ADS4293 LAB10

Chapter 16: Risk Analysis and Simulation

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LAB SETUP

- Submission:
  - Submit your **Excel file** on Brightspace (Owl)

QUESTION 1

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28. A manager works on a project with many team members and a series of complex tasks. She estimates that in the worst-case scenario, the project will take 213 days to complete, and, in the best-case scenario, it will take 105 days. Based on her past experience, she thinks that the project will most likely be completed in about 175 days. Use Excel's Analysis ToolPak, R, or Python to simulate 250 trials based on the triangular probability distribution to examine the duration of the project.

    a. Based on the 250 observations, what is the probability that the project will be completed in less than 150 days?

    b. Based on the 250 observations, what is the probability that the project will take longer than 200 days?

A.1 IN R

From the question, we assume the Triangular distribution (a, c, b).

TRIANGULAR DISTRIBUTION

Based on the value of a random number, a random observation generated from a triangular distribution is found as:

$$\text{Random observation} = \begin{cases} min + \sqrt{(max - min)\,(mode - min)x} \text{ for } x < \dfrac{(mode - min)}{(max - min)} \\ max - \sqrt{(max - min)\,(max - mode)\,(1 - x)} \text{ for } x \geq \dfrac{(mode - min),}{(max - min)} \end{cases}$$

where x denotes a random number whose value is uniformly distributed between 0 and 1, *min* denotes the minimum value, *max* denotes the maximum value, and *mode* denotes the mode or most likely value.

Why Triangular distribution? it is used when there is no historical dataset and only expert estimates for min, most likely, max, and we want quick risk simulation.

1. **Store the three scenario values:**

shortest <- ?
longest <- ?
mostLikely <- ?

to be continued on next slide...

A.1 IN R

2. **Set trail size n <- 250** this tells R how many simulations to run, and **set.seed(1)** to ensure consistent results.

3. **Calculate the threshold using** (use your variables from step 1)**:** $\frac{(mode - min)}{(max - min)}$

   threshold <- ???

4. **Use runif function to generate n random numbers, with values between 0 and 1: randomNumbers <- runif(n, 0, 1)**

5. **We calculate two possible profit values for each random observation based on the formula:**

$$\text{Random observation} = \begin{cases} min + \sqrt{(max - min)(mode - min)x} \text{ for } x < \dfrac{(mode - min)}{(max - min)} \\ max - \sqrt{(max - min)(max - mode)(1 - x)} \text{ for } x \geq \dfrac{(mode - min),}{(max - min)} \end{cases}$$

**hint: use variable names from step 1, x is randomNumbers*

resultLT <- ?? + sqrt(??)
resultGT <- ?? - sqrt(??)

A.1 IN R

6. **To determine profit the level, use ifelse to compare it to the threshold.** If the random draw falls on the left side of the triangular distribution (before the mode), we select the value from the left-side formula; if it falls on the right side (after the mode), we select the value from the right-side formula.

result <- ifelse(randomNumbers < threshold, resultLT, resultGT)

7. Get the statistics to anwer a and b:

a. Based on the 250 observations, what is the probability that the project will be completed in less than 150 days?

b. Based on the 250 observations, what is the probability that the project will take longer than 200 days?

length(which(result < 150))
length(which(result < 150)) / length(result)

Counts how many of the 250 trials finished in less than 150 days, and converts that count into a probability.

length(which(result > 200))
length(which(result > 200)) / length(result)

Counts how many of the 250 trials finished in more than 200 days, and converts that count into a probability.

In excel: Interpret your simulation results, talk about what the two probabilities imply about project risk!

Part a. 23.60% (59/250 observations)

Part b. 2.80% (7/250 observations)

QUESTION 2 MONTE CARLO SIMULATION

37. A medical supply provider manufactures disposable N95 respirator masks and packages them into air-sealed boxes, with each box containing 200 individual masks. Once a week, the company produces the masks and distributes them to several regional hospitals. The company also produces other types of masks and medical supplies that require the same resources. As a result, its production capacity for the N95 masks varies from week to week. The accompanying frequency distribution shows the weekly N95 mask production capacity from the previous 50 weeks.

Boxes of N95 masks	Frequency (in weeks)
100	3
150	8
200	10
250	17
300	12

During a pandemic, the company has difficulties predicting the demand for the N95 masks and can only speculate that, at minimum, the hospitals will need 170 boxes of the masks on a weekly basis. After consulting with the local public health officials, the company believes that the hospitals will not require more than 400 boxes of N95 masks per week, and the most likely demand would be about 200 boxes each week.

a. Use Excel's Analysis ToolPak, R, or Python to develop a Monte Carlo simulation with 500 trials. What are the mean and standard deviation of the demand and production capacity?

b. Based on the simulation, what is the probability that the company cannot produce enough N95 masks to support the regional hospitals in a given week?

c. Based on the simulation, what is the probability that the company will have an excess production capacity in a given week?

A.2 IN R

a. Use Excel's Analysis ToolPak, R, or Python to develop a Monte Carlo simulation with 500 trials. What are the mean and standard deviation of the demand and production capacity?

