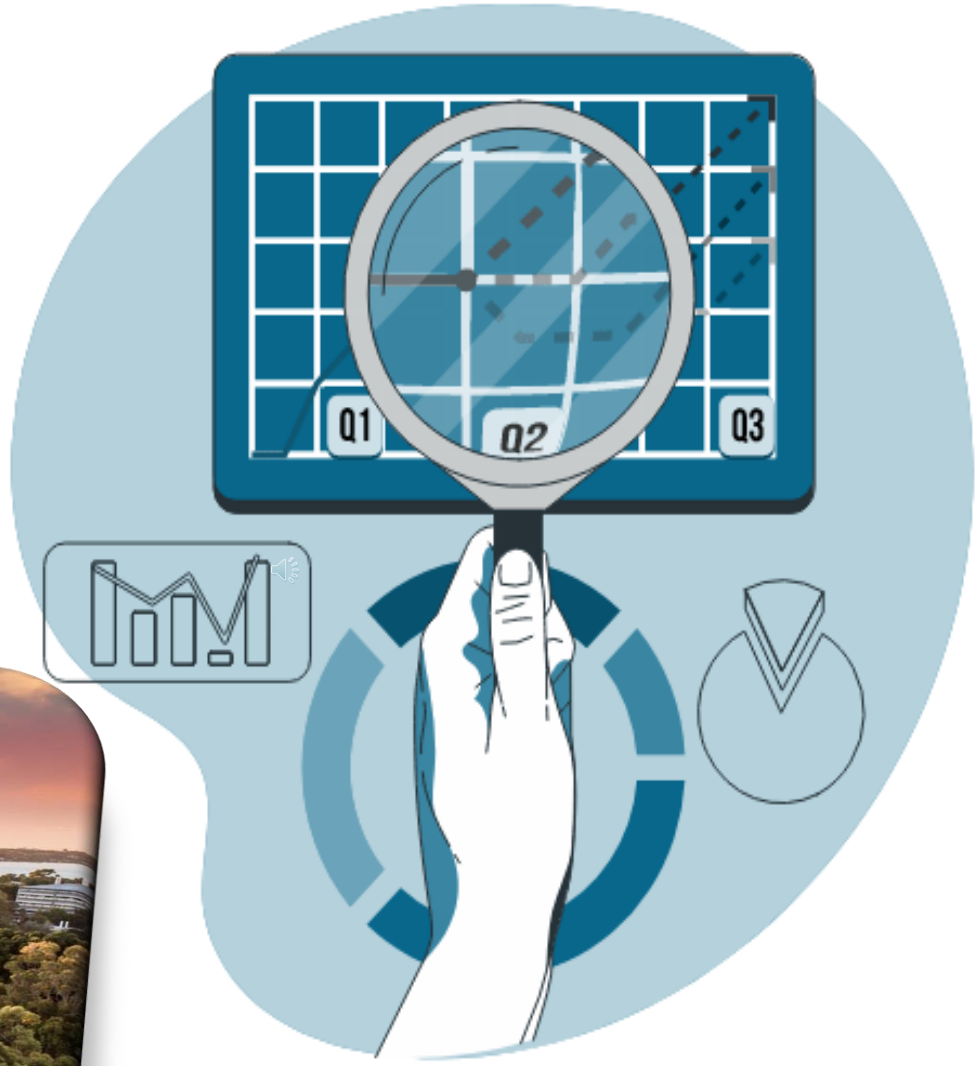
INMT5518
Supply Chain Analytics



Week 4: Descriptive Analytics in Supply Chains (SCs)

Presented by:
Dr. Mehdi Rajabi Asadabadi

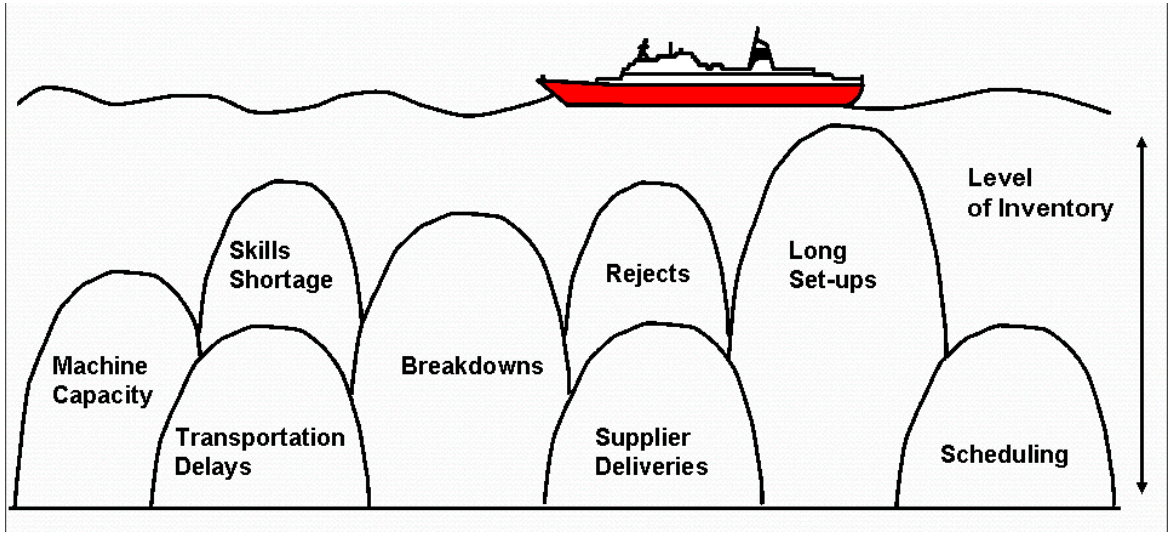
INVENTORY MANAGEMENT

Inventory is another name for materials and is any material that a firm holds in order **to satisfy customer demand**.

When the raw materials are processed, but are not yet completely finished, they are called ***work in progress***.

- Inventory costs money!
- The money could have been invested elsewhere.
- However, inventory cannot be wiped to zero.

Inventory covers issues



Opportunity cost (lost on carrying inventories)

This is the amount of money the firm would have earned if the money were invested elsewhere other than in inventory.

Sustainability Concerns (associated with carrying inventories)

Change of customer tastes and preferences

Power and resources used to carry inventories

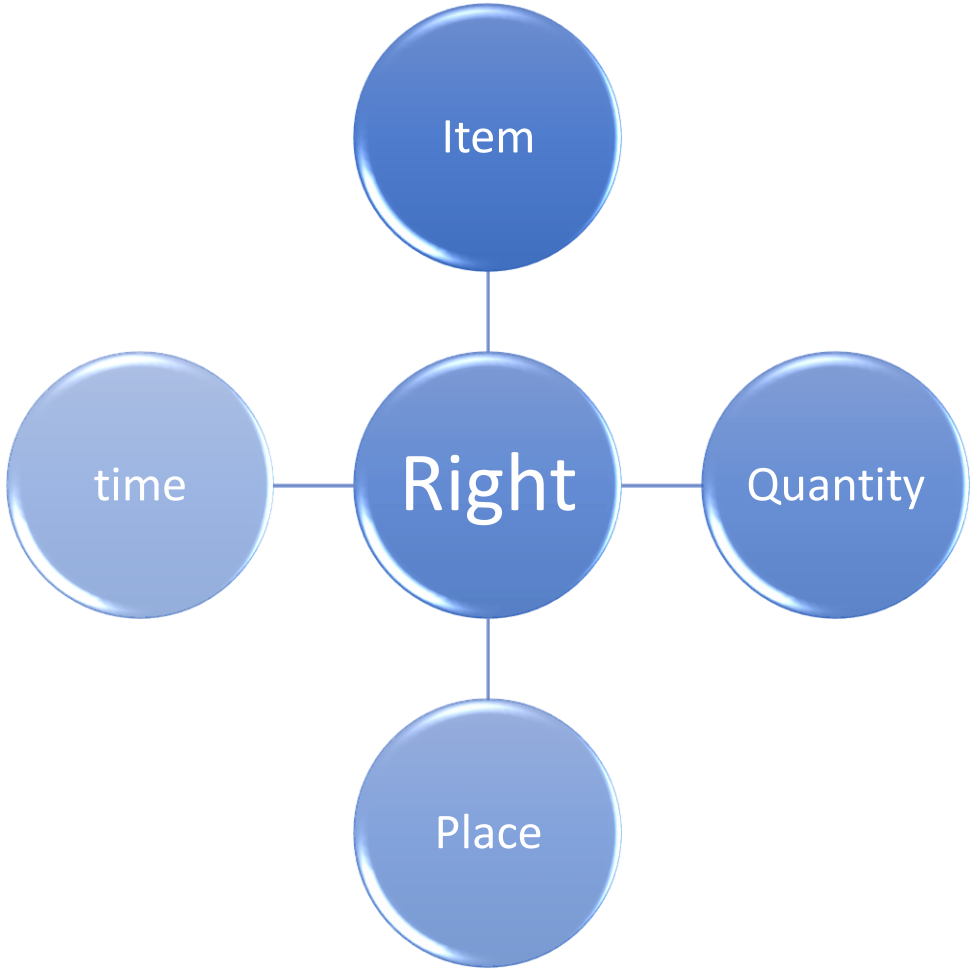
<u>Example (from the fashion world):</u>

In 2018, Burberry burned down $37m worth unsold goods

Key Concepts

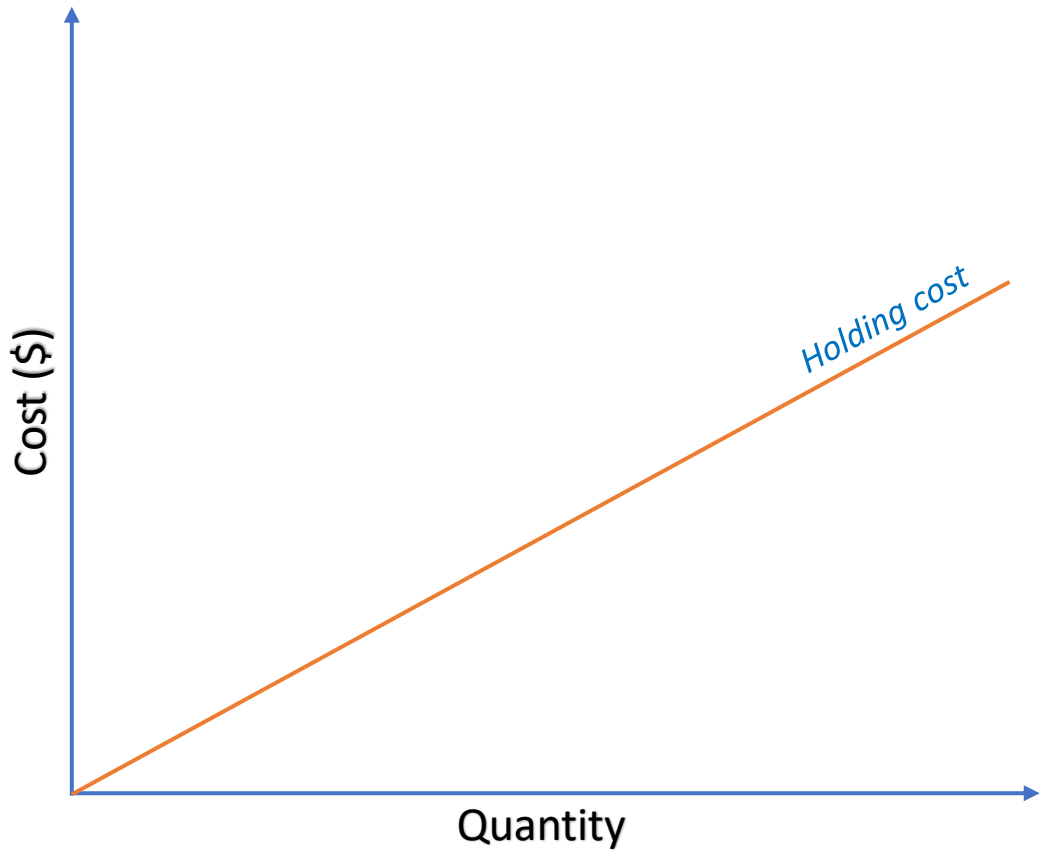
BIG

inventories?



Key Concepts

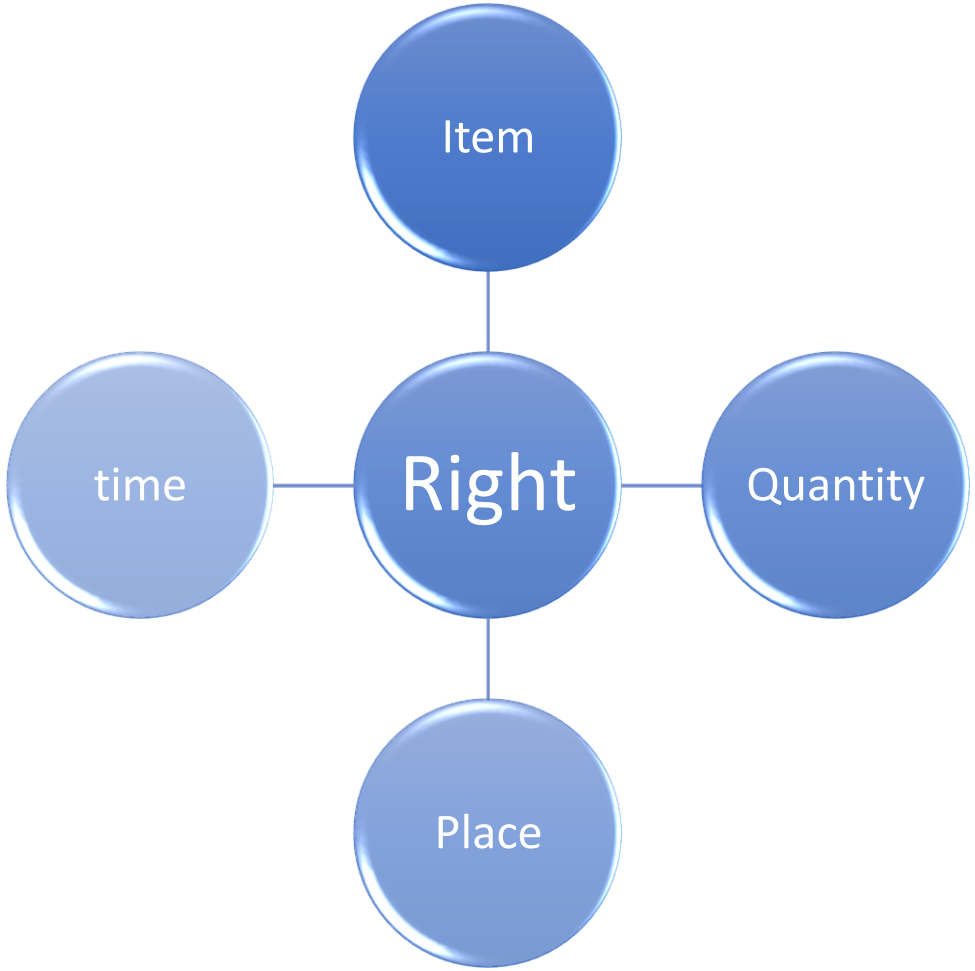
- Holding cost: calculated by days
  - Storage
  - Insurance
  - Tax
  - Maintenance
  - Obsolescence
  - Opportunity costs



