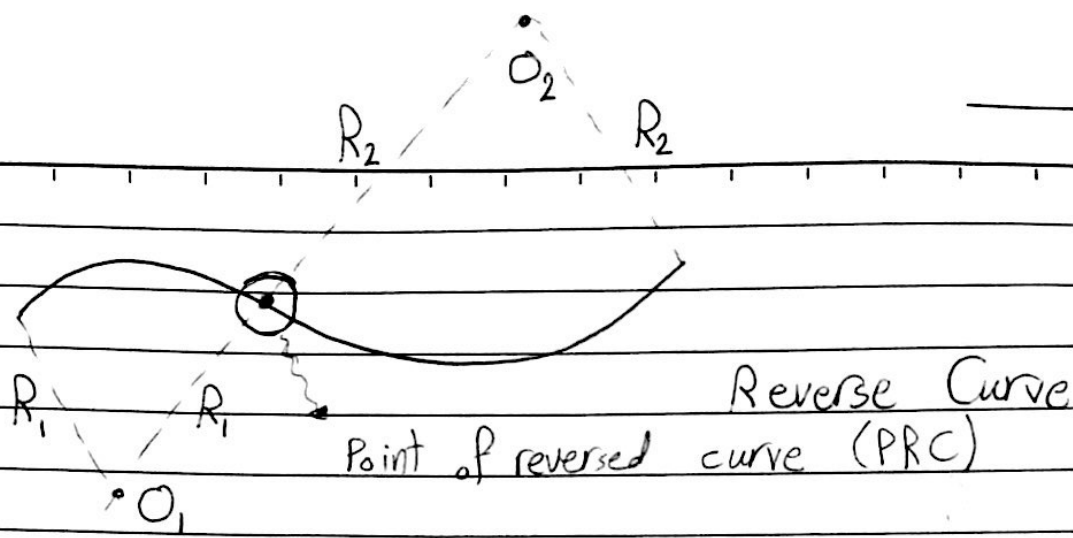
Δ_c : the new deflection angle of the shifted SCC



$R_1 : R_2$
1.5 : 1
compound curves

compound curve
(simple curve + spiral)

gradual change in both curvature and centrifugal force



Higher cost more difficult to construct wholly transition curve (spiral + spiral)

According to (AREA), the recommended formula for the minimum length of the spiral is :

Minimum Length :

V_s - Customary

Design speed mph

$$L_{min} (\pm)_{ft} = 1.6 E_u V_s \sqrt[3]{r}$$

inches

$$L_{min} (ft) = 62 E_a$$

E_u : Unbalanced elevation

E_a : actual elevation

Metric

$$L_{min} (m) = 0.01216 E_u V \leftarrow \text{km/hr}$$

L_{min}

OR

$$L_{min} (m) = 0.744 E_a$$

L_{min}

Select the higher L_{min}

in case where $L_{min} = 1.63 E_u V$

$$L_{min} = 0.01216 E_u V$$

may result in excessive costly length of spiral,
the following equ. may be used insted:

US - Customary

$$L_{min} = 1.22 E_u V$$

Metric

$$L_{min} = 0.0091 E_u V$$

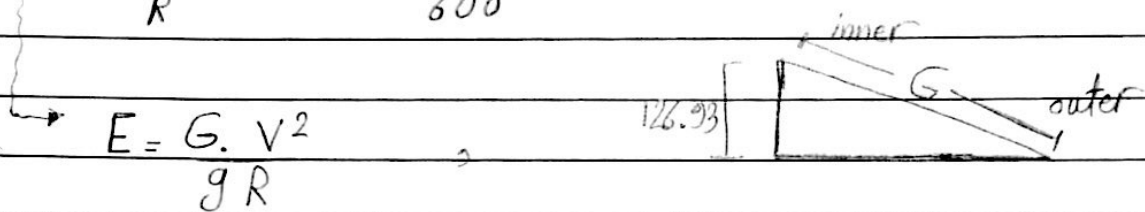
$$E_u = E_b - E_a$$

E_b

Ex1 Determine the equilibrium elevation for a railroad curve with a radius of 600m, given design speed of 80 Km/hr?

