Review Session 2 (MGTA456)

Review of Assignment 1

Lily Poursoltan

University of California San Diego
Rady School of Management

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Logistics

- May 4 In-Person Class
- June 8 In-Person Final Exam
- Team Formation before session 3

Outline

- Review of assignment 1
- Some comments on assignment 2

Review of assignment 1: setup

- You own a bookstore.
- A new book "Chip War" by Chris Miller is published at Oct. 4, 2023.
- You purchase from the Publisher, Scribner, at $\$14$ a copy, and it will sell to the customers at the retail price of $\$22$ a copy.
- You need to decide how many books to order.
- You have a demand forecast from the past demands of similar books. The demand/forecast data is given in Canvas.
- After talking with the publisher's sales agent, you learned that it costs $\$2$ per book for the publisher to print one hard copy.

Review of assignment 1: Q1

Q1: Consider that the publisher, Scribner, acquired your bookstore, BN, i.e., you manage the whole supply chain, both the Publisher and the bookstore. In this case, **what is the cost of understocking, the cost of overstocking, and the target service level of the supply chain** (Note that the supply chain here means the Publisher and the bookstore)? **How many books** the supply chain should print? In this case, what is the supply chain average profit based on the data?

Solution

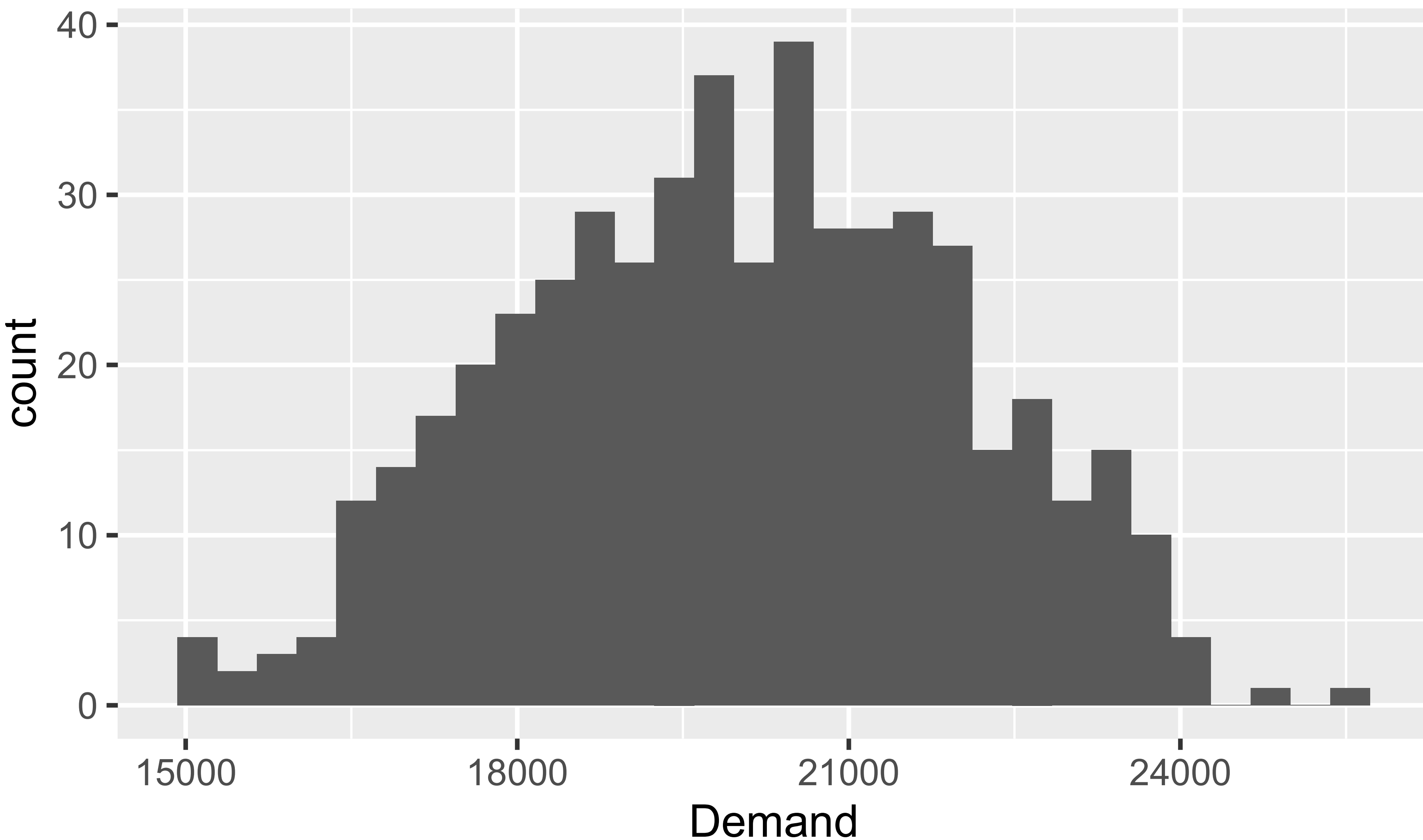
- Load excel file using `read_excel`

```
book <- readxl::read_excel("../data/BookDemand.xlsx")
```

