**TESTBANK**

*Management Science: The Art of Modeling with Spreadsheets*

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**Model Building Problems**

1. **Benefits and Costs in a Hospital Merger**

The St. Mary (‘Mary’) and Mt. Sinai (‘Sinai’) hospitals are planning to merge. Together, they must design a new employee benefits plan that will cover all employees in the merged hospital. To save on administration costs, they have decided to adopt for the entire merged hospital *either* Mary’s plan *or* Sinai’s current plan.

The table below shows that Sinai’s average benefits are more generous than Mary’s. For example, an employee *with* a family receives, on average, $550 in annual benefits under Mary’s plan and $830 in benefits under Sinai’s plan. In total, the employee with a family would receive an average of $550+$90+$40+$15=$695 under Mary’s plan and significantly more under Sinai’s. Overall, 65% of all employees at both hospitals enroll under a family plan and the remainder enrolls under the individual plan.

|  |  |  |  |
| --- | --- | --- | --- |
| Benefit category | Type of employee | Mary | Sinai |
| Medical | Individual | $300 | $400 |
|  | Family | $550 | $830 |
| Dental |  | $90 | $85 |
| Life Insurance |  | $40 | $80 |
| Disability Insurance |  | $15 | $15 |

**Average annual benefits costs, per employee, for current plans**

The table displays average benefits, but either decision will significantly reduce benefits for some employees. Mary has 1200 employees, and if Sinai’s plan is adopted then 12% of Mary’s employees are expected to leave because of the reduction in benefits. Sinai has 750 employees, and if Mary’s benefits are adopted then 30% are expected to leave Sinai. On average, it will cost $45,000 to replace an employee who leaves either hospital. Replacement employees are similar to current workers: average costs are equal to those in the table and 65% enroll in a family plan.

The hospitals would like to assess the total cost over the next 8 years of applying each plan to the entire merged hospital. Assume that the following events will occur now: the new plan is announced, some employees leave because of a reduction in benefits, and these employees are immediately replaced. Then, the costs described in the table above will be booked after 1 year. During years 2-8, total benefits costs will grow by 8% annually. Management uses a discount rate of 5%.

Build a spreadsheet model to answer the following questions.

1. Which benefits plan has the lower cost (expressed as an NPV)? Plan: \_\_\_\_\_\_\_\_  
   NPV of the lower-cost plan: $\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. At what growth rate in benefits costs do the two plans have an equal NPV? \_\_\_\_\_\_\_%

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1. **Assortment Planning at Skihaus**

Skihaus is a retail chain that specializes in the sales of Alpine skis. Skihaus sells its own brand of skis in three styles: S, DX and LX. The three skis cost Skihaus $260, $400, and $480, respectively, to purchase from the manufacturer. Throughout the selling season the chain will sell them to consumers for $300, $450, and $550, respectively. At the end of the season if the skis are not sold then they will be sold to a liquidator for $50, $230, and $290. Skis are purchased from the manufacturer once, before the selling season.

Skihaus has identified two distinct segments of customers who purchase from the store: early buyers who prefer top-of-the-line skis (*Earlies*) and bargain-hunters (*Bargains*). As their name implies, Earlies arrive first in the season, and you may assume that *all* Bargains arrive at the end of the season, after all Earlies.

The two segments have different preferences for skis. Earlies prefer to buy LX skis. If LX skis are sold out, they will always buy DX skis, and if LX and DX skis are sold out, Earlies will always buy S skis. Bargains prefer S, then DX, and will not buy LX skis. Assume each customer buys one pair of skis.

Skihaus expects to see 5,000 buying customers during the season, of which 60% are Earlies and 40% are Bargains. Skihaus’ purchasing manager plans to begin its season with 1,300 LX skis, 2,200 DX skis and 1,900 S skis, but she is considering alternate order quantities.

1. Build a spreadsheet model that *evaluates* the base-case plan described above. You are not expected to optimize this model. The model should be flexible, allowing all of the parameters and decisions to change. You may, however, assume here that the *preferences* described above for each market segment will not change (e.g., you may assume in your calculations that Earlies will always prefer LX to DX to S).  
     
   Objective function value of your model: $\_\_\_\_\_\_\_\_\_\_\_\_\_
2. In the real world, customer preferences can be uncertain. Market research may show, for example, that Earlies really prefer DX to S and will not buy LX. Take your model from part (a), copy it to a new worksheet, and change it so that customer preferences can be updated easily. In other words, parameterize customer preferences.  
     
   Once you have built the model, find the objective function value with all parameters the same as in part (a) except that Earlies now prefer DX to S and will not buy LX: $\_\_\_\_\_\_\_\_\_\_\_\_\_

**3. Evergreen College Endowment**

Evergreen College holds an endowment currently worth $700 million (an endowment is a permanent fund of money that generates income and also can be used to pay for projects). The Chief Investment Officer of the endowment has hired you to predict the performance of the endowment over the next 10 years.

Given the current investment strategy, money invested in the endowment is expected to grow by 8% per year. Over the next 7 years, Evergreen’s development office is running a major capital campaign among its alumni. During the entire 7-year campaign the college expects to collect a total of $300 million in contributions that will be added to the endowment, although the campaign may collect a total as low as $150 million and as high as $400 million.

A portion of the endowment is also spent each year to support ongoing activities at the college (this is called the *draw*). During this past year, the draw was $65 million. During the next ten years the draw in each year will be calculated according to a formula that is the sum of two terms: (i) 70% of the *previous year’s* draw and (ii) a certain percentage (*p*) of the value of the endowment at the beginning of the year. This percentage *p* depends on the level of the endowment itself, and is given in the following table:



For example, if the endowment is $650 million at the beginning of the year, then the draw is equal to (70%)\*(previous year’s draw) + (2%)\*($650 million).

a. Assume that the capital campaign collects $300 million.

Build a spreadsheet to calculate the value of the endowment after the next 10 years. Your spreadsheet will be graded both for its technical correctness and for its adherence to the principles of spreadsheet engineering. Note that documentation of each calculation is not required, nor is extensive formatting for appearance. *However, if you need to make any assumptions beyond the problem description given above, you should include an explanation of these assumptions at the top of the spreadsheet.*

Endowment value at the end of year 10: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. In addition to the draw, the college mayspend part of the endowment for a new science building. The decision to begin spending and construction for the building in any particular year depends on two goals being met: (i) the capital campaign reaching at least $200 million by the beginning of the year and (ii) the total endowment reaching at least $800 million by the beginning of the year. If and when both these goals are met, then the college will spend $50 million from the endowment during the first year of construction and $60 million during the second, for a total building cost of $110 million. If the two goals are not met during the 10 years then the building will not be built.

Copy your model from part (a) onto a new worksheet and then extend the model to include this new information. Again, if you need to make any assumptions beyond the problem description given above, you should include an explanation of these assumptions at the top of the spreadsheet.

Given the parameters described above, including those in part a, find the value of the endowment after the next 10 years.

Endowment value at the end of year 10: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Now suppose that the capital campaign collects only $150 million. What is the final endowment value?

Endowment value at the end of year 10: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Now suppose that the capital campaign collects $300 million, but that the initial endowment value is only $250 million. What is the final endowment value?

Endowment value at the end of year 10: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**4. Kurbe Marketing Research**

Kurbe Marketing Research (KMR), located in Boston, specializes in marketing research in the consumer goods industry. Each year KMR conducts hundreds of research studies for a variety of clients utilizing focus groups, internet surveys and telephone surveys. KMR is currently studying the resources it dedicates to telephone surveys.

Demand for KMR’s telephone research varies throughout the year. KMR conducts the vast majority of its research in-house, but if it cannot handle all of the work at peak demand times, it is forced to subcontract some of the phone interviewing, which results in a lower profit margin. Also, outsourcing the phone interviews means that KMR loses some control of the process. This can result in problems such as missed deadlines and a decrease in quality. However, dedicating enough resources to ensure no outsourcing would not be very efficient, since it would result in more costs and decreased productivity due to idle time during slower periods. Nonetheless, based on the recent amount of outsourcing, KMR management feels that the company has too few operators conducting telephone survey research. You have been assigned the task of studying this problem and making a recommendation.

