Business Fundamentals for Analytics

Supply Chain Management

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Bullwhip Effect

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Learning Objectives

- Discuss the supply chain phenomena known as the Bullwhip Effect
- Explain the causes of the Bullwhip Effect
- List some solutions to mitigate the Bullwhip Effect

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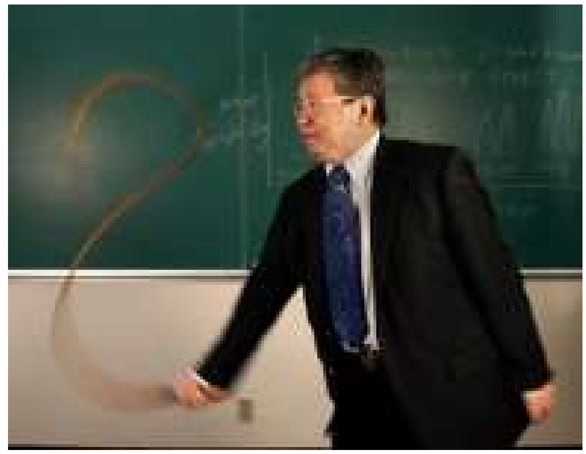
Bullwhip Effect

- Hau Lee investigate the ‘Bullwhip Effect’ after observing multi-echelon supply chain inventory problems (first described by Forrester in 1961)
- First documented the problem with Pampers
- Then found similar phenomenon in other industries, specifically HP printers.



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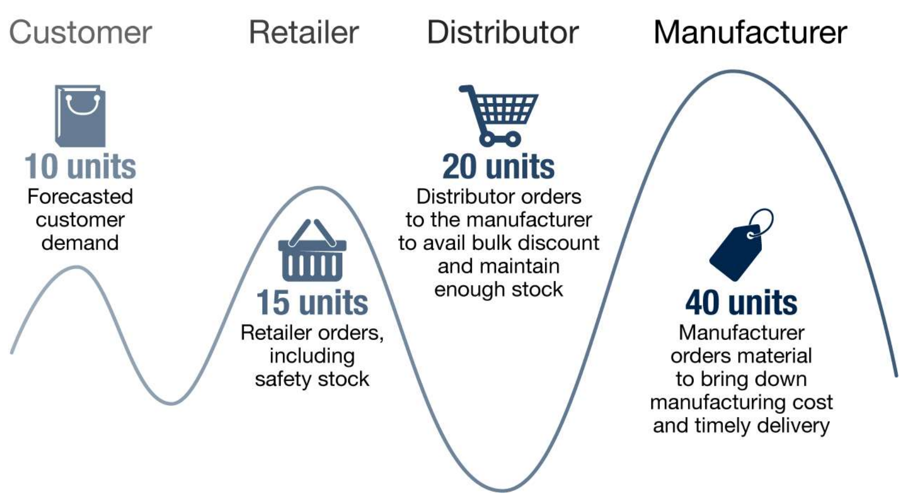
Magnification of orders

Magnification of orders as we move upstream in a supply chain from the customer



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Causes

- Price Fluctuations (placing items on sale)
  - Sell out due to "artificial" demand, thus order more
  - Upstream perceives this as "actual" demand and ramps up production
- Order Batching
  - Upstream cannot distinguish change in batch size from change in demand
- Shortage Gaming
  - Suppliers ration orders
  - Buyers overcompensate to ensure they have product
- Forecast Inaccuracies

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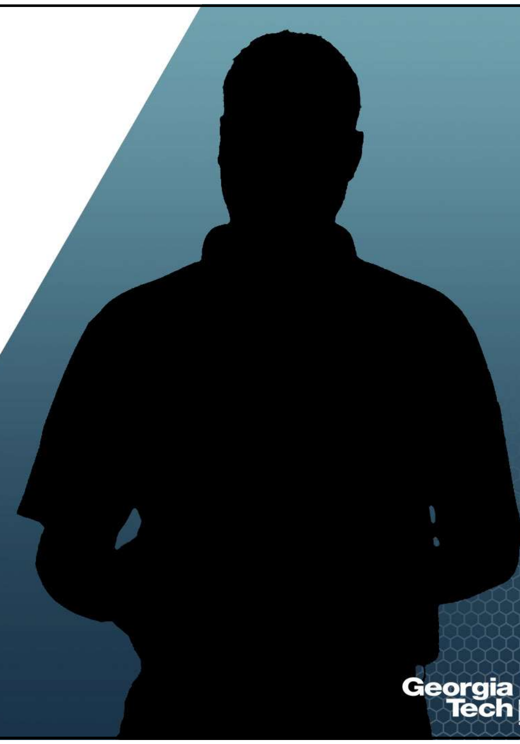
Solutions/How to Mitigate