- Visualize empirical distribution

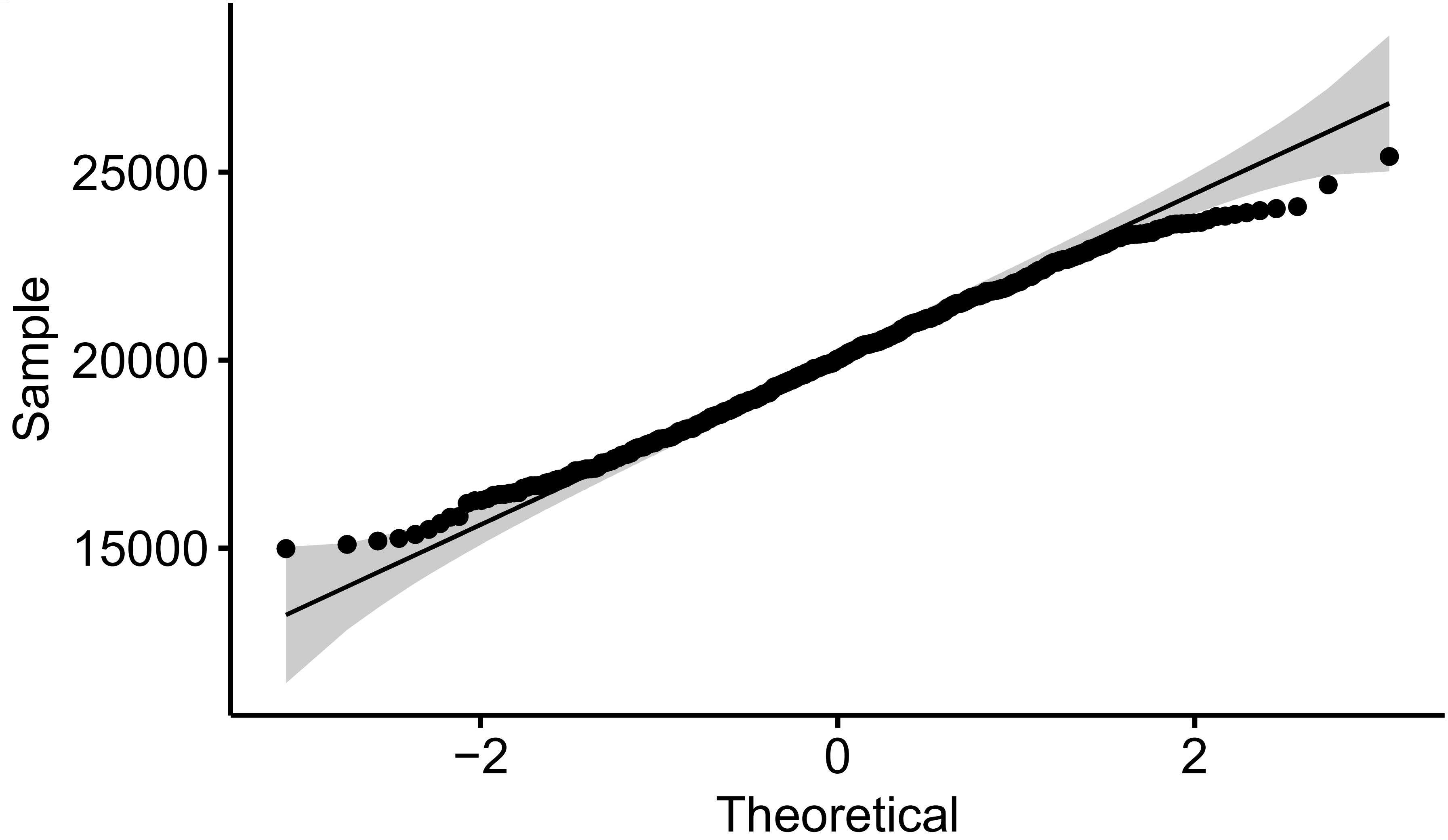
```r
book %>%
  ggplot(aes(x = Demand)) +
  geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```r
# st(book, out = "latex")
skim(book)
```

```
ggqqplot(book$Demand)
```



- Thus, we reject the null and this distribution is **NOT** following normal distribution!

