Micron Educator Hub

# Intro to Newsvendor Model and Applications In Semiconductors

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# Section 1

1. Goal, Objectives, and Target Audience
2. Intro to Newsvendor Problem
3. Using Statistics to Identify Solution
4. Apply Newsvendor Model in Micron Supply Chain

# Newsvendor Model - Goal and Objectives

This presentation provides an overview of the Newsvendor Model, the statistics used to find solutions, and examples of the practical business application at Micron.

Objectives:

1. Understand the Newsvendor model as a fundamental theory in supply chain management
2. Describe how the Newsvendor model is used to determine optimal target service level in the presence of uncertainty in demand
3. Describe the statistic used to find solutions
4. Explore examples of the practical business applications at Micron

# Newsvendor Model - Target Audience

- Individuals interested in a career in supply chain and how data driven supply chain works.
- Interns, NCGs (New College Grads), and new employees in supply chain roles need to understand these concepts
- Examples of critical target audience roles at Micron that utilize these concepts:
  - Supply Chain Engineer
  - Supply Chain Optimization Engineer
  - Inventory Optimization Engineer
  - Operations Research Engineer
  - Product Operation
  - Capacity Planner
  - Strategic Planner
  - Data Scientist working on Supply Chain domain

Pro Tip: everyone interviewing at Micron can use this presentation to prepare for the interview by learning foundational information about supply chain. Check out the candidate guides for Business, Engineering, and Technician roles:

- Micron business candidate guide
- Micron engineering candidate guide
- Micron technician candidate guide

# Section 2

1. Goal, Objectives, and Target Audience
2. Intro to Newsvendor Problem
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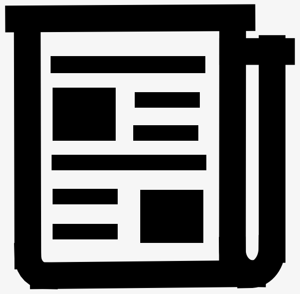
4. Apply Newsvendor Model in Micron Supply Chain

# The Problem for a Newsvendor

John decides to open a Newspaper stall.

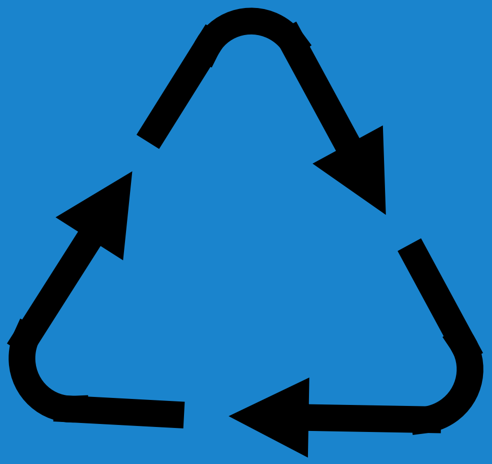


Sets / Identifies the following parameters:

- Price ($p$ = \$ 1.00)

- Cost ($c$ = \$ 0.40)

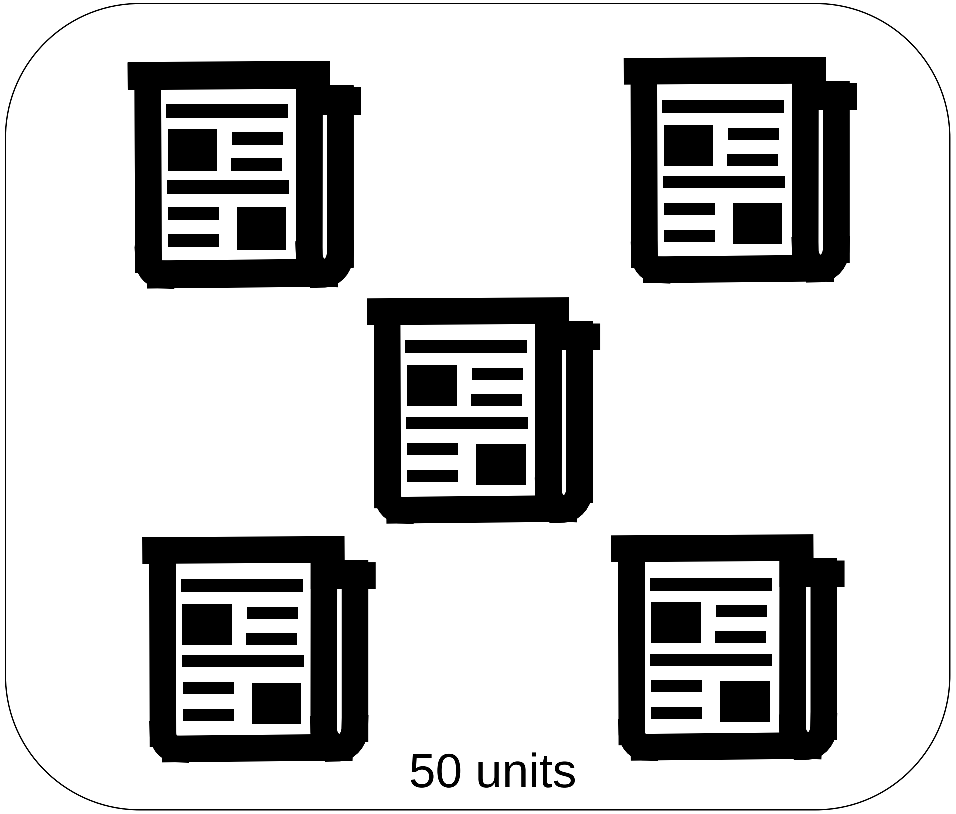
- Scrap Value ($S$ = \$ 0.10)



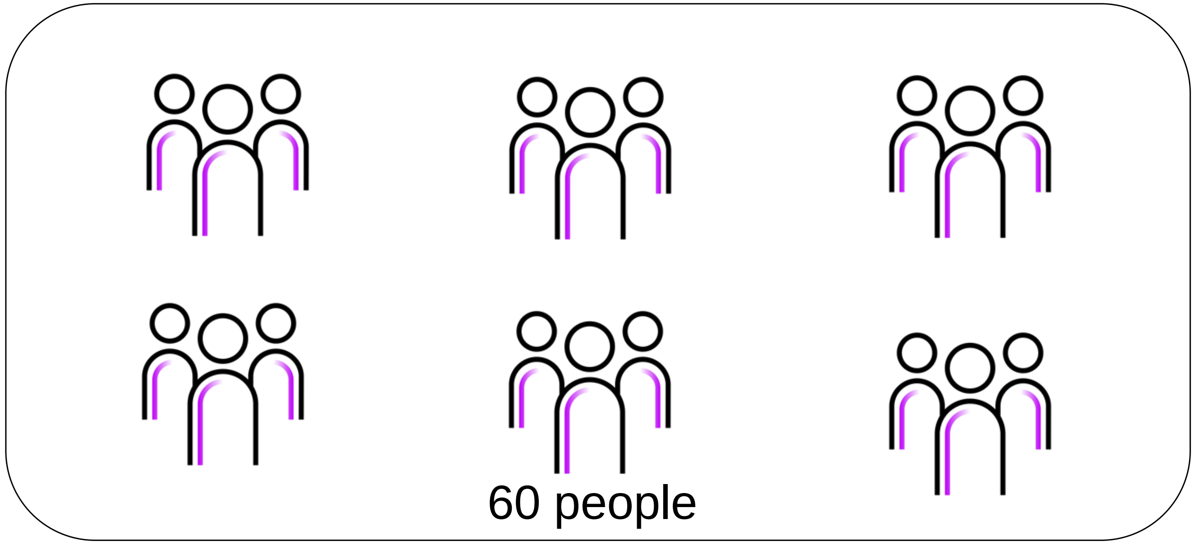
Newsvendor Model

# The Inventory Decision

Inventory/Supply



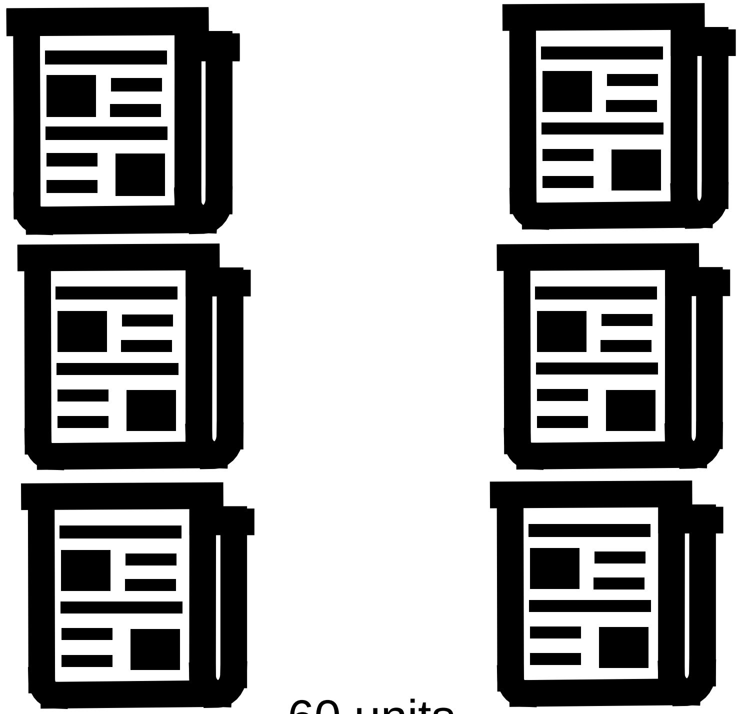

Uncertain Demand




60 people
# of unsatisfied customer = 10
Loss of profit = $6.00
Per unit understocking cost = $0.60

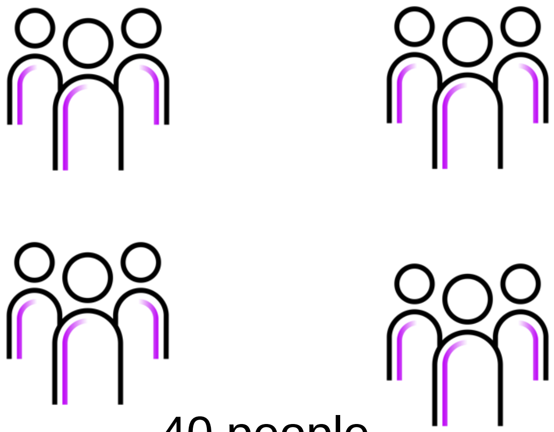
# The Inventory Decision

## Inventory/Supply



60 units

## Uncertain Demand



40 people

40 people
# of excess inventory = 20
Loss of profit = $6.00
Per unit overstocking cost = $0.30

# John's Dilemmas

| | |
|---|---|
| 1 | John needs to decide how many inventories to stock before the demand quantity is realized, knowing that unsold copies will be worthless at the end of the day. |
| 2 | Trade-off between the understocking cost of stocking too less versus the overstocking cost of buying too many. |
| 3 | Also, John needs to look for the demand pattern from historical data. |

