

Out[2]:

Q1 - 1

The following problem has been obtained by solving the set of following LP formulation:

Maximize Objective: 50 x_dh + 45 x_fn + 10 x_kbh + 60 x_kh

Decision variables:

- x_fn: quantity of FN
- x_dh: quantity of DH
- x_kh: quantity of KH
- x_kbh: quantity of KBH

Subject To

- Demand_1: x_fn <= 250
- Demand_2: x_dh <= 120
- Demand_3: x_kh <= 90
- Demand_4: x_kbh <= 550
- Non_Zero_Constraint_1: x_fn >= 0
- Non_Zero_Constraint_2: x_dh >= 0
- Non_Zero_Constraint_3: x_kh >= 0
- Non_Zero_Constraint_4: x_kbh >= 0
- Supply_1: 0.2 x_dh + 0.3 x_fn + 0.3 x_kbh + 0.4 x_kh <= 500
- Supply_2: 0.5 x_dh + 0.4 x_fn + 0.8 x_kbh + 0.8 x_kh <= 450
- Supply_3: 0.3 x_dh + 0.4 x_fn + 0.1 x_kbh + 0.1 x_kh <= 75
- Supply_4: 0.3 x_dh + 0.2 x_fn + 0.5 x_kbh + 0.6 x_kh <= 300
- Supply_5: 0.5 x_dh + 0.5 x_fn + 0.8 x_kbh + 0.4 x_kh <= 200

- The optimal values for the Problem are as follows.

fn :: 75.0 ::
dh :: 120.0 ::
kh :: 90.0 ::
kbh :: 0.0 ::
Objective 14775.0

# %load HNMix.sen								
GLPK 4.65 - SENSITIVITY ANALYSIS REPORT								
Page 1								
Problem:								
Objective: Objective = 14775 (MAXimum)								
No.	Row name	St	Activity	Slack Marginal	Lower bound Upper bound	Activity range	Obj coef range	Obj value at Limiting break point variable
1	Demand_1	BS	75.00000	175.00000 .	-Inf 250.00000	50.37037 165.00000	-5.00000 21.66667	14400.00000 x_kbh 16400.00000 Demand_2
2	Demand_2	NU	120.00000	.	-Inf	.	-16.25000	12825.00000
	Non_Zero_Constraint_2			16.25000	120.00000	220.00000	+Inf	16400.00000
	Non_Zero_Constraint_1							
3	Demand_3	NU	90.00000	.	-Inf	.	-48.75000	10387.50000
	Non_Zero_Constraint_3			48.75000	90.00000	331.81818	+Inf	26563.63636 Supply_5
4	Demand_4	BS	.	550.00000 .	-Inf 550.00000	.	-Inf 1.25000	14775.00000 14775.00000 x_kbh
5	Non_Zero_Constraint_1	BS	75.00000	-75.00000 .	. +Inf	50.37037 165.00000	-5.00000 21.66667	14400.00000 x_kbh 16400.00000 Demand_2
6	Non_Zero_Constraint_2	BS	120.00000	-120.00000 .	. +Inf	. 120.00000	-16.25000 +Inf	12825.00000 Demand_2 +Inf
7	Non_Zero_Constraint_3	BS	90.00000	-90.00000 .	. +Inf	. 90.00000	-48.75000 +Inf	10387.50000 Demand_3 +Inf
8	Non_Zero_Constraint_4	BS	.	.	. +Inf	.	-Inf 1.25000	14775.00000 14775.00000 x_kbh
9	Supply_1	BS	82.50000	417.50000	-Inf	53.25000	-150.00000	2400.00000 Demand_3

			.	500.00000	104.66667	5.55556	15233.33333	x_kbh	
10	Supply_2	BS	162.00000	288.00000	-Inf	99.00000	-69.64286	3492.85714	Demand_3
			.	450.00000	230.96296	1.78571	15064.28571	x_kbh	
GLPK 4.65 - SENSITIVITY ANALYSIS REPORT									Page 2
Problem:									
Objective: Objective = 14775 (MAXimum)									
No.	Row name	St	Activity	Slack Marginal	Lower bound Upper bound	Activity range	Obj coef range	Obj value at break point	Limiting variable
11	Supply_3	NU	75.00000	.	-Inf	45.00000	-112.50000	11400.00000	
Non_Zero_Constraint_1				112.50000	75.00000	128.20000	+Inf	20760.00000	Supply_5
12	Supply_4	BS	105.00000	195.00000	-Inf	55.50000	-88.63636	5468.18182	Demand_3
			.	300.00000	149.33333	2.77778	15066.66667	x_kbh	
13	Supply_5	BS	133.50000	66.50000	-Inf	96.00000	-90.00000	2760.00000	Supply_3
			.	200.00000	336.00000	1.85185	15022.22222	x_kbh	
GLPK 4.65 - SENSITIVITY ANALYSIS REPORT									Page 3
Problem:									
Objective: Objective = 14775 (MAXimum)									
No.	Column name	St	Activity	Obj coef Marginal	Lower bound Upper bound	Activity range	Obj coef range	Obj value at break point	Limiting variable
1	x_dh	BS	120.00000	50.00000	.	.	33.75000	12825.00000	Demand_2
			.	+Inf	120.00000	+Inf	+Inf	+Inf	
2	x_fn	BS	75.00000	45.00000	.	50.37037	40.00000	14400.00000	x_kbh
			.	+Inf	165.00000	66.66667	16400.00000	Demand_2	
3	x_kbh	NL	.	10.00000	.	.	-Inf	14775.00000	
Non_Zero_Constraint_4				-1.25000	+Inf	98.51852	11.25000	14651.85185	Supply_5
4	x_kh	BS	90.00000	60.00000	.	.	11.25000	10387.50000	Demand_3
			.	+Inf	90.00000	+Inf	+Inf	+Inf	
End of report									