Solve the Newsvendor problem by analytical approach

- Set constants (at baseline)

```r
price <- 22 # retail price
salvage <- 0
cost <- 14

Cu <- price - cost
Co <- cost - salvage
TSL <- Cu / (Cu + Co)
print(TSL)
```

```
## [1] 0.3636364
```

Under vertical integration

```r
price <- 22 # retail price
salvage <- 0
cost <- 2

Cu <- price - cost
Co <- cost - salvage
TSL <- Cu / (Cu + Co)
print(TSL)
```

```
## [1] 0.9090909
```

Analytical formula

- optimal inventory

$$q^* = F^{-1}(TSL)$$

where F^{-1} is the quantile function of the empirical demand distribution

```
q_star <- quantile(book$Demand, TSL)
print(q_star)
```

```
## 90.90909%
##   22767.27
```

- Profit

```
profit <- price * pmin(q_star, book$Demand) + salvage * pmax(q_star - book$Demand, 0) - cost * q_star
AvgProf <- mean(profit)
print(AvgProf)
```

```
## [1] 393114.4
```

Solve the Newsvendor problem by numerical approach

Try each value of stocking and calculate the profit

- Set the search range for stockings

```
stocking <- c(min(book):max(book))
length(stocking)
```

```
## [1] 10431
```

Simulation

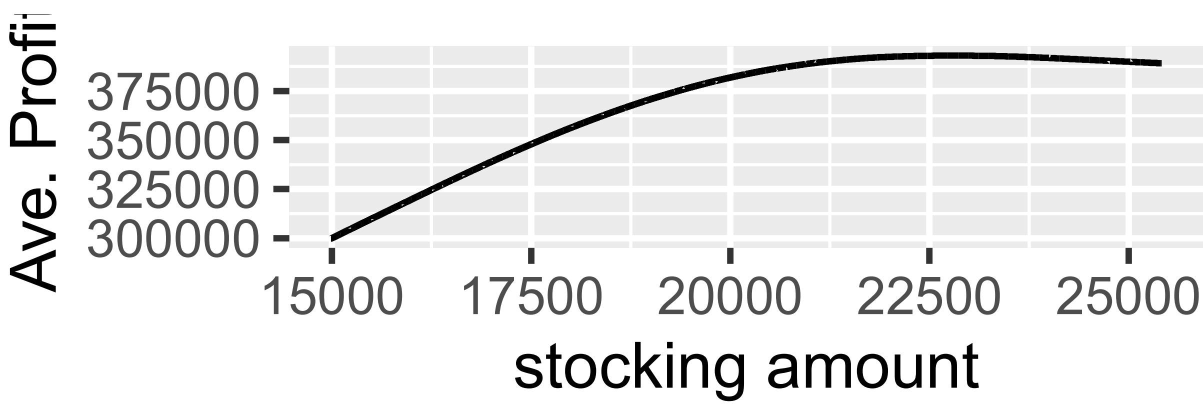
```r
# using loop
profit <- matrix(0, nrow = nrow(book), ncol = length(stocking))
for (i in 1:length(stocking)) { # loop for each stocking level
  q <- stocking[i]

  for (j in 1:nrow(book)) { # loop for each realized demand
    profit[j,i] <- price * min(q, book$Demand[j]) + salvage * max(q - book$Demand[j], 0) - cost * q
  }
}
# make summary table
summary_table <- data.frame(
  stocking = stocking,
  AvgProf = apply(profit, 2, mean), # column means
  StdProf = apply(profit, 2, sd) # column sd
) |>
  arrange(desc(AvgProf))
write.csv(summary_table, "summary_table.csv")
```

Find optimal inventory

```r
summary_table <- read.csv("summary_table.csv")
kable(head(summary_table, 10), format = "latex", digits = 3, align = 'c')
```

X	stocking	AvgProf	StdProf
1	22780	393114.7	41748.67
2	22781	393114.7	41751.64
3	22779	393114.7	41745.64
4	22782	393114.7	41754.61
5	22778	393114.7	41742.60
6	22783	393114.7	41757.58
7	22777	393114.6	41739.57
8	22776	393114.6	41736.54
9	22775	393114.6	41733.51
10	22784	393114.6	41760.49

```r
summary_table %>%
  ggplot(aes(x = stocking, y = AvgProf)) +
  geom_line() +
  xlab("stocking amount") +
  ylab("Ave. Profit")
```



Review of assignment 1: Q2

- Q2: Consider the original case that we studied in class, i.e., the bookstore is BN, and the Publisher is a separate entity. You, as a bookstore owner, decides how many books to order considering the wholesale price and the buy-back price. We considered the buy-back contract, in which the buy-back price was $\$12$ in class.
- Can you find **the pair of the wholesale price** (note that the status-quo wholesale price is $\$14$) *and the buy-back price* that will make **both the bookstore and the publisher better off** compared to the price pair of the wholesale price $\$14$ and the buy-back price $\$12$? As you change the wholesale price and the buy-back price, the order quantity of books will change.