## Newsvendor Model

# A Hand's On Approach to Find Optimum

| | |
|---|---|
| 1 | John looks at historical data and sees that the demand of newspaper is: $50\ units \pm 20\ units$ |
| 2 | Demand lies between $30\ units$ and $70\ units$ |
| 3 | Inventory decision depends on Overstocking Cost and Understocking Cost |
| 4 | If Overstocking Cost = Understocking Cost, John would order $50\ units$ (Middle of the demand horizon) |
| 5 | Higher the Understocking Cost (compared to Overstocking Cost), closer John would move towards $70\ units$ |
| 6 | Lower the Understocking Cost (compared to Overstocking Cost), closer John would move towards $30\ units$ |

Newsvendor Model

# Pictorial Representation

Inventory Decision

Higher Over-stocking cost ⟷ Higher Under-stocking cost

Min Demand ▬▬▬ Max Demand

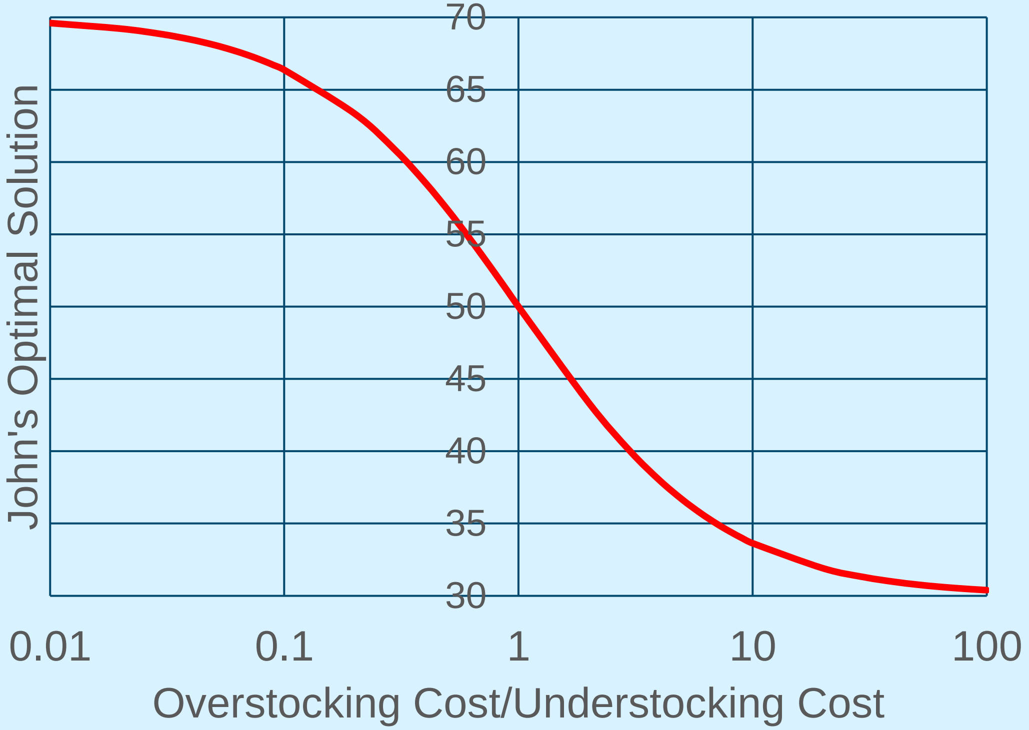
Since in John’s Case, Understocking Cost : Overstocking Cost = 2 : 1, John’s decision of inventory would be 2/3rd way of the demand horizon towards 70 units, that is:

$$30\ units + 0.67 \times (70 - 30)\ units \approx 57\ units$$

# Factors Affecting John's Inventory Decision

- **Overstocking and Understocking Costs**
- Mean Demand (Central tendency of the uncertain demand variable)
- Range of Demand (Dispersion of the uncertain demand variable)

Sensitivity of John's Solution w.r.t.
Overstocking Cost and Understocking Cost



# Factors Affecting John’s Inventory Decision

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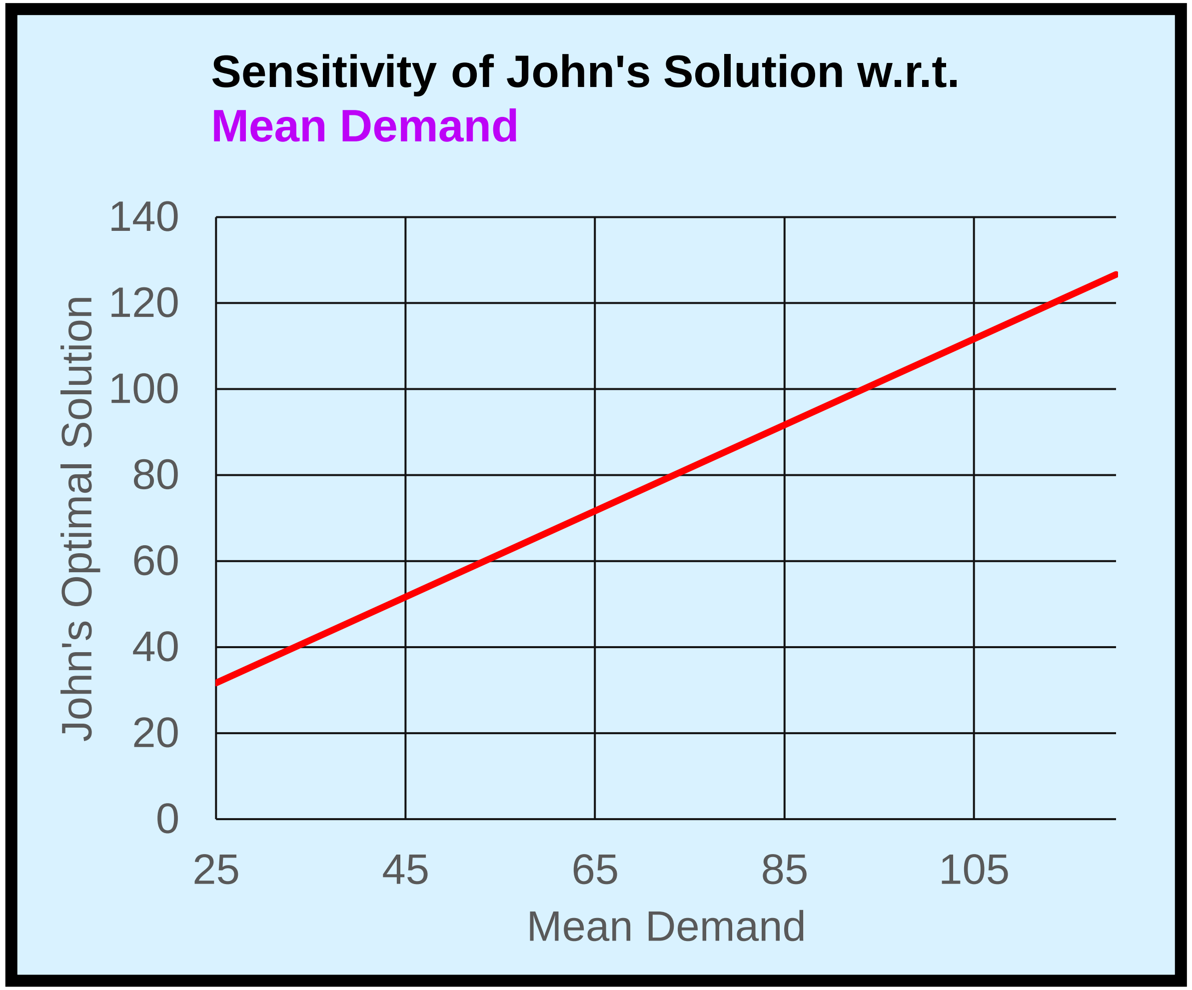
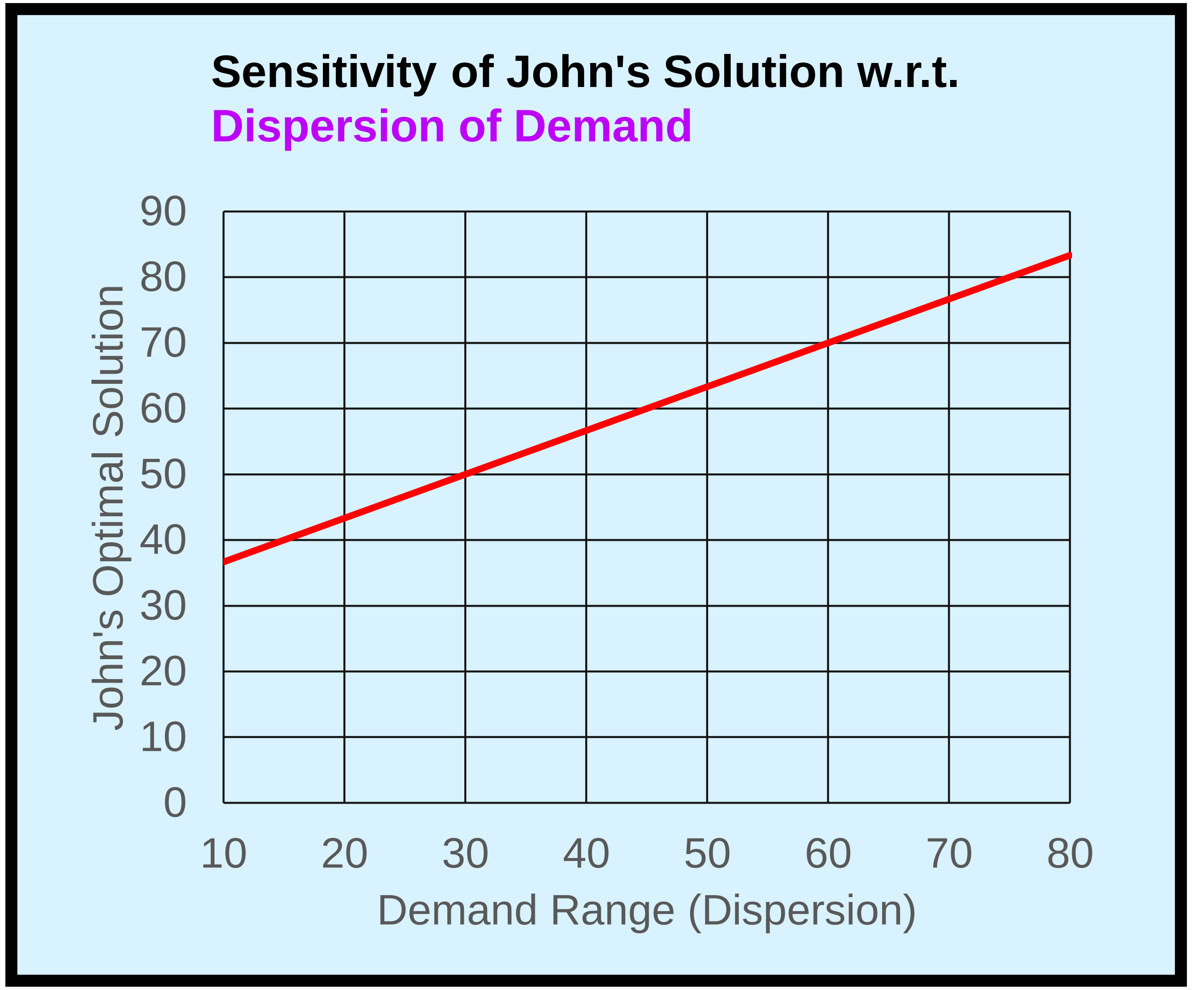


# Factors Affecting John's Inventory Decision

- Overstocking and Understocking Costs
- Mean Demand (Central tendency of the uncertain demand variable)
- **Range of Demand (Dispersion of the uncertain demand variable)**



# Section 3

1. Goal, Objectives, and Target Audience
2. Intro to Newsvendor Problem
3. Using Statistics to Identify Solution
4. Apply Newsvendor Model in Micron Supply Chain

# Using Statistics to Identify Solution

## Capturing Demand Uncertainty

- The source of our problem is that the demand is uncertain.