The annual fixed costs (management, facilities and other overhead charges) associated with the telephone survey group are $320,000. Every operator needs a computer-assisted telephone interviewing station (known as a CATI). Currently KMR has 48 CATIs and they are considering purchasing additional ones this year. Of the 48 CATIs currently on hand, 16 per year will be replaced each year for the next 3 years. New CATIs will not need replacement over this time period.

The purchase cost of a CATI is $36,000 and is likely to remain stable for the next 3 years. The cost of an operator (one per CATI) per month is $2,200. Assume that only additional CATIs (beyond the current number of 48) require training (replacement CATIs do not since they already have operators).

The time frame for the study is the next three years. Demand varies by month and forecasted demand for the coming year is shown in the table below (demand is expressed in dollars of revenue). A CATI can handle approximately $12,000 of work per month. Demand is expected to grow by 10% per year (the forecasted amounts in the table have already factored this in for next year). Assume that each month’s demand will grow by this amount in years 2006 and 2007. This increase in revenue will come from increased volume of work rather than increases in pricing (the forecast assumes stable pricing).

**Month Demand ($000)**

January $890

February $820

March $575

April $860

May $695

June $330

July $740

August $700

September $255

October $750

November $170

December $160

***Forecasted demand (in dollars of revenue) for 2005***

Management is looking for the best level of in-house operation (number of CATIs). KMR receives 15% of the revenue for the work that is outsourced to an outside vendor. Finally, for studies such as this, KMR uses an annual discount rate of 10% and their tax rate is 34%.

a. Build a spreadsheet to help KMR analyze this situation. In your base case, evaluate the NPV of net income after taxes assuming KMR maintains 48 CATIs in all years.

You may use the following page to sketch your spreadsheet (although your sketch will not be graded). Your spreadsheet will be graded both for its technical correctness and for its adherence to the principles of spreadsheet engineering. Note, however, that documentation is not required, nor is extensive formatting for appearance.

b. Construct a graph on a separate sheet in your workbook to show the sensitivity of the NPV of net income after taxes to the number of CATIs. Sketch your results here, showing numerical scales for the horizontal and vertical axes, and clearly identify the optimal number of CATIs.

c. In the base case (with 48 CATIs) how much lower does KMR’s tax rate have to be to increase the NPV of net income after taxes by 10%?

**Database Analysis**

**1. The Population Database**

*Note*: To answer this question you will need to use the database *PopulationData.xlsx*, which shows U.S. state populations from 1990 to 1999.

a. Which state(s) had a 1990 population less than 5 million and a 1999 population more than 5.5 million?

b. Which state had the largest *absolute* growth in population over the period 1990-1999?

c. Which state had the largest *relative* (percentage) growth in population over the period 1990-1999?

d. By how many more people has the average of the population of the 50 states grown from 1995-1999?

**2. The Tissues Database**

*Note*: To answer this question you will need to use the database *TissueData.xlsx*, which describes

purchases of bathroom tissues at stores in a grocery chain over a period of several weeks.

a. What was the total number of cases sold for all brands over this period (calculate a single, grand total)?

b. What was the total number of cases sold by Kleenex over this period?

c. What was the total number of cases sold by Kleenex in Size 12 over this period?

d. Which brand had the highest total number of *rolls* sold over this period? Also state the number of rolls.  
 brand: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
   
 number of rolls: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**3. The Airline Ticket Database**

The file *TicketData.xlsx* contains a random sample of one-way airline tickets from the first quarter of 2006. Each record represents one ticket. Note that a single ticket may allow multiple passengers to fly (e.g., these ‘tickets’ may be bulk purchases by corporations and travel agencies). Copy this database to a clean worksheet and use it to answer the following questions.

a. List the 3 highest MARKET\_FARES for tickets operated by DL.

b. List the MARKET\_FAREs of all tickets operated by Delta (DL) from LAX to SAV.

c. How many tickets have UA as the OPERATING\_CARRIER and a MARKET\_DISTANCE greater than 2200 and less than 2400?

d. What combination of TICKET\_CARRIER and DISTANCE\_GROUP has the most tickets in the database?

e. For each DISTANCE\_GROUP, find the maximum MARKET\_FARE.   
  
f. Estimate the average MARKET\_DISTANCEs in DISTANCE\_GROUP 4 and in DISTANCE\_GROUP 5. If you have to make any assumptions when calculating these averages, then state them below.

g. Find the average revenue *per passenger* for each DISTANCE\_GROUP.

**4. The Rental Truck Database**

The file *TruckData.xlsx* contains repair data on 1884 rental trucks. Copy this database to a clean worksheet and use it to answer the following questions.

a. How many months old is the oldest vehicle?

b. How many *distinct* types of transmission manufacturers are represented in the database?

c. List the vehicle numbers for all the trucks from vehicle manufacturer B.

d. What is the odometer reading for all trucks with a gear ratio over 4.0, age less than 60, and transmission J?

e. What is the average odometer reading for all records in the list?

f. Which transmission manufacturer has the highest average odometer reading?

g. Which transmission manufacturer has the lowest average odometer reading for gear ratios of 3.90?

h. Which transmission manufacturer has the highest maximum age?

i. Create (and record below) a table for the maximum age by transmission manufacturer and engine manufacturer (exclude blanks.)

**5. The IPO Database**

The file *IPOdata.xlsx* contains raw data on 78 IPOs (Initial Public Offerings of stock) issued between 1994 and 1999. Copy this database to a clean worksheet and use it to answer the following questions.

a. What is the average revenue, *by underwriter*, for the IPO year (REV IPO YR-0) and for the following year (REV IPO YR-1)?

Average Revenue

Underwriter YR-0 YR-1

b. What was the net income in the IPO year (NI IPO YR-0) for the five smallest IPOs in terms of the number of employees?

Net Income

1

2

3

4

5

c. Among IPOs issued in 1999, which one had the largest difference between the high and low ranges *as a percent of the actual price*?

d. How many IPOs were issued by *either* Chase or Goldman in 1996?

**Sensitivity Analysis and Bugs**

**1. Medical Supplies for Banjul**

You are the team leader of a unit of a US non-profit organization based in Banjul, Gambia. The non-profit’s mission is to ensure that rural populations worldwide have access to health and sanitation-related supplies. Due to the sudden departure of one of your team leaders, you are taking over the responsibility for ordering certain medical supplies for three villages.

The spreadsheet *Banjul.xlsx* has been built to assist in ordering supplies for five products listed in column A. Columns B and C give the number of items per package and the cost per package. Columns D-G give the number of items needed per person for four population groups and the number in each of those groups.

The results are calculated starting in column I. Columns I and J determine the number of each item and the number of packages needed, respectively. Columns K and L give the number currently in stock (currently set at zero for all items) and the number that need to be ordered. Costs are calculated in column M and totaled in cell M10.

**Note:** each question should be answered independently of the others, *starting with the base case for each question*.

a. How many *additional* Other Adults (over the current 9000) could be added to the population before the total cost would exceed $7,000?

b. A check of the stock on hand shows an inventory of 124 packages of A-bandages, 16 packages of B-bandages, 82 packages of C-bandages, 72 rolls of tape, and 4 hearing aids. What amounts will be required for ordering supplies?

A bandages \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

B bandages \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

C bandages \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Tape rolls \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Hearing aids \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c. Construct a table showing how the total cost for the order would vary if the unit cost of a package of *all three* types of bandages rose by $0.25, $0.50, and so on, up to $3.00 per package.

d. This model uses 23 parameters in the range B4:G10. If each one were to vary by 15% around its base case value, which *three* would have the biggest impact on total costs?

e. Assume that the population of Children varies around its base case value by 15%, the population of Teens varies by 10% and the population of Seniors by 5%. List the size of the ranges of the Total Cost of Order (the distances from the bottom of the range to the top, in $) as each of these parameters varies.

Children \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Teens \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Seniors \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**2. MediDevice**

A U.S. medical device manufacturer, MediDevice Inc., has developed a new blood analyzer for rapid in-the-doctor’s-office testing. The much-anticipated device will receive final regulatory approval in time for a January 2005 launch. MediDevice has the next 12 months to work out the details for their commercial plans. The date for the analysis is January, 2004.

