Solutions Manual

Transportation Engineering

An Introduction

Third Edition

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Preface

Every effort has been made to provide complete solutions to all the numerical problems. Some problems are open-ended, and thus make use of assumptions based on the judgment of the authors and are in line with the material presented in the textbook. Solutions related to highway capacity problems make use of available software. There are other problems that could easily be translated to a spreadsheet format. We would like to hear of instructors' experience with the presentation of the solutions.

Despite our best care, it is inevitable that the reader may encounter errors of omission for which we, as authors, take complete responsibility. Please advise as necessary so that the future editions may be improved. Please use email or other means of communication.

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CHAPTER 1
TRANSPORTATION AS A SYSTEM

<1.8>

This problem should be graphed similar to Figure 1-12. If there is an imbalance in the street system there would be over - or under - utilization of the various components of the system.

<1.11>

(a) 1 mile = 1.6 km

Distance		Theoretical Speed		Time
km	mile	kph	mph	min
0.4	0.25	4.8	3.0	5
1.0	0.63	9.1	5.7	6.6
4.0	2.50	24.0	15.0	10.0
10.0	6.25	45.5	28.4	13.2
40.0	25.0	120.0	75.0	20.0
100.0	62.50	228.0	142.5	26.4
1000.0	625.00	1140.0	712.5	52.8

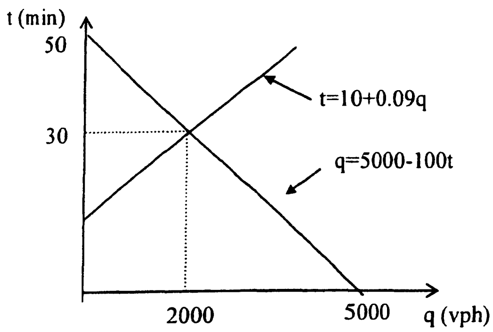
(b) In general, $t = a\, d^{\, b}$

It has been shown that $t = 6.6\, d^{\,0.3}$ where t is in min, and d is measured in km, There are two ways of finding out the values of a and b. First, regress t (min) with respect to d (miles) resulting in a = 7.60, and b = 0.3. Thus $t = 7.60d^{0.3}$.
Second, t (min) = $(6.6 \times 1.6)\, d^{\,0.3}$ miles
$= 7.60\, d^{\,0.3}$
[To check if this expression is correct; if d = 0.25 miles t = 7.60 x (0.25) 0.3 $\approx$ 5 min.]

CHAPTER 2
TRANSPORTATION ECONOMICS

<2.1>

$t = 10 + 0.09q$
$q = 5000 - 100t$



a)

$t = 10 + 0.01q \Rightarrow \qquad q = \dfrac{t-10}{0.01} = 100t - 1000$

$$100t^* - 1000 = 5000 - 100t^*$$

$$200t^* = 6000$$

$$\boxed{\begin{array}{l} t^* = 30\min \\ q^* = 5000 - 100 \times 30 = 2000 veh/hr \end{array}}$$

b) L = 22.5 miles, where L = length in miles.

$t = 30\min$

$$\boxed{v = {}^{22.5}\!/_{30} \times 60 = 45 mph}$$

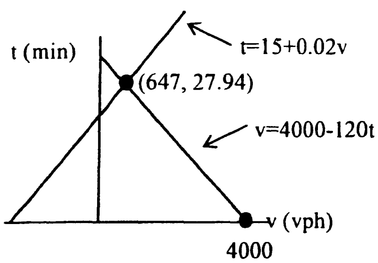
c) t* . 10 + 0.005q ⇒ q* = 200t - 2000
200t* - 2000 = 5000 - 100t*
300t* = 7000

$$\boxed{\begin{array}{l} t^* = 23.33\min \\ q^* = (5000 - 100) \times 23.33 = 2667 \ \ veh/hr \end{array}}$$

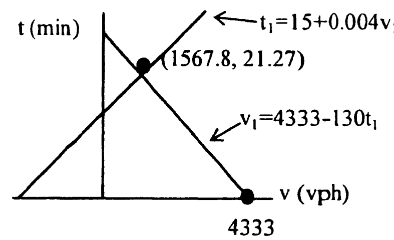
$$v = \frac{22.5}{23.3} \times 60 = 58 mph$$

<2.2>

a)



Existing Situation



Proposed Situation

b)

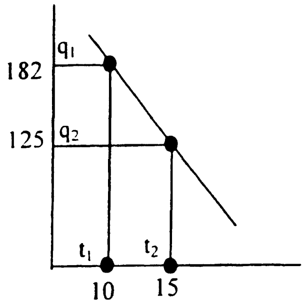
$$v = 4333 - 130(15 + 0.004v)$$
$$v = 4333 - 1950 - 0.52v$$
$$1.52v = 2383$$
$$\boxed{\begin{array}{l} v = 1567.8 \ veh/hr. \\ t = 15 + (0.004 \times 1567.8) = 21.27 \ \text{min.} \end{array}}$$

c)

$$l = 20 \text{ miles}$$
$$t = 21.27 \text{ min}$$
$$v = \frac{l}{t} \cdot 60 = {}^{20}\!/_{21.27} \times 60 = 56.42 \, mph$$

<2.3>

Assume that the demand function is valid in the time range between t = 10 & t = 15 min



$$\begin{aligned} \Delta veh - \min s &= q_1 t_1 - q_2 t_2 \\ &= q_1 t_1 - q_2 t_2 \\ &= (125)(15) - (182)(10) \\ &= 55 \text{ veh - mins are lost due to congestion} \end{aligned}$$

<2.4>

Assuming the demand function to be linear we get the following equations:
$2000 = \alpha - 1.5\ \beta$
$1000 = \alpha - 2.0\ \beta$

Hence $\alpha = 5000$, and $\beta = 2000$ $\qquad q = 5000 - 2000\ p$

a) when the fare is 50c, $q = 5000 - (2000 \times 0.5) = 4000$
b) If the transit system were free, p = 0, and q = 5000, which is the latent demand.