Solve the Newsvendor problem by analytical approach

- Set constants (at baseline)

```
price <- 22 # retail price
salvage <- 12 # buyback price
wholesale <- 14 # wholesale price
cost <- 2

# for bookstore
Cu <- price - wholesale
Co <- wholesale - salvage
TSL <- Cu / (Cu + Co)
print(TSL)
```

```
## [1] 0.8
```

Analytical formula at baseline

- optimal inventory

```
q_star <- quantile(book$Demand, TSL)
print(q_star)
```

```
##     80%
## 21824.2
```

- Profit

```
profit_pub <- wholesale * q_star - salvage * pmax(q_star - book$Demand, 0) - cost * q_star
profit_book <- price * pmin(q_star, book$Demand) + salvage * pmax(q_star - book$Demand, 0) - wholesale * q
AvgProf_pub_baseline <- mean(profit_pub)
AvgProf_book_baseline <- mean(profit_book)
print(AvgProf_pub_baseline)
```

```
## [1] 237702.8
```

```
print(AvgProf_book_baseline)
```

```
## [1] 154437.3
```

```
total_profit_baseline <- AvgProf_pub_baseline + AvgProf_book_baseline
print(total_profit_baseline)
```

```
## [1] 392140.1
```

Blute-force search

Strategy 1

- Try a set of wholesale and buyback prices
- Find the most profitable pair among the trial sets

Strategy 2

- Try a set of wholesale and buyback prices
- Stop when the profit is higher than the baseline

Prepare a set of wholesale and buyback prices

- Make sure the search range is granular enough!

```
search_set <- expand_grid(wholesale = seq(1, price, length.out = 1000), salvage = seq(1, price, length.out
  filter(wholesale >= salvage) |>
  mutate(TSL = (price - wholesale) / (price - wholesale + wholesale - salvage))
head(search_set)
```

```
## # A tibble: 6 x 3
##   wholesale salvage   TSL
##       <dbl>   <dbl> <dbl>
## 1      1       1     1
## 2      1.02    1     0.999
## 3      1.02    1.02  1
## 4      1.04    1     0.998
## 5      1.04    1.02  0.999
## 6      1.04    1.04  1
```

```r
res <- search_set |>
  dplyr::rowwise() |>
  mutate(
    q_star = quantile(book$Demand, TSL)
  ) |>
  ungroup()
res <- res |>
  dplyr::rowwise() |>
  mutate(
    AvgProf_pub_search = mean(wholesale * q_star - salvage * pmax(q_star - book$Demand, 0) - cost * q_star
    AvgProf_book_search = mean(price * pmin(q_star, book$Demand) + salvage * pmax(q_star - book$Demand, 0)
  ) |>
  ungroup() |>
  filter(AvgProf_pub_search > 0 & AvgProf_book_search > 0) |>
  mutate(total_profit = AvgProf_pub_search + AvgProf_book_search)

write.csv(res, "res_bw_pair.csv")
```

```r
res <- read.csv("res_bw_pair.csv")
res |>
  filter(AvgProf_pub_search >= AvgProf_pub_baseline & AvgProf_book_search >= AvgProf_book_baseline) |>
  arrange(desc(total_profit)) |>
  head(5)
```

```
##        X wholesale  salvage       TSL   q_star AvgProf_pub_search
## 1 194348  14.13814 13.36036 0.9099757 22780.23           238560.2
## 2 193722  14.11712 13.33934 0.9101942 22780.56           238141.0
## 3 193097  14.09610 13.31832 0.9104116 22780.89           237721.8
## 4 194349  14.13814 13.38138 0.9121951 22790.60           238499.8
## 5 193096  14.09610 13.29730 0.9082126 22751.93           237780.9
##   AvgProf_book_search total_profit
## 1            154554.6     393114.7
## 2            154973.7     393114.7
## 3            155392.9     393114.7
## 4            154614.3     393114.2
## 5            155333.1     393114.0
```

Intuition

- Vertical integration could increase the pi of the profit
- Relative to the baseline, the supply chain could increase the pi by changing the contract (buyback and wholesale price)
- A way to think is that 1) increase the pi, 2) then decide/negotiate/bargain how to split the pi (in reality, it is affected by the bargaining power and the outside option for each party)

Instead of blute force...