This device is revolutionary and has worldwide appeal; target markets are U.S., Europe and Japan.

Demand for this product is driven by the fraction of doctor offices adopting the technology. Forecasts indicate 10% of doctor offices in any country would potentially adopt this type of device. The time it takes to achieve this technology adoption (starting from 0% adoption) is expected to be 2-5 years, depending on factors including the effectiveness of the sales force in each country.

Each office would buy only one analyzer, but once an office buys the analyzer MediDevice receives recurring revenue from each office from royalties on analyzer supplies (sold by a third party). These annual royalty revenues will continue until MediDevice's analyzer is displaced by next-generation technology.

MediDevice expects to be first to market but a major Japanese competitor is working on a superior next-generation device. When this competitive device hits the market (a number of years away), it will most likely displace the MediDevice analyzer from a portion of MediDevice's installed base of doctor's offices – but some of the installed base will continue in use until third-generation competitive devices ultimately take over the entire market.

The MediDevice board has commissioned you to perform a cash flow analysis of this new device. Their assessments of the key parameters are summarized below.

Market size

U.S. doctor’s offices 600,000

Europe doctor’s offices 450,000

Japan doctor’s offices 140,000

Taxes, depreciation, and discounting

Tax rate 40%

Depreciation straight line over 10 years

Discount rate 10%

Market penetration

Launch year 2005

Peak year 2009

Initial share 0%

Peak share 10%

Note: Market share is expected to rise linearly from the Launch Year to the Peak Year and remain constant thereafter until new products arrive in the market.

Second generation technology

Entry year 2010

Share of installed base captured 30%

Third generation technology

Entry year 2014

Share of installed base captured 100%

Price controls

Date introduced 2008

Price reduction 10%

Note: The regulatory authorities are expected to introduce price controls on this device sometime in the future.

Prices

Device $10,000 per device

Royalty on Supplies $1,000 per year

Costs

Unit manufacturing $4,000 per unit

Sales force $15 million

US plant cost $25 million

Rest of world plant cost $20 million

The spreadsheet model is in *MediDevice.xlsx*. In the model, cash flows in each column occur at the end of the year.

This question is in two parts. In Part A you will *take the model as given* and perform sensitivity analyses on it. Do NOT alter the model for Part A. In Part B you will identify bugs in the model.

**Part A:**

Note: In *each* of the following questions you are to *start with the base case model*.

a. Sketch the relationship between the deprecation lifetime and the NPV. Consider values for the depreciation lifetime between 5 and 15 years. Show the exact numerical values for lifetimes of 5 and 15 years on your sketch.

b. Sketch the relationship between the unit manufacturing cost and the NIAT in Year 2009. Consider values for the unit manufacturing cost between $1 and $10. Show the exact numerical values for costs of $1 and $10 on your sketch.

c. Vary the discount rate between 5 and 15% and the peak share for market penetration between 0 and 10%. Describe business insights about the device that you learn from the results.

d. Vary all parameters in the model *except the dates* by +15%. List below the *three* parameters that have the strongest impact on the NPV.

**Part B:**

The model as currently built has a number of bugs. Your task in this part is to find these bugs. The *only* types of bugs you are to look for include:

*wrong input*: a numerical input does not correspond to the problem description

*hard-coded input*: the numerical value of an input appears in a formula (this excludes the value zero in a cell)

*wrong reference:* a formula uses an incorrect cell reference (i.e., points to the wrong cell)

*logic:* a formula is used incorrectly.

You should assume the *accounting logic* of the model is correct unless it explicitly contradicts the problem statement. Thus, for example, negative taxes are allowable in row 81.

List the cell address or addresses of the bugs you find below and give a brief explanation of *why* it is an error and *how* you would fix it.

**Cell Address(es) Explanation and Fix**

Etc…

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**3. Finding bugs in the Material X model**

Open the workbook *MaterialBugs.xlsx.*

This model was built to estimate the market potential for a consumer product that uses Raw Material X as a key ingredient. Unfortunately, this model has bugs.

You may assume that the three supporting worksheets (Market Share Projections, Market Data, and Price Data) are error-free. All the bugs are on the Model worksheet.

There are three *types* of bugs in this worksheet:

*Reference errors*: a formula refers to the wrong cell or cells

*Hard-copy errors*: a formula contains a number that appears as a parameter elsewhere

*Logic errors*: a formula uses faulty logic

Identify all the bugs and fix them as you go. List them below, giving the cells involved, the type of bug, and a short description of how you fixed the bug.

**Cell Location(s) Type of bug Fix**

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**Note:** The number of lines does not necessarily reflect the number of bugs.

Once you have made your changes and the spreadsheet is correct, what is the NPV in cell C10?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**4. Capacity model with bugs**

*Your task in this question is to identify all the bugs in a spreadsheet built for you. (Note: a “bug” here refers to an error that causes the spreadsheet to return the wrong value of the output, not a poor choice of layout or format or other poor practices. A bug can involve an error in the data or an error in a formula.) The situation being modeled is described below. You may assume that the accounting in the model is conceptually correct.*

Lang Drug needs to determine the proper capacity level for a new drug, Niagara. Their goal is to maximize the expected NPV earned from the drug over the next 15 years, assuming a discount rate of 10 percent per year. It costs $10 to build enough capacity to produce one unit of drug per year. All construction costs are assumed to be paid at time 0, while the first profits come in at the end of the first year. It costs $1 per year to maintain a unit of annual production capacity. In year 1, we know demand will be for 160,000 units of Niagara. The annual percentage growth of demand for Niagara is 15 percent. During year 1, each unit of Niagara sells for $8. The price of Niagara will grow at 5 percent per year. Unit variable cost is known to be 40 percent of sales price. The depreciation rate is 10 percent and the tax rate is 35 percent.

1. Copy the spreadsheet *CapacityBugs.xlsx* to a worksheet in your own exam workbook. Identify all the bugs and fix them as you go (this will help you to find them all). List them below, giving the cells involved and a short description of how you fixed the bug.

**Bug Cell Location(s) Fix**

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Note: The numbers of lines does not necessarily reflect the number of bugs.

1. Once you have made your changes and the spreadsheet is correct, what is the NPV?

NPV of corrected model \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**5. Sensitivity analysis for the Northern Museum**

The model *Museum.xlsx* is a prototype planning model for a small regional museum. The model projects revenues, costs, operating surplus/deficit and the endowment out to 2014, based on 2003 and 2004 actuals and assumed growth rates. The most important outcome measure is the level of the endowment in 2014, cell N39.

Copy this model to your computer and use it to answer the following questions. You may assume this model is logically correct. Write in the answers here and also document the answer to each of the questions on a separate worksheet.

Note: each question should be answered independently of the others, starting with the base case.

a. The model is based on 16 parameters in column D. Which *four* have the biggest impact on the outcome? (To answer this question, you should assume that each parameter can vary by plus or minus 10% of its base case value.) List them here in order of importance.

Parameter

1

2

3

4

b. Assume that all 10 growth rates for revenues can vary by +/- 20%, the five cost parameters by +/- 10%, and the interest rate parameter by 15%. Which *four* have the biggest impact on the outcome? List them here in order of importance.

Parameter

1

2

3

4

c. What interest rate (cell D38) would the Museum have to earn to ensure that the endowment in 2014 was equal to its value at the end of 2003?

d. One faction on the Museum Board is concerned about the vulnerability of the endowment to the interest rate. Sketch a graph that will show how the endowment value in 2014 changes as the interest rate varies from a low of 0% to a high of 15%. For grading purposes, clearly label the numerical values at 0% and 15%.

e. Another faction of the Board is interested in ensuring that the endowment in 2014 exceeds $3 million. Create (and record below) a table which shows the *combinations* of the growth rate in municipal grants (cell D11) and the interest rate (cell D38 that will bring this result about? (Each parameter can vary between 0 and 15%).

