**INFO 4590— Optimization**

**Portfolio 3—Pyomo Modeling Problems**

Because the objective of this block is to learn the software, we are going to use Pyomo to solve the problems we have already conquered with the Excel Solver. We will only work on a subset of those problems, and in fact, only the more “canned” or standard ones, which will give us an appreciation of the power of Pyomo, and will develop our skills as Pyomo programmers.

This portfolio will be submitted in an MS Word doc, and will include the original Pyomo code and the Pyomo output, pasted into the document with page headers separating each new problem. (Once again, those headers should correspond to the **Bold** text in this assignment.) Note that these do not need to be Jupyter notebook screenshots—you can just paste in the code you wrote and the output you got.

•Optimization Project Descriptions

-Product Mix, Product Mix Continued, Dual Problem, and the Product Mix Challenge

-Golf Bags -Baseball Gloves

-Bike Frames -Investment Portfolios

-Project Selection -Production Scheduling

-Assembly Line Equipment -Manufacturing and Distribution

-Crushing More Rocks -Hospital Scheduling

-Butter -Pet Food

-Employee Scheduling -Lockbox Problem

-Farming -Inventory Management

-Inventory Depletion -Son of Employee Scheduling

-Multi-Period Planning -Snow Removal

-Network Flow Modeling

**Product Mix Problem**

Your company grows two types of plants, A and B (e.g., roses and begonias).

Both plant types require two types of fertilizer throughout the growing season, Fertilizer 1 and Fertilizer 2.

A single plant A will require 2 pounds of fertilizer 1 and 1 pound of fertilizer 2.

A single plant B will require 1 pound of fertilizer 1 and 2 pounds of fertilizer 2.

Your distributer has 4000 pounds of fertilizer 1 and 5000 pounds of fertilizer 2 available for delivery at the beginning of the season.

You know that every plant A you grow will generate $2.25 profit, and every plant B you grow will generate $2.60 profit.

How much do you plant? (What is your business decision?) How much profit does this get you?

**Product Mix Continued**

If your fertilizer storage capacity is 8000 pounds, what is your new product mix, and how much of each fertilizer should you order? What would you be willing to pay for additional storage capacity?

Now how much do you plant?

**The Dual Problem**

Configure the Dual of the Product Mix Continued Problem, and find the solution.

**Product Mix Challenge**

You manufacture two products, A and B, each of which you sell for $1 profit. Product A requires 5 blobs and 3 globs, and product B requires 3 blobs and 5 globs. Your supplier has 120 blobs and 120 globs available. To maximize profit, how much of each product should you produce? How much profit can you make?

**Golf Bags**

Your company manufactures two types of golf bags, Standard and Deluxe. You make $10 profit per Standard bag, and $9 profit per Deluxe bag that you sell.

Production times (in *minutes*) of each bag type are shown below, based on data you have collected from your assembly line.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Cutting and Dyeing | Sewing | Finishing | Inspection and Packaging |
| Standard | 42 | 30 | 60 | 6 |
| Deluxe | 60 | 50 | 40 | 15 |

Over the next 3 months, you estimate you have 630 *hours* of cutting and dyeing time, 600 hours of sewing time, 708 hours of finishing time, and 135 hours of inspection and packaging time available.

How many of each bag type should you manufacture over the next three months in order to maximize profit?

**Baseball Gloves**

Your company manufactures two types of baseball mitts, Fielder and Catcher. The Fielder gloves generate $5 profit, and the Catcher gloves generate $8 profit.

Production times (in *minutes*) of each glove type are shown below, based on data you have collected from your assembly line.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Cutting and Sewing | Finishing | Packaging and Shipping |
| Fielder | 60 | 30 | 12.5 |
| Catcher | 90 | 20 | 15 |

Over the next month, you estimate you have 900 hours of cutting and sewing time available, 300 hours of finishing time, and 100 hours of packaging and shipping time available.

How many of each glove type should you manufacture over the next month in order to maximize profit?