Q1 - 2

- From the **SENSITIVITY ANALYSIS REPORT** report above we can clearly see that amount of KBH to be produced to maximize profit under current profit rates is Zero (0)

The **Reduced Cost / Marginal Cost for Objective Coefficient** for KBH is -1.25 implying the profit will reduce by 1.25 units if AH are to produce one unit of KBH. It is a Non-Basic variable with coefficient equal to Zero

Q1 - 3

- From the **SENSITIVITY ANALYSIS REPORT** report above we can clearly see that **Supply_1 Constraint (Availability of Maida = 500 Kg)** is not a binding constraint. There is already 417 Kg of extra (SLACK) Maida available with the supplier. Hence he should not be procuring the extra Maida from his friend.

We are assuming his friend will provide Maida at Market price and not free of cost

Q1 - 4

Assuming this question is for KH

- AH is producing 90Kg of KH @ Profit of 60/unit. Hence he can accept the order of 20Kg from the Halva Shop

Assuming this question is for additional 20 Kg of KH (above 90Kg)

- As per the sensitivity report we see that upper bound for KH production is 90, i.e. if they are to produce additional 20 Kg, then we need to change the Constraints and re-solve the LP. Current Optimal Solution will not remain same

Assuming this question is for KBH

- From the Sensitivity Report we can see that, Reduced Cost / Marginal Cost for Objective Coefficient for KBH is -1.25. In order for him to accept any orders for KBH the minimum value of Profit from KBH should be 11.25/unit. Hence he should increase the Profit on KBH by 1.25/unit, if he is to accept this order

Q1 - 5

- From the Sensitivity Report we can see that the Profit on DH can be reduced by max of 16.25/unit for the current solution to remain optimal. Hence providing a discount of 10 INR/unit of DH **does not change** the optimal production plan

Q1 - 6

- ASSUMPTIONS for the following solution
 - We are increasing the profit amounts by 20% implying the Profit of KBH will increase from 10 to 12

Increased Profit for DH = 54.0
Increased Profit for FN = 60.0
Increased Profit for KH = 72.0
Increased Profit for KBH = 12.0

- Since the simultaneous increase in the coefficients of the Non-Basic Variables (non Zero) are within the permissible ranges (as seen from the Sensitivity Report) and the sum of percentage increase is less than 100%, hence as per the 100% Rule there is **no change in the optimal Solution**
- We are still assuming that KBH is not being produced

Current Profit due to change in Profit Values = 17730

Q1 - 7

- As per the sensitivity Report the Constraint Supply_3 is binding and has the highest Marginal Cost (112.5). This constraint corresponds to the Supply Constraints for Fruits and Nuts.
- What this implies:
 - Increasing availability of Fruits and Nuts from 75 Kg by one unit increases profit by 112.5 INR
 - The above is valid only in the amount of Fruits and Nuts are increases from current available level of 75 till 128. Beyond this range if availability is increased then the current shadow price will not hold true

Q1 - 8

- From the Sensitivity Report we can see that the Profit on DH can be reduced to 33.75/unit for the current solution to remain optimal.
- From the Sensitivity Report we can see that the Profit on KH can be reduced to 11.25/unit for the current solution to remain optimal.
- As per the problem statement the reduction in DH is 8/Unit and reduction in KH is 24/Unit
- We will compute the % change and use the 100% Rules to check if the changes are below 100% or not. Since both are Non-Basic Variables hence if the allowed change is less than 100% hence from using the 100% Rule for change in Objective coefficients we know the Optimal Solution will remain unchanged

% change in DH in the allowed direction = 0.49230769230769234
% change in KH in the allowed direction = 0.49230769230769234

Sum of the % changes in the allowed directions is < 100%, hence there is no change in the Optimal Solution

Q2 - a

Decision Variables: 15 Binary Variables for each compartment and each Fuel Type. This will indicate which type of Fuel should be carried in which container.

e.g. $ys_1 = 1$, will indicate Fuel S is being carried in Container 1 We use Python (PULP and GLPK Solver to solve the solution). Hence the DV will be as follows:

compartments = ['1', '2', '3', '4', '5']

- $ys = \text{LpVariable.dicts("Ys_", compartments, 0, None, cat = LpBinary)}$ # 5 Variables for Fuel S
- $yr = \text{LpVariable.dicts("Yr_", compartments, 0, None, cat = LpBinary)}$ # 5 Variables for Fuel R
- $yu = \text{LpVariable.dicts("Yu_", compartments, 0, None, cat = LpBinary)}$ # 5 Variables for Fuel U