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**6. Office Building with bugs**

*Your task in this question is to identify all the bugs in a spreadsheet built for you. (Note: a “bug” here refers to an error that materially changes the results of the spreadsheet, not a poor choice of layout or format. A bug can involve an error in the data or an error in a formula.) The situation being modeled is described below. You may assume that the accounting in the model is conceptually correct.*

The objective of this model is to predict the after-tax cash flow resulting from constructing and operating an office building over a five year period. At a planned size of 180,000 square feet, the expected cost is $80 per square foot. The investors plan to take out a mortgage for 85 percent of the cost of the building (paying the remainder in cash), and they have been guaranteed a rate of 12 percent for a term of 30 years. The owners must pay for the cost of operating the building, which includes taxes, insurance, maintenance, and certain utilities. They assume that the average operating cost per square foot will be $1.20. They have also estimated the rental rate they can charge is $15 per square foot, with an occupancy rate of 70%. The building has a depreciable life of 20 years; the effective tax rate is 34%; the discount rate is 10%. Rents in the future are expected to grow 5% per year, while operating expenses grow 10% and the occupancy rate drops 4 percentage points yearly as the building ages.

Copy the spreadsheet *OfficeBugs.xlsx* to a worksheet in your own exam workbook. Identify all the bugs and fix them as you go (this will help you to find them all). List them below, giving the cells involved and a short description of how you fixed the bug.

**Bug Cell Location(s) Fix**

1

2

3

etc.

**7. Sensitivity analysis of EToys**

The model *EToys.xlsx* forecasts the total net income over four years (cell H30) from a new product. Copy this model to your computer and use it to answer the following questions. You may assume this model is logically correct. Write in the answers here and also document the answer to each of the questions on a separate worksheet. Note: each question should be answered independently of the others, starting with the base case.

a. The model is based on 16 parameters. Which *four* have the biggest impact on total net income? (To answer this question, you should assume that each parameter can vary by plus or minus 25% of its base case value.)

Parameter

1

2

3

4

b. How high would we have to set the initial sales price if our goal was to achieve a total net income of $5,000,000? (Answer to the nearest penny.)

c. How much would we have to increase the price in year 4 in order to increase the total net income to $3,000,000? (Answer to the nearest penny.)

d. Imagine that unit sales increase by the same percentage in years 2, 3, and 4. Sketch the graph of total net income as the unit sales increase varies from 10 to 20% in steps of 1%. Label the first and last values clearly (that is, to the nearest dollar).

**Optimization Problems**

1. **Optimizing a Portfolio of Assets**

One of the most common applications of optimization in finance involves selecting optimal portfolios. An optimal portfolio is one that maximizes overall return while satisfying constraints that represent the investor’s attitude toward risk.

The accompanying spreadsheet *Assets.xlsx* contains data on the annual percentage return on stocks, gold, and Treasury bills over the period from 1987 to 2007. A certain investor would like to determine the percentages of her portfolio to invest in these three asset categories. Her objective is to maximize the expected return on the portfolio while not investing less than 20% or more than 50% in each asset class. You may estimate the expected return on each asset with its average return over the period 1987-2007.

The *risk index* of an asset is measured by the average absolute percentage change over time. You may estimate the risk indices for stocks, gold, and Treasury bills over 1987-2007. The risk index for a portfolio is the weighted average of the risk indices of its component assets, where the weights are the percentages invested in each asset. For example, in the data we see that the risk index for stocks is 16.9. Our investor would like the risk index of her portfolio to equal 15.

a. What are the optimal percentages to invest in each asset class?  
  
b. Describe how her average return and the percentages invested in each asset change as she increases her acceptable risk index from 15 to 18.

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**2. Real-Time Flight Management**

**Part a**

Alpha Airlines Flight 1, carrying 265 passengers, has just taken off from Chicago and is flying to the Alpha hub in Denver. Because the flight was delayed in Chicago, if the airplane flies at normal speed then it will arrive 18 minutes late. The airplane can speed up, but speeding up increases fuel consumption and therefore increases costs. Specifically, to reduce travel time by *x* minutes adds $7.5x2 to the cost of the flight (for example, reducing the flying time by 10 minutes would cost $7.5\*102 = $750). Alpha will not slow down the plane and will not speed up so much that the airplane arrives early.

Because each delayed passenger can delay the departure of a connecting flight at the hub, Alpha calculates that there is a significant cost for each delay to each passenger. Here, assume that delays to Flight 1 cost $0.45/passenger/minute delayed.

(i) By how much should Alpha speed up flight 1? \_\_\_\_\_\_\_\_\_\_

What is Alpha’s total cost, given your answer above? \_\_\_\_\_\_\_\_\_  
  
(ii) In this question *only*, assume that the cost of delay is $2.00/passenger/minute. Now,

By how much should Alpha speed up flight 1? \_\_\_\_\_\_\_\_\_\_

What is Alpha’s total cost, given your answer above? \_\_\_\_\_\_\_\_\_

**Part b**

Alpha is currently managing the speeds of 4 late incomingflights. Flights 1-4, which were originally scheduled to arrive at the hub at the same time (assume that all 4 flights can land together because the hub has multiple runways). All of the passengers on these flights will change planes at the hub and then depart on four outgoingflights (Flights 5-8). The file *Flight.xlsx* contains the number of passengers on the four incoming flights and the number of those passengers who will be transferring to the four outgoing flights. For example, Flight 3 has 130 passengers who transfer to outgoing flight 6. The file also shows the number of minutes the flights are currently late (18, 15, 8 and 6 minutes for Flights 1-4, respectively). There are no other incoming flights, and all flights have a sufficient number of seats to hold all passengers.

Alpha’s policy is to hold outgoing flights until *all* connecting passengers are aboard. Scheduled connection times at the hub would allow on-time departures of outgoing flights if all incoming flights were on-time, but connection times contain no extra time. Therefore, if a passenger’s incoming flight is delayed by a certain number of minutes, that passenger’s outgoing flight must be delayed by at least the same number of minutes. For example, if Flight 3 does not speed up and is late by 8 minutes, then Flight 6 must be delayed by at least 8 minutes (Flight 6 may be delayed longer than 8 minutes if other connecting flights are even later). Again, every outgoing flight will take off as soon as all connecting passengers are aboard.

Here, Alpha measures its delay costs in terms of delays to passengers on *outgoing* flights because passengers care about when they arrive at their final destination; they do not really care if their arrival at the hub is delayed. Delay costs are $0.45/passenger/minute of outgoing flight delay. As in part (a), speeding up by *x* minutes costs $7.5x2 .

By how much should Alpha speed up each incoming flight?

Flight 1 \_\_\_\_\_\_\_\_\_\_

Flight 2 \_\_\_\_\_\_\_\_\_\_

Flight 3 \_\_\_\_\_\_\_\_\_\_

Flight 4 \_\_\_\_\_\_\_\_\_\_

What is Alpha’s cost, given your answer above? \_\_\_\_\_\_\_\_\_

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**3. Scheduling staff**

You are the Director of the Computer Center for Gaillard College and responsible for scheduling the staffing of the center, which is open from 8 a.m. until midnight. You have monitored the usage of the center at various times of the day and determined that the following numbers of computer consultants are required:

*Minimum Number of*

*Consultants Required*

*Time of Day to be on Duty*

8 AM – noon 4

Noon – 4 PM 8

4 PM – 8 PM 10

8 PM – midnight 6

Two types of computer consultants can be hired: full-time and part-time. The full-time consultants work for eight consecutive hours in any of the following shifts: morning (8 AM – 4PM), afternoon (noon – 8 PM), and evening (4 PM – midnight). Full-time consultants are paid $14 per hour.

Part-time consultants can be hired to work any of the four shifts listed in the table. Part-time consultants are paid $12 per hour. An additional requirement is that during every time period, there must be at least one full-time consultant on duty for every part-time consultant on duty.

The staffing model in the file *Staffing.xlsx* can be used to find an optimal staffing plan.

**Note: all questions are independent and should be based on the original model.**

*Questions*

a. Determine a minimum-cost daily staffing plan for the center. Record your results here:

Minimum daily cost: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Total full-time staff: \_\_\_\_\_\_\_\_\_\_\_\_\_

Total part-time staff: \_\_\_\_\_\_\_\_\_\_\_\_

b. How much could the Center *save* if it were to ignore the requirement that at least one full-time consultant must be on duty for every part-time consultant?

