FILATOI RIUNITI

The northern regions of Italy are the heartlands of the Italian textile industry, providing textile products for many great Italian (and non-Italian) fashion houses. Most of today's companies were founded at the turn of the century and have grown and thrived despite a series of twentieth century catastrophes, including the Great Depression and World War II. Sales in the entire Italian textile and apparel industry were about $80 billion in 2007. The Italian textile-fashion industry employs over 400,000 people.

Filatoi Riuniti is a family-owned spinning mill located in northwest Italy. They produce cotton yarn, which is one of the raw materials that is used to produce the fabrics that are then cut and sewn by Italian stylists into the worldwide famous Italian clothes.

Demand for Filatoi Riuniti's production is strong, but their spinning machine capacity is insufficient to meet its production orders. They decided to outsource part of the spinning production to six local family-owned spinning mills: Ambrosi, Bresciani, Castri, De Blasi, Estensi, and Giuliani. The local mills charge higher prices for spinning finer yarns, so Filatoi Riuniti has decided to spin as much as possible of the finer yarns entirely in-house and to outsource only the spinning of low-end (coarser) yarns. Last month, they faced a total demand of 104,500 kg of cotton and they outsourced 32,000 kg of the low-end sizes.

Filatoi Riuniti hired a consulting firm to see if the outsourcing strategies to the six local mills could be improved. After analyzing the data, they immediately saw the potential for very large savings through more optimal outsourcing strategies. In this problem, we'll improve the outsourcing strategy of Filatoi Riuniti using linear optimization. (Note: This problem is based off of a real case, but the names have been changed for privacy reasons.)

PROBLEM 1.1 - FORMULATING THE OPTIMIZATION PROBLEM (1/1 point)

Filatoi Riuniti produces four different sizes of yarn: extra fine, fine, medium, and coarse. Their current strategy is to produce all of the fine and extra fine yarn in-house, outsource some of the medium yarn to the lowest-price mill, and outsource all of the coarse yarn to the other mills. To try to improve this strategy, let's set up an optimization problem.

The spreadsheet FilatoiRiuniti.ods (/c4x/MITx/15.071x/asset/F Riuniti.ods) for LibreOffice or OpenOffice, and FilatoiRiuniti.xlsx (/c4x/MITx/15.071x/asset/FilatoiRiuniti.xlsx) for Microsoft Excel, contains data for the problem. This data includes information about production hours, capacities, costs, and demand. Ambrosi and De Blasi can't produce extra fine yarn, so no data is provided for extra fine yarn at these mills.

The decision variables are the amount of yarn of each size that each company should be assigned to produce. There are four sizes, and seven companies (including Filatoi Riuniti). These decision variables are set up in the spreadsheet. Note that the decision variables should be non-negative - none of the mills can produce a negative amount of yarn!

The objective is to minimize costs. The prices charged by the six local mills for production, as well as the production cost at Filatoi Riuniti, are provided in the spreadsheet. Additionally, the yarn that is spun by the six local mills needs to be transported. The transportation costs per kg of yarn are also provided in the spreadsheet.

Our model has two types of constraints: capacity constraints and demand constraints. The spreadsheet contains a table showing the production capacity and production rate per product for each of the mills (including Filatoi Riuniti). For example, at the Bresciani mill, it takes 0.70 hours to produce one kg of extra fine yarn, and there are a total of 3,000 machines hours per month available at this mill. There is also a table that estimates the demand for the four yarn sizes in the current month. We should produce at least the demand for each yarn type.

Formulate and solve this problem in LibreOffice (or in the spreadsheet software you are using). The objective should minimize the sum of the production and transportation costs. You should have the following constraints: non-negative decision variables, a capacity constraint for each mill, and a demand constraint for each type of yarn. Remember that Ambrosi and De Blasi can't produce extra fine yarn, so you should also account for this.

What is the objective value of the solution?

1382544

1382544

Answer: 1382544.334

EXPLANATION

After setting up and solving the problem, the objective value of the solution is $1,382,544.33.

The formula for the objective is:

SUMPRODUCT(B53:E59;B25:E31) + SUMPRODUCT(B53:E59;B35:E41)

You should select that you want to minimize the objective in Solver.