- **We use a triangular distribution to model demand because we only know the minimum, most likely, and maximum values.**
- **We use Monte Carlo simulation to repeatedly sample from this distribution and estimate probabilities.**

1. **Simulate the weekly demand using the triangular distribution**

```
minimum   <- ??
maximum   <- ??
mostLikely <- ??
set.seed(1)
randomNumbers <- runif(??, 0, 1) *hint: ?? is # of trials
threshold <- ?? *hint: use your variables min max and mostlikely

resultLTThreshold <- ??
resultGTThreshold <- ??
demand <- ??
```

2. **Get the mean & standard deviation of simulated demand in step 1:**

```
mean(demand)
sd(demand)
```

to be continued on next slide...

A.2 IN R

a. Use Excel's Analysis ToolPak, R, or Python to develop a Monte Carlo simulation with 500 trials. What are the mean and standard deviation of the demand and production capacity?

3. **Simulate weekly production capacity using the historical frequencies, using the table:**

Boxes of N95 masks	Frequency (in weeks)
100	3
150	8
200	10
250	17
300	12

a. **Create a vector and store the possible capacity levels (weekly production levels)**
   capacity <- c(???)
b. **Create another vector and store how many weeks each capacity occurred**
   frequencies <- c(???)
c. **Convert frequencies to probabilities and save it into "relativeFreq"**
   relativeFreq <- ??
d. **Build the cumulative probability distribution using cumsum function and save it into "cumulativeProb".**
   cumulativeProb <- ??

to be continued on next slide...

A.2 IN R

a. Use Excel's Analysis ToolPak, R, or Python to develop a Monte Carlo simulation with 500 trials. What are the mean and standard deviation of the demand and production capacity?

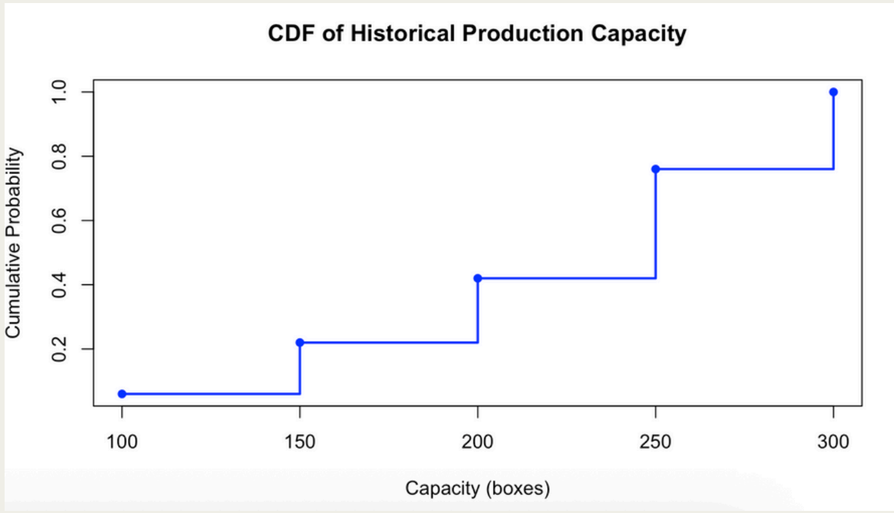
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e. Use inverse sampling to assign capacity

```
supply <- ifelse(randomNumbers >= cumulativeProb[4], capacity[5],
          ifelse(randomNumbers >= cumulativeProb[3], capacity[4],
            ifelse(randomNumbers >= cumulativeProb[2], capacity[3],
              ifelse(randomNumbers >= cumulativeProb[1], capacity[2], capacity[1]))))
```

**You dont need to do the graph, it is there for you to visualize whats happening in e*

- The first point at 100 boxes is around 0.06:
  about 6% of weeks had production at 100 boxes or less.
- The step jumps at 150 boxes to about 0.22
  22% of weeks had production 150 or below.
- ……..
- Finally, the curve reaches 1.0 at 300 boxes
  100% of weeks had production 300 or below (this is the max).



Example:

- If the random number is 0.35 → falls between the 200 and 250 cutoffs → choose 250
- If the random number is 0.18 → falls between the 150 and 200 cutoffs → choose 200

f. Get the mean & standard deviation of simulated capacity

```
mean(supply)
sd(supply)
```

to be continued on next slide…

A.2 IN R

b. Based on the simulation, what is the probability that the company cannot produce enough N95 masks to support the regional hospitals in a given week?

4. **Probability the company CANNOT meet demand:**

- Create a “shortage” variable, use ifelse: 1 = demand > supply, else 0

shortage <- ifelse(??)

- Count how many weeks had shortages, and convert that count into a probability.

length(which(shortage == 1))
length(which(shortage == 1)) / length(randomNumbers)

c. Based on the simulation, what is the probability that the company will have an excess production capacity in a given week?

5. **Probability the company has EXCESS capacity**

- Create an “excess” variable, use ifelse: 1 = supply > demand, else 0

excess <- ifelse(??)

- Count how many weeks had excess, and convert that count into a probability.

length(??)
length(??) / ??

Part a. The simulated demand has a mean of 256.0127 boxes and standard deviation of 50.6467 boxes. The simulated capacity has a mean of 227.6000 boxes and standard deviation of 56.6981 boxes.

Part b. 85.00% (425/500 weeks)
Part c. 15.00% (75/500 weeks)

Thank you!