Cost savings: \_\_\_\_\_\_\_\_\_\_\_\_

c. Demand for consultants has been rising in time slot 3 (4 PM – 8 PM), but you have been given a budget of $2,000 for your daily costs. At what level of demand for consultants in time slot 3 does the minimum cost first exceed your budget?

Demand for time slot 3: \_\_\_\_\_\_\_\_\_\_\_\_

d. In the future, the minimum number of consultants required on *each shift* is expected to increase by 1 to 5 people, as illustrated below:

*Time of Day Base Increase of 1*

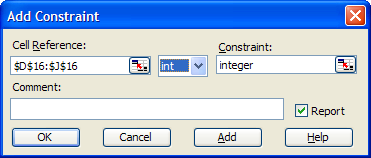
8 AM – noon 4 5

Noon – 4 PM 8 9

4 PM – 8 PM 10 11

8 PM – midnight 6 7

Include the constraint that all decision variables must be integers:



Sketch a graph to show how a) the total number of full-time consultants and b) the total number of part-time consultants changes as the requirements increase.



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**4. Coordinating advertising and production**

The Hawley Lighting Company manufactures four families of household lighting at its factory. The product families are table lamps, floor lamps, ceiling fixtures, and pendant lamps. The table below shows the average material costs for each of the products.

*Product Table Floor Ceiling Pendant*

*Material cost* $66 85 50 80

Each product is made in one of two production processes. Table lamps and floor lamps go through the process in Department 1, while ceiling fixtures and pendants go through the process in Department 2. Variable production costs and capacities (measured in units of product) are shown in the table below. Note that there are regular and overtime possibilities for each department.

*Regular time Overtime*

*Capacity Capacity*

*Process Unit cost in units Unit cost in units*

Department 1 $16 100,000 $18 25,000

Department 2 12 90,000 15 24,000

Average selling prices for the four products are known, and estimates have been made of the market demand for each product at these prices. These figures are shown in the following table.

*Product Table Floor Ceiling Pendant*

Selling price $120 150 100 160

Potential sales 60,000 20,000 100,000 35,000

a. What is the optimal production plan for the company? (Give the optimal profit and how much of each product to produce on regular time and on overtime.)

Hint: use four decision variables for production of each product in regular time, and four decision variables for production of each product in overtime.

b. Advertising raises an additional complication because sales levels can be affected by advertising expenditures. Each $1,000 spent on advertising for a particular product raises demand above the base level by the percentage given below. For example, an expenditure of $5,000 on advertising for table lamps would raise demand by 6% (5x1.2%), or 3,600 units (60,000x6%). (Expenditures of fractions of $1,000 have proportional effects.) However, there is a budget limit of $18,000 on the total amount to be spent on advertising among all four products.

*Product Table Floor Ceiling Pendant*

Advertising Effect 1.2% 1.0% 0.8% 1.5%

Amend your model to include the advertising decisions and use it to determine the optimal production and advertising plan for the company. (Give the optimal profit, how much of each product to produce on regular time and on overtime, and how much to advertise for each product.)

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**5. Environmental Planning**

You are the operations manager of a chemical company which produces five products in a common production facility. The following table gives potential sales for each product, along with variables costs and revenues. Production in any year cannot exceed the sales potential.

**Product Sales potential Variable costs Revenues**

(tons/year) ($/ton) ($/ton)

A 2000 700 1000

B 1600 600 800

C 1500 1000 1500

D 1000 1600 1800

E 600 1300 1700

Your production facility rotates through the product line because it can produce only one product at a time. The production rates differ for the various products. It takes 0.3 hours to make 1 ton of A, 0.5 hour for a ton of B, and 1 hour each for a ton of C, D, or E. The facility can be operated up to 4000 hours per year.

The file *EnviroPlanning.xlsx* contains all the information given above in a format designed for optimization. Use this template to answer the following questions.

a. Determine the maximum profit the company can achieve from its product line in the coming year.

$\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. What is the shadow price on the sales potential for product C?

$\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Parts (c), (d) and (e) are independent: changes described in one part do not apply to the other parts. For example, part (c) involves changing the sales potential of product C from 1000 to 2500 tons. For parts (d) and (e), the sales potential should be set back to the original 1500 tons.

c. Describe in words how the *optimal production plan* and *profit* change as the sales potential on Product C changes from 1000 to 2500 tons.

d. An engineering firm is offering to improve the efficiency of the process for manufacturing products C, D, and E. This process improvement will reduce the time required for all three products by up to 10%. How big an improvement to all three products is necessary in order to offset the cost of $30,000? Your answer should be a percentage between 0% and 10% (answer to the nearest integer percentage). Include a table of results to justify your answer.

Required improvement: \_\_\_\_\_\_\_\_\_\_\_

TABLE:

e. The EPA is proposing to limit particulate emissions from your company over the next five years to the amounts specified below. The sales potential for each of the five products is expected to remain stable over this period.

**Year Total Emissions**

(tons)

1. 100
2. 80
3. 60
4. 40
5. 20

The emissions produced by each product are given below.

**Product Particulate Emissions**

(tons/ton produced)

A 0.0010

B 0.0025

C 0.0300

D 0.0400

E 0.0250

The company plans to satisfy these requirements by modifying the product mix each year. What would the optimal profits be in each of the next five years?

**Year Profit**

1. $\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. $\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. $\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. $\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. $\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**6. Cash Matching**

Integra Marketing is a small brand development firm that has just received the final payment from a large contract. Integra’s cash level is now $1,500,000, and the CFO must decide what to do with the money. In the short term Integra will have a steady stream of income and expenses, but its major contracts end in 5 years. Therefore, the CFO would like to maximize the amount of cash available at the end of year 5.

All transactions (costs, revenues, investments, return on investment, and interest on cash) are recorded at the end of the year. ‘Now’ can be considered as the end of year 0.

During year 1, Integra will have $850,000 in costs and $600,000 in revenue. For years 2-5, the annual rate of cost growth will be 3% and the annual rate of revenue growth will be 10%. There will also be a one-time cost of $100,000 for a loan due at the end of year 4.  
  
The CFO is considering three different fixed-income investments:

Investment A: Each dollar invested in A returns $1.54, *5 years later*. For example, if $1 million is invested at the end of year 0 then $1.54 million is available as cash at the end of year 5.

Investment B: Each dollar invested in B returns $1.25, *3 years later*.

Investment C: Each dollar invested in A returns $1.14, *2 years later*.

Any of the three investments may be purchased at the end of any year, including year 0. For all three investments, the money invested cannot be cashed out before the stated due-date (5, 3 and 2 years for A, B and C, respectively). When any of the three investments is cashed out at the end of a year, the money is available for immediate reinvestment at the end of the same year, or the money can be left as cash.

Money left as cash earns interest at an annual rate of 2%. Finally, the CFO requires that at least $50,000 be available in cash at the end of each year, including year 0.

a. Build a model to evaluate the following proposed plan. Determine not only the value of the plan at the end of year 5, but also whether it is *feasible*.

**Investment type  
Year-End (A, B or C) Amount**

**0 A $600,000**

**0 B $250,000**

**0 C $200,000**

Report here the value of this plan. Also, list *all* constraints the plan must meet and whether each is satisfied under this plan.

**Cash at end of year 5: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Constraint Satisfied?**

b. Use your model to evaluate the following alternate plan. Determine not only the value of the plan at the end of year 5, but also whether it is *feasible*.

**Investment type  
Year-End (A, B or C) Amount**

**0 A $600,000**

**1 B $250,000**

**1 C $200,000**

Report here the value of this plan. Also, list *all* constraints the plan must meet and whether each is satisfied under this plan.

**Cash at end of year 5: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Constraint Satisfied?**

c. Devise an investment plan for Integra that maximizes the amount of cash that will be available at the end of five years. How much cash will be available at the end of five years?   
  
**Cash at the end of year 5: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  
  
Describe the optimal investment plan (you may not need all rows):

**Investment type  
Year-End (A, B or C) Amount**

**\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_**

**\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_**

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d) Suppose that if Investment A is used, at least $800,000 of Investment A must be bought. All other information remains the same, as described above.  
  