The formulas for the constraints are as follows:

Ambrosi No Extra Fine Yarn: B53 = 0

De Blasi No Extra Fine Yarn: B56 = 0

Ambrosi Capacity: SUMPRODUCT(B53:E53;B5:E5) <= B15

Bresciani Capacity: SUMPRODUCT(B54:E54;B6:E6) <= B16

Castri Capacity: SUMPRODUCT(B55:E55;B7:E7) <= B17

De Blasi Capacity: SUMPRODUCT(B56:E56;B8:E8) <= B18

Estensi Capacity: SUMPRODUCT(B57:E57;B9:E9) <= B19

Filatoi Riuniti Capacity: SUMPRODUCT(B58:E58;B10:E10) <= B20

Giuliani Capacity: SUMPRODUCT(B59:E59;B11:E11) <= B21

Extra Fine Demand: SUM(B53:B59) >= B45

Fine Demand: SUM(C53:C59) >= B46

Medium Demand: SUM(D53:D59) >= B47

Coarse Demand: SUM(E53:E59) >= B48

Hide Answer *You have used 2 of 6 submissions*

PROBLEM 1.2 - FORMULATING THE OPTIMIZATION PROBLEM (1/1 point)

How many kg of medium yarn is outsourced?

9182.982

9182.982

Answer: 9182.982

EXPLANATION

We need to sum the values of the decision variables for medium yarn at the other mills. We outsource 2040.125 kg of medium yarn to De Blasi, and 7142.857 kg of medium yarn to Giuliani, for a total of 9182.982 kg.

Hide Answer *You have used 1 of 3 submissions*

PROBLEM 1.3 - FORMULATING THE OPTIMIZATION PROBLEM (1/1 point)

How many kg of fine yarn is outsourced?

6250

6250

Answer: 6250.00

EXPLANATION

We outsource 6250 kg of fine yarn to Ambrosi, and produce the rest in-house. So a total of 6250 kg of fine yarn is outsourced.

Hide Answer *You have used 1 of 3 submissions*

PROBLEM 1.4 - FORMULATING THE OPTIMIZATION PROBLEM (1/1 point)

At which mills does Filatoi use the maximum capacity available?

- [x] Ambrosi
- [x] Bresciani
- [x] Castri
- [ ] De Blasi
- [x] Estensi
- [x] Filatoi Riuniti
- [x] Giuliani

EXPLANATION

To answer this question, we need to look at the capacity constraints, and see which ones are satisfied at equality. We use the maximum capacity available at all mills except for De Blasi, where we only use 714 of the 2600 hours available.

Hide Answer *You have used 1 of 2 submissions*

PROBLEM 2.1 - SENSITIVITY ANALYSIS (1/1 point)

In Problems 2 and 3, we'll be checking how sensitive our model is to the data and constraints. If you change the constraints or data values to answer any of the questions, make sure to change them back to the original values before continuing on to the next problem.

Filatoi Riuniti should obviously consider increasing its spinning machine capacity. They could slightly expand the production capacity of the existing machines by renting an upgrade. This would increase their spinning production capacity by 600 hours/month. The monthly rental cost is $1,500/month. Would you recommend that they rent the upgrade?

- ( ) Yes, they should rent the upgrade
- (•) No, they should not rent the upgrade

EXPLANATION

Increasing Filatoi Riuniti's spinning capacity by 600 hours/month and resolving the problem decreases the objective value to $1,381,273.75, which means that they save $1270.59 in costs. But since the cost of the upgrade is $1,500, it is not worth it to rent the upgrade.

Hide Answer *You have used 1 of 1 submissions*

PROBLEM 2.2 - SENSITIVITY ANALYSIS (1/1 point)

Alternatively, Filatoi Riuniti could increase its spinning machine capacity by renting another spinning machine for the production of **only medium size yarn**, for a monthly rental cost of $3,000. The machine has a production capacity of 300 hours per month (the machine would run at the same rate of 0.425 hours/Kg). Suppose that the estimated production cost of running this machine is less than that for Filatoi Riuniti's existing machines and is estimated to be $5.70/Kg (as opposed to $11.40/Kg for their existing machines). Would you recommend that Filatoi Riuniti rent the machine?

- (•) Yes, they should rent the machine. ✔
- ( ) No, they should not rent the machine.

EXPLANATION

For this problem, the extra capacity is only for medium sized yarn. We can look at our optimal solution and see how medium yarn is currently being produced. We are producing 18,817.017 kg in-house, 2,040.125 kg at De Blasi, and 7,142.857 kg at Giuliani. If we look at the total costs, we can see that the most expensive place that we are currently producing at is De Blasi, at a cost of $12.30 per kg (production plus transportation costs). An extra 300 hours of medium production capacity at Filatoi allows us to produce 300/0.425 = 706 kg of additional medium sized yarn, so we would take these kg away from De Blasi and produce them in-house. The benefit of doing so is 706($12.30 - $5.70) = $4660. Since this is larger than the rental cost of $3,000, we should rent the machine.

Alternatively, you could adjust the production capacity and analyze how the model changes. If you add 300 production hours for Filatoi, the objective decreases by $635.29. However, since we're producing more than 705.88 kg of medium yarn in-house, we know that we're getting the 705.88 from that machine at $5.70/kg cheaper than the objective thinks we are, meaning the real cost is actually $5.70*705.88=$4023.53 lower, and we have a total savings of $4023.53+$635.29=$4658.82, more than the cost of $3000.

