1\. 2013 MANG 81 PAPER3 Q1 DAVID WEITBRECHT.

A. Give a brief outline of the differences between linear and goal programming

linear.

- Optimisation of a linear objective function
- linear constraints
- One objective function to find max/min of a function
- No priority levels each constraint equally important

Obj 1st then constraints

Objective first then constraints after.

Goal

- A branch of multiobjective optimisation
- Optimisation program
- Extension of linear program to hand multiple, normally conflicting objectives measure
- Each measure has a priority level. Hard Contraints. Multiple Constraints
- Priority level 1 is most important
- P1 takes precedence and next constraints must not upset solution for P1
- Each measure has its own goal or target value
- Try to minimise deviation above/below target value
- Includes deviation variables

Contraints 1st the Obj Fn. Constraints first then objective function.

B Formulate a linear program and set up initial simplex tableau

$$\text{Max } Z = 500x_1 + 7000x_2$$

$$\text{ST: } 3000x_1 + 4000x_2 \le 6000$$

$$5x_1 + 4x_2 \le 100$$

$$x_2 \le 7$$

$$x_1 \quad x_2 \ge 0$$

2.

Basis	value	X_1	X_2	S_1	S_2	S_3		ratio
		5000	7000	0	0	0		
S_1	0	3000	4000	1	0	0	60000	$\frac{60000}{4000}$ =15
S_2	0	5	4	0	1	0	100	$\frac{100}{4}$ =25
S_3	0	0	1	0	0	1	7	$\frac{7}{1}$ =7
Z_j		0	0	0	0	0	0	
$C_j - Z_j$		5000	7000	0	0	0		

i The Optimum Solution

$X_1 = 10.67$ value $= 5000(10.67) + 7(7000) = 102333.33$

$X_2 = 7$

$S_2 = 18.67$

$S_1 = 0$

$S_3 = 0$

ii. Binding Constraints

S with value of zero $\Rightarrow$ S_1 = constraint 1 = binding

S_3 = constraint 3 = binding

Non Binding

S with value 70 $\Rightarrow$ S_2 = Constraint 2 = non binding

iii Final table

Basis	OF value	X_1	X_2	S_1	S_2	S_3	
		5000	7000	0	0	0	
X_1	5000	1	0	$\frac{1}{3000}$	0	$-4/3$	10.67
S_2	0	0	0	$-\frac{1}{600}$	1	2.67	18.67
X_2	7000	0	1	0	0	1	7
Z_j		5000	7000	$5/3$	0	$\frac{1000}{3}$	102333.33
$C_j - Z_j$		0	0	$-5/3$	0	$-\frac{1000}{3}$	

3 2013 MANG SCI PAPER 3 Q1 DAVID WEITBRECHT

iii. Shadow Price

Constraint 1 $= 5/3$

Constraint 3 $= 1000/3$

iv. Right hand Side Ranges:

Constraint 1 old + new

$$\begin{bmatrix} 32/3 \\ 56/3 \\ 7 \\ 102333.33 \end{bmatrix} \quad \Delta b_1 \begin{bmatrix} 1/3000 \\ -1/600 \\ 0 \\ 5/3 \end{bmatrix}$$

$\frac{32}{3} + \Delta b_1 \frac{1}{3000} \geq 0$ $\Delta b_1 \geq -32000$

$56/3 - \Delta b_1 \frac{1}{600} \geq 0$ $\Delta b_1 \leq 11200$

$7 - 0$ —

$102333.33 + \Delta b_1 (5/3) \geq 0$ $\Delta b_1 \geq -61399.8$

$-32000 \leq \Delta b_1 \leq 11200$ $b_1 = 60000$

$60000 - 32000 \leq b_1 \leq 60000 + 11200$

$28000 \leq b_1 \leq 71200$

Constraint 2

old + new

$$\begin{bmatrix} 32/3 \\ 56/3 \\ 7 \\ 102333.33 \end{bmatrix} + \Delta b_2 \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$

—

$56/3 + \Delta b_2 \geq 0$ $\Delta b_2 \geq -56/3$

—

—

$-56/3 \leq \Delta b_2 \leq \infty$ $b_2 = 100$

$100 - 56/3 \leq b_2 \leq \infty$

$244/3 \leq b_2 \leq \infty.$

Constraint 3

$$\begin{bmatrix} 32/3 \\ 56/3 \\ 7 \\ 102333.33 \end{bmatrix} + \Delta b_3 \begin{bmatrix} -4/3 \\ 8/3 \\ 1 \\ 1000/3 \end{bmatrix}$$