**Bike Frames**

Your company produces bike frames using two different material blend, Professional grade and Standard grade. The cost per yard of the blends are $7.50 per yard for Standard and $9.00 per yard for Professional.

The material content (in percent) of your blends are given in the following table:

|  |  |  |
| --- | --- | --- |
|  | Standard | Professional |
| Fiberglass | 0.84 | 0.58 |
| Carbon Fiber | 0.1 | 0.3 |
| Kevlar | 0.06 | 0.12 |

You have a new contract to produce bike frames that require 30 total yards of material per frame. The frames must have a carbon fiber content of at least 20%, and a Kevlar content of not more than 10%. How many yards of each material blend (Standard and Professional) should go into each frame in order to minimize cost?

**Investment Portfolios**

Your company manages investments for your clients, where you build portfolios based on anticipated yield and risk. (Yield and risk are generally based on historical performance of the investment instruments.)

The three instruments you are considering for a client are growth, income, and money market funds, which you determine to have risks of .1, .05, and .01 respectively. Furthermore, you project the yields of these funds to be 20%, 10%, and 6% respectively.

Your client insists that you diversify, with at least 10% in each of the growth and income funds, and at least 20% in the money market fund.

Your client wants to assume no more that 5% risk, where overall risk is calculated based on a weighted average of the risks of each individual instrument, and where the weightings are the percents of the investment that go towards each instrument.

If your client has $1,000,000 to invest, how should you allocate his funds?

~~How much can your yield estimates for each instrument change (individually) before you have to change this allocation?~~

**Project Selection**

Your company is prepared to undertake several new projects over the next five years. Each Division has submitted a number of project proposals that include the annual budgets and anticipated profit. Your company’s annual budgets for the next five years are as follows. (Amounts are X$1000)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| YEAR | 2016 | 2017 | 2018 | 2019 | 2020 |
| FUNDS | 3500 | 4500 | 4000 | 3450 | 4500 |

The project proposals (for a total of fifteen possible projects) are as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Project | 2016 | 2017 | 2018 | 2019 | 2020 | Profit |
| 1 | 400 | 230 | 330 | 400 | 230 | 1500 |
| 2 | 500 | 270 | 260 | 500 | 270 | 2000 |
| 3 | 200 | 430 | 430 | 200 | 430 | 2500 |
| 4 | 300 | 220 | 270 | 300 | 220 | 7000 |
| 5 | 450 | 500 | 400 | 450 | 500 | 4000 |
| 6 | 650 | 450 | 320 | 650 | 450 | 3000 |
| 7 | 350 | 530 | 330 | 350 | 530 | 4500 |
| 8 | 300 | 700 | 260 | 300 | 700 | 3500 |
| 9 | 500 | 800 | 430 | 500 | 800 | 1500 |
| 10 | 600 | 250 | 270 | 600 | 250 | 2000 |
| 11 | 150 | 500 | 400 | 150 | 500 | 2500 |
| 12 | 250 | 340 | 320 | 250 | 340 | 7000 |
| 13 | 220 | 400 | 250 | 220 | 270 | 4000 |
| 14 | 170 | 300 | 300 | 170 | 300 | 3000 |
| 15 | 420 | 400 | 260 | 420 | 400 | 4500 |

What project selection should your company choose? (You decide what criterion to use, but recall that this is not the Daniels College of Philanthropy.)

~~Where are resources the most constrained? If you had more funds available, where would you put them?~~

~~Can you move resources to improve your outcome?~~

~~What if personnel constraints dictate you may do at most one of projects 11, 12, and 13?~~

*~~Can you think of a scenario where a company might face a decision with this type of data available?~~*

**Production Scheduling**

Your company manufactures printer cases on two different injection molding machines. The M-100 has a capacity of 25 cases per hour, and the M-200 has a capacity of 40 cases per hour.

Both machines use the same chemicals in the manufacturing process; the M-100 uses 40 pounds of material per hour, and the M-200 uses 50 pounds per hour.