- Increase information sharing of data thru the supply chain. Ex: share POS data upstream.
- Reduce order costs (reduces desire to order in larger batches)
- Eliminate discounts and promotions (reduces "artificial" demand)



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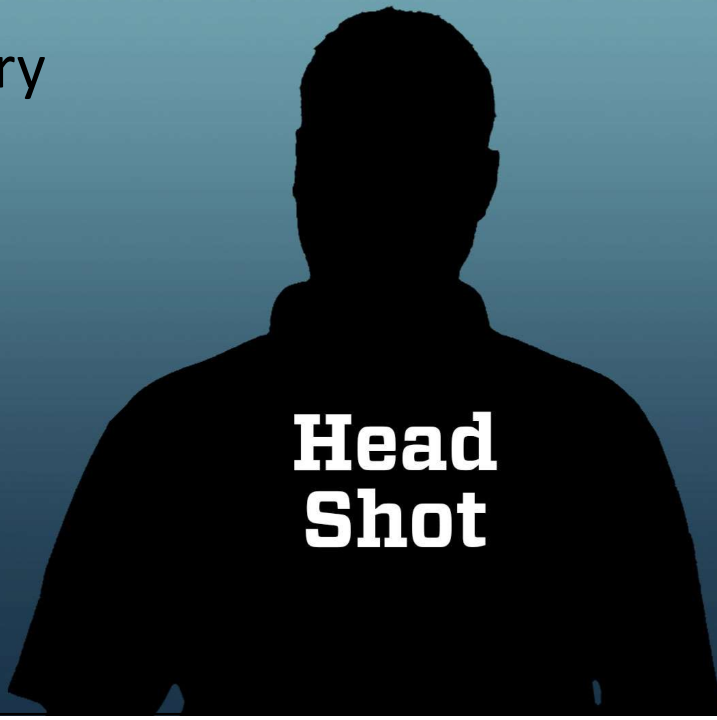
Summary



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Newsvendor Model

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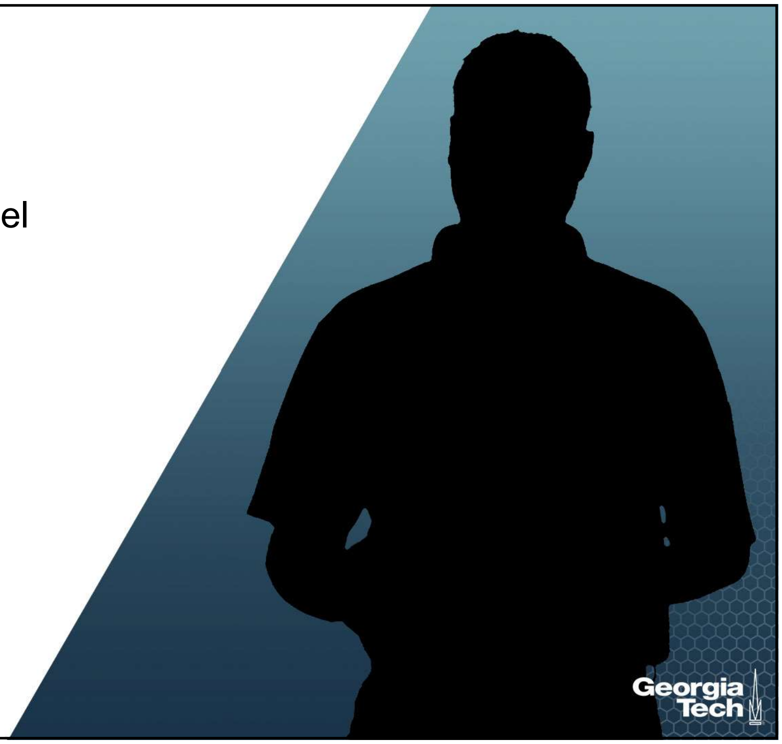
Learning Objectives

Discuss the Newsvendor Model



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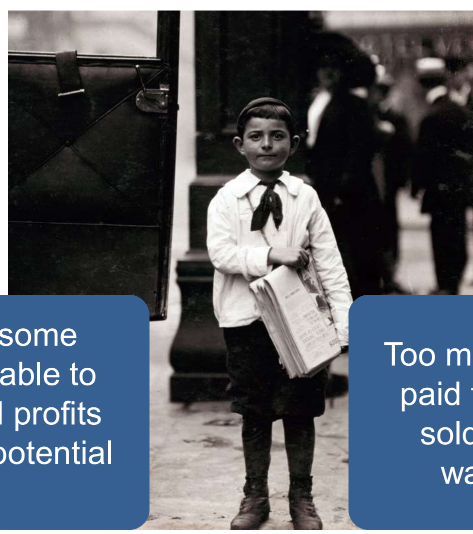
How many newspapers should he get today?