- Uncertainty is generally captured by two measurements:
  - Measurement of central tendency
  - Measurement of dispersion

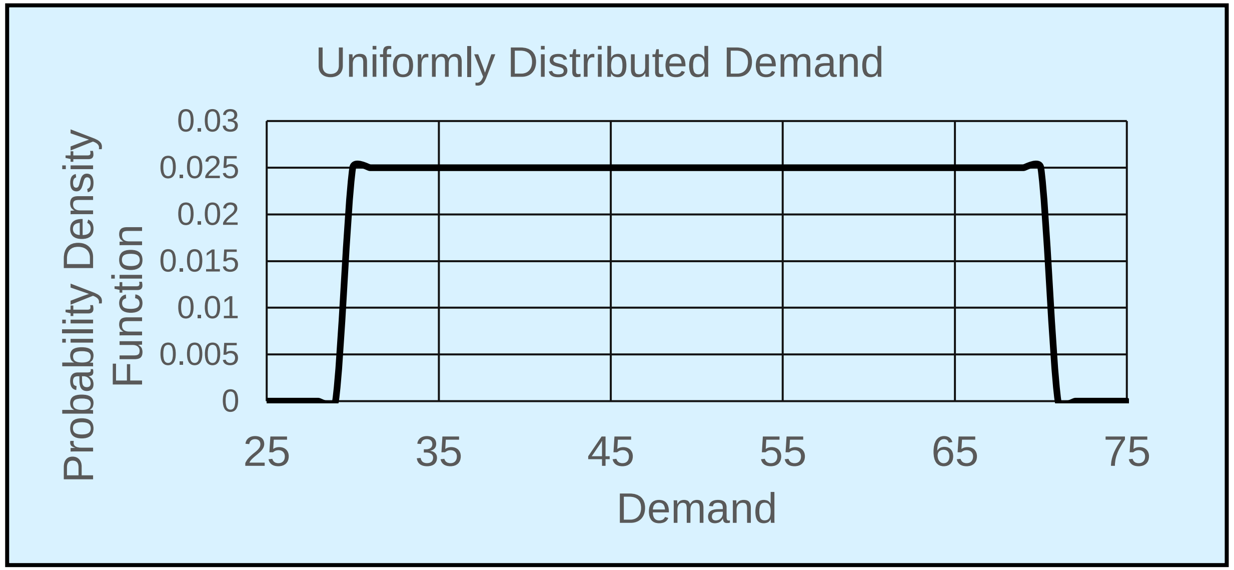
- Central Tendency reflects the average behavior of the random variable (here, demand).
  - It is generally captured by Mean/Expected value
  - For example: John expects that, on average, the demand of newspapers is 50 units

- Dispersion reflects the deviation of the actual values (demands) with respect to the central tendency measurement.
  - The actual demand of newspapers can be any value including 50 units.
  - The difference between actual demand, say 35; and the mean value, 50, is captured in the form of dispersion.

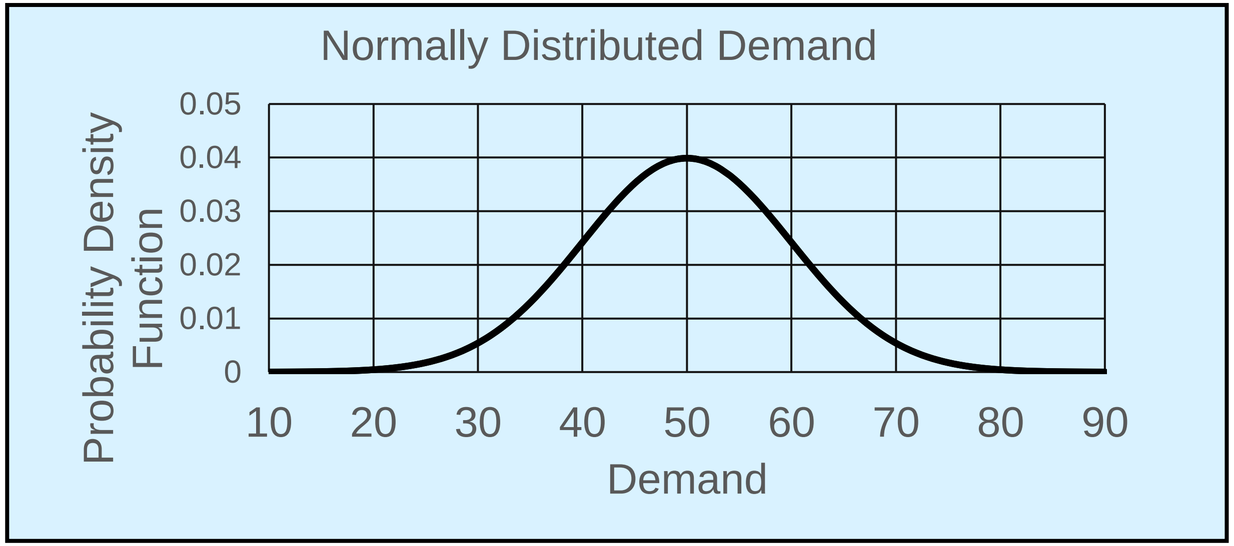
# Using Statistics to Identify Solution

A View of Demand Distribution

- Here the demand can be anything between 30 and 70 and each value is equally likely to occur (The probabilities are same between 30 and 70).




- Here probability of demand reduces as it moves away from mean.
- Demand being equal to 49 is more likely to occur than demand being equal to 30.

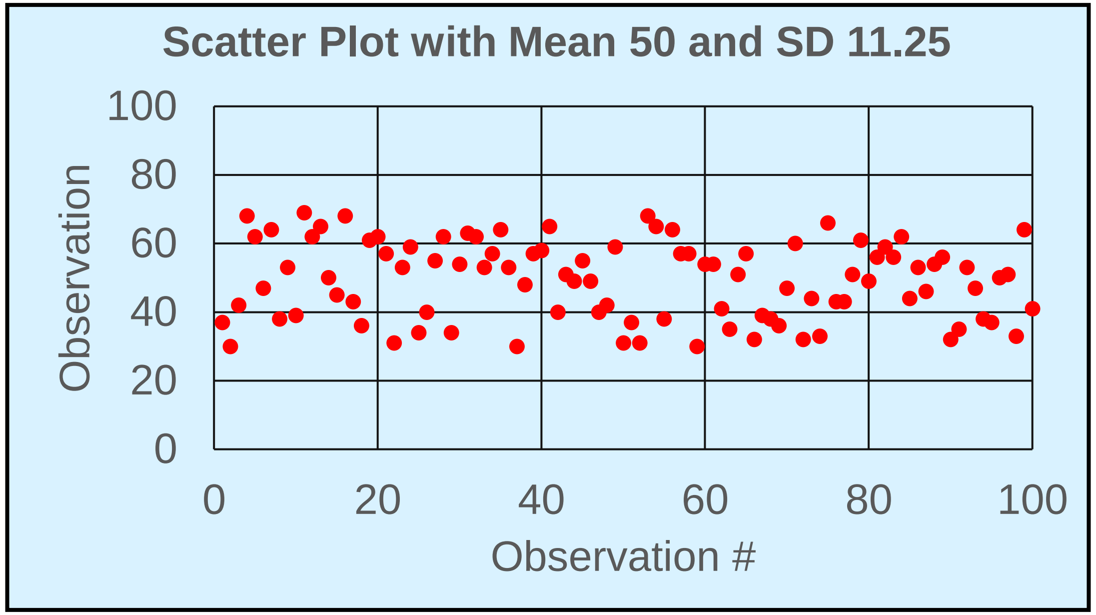


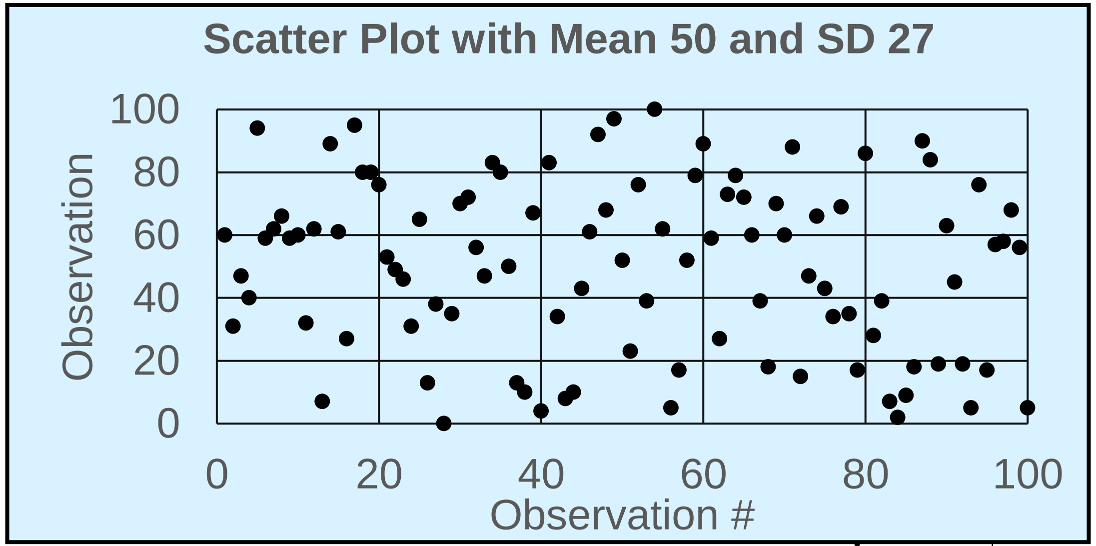
# Using Statistics to Identify Solution

Standard Deviation or Sigma

- Dispersion is a significant factor affecting the optimal inventory level.
- A crude measurement of dispersion is range, as used by John.
- A more common measurement of dispersion is standard deviation or *Sigma.*
- Sigma is measured as average deviation of individual values with respect to the mean value, and is formulated by,