Key Concepts

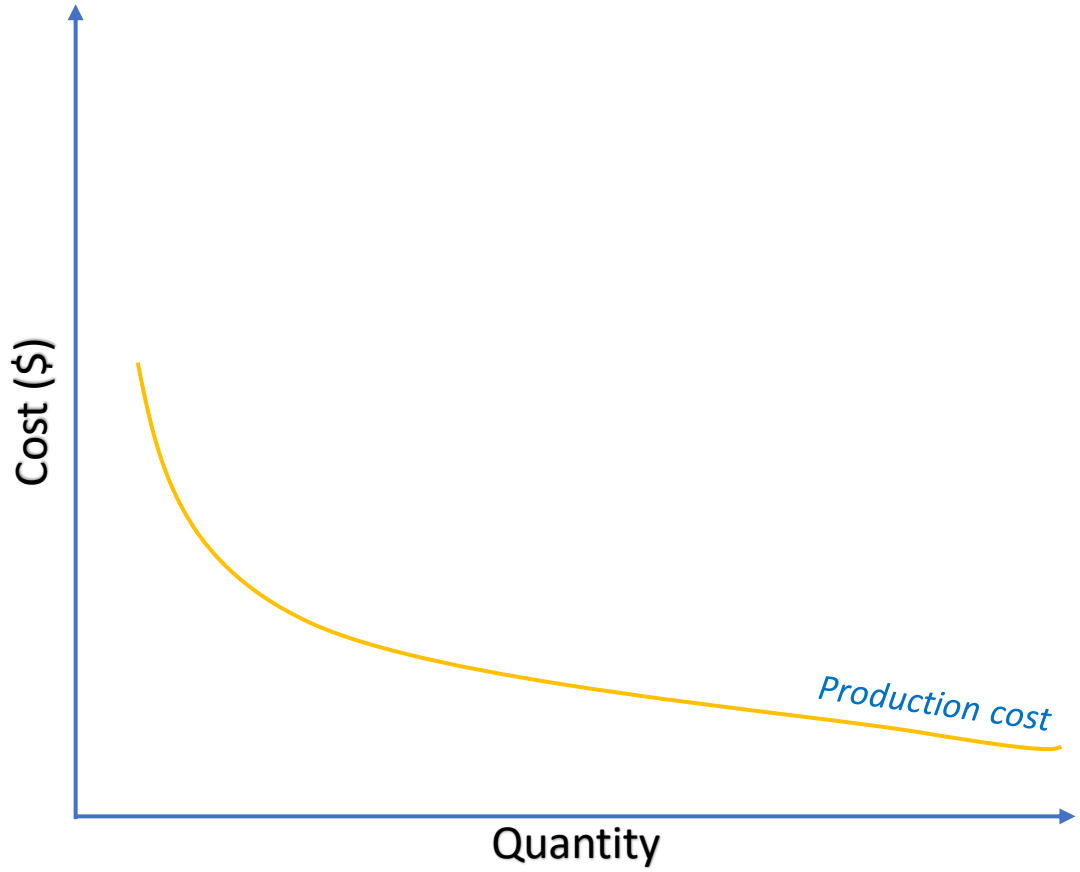
Small

inventories?