<2.5>

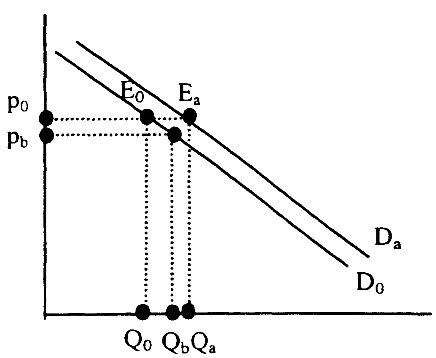
$\rho_o = 50^{¢}$ / ride $\qquad q_0 = 500{,}000$ per / day
$\rho_1 = 60^{¢}$ / ride $\qquad q_1 = 470{,}000$ per / day

a) $$\in = \frac{(Q_1 - Q_0)}{(\rho_1 - \rho_0)} \frac{(\rho_1 + \rho_2)/2}{(Q_1 + Q_2)/2} = \frac{(470-500)(50+60)/2}{(60-50)(500+470)/2} = -0.34 \text{ (inelastic)}$$

b) $0.50 \times 500{,}000 = \$250{,}000 / day$
$\underline{0.60 \times 470{,}000 = \$282{,}000 / day}$
$\boxed{\text{Total gain} \quad = \$32{,}000 / day}$

<2.6>

Assume (1) that the demand function remains unchanged, and (2) that the cost of improving the service is ignored.



a) Initial demand function (D_o)
$Q_o = 2125 - 1000\ P_o$
Option (a), demand function (D_a)
$Q_a = 2150 - 1000\ P_o$
Additional Revenue ΔTR_a
$= P_oQ_a - P_oQ_o$
$= 1.30\ [(2150 - 1000P_o) - (2125 - 1000P_o)]$
$= \$32.50$

b) New price reduced to P_b $= \$1.00$/ride

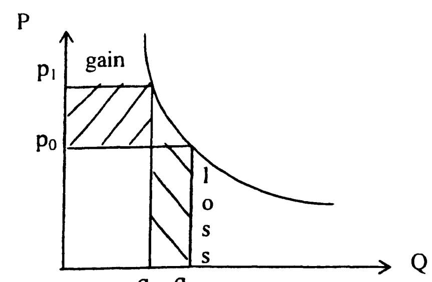
ΔTR_b $= 1.00\ [2125 - 1000\ (1.00)] - 1.30\ [2125 - 1000\ (1.30)]$
$= \$52.50$

Since $\Delta TR_b > \Delta TR_a$, option b is better.

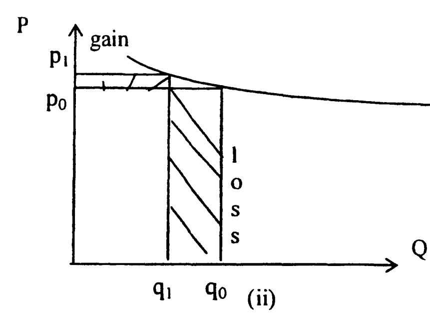
<2.7>

(i) Price elasticity = - 0.4 (inelastic) $\therefore$ price rise would lead to a fall in patronage but a total revenue gain. So fears are not justified.

(ii) In this case, $\in_p = -1.3$ (elastic) in which case a rise in fare not only leads to a total loss of revenue, but a decrease in patronage. It would therefore not be advisable to raise the fare.



(i)



(ii)

<2.8>

Using arc-price elasticity
$P_1 = \$100$; $P_2 = \$120$; $Q_1 = 5000$; and $Q_2 = ?$. Also e = - 1.2
Notice that the price is elastic, and in general when price is elastic (-1.2), raising the price will result in total loss, but lowering the price will result in total gain.

$$-1.2 = \left(\frac{5000 - Q_2}{100 - 120}\right)\left(\frac{100 + 120}{5000 + Q_2}\right) \qquad \text{therefore, } Q_2 = 4016$$

Total difference in revenue = (100 x 5000) - (120 x 4016)
Total loss = \$ -18,080

This loss should come as no surprise to the airlines and should have been taken into account before raising the fare.

<2.9>

This problem could be solved in several ways. The simplest is to follow classic economic style which states that price elasticity is the % change in quantity demanded which accompanies a 1% change in price.

$$\therefore e_p = \frac{10\%}{40\%} = 0.25 \text{ (inelastic)}$$

If scooter - sellers raise prices of scooters by 50% then the number of scooters sold will decrease by (0.25 x 50%) = 12.5%; but total revenue will rise by (1 - 0.25) x 50% = 37.5%.

This problem can also be solved by using arc-price elasticity and the results will be about the same.

<2.10>

A. Complements

B. Complements

C. Substitutes

D. Substitutes

E. Complements

F. Complements (if sold together)

<2.11>

$Q = \alpha P^{\beta}$

$12500 = \alpha(50)^{-0.75}$

$\alpha \quad = 235{,}038$

An increase in fare from 50¢ to 70¢ will attract $Q \quad = 235{,}038(70)^{-0.75}$

$= 9712$ passengers

Revenue-wise we have

At 50¢/ride x 12500	= \$6250
At 70¢/ride x 9712	= \$6798
Gain (total)	= \$548

Advice to management would be to raise fare to 70¢/ride

[Since $\in = -0.75$, elastic, it is obvious what the conclusion would be]

<2.12>

(a)

$$\frac{\Delta Q/Q}{\Delta A/A} = -2.2 \Rightarrow$$ 1% reduction in travel time by auto will result in a 2.2% increase in automobile trips

$\dfrac{\Delta Q/Q}{\Delta B/B} = 0.13 \Rightarrow$ 1% reduction *o*f travel time by bus will result in a 0.13% reduction in auto trips

$\dfrac{\Delta Q/Q}{\Delta C/C} = -0.4 \Rightarrow$ 1% reduction in the avg cost of travel by auto will result in a 0.4% increase in auto trips