Use $G = 1511 \text{ mm}$

$$E = \frac{11.9}{R} V^2 = \frac{11.9}{600} (80)^2 = 126.93 \text{ mm}$$



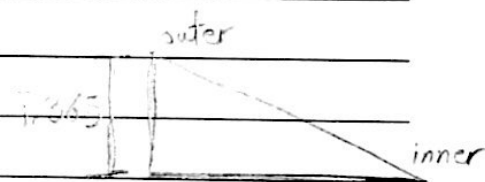
$$E = \frac{G}{gR} V^2$$

Ex2 Determine the equilibrium elevation in inches, for a $1^\circ 45'$ railroad curve given a design speed of 60 mph?

$$\frac{\sin D_c}{2} = \frac{50}{R}$$

$$\sin \frac{1^\circ 45'}{2} = \frac{50}{R} = 3274.1'$$

$$E_b = \frac{3.97}{R} V^2 = \frac{3.97}{3274.1} (60)^2 = 4.365''$$



Ex3 It is policy of railroad agency to use a 150 mm maximum elevation of the outer rail. Given a 100 Km/hr speed and a curve radius of 550 m.

Determine (1) $E_b = \frac{11.9}{R} V^2 = \frac{11.9}{550} (100)^2 = 216.14 \text{ mm}$

(2) $L_{min} = ??$

$$E_u = E_b - E_a$$

$$= 216.4 - 150 = 66.4 \text{ mm}$$

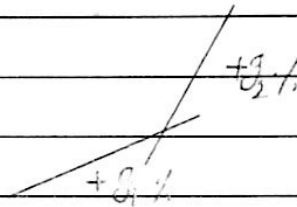
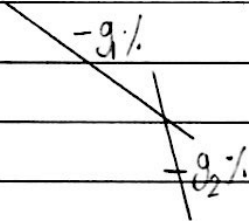
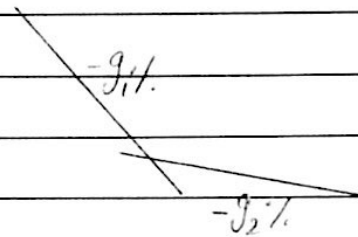
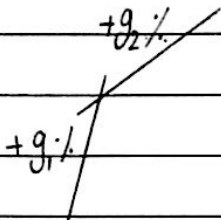
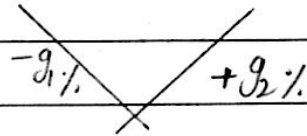
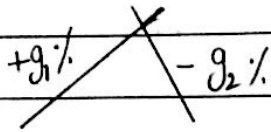
Use $L_{min} = 111.6 \text{ m}$

$$L_{min} = 0.744 E_u = 0.744 (150) = 111.6 \text{ m}$$

$$L_{min} = 0.01216 E_u V = 0.01216 (66.4) (100) = 80.256 \text{ m}$$

3/4/2016

Vertical Alignment of railways and guideways



Crest: $A - ve$

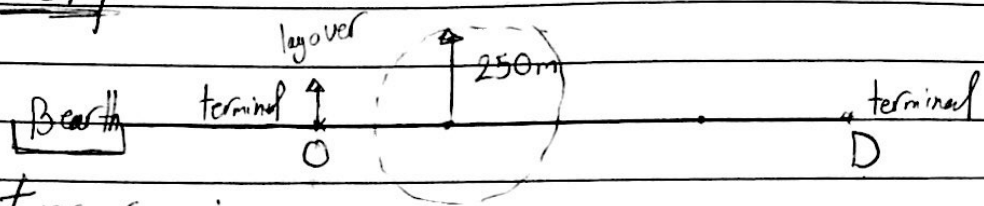
Sag: $A + ve$

• (cut + Sag) $\rightarrow \times$

$\rightarrow$ Because large clearance difficulty

10/4/2016

C. Bus Stop



Bus stops spacing:

- Age
- Gender
- type of terrain ^{والمكان}

Accessibility: is measured with a radius of 250-800m of walkable distance.

layover: Start time for before next service.

terminal: a location where the bus is being service

Berth: a bus loading area

→ types of berths:

① linear (one side): Can operate in series and have capacity characteristics similar to one-street bus stops.

② Saw tooth: popular in urban transit centers, designed to permit independent movements into and out of each bay.

③ Angle: this loading type is limited to one bus/bay requires buses to back out, often used for inter-city terminals with long dwell time.

دقت و توقف داخل الموقف

④ Drive through: Do not require buses to back out and may accommodate multiple vehicles.

