Case Summary:

- The basic raw materials used in sugar production are:
  - Sugar beet (bought from the domestic market)
  - Steam power (generated in the refineries by steam plants using coal)
- Two basic types of steam plants to produce steam power:
  - Type 1: Uses coal with low calorific value,
  - Type 2: Uses coal with high calorific value.
- The calorific value requirement of each refinery can be satisfied
  - directly from a particular coal mine
  - or can be satisfied through a blending process.
- For the latter case, supplying coal in different calorific values from different mines, each refinery has different stipulations concerning the minimum and the maximum calorific values of the coal that can be used in the blending process for its steam plants.
- It is assumed that calorific values blend linearly by the coal amount.
  - Example:
  - The blending of one ton of coal with 2000 calorific value and one ton of coal with 3000 calorific values results in two tons of coal with 2500 calorific value (i.e., (1x2000+1x3000)/(1+1) = 2500 tons-calorific value).
  - This example can also be used to explain the minimum and maximum calorific values.
  - Suppose that we have a mix of 1.5 tons of coal with 3000 calorific value and 0.25 tons of coal with 2000 calorific value that results in 1.75 (1.5+0.25) tons of coal with (1.5x3000+0.25x2000)/1.75 = 2857.14 calorific value.
  - Assume that a steam plant would consider to use this mix. If the minimum and the maximum calorific values are 2400 and 2800, respectively, for that plant, then the mix would not be a feasible blend.
  - However, the blend will be feasible for a plant having a minimum calorific value of 2400 and a maximum calorific value of 3000.
- Major concern: minimize cost
- Another major concern: the Office specifies an upper limit on the coal amount (in tons) that can be bought from a mine for a refinery so that a particular mine cannot offer more than a certain percentage of the total coal (in tons) demanded by a particular refinery.

Table-1: Demand data

	Low Calorie Plant				**High Calorie Plant**		
Refineries	Ton x Cal.value	Minimum Cal.value	Maximum Cal.value		Ton x Cal.value	Minimum Cal.value	Maximum Cal.value
Adapazari	42000 x 2600	2400	2800		28000 x 4400	4000	4800
Afyon	106000 x 2600	2400	3000		-	-	-
Agri	14000 x 3200	3000	3400		28000 x 4400	4000	4800
Alpullu	-	-	-		48000 x 4500	4000	6000
Amasya	-	-	-		52000 x 4500	4000	6000
Bor	60000 x 3200	3000	3400		-	-	-
Burdur	50000 x 2600	2400	2800		30000 x 4000	4000	4800
Carsamba	42000 x 3200	3000	3400		-	-	-
Corum	40000 x 3200	3000	3400		-	-	-
Elbistan	82000 x 3200	3000	3400		-	-	-

Table-2: Supply data

Mine	Capacity (tons)	Cal.value	Coal type	Mine	Capacity (tons)	Cal.value	Coal type
1. Amasya	30000	3200	L/H	9. Ilgin	300000	2200	L
2. Bayat	15000	3200	L/H	10. Tuncbilek	500000	3200	L/H
3. Duraksan	50000	2500	L	11. Cemag	605000	4400	L/H
4. Heris	35000	3200	L/H	12. Dilmac	10000	5000	H
5. Kias	30000	2600	L	13. Gungen	60000	5200	H
6. Soma	15000	3273	L/H	14. Intercem	200000	5900	H
7. TKI1	300000	3500	L/H	15. TKITunc	300000	4200	L/H
8. TKI2	300000	3000	L/H				

Table-3: Relation between refineries and mines

Mine	Price(TL/ton)	Percentage
1. Amasya		
Corum	128	0.60
Carsamba	139	0.60
2. Bayat		
Corum	160	0.85
3. Duraksan		
Agri	120	0.65
4. Heris		
Burdur	100	1.0
Adapazari	143	0.5
Bor	160	0.5
Carsamba	193	0.5
5. Kias		
Adapazari	100	0.5
6. Soma		
Adapazari	130	0.65
7. TKI1		
Corum	210	0.65
Carsamba	235	0.65
8. TKI2		
Corum	95	0.75
Carsamba	120	0.75
9. Ilgin		
Afyon	108	0.7
Bor	121	0.55
Burdur	131	0.7
10. Tuncbilek		
Afyon	105	0.8
Burdur	132	0.8
Corum	158	0.5
Bor	170	0.5
Carsamba	179	0.5
Elbistan	203	0.8

Mine	Price(TL/ton)	Percentage
11. Cemag		
Bor	341	0.65
Elbistan	341	0.65
Burdur	352	0.65
Corum	367	0.65
Amasya	370	0.65
Carsamba	378	0.65
Adapazari	382	0.65
Alpullu	410	0.65
Agri	425	0.65
12. Dilmac		
Adapazari	225	0.65
Alpullu	240	0.65
13. Gungen		
Bor	337	0.65
Elbistan	345	0.65
Corum	362	0.65
Carsamba	377	0.65
Agri	400	0.65
14. Intercem		
Alpullu	293	0.60
Burdur	297	0.60
Carsamba	297	0.80
Adapazari	297	0.80
Amasya	302	0.80
Corum	303	0.80
15. TKITunc		
Afyon	175	0.30
Burdur	202	0.40
Corum	228	0.20
Carsamba	249	0.20
Elbistan	273	0.50

Base: Formulate a linear programming model for this problem.

1. In practice, mines can not operate each year. Suppose that:
   i. TKI2 is closed,
   ii. Intercem is closed.
2. Find the price range for which Carsamba buys coal from TKITunc.
3. TKI2 wants to sell more. What price should it offer?
4. State which plants should revise their minimum and maximum calorific value units. How would the change in the values affect the solution in terms of cost and amount of coal supplied, i.e. should they use less or more coal?
5. The State Office of Turkish Sugar Factories directors foresee that there will be an economic crisis in 2017. They expect that demand will decrease and prices will increase. Provide what-if analysis. Your analyses should include the cost function from %5 to %15 changes in both demand and price as in the table below:

   Table 4: What-if analysis

Price / Demand	%5	%10	%15
%5			
%10			
%15			

6. Suppose that directors consider to minimize the maximum amount of high calorific coal delivery from each mine to each refinery. Show results and compare with the current condition.
7. **a.** The State Office of Turkish Sugar Factories directors realizes that they did not consider warehouse capacity issues. They want to see the alternative total costs corresponding to different levels of total warehouse capacity usage. Besides, try to report the change of shipment plan in a general sense.
   b. What if maximum calorific values of each refineries are increased by 10%? Repeat the analysis that you performed in part A and comment on the difference between results of A and B.
8. **a.** Report the changes when L/H restrictions are omitted.
   b. The State Office of Turkish Sugar Factories directors' want to make a policy to provide equality and prevent monopoly of some mines. Thus the difference between total shipment amounts from each mine should be less. They have no idea how much "less" should it be. Help them by giving some analyses.