$\frac{32}{3} - 4/3 \Delta b_3 \geq 0$ $\Delta b_3 \leq 8.$

$56/3 + 8/3 b_3 \geq 0$ $\Delta b_3 \geq -7$ $b_3 = 7.$

$7 + \Delta b_3 \geq 0$ $\Delta b_3 \geq -7.$

$102333.33 + \frac{1000}{3} \Delta b_3 \geq 0$ $\Delta b_3 \geq -307.$

$7 - 7 \leq \Delta b_3 \leq 7 + 8$

$0 \leq b_3 \leq 15$

4

v. Range for the coefficient in the objective function

For X_1:

$+\frac{4}{3}c_1 - 7000 \le 0$ $\qquad -\frac{1}{3000}c_1 < 0$

$\frac{4}{3}c_1 \le 7000$ $\qquad c_1 \ge \frac{1}{3000}$

$c_1 \le 5250.$ $\qquad 0 \; \cancel{\frac{1}{3000}} \le c_1 \le 5250$

For X_2: $-\left(-\frac{4}{3}(5000) + c_2\right) \ge 0$

$\frac{20000}{3} - c_2 \ge 0$

$c_2 \le \frac{20000}{3}$

No upper limit

State Let x = No of Tel
y = " " Per

C. Goal Programming

$\text{Min} \quad P_1(d_1^-) + P_2(d_2^+) + P_3(d_3^-)$

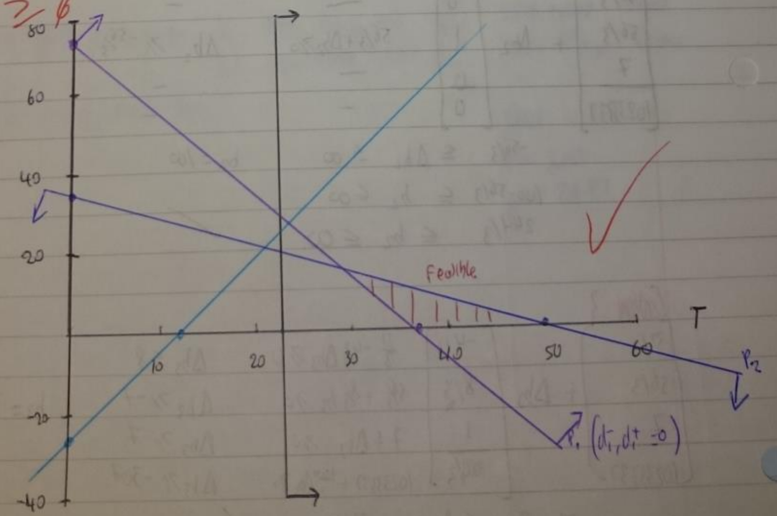
P_1 ST: $80t + 40p - d_1^+ + d_1^- = 3000$

P_2 $\quad 50t + 70p - d_2^+ + d_2^- = 2500$

P_3 $\quad 80t \; \cancel{40p} - d_3^+ + d_3^- = 1000$

All vars ≥ 0

(ii



5. 2013 MANG SCI PAPER 3 Q1 DAVID WETMBRECHT

Priority 1: $80t + 40p = 3000$ $t=0, p=75, p=0\ t=37.5$

$d_1^+, d_1^- = 0.$

Priority 2: $d_1^+, d_1^- = 0$

$50t + 70p = 2500$ $(d_2^+, d_2^- = 0)$ $\Rightarrow t=0\ 35.7, p=0\ 50$

Priority 1 and 2 Satisfied ✓.