15 Variables for quantity of fuel carried in each compartment. If corresponding binary indicator is 1, this will have non zero value.

e.g. $ys_1 = 1$, $s_1 = 2800$

In Python we will define these variables as follows:

- $S = \text{pulp.LpVariable.dict('S_ %s', compartments, lowBound = 0)}$
- $R = \text{pulp.LpVariable.dict('R_ %s', compartments, lowBound = 0)}$
- $U = \text{pulp.LpVariable.dict('U_ %s', compartments, lowBound = 0)}$

2 - b

Constraints

- Demand_Constraint_for_R_Fuel: $R_1 + R_2 + R_3 + R_4 + R_5 \leq 4000$
- Demand_Constraint_for_S_Fuel: $S_1 + S_2 + S_3 + S_4 + S_5 \leq 2900$
- Demand_Constraint_for_U_Fuel: $U_1 + U_2 + U_3 + U_4 + U_5 \leq 4900$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_1: $Yr_1 + Ys_1 + Yu_1 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_2: $Yr_2 + Ys_2 + Yu_2 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_3: $Yr_3 + Ys_3 + Yu_3 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_4: $Yr_4 + Ys_4 + Yu_4 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_5: $Yr_5 + Ys_5 + Yu_5 \leq 1$
- Maximum_Capacity_of_R_Fuel_if_Container_1_has_R: $R_1 - 2700 Yr_1 \leq 0$
- Maximum_Capacity_of_R_Fuel_if_Container_2_has_R: $R_2 - 2800 Yr_2 \leq 0$
- Maximum_Capacity_of_R_Fuel_if_Container_3_has_R: $R_3 - 1100 Yr_3 \leq 0$
- Maximum_Capacity_of_R_Fuel_if_Container_4_has_R: $R_4 - 1800 Yr_4 \leq 0$
- Maximum_Capacity_of_R_Fuel_if_Container_5_has_R: $R_5 - 3400 Yr_5 \leq 0$
- Maximum_Capacity_of_S_Fuel_if_Container_1_has_S: $S_1 - 2700 Ys_1 \leq 0$
- Maximum_Capacity_of_S_Fuel_if_Container_2_has_S: $S_2 - 2800 Ys_2 \leq 0$
- Maximum_Capacity_of_S_Fuel_if_Container_3_has_S: $S_3 - 1100 Ys_3 \leq 0$
- Maximum_Capacity_of_S_Fuel_if_Container_4_has_S: $S_4 - 1800 Ys_4 \leq 0$
- Maximum_Capacity_of_S_Fuel_if_Container_5_has_S: $S_5 - 3400 Ys_5 \leq 0$
- Maximum_Capacity_of_U_Fuel_if_Container_1_has_U: $U_1 - 2700 Yu_1 \leq 0$
- Maximum_Capacity_of_U_Fuel_if_Container_2_has_U: $U_2 - 2800 Yu_2 \leq 0$
- Maximum_Capacity_of_U_Fuel_if_Container_3_has_U: $U_3 - 1100 Yu_3 \leq 0$
- Maximum_Capacity_of_U_Fuel_if_Container_4_has_U: $U_4 - 1800 Yu_4 \leq 0$
- Maximum_Capacity_of_U_Fuel_if_Container_5_has_U: $U_5 - 3400 Yu_5 \leq 0$
- Maximum_Shortfall_(500)Constraintfor_R_Fuel: $R_1 + R_2 + R_3 + R_4 + R_5 \geq 3500$
- Maximum_Shortfall_(500)Constraintfor_S_Fuel: $S_1 + S_2 + S_3 + S_4 + S_5 \geq 2400$
- Maximum_Shortfall_(500)Constraintfor_U_Fuel: $U_1 + U_2 + U_3 + U_4 + U_5 \geq 4400$
- Binaries $Yr_1 Yr_2 Yr_3 Yr_4 Yr_5 Ys_1 Ys_2 Ys_3 Ys_4 Ys_5 Yu_1 Yu_2 Yu_3 Yu_4 Yu_5$
- Non Zero: $S_1, S_2, S_3, S_4, S_5, R_1, R_2, R_3, R_4, R_5, U_1, U_2, U_3, U_4, U_5 \geq 0$

2 - c

Objective

Minimize Objective: $-8 R_1 - 8 R_2 - 8 R_3 - 8 R_4 - 8 R_5 - 10 S_1 - 10 S_2 - 10 S_3 - 10 S_4 - 10 S_5 - 6 U_1 - 6 U_2 - 6 U_3 - 6 U_4 - 6 U_5$

- 8 = Penalty on not fulfilling R typer Fuel / Litre
- 10 = Penalty on not fulfilling S typer Fuel / Litre
- 6 = Penalty on not fulfilling U typer Fuel / Litre
- Decision Variables : Fuel of Type S/R/U in Container 1/2/3/4/5: $S_1, S_2, S_3, S_4, S_5, R_1, R_2, R_3, R_4, R_5, U_1, U_2, U_3, U_4, U_5 \geq 0$

