Washington University in St. Louis
OLIN BUSINESS SCHOOL

Assignment 3 (Individual)

Read the case Filatoi Riuniti provided below (the tables in the case are available electronically on Canvas).

Submission Guidelines

You need to submit two files electronically through Canvas:
1) **a typed summary report** of your answers to the following questions.
2) your spreadsheet model(s), including **answer report** and **sensitivity report**.

The file name should be your last name; that is, *lastname.xlsx* and lastname.doc.

Reminder: This is an INDIVIDUAL assignment.

Questions

1. What is the optimal supply strategy for the month of March? What is the optimal cost?
    a. Formulate (**in math**) a linear program model for this problem. That is, specify the *decision variables*, *the objective function*, and the constraints of the model in the **summary report**.
    b. Construct a spreadsheet model of your formulation and solve it using **Excel's Solver**. Please make sure that
        i. Simplex LP is the solution method for the problem
        ii. **No integer constraints** should be added to the formulation (Solver will not provide a sensitivity report if an integer constraint is added).
    c. Present the optimal supply strategy in a table format.

Questions 2-6 are independent of each other.

Requirements that applied to all the following questions:

- **Use the sensitivity report to answer the question if information in the original sensitivity report is applicable.**
- Re-formulate and Re-optimize the problem ONLY when you don't think the sensitivity report provides the information needed.
- If the question requires re-formulation, please **state in the summary report the changes** that you made to the original formulation. There is no need to provide the complete formulation again.
    - Use a new worksheet in the excel file for the re-formulation, and label the worksheet using the question number, e.g., Q2, Q3.
- Provide **clear reasoning (analysis)** and **clear answer** for each question in the summary report.

2. Assess production capacity opportunity. Filatoi could slightly expand the production capacity of its existing spinning 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? Why or why not?

3. Assess impact of information update. Your outsourcing production strategy optimization model is based in part on the prices charged by the local mills to Filatoi and on an estimate of Filatoi's internal production costs. The plant manager, the accounting department, and you estimate that Filatoi's internal production costs could vary within a 5% range of the figures originally estimated. Consider the following two cases:

    a. All of Filatoi's internal unit product costs increase by 5%

b. All of Filatoi's internal unit production costs decrease by 5%

Would your recommendation in Question 1 change? Why or why not?

4. Assess impact of information update. You estimate that the production capacity of **De Blasi** could vary within a 20% range of the figure shown in Table 2. Would your recommendation change in the two extreme cases: Why or why not?

   (a) +20% increase,
   (b) -20% decrease.

5. Use the model to support the available-to-promise function. A client has just called asking for an additional 5,000 kg of the medium size yarn. The original demand still has to be met but Filatoi is considering whether it should accept the new order and what is the minimum price ($/kg) it should charge for it. You can assume that Filatoi can adjust its outsourcing orders with the suppliers.

6. Use the model to support the outsourcing negotiation. Suppose you presented your proposed outsourcing plan to the owners of the Ambrosi mill. They complain to you that their mill cannot easily produce fine size yarn; in fact they presently can only produce medium and coarse size yarn, and they would incur substantial one-time set-up costs to ramp up the production of fine size yarn. However, the optimal solution of the model indicates that it would be in Filatoi Riuniti's interests for the Ambrois mill to produce fine size yarn. The owners want to maintain good relations with Filatoi Riuniti, but they do not want to bear the full cost of ramping up for production no fine yarn. The contracts that Filatoi Riuniti currently has with its customer will not expire for at least another 12 months. Up to what amount would you be willing to share the one-time set-up costs for production of fine yarn with the owners of the Ambrosi mill?

Filatoi Riuniti[1]

The Italian textile industry

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. The industry's history reaches back to Roman times when Biella (a town in the northwestern Alps) was a center for wool production. Most of today's companies were founded at the tum of the century and have grown and thrived despite a series of twentieth century catastrophes, including the great Depression (which crushed the silk industry), World War II, and the flash floods of 1968 (which destroyed many of Biella's mills). The families that run the wool-producing companies, many of whose ancestors had worked the land for centuries, have always come back with great competitive spirit.

Sales in the entire Italian textile and apparel industry were about $50 billion in 1994 with exports of $23 billion, according to Italy's National Statistics Institute. The entire textile sector employs over 700,000 people. Italy's largest export markets in the textiles sector are Germany, France, Great Britain, the United States, and Japan. In 1994, over 1,200 companies exported textile products to the United States totaling about $625 million (over 6% of Italy's overall textile exports).