Priority 3: ~~$80t - 40p = 1000 \Rightarrow t=0\ p=25\ p=0$~~

~~minimise $(d_3^+, d_3^-) = 0$ $t=0\ p=-25$~~ $p=0\ 12.5.$

at least 1000t

$80t \geq 1000$

$t \geq 25.$

All three priority levels Satisfied ✓

Points are $\Rightarrow (37.5, 0)$ $(50,0)$ or

$80\left(\frac{2500-70p}{50}\right) + 40p = 3000$

$4000 - 1120p + 40p = 3000$

(1) $80t + 40p = 3000$ $\boxed{\times 7}$ $560t + 280p = 21000$

(2) $50t + 80p = 2500$ $\boxed{\times 4}$ $200t + 280p = 10000$

$360t = 11000$

$t = 30.55$

$p = 22.22$

$(37.5, 0) \Rightarrow 1875.$

$(50, 0) \rightarrow 2500.$

$(30.55, 22.22) \Rightarrow 30.55, 13.9 = 2500+$

Choose 37.5 telephone interviews, minimises cost and satisfies all constraints given and each priority level

$t = 30.5556$ $p = 13.8889$

2010/2011 $\boxed{3}$ Q3

3 a Formulate problem by:

- Minimising objective function by multiplying by -1 if it is a max problem
- All coefs of min O.F. must be positive.
  If negative replace variable x_J with $(1-x_J)$ and drop the resulting constant.
- If $x_J = (1-x_J)$ was used, substitute it into the constraints
- Constraints must be all in form of $\leq$
  If not; multiply both sides by -1 and swap equality
- Start with solution where all variables = 0.
  Check for feasibility
- Pick x_J in O.F. with smallest coef and assign value of 1 to it leaving other x_J at 0.
- If feasible you have found solution
- If not, pick second lowest x_J and set remaining to 0.
  Check for feasibility, if not repeat step until you find feasibility
- Keep iterating until solution is found
- Remember that if you substituted $x_J = 1-x_J$ you must enter value in at end to get proper solution

2

h max $90x_1 + 40x_2 + 10x_3 + 37x_4$

ST:

$C_1: 15x_1 + 10x_2 + 10x_3 + 15x_4 \le 40$

$C_2: 20x_1 + 15x_2 + 0 + 10x_4 \le 50$

$C_3: 20x_1 + 20x_2 + 0 + 10x_4 \le 40$

$C_4: 15x_1 + 5x_2 + 4x_3 + 10x_4 \le 35.$

1. Change O.F. to minimisation by multiplying by (−1)

$-90x_1 - 40x_2 - 10x_3 - 37x_4$

coef's must be positive, $x_J = (1 - x_J)$

$-90(1-x_1) - 40(1-x_2) - 10(1-x_3) - 37(1-x_4)$

$90x_1 + 40x_2 + 10x_3 + 37x_4 - \cancel{177}$

drop the constant

2 Substitute $x_J = 1 - x_J$ into 4 constraints, no need to change equality

$C_1: 15(1-x_1) + 10(1-x_2) + 10(1-x_3) + 15(1-x_4) \le 40$

① $-15x_1 - 10x_2 - 10x_3 - 15x_4 \le -10$

$C_2: 20(1-x_1) + 15(1-x_2) + 0 + 10(1-x_4) \le 50$

② $-20x_1 - 15x_2 - 10x_4 \le 5$

$C_3: 20(1-x_1) + 20(1-x_2) + 0 + 10(1-x_4) \le 40$

③ $-20x_1 - 20x_2 - 10x_4 \le -10$

$C_4: 15(1-x_1) + 5(1-x_2) + 4(1-x_3) + 10(1-x_4) \le 35$

④ $-15x_1 - 5x_2 - 4x_3 - 10x_4 \le 1$

4

Max $10x + 8y$

ST: $x + y + S_1 = 10$

$5x + y + S_2 = 20$ $\quad x, y \geq 0$

Basis	C_B	x 10	y 8	S_1 0	S_2 0		
S_1	0	1	1	1	0	10	$\frac{10}{1} = 10$
S_2	0	5	1	0	1	20	$\frac{20}{5} = 4$
Z_J		0	0	0	0	0	
$C_J - Z_J$		10	8	0	0		

Want $\frac{0}{1}$ row2 ÷ 5

row1 − row2

Basis	C_B	x 10	y 8	S_1 0	S_2 0		
S_1	0	0	$4/5$	1	$-1/5$	6	$\frac{6}{0.8} = 7.5$
x	10	1	$1/5$	0	$1/5$	4	$\frac{4}{0.2} = 20$
Z_J		10	2	0	2	40	
$C_J - Z_J$		0	6	0	−2		

Want $\frac{1}{0}$ row 1 × $5/4$

row 2 − $1/5$ row1

Basis	C_B	x 10	y 8	S_1 0	S_2 0	
y	8	0	1	$5/4$	$-1/4$	$15/2$
x	10	1	0	$-1/4$	$1/4$	$5/2$
Z_J		10	8	$10-4$ 7.5	0	85
$C_J - Z_J$		0	0	−7.5 $-10+4$	0	