Create a new model (or new models) to help the CFO maximize the amount of cash that will be available at the end of five years. Describe in words the changes you made to your original model:

Changes to original model:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Use your new model(s) to devise a new optimal investment plan for Integra. How much cash will be available at the end of five years?   
  
**Cash at the end of year 5: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**  
  
Describe the optimal investment plan (You may not need all rows):

**Investment type  
Year-End (A, B or C) Amount**

**\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_**

**\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_**

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**\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_**

**7. Carson Staplers**

Open the file *Carson.xls*.

The Carson Stapler Manufacturing Company forecasts a 5000-unit demand for its Sure-Hold model during the next quarter. This stapler is assembled from three major components: base, cartridge, and handle. Each of these three components must be processed in each of three departments: Forming, Finishing, and Testing. Until now Carson has manufactured all three components itself. However, the forecast of 5000 units is a new high in sales volume, and it is doubtful that the firm will have sufficient production capacity to make all the components. The company is considering contracting with a local firm to produce at least some of the components. The production time requirements per unit are as follows:

*Time Required (hours /unit) Capacity Available*

*Department Base Cartridge Handle (hours)*

Forming 0.03 0.02 0.05 400

Finishing 0.04 0.02 0.04 400

Testing 0.02 0.03 0.01 400

After considering the firm’s variable labor, material and overhead costs, the accounting department has determined the unit manufacturing cost for each component. These data, along with the purchase price quotations by the external supplier, are as follows:

*Manufacturing Purchase*

*Component Cost Cost*

Base $0.75 $0.95

Cartridge $0.40 $0.55

Handle $1.10 $1.40

a. Build a model with which you can evaluate the following proposed plan. You must be able to determine not only the total cost of the plan but also whether it is *feasible*.

### **Base Cartridge Handle**

**Produce** 5000 4000 4000

**Purchase** 0 1000 1000

Report here the total costs of this plan. Also, list *all* constraints the plan must meet and whether each is satisfied under this plan.

**Total cost: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Constraint Satisfied?**

b. Determine the production and purchasing plan that *minimizes total cost*. Report here the plan itself and the minimum cost.

### **Base Cartridge Handle**

**Produce**

**Purchase**

**Total cost: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

c. What is the impact of changes in the manufacturing costs of the Base component on the total cost? Consider variations in the cost from $0.50 to $1.00 in steps of $0.05. Report your results in the table below.

**Manufacturing cost Total cost**

$0.50

0.55

0.60

0.65

0.70

0.75

0.80

0.85

0.90

0.95

1.00

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

8**. Optimizing a Portfolio of Stocks**

Open the file *Stocks.xlsx*.

Four stocks are available for creating a portfolio: Microsoft, ATT, GM, and GE. We have data on the mean, standard deviation, and the covariance of returns. If we chose to invest certain percentages of our assets in each of the four stocks we can determine the mean and standard deviation of the resulting portfolio, as in the accompanying spreadsheet.

One way to formulate the problem of determining the *optimal* portfolio for an individual is to combine the mean and standard deviation of the return into a single measure of the overall utility of the portfolio. This can be done using a *penalty factor* (*p*) for the standard deviation, so that the utility is given by the mean return less a penalty for the standard deviation:

# U = Mean – *p*\*Standard Deviation

The portfolio optimization problem then becomes one of finding the appropriate percentages, or *weights*, for each of the four stocks to maximize this utility measure. Note: all four weights must be non-negative.

a. Assume you have a client whose penalty factor equals 2.0. Determine the optimal portfolio. Report here the four *weights*, as well as the *mean* and *standard deviation* of the optimal portfolio.

Portfolio mean \_\_\_\_\_\_\_\_\_\_\_\_\_

Portfolio standard deviation \_\_\_\_\_\_\_\_\_\_\_\_\_

Weight for Microsoft \_\_\_\_\_\_\_\_\_\_\_\_\_

Weight for ATT \_\_\_\_\_\_\_\_\_\_\_\_\_

Weight for GM \_\_\_\_\_\_\_\_\_\_\_\_\_

Weight for GE \_\_\_\_\_\_\_\_\_\_\_\_\_

b. Let the penalty factor vary from 0 to 3 in increments of 0.5. Determine the optimal portfolio for each value of *p*. Report here the optimal utility, portfolio mean return, and portfolio standard deviation.

|  |  |  |  |
| --- | --- | --- | --- |
| *p* | Optimal utility | Portfolio mean  return | Portfolio standard  deviation |
| 0.0 |  |  |  |
| 0.5 |  |  |  |
| 1.0 |  |  |  |
| 1.5 |  |  |  |
| 2.0 |  |  |  |
| 2.5 |  |  |  |
| 3.0 |  |  |  |

c. Describe in words how and why the pattern of weights varies as the penalty factor *p* varies from 0 to 3.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**9. Learning Curve Based Production Planning**

Open the file *Learning.xlsx*.

Many labor-intensive production operations experience a learning curve effect. The learning curve specifies that the cost to produce a unit is a function of cumulative production, that is, as production volume increases, the cost to produce each unit drops. One form of the learning curve is as follows: Ci = p\*(i)q where Ci is the cost of producing the ith unit. The parameter *p* is called the first unit cost and *q* is the learning slope parameter. The total cost of producing a batch of size *x* can then be approximated by

(p x1+q)/(1+q).

We now consider a specific production setting where there is learning. Demands for our single product over the next five periods are 100, 150, 300, 200, and 400. Holding cost per unit per period is $.30.

a. In the worksheet *Learning.xlsx*, use Solver to find the best fitting learning curve (that is, find the values of *p* and *q*) so as to minimize the sum of squared error where the predicted value of unit i is p\*(i)q. Report your results below.

**Value of *p*:**  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Value of *q*:**  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Sum of Squared Errors:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. Based on your results from part a), use the approximation (px1+q)/(1+q) as the cost (in dollars) of producing a batch of size *x*. Assume that the learning from one time period to another is lost (so there is no transfer of learning between time periods) and the amount we produce in a given period is one batch. Solve the production planning problem of minimizing the sum of production and inventory costs, while satisfying demand. Assume we must have an ending inventory in period 5 of at least 50. Report your results below.

**Total Cost:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c. Solve the same production planning problem ignoring the learning curve, that is, assume that every unit costs *p* dollars (where the parameter *p* was estimated in part a) above). Report your results below.

**Total Cost:**  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

d. Compare the optimal production plans you obtained in b) and c). Explain any differences.

**Simulation Problems**

**1. Hybrid Car Development**

**Note:** Refer to the model *Hybrid.xlsx* for this problem. This is a deterministic version of the model that you must convert into a simulation model. You should assume the model logic is correct.

ADC Auto Corporation is developing a new type of hybrid car. This car will generate sales over the next 10 years. Analysts have gathered the following information about the financial side of this decision from the marketing and engineering departments.

**Fixed cost:** Fixed costs are assumed to be normally distributed with a mean of $2.3 billion and a standard deviation of $0.5 billion. Assume fixed costs will be incurred at the beginning of year 1, before any sales are recorded.

**Variable production cost:** This cost, which includes all variable production costs required to build a single car, is assumed to be normally distributed in the first year of production with a mean of $7,800 and a standard deviation of $600. After the first year, variable costs will inflate in each year by an amount given by a normal distribution with a mean of 1.05 (a 5% increase) and a standard deviation of 0.015. Each year’s inflation factor is independent of the other years. All production costs in a year are incurred at the end of that year.

**Selling price:** The price in the first year is set at $11,800. After the first year the price will inflate by the same inflation factor that drives variable production costs. Revenues are realized at the end of the year.

**Demand:** Demand is normally distributed in the first year with a mean of 100,000 units and a standard deviation of 10,000. After the first year, demand is expected to increase each year by an amount given by a triangular distribution, with a minimum value of 0%, a maximum value of 10%, and a most likely value of 3%. The growth rate from year to year is independent of all other years.

**Production:** DC bases its production decision each year on demand in the *previous* year. (The first year’s production will be 100,000.) DC’s policy is to produce an amount equal to demand in the previous year plus a multiple *k* of the standard deviation of demand (10,000). For example, if *k* = 0 then DC will produce just the previous year’s demand. The higher the *k*-factor, the higher the likelihood that production will cover demand. If demand is higher than production in any year, the excess demand is lost. However, if production in any year is greater than demand, DC will sell the excess cars at an end-of-year discount of 50% off the normal price.