The major Italian textile companies are fighting hard to stay at the forefront of the world textile market, and the battles are numerous. Competition from east Asia, a tug-of-war with China over silk and cashmere exports, lack of sufficient qualified employees, and a fast-moving fashion industry (which requires the mills to create and deliver rapidly) are among the new challenges facing the industry. In the face of these challenges, many Italian textile firms are committed to making massive investments in state-of-the-art machinery and in research into new finishings.

Italian manufacturers are confident that Italian textile producers will always have an edge on the competition because of the high concentration of dyeing, finishing, and printing specialists in Italy. "Italy's textile sector is unique because there is this microcosm of small companies who are very creative and always up-to-date on the latest trends. They provide a constant stimulus and an endless source of ideas for manufacturers. In the end, this means continued creativity and flexibility of the industry," says industry spokesperson Enrico Cerruti. "The trump card for the Italian textile industry is its cultural tradition and human resources.... You can copy technology, you can copy design, but you can't duplicate the people here. It takes 100 years to build that and it's our greatest advantage."

[1] Source: Dimitris Bertsimas and Robert M. Freund, “Data, Models, and Decisions: The Fundamentals of Management Science”, Dynamic Ideas, 2004, pages 389-395.

How cotton yarn is produced

Prior to the Industrial Revolution textiles were spun by hand using a spinning wheel.

Today most commercial yarns are produced in textile mills, and although the tools and techniques used are different from hand spinning, most of the processes are still the same. Most yarns are spun from staple fibers made using one of three systems: the Cotton Process, the Woolen Process, or the Worsted Process. These processes vary only slightly from each other but they all include the three basic processes of preparation, spinning, and finishing.

The Cotton Process is used to spin cotton fibers between 3/4" and 2" in length. Synthetic fibers can also be blended with the cotton to form blended yarns. Likewise the Worsted and Woolen Processes are used to spin wool fibers and wool blends. The cotton process method employs the following steps:

1. **Preparation.**
   (a) **Opening & Loosening**. Upon arrival at the mill, the cotton bails are opened and loosened. This helps separate and clean the cotton before it is fed into carding machines. Impurities such as rocks, coins, and other solid objects (there are stories about bullets found in the raw cotton!) are removed.
   (b) **Carding**. Carding machines further loosen and separate the cotton fibers by passing the fibers between two rotating metal drums covered with wire needles. This aligns the cotton in a thin web of parallel fibers, which is formed into a rope-like strand called a sliver. The sliver is collected in a sliver can in preparation for roving. For high quality yarns the sliver is combed after carding to make the fibers more parallel and to remove smaller fibers.
   (c) **Drawing and Roving**. Slivers are then drawn out, blending the fibers and making them more parallel. No twist is added to the sliver during drawing, but several slivers can be blended together. Slivers can go through multiple drawings for further parallelization and blending. Drawn out slivers are then fed to the roving frame where they are drawn further while a slight twist is added. The roving strands are collected in cans and fed to the spinning machine.
2. **Spinning and Winding**. The spinning machine draws out the roving strand, adds twist, and winds the yarn onto bobbins. The slivers, which are relatively short segments of cotton, are twisted against each other into a long, continuous strong yarn. Multiple bobbins of yarn are then wound onto larger spools called cheeses. Now the yarn *is* ready for texturing and dying and finally weaving into fabric.
3. **Re-spooling/texturizing**. Some finer qualities of thread require an additional step of spooling or passage in a gas-saturated room. This further step is necessary to chemically eradicate remaining impurities or to impart aesthetic and/or functional properties to the yarn.

Filatoi Riuniti

Filatoi Riuniti is a family-owned spinning mill located in Piemonte, a region in northwest Italy. Filatoi Riuniti produces cotton yarn, which is one the raw materials (together with wool) that is used to produce the fabrics that are then cut and sewn by Italian stylists into the worldwide famous Italian clothes.

Filatoi Riuniti was founded at the beginning of the 19th century by an Italian entrepreneur who built a spinning machine and began to produce cotton yarn on a low scale in the barn in his backyard. The company grew tremendously in the period 1880-1920. After World War I, Filatoi Riuniti benefited from the development of certain machine tool industries, and replaced and otherwise modernized most of their machine capacity. Unfortunately, after World War II, Italy had to rebuild its economy almost from scratch; Filatoi Riuniti struggled to remain solvent and it was many years before they had the capital needed to replenish and then expand their production facilities.