Your client has asked you to produce as many cases as possible next week, and they will pay $18 for every case you can deliver.

Unfortunately, you had scheduled maintenance down-time for both of your machines next week, so the M-100 will only be available for 15 hours maximum, and the M-200 will only be available for 10 hours maximum. However, due to the high setup costs, if you run either machine during the week, they must run for a minimum of 5 hours.

The operating costs of the machines are $50/hour for the M-100 and $75/hour for the M-200.

Your chemical supplier has 1000 pounds of chemicals available next week at a cost of $6 per pound.

What is your business decision for next week, and how much profit will it generate?

**Assembly Line Equipment**

Your Company makes five types of metal casings for laptops, and you are in the process of replacing your current equipment with state-of-the-art stamping machines (the RoboI, RoboII, and RoboIII). The machines cost $18,500, $25,000, and $35,000 respectively. Once you program each machine, it can stamp the following number of each type of casing per hour:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Casings Stamped per hour | | |  |  |
| Machines | Type1 | Type2 | Type3 | Type4 | Type5 |
| I | 100 | 130 | 140 | 210 | 80 |
| II | 265 | 235 | 170 | 220 | 120 |
| III | 200 | 160 | 260 | 180 | 220 |

You have the following hourly production demands for each type of casing:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Type1 | Type2 | Type3 | Type4 | Type5 |
| ProdGoal | 3200 | 2500 | 3500 | 3000 | 2500 |

In order to most efficiently meet your production needs, how many of each type of machine should you buy, and what is the total cost?

**Manufacturing and Distribution**

Your company manufactures commercial security locks at four factories in Macon, Louisville, Detroit, and Phoenix. You have seven wholesale distributors in seven cities across the country. The costs of shipping a lock from a factory to a distributor is shown in the following table:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Shipping Costs | | (Dollars per unit) | |  |  |  |  |
| Plants | Tacoma | San Diego | Dallas | Denver | St. Louis | Tampa | Baltimore |
| Macon | 2.5 | 2.75 | 1.75 | 2 | 2.1 | 1.8 | 1.65 |
| Louisville | 1.85 | 1.9 | 1.5 | 1.6 | 1 | 1.9 | 1.85 |
| Detroit | 2.3 | 2.25 | 1.85 | 1.25 | 1.5 | 2.25 | 2 |
| Phoenix | 1.9 | 0.9 | 1.6 | 1.75 | 2 | 2.5 | 2.65 |

The anticipated demand at each distributor for the next year is as follows:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Plants | Tacoma | San Diego | Dallas | Denver | St. Louis | Tampa | Baltimore |
| DEMAND: | 8500 | 14500 | 13500 | 12600 | 18000 | 15000 | 9000 |

The costs (in dollars) of manufacturing a lock at each location, and the annual capacities of each factor, are as follows:

|  |  |  |
| --- | --- | --- |
| Plants | Capacity | Cost/Unit |
| Macon | 18000 | 35.5 |
| Louisville | 15000 | 37.5 |
| Detroit | 25000 | 39 |
| Phoenix | 20000 | 36.25 |

You know you will not fill all of your orders, but you would like to fill at least 80% of the demand at each location. How many locks should be manufactured at each location, and where should they be shipped?

~~If there is any unused capacity at any plant, how should that best be used and distributed?~~

**Crushing More Rocks**

You own a large machine that pulverizes rock, because: “Why Not?” Actually, it’s part of a mining operation where you extract rock from the ground and you crush it into small rocks that can be bundled and sold as construction materials

The materials you sell have four grades: Limestone, Chat, Redi-Mix, and Rough.