$\dfrac{\Delta Q/Q}{\Delta D/D} = 0.75 \Rightarrow$ 1% reduction in the avg cost of travel by bus will result in a 0.75% reduction in auto trips

The signs are justified.

b) $A = 20\% \nearrow$
$B = 10\% \nearrow$
$C = 5\% \nearrow$
$D = 15\% \searrow$

$$Q_0 = aA^{-2.2}B^{-0.4}C^{-0.4}D^{0.75}$$

$$Q_1 = a(1.20A)^{-2.2}(1.10B)^{0.13}(1.05C)^{-0.4}(0.85D)^{0.75}$$

$$Q_1 = 0.589aA^{-2.2}B^{0.13}C^{-0.4}D^{0.75}$$

$$\frac{Q_1 - Q_0}{Q_0} = (0.589 - 1) = -0.411 \Rightarrow 41.1\% \text{ decrease in automobile trip}$$

c) $B = 10\% \searrow$
$D = 10\% \nearrow$

$$Q_1 = aA^{-2.2}(0.9B)^{0.13}\ C^{-0.4}\ (1.10D)^{0.75} = 1.06$$

$$\frac{Q_1 - Q_0}{Q_0} = (1.06 - 1) = 0.06 \Rightarrow 6\% \text{ increase in automobile trip}$$

<2.13>

The cross elasticity coefficient indicates that the % change of express-bus riders (Q) will equal 2 times the % change in the price (P) of the ordinary bus

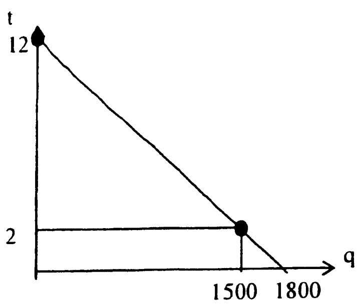
$$\in = \frac{\%\Delta Q \text{ of express bus riders}}{\%\Delta \text{P of ordinary bus riders}} = 2$$

$$\therefore\ \%\Delta Q \text{ of express bus riders} = 2 \times \%\Delta \text{P of ordinary bus riders} = 2\left[\frac{(P_2 - P_1)100}{(P_2 + P_1)/2}\right]$$

$$= 2\left[\frac{(0.5 - 0.75)100}{(0.5 + 0.75)/2}\right] = -80\%$$

which means that express bus riders and revenue will decline by 80%, if the price of express bus service remains the same.

<2.14>



$$q = 1800 - 150t$$

$$\epsilon_t = \left(\frac{dq}{dt}\right)\left(\frac{t}{q}\right)$$

$$= (-150)\left(\frac{2}{1500}\right)$$

$$= -0.2 \text{ (inelastic)}$$

<2.15>

$$\frac{\partial Q}{Q} \bigg/ \frac{\partial P}{\text{P}} = -0.75 \text{ (inelastic) or } \frac{20\%}{X\%} = -0.75, \; X\% = -26.7\%$$

a 26.7% decrease in fare = 73.3 cents and a new seating arrangement of 2400. Change in

$$\text{Consumer's surplus} = \frac{2000 + 2400}{2} \times 0.267 = \$587.4 \text{ per hour}$$

$$\text{Existing Revenue} = (2000)(1) = 2000$$

$$\text{Revised revenue} = (2400)(0.73) = 1760$$

$$\text{Loss} = \$240$$

Obviously, if the demand is sufficient, there is no need to decrease the fare.

<2.16>

Assume that the given price elasticity is valid in the range of the 10% change in the number of buses:

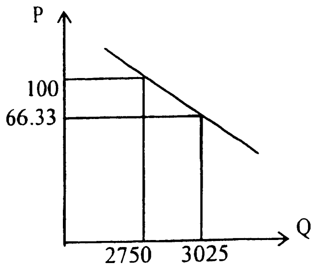
A 10% increase in the number of buses implies a 10% increase in the number of seats.

Price elasticity of - 0.3 means

$$\frac{\Delta Q}{Q} \bigg/ \frac{\Delta P}{\text{P}} = -0.3$$

or a 3% increase in Q results from a 10% decrease in P. $\therefore$ a 10% increase in Q would result in a 33.33% decrease in fare (P).

Original capacity: 50 x 55 = 2750   New capacity: 2750 + 275 = 3025



$$\text{Additional Consumer Surplus} = \frac{2750 + 3050}{2}(33.33)$$
$$= \$962.40$$

<2.17>

a) $p_o^{lux} = \$2.00$
$p_1^{lux} = \$2.50$

<u>Luxury</u>

$$e = -0.20$$
$$\left(\Delta p / p\right)^{lux} = (2.50 - 2.00)/(2.50 + 2.00)/2 = 0.22$$
$$\left(\Delta Q / Q\right)^{lux} = -0.20 * 0.22 = -0.044 \Rightarrow 4.4\% \text{ decrease}$$
$$(Q_1 - 7000)/(Q_1 + 7000)/2 = -0.044$$
$$\Rightarrow \boxed{Q_1^{lux} = 6696}$$

<u>Regular</u>

$$c = 0.05$$
$$(\Delta Q/Q)^{reg} = 0.05 * 0.22 = 0.011 \Rightarrow 1.1\% \text{ increase}$$
$$(Q_1 - 5000)/(Q_1 + 5000)/2 = 0.011$$
$$\boxed{Q_1^{reg} = 5055}$$

b) <u>Luxury</u>

$$e = -0.07$$
$$(\Delta p/p)^{lux} = (25 - 30)/(25 + 30)/2 = -0.182$$
$$(\Delta Q/Q)^{lux} = -0.182 * (-0.07) = 0.0127 \Rightarrow 1.27\% \text{ increase}$$
$$\boxed{Q_1^{lux} = 7090}$$