Filatoi Riuniti's current situation

For the past twenty years, Filatoi Riuniti had followed a strategy of rapid expansion to increase market share. As the Italian fashion industry grew in both stature and revenues, demand for Filatoi Riuniti's products increased, and management expected this pattern to continue. Filatoi Riuniti invested aggressively in new machine capacity to meet the demands of its current clients as well as to serve anticipated new customers. Filatoi Riuniti began to experience financial problems in the early 1990s and had to halt this expansion strategy due to an economic recession in Italy that was accompanied by a strengthening of the Italian lira:

> "Recession has hit the European textile industry from all sides ... cotton yarn weavers are having an exceptionally hard time .... Some companies collapsed only to re-emerge shrunk to a third of their initial size" (Daily News Record, March 29, 1993).

> "The '80s ... were very good in both sales and profitability, but there are market cycles and now we're facing a descending cycle .... The decrease in overall consumption of apparel, new competition, market problems in the U.S. and the strength of the lira against the deutsche mark and yen present uncertain signs for the future." (Daily News Record, December 5, 1993).

In the face of disappointing demand in the early 1990s, it might seem obvious that Filatoi Riuniti should have adjusted its production and its production capacity downward. Such down-sizing is not so easy to do in Italy's unionized industries. Italian trade unions achieved substantial gains in power and stature during the 1970s and 1980s. As a result, it was (and still is) very difficult for a company to lay off employees solely due to a fall in sales, unless the company could prove to the government that it was in severe financial distress. If the company could prove such financial distress, they could lay off employees (who would then be paid a minimal wage by the government). However, companies are very hesitant to take this course of action, because being labeled as "financially distressed" makes it almost impossible to buy from suppliers on account or to borrow money at low interest rates.

Filatoi Riuniti's management chose not to lay off any employees in the early 1990s. The resulting cash-flow problems severely limited the funds Filatoi Riuniti could use to increase their Spinning capacity (the second step). This was most unfortunate, since Filatoi Riuniti had previously expanded their Preparation machine capacity (first step) and Finishing capacity (third step), and their Spinning capacity needed to be expanded to fully balance their production facilities.

Outsourcing Spinning Production

With the recent upturn in the Italian economy, demand for Filatoi Riuniti's production is strong again, but Filatoi Riuniti's spinning machine capacity is insufficient to meet its production orders; and they decided six months ago to outsource part of the spinning production to six local family-owned spinning mills named Ambrosi, Bresciani, Castri, De Blasi, Estensi, and Giuliani (all six mills operate primarily for local markets such as Filatoi Riuniti). Filatoi Riuniti currently processes the raw material (combed cotton) and then sends part of the combed cotton to these six spinning mills for the spinning step. The semi-finished product is then returned to Filatoi Riuniti's production site where it is finished and stored until delivery to customers. The local mills charge higher prices for spinning finer yarns and for this reason Filatoi Riuniti has decided to spin as much as possible of the finer yarn sizes entirely in-house and to outsource oniy the spinning of low-end (coarser) yarns. Last month, for example, Filatoi Riuniti faced a total demand of 104,500 Kg of cotton and they outsourced 32,000 Kg of the spinning of the low-end sizes. Table 1 shows the production schedule and the prices charged by the six mills for February.

Table 1: Outsourcing production schedule and prices charged to Filatoi Riuniti - February

Production Schedule for February (Kg)					*Prices Charged to Filatoi Riuniti ($/Kg)*			
	Size				*Size*			
Supplier	***Extrafine***	***Fine***	***Medium***	***Coarse***	***Extrafine***	***Fine***	***Medium***	***Coarse***
Ambrosi			3,000			13.00	10.65	9.60
Bresciani				12,000	17.40	14.10	11.20	9.45
Castri				10,000	17.40	14.22	11.00	9.50
De Blasi				1,000		14.30	11.25	9.60
Estensi					17.50	13.80	11.40	9.60
Filatoi R.	25,000	26,500	21,000					
Giuliani				6,000	19.75	13.90	10.75	9.40

Demand to Meet					
Size	***Extrafine***	***Fine***	***Medium***	***Coarse***	***Total***
(Kg/month)	25,000	26,500	24,000	29,000	104,500

Milan Consulting Group Inc.