Your machine has three settings: Fine, Medium, and Coarse. The following table shows the resulting grades (in tons) produced from one ton of input rock based on the settings, in addition to showing the cost per ton of running the machine on each setting. (You only process rock in one-ton increments.)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Limestone | Chat | Redi-Mix | Rough | Operating Cost/Ton |
| Fine | 0.5 | 0.3 | 0.2 | 0 | $8 |
| Medium | 0.2 | 0.4 | 0.3 | 0.1 | $5 |
| Coarse | 0.05 | 0.2 | 0.35 | 0.4 | $3 |

Your orders for each grade for the next week include 50 tons of Limestone, 60 tons of Chat, 70 tons of Redi-Mix, and 30 tons of Rough. You need to determine how many tons of rock you should process at each setting to most economically meet your demand. However, because of the high cost of reconfiguring the machine, you must process a minimum of 50 tons of rock on a setting if you decide to use that setting.

How many tons of rock should you process on each setting, and what will the total processing cost be for the coming week?

**Hospital Scheduling**

The surgical unit of a small clinic is becoming more concerned about finances. The clinic cannot control or set many of the important factors that determine its financial health. For example, the length of stay in the hospital for a given type of surgery is determined in large part by government regulation. The amount that can be charged for a given type of surgical procedure is controlled largely by the combination of the market and government regulation. The clinic’s surgical procedures are elective (see below), so they have considerable control over which patients and associated procedures are attracted and admitted to the hospital. The surgical unit has effectively two scarce resources, the hospital beds available to it (70 in a typical week), and the surgical suite hours available (165 hours in a typical week). Patients admitted to this surgical unit can be classified into the following three categories:

**Patient Type Days of Stay Surgical Suite Hours Financial Contribution**

Face Lift 3 2 $240

Lipo 5 1.5 $225

Implants 6 3 $425

For example, each Lipopatient admitted will use 5 days of the 7 × 70 = 490 bed-days available each week, and 1.5 hours of the 165 surgical suite hours available each week. One doctor has argued that the surgical unit should try to admit more Face Liftpatients. Her argument is that, “in terms of $/days of stay, Face Lifts are clearly the best, while in terms of $/(surgical suite hour), they are not much worse than Lipoand Implants.”

Suppose the surgical unit can in fact control the number of each type of patient admitted each week (since, clearly, demand from the Kardashian family alone exceeds capacity). How many of each type patient should be admitted each week? What will the profit be?

**Butter**

Quart Industries produces a variety of bottled food products at its various plants. At its Americus plant, it produces two products, peanut butter and apple butter. There are two scarce resources at this plant: packaging capacity and sterilization capacity. Both have a capacity of 40 hours per week. Production of 1000 jars of peanut butter requires 4 hours of sterilizer time and 5 hours of packaging time, whereas it takes 6 hours of sterilizer time and 4 hours of packaging time to produce 1000 jars of apple butter. The profit contributions per 1000 jars for the two products are

$1100 and $1300, respectively. Apple butter preparation requires a boil-down process best done in batches of at least 5000 jars. Thus, apple butter production during the week should be either 0, or 5000 or more jars. How much should be produced this week of each product? What is the profit?

**Pet Food**

Your company manufactures two products, bird food and dog food. You have two departments: blending and packaging. The requirements in each department for manufacturing a ton of either product are shown in hours in the following table:

**Hours per Tons of Product**

**Blending Packaging**

**Bird food** 0.25 0.10

**Dog food** 0.15 0.30

Each department has 8 hours available per day.

Bird food is made from the three ingredients: seeds, ground stones, and cereal. Dog food is made from the three ingredients: meat, fishmeal, and cereal. Descriptions of these five materials are as follows.

**Descriptions of Materials in Percents**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Protein** | **Carbohydrates** | **Trace Minerals** | **Abrasives** | **Cost (in $/ton)** |
| **Seeds** | 10 | 10 | 2 | 1 | 700 |
| **Stones** | 0 | 0 | 3 | 100 | 100 |
| **Cereal** | 3 | 30 | 0 | 0 | 200 |
| **Meat** | 12 | 10 | 1 | 0 | 600 |
| **Fishmeal** | 20 | 8 | 2 | 2 | 900 |

The minimum composition requirements of the two products in percents are as follows:

**Composition Requirements of the Products in Percents**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Protein** | **Carbohydrates** | **Trace Minerals** | **Abrasives** | **Seeds** |
| **Bird food** | 5 | 18 | 1 | 2 | 10 |
| **Dog food** | 11 | 15 | 1 | 0 | 0 |

Bird food sells for $750 per ton while dog food sells for $980 per ton. What should be the composition of bird food and dog food and how much of each should be manufactured each day?