- You can do constrained optimization (excel solver example is in excel sheet)
  - both parties profit should be equal or greater than the baseline ones
  - $\frac{p-w}{(p-w+w-s)} = 0.9$
- (your exercise) Try doing it in R/python as well
- (your exercise) Try numerical way instead of analytical way

More exercise on Newsvendor formula

- What if the cost increased?
  - the target SL decreases.
  - then, the quantile decreases.
  - So, the optimal quantity should decrease.
- What if the salvage increased?
  - the target SL increases.
  - then, the quantile increases.
  - So, the optimal quantity should increase.

Some comments on assignment 2

- Q2
- Q6

Q2

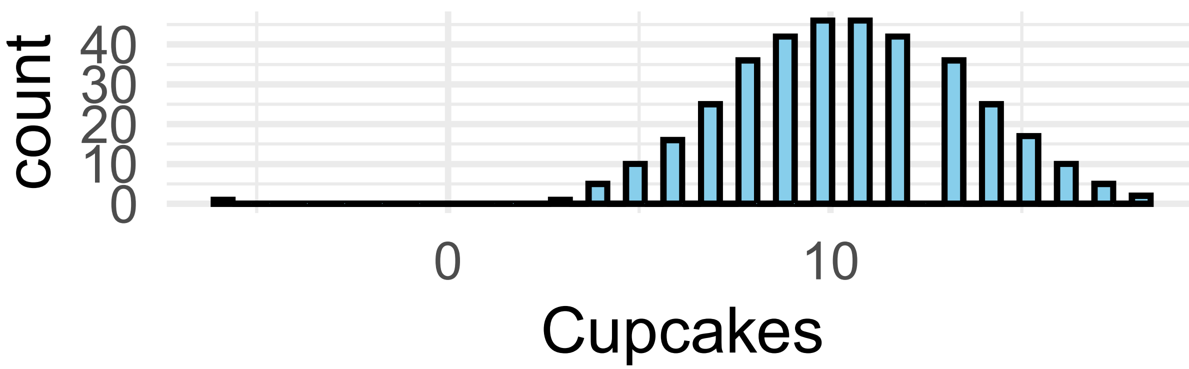
Suppose that we improve our forecasting using more sophisticated machine learning methodology. Specifically, the forecasting errors are reduced more than 50% compared to a previous traditional forecasting model. In this case, what happens to the target service level when we use the machine learning forecasting model instead of the previous traditional forecasting model?

Q6

Consider the cupcake problem. The full retail price is \$2.49, and unit cost is \$1.24. The salvage value used to be \$0.99. However, the bakery decided to donate all the leftovers, which makes the salvage value to 0. In this case of zero salvage values, what is the target service level?

- TSL $= \frac{p-c}{p} = \frac{2.49-1.24}{2.49} = 0.502$

```r
demand_df <- read.csv("../data/demand_data_session1_2022.txt", sep = "\t")
cupcakes <- demand_df |> select(Cupcakes)

cupcakes |>
  ggplot(aes(x = Cupcakes)) +
  geom_histogram(bins = 50, fill = "skyblue", color = "black") +
  theme_minimal()
```



D	P(Dem = D)	P(Dem ≤ D)
3	0.5%	0.5%
4	1.4%	1.9%
5	2.8%	4.6%
6	4.6%	9.3%
7	6.9%	16.2%
8	9.7%	25.9%
9	11.6%	37.5%
10	12.5%	50.0%
11	12.5%	62.5%
12	11.6%	74.1%
13	9.7%	83.8%
14	6.9%	90.7%
15	4.6%	95.4%
16	2.8%	98.1%
17	1.4%	99.5%
18	0.5%	100%

Should we bake 10 or 11?

- Answer. You should bake 11!
- Why? Because at the margin, baking one extra unit is profitable $\Pr(D > q) * Cu > \text{Prob}(D <= q) * \text{Co}$, that is $1.25 * (1 - 0.50) > 1.24 * 0.50$ while $1.25 * (1 - 0.625) < 1.24 * 0.625$
- Or, you can check by calculation

```
price <- 2.49
cost <- 1.24
TSL <- 0.502

print(mean(price * pmin(10, cupcakes$Cupcakes) - cost * 10))
```

```
## [1] 10.0714
```

```
print(mean(price * pmin(11, cupcakes$Cupcakes) - cost * 11))
```

```
## [1] 10.07981
```