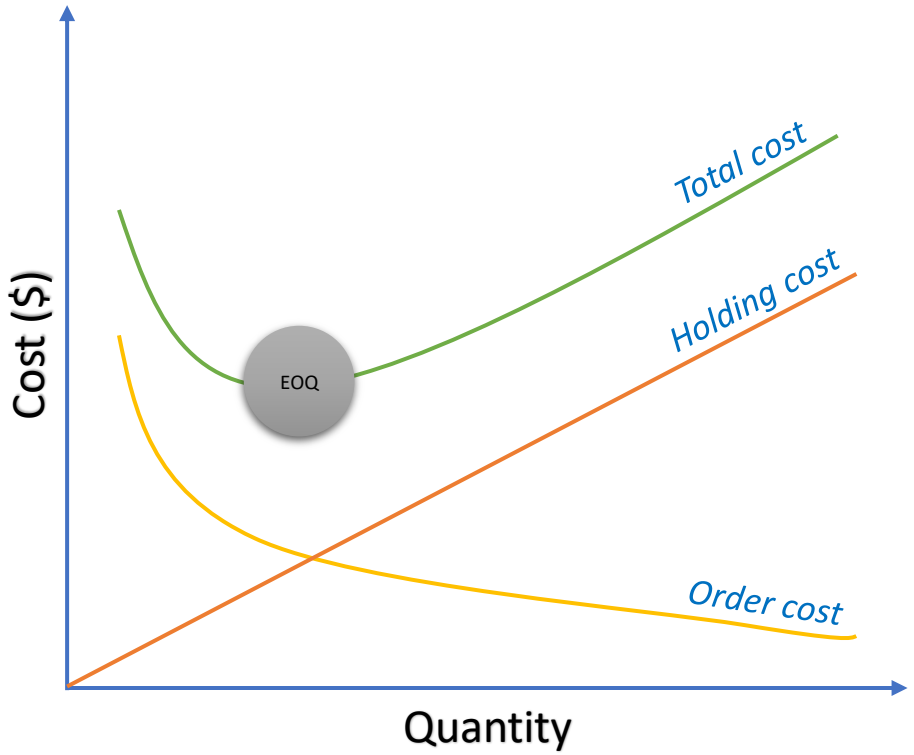
Key Concepts

- Production cost
  - Fixed cost
  - Variable cost



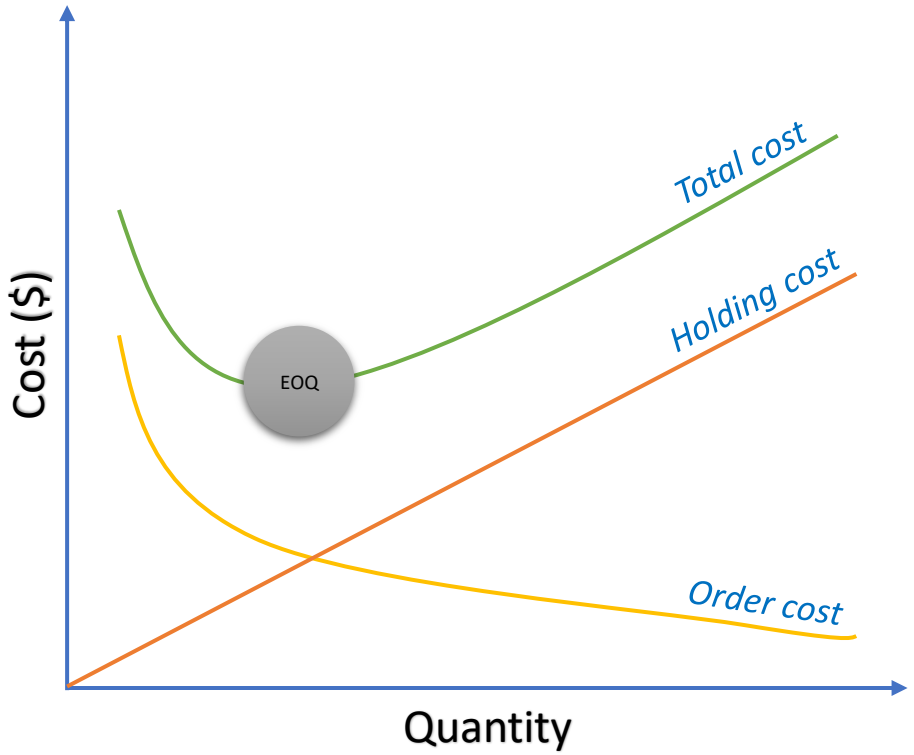
Key Concepts

- Economic Order Quantity EOQ

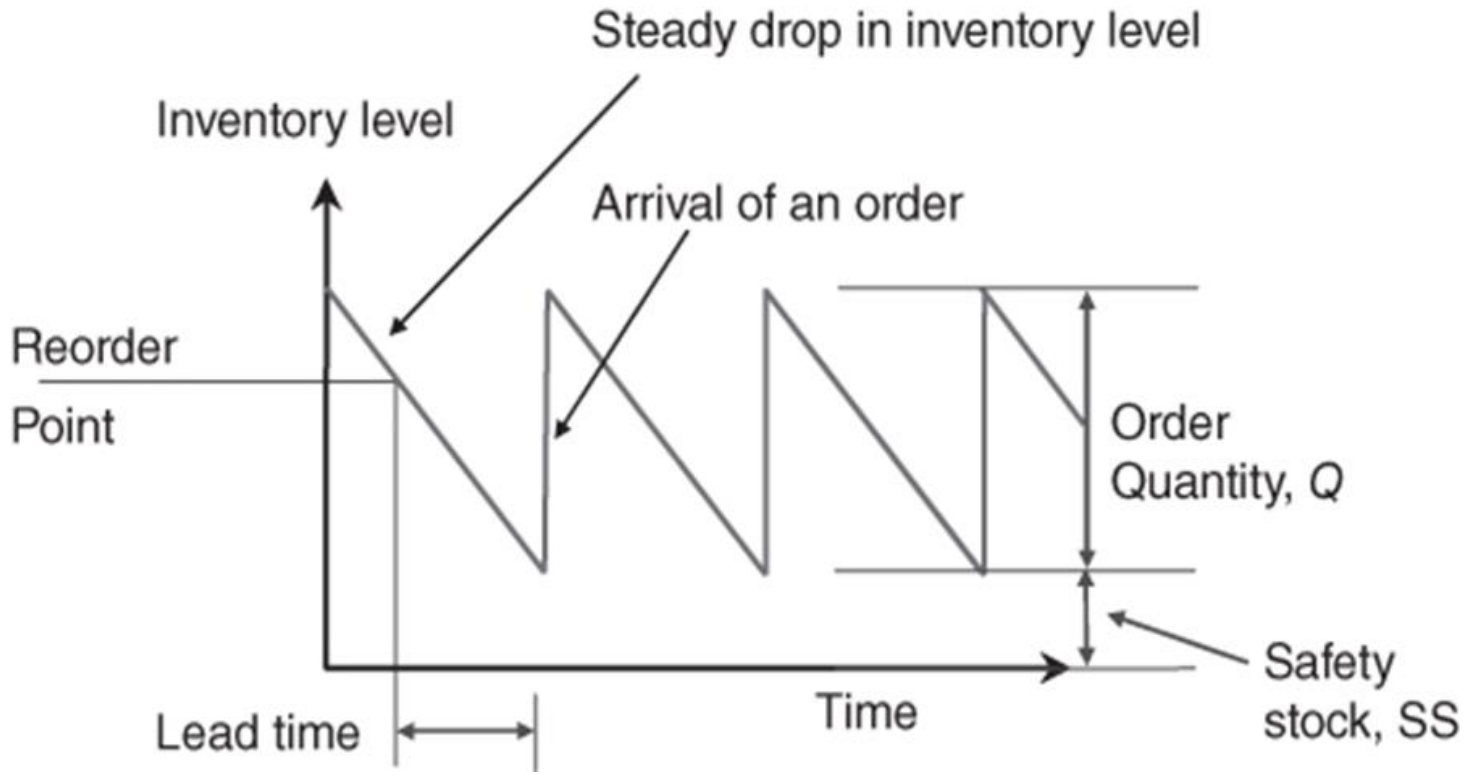


Key Concepts

- Economic Order Quantity EOQ

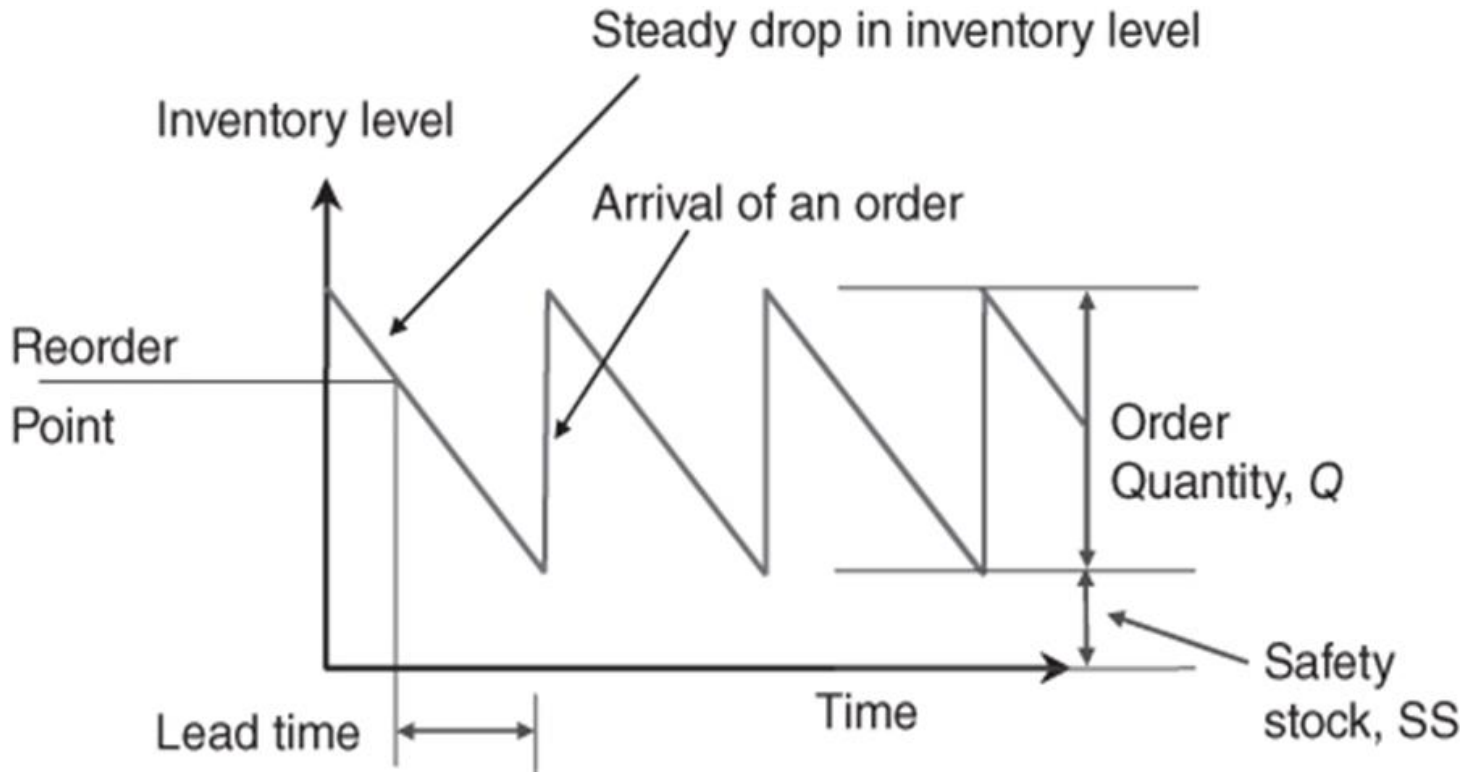


Basic Definitions



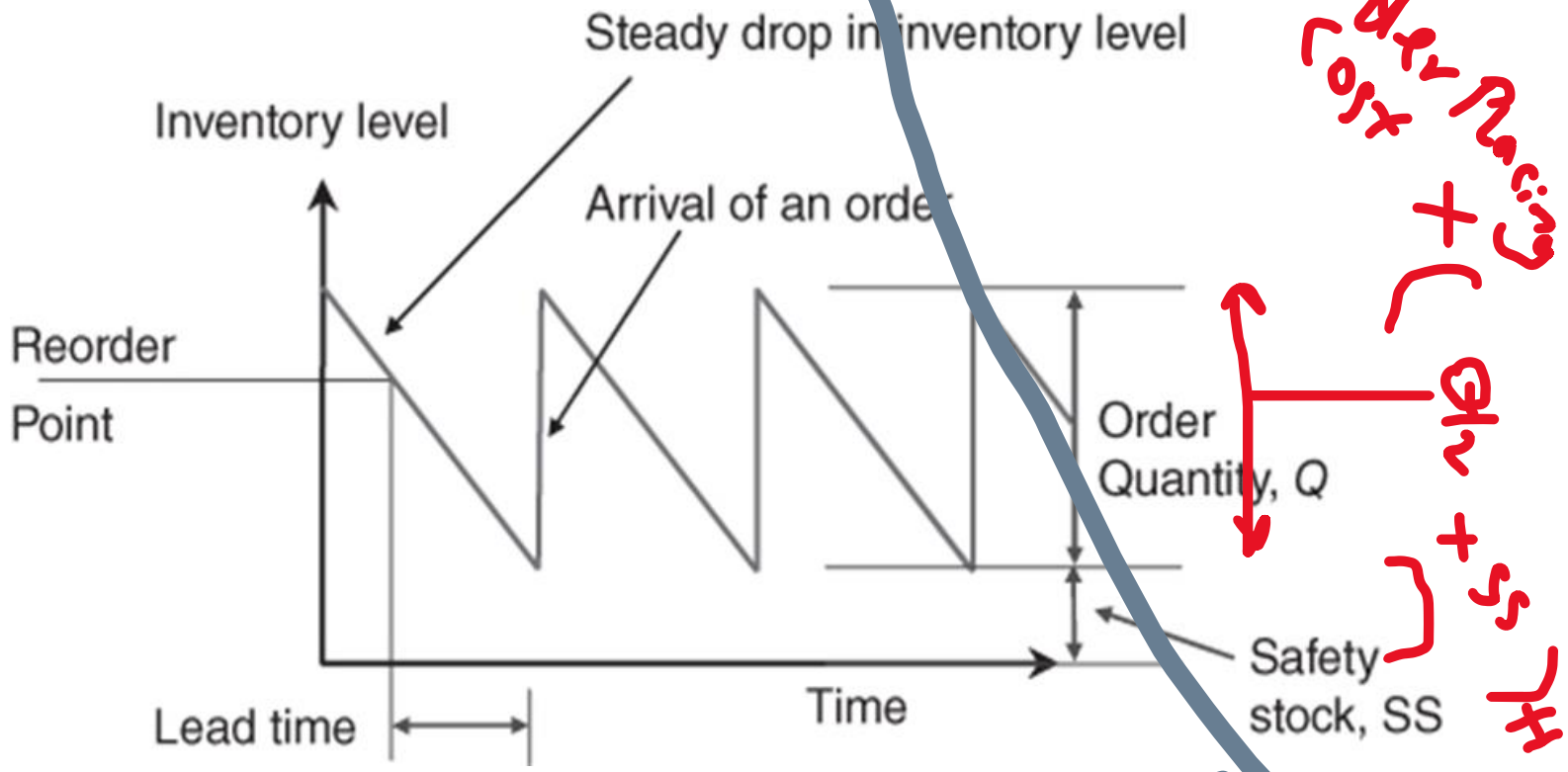
Total cost of inventory

- **Average inventory level**=(SS+Q+SS)/2=SS +Q/2
- And **the annual holding cost**=(SS+Q/2)H
- If *S* is the order processing cost per order:
- **Annual order processing cost**=(D/Q)S
- Adding these three costs the total annual inventory costs associated with this item are calculated below.
- Total annual cost(TAC)=
- Purchase cost+Holding cost+Order processing cost=
- (SS+Q/2)Price+(SS+Q/2)Holding Cost +(D/Q)Set Up Cost

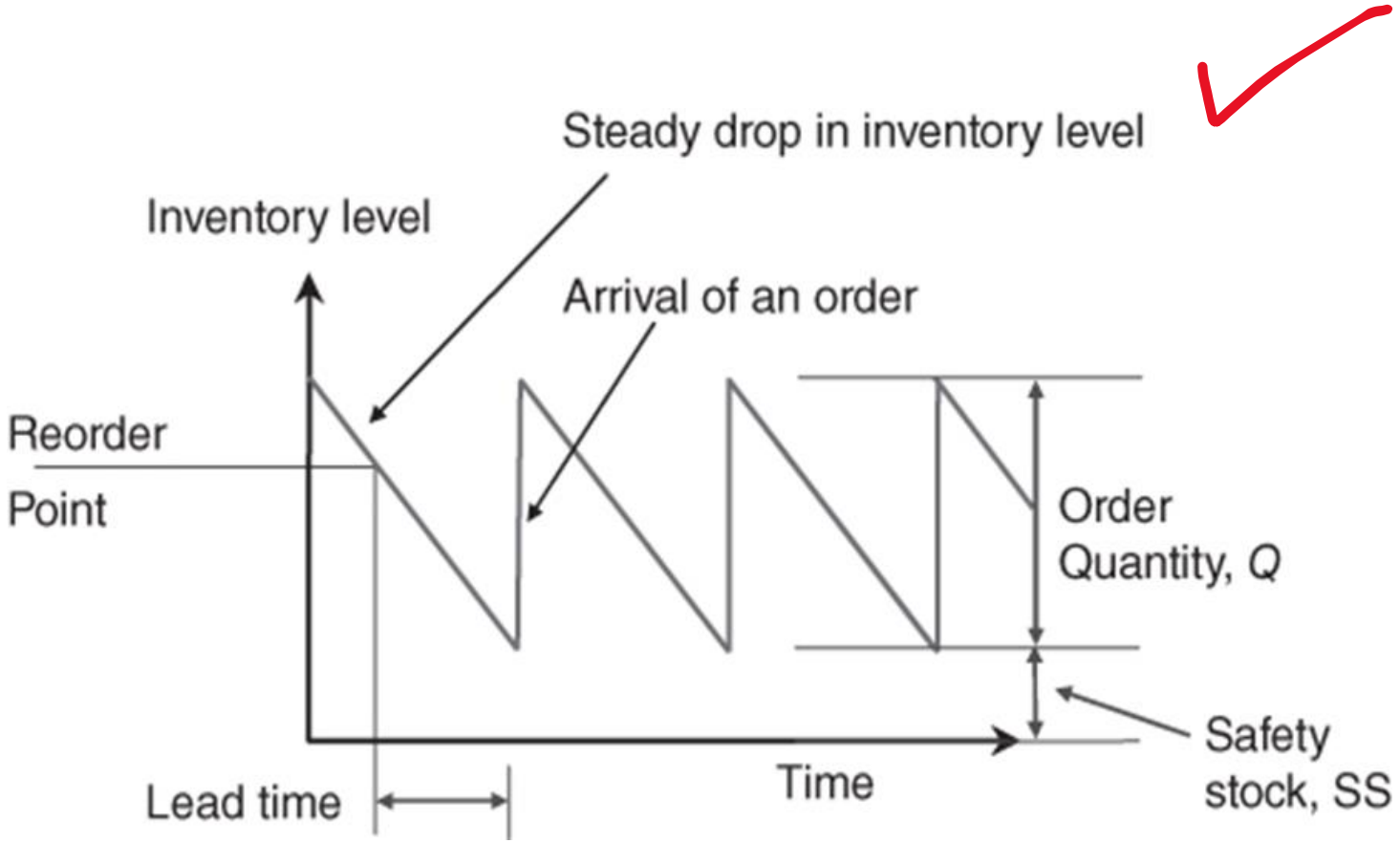


Total cost of inventory

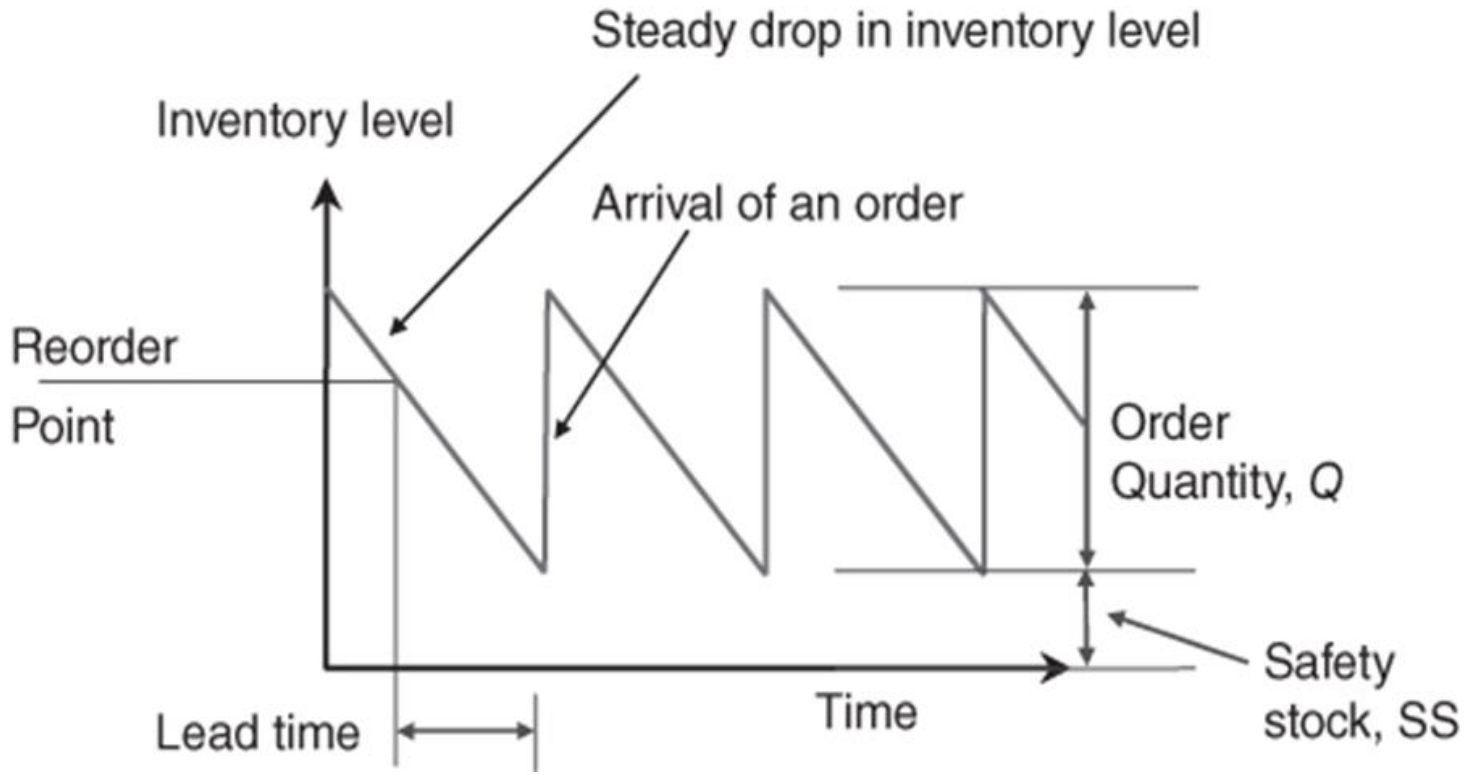
- **Average inventory level**=(SS+Q+SS)/2=SS +Q/2
- And **the annual holding cost**=(SS+Q/2)H
- If *S* is the order processing cost per order:
- **Annual order processing cost**=(D/Q)S
- Adding these three costs the total annual inventory costs associated with this item are calculated below:
- Total annual cost(TAC)=
- Purchase cost+Holding cost+Order processing cost=
- (SS+Q/2)Price+(SS+Q/2)Holding Cost +(D/Q)Set Up Cost



Total cost of inventory



Safety Stock Formula (Simple Version)



Safety stock

= (maximum daily sales x maximum days of lead time)

– (average daily sales x average days of lead time)


This is when you
tell me WE NEED
MORE MILK!
NOT HERE!!


This is when you
tell me WE NEED
MORE MILK!
NOT HERE!!

Safety Stock (Buffer)

This is the amount of inventory **stocked by the system in case of unforeseen events arising**. For example, late **deliveries**, or a sudden increase in **demand.**

Other reasons for maintaining safety stock include:

A safeguard against issues such as **poor quality**, production problems and transportation problems.

The root reason for safety stock could be described as variation – variation of **demand**, variation of **lead time**, variation of **production rate**, etc.

If there was no variation, firms would not need safety stock.

Safety stock costs – unused inventory!

An Important KPI: Inventory Turnover

Inventory turnover=

(cost of all goods sold)/(value of average inventory)

PROBLEM

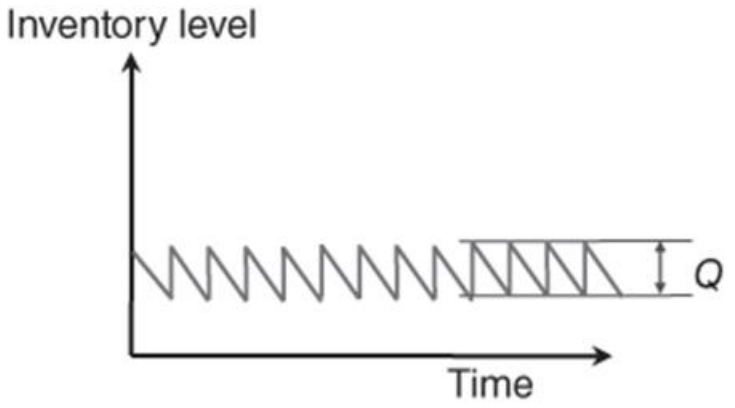
The YouRace Company builds racing cars. In 2022, the **total cost of cars sold** was $3 million. Its total inventory holding changed throughout the year, but **the average inventory holding** was worth $250,000.

At the end of 2023, it implemented just-in-time principles to improve its inventory performance. In 2023, its sales increased and **the cost of cars was** $4.5 million, while **the average inventory holding** was $300 000. Has the KPI improved?