What is the resulting daily profit?

**Employee Scheduling**

You are the manager of an Air-Express hub in Denver, where your company guarantees overnight delivery of packages anywhere in the continental United States. The hub operates seven days a week, and you have collected data over the past fifty-two weeks in order to determine the expected number of packages on any given day. Your research has determined the following:

|  |  |  |
| --- | --- | --- |
| Day |  | *s* |
| Sunday | 14927 | 1021 |
| Monday | 22123 | 1508 |
| Tuesday | 18482 | 1126 |
| Wednesday | 21088 | 1647 |
| Thursday | 19339 | 1812 |
| Friday | 18174 | 952 |
| Saturday | 13180 | 1946 |

You have created histograms of the data, and have determined that the distributions of each day are reasonably “bellish.”

You have decided to hire employees to ensure that you can process the required numbers of packages at least 99% of the time. Each of your employees can process an average of 1000 packages per day.

You hire employees on five-day shifts. Because of contract negotiations, you must pay more to employees who do not get the standard Saturday/Sunday weekends off. The pay schedule for each shift (based on days off) is given below:

|  |  |  |
| --- | --- | --- |
| Shift | Days off | Cost Per |
| 1 | S-M | 680 |
| 2 | M-T | 705 |
| 3 | T-W | 705 |
| 4 | W-Th | 705 |
| 5 | Th-F | 705 |
| 6 | F-Sa | 680 |
| 7 | Sa-S | 655 |

How many employees of each shift do you have to hire?

Where will you end up with excess employees?

On which days are you assuming the most risk? Given that the manager has to fill in when your employees cannot meet the requirements, when do you expect to have to be in at the hub?

**Lockbox Problem**

A major credit card company (call it “MasterDebt”) receives checks from all different regions in the country on a daily basis. Once these checks are mailed, the time a check spends in the mail (called “float”) creates loss for MasterDebt, for as soon as they receive the checks they can cash them and collect interest on the funds. MasterDebt can make 15% annual interest on their cash holdings (since that’s what they charge their customers in credit card interest).

In order to reduce the amount of float loss for these checks, MasterDebt is considering opening “Lockbox” locations across the country where the checks can be received and processed. The locations and the projected annual cost of operations (labor and overhead) at each location are as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ANNUAL COSTS (X$1000) | | |  |  |  |
| Sacramento | Denver | Chicago | Dallas | New York | Atlanta |
| 25 | 60 | 35 | 35 | 30 | 35 |

The average number of days that a check would float between each region and each lockbox location is shown in the following chart.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | AVERAGE FLOAT DAYS | |  |  |  |  |
| REGION | Sacramento | Denver | Chicago | Dallas | New York | Atlanta |
| Central | 4 | 2 | 2 | 2 | 3 | 3 |
| Mid-Atlantic | 6 | 4 | 3 | 4 | 2 | 2 |
| Midwest | 3 | 2 | 3 | 2 | 5 | 4 |
| Northeast | 6 | 4 | 2 | 5 | 2 | 3 |
| Northwest | 2 | 3 | 5 | 4 | 6 | 7 |
| Southeast | 7 | 4 | 3 | 2 | 4 | 2 |
| Southwest | 2 | 3 | 6 | 2 | 7 | 6 |

The average daily payments received from each region are shown in the following chart (in thousands of dollars).

|  |  |
| --- | --- |
| REGION | Payments |
| Central | 45 |
| Mid-Atlantic | 65 |
| Midwest | 50 |
| Northeast | 90 |
| Northwest | 70 |
| Southeast | 80 |
| Southwest | 60 |

The annual interest lost can be computed for each region-lockbox location by taking the average daily payments times the float time and multiplying by fifteen percent. For example, if payments from the Central region are sent to New York, then on any given day there is an average of $135,000 of undeposited checks, which costs MasterDebt $20,250 annually in interest.