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$



# Using Statistics to Identify Solution

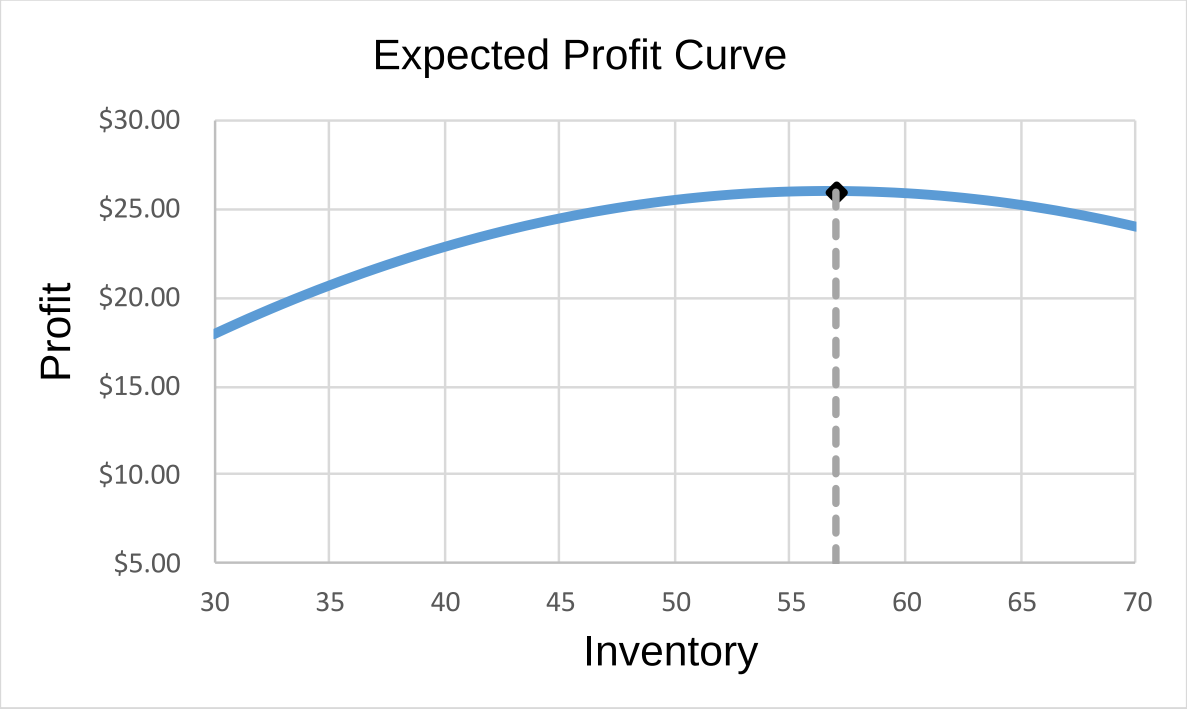
Quality of John's Solution

- John's approximation is not bad.
- For uniformly distributed demand, John's approximation gives exact solution.

| | |
|---|---|
| Understocking Cost | 2 |
| Overstocking Cost | 1 |
| John's Solution | 57 |

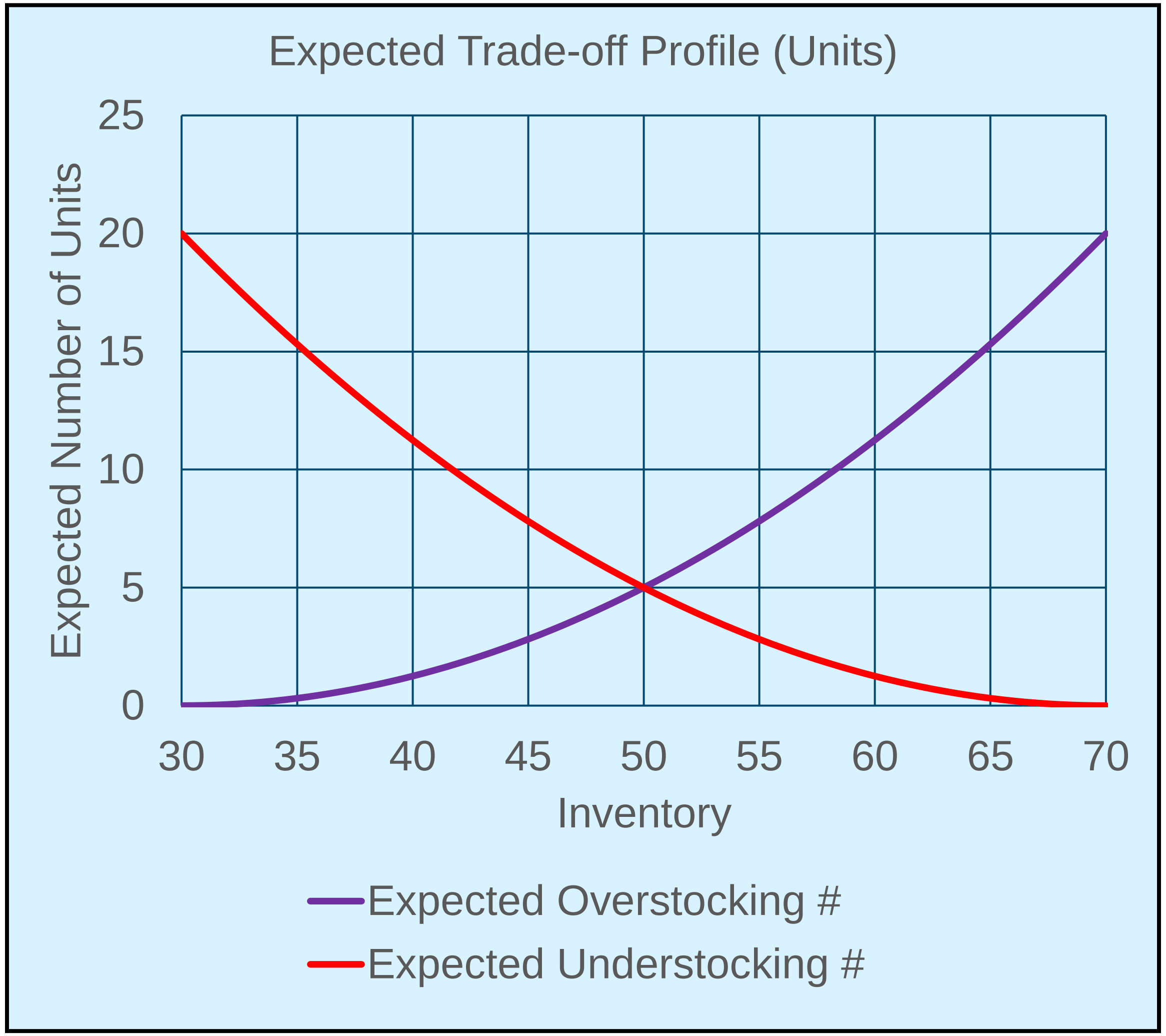
- Unfortunately, we don't always have uniform demand.
- Also, trial and error approach cannot work in a large scale operation scenario.