2 - d

In order to incorporate the new Penalty Structure, I will modify the objective and the constarints in the following manner:

New Decision Variables:

- $D1_0$ = Non Zero value means S1 deficit is more than 250 by $D1_0$ amount. $D1_0$ will zero if Total deficit is less 250. e.g. If $D1_0 = 10$, deficit = $250+10=260$
- $D1_1$ = Non Zero value means S1 deficit is less than 250 by $D1_1$ amount. $D1_1$ will zero if Total deficit is more 250. e.g. If $D1_1 = 10$, deficit = $250-10=240$
- $D2_0$ = Same logic for quantity > 250 for R
- $D2_1$ = Same logic for quantity < 250 for R
- $D3_0$ = Same logic for quantity > 250 for U
- $D3_1$ = Same logic for quantity < 250 for U

New Objective

- Minimize Objective: $10 * (250 - d1[1]) + 11 * d1[0] + 8 * (250 - d2[1]) + 8.8 * d2[0] + 6 * (250 - d3[1]) + 6.6 * d3[0]$

Logic:

- If quantity > 250: # assume 260 for S1
- $D1_1 = 10, D1_0 = 0, \text{Penalty} = 10 * (250 - D1_0) + 11 * D1_1$

Logic:

- If quantity < 250: # assume 240 for S1
- $D1_1 = 0, D1_0 = 10, \text{Penalty} = 10 * (250 - D1_0) + 11 * D1_1$

Subject To

- New Constraints
 - $C1: S_1 + S_2 + S_3 + S_4 + S_5 + 250 + d1_0 - d1_1 \leq 2900$
 - $C2: R_1 + R_2 + R_3 + R_4 + R_5 + 250 + d2_0 - d2_1 \leq 4000$
 - $C3: U_1 + U_2 + U_3 + U_4 + U_5 + 250 + d3_0 - d3_1 \leq 4900$

Earlier Constraints

- Demand_Constraint_for_R_Fuel: $R_1 + R_2 + R_3 + R_4 + R_5 == 4000$
- Demand_Constraint_for_S_Fuel: $S_1 + S_2 + S_3 + S_4 + S_5 == 2900$
- Demand_Constraint_for_U_Fuel: $U_1 + U_2 + U_3 + U_4 + U_5 == 4900$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_1: $Yr_1 + Ys_1 + Yu_1 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_2: $Yr_2 + Ys_2 + Yu_2 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_3: $Yr_3 + Ys_3 + Yu_3 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_4: $Yr_4 + Ys_4 + Yu_4 \leq 1$
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_5: $Yr_5 + Ys_5 + Yu_5 \leq 1$

- Maximum_Capacity_of_R_Fuel_if_Container_1_has_R: R_1 - 2700 Yr__1 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_2_has_R: R_2 - 2800 Yr__2 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_3_has_R: R_3 - 1100 Yr__3 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_4_has_R: R_4 - 1800 Yr__4 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_5_has_R: R_5 - 3400 Yr__5 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_1_has_S: S_1 - 2700 Ys__1 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_2_has_S: S_2 - 2800 Ys__2 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_3_has_S: S_3 - 1100 Ys__3 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_4_has_S: S_4 - 1800 Ys__4 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_5_has_S: S_5 - 3400 Ys__5 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_1_has_U: U_1 - 2700 Yu__1 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_2_has_U: U_2 - 2800 Yu__2 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_3_has_U: U_3 - 1100 Yu__3 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_4_has_U: U_4 - 1800 Yu__4 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_5_has_U: U_5 - 3400 Yu__5 <= 0
- Maximum_Shortfall_(500)Constraintfor_R_Fuel: R_1 + R_2 + R_3 + R_4 + R_5 >= 3500
- Maximum_Shortfall_(500)Constraintfor_S_Fuel: S_1 + S_2 + S_3 + S_4 + S_5 >= 2400
- Maximum_Shortfall_(500)Constraintfor_U_Fuel: U_1 + U_2 + U_3 + U_4 + U_5 >= 4400
- Binaries: Yr__1 Yr__2 Yr__3 Yr__4 Yr__5 Ys__1 Ys__2 Ys__3 Ys__4 Ys__5 Yu__1 Yu__2 Yu__3 Yu__4 Yu__5 End

Q2 - e

New Objective:

Minimize Objective: - 10* (250 - d1[1]) + 11 * (250 + d1[0]) - 10 * 250 * (1 - y1[0]) - 11 * 250 * (y1[0]) +\ 8* (250 - d2[1]) + 8.8 * (250 + d2[0]) - 8 * 250 * (1 - y1[1]) - 8.8 * 250 * (y1[1]) +\ 6* (250 - d3[1]) + 6.6 * (250 + d3[0]) - 6 * 250 * (1 - y1[2]) - 6.6 * 250 * (y1[2])

Logic:

- If S deficit = 240,
 - d1__1 = 10, Y[1] = 1, hence Loss = 10 *240 + 11 * 250 - 0 - 11 * 250 ...
- If S deficit = 260,
 - d1__0 = 10, Y[1] = 0, hence Loss = 10 *250 + 11 * 260 - 10 * 250 - 8 ...