Where should MasterDebt open lockbox locations in order to save the most money each year?

Which regions should be assigned to those lockbox locations?

**Farming**

You operate three farms in Colorado. The acreage and irrigation water available for the three farms are shown below:

**Water Available**

**Farm Acreage (acre feet)**

1 400 1500

2 600 2000

3 300 900

Three crops can be grown. However, the maximum acreage that can be grown of each crop is limited by the amount of appropriate harvesting equipment available. The three crops are described below:

**Total**

**Harvesting Water Expected**

**Capacity Requirements Profit**

**Crop (in acres) (in acre**-**feet/acre) (in $/acre)**

Milo 700 6 400

Cotton 800 4 300

Wheat 300 2 100

If any combination of crops can be grown on each farm (within the constraints) then what should you plant on each farm? What will the resulting profit be?

**Inventory Management**

Your company keeps fleets of vehicles at a number of sites around the country. At each site the vehicles can be classified into two types: light and heavy. A heavy vehicle costs more per day, but it can do any task that a light vehicle can do. You would like to determine what mix of vehicles your company should have at each site. If you do not have enough vehicles of the appropriate size to meet the demand on a given day, you must rent the vehicles. Some cost data were collected on the cost of various vehicle types:

**Vehicle Type Daily fixed cost Daily variable cost (if used)**

Owned Light $32 $40

Owned Heavy $44 $54

Rented Light 0 $175

Rented Heavy 0 $225

At a particular site, your company collected demand data for the number of vehicles required on each of seven days:

**Day Lights Heavies**

1 6 0

2 3 2

3 5 4

4 8 3

5 2 1

6 4 4

7 1 2

Based on just the above data, what is your recommendation for the number of vehicles to own of each type at this site? What is your weekly cost?

**Inventory Depletion**

The R. R. Bean Company produces, packages, and distributes freeze-dried food for the camping and outdoor sportsman market. R. R. Bean is ready to introduce a new line of products based on a new drying technology that produces a higher quality, tastier food, so they want to discontinue their current line. The basic ingredients of the current line are dried fruit, dried meat and dried vegetables. There are two products in the current line: the "Weekender" and the "Expedition." In its close-out catalog, the selling prices of the two products are $3.80 and $7.00 per package, respectively. Handling and shipping costs are $1.50 per package for each package, which are provided at no charge. The "Weekender" package consists of 3 ounces of dried fruit, 7 ounces of dried meat, and 2 ounces of dried vegetables. The "Expedition" package has 5 ounces of dried fruit, 18 ounces of dried meat, and 5 ounces of dried vegetables. R. R. Bean would like to deplete its inventories of "old technology" fruit, meat, and vegetables before introducing the new line. The current inventories are 10,000 ounces, 25,000 ounces, and 12,000 ounces respectively of fruit, meat, and vegetables. The book values of these inventories are $2000, $2500, and $1800. Any leftover inventory will be given to the local animal shelter at no cost or benefit to R. R. Bean. R. R. Bean is confident that it can sell all that it makes of the two products. What combination of current products should they produce to sell?

**Son of Employee Scheduling**

Your agency provides telephone consultation to the public from 7 a.m. to 8 p.m., five days a week. The telephone load on your agency is heaviest in the months around April 15 of each year. You would like to set up staffing procedures for handling this load during these busy months. Each telephone consultant you hire starts work each day at either 7, 8, 9, 10, or 11 a.m., works for four hours, is off for one hour, and then works for another four hours. A complication that has become more noteworthy in recent years is that an increasing fraction of the calls handled by your agency is from Spanish-speaking clients. Therefore, you must have some consultants who speak Spanish.