Last fall, Giorgio Armeni was named the new CEO of Filatoi Riuniti. Faced with a myriad of challenging issues at Filatoi Riuniti and sensing that Filatoi Riuniti's internal management team was not up to the task of radical internal re-engineering, he decided to hire Milan Consulting Group Inc. (MCG) to help address some of the company's ongoing problems. MCG's team was composed of Maurizio Donato, a junior partner, and Roberto Benello and Sofia Cominetti, two young associates in their first engagements. The three consultants spent four days at Filatoi Riuniti touring the production facilities, reviewing operations, interviewing managers, and studying mounds of data. After a weekend of hard thinking back in Milan, Maurizio Donato started the next Monday's project meeting with his two young associates with the words: "Our first priority is to find ways to reduce the costs that our client faces which are jeopardizing the future of the factory and the jobs of the almost 200 employees. Our goal is to come up with smart workable ideas, *e subito!*" He then outlined what he thought were four areas for obvious cost reduction:

(a) reducing machine down-time through improved inspection strategies,

(b) differential scheduling of machine maintenance,

(c) different management of overtime on production shifts, and

(d) Improved outsourcing strategies from the six local spinning mills.

Roberto and Sofia immediately went to work on the analysis of these four proposals. They found that the total expected cost savings from the first three proposals would probably amount to roughly $200,000 per year. This was not a particularly large sum of money in comparison to Filatoi Riuniti's sales of $15 million (although it easily justified their consulting fees!). However, when they started to work on the fourth proposal, they immediately saw the potential for very large savings through more optimal outsourcing strategies with the six local spinning mills.

Optimizing the Outsourcing of Spinning Production

Filatoi Riuniti produces four different sizes of yarn (coarse, medium, fine, and extra fine) and there is an autonomous demand for each of the four sizes. Filatoi Riuniti can prepare enough raw cotton to meet their total demand, but they lack sufficient machine capacity to spin the four sizes of yarn, and as discussed above, they have been outsourcing part of the spinning production to six local mills: Ambrosi, Bresciani, Castri, De Blasi, Estensi and Giuliani. Table 1 shows February's spinning production schedule. Of the total demand of 104,500 Kg of yarn, 32,000 Kg were outsourced to the six local mills. All of the spinning of Coarse yarn was outsourced (29,000 Kg), and 13% of the spinning of Medium yarn was outsourced. The exhibit also shows the prices charged by the six mills to Filatoi Riuniti. The head of the purchasing department at Filatoi Riuniti said "We spin the finer sizes in-house and outsource the rest of the work. We outsource each yarn size to the lowest-price mill and then meet demand with the next-lowest-price mill." Roberto and Sofia thought that this outsourcing strategy could easily lead to sub-optimal outsourcing decisions, since outsourcing decisions were optimized only one at a time as opposed to optimizing all outsourcing simultaneously. In order to analyze the potential savings from optimizing the outsourcing of spinning production, they started to work with the client to identify the decision variables, the constraints, and the objective function to optimize.

Decision variables. Given the amount of each yarn size that Filatoi Riuniti needs to deliver to meet demand, the problem was how to allocate spinning production (both at Filatoi Riuniti and at the six local mills) in order to minimize costs. The decision variables of the optimization model are denoted x_{ij} which represents the amount of yarn of size i that the company j would be assigned to produce. In this context, i = 1, 2, 3, and 4 means "extra fine," "fine," "medium," and "coarse," respectively. Similarly, j =A, B, C, D, E, F, G mean Ambrosi, Bresciani, Castri, De Blasi, Estensi, Filatoi Riuniti, and Giuliani. See the blank table "Decision Variables" of the spreadsheet FILATOIR.XLS as a guide. Each x_{ij} must of course be nonnegative because none of the mills can produce negative amounts of spun yarn.

Variable Costs of Production. Roberto and Sofia knew the prices charged to Filatoi Riuniti by the six local mills (see Table 1). For internal purposes, they also needed to know Filatoi Riuniti's internal production costs in order to determine how much of each yarn size should optimally be produced internally versus externally. After a couple of days spent with the plant managers and the chief accountant, they came up with a fair estimate of the production cost for each of the four yarn sizes. See Table 2. The two blanks in the table indicate that Ambrosi and De Blasi cannot produce extra fine yarn.