The constraints to factor the above in added below:

Subject To

New Constraints

- C10: - 250 Y1__2 + d31 <= 0
- C11: d30 + d3__1 <= 250
- C12: 250 Y1__2 + d30 <= 250
- C4: - 250 Y1__0 + d11 <= 0
- C5: d10 + d1__1 <= 250
- C6: 250 Y1__0 + d10 <= 250
- C7: - 250 Y1__1 + d21 <= 0
- C8: d20 + d2__1 <= 250
- C9: 250 Y1__1 + d20 <= 250

Older COnstraints

- C1: S1 + S__2 + S__3 + S__4 + S__5 + 250 + d1__0 - d1__1 <= 2900
- C2: R1 + R__2 + R__3 + R__4 + R__5 + 250 + d2__0 - d2__1 <= 4000
- C3: U1 + U__2 + U__3 + U__4 + U__5 + 250 + d3__0 - d3__1 <= 4900
- Demand_Constraint_for_R_Fuel: R_1 + R_2 + R_3 + R_4 + R_5 <= 4000
- Demand_Constraint_for_S_Fuel: S_1 + S_2 + S_3 + S_4 + S_5 <= 2900
- Demand_Constraint_for_U_Fuel: U_1 + U_2 + U_3 + U_4 + U_5 <= 4900
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_1: Yr__1 + Ys__1 + Yu__1 <= 1
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_2: Yr__2 + Ys__2 + Yu__2 <= 1
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_3: Yr__3 + Ys__3 + Yu__3 <= 1
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_4: Yr__4 + Ys__4 + Yu__4 <= 1
- Integer_Constraint_for_One_Type_of_Fuel_in_Container_5: Yr__5 + Ys__5 + Yu__5 <= 1
- Maximum_Capacity_of_R_Fuel_if_Container_1_has_R: R_1 - 2700 Yr__1 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_2_has_R: R_2 - 2800 Yr__2 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_3_has_R: R_3 - 1100 Yr__3 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_4_has_R: R_4 - 1800 Yr__4 <= 0
- Maximum_Capacity_of_R_Fuel_if_Container_5_has_R: R_5 - 3400 Yr__5 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_1_has_S: S_1 - 2700 Ys__1 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_2_has_S: S_2 - 2800 Ys__2 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_3_has_S: S_3 - 1100 Ys__3 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_4_has_S: S_4 - 1800 Ys__4 <= 0
- Maximum_Capacity_of_S_Fuel_if_Container_5_has_S: S_5 - 3400 Ys__5 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_1_has_U: U_1 - 2700 Yu__1 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_2_has_U: U_2 - 2800 Yu__2 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_3_has_U: U_3 - 1100 Yu__3 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_4_has_U: U_4 - 1800 Yu__4 <= 0
- Maximum_Capacity_of_U_Fuel_if_Container_5_has_U: U_5 - 3400 Yu__5 <= 0
- Maximum_Shortfall_(500)Constraintfor_R_Fuel: R_1 + R_2 + R_3 + R_4 + R_5 >= 3500
- Maximum_Shortfall_(500)Constraintfor_S_Fuel: S_1 + S_2 + S_3 + S_4 + S_5 >= 2400
- Maximum_Shortfall_(500)Constraintfor_U_Fuel: U_1 + U_2 + U_3 + U_4 + U_5 >= 4400
- Binaries: Yr__1 Yr__2 Yr__3 Yr__4 Yr__5 Ys__1 Ys__2 Ys__3 Ys__4 Ys__5 Yu__1 Yu__2 Yu__3 Yu__4 Yu__5 y1__0 y1__1 y2__0 y2__1 y3__0 y3__1 End

Q3 - 1

- Optimal Production Plan
 - Alloy 1 - 0
 - Alloy 2 - 1500
 - Alloy 3 - 500
 - Alloy 4 - 1000

These can be derived from the Constraints Section of the Sensitivity Report

Objective Function Value = 495000

Q3 - 2 - Check / Object will definitely increase

As per the sensitivity Report Maximum Allowable increase in Metal 3 is 100 GM. Hence if 200 GM of metal is imported then this exceeds allowable increase for the Optimal Solution. This will change the current Optimal Solution, unfortunately the sensitivity report does not tell how it will change.

From Solving the dual solution we see that the Shadow Price for Y3 is 555 (Please see ans to 3-4, details are provided). Hence even if we procure 100 Gm of Metal 3, cost incurred is 20000, while for the 100 GM we know a additional revenue of 55500 can be made.

If we have to procure all 200GM they can procure even if they decide not to use the additional 100 GM as it will change the optimal solution.

Hence we can procure the amount.