You are able to hire two kinds of consultants: English-speaking only, and bilingual (i.e., both

English- and Spanish-speaking). A bilingual consultant can handle English and Spanish calls equally well. It should not be surprising that a bilingual consultant costs 1.1 times as much as an

English-only consultant. You have collected some data on the call load by hour of the day and language type, measured in consultants required, for one of your more important offices. These data are summarized below:

**Hour of the day:** 7 8 9 10 11 12 1 2 3 4 5 6 7

**English load:** 4 4 5 6 6 8 5 4 4 5 5 5 3

**Spanish load:** 5 5 4 3 2 3 4 3 2 1 3 4 4

For example, during the hour from 10 a.m. to 11a.m., you must have working at least three

Spanish-speaking consultants plus at least six more who can speak English.

How many consultants of each type would you start at each hour of the day?

**Multi-Period Planning**

The Toute de Suite Candy Company includes in its product line a number of different mixed nut products.

The Chalet nut mix is required to have no more than 25 percent peanuts and no less than 40 percent almonds. The Chalet mix sells for 80 cents per pound.

The Hovel mix can contain no more than 60 percent peanuts and no less than 20 percent almonds. Hovel sells for 40 cents per pound.

At most, 700 pounds can be mixed per month.

The nuts available, their prices, and their availabilities this month are as follows:

**Nut Price Availability**

Peanuts 20¢/lb. 400 lbs.

Walnuts 35¢/lb. No limit

Almonds 50¢/lb. 200 lbs.

The expected situation next month is:

**Nut Price Availability**

Peanuts 19¢/lb. 500 lbs

Walnuts 36¢/lb. No limit

Almonds 52¢/lb. 180 lbs.

Next month you anticipate Chalet to sell for 81¢/lb, and Hovel to sell for 39¢/lb.

It cost 2 cents per pound to store nuts (plain or mixed) for one month. Because of a contract commitment, at least 200 pounds of Chalet mix must be sold next month.

What is your business decision? What is the associated profit?

**Snow Removal**

The city of Montreal maintains five snow-removal sites, where snow may be dumped after being collected from ploughed streets. (Due to environmental constraints, dumping directly to the rivers is not an option.) The annual capacities for the five sites (in 1000s of cubic meters) are as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SITE: | A | B | C | D | E |
| Capacity | 350 | 250 | 500 | 400 | 200 |

Montreal is divided into ten sectors for the purpose of snow removal. The distances in Km (measured from the center of each sector) to the five dump sites are given in the following table:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | DISTANCES | A | B | C | D | E |
| Zones | 1 | 3.4 | 1.4 | 4.9 | 7.4 | 9.3 |
|  | 2 | 2.4 | 2.1 | 8.3 | 9.1 | 8.8 |
|  | 3 | 1.4 | 2.9 | 3.7 | 9.4 | 8.6 |
|  | 4 | 2.6 | 3.6 | 4.5 | 8.2 | 8.9 |
|  | 5 | 1.5 | 3.1 | 2.1 | 7.9 | 8.8 |
|  | 6 | 4.2 | 4.9 | 6.5 | 7.7 | 6.1 |
|  | 7 | 4.8 | 6.2 | 9.9 | 6.2 | 5.7 |
|  | 8 | 5.4 | 6 | 5.2 | 7.6 | 4.9 |
|  | 9 | 3.1 | 4.1 | 6.6 | 7.5 | 7.2 |
|  | 10 | 3.2 | 6.5 | 7.1 | 6 | 8.3 |

Using historical snowfall data, the following amounts of snow (X1000 m3 can be anticipated for each sector:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Amount | 153 | 152 | 154 | 138 | 127 | 129 | 111 | 110 | 130 | 135 |

It costs $0.10 to transport one cubic meter of snow one Km.

If union restrictions require that the snow from each zone may only be dumped at one site, what is the least amount Montreal will have to spend on snow removal?