Hide Answer *You have used 1 of 1 submissions*

PROBLEM 2.3 - SENSITIVITY ANALYSIS (1/1 point)

Suppose that the shadow price of the medium yarn demand constraint is $12.30, with an allowable increase of 5388. Recall that the shadow price is the amount that the objective increases per unit increase in the right hand side of the constraint. So a shadow price of $12.30 for the medium yarn demand constraint means that the cost increases by $12.30 for every unit increase in the medium yarn demand. The allowable increase of 5388 means that this shadow price hold up to an increase of 5388 in the right hand side of this constraint. If we increase the right hand side by more than 5388, the shadow price will change, and it is impossible to know how it changes without re-solving the model.

A new client is interested in purchasing up to 5,000 kg/month of medium size yarn. What is the minimum price per kg of yarn that Filatoi Riuniti should quote to this new client? (In answering this question, assume that Filatoi has not decided to increase its spinning machine capacity, and that Filatoi does not want to change the prices that they currently charge their existing clients.)

12.30

12.30

Answer: 12.30

EXPLANATION

Filatoi should charge at least $12.30 per kg to the new client, since this is the amount it will cost per-unit to increase the medium yarn demand by 5,000.

Hide Answer *You have used 1 of 3 submissions*

PROBLEM 2.4 - SENSITIVITY ANALYSIS (1/1 point)

Now suppose that the client wants to purchase 6,000 kg/month of medium size yarn. Now what is the minimum price per kg of yarn that Filatoi Riuniti should quote to this new client? (In answering this question, assume that Filatoi has not decided to increase its spinning machine capacity, and that Filatoi does not want to change the prices that they currently charge their existing clients.)

12.44892

12.44892

Answer: 12.45

EXPLANATION

We can't answer this question using just the shadow price, since it only holds for an allowable increase of 5,388. But we can increase the demand for medium yarn by 6,000 (to 34,000) and re-solve our optimization problem. The new objective value is 1,457,237.88. Comparing this to the old objective of 1,382,544.33, the increase is 74,693.55. Dividing by 6,000, this is an increase of 12.45 per kg. This is the minimum price that we should charge the client per kg of yarn.

Hide Answer *You have used 2 of 3 submissions*

PROBLEM 3.1 - DATA ESTIMATES (1/1 point)

In many situations, the problem data is estimated but is not known for sure. In this problem, the optimization model is based in part on the prices charged by the local mills to Filatoi Riuniti and on an estimate of Filatoi Riuniti's internal production costs. The plant manager, the accounting department, and you estimate that Filatoi Riuniti's internal production costs could vary within a 5% range of the numbers given.

If Filatoi Riuniti's production costs increase by 5%, by how much does the objective value of the solution change? You should adjust and re-optimize the model to answer this question.

48924.49

48924.49

Answer: 48924.5

EXPLANATION

Multiply each of Filatoi's production costs by 1.05, and resolve the optimization model. The objective value of the solution increases to 1,431,468.83, for a change of 48,924.5. This means that the overall cost is more, which makes sense since it is more expensive to produce in house.

Note that none of the decision variables change value. So even though it is more expensive, the strategy does not change if the internal production costs increase by 5%.

Hide Answer *You have used 1 of 3 submissions*

PROBLEM 3.2 - DATA ESTIMATES (1/1 point)

If Filatoi Riuniti's production costs decrease by 5%, by how much does the objective value of the solution change (in absolute difference)? You should adjust and re-optimize the model to answer this question.

48924.49

48924.49

Answer: 48924.5

EXPLANATION

Multiply each of Filatoi's production costs by 0.95, and resolve the optimization model. The objective value of the solution decreases to 1,333,619.84 for a change of 48,924.5. This means that the overall cost is less, which makes sense since it is less expensive to produce in house.

Note that none of the decision variables change value. So even though it is less expensive, the strategy does not change if the internal production costs decrease by 5%.

Hide Answer *You have used 1 of 3 submissions*

PROBLEM 3.3 - DATA ESTIMATES (1/1 point)

Now you think that the production capacity of one of your local mills, De Blasi, could vary within a 20% range of the estimated value. In the current solution, De Blasi produces 2040.125 kg of medium yarn, and none of the other types of yarn. If De Blasi's capacity is actually 20% higher or lower than the estimated value, will the solution change? HINT: Think about De Blasi's capacity constraint.

- ○ Yes
- ◉ No ✔

EXPLANATION

De Blasi's capacity constraint is not binding in the current solution. While they have a capacity of 2600 hours, we only use 714 hours. So even if the capacity changes by 20%, the solution will not change.

Hide Answer *You have used 1 of 1 submissions*

ACKNOWLEDGEMENTS

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