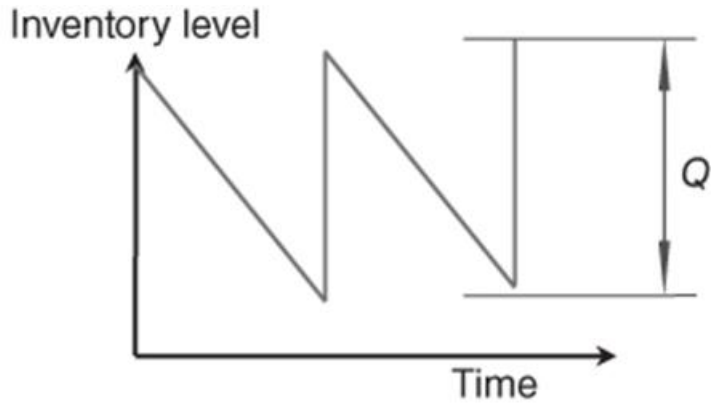
Answer:

- Inventory turnover in2022=3,000,000/250,000=12
- Inventory turnover in 2023=4,500,000/300,000=15

Economic Order Quantity (EOQ)



Small order quantity

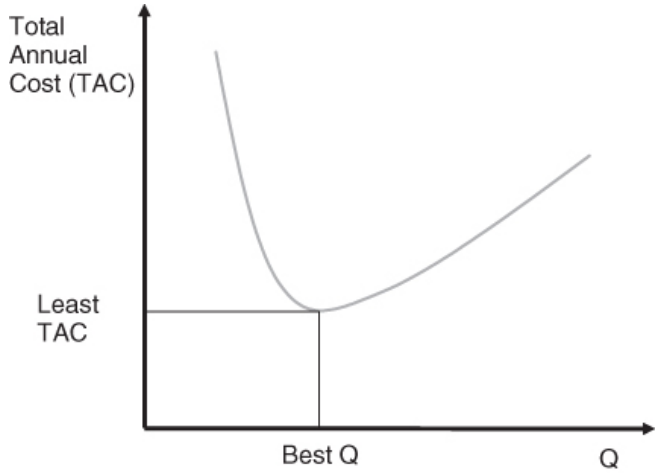


Large order quantity

To minimise the total annual cost, there is a best order quantity, known as the economic order quantity (EOQ), as depicted in the diagram.

$$EOQ = \sqrt{\frac{2 \times D \times S}{H}}$$

EOQ = The square root (√) of 2x (annual demand in units, multiplied by order cost per purchase order), divided by annual holding cost per unit



EOQ

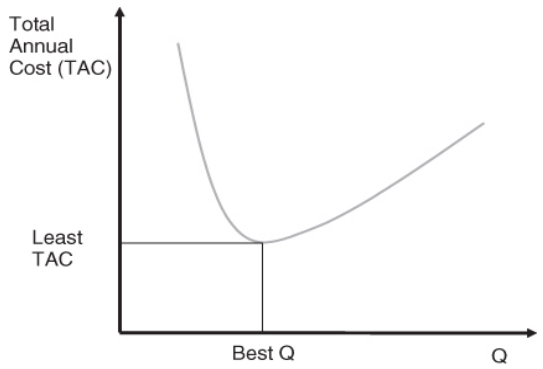
It is straightforward to derive the EOQ formula. Differentiating the expression for TAC and setting to zero for minimisation:

$$\frac{d(TAC)}{dQ} = 0,$$
$$\Rightarrow \frac{d\left(p \times D + \left(SS + \frac{Q}{2}\right)H + \frac{D}{Q}\right)S}{dQ} = 0$$
$$\Rightarrow \frac{H}{2} - \frac{D \times S}{Q^2} = 0$$

Assuming that the purchasing cost is constant (no bulk discounts). We also assume that the safety stock remains fixed as order quantity is changed:

$$\Rightarrow Q = \sqrt{\frac{2DS}{H}}$$

$$EOQ = \sqrt{\frac{2 \times D \times S}{H}}$$



EOQ

The Fine Garments Company sells fashion clothing. The forecasted annual demand for its premium leather jacket is 1200. The order processing cost per order is $25, and inventory holding cost is $50/item/year. How many leather jackets should it order in one shipment?

Answer:

$$EOQ = \sqrt{\frac{2 \times D \times S}{H}}$$

EOQ

The Fine Garments Company sells fashion clothing. The forecasted annual demand for its premium leather jacket is 1200. The order processing cost per order is $25, and inventory holding cost is $50/item/year. How many leather jackets should it order in one shipment?

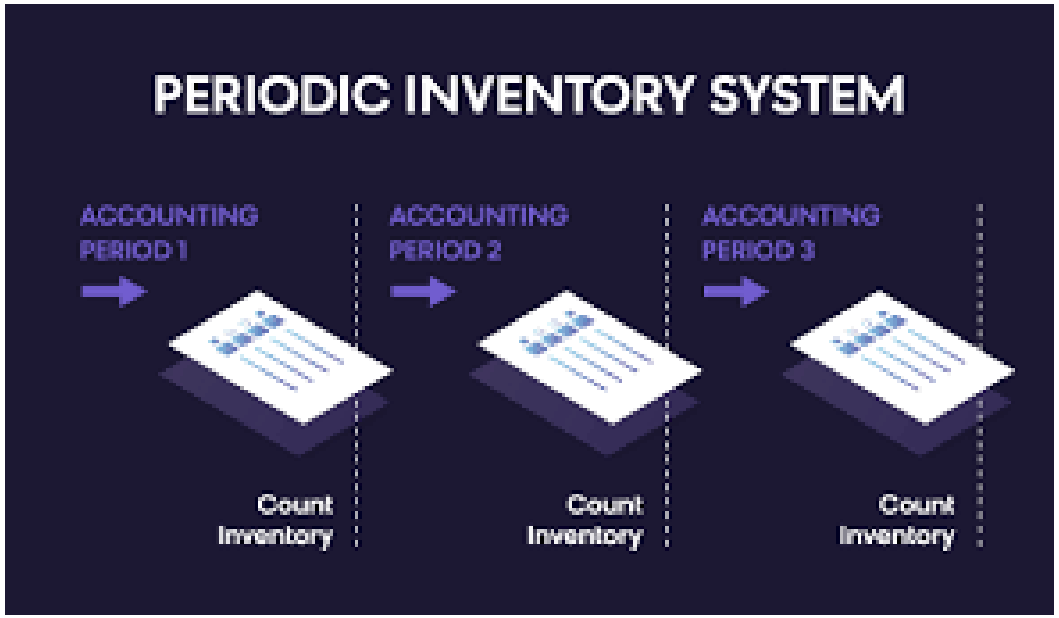
Answer:

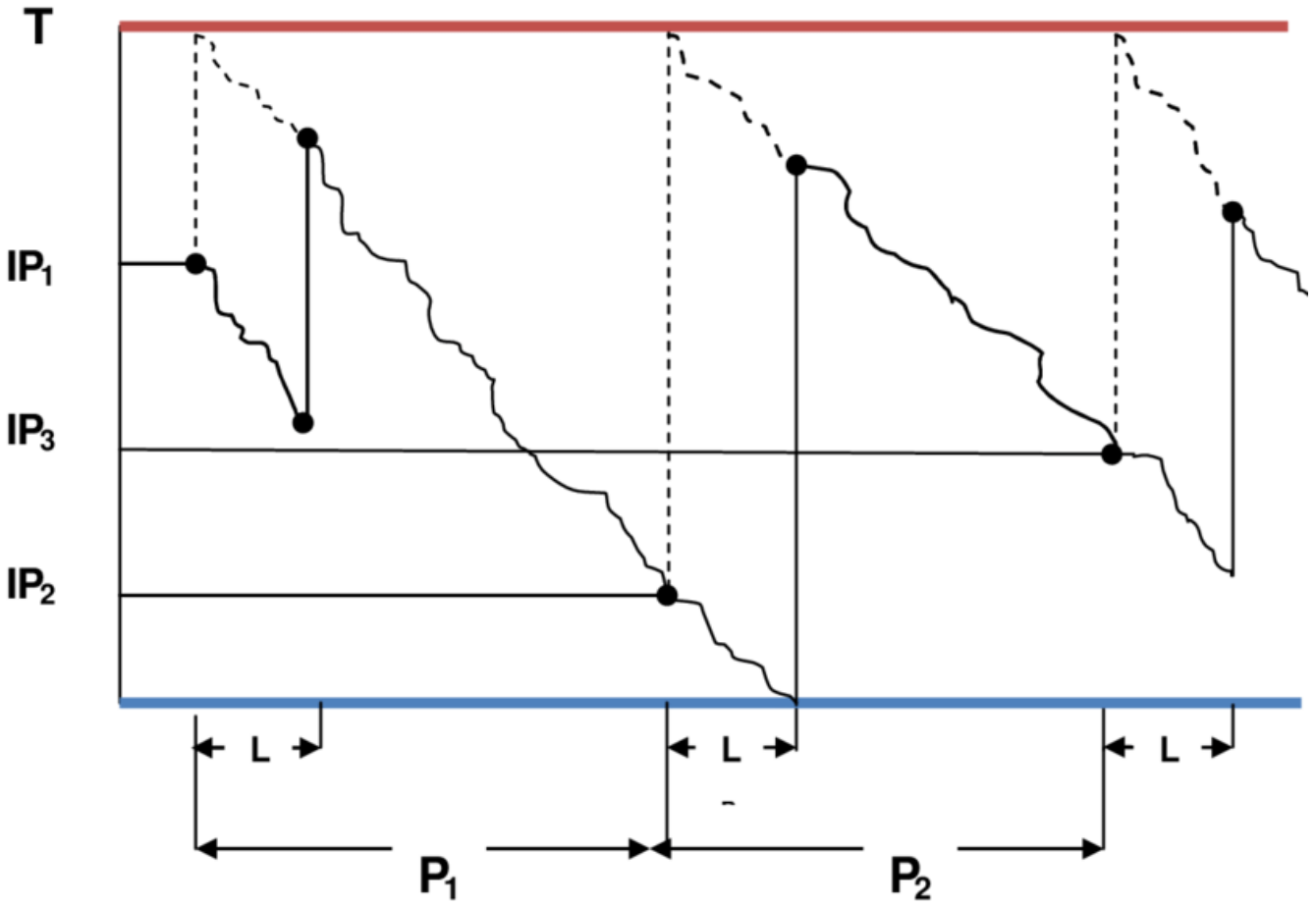
$$
\begin{aligned}
EOQ &= \sqrt{\frac{2DS}{H}} \\
&= \sqrt{\frac{2\times 1200\times 25}{50}} \\
&= 34.64 \\
&\approx 35
\end{aligned}
$$

To minimise its annual inventory costs, Fine Garments should request 35 leather jackets each time it places an order with its supplier.

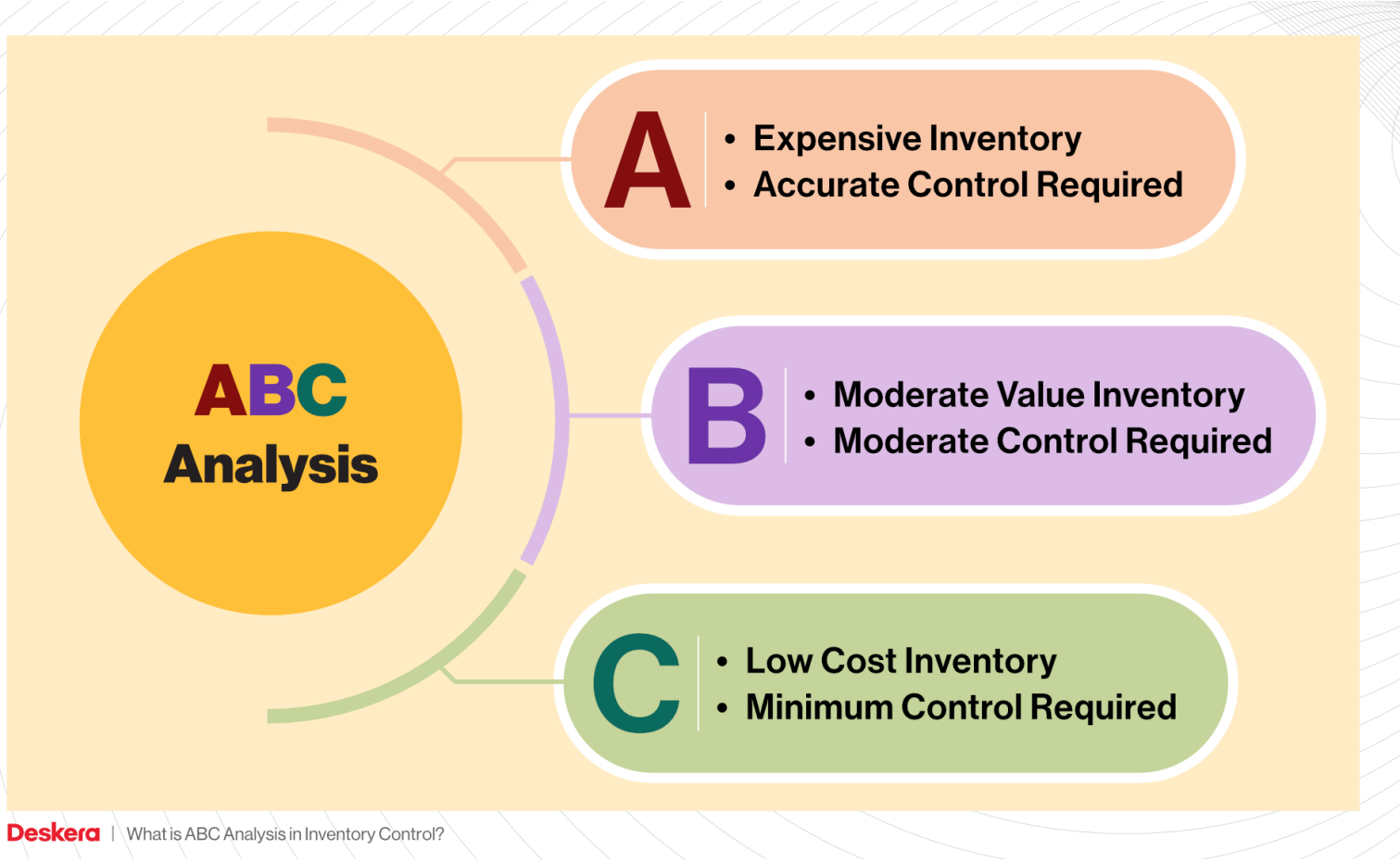
$$EOQ = \sqrt{\frac{2\times D\times S}{H}}$$

Priodic Inventory System





ABC analysis



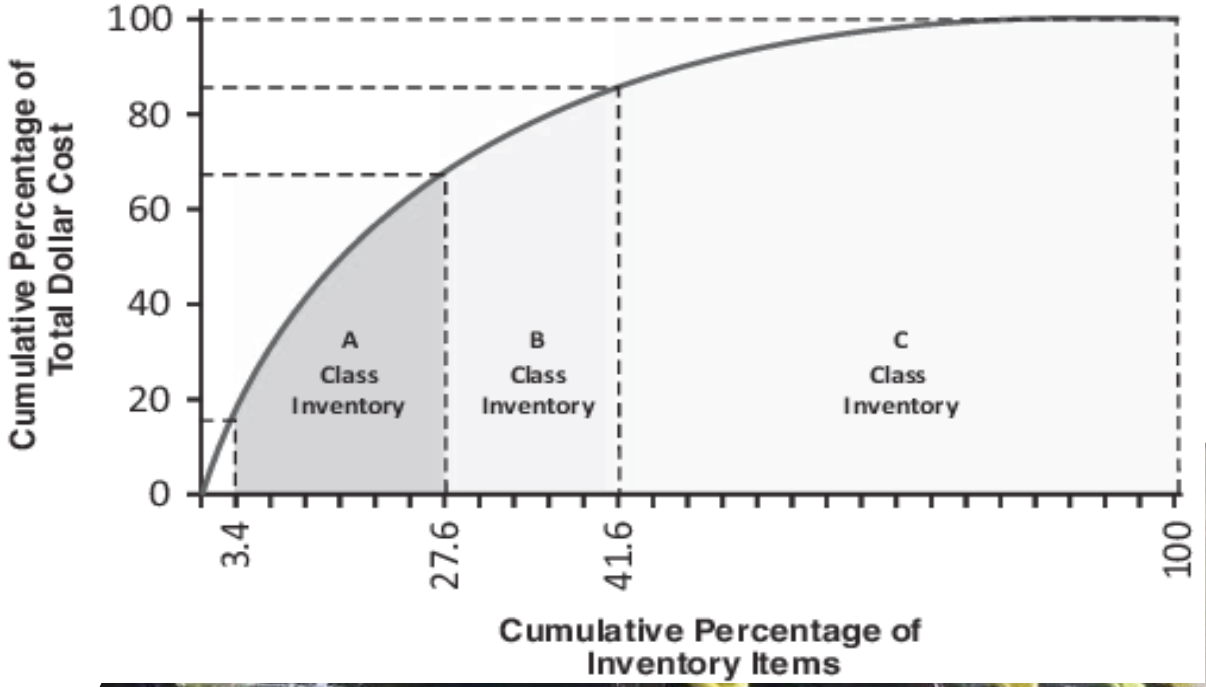
ABC analysis

This is derived from the ‘Pareto’ or ‘80/20’ rule

Most firms have far too many inventory items to manage. They often use a tool called **ABC analysis** to separate out the most important items so that more attention can be focused on those items.