Objective increases by 35000 to 530000

Q3 - 3

- From the sensitivity report we can see that the Demand for Alloy 3 can be increased by 750 units without changing the Optimal Solution. So if the demand increases by 200, it will not change the optimal solution.
- If we solve the Dual Formulation, the Dual Price for Y6 (Corresponding Variable for the Demand Constraint for Alloy 3) is 59 (See 3-4 for Details below). Hence they will add $5 * 200 = 11,800$. Overall Objective = 506800
- However, we know the profit per unit of Alloy 3 is 281. Ideally as per my understanding the Dual Price should have been same as the Profit (Objective Value), may be the numbers have been changed from the actual formulation. I will consider the increase in objective to be equal to the increase due to profit from selling the additional 200 units of Alloy 3. Hence the Objective will increase by $281 * 200 = 56200$,

Final Objective = 551200

Q 3 - 4

- The corresponding Dual formulations are:

$$0.2y_1 + 0.4y_2 + 0.4y_3 + y_4 + 0 + 0 + 0 \geq 186$$

$$0.2y_1 + 0.6y_2 + 0.2y_3 + 0 + y_5 + 0 + 0 \geq 111$$

$$0.3y_1 + 0.3y_2 + 0.4y_3 + 0 + 0 + y_6 + 0 \geq 281$$

$$0.5y_1 + 0.5y_2 + 0 + 0 + 0 + 0 + y_7 \geq 188$$

- Constraints 3, 6, 7 are binding in Primal, hence the corresponding Dual Variables are non-Zero. Hence y_3 , y_6 and y_7 are non zero.

Solving above equations we get: $y_3 = 555$ $y_6 = 59$ $y_7 = 188$

Substituting the value of y_3 in equation 1 we get the Surplus = 36. This is the Reduced Cost for x_1 . hence the profit needs to be increased by 36 (Profit = 222) for Sedon to accept the order

Q 3 - 5

- As we can clearly see that the increase in the profit values for all are well outside the range of the permissible values as per the sensitivity report. The Solution will no longer remain optimal with these revised objective values. We need to resolve to find new Optimal Solution with these Profits

Q 3 - 6

- From sensitivity report we see that maximum Allowed decrease of Alloy 2 is 500 from 2000.
- The government restriction which reduces sales of alloy 2 value to 1000, hence the current optimal Solution will not hold true

Q 3 - 7

- Maximum Permissible change (increase) for Alloy 3 = 500. Actual change = 500. Hence percentage increase is 100%
- Maximum Permissible change (decrease) for Alloy 2 = 500. Actual change = 500. Hence percentage increase is 100%

Since the simultaneous change is more than 100%, hence this violates the 100% Rule for change. The solution may no longer remain optimal. We need to resolve the problem before making any conclusions.

Moreover from ans to 3 - 6 we can see that reducing limit of production for Alloy 2 to 1000 will alter the existing optimal solution.

Q 3 - 8

- Alloy 5 is introduced

The new sets of Primal equations are:

- Objective:

$$186x_1 + 111x_2 + 281x_3 + 188x_4 + 220x_5$$

- Constraints:

$$0.2x_1 + 0.2x_2 + 0.3x_3 + 0.5x_4 + 0.5x_5 \leq 2000$$

$$0.4x_1 + 0.6x_2 + 0.3x_3 + 0.5x_4 + 0.4x_5 \leq 3000$$

$$0.2x_1 + 0.2x_2 + 0.4x_3 + 0x_4 + 0.1x_5 \leq 500$$

$$x_1 \leq 1000$$

$$x_2 \leq 2000$$

$$x_3 \leq 500$$

$$x_4 \leq 1000$$

$$x_5 \leq 1500$$

Let us assume that $x_5 = 0$, then the formulation remains optimal if the following dual constraint is feasible and non-binding:

$$0.5y_1 + 0.4y_2 + 0.1y_3 + 0 + 0 + 0 + 0 + 0 \geq 220$$

We know : $y_1, y_2 = 0$

$$y_3 = 555,$$

hence $55.5 \geq 220$, which is infeasible. Hence $x_5 \neq 0$, and with new alloy the old solution is no longer optimal

Q4

Decision Variables

- hiredEmpl_i, i = 1,2,3,4. Employees to be hired for Months September, October, January, February (Integers)
- transfrEmpl_i, i = 1..6, Employees to be transferred from other location all 6 months (Integers)
- Binary Variables: isReqHire_1 - (Hiring in March), isReqHire_2 - (Hiring in December)
- analyst_1 = 79, as of First Day of September

Minimize Objective: $36000 \text{ analyst_1} + 34800 \text{ hiredEmpl_1} + 29100 \text{ hiredEmpl_2} + 12000 \text{ hiredEmpl_3} + 6000 \text{ hiredEmpl_4} + 20000 \text{ isReqHire_1} + 20000 \text{ isReqHire_2} + 8000 \text{ transfrEmpl_1} + 8000 \text{ transfrEmpl_2} + 8000 \text{ transfrEmpl_3} + 8000 \text{ transfrEmpl_4} + 8000 \text{ transfrEmpl_5} + 8000 \text{ transfrEmpl_6}$