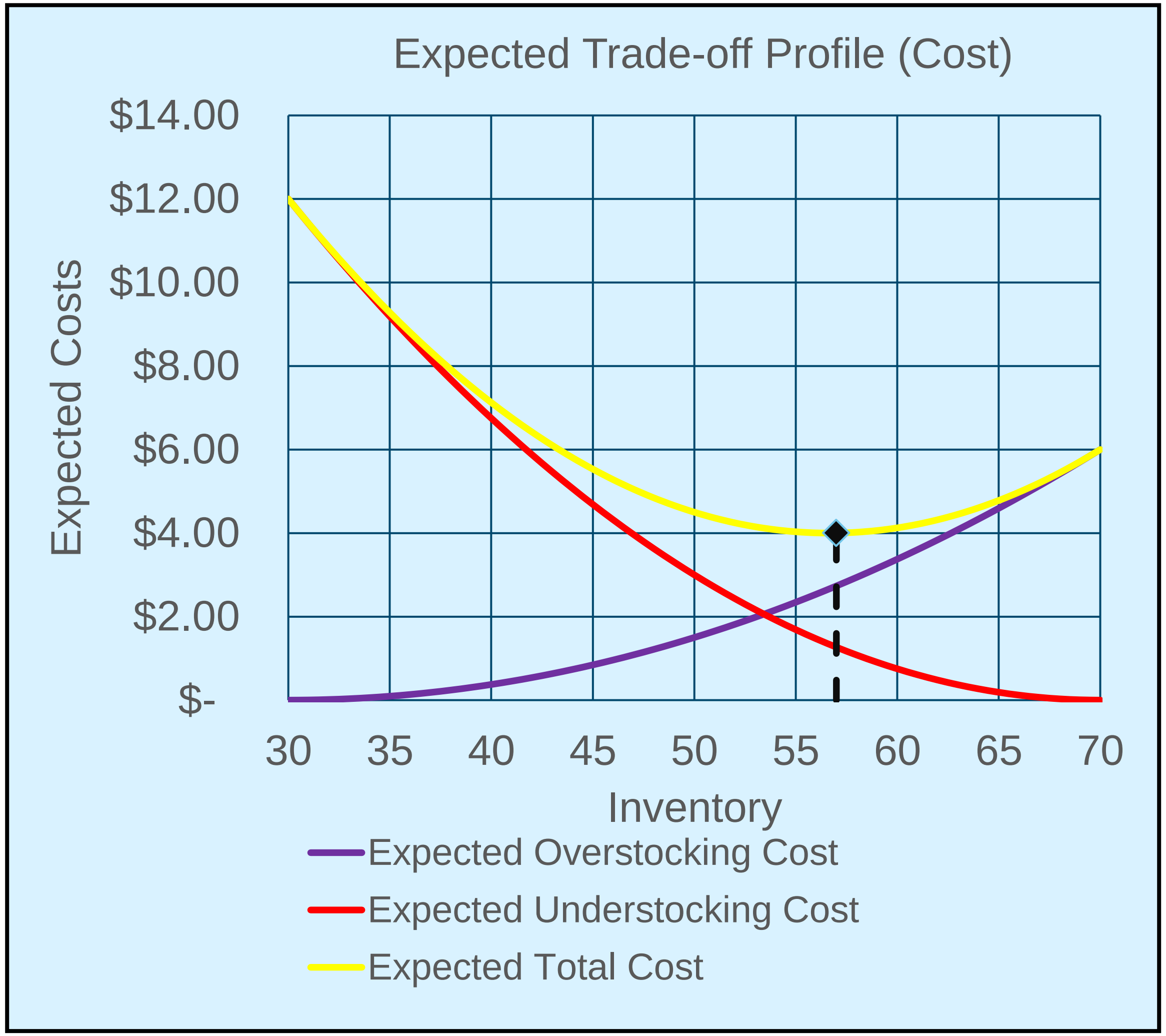
John's Expected Profit Curve



# Using Statistics to Identify Solution

The Cost Diagrams for the Newsvendor



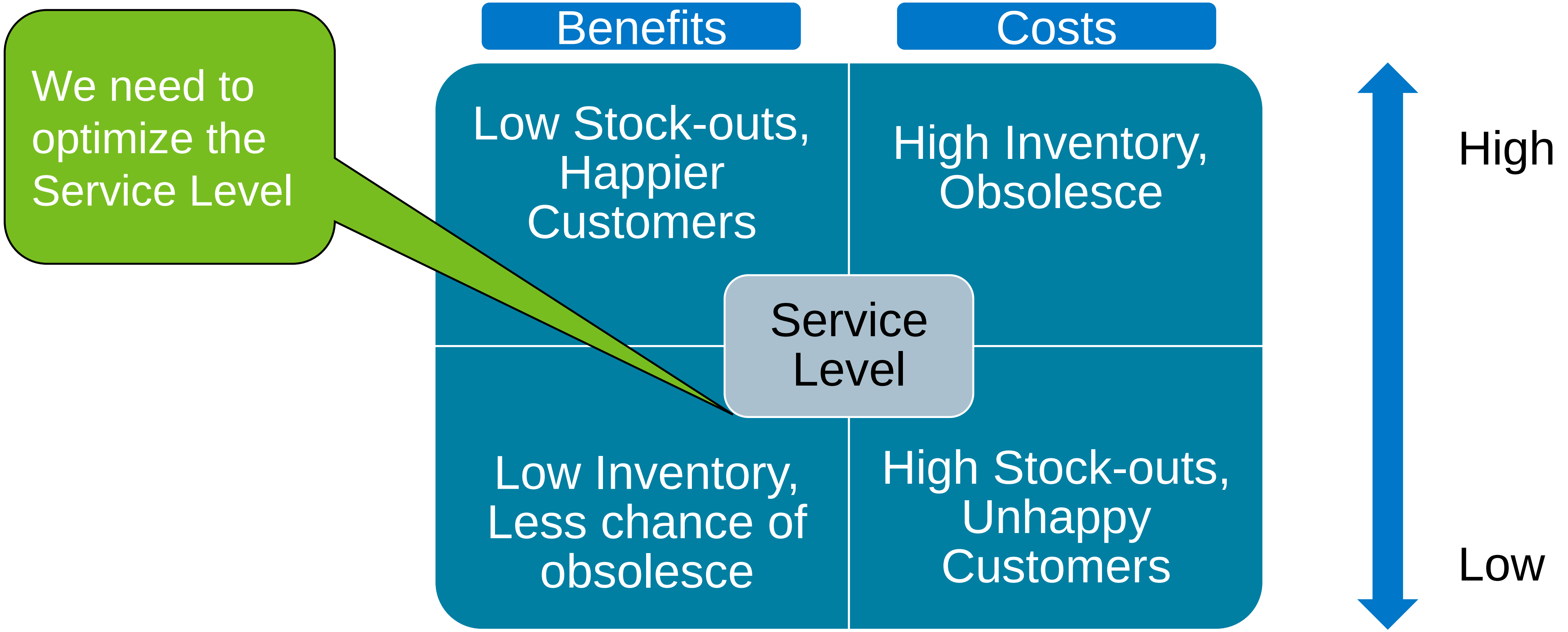



# Using Statistics to Identify Solution

- Till now, we talked about optimizing inventory level.
- A more general approach is optimizing service level. (Independent of the demand distribution).
- High / Low Service level means happy / unhappy customers.
- If we are meeting the demand, then our customers are happy.
- So, one measure of service level can be the percentage of time we are fulfilling the demand.
- Higher inventory, higher service level (One to one mapping between inventory and service level).
- Any optimization of inventory level can be translated to optimization of service level.

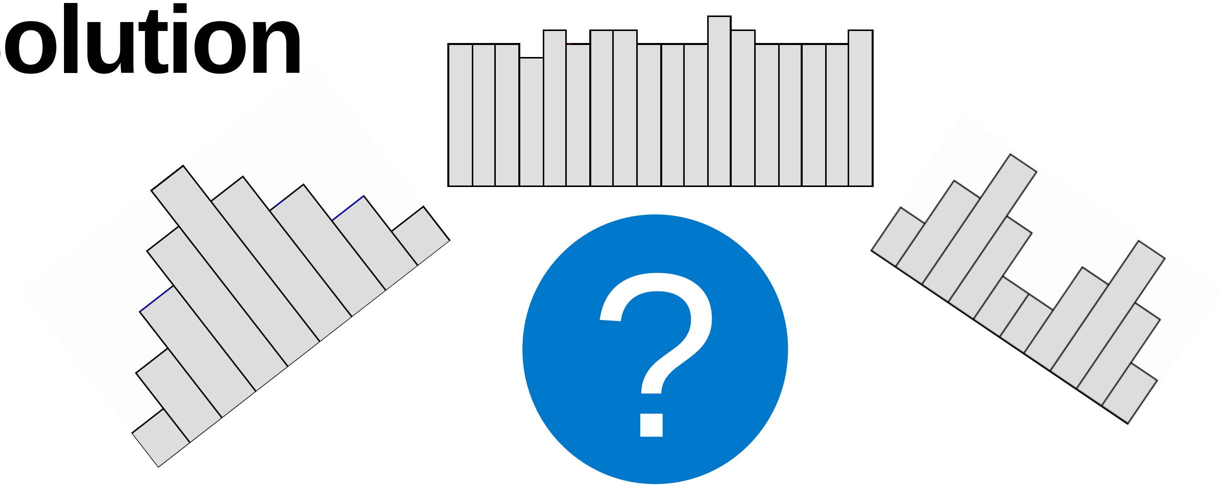
# Using Statistics to Identify Solution

The Trade-Off



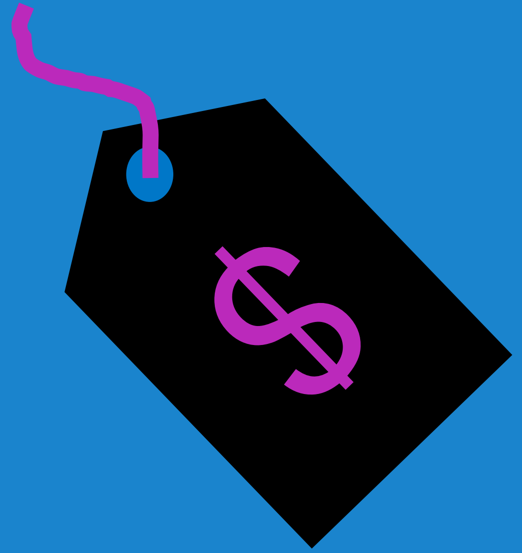
# Using Statistics to Identify Solution

Required Parameters



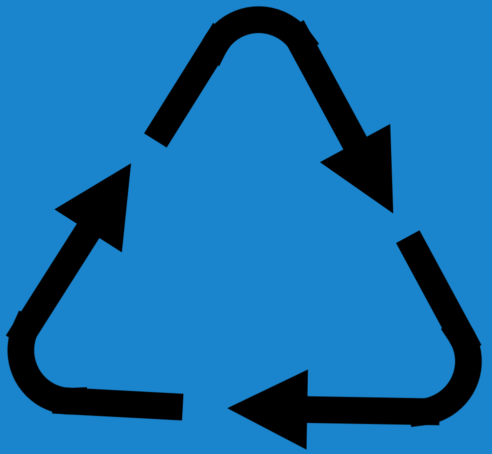
Demand Distribution
- Normal
  - Mean = 50
  - SD = 10

- Price ($p$ = $ 1.00)



- Cost ($c$ = $ 0.40)

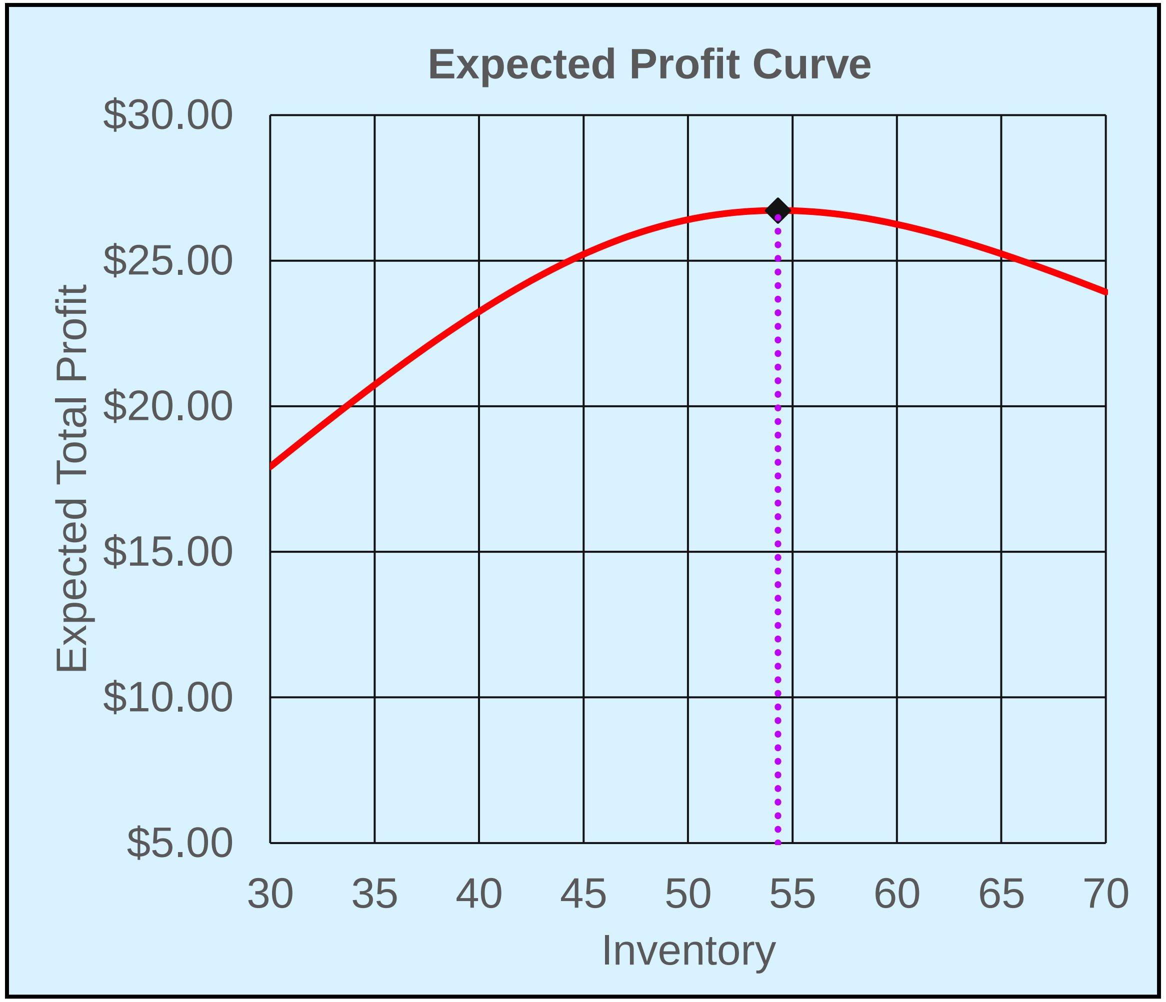
- Scrap Value ($S$ = $ 0.10)