ABC analysis is based on the principle that out of the myriad items an inventory manager needs to handle, there are only a few that account for most of the inventory expenses.

A: Engine major parts, transmission systems, fuel injection system
B: Windshield wipers, air conditioning compressors, exterior mirrors, floor mats, mudguards, roof racks
C: Screws, basic tools, gloves, cleaning solvents, toilet tissues, printer papers, tapes



ABC analysis

It can be seen that the top two items (# 373 and # 539) account for just over 65% of the expense.

'A' items may be controlled closely, using the reorder point system; the less demanding periodic system may be used for 'B' items; and 'C' items may be blanket purchased once or twice in a year.

Item	Annual Expenses	Percentage of Total	Classifications
373	46,335	45.77%	A
539	19,611	19.37%	A
455	8007	7.91%	B
769	6181	6.11%	B
441	5526	5.46%	B
65	5503	5.44%	B
205	3278	3.24%	C
401	3063	3.03%	C
352	2845	2.81%	C
543	603	0.60%	C
454	179	0.18%	C
432	111	0.11%	C
Total	101,242	100.00%	

INVENTORY REDUCTION PRINCIPLES

- Pool inventory

This is the case in inventory centralisation where demand from different locations is combined, or in delayed product differentiation where demand for different products is combined, or by using common components where demands for different components are combined.

- Reduce variation

Recall that the reason for holding safety stock is variation. Variation of lead time, variation of demand, variation of supply, variation of quality, all contribute to safety stock.

- Just-in-time inventory system (JIT)

JIT is as much a philosophy as it is a technique and emphasises on removing inventory with the goal of zero inventory.

Last week, we learnt Data Importing, Integrating, and Cleaning

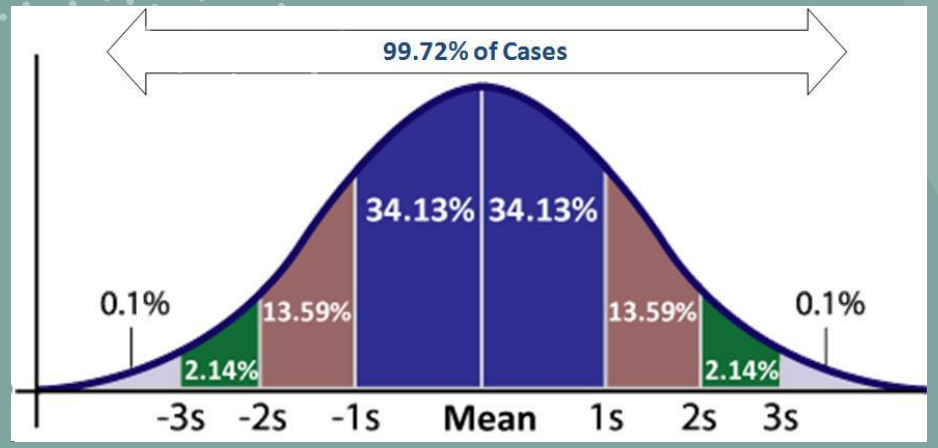
This week, we will learn how to extract information from this cleaned data. This helps us understand what is going on in our dataset (describing information). Describing such information facilitates data driven decision making and is called Descriptive Analytics.

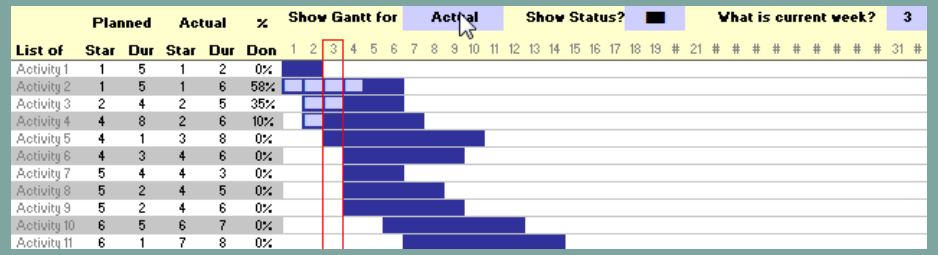
After data importing, integrating, and cleaning, we have the following types of analytics to do:

- **Descriptive Analytics**
- **Diagnostic Analytics**
- **Predictive Analytics**
- **And Prescriptive Analytics**

Descriptive Analytics

- Descriptive analysis is the simplest and most common way of using data in supply chains.
- It **answers the "what happened" type of questions**.
- It analyses numerical data and shows the mean, deviation, percentage and frequency of data.





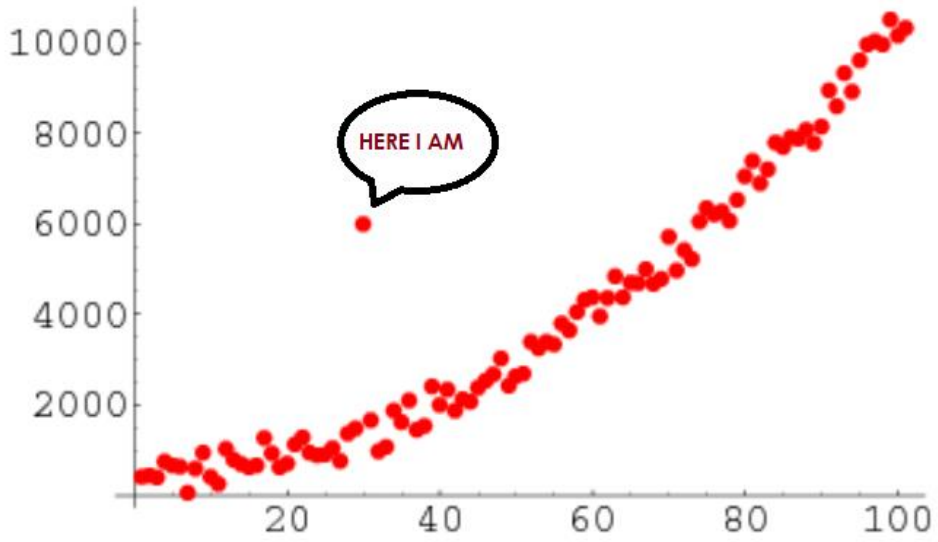
Descriptive Analytics: Advantages and Limitation

- It can be applied in day-to-day operations
- Its application doesn't necessarily require an extensive knowledge of analytics
- It points out errors and data outliers

Limitations

- It doesn't look beyond the surface of data
- It can be misleading

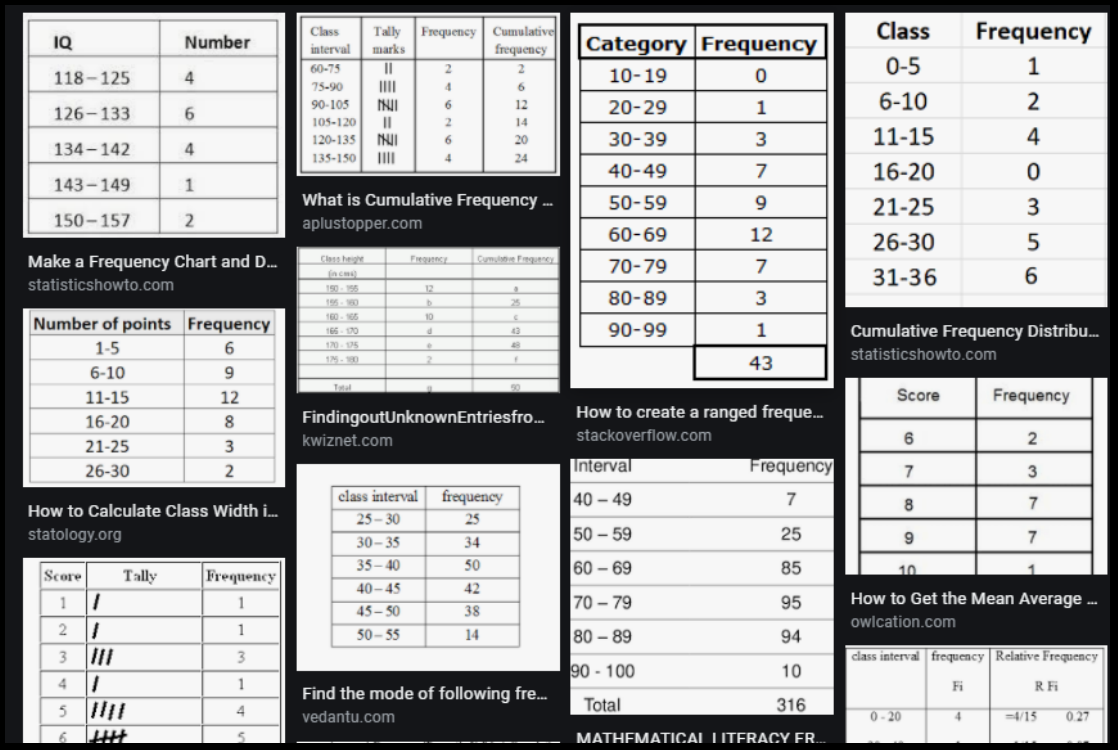
(e.g. tissue usage or average supplier delivery time in 2020)



Types of Descriptive Analytics

There are four major types of descriptive analytics:

- Measures of Frequency



IQ	Number
118 – 125	4
126 – 133	6
134 – 142	4
143 – 149	1
150 – 157	2

Make a Frequency Chart and D...
statisticshowto.com

Number of points	Frequency
1-5	6
6-10	9
11-15	12
16-20	8
21-25	3
26-30	2

How to Calculate Class Width i...
statology.org

Score	Tally	Frequency
1	/	1
2	/	1
3	///	3
4	/	1
5	////	4
6	////	5

Class interval	Tally marks	Frequency	Cumulative frequency
60-75	II	2	2
75-90	IIII	4	6
90-105	𝍸	6	12
105-120	II	2	14
120-135	𝍸	6	20
135-150	IIII	4	24

What is Cumulative Frequency ...
aplustopper.com

Class height (in cms)	Frequency	Cumulative Frequency
150 - 155	12	a
155 - 160	b	25
160 - 165	10	c
165 - 170	d	43
170 - 175	e	48
175 - 180	2	f
Total	g	50

FindingoutUnknownEntriesfro...
kwiznet.com

class interval	frequency
25 – 30	25
30 – 35	34
35 – 40	50
40 – 45	42
45 – 50	38
50 – 55	14

Find the mode of following fre...
vedantu.com

Category	Frequency
10-19	0
20-29	1
30-39	3
40-49	7
50-59	9
60-69	12
70-79	7
80-89	3
90-99	1
	43

How to create a ranged freque...
stackoverflow.com

Interval	Frequency
40 – 49	7
50 – 59	25
60 – 69	85
70 – 79	95
80 – 89	94
90 - 100	10
Total	316

MATHEMATICAL LITERACY FR...

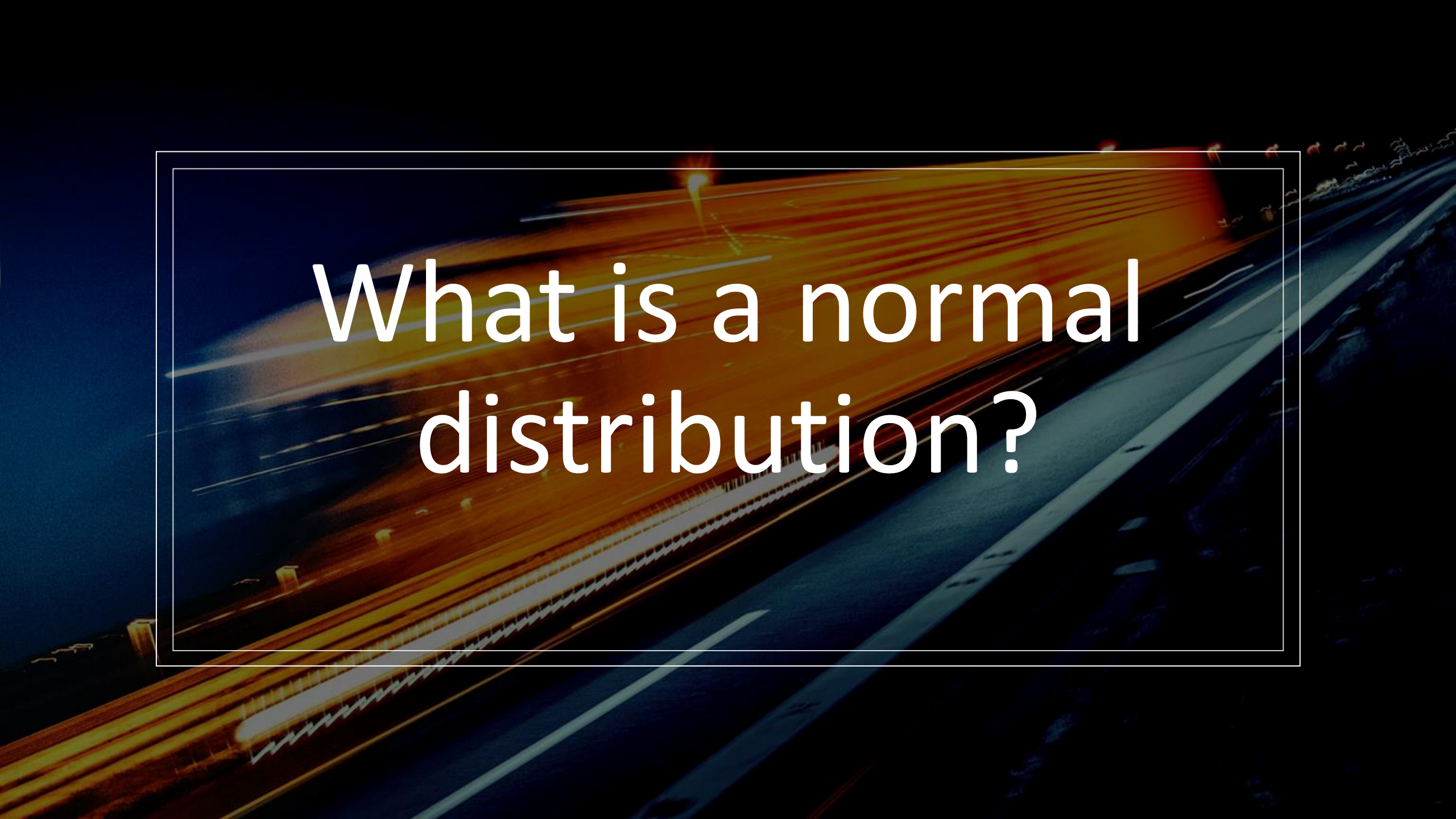
Class	Frequency
0-5	1
6-10	2
11-15	4
16-20	0
21-25	3
26-30	5
31-36	6