Subject To

- Demand_Dec: $\text{analyst_1} + 0.95 \text{ hiredEmpl_1} + 0.95 \text{ hiredEmpl_2} + 0.8 \text{ transfrEmpl_4} \geq 65$
- Demand_Feb: $\text{analyst_1} + 0.95 \text{ hiredEmpl_1} + 0.95 \text{ hiredEmpl_2} + \text{hiredEmpl_3} + \text{hiredEmpl_4} + 0.8 \text{ transfrEmpl_6} \geq 90$
- Demand_Jan: $\text{analyst_1} + 0.95 \text{ hiredEmpl_1} + 0.95 \text{ hiredEmpl_2} + \text{hiredEmpl_3} + 0.8 \text{ transfrEmpl_5} \geq 80$
- Demand_Nov: $\text{analyst_1} + 0.95 \text{ hiredEmpl_1} + \text{hiredEmpl_2} + 0.8 \text{ transfrEmpl_3} \geq 90$
- Demand_Oct: $\text{analyst_1} + \text{hiredEmpl_1} + \text{hiredEmpl_2} + 0.8 \text{ transfrEmpl_2} \geq 105$
- Demand_Sept: $\text{analyst_1} + \text{hiredEmpl_1} + 0.8 \text{ transfrEmpl_1} \geq 110$
- Initial_Number_of_confirmed_Analyst_as_of_Sept01: $\text{analyst_1} = 79$
- Transferred_Employee_20%Constraint: $1.2 \text{ analyst1} + 1.16 \text{ hiredEmpl_1} + 0.97 \text{ hiredEmpl_2} + 0.4 \text{ hiredEmpl_3} + 0.2 \text{ hiredEmpl_4} - \text{transfrEmpl_1} - \text{transfrEmpl_2} - \text{transfrEmpl_3} - \text{transfrEmpl_4} - \text{transfrEmpl_5} - \text{transfrEmpl_6} \geq 0$
- Hired Employees per month C1: $\text{hiredEmpl1} - 50 \text{ isReqHire_1} \leq 0$
- C2: $\text{hiredEmpl2} - 50 \text{ isReqHire_1} \leq 0$
- C3: $\text{hiredEmpl3} - 50 \text{ isReqHire_2} \leq 0$
- C4: $\text{hiredEmpl4} - 50 \text{ isReqHire_2} \leq 0$
- $0 \leq \text{hiredEmpl_1}$
- $0 \leq \text{hiredEmpl_2}$
- $0 \leq \text{hiredEmpl_3}$
- $0 \leq \text{hiredEmpl_4}$
- $0 \leq \text{transfrEmpl_1}$
- $0 \leq \text{transfrEmpl_2}$
- $0 \leq \text{transfrEmpl_3}$
- $0 \leq \text{transfrEmpl_4}$
- $0 \leq \text{transfrEmpl_5}$
- $0 \leq \text{transfrEmpl_6}$

End

```
Transferred Employee by Month 1 :: 25 ::
Transferred Employee by Month 2 :: 19 ::
Transferred Employee by Month 3 :: 1 ::
Transferred Employee by Month 4 :: 0 ::
Transferred Employee by Month 5 :: 0 ::
Transferred Employee by Month 6 :: 1 ::
Is Hiring required Period 1 :: 1 ::
Is Hiring required Period 2 :: 0 ::
Number of Hired Employees by Month1 :: 11 ::
Number of Hired Employees by Month2 :: 0 ::
Number of Hired Employees by Month3 :: 0 ::
Number of Hired Employees by Month4 :: 0 ::
Number of Analyst on Month 1 (September) 1 :: 79.0 ::
Objective 3614800.0
```

Q5

- Problem is not solving if we have to match monthly demand. For Month 5 Demand == 2000, this cannot be achieved (Max that can be achieved is 1600 for month 5)
- LP will solve if monthly constraints does not have to be met. Hence we will design a solution to meet overall demand of 7000 Stones

Decision variables (DV)

- Q1_Stone_i, i = 1..6
- Q2_Stone_i, i = 1..6
- carryFwd_i, i = 1..6 Carry for each period (Extra Stones)
- unMetDemand_i, i = 1..6 Unmet Demand for each period (Less stones Stones to be met in subsequent years)

Minimize Objective: 1000 carryFwd_0 + 1000 carryFwd_1 + 1000 carryFwd_2 + 1000 carryFwd_3 + 1000 carryFwd_4 + 1000 carryFwd_5 + 1000 carryFwd_6 + 215000 q1Stones_1 + 215000 q1Stones_2 + 215000 q1Stones_3 + 207500 q1Stones_4 + 207500 q1Stones_5 + 207500 q1Stones_6 + 240000 q2Stones_1 + 240000 q2Stones_2 + 240000 q2Stones_3 + 232500 q2Stones_4 + 232500 q2Stones_5 + 232500 q2Stones_6