# Using Statistics to Identify Solution

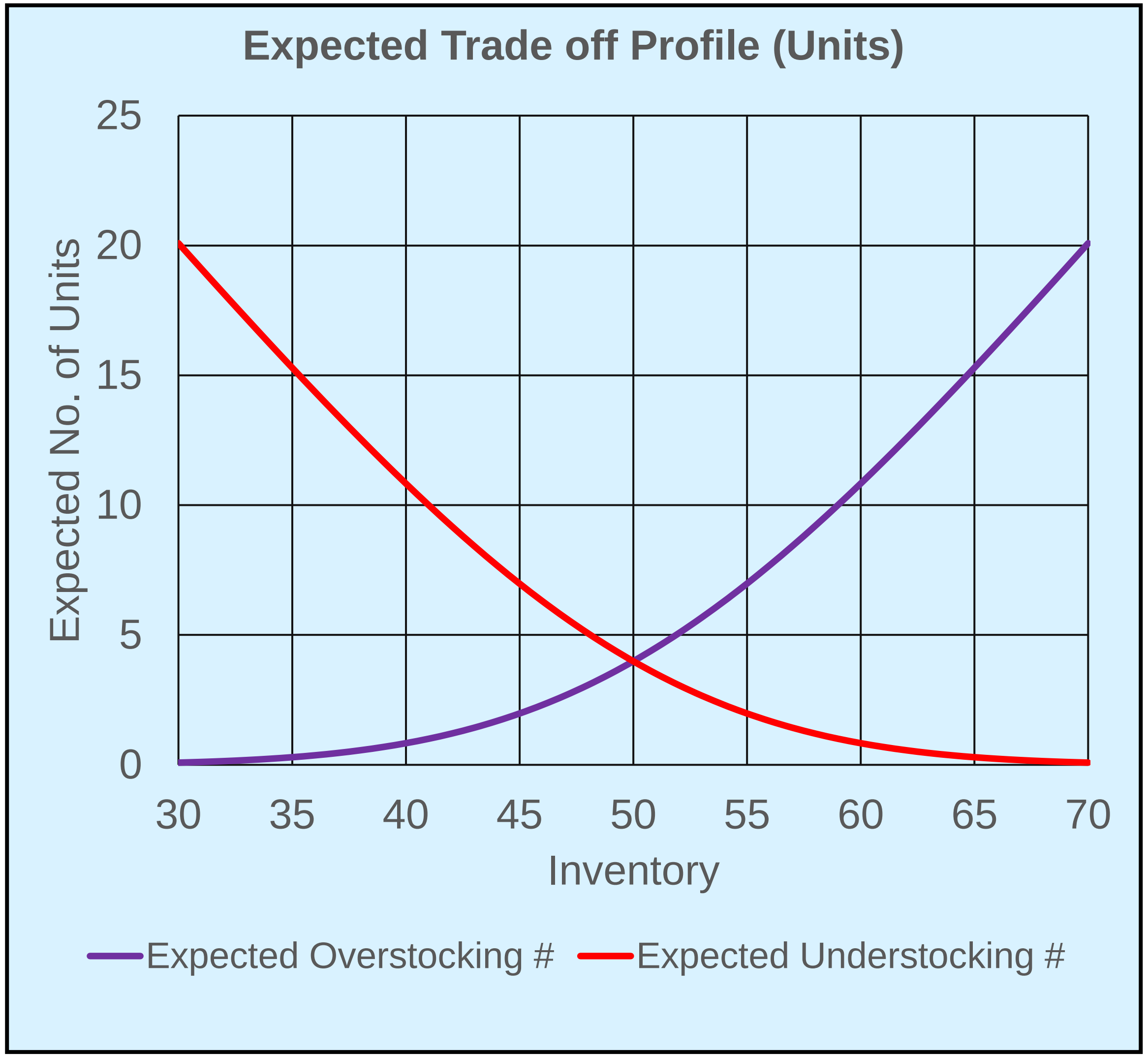
Optimization: Blunt Force Method

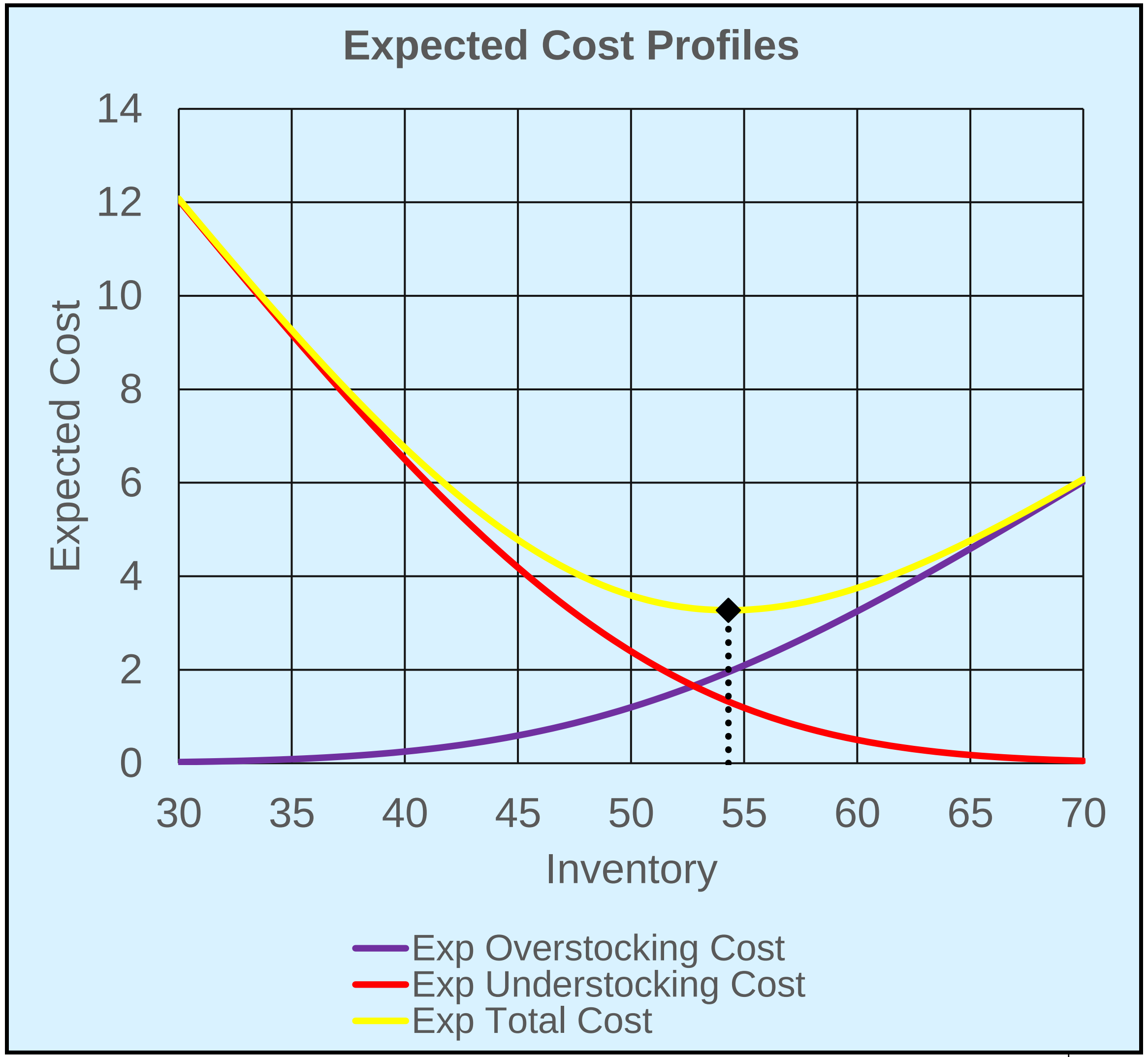
| | |
|---|---|
| 1 | Take different “Inventory” values. |
| 2 | Calculate the Expected Total Profit for all “Inventory” values. |
| 3 | Plot the Expected Total Profit on a graph. |
| 4 | Identify the optimum. |