Regular $e = 0.02$

$$(\Delta Q/Q)^{reg} = 0.02 * (-0.182) = 0.004 \Rightarrow 0.4\% \text{ decrease}$$

$$\boxed{Q_1^{reg} = 4982}$$

c) Regular $e = -0.03$

$$(\Delta p/p)^{reg} = (50-45)/(50+45)/2 = 0.105$$

$$(\Delta Q/Q)^{reg} = (-0.03)(0.105) = 0.003 \Rightarrow 0.3\% \text{ decrease}$$

$$\boxed{\Rightarrow Q^{reg} = 4984}$$

Luxury $e = 0.05$

$$(\Delta Q/Q)^{lux} = 0.05 * (0.105) = 0.00525 \Rightarrow 0.53\% \text{ increase}$$

$$\boxed{Q_1^{lux} = 7037}$$

d) a) Luxury

$6696 * 2.50 =$ 16740
$7000 * 2.00 =$ 14000
$2740 Total gain

Regular

$5055 * 1 =$ 5056
$5000 * 1 =$ 5000
$56 total gain

b) Luxury

$7090 * 2 =$ 14180
14000
$180 total gain

Regular

$4982 * 1.00 =$ 4982
-5000
$ 18 total loss

c) Luxury

$7037 * 2 =$ 14074
14000
$ 74 total gain

Regular

$4984 * 1.00 =$ 4984
5000
$16 total loss

<2.18>

(a) Given that the train ticket costs \$25/trip, a student will take only 2 trips because any more trips are valued at less than \$25. In this case the consumer surplus = \$15 + \$5 = \$20 for the trips 1 and 2.

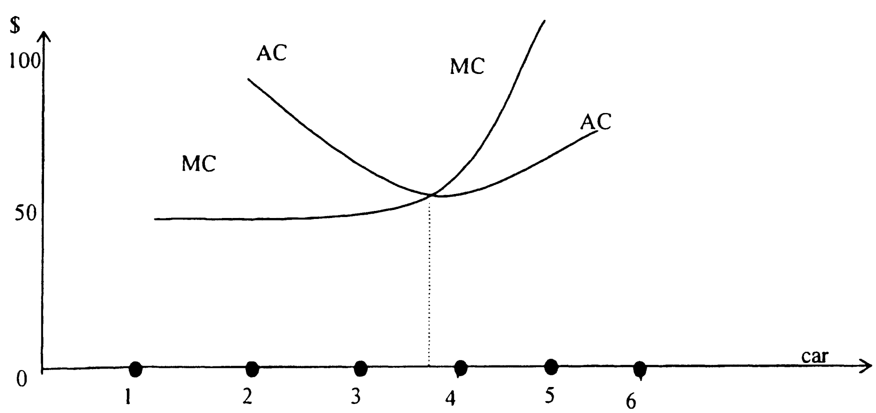
(b) If the travel club were not there, a student's value for traveling to the resort would be:
\$40 + 30 + 20 + 15 + 5 = \$110/month.

However, to retain the same consumer surplus as before, a student would at most pay \$110 - \$20 = \$90/month.

<2.19>

#cars	Fixed	Variable	Total	Average	Marginal Cost
1	45	30	75	75	24
2	45	54	99	49.5	22
3	45	76	121	40.3	26
4	45	102	147	36.7	48
5	45	150	195	39.0	75
6	45	225	270	45.0	85
7	45	310	355	50.7	

The results indicate that a 4-car combination would be optimal. The final choice would also depend on patronage.



<2.20>

Column A represents overhead $50/hr.
Column B represents overhead $60/hr.

# Men	Hour Output	Total Cost		Average Cost		Marginal Cost	
		A	B	A	B	A	B
2	56	60	67	1.07	1.19	1.07	1.19
3	120	65	71	0.54	0.58	.078	.054
4	180	70	74	0.39	0.41	.08	.058
5	200	75	78	0.38	0.39	.25	.175
6	210	80	81	0.38	0.38	.50	.35
7	218	85	85	0.39	0.39	.61	.43
8	224	90	88	0.40	0.39	.83	.58

Lowest average cost = 0.38. Six non-skilled workers could be hired, or six semi-skilled workers could be hired.

<2.21>

In general, if $v - a - bq \ldots (1)$ and $p = c + \frac{d}{v} \cdots (2)$

Then, the cost of travel (private) for individual trip-makers is $p = c + \frac{d}{a - bq} \ldots\ldots\ldots (3)$

And the cost, c, to all trip-makers is $c = (p)(q) = \left[c + \frac{d}{a - bq}\right](q) \ldots\ldots. (4)$

Marginal cost, $\partial c/\partial q = \left[c + \frac{da}{(a - bq)^2}\right]$

Now,

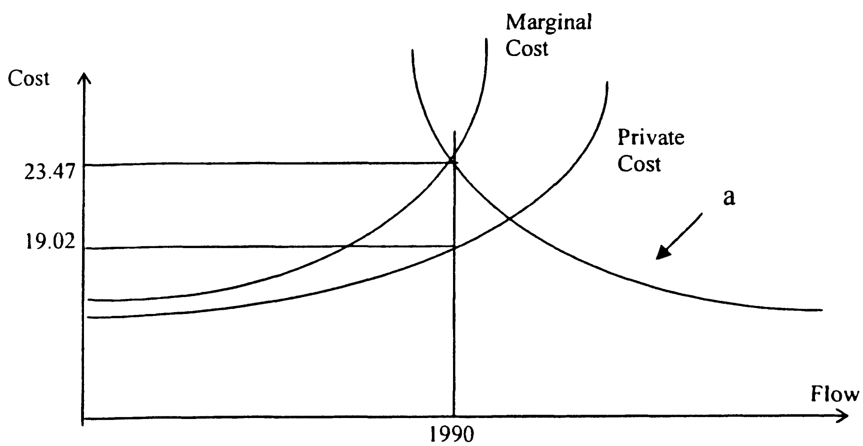
$v = a - bq = 60 - q/120$

$p = c + d/v = 2.5\left(3 + 200/v\right) = 7.5 + \frac{500}{v}$

$$\text{Marginal Cost} = c + \frac{da}{(a-bq)^2} = c + \frac{da}{v^2}$$
$$= 7.5 + 30{,}000 / v^2$$