Optimal Solutn $C_J - Z_J$ row are all 0 or negative

5. $\boxed{3}$ 2010/2011 Q3 Mayse

c i. Optimal Solution = $x = 2.5$
$y = 7.5$

ii. Shadow price $x = 10$
$y = 8$

iii. X coefficient $-10 + c_1 \leq 0$ and $2 - c_1 \leq 0$
$c_1 \leq 10$ $c_1 \geq 2$
$2 \leq c_1 \leq 10$

y cof. $-c_2 - 2.5 \leq 0$ $+c_2 - 2.5 \leq 0$
$c_2 \geq -2.5$ $c_2 \leq 2.5$
$-2.5 \leq c_2 \leq 2.5$

iv. RHS old

Constraint 1

$$\begin{bmatrix} 7.5 \\ 2.5 \\ 85 \end{bmatrix} + \Delta b_1 \begin{bmatrix} 5/4 \\ -1/4 \\ 7.5 \end{bmatrix}$$

$7.5 + \frac{5}{4}\Delta b_1 \geq 0$ $\Delta b_1 \geq -6$

$2.5 + \frac{1}{4}\Delta b_1 \geq 0$ $\Delta b_1 \leq 10$

$85 + \Delta b_1 7.5 \geq 0$ $\Delta b_1 \geq -\frac{34}{3}$

$-6 \leq \Delta b_1 \leq 10$

$10 - 6 \leq \Delta b_1 \leq 10 + 10$

$4 \leq \Delta b_1 \leq 20$ $\boxed{C_1}$

RHS C2

$$\begin{bmatrix} 7.5 \\ 2.5 \\ 85 \end{bmatrix} + \Delta b_2 \begin{bmatrix} -1/4 \\ 1/4 \\ 0 \end{bmatrix}$$

$7.5 - \frac{1}{4}\Delta b_2 \geq 0$ $\Delta b_2 \leq 30$

$2.5 + \frac{1}{4}\Delta b_2 \geq 0$ $\Delta b_2 \geq -10$

$85 + 0 b\Delta \geq 0$ —

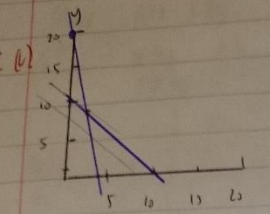
$-10 \leq \Delta b_2 \leq 30$

$20 - 10 \leq \Delta b_2 \leq 20 + 30$

$10 \leq \Delta b_2 \leq 50$ $\boxed{C_2}$

6.

c (ii)



(2.5, 7.5)

(1

$10x + 8y = 80$

$x=0 \quad y=\frac{1}{4}$

$y=0 \quad x=\frac{8}{10}$

4, 8

(4, $\cancel{6}$) (4, $\cancel{5}$)

(3, 5) (3, $\cancel{6}$) (3, $\cancel{7}$)

30+40   2, 6,   2, 7,   2, 8   1, 9,   0, 10

70   20+48 68   76   (8, 4)   82   80

(2, 8) ~~mos~~ blue

3 2013 Q1 Mang Scien

A. linear vs goal programming

<u>linear</u>

- Optimisation of a linear objective function
- linear constraints
- One objective function to find a max/min of a linear expression

<u>Goal programming</u>

- A branch of multiobjective optimisation.
- Optimisation program
- Extension of linear programming to handle multiple, normally conflicting objective measures
- each measure has its own goal or target value
- Unwanted deviations from these targets are then minimised
- There are different priority levels for each goal (ie. one is more important than the other).
- Includes deviation variables

b $Z_{max} = 5000x_1 + 7000x_2$

$$3000x_1 + 4000x_2 \le 6000$$
$$5x_1 + 4x_2 \le 100$$
$$x_2 \le 7$$
$$x_1, x_2 \ge 0$$

Basis	C_B	x_1	x_2	s_1	s_2	s_3	
		5000	7000	0	0	0	
s_1	0	3000	4000	1	0	0	6000
s_2	0	5	4	0	1	0	100
s_3	0	0	1	0	0	1	7

bi. optimum solution.