# Using Statistics to Identify Solution

The Cost Diagrams

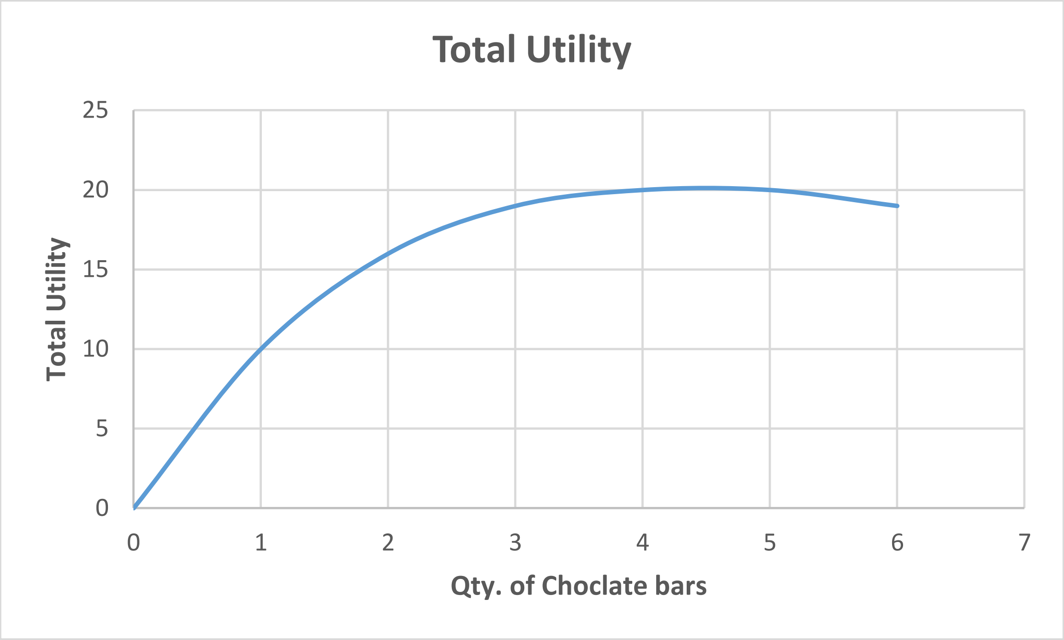


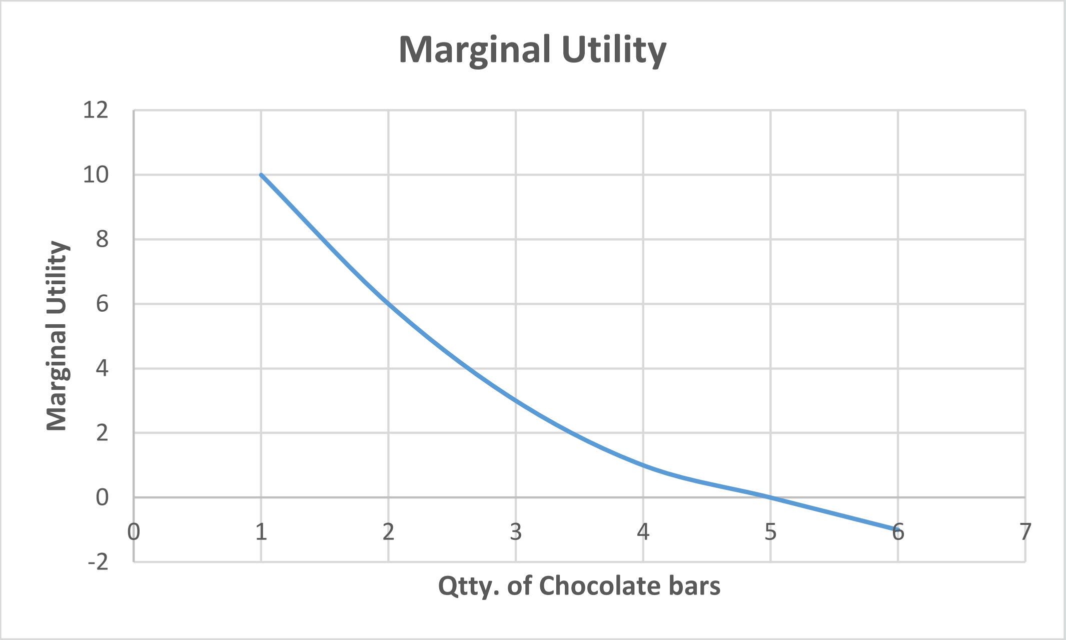



# Using Statistics to Identify Solution

## Law of Diminishing Marginal Utility

- Also known as “Gossen's First Law” in Economics.
- The marginal utility of each homogenous unit decreases as the supply of units increases.



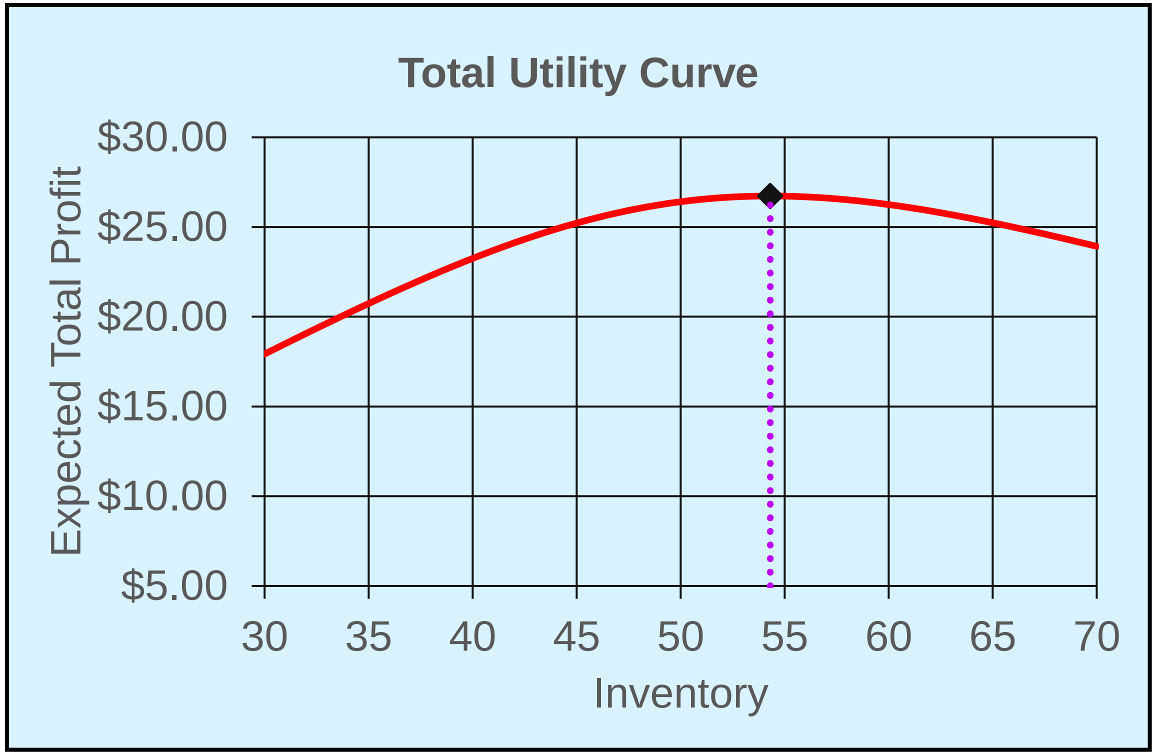



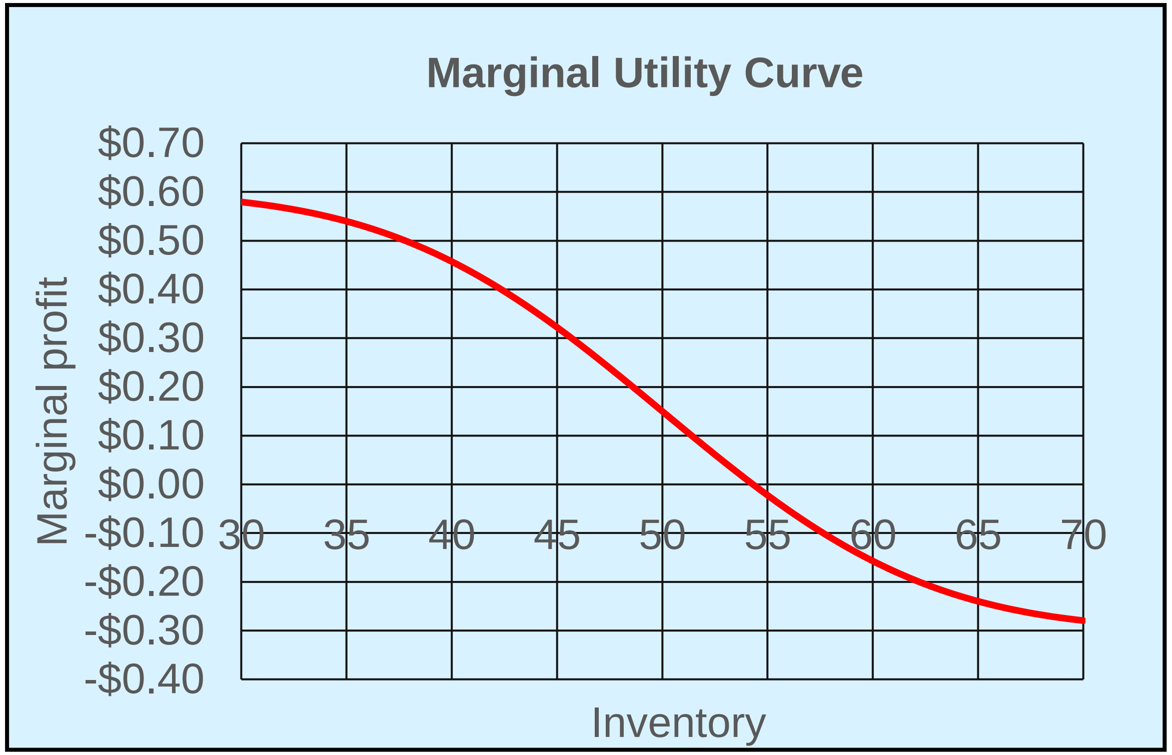

- True for most of the economic scenarios (including the utility of the number of units ordered from the supplier).

# Using Statistics to Identify Solution

## Newsvendor’s Marginal Utility Curve

- For the newsvendor, total utility is equivalent to total profit, and marginal utility is equivalent to marginal contribution, i.e., marginal revenue – marginal cost.




- As long as the marginal utility is positive, the newsvendor keeps on piling his/her order, because the additional unit is contributing positively to the profit.

# Using Statistics to Identify Solution

## Marginal Utility Calculation

**BENEFIT**

- By ordering an additional unit, we are saving the firm from stockout for one additional customer, termed as understocking cost ($C_u$).
- However, this will happen only if we are able to sell that unit.

**COST**

- By ordering an additional unit, we are incurring the cost of holding that additional unit, termed as overstocking cost ($C_o$).
- This will happen only if we are not being able to sell that unit.

Therefore, marginal utility of that additional unit is,

$$C_u \times \text{Prob(We are able to sell the unit)} - C_o \times \text{Prob(We are not able to sell the unit)}$$
$$= C_u \times \text{Prob(Demand} > \text{Existing Quantity)} - C_o \times \text{Prob(Demand} \leq \text{Existing Quantity)}$$

# Using Statistics to Identify Solution

Optimum Order Quality

- At optimum ($Q = Q^*$), marginal utility of an additional unit = 0.
- Therefore,

$$C_u \times \text{Prob}(\text{Demand} > Q^*) - C_o \times \text{Prob}(\text{Demand} \leq Q^*) = 0$$

- But demand follows normal distribution with mean $\mu$ and standard deviation $\sigma$.

$$\text{Prob}(\text{Demand} > Q^*) = 1 - \text{Prob}(\text{Demand} \leq Q^*) = 1 - F(Q^*)$$

- where $F(\cdot)$ denotes the cumulative distribution function of the demand variable.