Flows q	Speed $v = 60 - q/120$	Private Cost $\rho = 7.5 + 500/v$	Marginal Cost $MC = 7.5 + 30{,}000/v^2$	Demand $3.8 \times 10^4/\rho$
500	56	16.43	17.07	2313
1000	52	17.12	18.59	2220
1500	48	17.92	20.52	2121
1800	45	18.61	22.31	2042
1960	43.67	18.95	23.23	2005
➔ 1990	43.42	19.02	23.47	1998 ←
2000	43.33	19.03	23.48	1997
2010	43.25	19.06	23.54	1993
2200	42	19.40	24.51	1958
2400	40	20.00	26.25	1900
2500	39	20.32	27.22	1870

From the above table it is obvious that the intersection of the demand curve (a), and the marginal curve lies very close to the coordinates (1990; 23.47) as shown on the graph below. Here demand is almost equal to flow (1990 and 1998).



The optimum flow is 1990 vph, and for this to occur a toll of [23.47 - 19.02] = 4.45 cents/mile. When this toll is charged the flow conditions will resemble the marginal cost curve. For practical purposes it would be quite appropriate to charge 5 cents/mile.

<2.22>

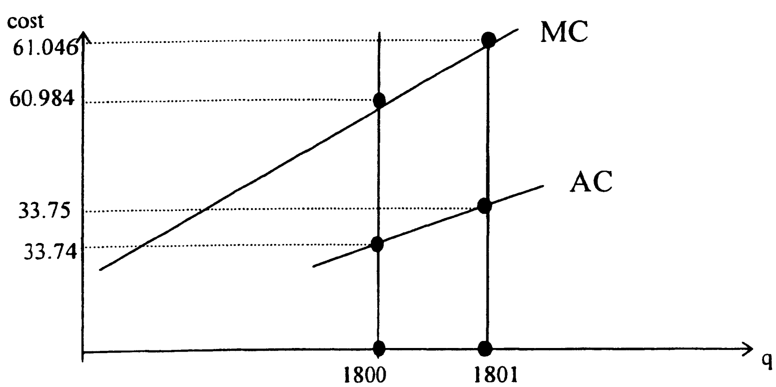
$$\text{Average Cost/mile/vehicle} = 8.0 + \frac{350}{28 - 0.008q}$$

$$\text{Marginal Cost/mile/vehicle} = \text{Av.Cost} + \frac{2.8q}{(28 - 0.008q)^2}$$

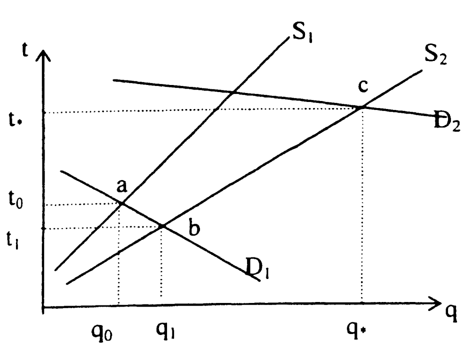
$$t = \frac{1}{28 - 0.008q} \quad \text{veh - hr / vehml}$$

	1800	1801 veh/hr
Average Cost	33.735	33.750
Marginal Cost	60.984	61.046
Travel Time, sec/mile	264.862	264.706

The results show that the addition of one vehicle , when flow is 1800 veh/hr, increases the average travel time/mile by 0.156 sec. This delay is reflected in an increase in average trip cost from 33.74 to 33.75 cents/mile. Note that though each individual vehicle experiences only 0.156 sec. increase in average travel time, the total extra time for 1801 vehicles = 0.156 x 1800 = 280.8 seconds delay. Also, when the flow rate increases from 1800 to 1801 veh/hr, the additional cost to all vehicles is 61.05 cents.



<2.23>



Refer to the figure which shows

D_1 is the demand curve before addition of lane
D_2 is the demand curve after the addition of lane
S_1 represents the supply curve before addition of lane
S_2 represents the supply curve after the addition of lane.

The intersection of D_1 and S_1 is represented by "a" where q_o is the flow with t_0 (min). Similarly, after the addition of the lane, the supply curve S_2 intersects the demand curve D_1, at "b" which indicates that in the short run the time (min) to traverse the 10 miles has decreased and the flow has increased from q_o to q_1. Thus, in the short run it appears that the addition of a lane has improved the situation. However, in the long run it appears, due to the convenience afforded by the improvement, the demand curve will have shifted from D_1 to D_2, and the intersection of D_2 and S_2, represented by "c" shows that the time needed to traverse the 10 miles has increased to t* with the flow at q*. The lesson to the learned is that on a congested freeway, the addition of a lane will not reduce congestion in the long run. One way of reducing congestion would be "road pricing"

<2.24 >

$$C = 5 + 7q$$

(a) $$MC = \frac{dC}{dq} = \frac{d(5+7q)}{dq} = 7$$

$$AC = \frac{C}{q} = \frac{5+7q}{q} = \frac{5}{q} + 7$$

(b) $$e = \frac{MC}{AC} = \frac{7q}{5+7q}$$

(c) Yes, average cost decreases as q increases

(d) Yes, because an economy of scale exists.

<2.25>

$$C = 7q$$

(a) $$MC = 7$$

$$AC = \frac{7q}{q} = 7$$

(b) $e = 1$

(c) No economy of scale exists (assuming fixed costs are equal to zero)

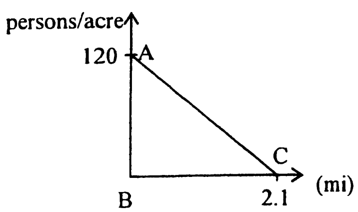
(d) Do not recommend providing extra capacity.

CHAPTER 3
THE LAND USE/TRANSPORTATION SYSTEM

<3.1>

The usual population density pattern for North American cities is a high density in and around downtown and a progressively decreasing density as one moves to the edge of town. Since the population is 360,000 spread over an area of 9000 acres, the average density = 40 persons/acre. The following two patterns seem to be logical. Topographical and man-made features would naturally play an important role in affecting the actual distributions (including zoning regulations).