**Network Flow** (and the Excel Dashboard)

The U.S. natural gas pipeline network is a highly integrated transmission and distribution grid that can transport natural gas to and from nearly any location in the lower 48 States. The natural gas pipeline grid comprises:

* More than 210 natural gas pipeline systems.
* 305,000 miles of interstate and intrastate transmission pipelines.
* More than 1,400 compressor stations that maintain pressure on the natural gas pipeline network and assure continuous forward movement of supplies.
* More than 11,000 delivery points, 5,000 receipt points, and 1,400 interconnection points that provide for the transfer of natural gas throughout the United States.
* 24 hubs or market centers that provide additional interconnections.
* 400 underground natural gas storage facilities.
* 49 locations where natural gas can be imported/exported via pipelines.
* 8 LNG (liquefied natural gas) import facilities and 100 LNG peaking facilities.

This project will only analyze a miniscule subset of this massive system, focusing on only one of the local networks. It will, however, use the same techniques that are used to solve the Nation’s LNG network flow problem on a constant basis.

Old Dominion Energy’s pipeline network between its natural gas depots allows it to transport gas between eleven different storage facilities for use in power generation. Flow among the pipes is bi-directional. The transmission capacities of the pipes range from 10,000 cubic feet per day to 50,000 cubic feet per day.

These are costs associated with shipping LNG along the pipelines, where the costs range from $.28 per 1000 cubic feet to $.52 per 1000 cubic feet.

When ODE has a need for LNG at one of their locations, they look for excess capacity at their other locations, and then must determine if it is economical to meet the demand by shipping along their pipeline system. This is based on what the receiving locations are willing to pay (per 1000 cubic feet) and what the costs will be to ship through the pipeline system.

If it is economical to ship the gas, then the optimal path may be determined in order to maximize profit.

Figure 1 shows the pipeline system, with the pipeline capacities (X 1000 cubic feet) and the costs (in dollars per 1000 cubic feet) to transport gas along the pipelines.

[HINT: You may want to start by building pipeline capacity and transportation cost data tables into a spreadsheet for use in your profit optimization model.]

[HINT: It may be useful to model nonexistent pipelines as having capacity = 0.]

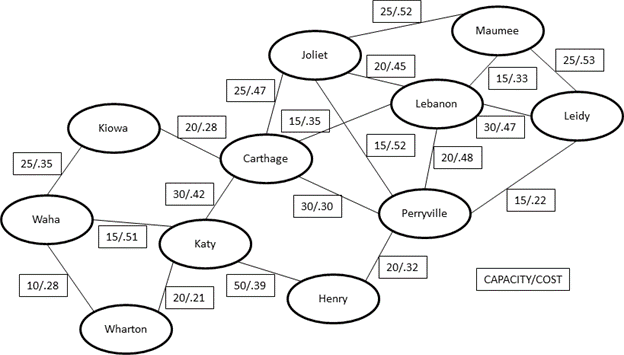


Figure 1. ODE LNG Network with Capacities and Costs

**REQUIREMEN**T: Build an Excel “Dashboard” that ODE can use to determine whether or not they should meet a demand with their own pipeline system and unused capacity, and what set of pipes and stations they should use to transport the gas. The Dashboard should have the following characteristics:

1. Gas demands should be entered for each station (in 1000 cu. ft.).

2. Excess capacity should be entered for each station (in 1000 cu. ft.).

3. The price each station is willing to pay should be entered (in $/1000cuft).

4. The Dashboard should include instructions for implementing the Excel Solver to obtain a solution.

5. The output should include the profit achieved by transporting the gas.

6. The output should include the pipelines used and amounts to be transported along each pipeline.

7. The output should include any unmet demand.

Use the dashboard to solve the following scenario:

ODE currently has 100,000 cf of gas in storage at Katy. Customers in Joliet are willing to pay $4.35 per thousand cf for up to 35,000 cf of gas, and customers in Leidy are offering $4.63 per thousand cf for up to 60,000 cf of gas.