$x_1 = 10.67 \qquad x_2 = 7$

$5000(10.67) + 7000(7) = 102350$

optimum solution $z = 102333.33$ from tableau

ii. binding constraints

binding when $S_1 = 0$. and $x_2 \leq 7$.

$3000x_1 + 4000x_2 = 60000$

non-binding

$S_2 = 18.67$ = non binding = $5x_1 + 4x_2 = 100$ is binding.

iii. Shadow prices for each constraint

for constraint 1 $= S_1 =$ z row. $= +5/3 = +1.66$

constraint 2 $= S_2 = 0$

constraint 3 $= S_3 = 1350$

iv RHS values

~~$S_1 = 1.67$ will increase profit by 1.67~~

~~$S_3 = 333.33$ will have greater positive impact.~~

~~$S_2 = 0$ worthless to them~~

iv. ~~Objective function coef~~ RHS.

$$= \cancel{\begin{bmatrix} 10.67 \\ 18.167 \\ 7 \\ 102333.33 \end{bmatrix} + \Delta b_1 \begin{bmatrix} 1.67 \\ 1/3000 \\ -1/6000 \\ 0 \end{bmatrix}}$$

~~$10.67 + \Delta b_1 1.67 \geq 0$~~ ~~$b_1 \geq -6.389$~~

~~$18.16 + \Delta b_1 \frac{1}{3000} \geq 0$~~ ~~$b \geq -56010$~~

~~$7 + \frac{-1}{6000}\Delta b_1 \geq 0$~~ ~~$b \leq 42000$~~

0

~~$-6.389 \leq b \leq 42000$~~

~~$60000 - 6.389 \leq b \leq 60000 + 42000$~~

~~$59993.61 \quad b \leq 102000$~~ constraint 1

1.

Basis	C_B	x_1	x_2	s_1	s_2	s_3	
		5000	7000	0	0	0	
x_1	7000	1	0	1/3000	0	-4/3	32/3
s_2	0	0	0	-1/600	1	8/3	56/3
x_2	7000	0	1	0	0	1	7
Z_j		7000	7000	5/3	0	1000/3	10233.33
$C_j - Z_j$		0	0	-5/3	0	-1000/3	

i. Optimal $x_1 = 32/3$ $x_2 = 56/3$

$32/3\,(7000) + 56/3\,(5000) = 102333$

ii. s_1, s_3 binding s_2 nonbinding

iii. Shadow price constraint 1 : $5/3 = 1.667$

2 : 0

3 : 333.33

iv. constraint one

$$\underset{\text{old}}{\begin{bmatrix} 32/3 \\ 56/3 \\ 7 \\ \hline 10233.33 \end{bmatrix}} + \Delta b_1 \underset{\text{new}}{\begin{bmatrix} 1/3000 \\ -1/600 \\ 0 \\ \hline 5/3 \end{bmatrix}}$$

$32/3 + \Delta b_1(3000) \geq 0$ $\Delta b_1 \geq -3200$

$56/3 + \Delta b_1(-1/600)$ $\Delta b_1 \leq 11200$

$7 + \Delta b_1(0)$ —

$10233.33 + \Delta b_1(5/3) \geq 0$ $\Delta b_1 \geq -6139.98$

$-3200 - \cancel{6139.98} \leq \Delta b_i \leq 11200$

$6000 - \cancel{3200} < b_1 \leq 6000 + 11200$

$\cancel{2800} \leq b_1 \leq 7120$

28 000

3 2013 Q1 Mang Science

biv. constraint 2 old + chng new

$$\begin{bmatrix} 10.67 \\ 18.67 \\ 7 \\ \hline 102333.33 \end{bmatrix} + \Delta b_2 \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \quad 18.67 + \Delta b_2 \geq 0 \quad b_2 \geq -18.67$$

$\cancel{7+\Delta b_2 \geq 0}$ $\cancel{b_2 \geq -7}$

$\cancel{100-7 \leq b_2}$

$\cancel{93 \leq b_2 \leq 100}$

$100 - 18.67 \leq B_2$

$81.23 \leq B_2 \leq \infty$

constraint 3

$$\begin{bmatrix} 10.67 \\ 18.67 \\ 7 \\ \hline 10233.33 \end{bmatrix} + \Delta b_3 \begin{bmatrix} -1.67 \\ 2.67 \\ 1 \\ \hline 3333.3 \end{bmatrix}$$