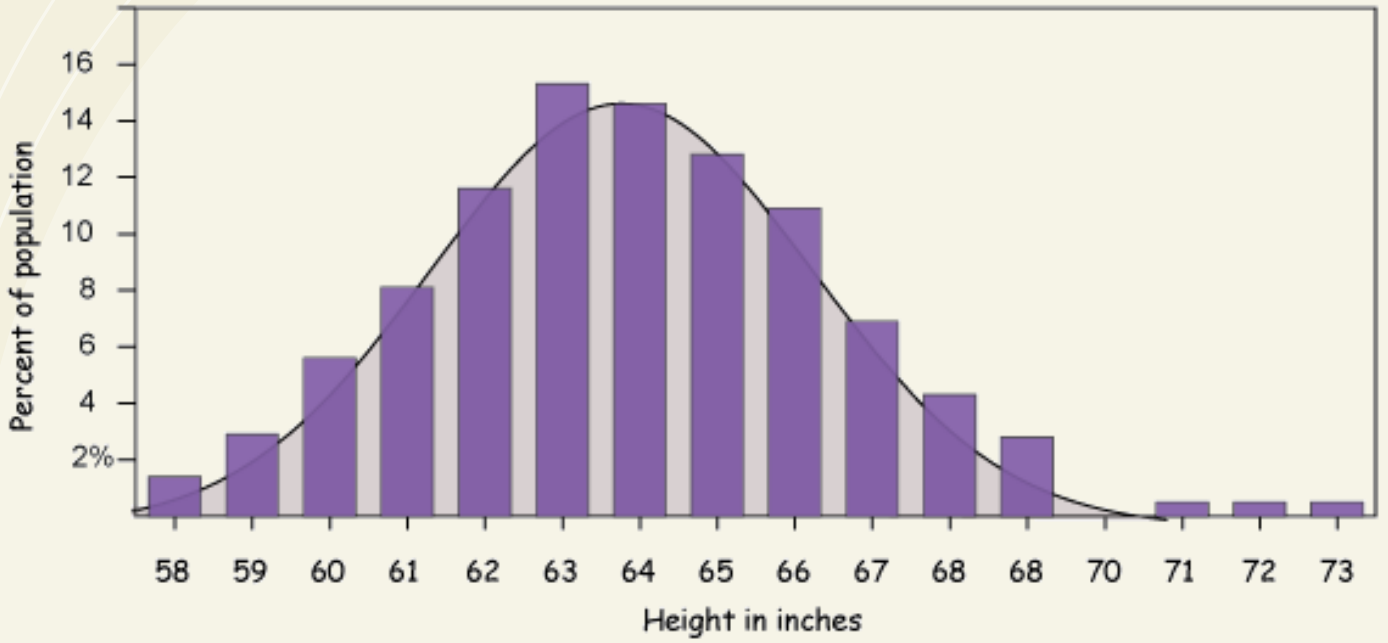
Cumulative Frequency Distribu...
statisticshowto.com

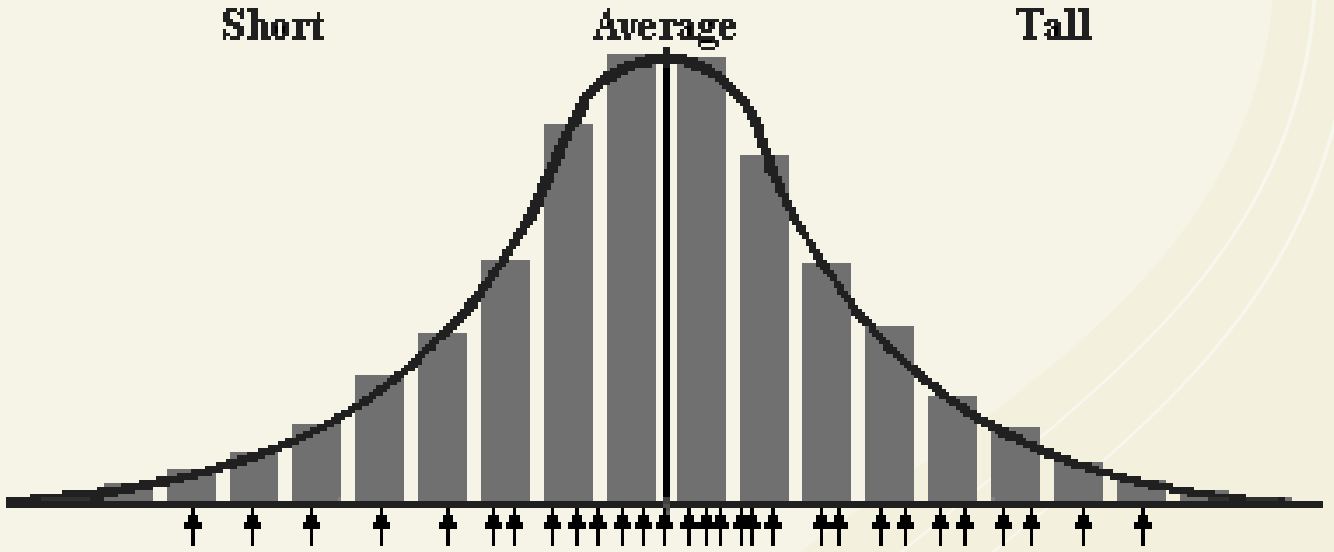
Score	Frequency
6	2
7	3
8	7
9	7
10	1

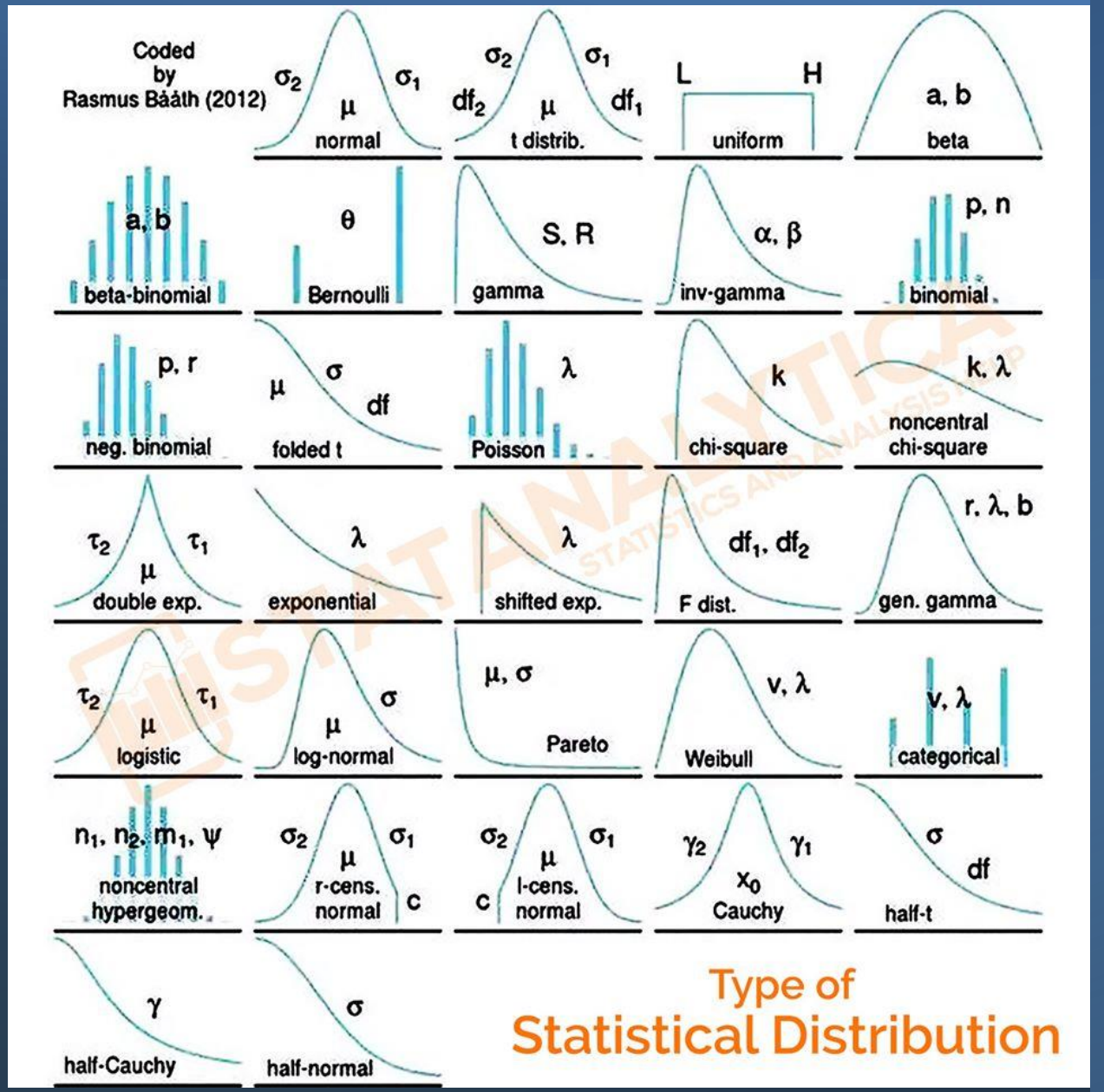
How to Get the Mean Average ...
owlcation.com

class interval	frequency Fi	Relative Frequency R Fi	
0 - 20	4	=4/15	0.27


What is a normal distribution?


Percent of population
16
14
12
10
8
6
4
2%
58
59
60
61
62
63
64
65
66
67
68
68
70
71
72
73
Height in inches


Short
Average
Tall


Coded
by
Rasmus Bååth (2012)
σ2
σ1
μ
normal
df2
df1
t distrib.
L
H
uniform
a, b
beta
a, b
beta-binomial
θ
Bernoulli
S, R
gamma
α, β
inv-gamma
p, n
binomial
p, r
neg. binomial
σ
df
folded t
λ
Poisson
k
chi-square
k, λ
noncentral
chi-square
τ2
τ1
double exp.
exponential
shifted exp.
df1, df2
F dist.
r, λ, b
gen. gamma
logistic
log-normal
μ, σ
Pareto
ν, λ
Weibull
categorical
n1, n2, m1, ψ
noncentral
hypergeom.
r-cens.
normal
c
l-cens.
γ2
γ1
x0
Cauchy
half-t
γ
half-Cauchy
half-normal
Type of
Statistical Distribution

Types of Descriptive analytics

- There are four major types of descriptive analytics:
  - Measures of Frequency
  - Measures of Central Tendency

Measure of Central Tendency

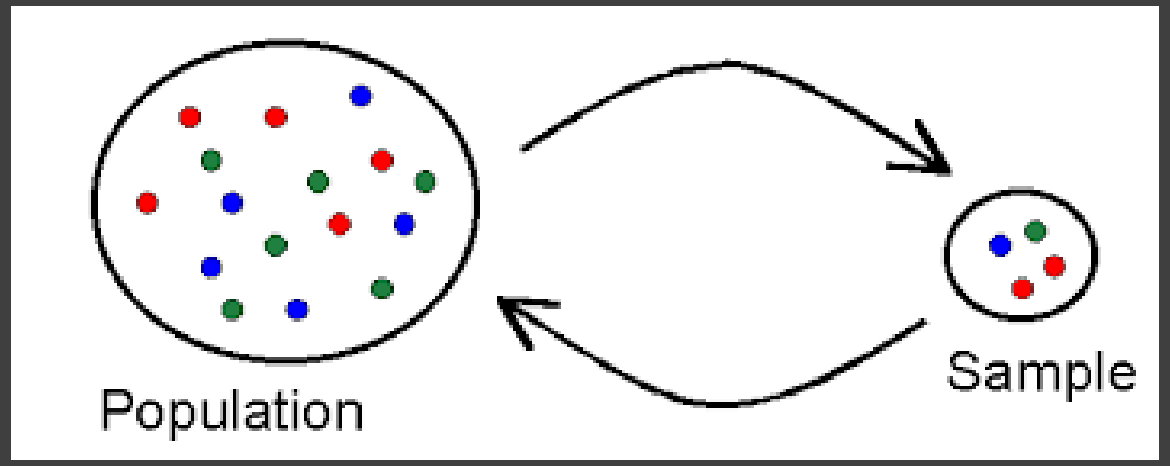
- Mean is the average: X= (Σ x)/n

Mean activity duration: (1+3+4+6+6+7+8)/7

- Median is the middle number: arrange from the smallest to the largest, then select the middle one
- Mode is the most repeated value

Mean is the best measure of central tendency as it considers all the data values

Weighted mean: Weighted mean is values that have different weightings assigned to them. x= Σ(x*w)/Σw



Population Mean	Sample Mean
$\mu = \frac{\sum_{i=1}^{N} x_i}{N}$	$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n}$
N = number of items in the population	n = number of items in the sample

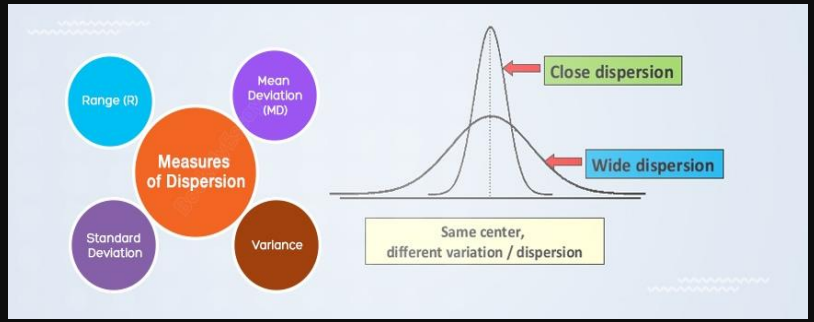
Measures of Central Tendency

Types of Descriptive Analytics

- There are four major types of descriptive analytics:
  - Measures of Frequency
  - Measures of Central Tendency
  - Measures of Dispersion or Variation

$$\text{variance} = \sigma^2 = \frac{\sum (x_r - \mu)^2}{n}$$

$$\text{standard deviation} \quad \sigma = \sqrt{\frac{\sum (x_r - \mu)^2}{n}}$$



Measures of Dispersion or Variation

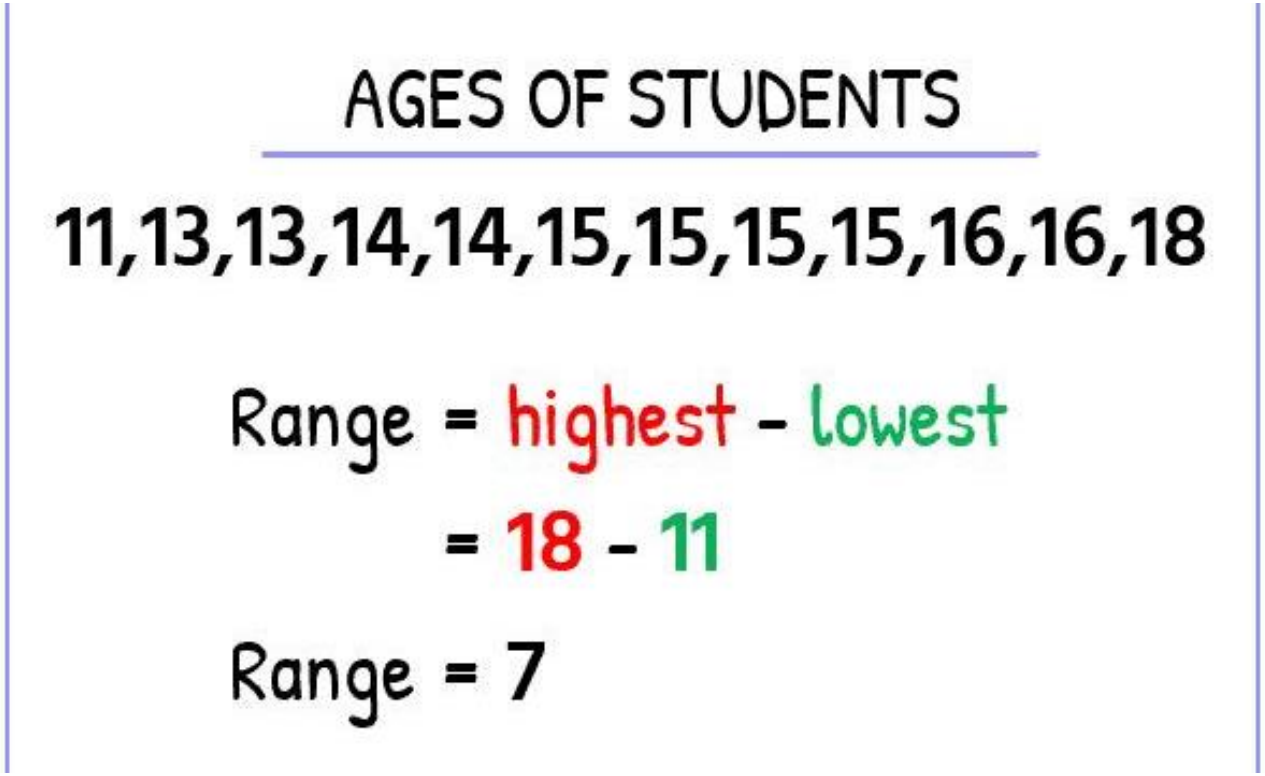
Range, Variance(σ^2), Standard Deviation (σ)