- So, solving for $F(Q^*)$ in the marginal utility equation,

$$F(Q^*) = \frac{C_u}{C_o + C_u}$$

Critical Ratio / Optimal Service Level

$$Q^* = F^{-1}\left(\frac{C_u}{C_o + C_u}\right)$$

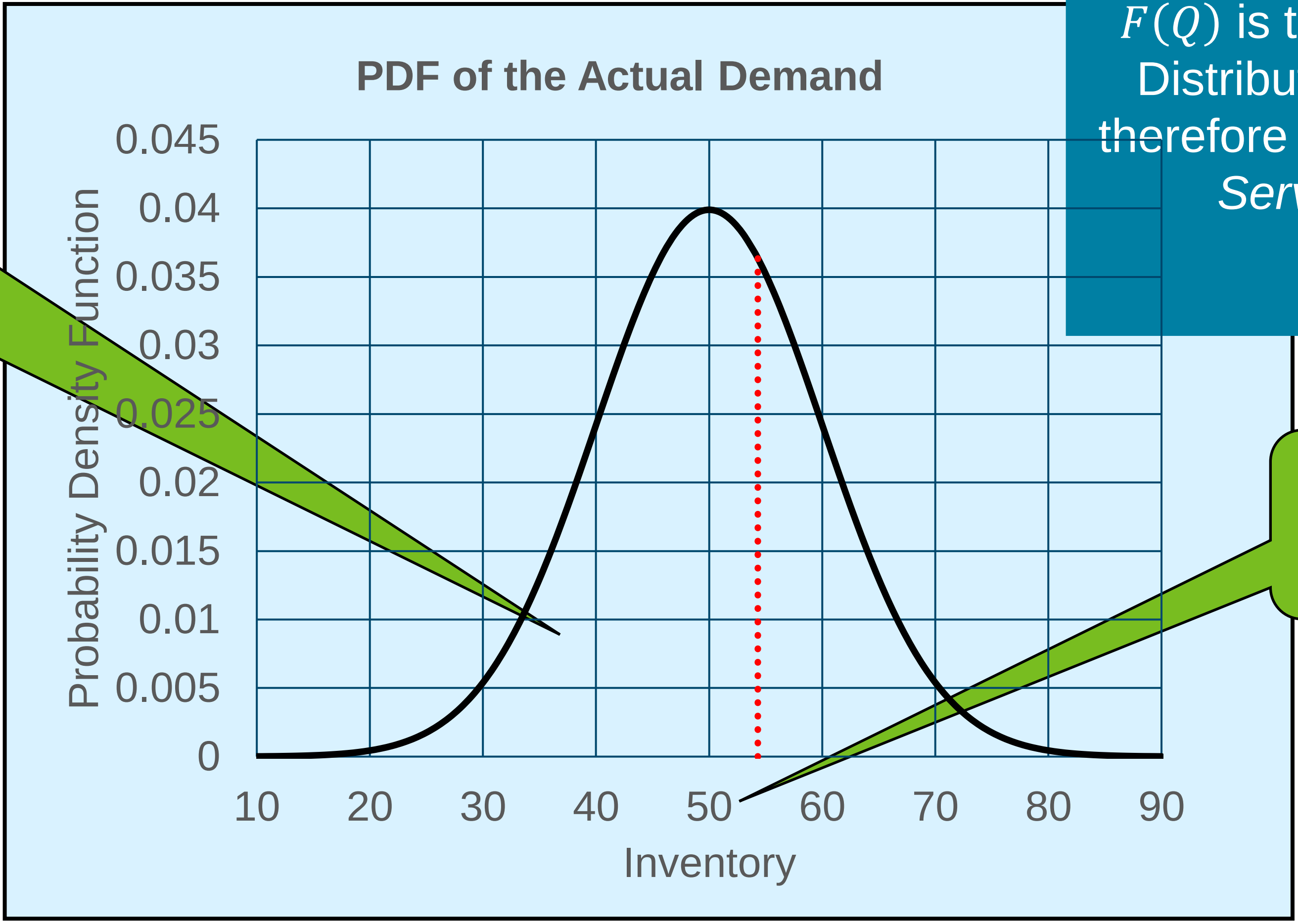
The distribution consideration is only at this stage

# Using Statistics to Identify Solution

## Graphical Representation of the Solution

- Service level: $\alpha = \text{Prob}(\text{Demand} \leq \text{Inventory on hand})$

Area under the curve = Optimal Service Level = $\frac{C_u}{C_o+C_u}$

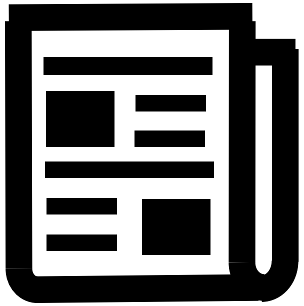



$F(Q)$ is the Cumulative Distribution Function, therefore synonymous to *Service Level*

$$Q^* = F^{-1}\left(\frac{C_u}{C_o + C_u}\right)$$

# Using Statistics to Identify Solution

## Optimum Service Level for John



$$C_u = p - c = \$1.00 - \$0.40 = \$0.60$$

$$C_o = \$0.40 - \$0.10 = \$0.30$$

$$F(Q^*) = \frac{0.6}{0.6 + 0.3} = 67\%$$

- Assuming Demand follows normal distribution with mean 50 and standard deviation 10:

$$Q^* = NORM.INV(67\%, 50,10) \approx 54$$

- If demand followed Uniform distribution between 30 and 70,

$$Q^* = F^{-1}(67\%, a = 30, b = 70) \approx 57$$

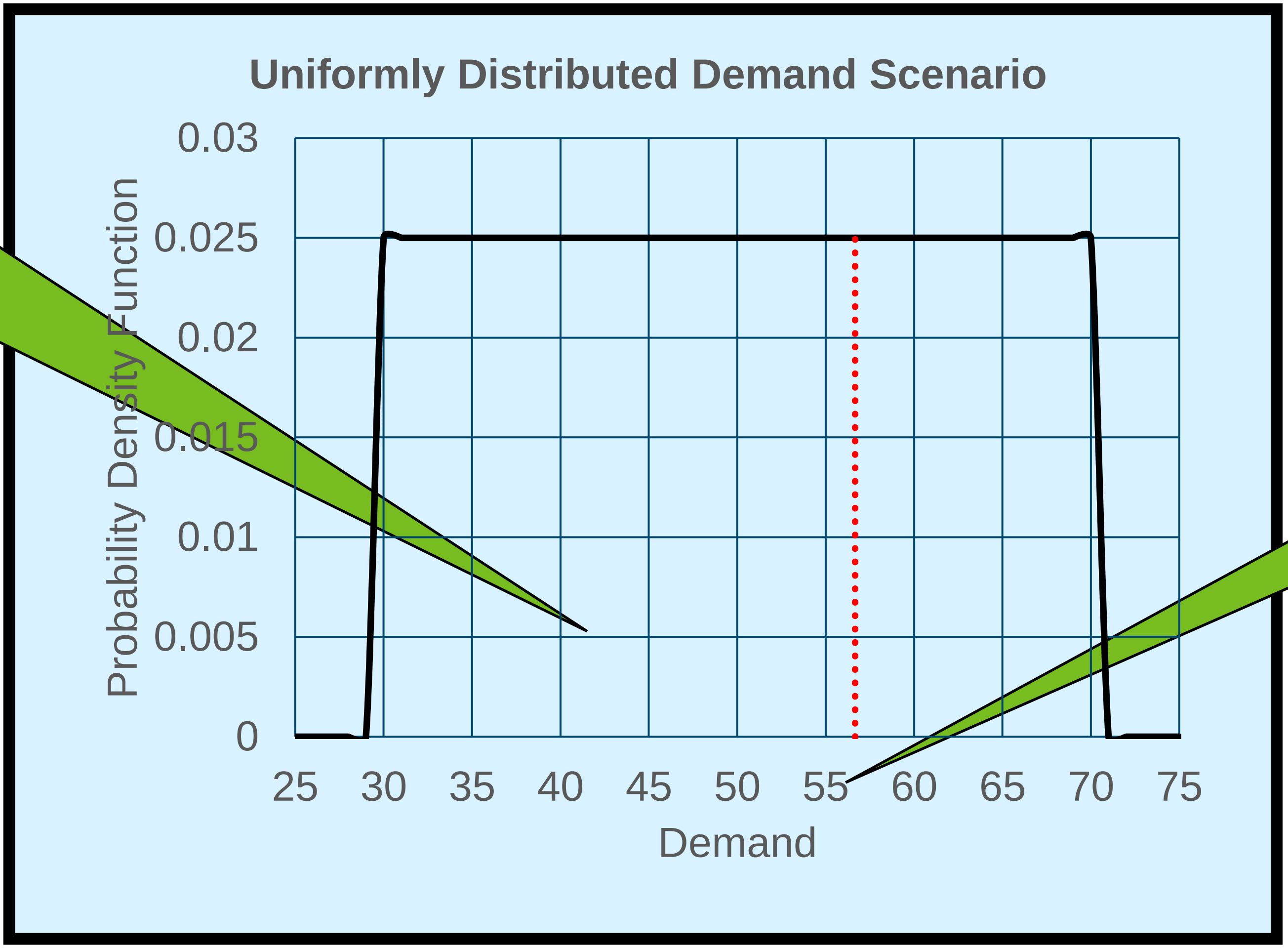
(identical to John's Solution)

# Using Statistics to Identify Solution

## Graphical Representation of Uniform Demand Solution

- Service level: $\alpha = \text{Prob}(\text{Demand} \leq \text{Inventory on hand})$

Area under the curve = Optimal Service Level = $\frac{C_u}{C_o+C_u}$



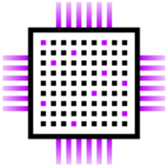

$$Q^* = F^{-1}\left(\frac{C_u}{C_o + C_u}\right)$$

# Section 4

1. Goal, Objectives, and Target Audience
2. Intro to Newsvendor Problem
3. Using Statistics to Identify Solution
4. **Apply Newsvendor Model in Micron Supply Chain**

# Newsvendor Model in Real Business Scenario

## Applying Newsvendor in Supply Chain

| | | | Understocking Cost | Overstocking Cost |
|---|---|---|---|---|
|  | Inventory Safety Stock | Demand Uncertainty | Missed Opportunity (Product Margin) | Inventory Depreciation and Excess Cost |
|  | Flexibility in Capacity Decision | | | Depreciation Cost of Idle Capacity |
|  | Material Safety Stock Decision | | | Material Depreciation and Excess Cost |

# Newsvendor Model in Semiconductors

## Other Applications of Service Level

| | | |
|---|---|---|
| 1 | Production Quantity / Site Utilization Decisions | Trade off between inventory cost and underutilization cost + cost of missed opportunity |
| 2 | Capacity Related<br>• Site Qualification Decisions<br>• Outsourcing Decisions | Trade of between<br>• Qualification cost (cost of flexibility) and cost of missed opportunity<br>• In-house underutilization cost and premium paid to the subcontractor |
| 3 | Inventory Related<br>• Achieving Desired Days of Inventory Outstanding (DIO) | Trade off between inventory cost and underutilization cost + cost of missed opportunity |
| 4 | Customer Related<br>• Customer Specific Service Level Decisions | Trade off between capacity/inventory cost and cost of missed opportunity for the respective customers |

And many more!!!

# Educator Hub

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