Transportation costs. The yarn that is spun by the six local mills needs to be transported from Filatoi Riuniti to the mills for spirming and then be transported back to the production plant of Filatoi Riuniti in order to refine it and store it prior to delivery to customers. Sofia realized that they needed to obtain accurate data on transportation costs. One of the operations managers explained to her: "We have an agreement with a local truck company which takes care of all the transportation. The contract with the truck company is very simple. They charge a fixed amount per kilometer per unit volume." Each product has a different density and therefore takes up a different volume per Kg. One Kg of finer product is more dense and so is less expensive to transport on a per Kg basis. Of course, each local mill is located at a different distance from Filatoi Riuniti. Armed with the contract with the truck company, a road map with the location of the six local mills, and product specification data, Sofia was able to estimate the transportation cost per Kg of each product for all the local mills. These numbers are shown in the table "Cost of Transportation" in Table 2. For example, it costs $0.01 per Kg per Km to transport fine yarn, and the round trip distance from Filatoi Riuniti to the Giuliani mill is 2 X 25 = 50 Km. Therefore, the table shows that it costs (0.01 X 50) = $0.50 to transport one Kg of fine yarn to Giuliani and back.

Resource consumption. Another important task was to understand the actual spinning machine production capacity of the six local mills and of Filatoi Riuniti itself. During the time spent with the plant manager, Roberto learned that production capacity is measured in machine hours per month and each product size requires a different amount of machine hours per Kg of product. He spent some more time with the plant engineer trying

to estimate the six local mills' capacity in terms of machine hours per month and their production rate in terms of hours needed to produce one Kg of a given product size. Because each mill has different types of machines in different configurations, the number of machine hours required to produce one Kg of product differs among the mills. After a full day of work and very many telephone calls, fax, and email messages, Roberto and the plant engineer produced a table containing the production capacity and production rate per product for each of the six mills plus Filatoi Riuniti itself. These capacity and production rate numbers are shown in the two tables "Machine Hours Required for Production" and "Production Capacity" in Table 2. For example, at the Bresciani mill, it takes 0.70 hours to produce one Kg of extra fine yarn and there are at total of 3,000 machine hours per month available.

Product Demand. After talking to the marketing and sales manager at Filatoi Riuniti, Sofia estimated the demand for the four spun yarn sizes for March, which is shown in the table "Demand to Meet" in Table 2. Armed with all of this data, Roberto and Sofia felt that they had enough information to solve for the outsourcing production strategy that would minimize the costs of producing spun yarn.

Table 2: Production schedule, costs, and constraints - March

Decision Variables x_{ij}
Yarn produced by each factory (kg/month)

	Size			
Supplier	***Extrafine***	***Fine***	***Medium***	***Coarse***
Ambrosi				
Bresciani				
Castri				
De Blasi				
Estensi				
Filatoi R.				
Giuliani				

Machine Hours Required for Production (hours/kg)

	Size				***Production Capacity (machine hours per month)***
Supplier	***Extrafine***	***Fine***	***Medium***	***Coarse***	
Ambrosi		0.400	0.375	0.250	2500
Bresciani	0.700	0.500	0.350	0.250	3000
Castri	0.675	0.450	0.400	0.250	2500
De Blasi		0.450	0.350	0.200	2600
Estensi	0.650	0.450	0.400	0.250	2500
Filatoi R.	0.625	0.500	0.425	0.425	38000
Giuliani	0.700	0.450	0.350	0.400	2500

Cost of Production ($/kg)

	Size			
Supplier	***Extrafine***	***Fine***	***Medium***	***Coarse***
Ambrosi		13.00	10.65	9.60
Bresciani	17.40	14.10	11.20	9.45
Castri	17.40	14.22	11.00	9.50
De Blasi		14.30	11.25	9.60
Estensi	17.50	13.80	11.40	9.60
Filatoi R.	18.25	13.90	11.40	8.90
Giuliani	19.75	13.90	10.75	9.40

Cost of Transportation ($/kg)

	Size				***Round trip distance (km)***
Supplier	***Extrafine***	***Fine***	***Medium***	***Coarse***	
Ambrosi	0.30	0.30	0.45	0.45	30
Bresciani	0.40	0.40	0.60	0.60	40
Castri	0.80	0.80	1.20	1.20	80
De Blasi	0.70	0.70	1.05	1.05	70
Estensi	0.70	0.70	1.05	1.05	70
Filatoi R.	–	–	–	–	–
Giuliani	0.50	0.50	0.75	0.75	50
($/kg/km)	0.010	0.010	0.015	0.015	

Demand to meet (kg/month)

Extrafine	***Fine***	***Medium***	***Coarse***
25,000	26,000	28,000	28,000