$10.67 - \Delta b_3 1.67 \geq 0 \quad \Delta b_3 \leq 6.38$

$18.67 + \Delta b_3 2.67 \geq 0 \quad \Delta b_3 \geq -6.99$

$7 + \Delta b_3 \geq 0 \quad \Delta b_3 \geq -7$

$102333.33 + 3333.3 \Delta b_3 \geq 0. \quad \Delta b_3 \geq -30.70$

$-7 \leq b_3 \leq 6.38$

$7-7 \leq b_3 \leq 76.4$

$0 \leq \Delta b_3 \leq 13.4$

Constraint 1.

$$\begin{bmatrix} 10.67 \\ 18.67 \\ 7 \\ \hline 102333.33 \end{bmatrix} + \Delta b_1 \begin{bmatrix} 1/3000 \\ -1/600 \\ 0 \\ \hline 1.67 \end{bmatrix}$$

$10.67 + \frac{1}{3000}\Delta b_1 \geq 0 \quad \Delta b_1 \geq -32010$

$18.67 + (-\frac{1}{600})\Delta b_1 \geq 0 \quad \Delta b_1 \leq 11202$

—

$102333.33 + \Delta b_1 1.67 \geq 0 \quad \Delta b_1 \leq -61277''$

$-32010 \leq \Delta b_1 \leq 11201$

$60000 - 32010 \leq \Delta b_1 \leq 60000 + 11201$

$27990 \leq \Delta b_1 \leq 71201$

$\boxed{3}$ 2013 Q1 Mang Science

biv. constraint 2 old + chng new

$$\begin{bmatrix} 10.67 \\ 18.67 \\ 7 \\ \hline 102333.33 \end{bmatrix} + \Delta b_2 \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \qquad \begin{array}{ll} 18.67 + \Delta b_2 \geq 0 & b_2 \geq -18.67 \\ \cancel{7 + \Delta b_2 \geq 0} & \cancel{b_2 \geq -7} \end{array}$$

$$\cancel{100-7 \leq b_2} \qquad 100 - 18.67 \leq B_2$$

$$\cancel{93 \leq b_2 \leq 100} \qquad 81.23 \leq B_2 \leq \infty$$

constraint 3

$$\begin{array}{ccc} \text{old} & + \text{ change} & \text{new} \end{array}$$

$$\begin{bmatrix} 10.67 \\ 18.67 \\ 7 \\ \hline 102333.33 \end{bmatrix} + \Delta b_3 \begin{bmatrix} -1.67 \\ 2.67 \\ 1 \\ \hline 3333.3 \end{bmatrix} \qquad \begin{array}{ll} 10.67 - \Delta b_3 1.67 \geq 0 & \Delta b_3 \leq 6.38 \\ 18.67 + \Delta b_3 2.67 \geq 0 & \Delta b_3 \geq -6.99 \\ 7 + \Delta b_3 \geq 0 & \Delta b_3 \geq -7 \\ 102333.33 + 3333 \Delta b_3 \geq 0 & \Delta b_3 \geq -30.70 \end{array}$$

$$-7 \leq b_3 \leq 6.38$$

$$7-7 \leq b_3 \leq 76.4$$

$$0 \leq \Delta b_3 \leq 13.4$$

Constraint 1.

$$\begin{bmatrix} 10.67 \\ 18.67 \\ 7 \\ \hline 102333.33 \end{bmatrix} + \Delta b_1 \begin{bmatrix} 1/3000 \\ -1/600 \\ 0 \\ \hline 1.67 \end{bmatrix} \qquad \begin{array}{ll} 10.67 + \frac{1}{3000} \Delta b_1 \geq 0 & \Delta b_1 \geq -32010 \\ 18.67 + (-\frac{1}{600}) \Delta b_1 \geq 0 & \Delta b_1 \leq 11202 \\ \text{---} & \\ 102333.33 + \Delta b_1 1.67 \geq 0 & \Delta b_1 \leq -61277 \end{array}$$

$$-32010 \leq \Delta b_1 \leq 11201$$

$$60000 - 32010 \leq \Delta b_1 \leq 60000 + 11201$$

$$27990 \leq \Delta b_1 \leq 71201$$

(4)

Range for coefficient of objective function

b.v.