Subject To

- All DV >0
- Stopped_Production_1: q2Stones_4 = 0
- Stopped_Production_2: q2Stones_5 = 0
- Overall Demand_Constraints_6: q1Stones_1 + q1Stones_2 + q1Stones_3 + q1Stones_4 + q1Stones_5 + q1Stones_6 + q2Stones_1 + q2Stones_2 + q2Stones_3 + q2Stones_4 + q2Stones_5 + q2Stones_6 >= 7000
- Production_Constraints_Q1_1: q1Stones_1 <= 800
- Production_Constraints_Q1_2: q1Stones_2 <= 800
- Production_Constraints_Q1_3: q1Stones_3 <= 800
- Production_Constraints_Q1_4: q1Stones_4 <= 800
- Production_Constraints_Q1_5: q1Stones_5 <= 800
- Production_Constraints_Q1_6: q1Stones_6 <= 800
- Production_Constraints_Q2_1: q2Stones_1 <= 1400
- Production_Constraints_Q2_2: q2Stones_2 <= 1400
- Production_Constraints_Q2_3: q2Stones_3 <= 1400
- Production_Constraints_Q2_4: q2Stones_4 <= 1400
- Production_Constraints_Q2_5: q2Stones_5 <= 1400
- Production_Constraints_Q2_6: q2Stones_6 <= 1400
- Stone_Storage_Limit_1: carryFwd_1 <= 1200
- Stone_Storage_Limit_2: carryFwd_2 <= 1200
- Stone_Storage_Limit_3: carryFwd_3 <= 1200
- Stone_Storage_Limit_4: carryFwd_4 <= 1200
- Stone_Storage_Limit_5: carryFwd_5 <= 1200
- Stone_Storage_Limit_6: carryFwd_6 <= 1200
- Demand_C1: - carryFwd_1 + q1Stones_1 + q2Stones_1 + unMetDemand_1 <= 700
- Demand_C2: carryFwd_1 - carryFwd_2 + q1Stones_2 + q2Stones_2 - unMetDemand_1 + unMetDemand_2 <= 700
- Demand_C3: carryFwd_2 - carryFwd_3 + q1Stones_3 + q2Stones_3 - unMetDemand_2 + unMetDemand_3 <= 1000
- Demand_C4: carryFwd_3 - carryFwd_4 + q1Stones_4 + q2Stones_4 - unMetDemand_3 + unMetDemand_4 <= 1200
- Demand_C5: carryFwd_4 - carryFwd_5 + q1Stones_5 + q2Stones_5 - unMetDemand_4 + unMetDemand_5 <= 2000
- Demand_C6: carryFwd_5 - carryFwd_6 + q1Stones_6 + q2Stones_6 - unMetDemand_5 + unMetDemand_6 <= 1400

End

1

```
Carry Forward :: Period :: 0 :: 0.0 ::
Carry Forward :: Period :: 1 :: 100.0 ::
Carry Forward :: Period :: 2 :: 200.0 ::
Carry Forward :: Period :: 3 :: 800.0 ::
Carry Forward :: Period :: 4 :: 400.0 ::
Carry Forward :: Period :: 5 :: 0.0 ::
Carry Forward :: Period :: 6 :: 0.0 ::
Quarry1 :: Period :: 1 :: 800.0 ::
Quarry1 :: Period :: 2 :: 800.0 ::
Quarry1 :: Period :: 3 :: 800.0 ::
Quarry1 :: Period :: 4 :: 800.0 ::
Quarry1 :: Period :: 5 :: 800.0 ::
Quarry1 :: Period :: 6 :: 800.0 ::
Quarry2 :: Period :: 1 :: 0.0 ::
Quarry2 :: Period :: 2 :: 0.0 ::
Quarry2 :: Period :: 3 :: 800.0 ::
Quarry2 :: Period :: 4 :: 0.0 ::
Quarry2 :: Period :: 5 :: 0.0 ::
Quarry2 :: Period :: 6 :: 1400.0 ::
Unmet Demand :: Period :: 1 :: 0.0 ::
Unmet Demand :: Period :: 2 :: 0.0 ::
Unmet Demand :: Period :: 3 :: 0.0 ::
Unmet Demand :: Period :: 4 :: 0.0 ::
Unmet Demand :: Period :: 5 :: 800.0 ::
Unmet Demand :: Period :: 6 :: 0.0 ::
Objective 1533000000.0
```

Q - 6

Decision Variables:

- xi, i=1..5. Mins for each type of advertisement
- d1_0: if this takes positive value, then GRP Overall (Goal 1) >=100
- d1_1: if this takes positive value, then GRP Overall (Goal 1)<=100
- d2_0: if this takes positive value, then GRP Sport (Goal 2)>=20
- d2_1: if this takes positive value, then GRP Sport (Goal 2)<=20
- d3_0: if this takes positive value, then GRP Eng Chnl (Goal 2)>=5
- d3_1: if this takes positive value, then GRP Eng Chnl (Goal 2)<=5

Minimize Objective: d1_1 + d2_1 + d3_0

Subject To

- Goal1_C1: - d1_0 + d1_1 + 4.2 x1 + 3.5 x2 + 2.8 x3 + 2.5 x4 + 0.2 x5 >= 100
- Goal2_C2: - d2_0 + d2_1 + 4.2 x1 + 3.5 x2 >= 20
- Goal3_C3: d3_0 - d3_1 - 0.2 x5 >= -5
- Budget_C4: 120000 x1 + 85000 x2 + 70000 x3 + 60000 x4 + 25000 x5 <= 2000000
- All Variables >= 0

End

Cricket :: 0 ::
Oth Sport :: 8 ::
Hindi Serial :: 0 ::
Hindi Movie :: 22 ::
English News :: 0 ::
D1 0 :: 0.0
D1 1 :: 17.0
D2 0 :: 0.0
D2 1 :: 0.0
D3 0 :: 0.0
D3 1 :: 0.0
Objective 17.0::