1.An approximately circular city:



AB = pop: density at city center
BC = radius of city
9000 acres = 14.06 sq. miles

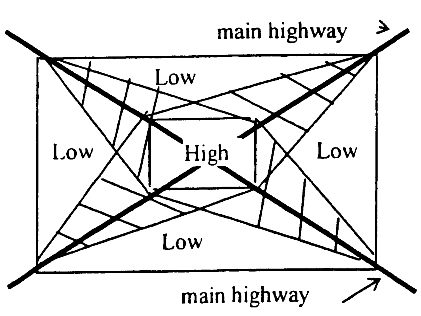
$$BC = \sqrt{\frac{14.6}{\pi}} = 2.12 \text{ miles}$$

Total pop = vol. of a solid cone, base = r
height = AB

$$V = \frac{\pi r^2 \left(\overline{AB}\right)}{3} \quad \overline{AB} = \frac{(3)(360{,}000)}{\pi (2.12)^2} = 76{,}486 \text{ persons / sq. mile}$$

$$= 120 \text{ persons / acre}$$

2. Star-shaped city: Communication links such as roads can influence a city and its land use patterns.



6000 acres at 20 persons / acre	=	120,000
3000 acres at 80 persons / acre	=	240,000
9000 acres	→	360,000

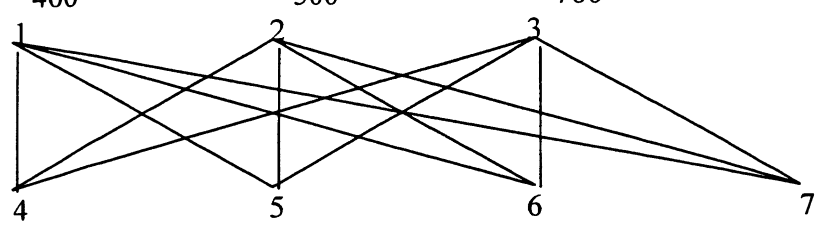
<3.3>

$$
\begin{aligned}
t_s &= 5 + 7.35\,U_s &&= 5 + (7.35 \text{ x } 2000) \\
& &&= 14{,}705 \\
t_a &= 7 + 6.25\,U_a &&= 7 + (6.25 \text{ x } 520) \\
& &&= 3257 \\
t_h &= 2 + 12U_h &&= 2 + (12 \text{ x } 3 \text{ x } 600) \\
& &&= 21{,}602 \\
&\text{Total trips} &&= 39{,}564
\end{aligned}
$$

Single family homes are pretty stable in producing trips, and so are apartments if hotels are much more variable.

<3.8>

Workers 400 500 700



Jobs 350 450 500 300

Calculate A_{ij} and A_i using

$$A_O = \sum Ed \Big/ \left(t_{od}\right)^b$$

$$A_1 = \frac{350}{10^{1.2}} + \frac{450}{12^{1.2}} + \frac{500}{14^{1.2}} + \frac{300}{15^{1.2}} = 78$$

$$A_2 = \frac{350}{8^{1.2}} + \frac{450}{9^{1.2}} + \frac{500}{10^{1.2}} + \frac{300}{12^{1.2}} = 108$$

$$A_3 = \frac{350}{4^{1.2}} + \frac{450}{6^{1.2}} + \frac{500}{8^{1.2}} + \frac{300}{15^{1.2}} = 171$$

$$\text{Total} = 357$$

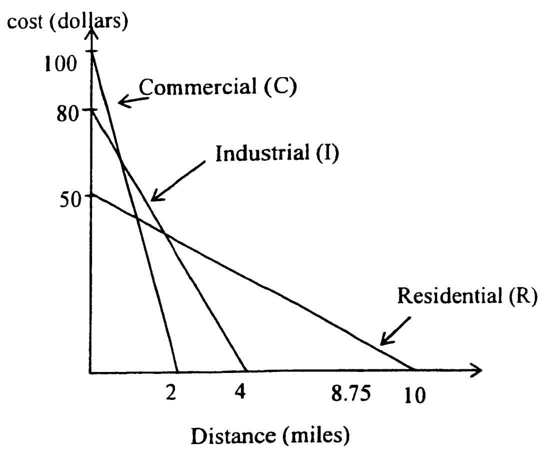
Relative Accessibility:

$$A_1 = 78/357 = 0.22$$

$$A_2 = 108/357 = 0.30$$

$$A_3 = 171/357 = \frac{0.48}{1.00}$$

<3.9>



$C = I \Rightarrow \quad 100 - 50x = 80 - 20x$

$x = \underline{\underline{0.67}}$ mile

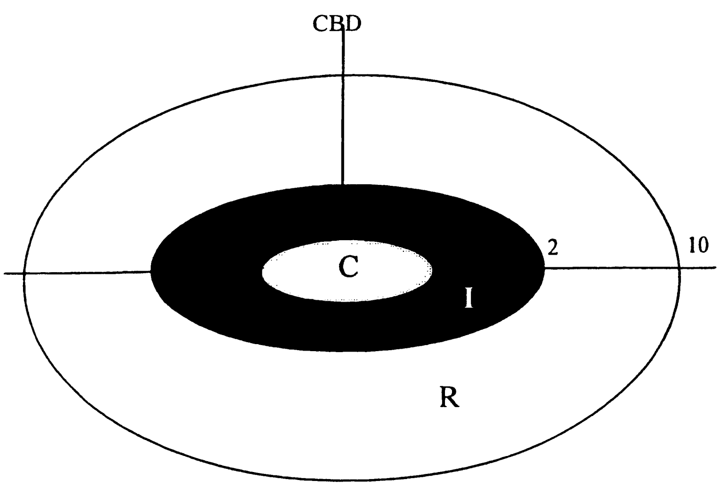
$I = R \Rightarrow \quad 80 - 20x = 50 - 5x$