basis	C_B	x_1	x_2	s_1	s_2	s_3	
		$5000c_1$	$7000c_2$	0	0	0	
x_1	$5000c_1$	1	0	$1/3000$	0	-1.67	10.67
s_2	0	0	0	$-1/600$	1	2.67	18.67
x_2	7000	0	$1c_2$	$0c_2$	0	1	7
Z_j		5000	7000	$5/3$	0	$+1350.$	10233333
$C_j - Z_j$		0	0	$-5/3$	0	$-\frac{1000}{3}$	
				$-\frac{1}{3000}c_1 + \frac{1}{600}$		$-\frac{4}{3}c_1 + 7000$	

$-\frac{1}{3000}c_1 + \frac{1}{600} \leq 0$ $\qquad -\frac{4}{3}c_1 + 7000 \leq 0$

$c_1 \geq 5$ $\qquad c_1 \geq -5250$

$c_1 \geq 5.$ $\qquad 5 \leq c_1 \leq \infty$

Coef of x_2 $\quad$ ~~$-\frac{5}{3} + \frac{1}{600}c_2 \leq 0 \quad +4/3(5000)$~~ $- c_2 \leq$

$-\frac{4}{3}(5000) - c_2 \leq 0$

$c_2 \geq -\frac{2000}{3}$

$\infty \geq c_2 \geq 666.66$

3 Q 1C 2013 MANG SCI.

P = Person min
T = teleplex

$80t + 40p \geq 3000$

$50t + 70p \leq 2500$

$\cancel{8}\ t \geq 1000$

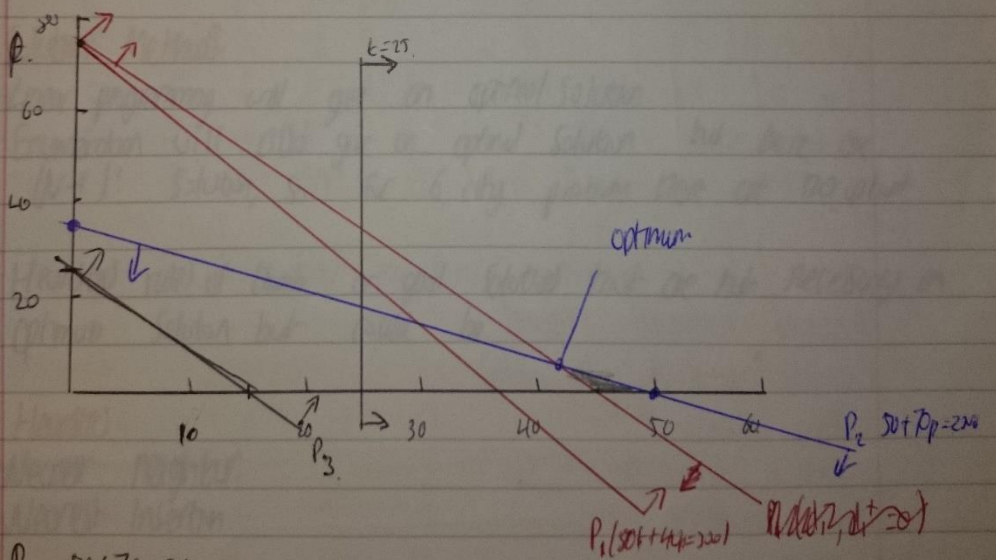
Min $P_1(d_1^-) + P_2(d_2^+) + P_3(d_3^-)$

ST: $80t + 40p - d_1^+ + d_1^- = 3000$

$50t + 70p - d_2^+ + d_2^- = 2500$

$80t - \cancel{40p} - d_3^+ + d_3^- = 1000$

P_1 $80t + 40p = 3000$ $t=0$ $p=75$ $p=0$ $t=45$.



P_2. $50t + 70p = 2500$

min (d_2^+) $t=0$ $p=35.7$ $p=0$ 50.

P_3 $t = 1000$ $80t\ \cancel{+40p} = 1000$ $p=0$ $t=12.5$

$t = 25$. $t=0$ $p=25$.

Optimum is where
of P_1 line and P_2 line

$80t + 40p = 3000 \times 7$ $\quad$ $560t + 280p = 21000$

$50t + 70p \quad 2500 \times 4$ $\quad$ $\overline{200}t + \overline{280}p = \overline{10000}$

$360t = 11000$

$t = 30.55.$

$\downarrow$

$p = 22.22.$

Satisfy P_1 and P_2 then and also satisfies P_3 as t is > 25 at value of 30.55.

All goals have been satisfied