مستقيم

12/4/2016

Operating characteristics

B. Service Frequency

h : Headway (min)

• if bus stop is designated as for alighting

$$h = t_{da} = aA + \underbrace{C}_{\text{clearance}}$$

• if bus stop is designated as for boarding

$$h = t_{db} = bB + C$$

• if bus stop is used for both alighting and boarding

$$h = t_{da} + t_{db}$$

$$= aA + bB + C$$

t_{da}, t_{db} : avg. dwell time for bus at a bus stop
for alighting, boarding respectively

Design of Land Transportation Terminals

Queuing theory: Characteristics ~~N~~ecessary of a queue:

FIFO: First-in-First-out (veh., pass.)

LIFO: Last-in-First-out (freight) etc.

$$\frac{\lambda}{\mu} > 1$$

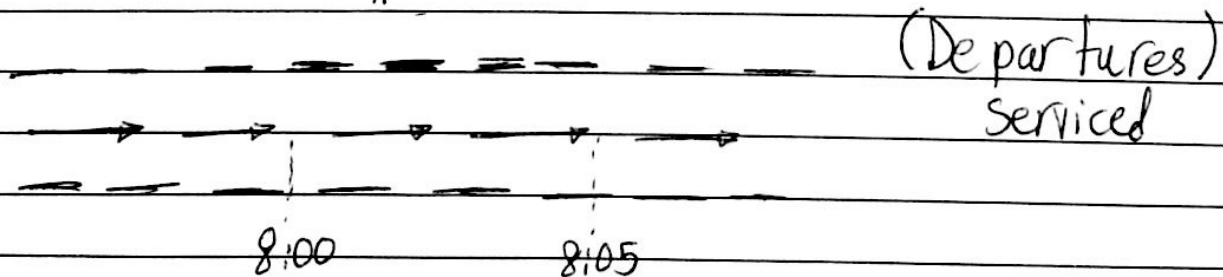
• Duration = 1 hr

no. of vehicles departing = 900

$$\mu = \frac{900}{1} = 900 \text{ veh/hr}$$

• avg. service time = (min / veh) = $\frac{1}{\mu}$

• avg. headway = $\frac{1}{\lambda}$ (inter arrival time) $8:05 - 8:00 \geq \frac{5 \text{ min}}{\text{Veh}}$



• no. of vehicles = 1000 veh

Duration = 1 hr

$$\lambda = \frac{1000}{1} = 1000 \text{ veh/hr}$$

veh.
↓

$$P(n=3) = \frac{(\lambda t)^n \cdot e^{-\lambda t}}{n!}$$

λ : arrival rate (units/hr) or (units/min)

t : time during which the probability of arrival is needed
sec. or hrs. or min.

Ex What's the probability of having exactly 3 vehicles arriving during the next 10 sec?

What's the probability of having Less than the next 10 sec?

$$\begin{aligned} P(n < 3) &= P(n=0) + P(n=1) + P(n=2) \\ &= \frac{\lambda^0 t^0 \cdot e^{-\lambda t}}{0!} + \frac{\lambda^1 t^1 \cdot e^{-\lambda t}}{1!} + \frac{\lambda^2 t^2 \cdot e^{-\lambda t}}{2!} \\ &= P(n \leq 2) \end{aligned}$$

$$P(n \geq 3) = 1 - P(n \leq 2)$$

Ex What is the probability of having 3 vch departing (being serviced) during the next 10 sec?

$$P(m=3) = \frac{(\mu t)^m \cdot e^{-\mu t}}{m!}$$

$$\text{interarrival rate} = \frac{1}{\lambda} \text{ (hr/veh)}$$

λ : Arrival rate (veh/hr)

μ : service (departure) rate [veh/hr]

$$\text{service time} = \frac{1}{\mu} \text{ [hr/veh]}$$

17/4/2016

if $\rho > 1$ } $\rho < 1$ } you can use $M/M/1$
 if $\rho < 1$ } you can use $M/M/N$

$$\rho = \frac{\lambda}{M}$$

$$\frac{1}{M} = 15 \text{ sec/veh}$$

$$M = \frac{1}{15} \text{ veh/sec}$$

$$\rho = \frac{\lambda}{M}$$

n_c : is the no. of channel

$$n_c = 1 \quad n_c = 2 \quad n_c = 3$$

$$\frac{\rho^0}{0!} + \frac{\rho^1}{1!} + \frac{\rho^2}{2!} + \frac{\rho^3}{3!(1-\frac{\rho}{3})}$$

N : no. of available channels

n : no. of vehicles