How can measures such as ‘variance’ and ‘standard deviation’ help?

Examples:

- Average suppliers’ delays is 3 weeks
- Average school kids height is 110 cm
- Average working hours of employees is 38 hours

Measures of Dispersion or Variation



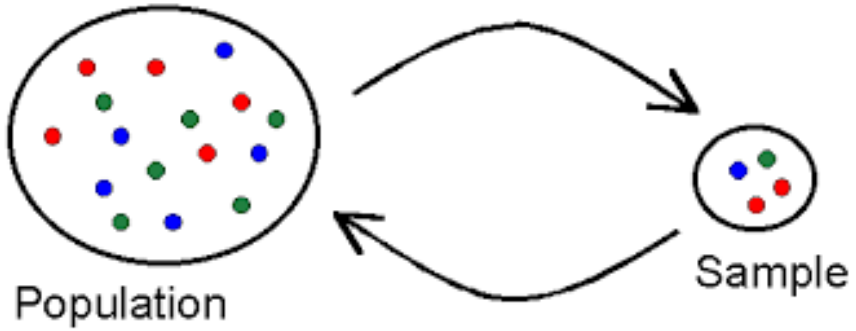
- Range, Variance(σ^2), Standard Deviation (σ)

Measures of Dispersion or Variation

$$\sigma^2 = \frac{\Sigma (x - \mu)^2}{N}$$ Population Variance

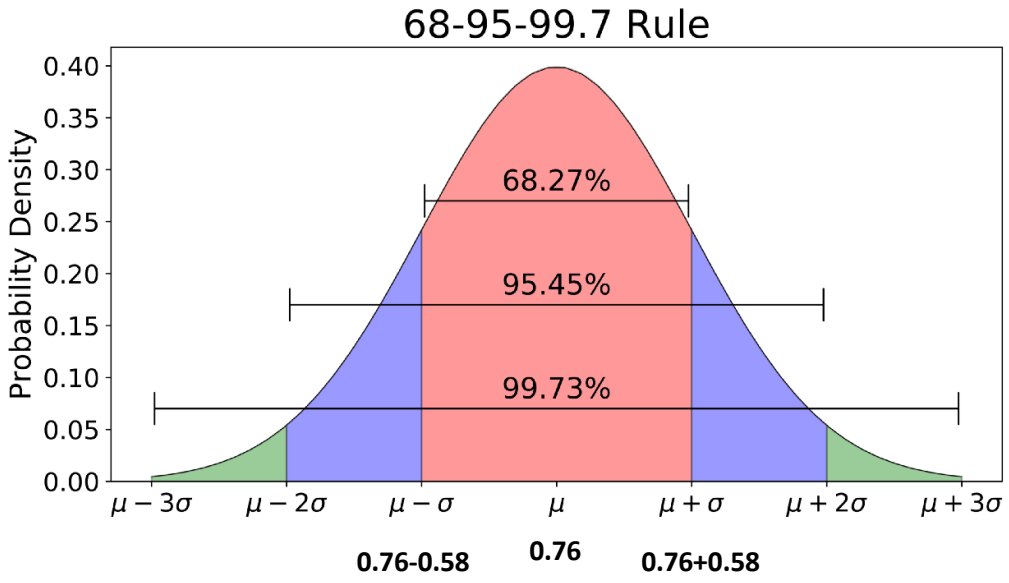
$$s^2 = \frac{\Sigma (x - \bar{x})^2}{n - 1}$$ Sample Variance

- Variance(σ^2)



Measures of Dispersion or Variation

- Range, Variance(σ^2), Standard Deviation (σ)



Population SD

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

σ → The Standard Deviation
n → The number of data points
$\bar{x}$ → Population mean
x → Each of the values of the data

Sample SD

$$S = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

S → Sample Standard Deviation
n → The number of data points
$\bar{x}$ → Sample mean
x → Each of the values of the data

Activity

For product #38

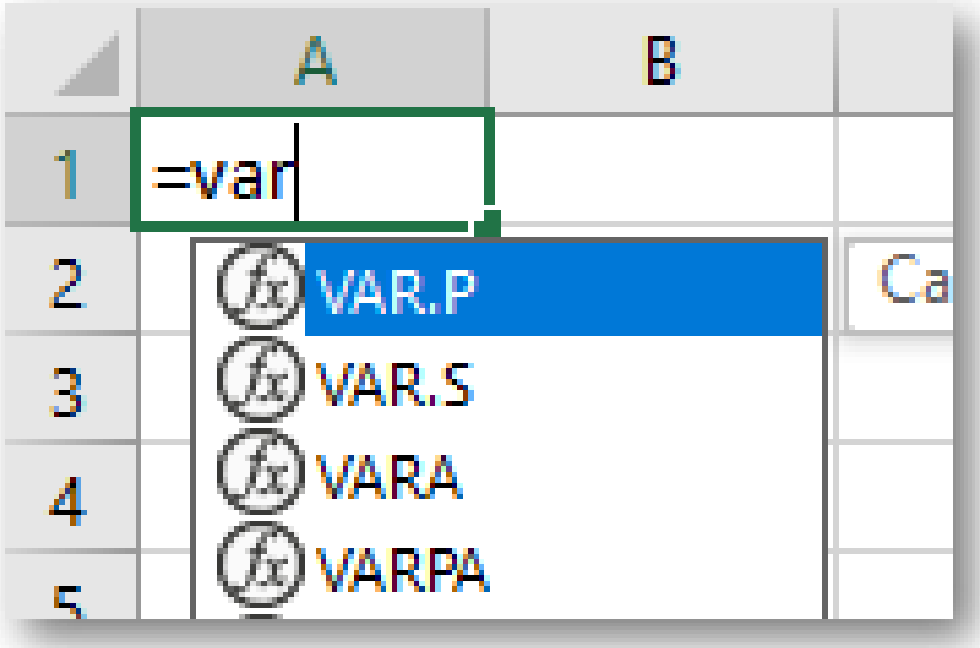
- ❑ Which store has the highest average starting inventory of product 38
- ❑ Which store has the lowest average starting inventory of product 38
- ❑ What is the range of average average starting inventory
- ❑ What is the average starting inventory of product 38 in all stores
- ❑ Find the variance of the starting inventories
- ❑ Find the standard deviation of the values

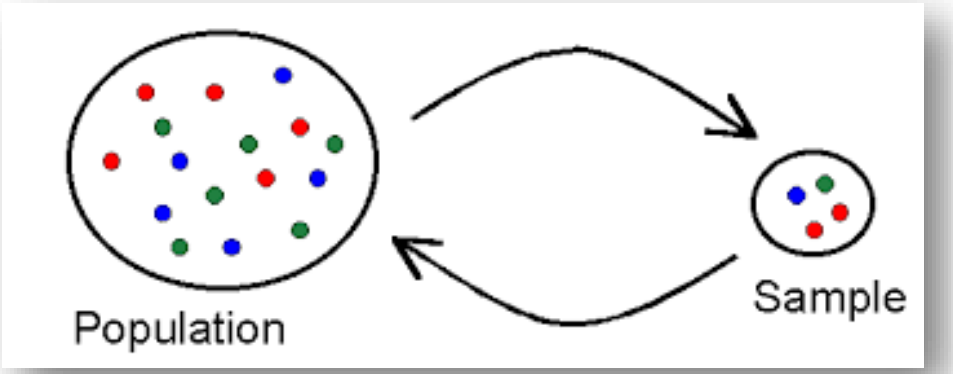
$$\sigma^2 = \frac{\Sigma (x - \mu)^2}{N}$$ Population Variance

$$s^2 = \frac{\Sigma (x - \bar{x})^2}{n - 1}$$ Sample Variance

$$\sigma^2 = \frac{\Sigma (x - \mu)^2}{N}$$ **Population Variance**

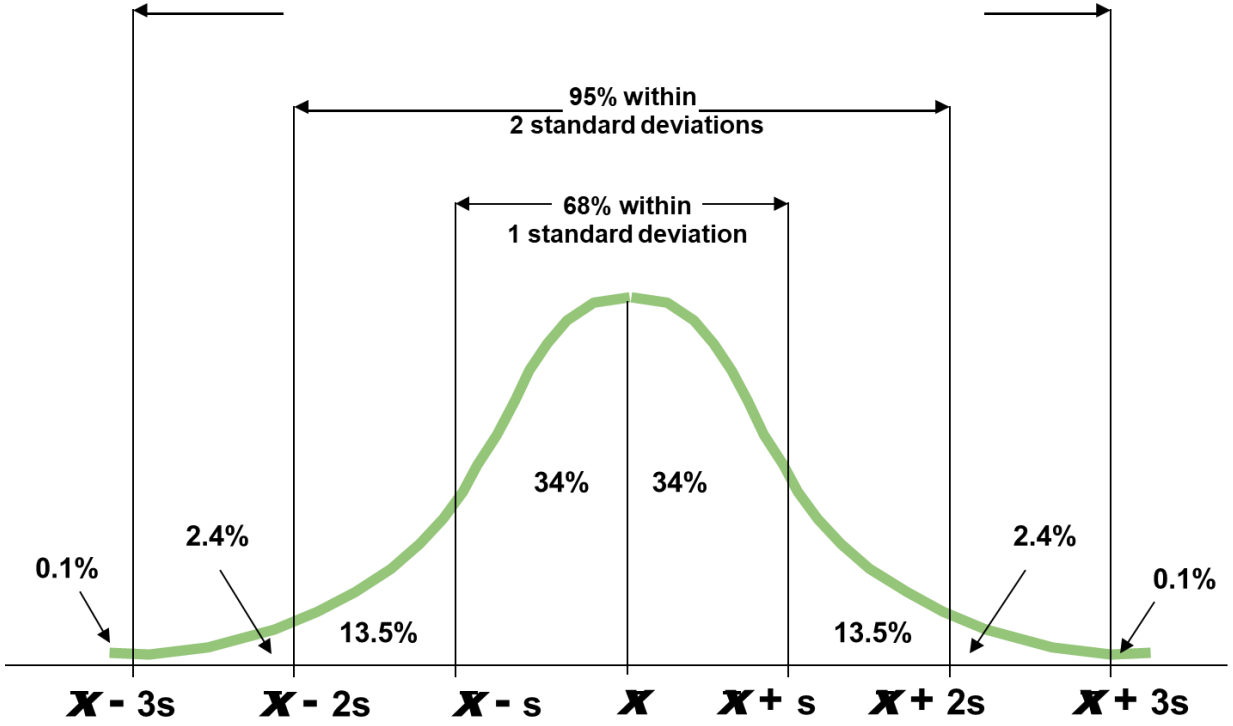
$$s^2 = \frac{\Sigma (x - \bar{x})^2}{n - 1}$$ **Sample Variance**

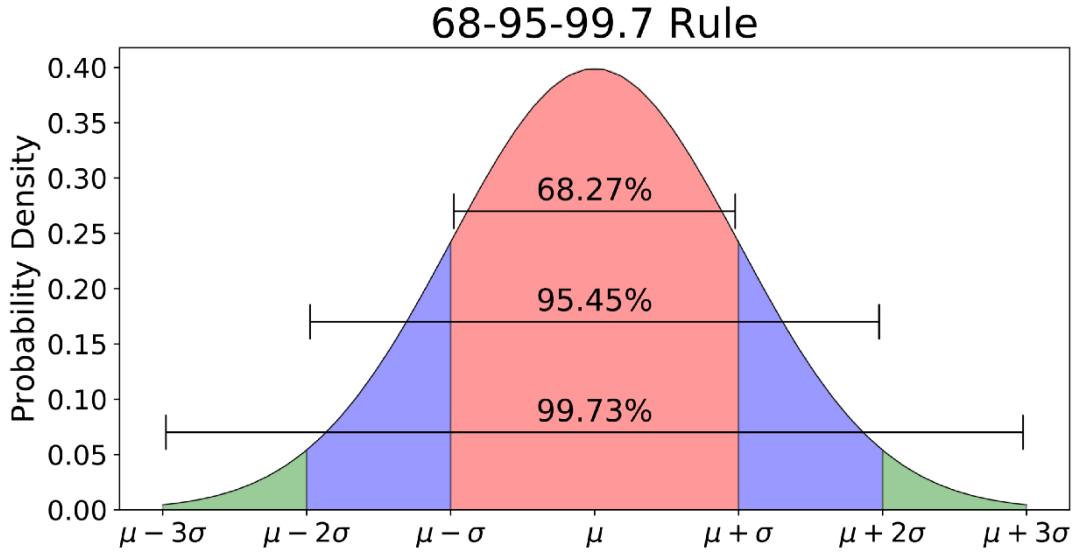




In a Normal Distribution:

How many percent of your values do you expect to be in the distance of one standard deviations from the mean?