**Interest rate:** DC plans to use a discount rate of 10% for future cash flows. Note that the fixed cost is not discounted, since it occurs at the beginning of the first year, but costs and revenues for the first year are discounted one year because we assume they occur at the end of the year.

ADC would like to determine the financial implications of these assumptions. In particular, it would like your recommendation as to an appropriate value for the parameter *k*.

Use 5,000 trials in all simulation runs.

1. Assume *k* = 0 for a base case. What is the mean Total NPV that ADC can expect from this new car?

**NPV:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Assume *k* = 0. What is the probability the Total NPV will be *less than* one standard deviation above the mean?

**Probability:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c. Assume *k* = 0. What is the probability that the Total NPV will exceed $1,800 million and Sales revenue in year 10 will exceed 3,000?

**Probability:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

d. What value of the safety factor *k* between 0.0 and 1.5 (to the nearest 0.1) should ADC choose in order to maximize the mean Total NPV?

**Optimal value of *k*:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

e. How does the optimal value for the safety factor *k* change with the standard deviation of Demand in year 1 (set at 10 in the base case)? Vary the standard deviation of “Demand in year 1” from 5 to 50 in increments of 5. Use the graph below to display your results. Show the exact numerical values of the optimal *k* for standard deviations of 5, 25 and 50 on your sketch.



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**2.** **Production planning**

Your company has agreed to produce 8000 ounces of shampoo for a retailer. This product is manufactured in batches that take 5 to 11 days according to the following distribution (this table is also in the file *Shampoo.xlsx*).

|  |  |
| --- | --- |
| Time to make a batch (days) | Probability |
| 5 | 0.05 |
| 6 | 0.10 |
| 7 | 0.20 |
| 8 | 0.30 |
| 9 | 0.20 |
| 10 | 0.10 |
| 11 | 0.05 |

Only one batch can be made at a time. Each batch yields an uncertain amount of product, ranging between a minimum of 600 ounces and a maximum of 1100 ounces, with a most likely value of 1000 ounces. Finally, 20% of the time a batch fails inspection and the entire batch must be discarded.

Your task is to build a model with which to forecast the *number of batches* and the *number* *of days* that will be required to meet the customer’s order of 8000 ounces.

Use 5,000 trials in all simulation runs.

1. What is the mean number of batches that will be required? \_\_\_\_\_\_\_\_\_\_\_\_

b. What is the mean number of days that will be required? \_\_\_\_\_\_\_\_\_\_\_\_  
  
c. What is the probability that the number of days required will exceed 125? \_\_\_\_\_\_\_\_

d. The retailer may want to order more than 8000 ounces, but only 150 days are available in the manufacturing plant. Your company’s goal for any order is that there is less than a 2% chance that the number of days required for the order exceeds 150 days. What is the largest order your company can accept and still achieve the goal? Give your answer to the nearest 100 ounces.  
  
Answer: \_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**3. Simulating the Evergreen College Endowment**

Evergreen College holds an endowment currently worth $700 million. The Chief Investment Officer of the endowment has hired you to predict the performance of the endowment over the next 10 years.

You are given a deterministic spreadsheet for this purpose, *Evergreen.xls*. The spreadsheet incorporates the following elements (you can assume that the spreadsheet is correct):

* Annual growth in the endowment due to financial investments;
* Contributions from a capital campaign;
* An annual *draw* on the endowment for ongoing activities, where the size of the draw incorporates percentages of the previous year’s draw and the current endowment;
* The cost, over 2 years, of a new science building. Spending and construction of the new building is conditional on meeting targets in the endowment and the capital campaign.

To improve the model you want to incorporate some measure of uncertainty. You have selected the following probability distributions:

* Annual rate of return: Each year’s rate of return is *lognormal* with a mean of 8% and a standard deviation of 2%. Each year’s rate is independent of all other years.
* Total collected in capital campaign: *triangular* with a minimum of $100 million, most likely value of $300 million, and maximum of $450 million.
* Length of the capital campaign: The campaign could last 6, 7 or 8 years, with these probabilities:

*Length of Campaign (years) Probability*

1. 0.2
2. 0.2
3. 0.6

**All of the following questions are independent. In other words, at the start of each of (a)-(f), return to the base case given in the original spreadsheet.**

a. Conduct a simulation run of 1,000 trials. Determine the following:

(i) Mean endowment at the end of year 10: $\_\_\_\_\_\_\_\_\_\_\_\_

(ii) 95% confidence interval for the mean

endowment at the end of year 10: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

**For all remaining questions, use simulation runs of 10,000 trials.**

b.

(i) What is the probability that the endowment at the end of year 10 (‘final   
 endowment’) is greater than $1 billion?

probability that final endowment > $1 billion: \_\_\_\_\_\_\_\_\_\_\_\_

(ii) What is the 90th percentile of the distribution of the final endowment?

90th percentile: \_\_\_\_\_\_\_\_\_\_

c. The final endowment can be increased by reducing the draw. Specifically, the final endowment can be increased by lowering the “% of previous year's spending” (cell C26 in *Evergreen.xls*). What is the largest value of “% of previous year's spending” that will ensure that the mean final endowment is greater than $1 billion? Answer to the nearest 1%.

% of previous year's spending: \_\_\_\_\_\_\_ %

d. Of course, the final endowment can also be enlarged by increasing the expected returns from investments. What is the minimum average annual rate of return needed to ensure that the *probability* that the final endowment is at least $1 billion is greater than 0.9? (You may assume that the standard deviation of returns remains at 2%.) Answer to the nearest 0.1%

Average rate of return: \_\_\_\_\_\_\_\_\_ %

e. What is the probability that construction of the new science building begins in year 5?

Probability: \_\_\_\_\_\_\_\_\_

f. The year in which construction of the new science building begins is random, for it depends upon the uncertain values of the endowment and the capital campaign. What is the mean and standard deviation of the first year of construction? Note: for this problem, if construction does not begin by the end of year 10 then you may assume that construction begins in year 11.

Mean: \_\_\_\_\_\_\_\_\_

Standard Deviation: \_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**4. Buy now or pay to buy later**

You are considering investing in a firm that is developing a new, promising technology. The firm will spend $5 million during each of the next 2 years while it files a crucial patent application and waits for the result. During year 2 the application will be approved (with probability 70%) or will be rejected. If the application is rejected then the firm will go out of business and will have no assets to sell off.

If the application is approved in year 2, the firm will immediately begin selling its patented product during year 3. The initial market size for the product (the number of units sold in year 3) will be normally distributed with a mean of 1 million and a standard deviation of 0.2 million. The growth rate in subsequent years will be normally distributed with a mean of 10% and a standard deviation of 5% (whatever the growth rate turns out to be, it will be the same in all future years). The unit margin is normally distributed with a mean of $50 and a standard deviation of $15 (whatever the unit margin turns out to be in year 3, it will be the same in all future years). The discount rate is 15% and the analysis should cover 15 years, in total. Assume all assets are worthless at the end of 15 years.

When modeling this problem, you should assume that all cash flows occur at the end of the year.

a. What is the expected NPV of the firm?  
  
$ \_\_\_\_\_\_\_\_\_\_

b. Suppose that you are offered the opportunity to pay $100 million (paid now) in exchange for a 50% share of the firm. This share entitles you to 50% of all cash flows in years 1-15, including negative cash flows (e.g. at the end of years 1 and 2 you would have to pay 50% of the firm’s expenses). For this deal,  
  
(i) What is the mean NPV?  
  
 $ \_\_\_\_\_\_\_\_\_\_  
  
(ii) What is the probability that you lose more than $50 million?  
  
 probability: \_\_\_\_\_\_\_\_\_\_\_

c. Suppose that you are offered the following deal:  
(i) Pay $10 million now.  
(ii) At the end of years 1 and 2 you must pay 50% of the firm’s expenses.  
(iii) If the patent is rejected, you can pull out of the deal.  
(iv) If the patent is approved, you pay $170 million at the end of year 2 and receive   
 50% of all cash flows in years 3-15.  
  