$x = \underline{\underline{2}}$ mile

$P_{(C)} = 100 - 50x$

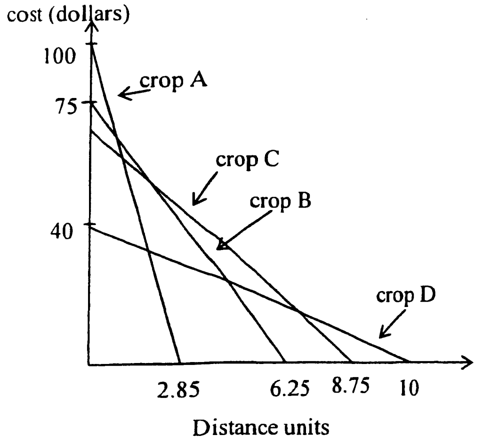
$P_{(I)} = 80 - 20x$

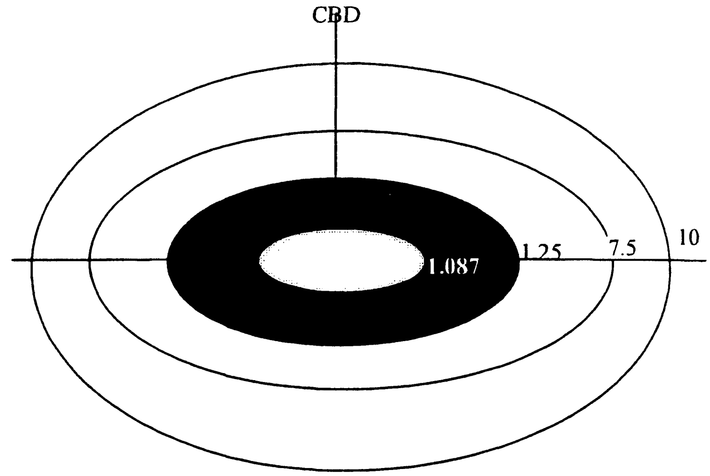
$P_{(R)} = 50 - 5x$



- from the center to 0.67 mile will be COMMERCIAL
- from 0.67 mile to 2 miles will be INDUSTRIAL
- from 2 mile to 10 miles will be RESIDENTIAL

<3.11>





Dist when profit = 0	A	B	C	D
	2.85	6.25	8.75	10

Crop A 0 to 1.087
Crop B 1.087 to 1.250

Crop C 1.25 to 7.5
Crop D 7.50 to 10 miles

<3.12>

The general equation for an exponential growth pattern is

$P_{t+n} = P_t(1+r)^n$

P = population

t = a time index

P_{t+n} = pop : (n units) in time t

r = growth rate

A more reasonable growth pattern is the modified exponential, which takes account of a maximum limit (capacity = K). Here $P_{t+n} = K - \left[(K - P_t)(V)^n\right]$ where V = constant.

Consider the employment

Year	0	2500
	2	3500
	4	4200
	6	4500

$$\frac{K-P_2}{K-P_1}=\frac{5000-3500}{5000-2500}=0.6$$

$$\frac{K-P_4}{K-P_2}=\frac{5000-4200}{5000-3500}=0.53$$

$$\frac{K-P_6}{K-P_4}=\frac{5000-4500}{5000-4200}=0.625$$

$$V=\frac{0.6+0.53+0.625}{3}=0.585$$

The employment will reach capacity when: $(5000-4500)(0.585)^n=1 \quad n\approx 12$ years

Yr	Emp	Emp. + Family (A)	Serv. Jobs	Serv. family (B)	Total
0	2,500	7,500	2,250	6,750	14,250
2	3,500	10,500	3,150	9,450	19,950
4	4,200	12,600	3,780	11,340	23,940
6	4,500	13,500	4,050	12,150	25,650
8					
10					
12	5,000	15,000	4,500	13,500	28,500

<3.13>

The results are

Trips = -42.24 + 0.17 home

R^2 = 0.93

<3.14>

Calculate A_{ij}

Zone	1	2	3	4	ΣA_i
1	87	16	38	12	153
2	19	118	72	6	215
3	13	20	802	13	848
4	8	3	27	87	125

Zone	A_i	H_i	D_i
1	153	300	45,900
2	215	280	60,200
3	848	500	424,000
4	125	350	43,750
			573,850

Calculate relative devp: potential.

Zone	D_i	$D_i/\Sigma D_i$	G_i
1	45,900	0.080 x 21,850	1,748
2	60,200	0.105 x 21,850	2,294
3	424,000	0.739 x 21,850	16,148
4	43,750	0.076 x 21,850	1,660
			21,850

City will grow to (3000 + 2500 + 9000 + 4500) x 1.15 = 21,850

<3.15>

There is no standard way of answering this question except by experimenting with various values of "b" in the expression $A_{ij} = E_j / d_{ij}^b$. Try $b = 1$, in which case,

Zone	1	2	3	ΣA_{ij}
1	1000	167	375	1542
2	333	333	600	1266
3	250	200	750	1200

Multiply A_i x H_i

Zone 1	1542 x 100	=	154,200
2	1266 x 200	=	253,200
3	1200 x 400	=	480,000
			887,400

Relative development potential of each zone

Zone	D_i	$D_i/\Sigma D_i$	G
1	154,200	.174	1,392
2	253,200	.285	2,280
3	480,000	.541	4,328
	887,400		8,000

The figures, 1392, 2280 and 4328 match the figures given by the expert.