Types of Descriptive Analytics

There are four major types of descriptive analytics:

- Measures of Frequency
- Measures of Central Tendency
- Measures of Dispersion or Variation
- Measures of Position

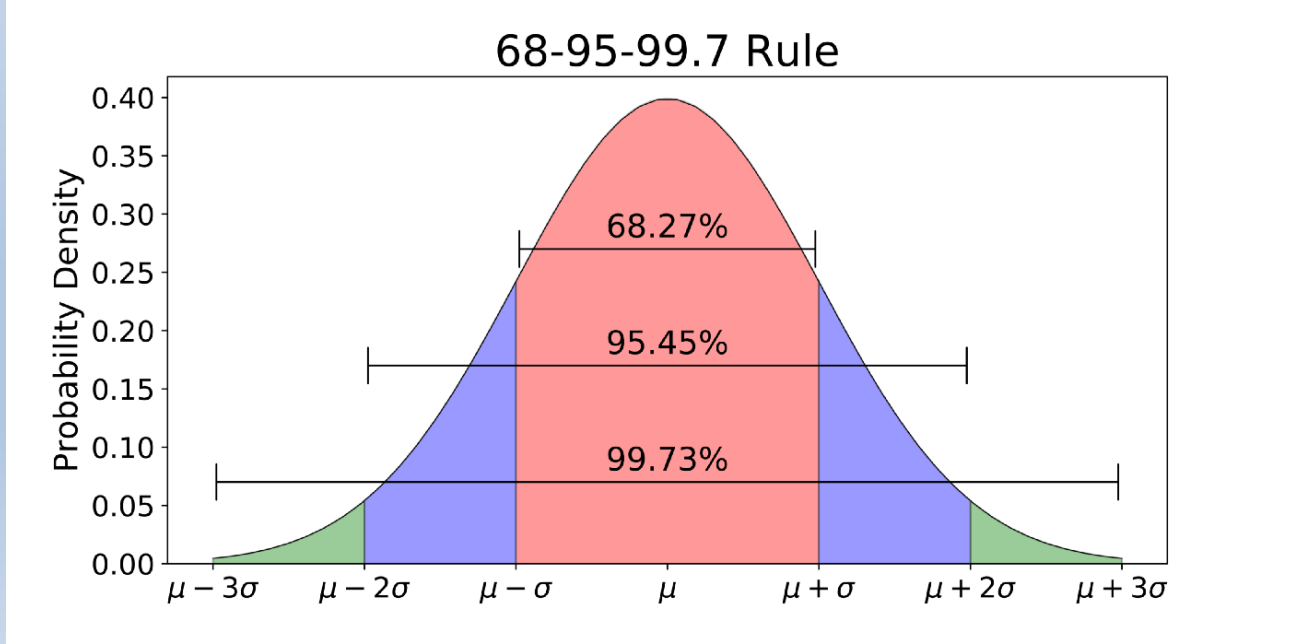
Measures of position

$$z_i = \frac{x_i - \bar{x}}{s}$$

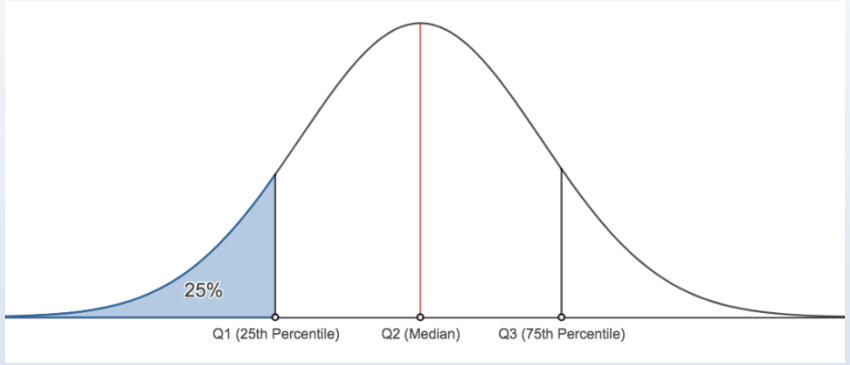
Example:

A manager of a store is requesting for promotion or extra budget due to their relatively high sales, you need to be able to find out how well they are doing.

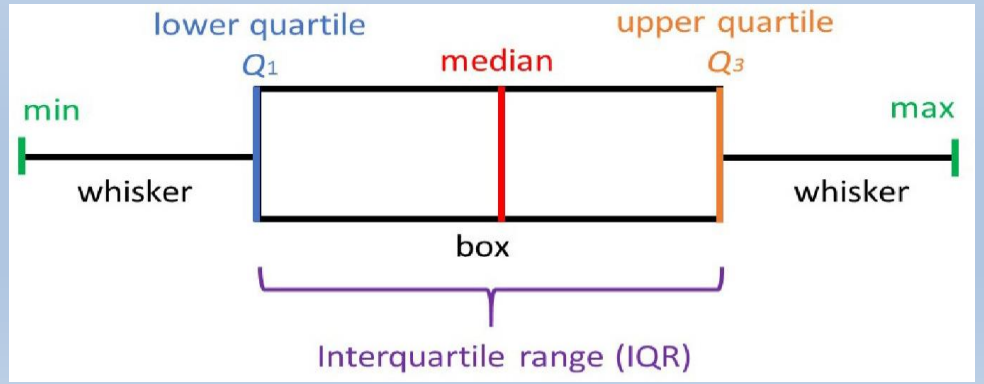
You want to offer some extra payments to employees and want to have a solid base for that extra payment. How would you distribute your limited budget?

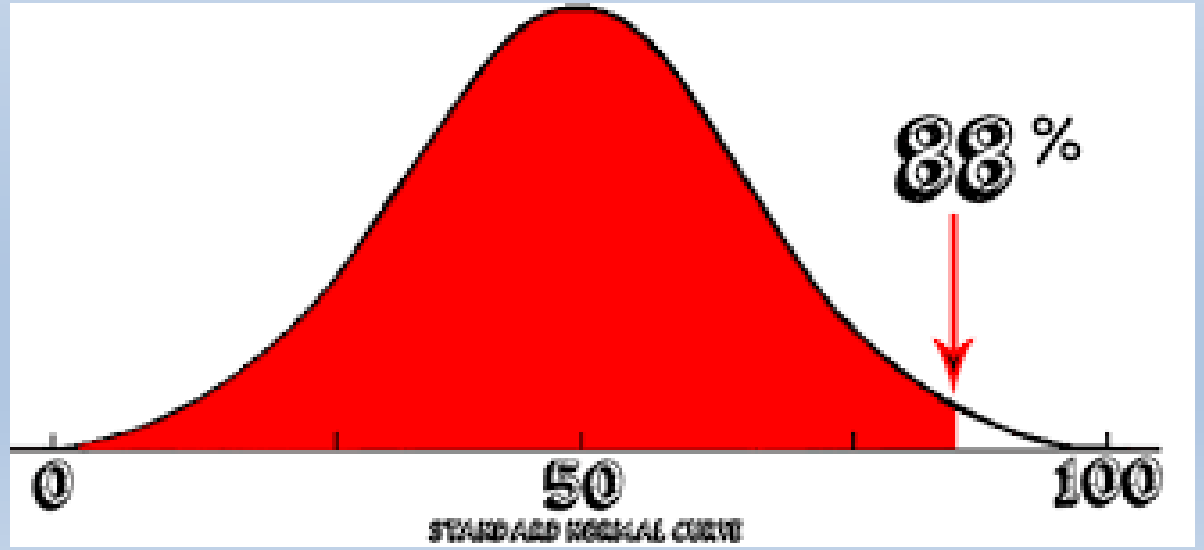


Measures of Position

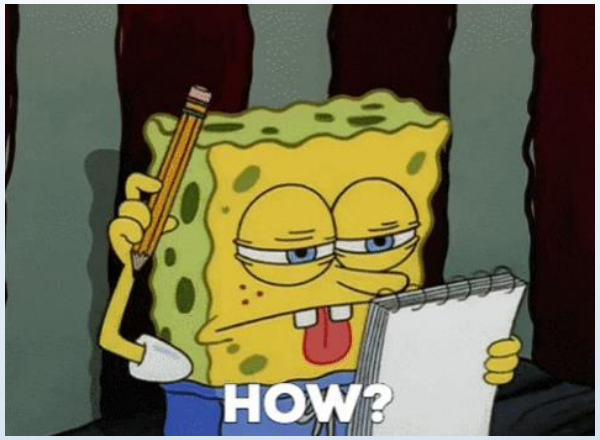


- Percentile Ranks, Quartile Ranks
- Describes how scores fall in relation to one another.
- Use this when you need to compare scores to a normalised score (e.g., a national norm)

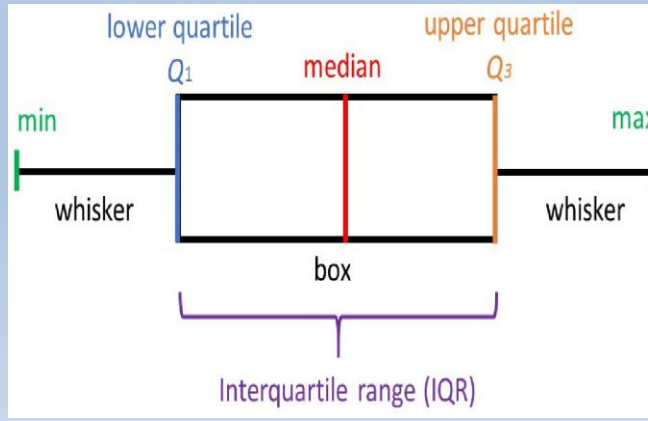




Activity



1. Create a table showing different quartiles using **"QUARTILE.INC"** function
2. Find the Median
3. Do this in Excel Insert>Insert Statistics Chart>then choose Box-and-Whisker Plot.



1 3 4 6 6 7 8

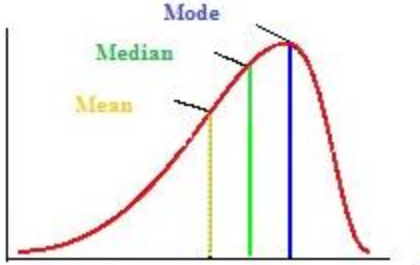
mean 5
average

mode 6
most common

median 6
middle

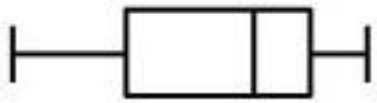
range 7
largest - smallest

Left-Skewed

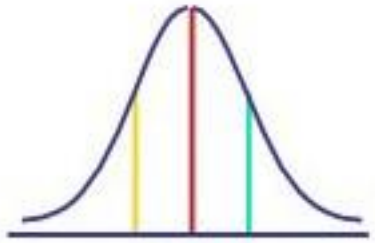


Left-Skewed (Negative Skewness)

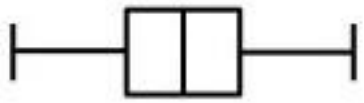
Q1 Q2 Q3



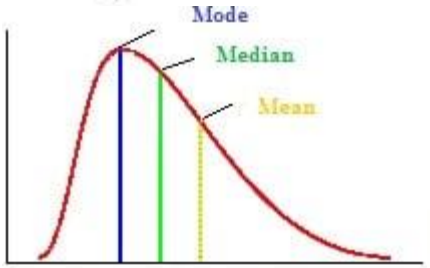
Symmetric



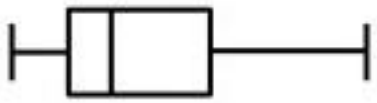
Q1 Q2 Q3

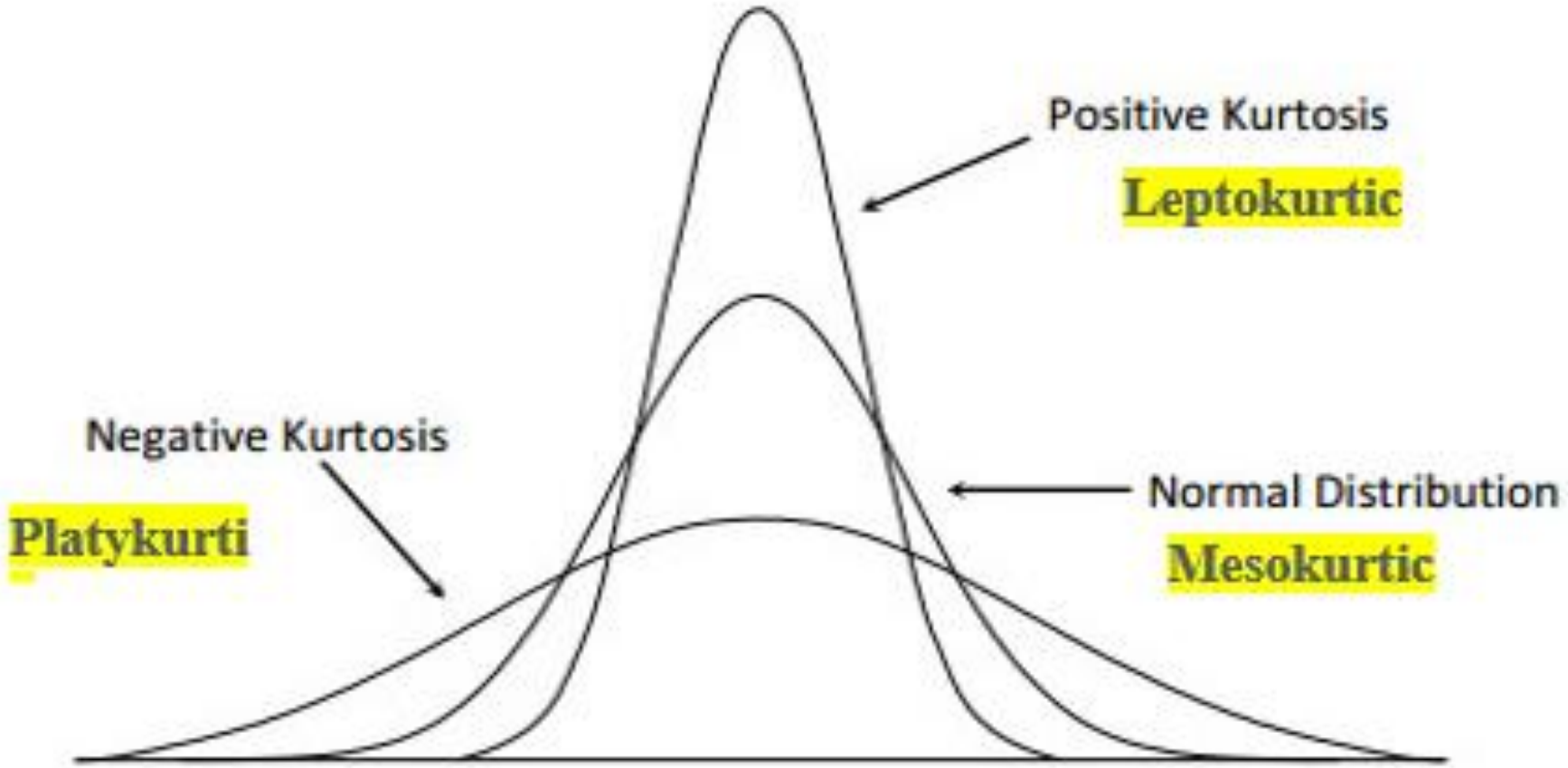


Right-Skewed



Right-Skewed (Positive Skewness)




Positive Kurtosis
Leptokurtic
Negative Kurtosis
Platykurti
Normal Distribution
Mesokurtic

Activity

- ❑ What is the average of starting inventories for different stores
- ❑ What is the data range
- ❑ What is the standard deviation
- ❑ What is the normal range which includes almost 68% of data
- ❑ What are the max and min
- ❑ What is the skewness of data