For this deal,  
  
(i) What is the mean NPV?  
  
 $ \_\_\_\_\_\_\_\_\_\_  
  
(ii) What is the probability that you lose more than $50 million?

probability: \_\_\_\_\_\_\_\_\_\_\_

1. The retailer may want to order more than 8000 ounces, but only 150 days are available in the manufacturing plant. Your company’s goal for any order is that there is less than a 2% chance that the number of days required for the order exceeds 150 days. What is the largest order your company can accept and still achieve the goal? Give your answer to the nearest 100 ounces.  
     
   Answer: \_\_\_\_\_\_\_\_\_\_

**5. EToys Simulated**

Open the file *ToySim.xlsx.*

EToysis trying to determine the total net income they can expect to receive over the next four years from a new toy. During the course of their analysis they have made some modifications to the model we discussed in class on October 7. In particular, they have incorporated a demand relationship between initial price and unit sales (see cell E8). The key parameter in this relationship is the price elasticity (cell E5).

They also have decided that three parameters are uncertain: the price elasticity itself (cell E5), the unit sales increase (cell F9), and the sales price increase (cell F16). The following probability distributions have been selected as representing their uncertainty:

* Price elasticity: *triangular* with minimum of –2.0, most likely of –1.5, and maximum of –1.0.
* Unit sales increase: *lognormal* with mean of 0.12 and standard deviation of 0.04.
* Sales price increase: *triangular* with minimum of 1.5, most likely of 2.0, and maximum of 3.0.

a. Make a simulation run of 5000 trials with the initial price (cell E15) set at $20. Determine the following:

(i) (1 point) average total net income: $\_\_\_\_\_\_\_\_\_\_\_\_

(ii) (1 point) probability total net income will exceed $2 million: \_\_\_\_\_\_\_\_\_\_\_\_

(iii) the 10th percentile of total net income: $\_\_\_\_\_\_\_\_\_\_\_\_\_

b. What is the *minimum* number of trials needed to reduce the Mean Standard Error of total net income to below $21,000? (Answer to the nearest 1000.)

\_\_\_\_\_\_\_\_\_\_\_\_ trials

c. Find the initial price (cell E15) that maximizes the expected total net income. Answer to the nearest $10, between $20 and $100. Provide a table of numbers that justifies your answer.

$\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TABLE:

d. How sensitive is the probability that net income will exceed $2 million to the initial sale price (for values from $20 to $100 in steps of $10). Provide a table of numbers that justifies your answer.

ANSWER:

TABLE:

e. The minimum price elasticity in the base case is -2.0. How sensitive is the optimal initial price to variations in the minimum price elasticity between -10 and -2? (The optimal initial price is the initial price that maximizes the expected total net income). Answer to the nearest $10, between $20 and $100. Provide a table of numbers that justifies your answer. Hint: set the number of trials to 1000.

ANSWER:

TABLE:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**6. Open Access for Doctors**

**Part I**

In the U.S. health care system at present, patients typically wait weeks, even months, to see a doctor. However, a new trend among private doctors is to eliminate most waiting through the “Open Access” system. In an open access system, the patient is guaranteed an appointment on the day after they call (calls on Friday and over the weekend are scheduled for Monday). If the time needed by the doctor to see all scheduled patients exceeds the time available on any particular day, then the doctor works overtime on that day.

Of course, if the doctor has too many patients wanting appointments then there will be too much overtime. The number of patients needing an appointment for each day depends upon the number of patients the doctor agrees to serve. This number is the doctor’s *panel size*. Typical panel sizes range from 1000 patients to 3000 patients.

Studies show that, on average, each patient has a 0.008 chance of needing an appointment for any particular day. Thus a panel of 1000 will generate an average of 0.008\*1000 = 8 patients/day. If the panel size is 3000, there will be an average of 0.008\*3000=24 patients/day. But of course the number of calls each day is variable; the random number of patients who need an appointment for each day can be described with a Poisson distribution with a mean equal to (0.008)\*(panel size).

The doctor’s work day is divided into 18 *slots*, each approximately 20 minutes in length. Seventy percent of patients require 1 slot, 20% require 2 slots, and 10% require 3 slots. The doctor can use overtime to create more slots in the day, if that is required to serve all the patients.

A doctor makes a profit of $30 for every slot in which he or she sees a patient. This figure represents revenue minus the variable costs of treating patients. The fixed costs of running the business can be ignored here.

However, if the doctor uses overtime then there is an additional cost of $80 per slot. Thus a doctor looses $50 for each overtime slot used. Despite this, under the open access system a doctor cannot turn away a patient.

The American Medical Association would like you to build a simulation model to find the best panel size for an individual doctor. The model should determine the doctor’s profit for *one day* as well as how often the doctor will need to work overtime.

a. Assume that the doctor uses a panel size of 2000 and use 5000 trials for your simulation run. What is the mean one-day profit?

**Mean profit:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. From the simulation run in part (a), report a 95-percent confidence interval for your estimate of the mean profit.

**Upper limit:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Lower limit:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c. What is the probability that the doctor will need to work overtime? Again assume that the doctor uses a panel size of 2000 and use 5000 trials for your simulation run.

**Probability:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

d. What is the average number of non-overtime slots that are idle (not used to serve a patient)? Again assume that the doctor uses a panel size of 2000 and use 5000 trials for your simulation run.

**Number of slots idle:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

e. What panel size maximizes profit? Support your conclusion with a table of profits over an appropriate range of panel sizes (answer to the nearest 100). Circle the optimal value.

**Panel size Mean Profit**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Table:**

**Part II**

Patients who request an appointment with the doctor can be divided into ‘urgent’ (70%) and ‘nonurgent’ (30%). Both urgent and nonurgent patients have the same distribution of slots, as described above: 70% need 1 slot, 20% need 2, 10% need 3. Again, the doctor has 18 slots available each day and the random number of patients who need an appointment for each day can be described with a Poisson distribution with a mean equal to (0.008)\*(panel size).

A new “open access” system allows doctors to create a short waiting list for nonurgent patients. All *urgent* patients are seen the next day, and overtime is used, if necessary, to see all urgent patients. However if all of the slots are filled on a day, a nonurgent patient may be delayed to the following day. Overtime is used for nonurgent patients on Friday to clear out the waiting list so that the doctor sees all patients before the weekend.

Build a simulation model to find the best panel size. The model should determine the doctor’s profit for *one 5-day week*.

To simplify the model you may assume

* Urgent patients are scheduled into a day before nonurgent patients;
* If a nonurgent patient needs more than one slot, the doctor may take care of some of those slots at the end of one day and take care of the remaining slots on the following day. (This is slightly unrealistic, but it introduces only a small error into the model.)

a). Assume that the doctor uses a panel size of 2000 and use 5000 trials for your simulation run. What is the mean one-week profit?

**Mean profit:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b). What panel size maximizes profit? What mean profit value does this panel size give you? (Answer to the nearest 100.)

**Panel size Mean Profit**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**7. Mutual Fund Performance**

The Magellan mutual fund had outperformed the Standard and Poor’s 500 index during 11 of the 13 years prior to 1990. It was widely thought that this performance indicated that it was possible to “beat the market” on a consistent basis. But just how unusual is this performance? A simple experiment will shed some light on this question.

Consider 50 mutual funds, each of which has a 50% chance each year of performing better than the Standard and Poor’s 500 (S&P500). Further, assume that each year’s performance is independent of the all other years’ performance, and that the performance of each fund is independent of the performance of all other funds.

a. Build a spreadsheet for one mutual fund to calculate the probability that a *single* mutual fund will outperform the S&P500 in 11 or more of 13 years. What is the probability that a single mutual fund will outperform the S&P500 in 11 or more of 13 years? *Use 5000 trials.*

**Probability:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. Build a spreadsheet to calculate the probability that the *best* performer out of 50 mutual funds will outperform the S&P500 in 11 or more of 13 years. What is the probability that the best performer of 50 mutual funds will outperform the S&P500 in 11 or more years out of 13 years? *Use 5000 trials*.

**Probability:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c. What is the probability that *two or more* of 50 mutual funds will outperform the S&P500 in 11 or more years out of 13 years?

**Probability:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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