<3.16>

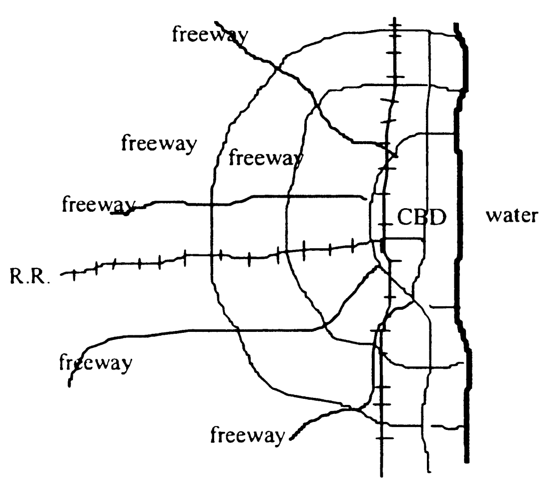
A fairly realistic distribution would be:

Landuse	Area sq.mi	%
Residential	180	18.0
Streets	150	15.0
Public Spaces (Open)	100	10.0
Transportation related	50	5.0
Manufacturing	25	2.5
Public Building	20	2.0
Commercial	20	2.0
Parks etc.	5	0.5
	550	
Vacant or not in use	450	45.0
Total	1000	

Semicircular city of 1000 sq.mi. $A = \frac{\pi r^2}{2}$ $\therefore r = 25$ miles

Residential density (persons / sq ml) $= \frac{5{,}000{,}000}{180} = 27{,}780$

Ratio: streets + alleys to residential area = 15/18 = 0.83



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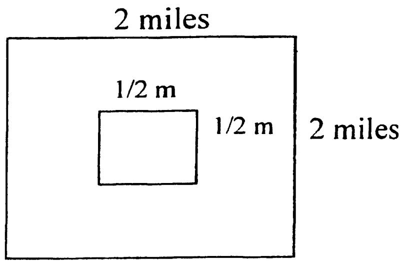

Area of CBD = 0.5 x 0.5 = 0.25 mi^2
Area of Non - CBD + (2 x 2) - 0.25 = 3.75 mi^2
Population in CBD = 0.25 x 640 x 100 = 16,000 persons

Population of Non - CBD = 3.75 x 640 x $\left(\frac{100+5}{2}\right)$ = 126,000 persons

Total population = 16000 + 126,000 = 142,000.

<3.18>

$$d_x = d_O e^{-bx}$$

At 2 miles $d_x = 21\, p/acre = 13{,}440\, p/sq\ m$

At 3 miles $d_x = q\ p/acre = 5{,}760\, p/sq\ m$

$$\left.\begin{aligned} \therefore 13{,}440 &= d_O e^{-2b} ......(1) \\ 5{,}760 &= d_O e^{-3b} .....(2) \end{aligned}\right\} \textit{Divided } 1 \text{ by } 2$$

$\therefore 2.33 = e^b$ $\quad \therefore b = 0.847$ and $d_o = 73035$ persons$/sq\ m.$

If x = radius of this circ : city works out to be about 13.22m and Area of City = 548.77sq m.

<3.19>

Pop. X	Gas St. Y	$\left(X_i - \bar{X}\right)^2$	X^2	Y^2	(X) (Y)	Predict $\hat{Y}_i$	Residential $Y_i - \hat{Y}_i$	Squared Residential $\left(Y_i - \hat{Y}_i\right)^2$
1	2	4	1	4	2	2.4	-.4	.16
5	7	4	25	49	35	7.6	-.6	.36
3	3	0	9	9	9	5.0	-2.0	4.0
2	5	1	4	25	10	3.7	+1.3	1.69
4	8	1	16	64	32	6.3	+1.7	2.89
		10						
$\Sigma X = 15$ $\bar{X} = 3$	$\Sigma Y = 25$ $\bar{Y} = 5$		$\Sigma X^2 = 55$ $\overline{X^2} = 11$	$\Sigma Y^2 = 151$ $\overline{Y^2} = 30.2$	$\Sigma XY = 88$ $\overline{XY} = 17.60$	25	0	9.1

$\bar{x} = 3$; $\bar{y} = 5$; $\overline{x^2} = 11$; $\overline{y^2} = 30.2$; $\overline{xy} = 17.6$

$$\hat{b} = \frac{\overline{xy} - (\bar{x})(\bar{y})}{\overline{x^2} - (\bar{x})^2} = \frac{17.6 - (3)(5)}{11 - 9} = 1.30$$

$$\hat{a} = \bar{y} - \hat{b}\bar{x} \quad = 5 - (1.30)(3) = -1.1 \qquad \therefore \bar{y} = 1.1 + (1.3)x$$

Coeff. of determination can be calculated as follows:

$$\text{Var } y = \overline{y^2} - (\bar{y})^2 = (30.2) - (5)^2 = 5.2$$

Since Var $y = SE_{(av)/n}$

$$SE_{av} = n(\text{Var } y) = (5)(5.2) = 26$$

$$r^2 = 1 - \frac{SE_{line}}{SE_{av}} = 1 - \frac{9.1}{26} = 0.65$$

$$r = 0.81$$

r^2 can also be calculated from

$$r^2 = \frac{\left(\overline{xy} - (\bar{x})(\bar{y})\right)^2}{\left(\overline{x^2} - (\bar{x})^2\right)\left(\overline{y^2} - \bar{y}^2\right)} = \frac{[17.60 - (3)(5)]^2}{(11 - 9)(30.2 - 25)} = \frac{6.76}{10.40} = 0.65$$

$$\text{Mean Square Error (MSE)} = \frac{SE_{line}}{(n-2)} = \frac{\Sigma\left(y_i - \hat{y}_i\right)^2}{(n-2)} = \frac{9.1}{3} = 3.03$$

$$t = \frac{\hat{b}}{\sqrt{\dfrac{MSE}{\Sigma\left(x_1 - \bar{x}\right)^2}}} = \frac{1.30}{\sqrt{\dfrac{3.03}{10}}} = 2.361$$

For a z - tailed test at 10% significance the critical value for 3 degrees of freedom is 2.353 which is just below 2.361 $\therefore$ OK

$$r^2 = 0.65$$

$$r = 0.81$$

We also wish to know whether the r could have arisen by chance

$$t = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}} = \frac{0.81\sqrt{5-2}}{\sqrt{1-0.65}} = \frac{1.403}{0.592} = 2.37$$

Here again the value of r just passed the t - test of $t = 2.353$ at the 10% level.