He buys for
$.80 a paper



He sells for
$1.00 a paper

Too few papers and some customers will not be able to purchase a paper, and profits associated with these potential sales are lost.

Too many papers and the price paid for papers that were not sold during the day will be wasted, lowering profit.

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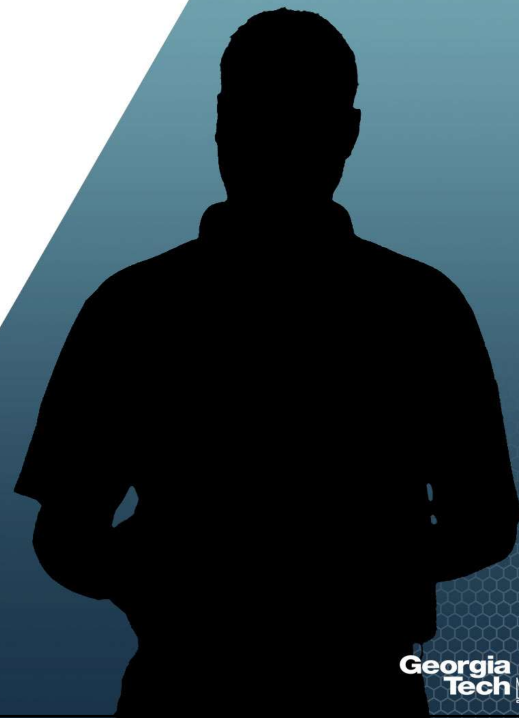
The Newsvendor Framework

- One chance to decide the stocking quantity for the product you are selling
- Demand for the product is uncertain (but you have a probability distribution)
- Known marginal profit for each unit sold and known marginal loss for ones that are bought and not sold
- GOAL: Maximize expected profit



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Where This Is Used

- Perishable goods
  - Meals in a cafeteria
  - Dairy foods
- Short selling season
  - Christmas trees
  - Flowers on valentines day
  - Fashion clothes
  - Newspapers
  - Event related goods

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Let's Define Some Variables

c: Cost of each item

p: Retail selling price for each item

s: Salvage value for unsold items

MP: Marginal profit from selling a stocked item = p-c

ML: Marginal loss from not selling a stocked item = c-s

x: Number of items you buy

P(x): Probability that the xth item is not sold

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Critical Fractile

Underage cost = opportunity cost of underestimating demand

Overage cost = cost of overestimating demand

c_u = Underage cost = p – c (retail price minus cost)

c_o = Overage cost = c – s (cost minus salvage value)

$$F(Q) = P(D \leq Q) \leq \frac{c_u}{c_u + c_o}$$

Where: D = demand

Q = quantity ordered

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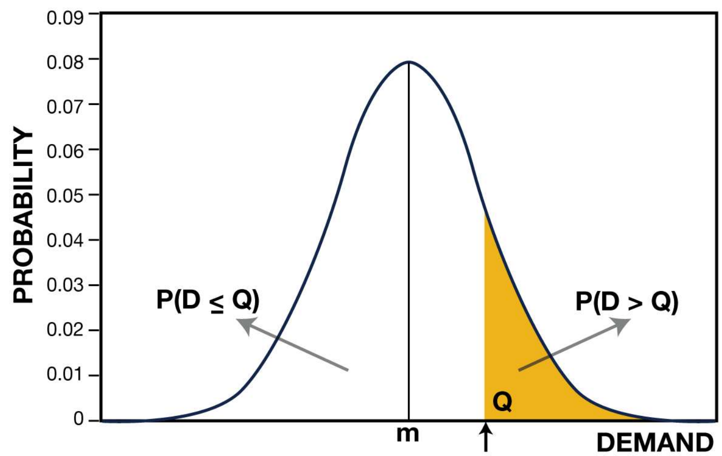
For a Normal Distribution of Demand



$$F(Q) = P(D \le Q) \le \frac{c_u}{c_u + c_o}$$

Solution with continuous distribution:

Choose Q such that *P* (*D* ≤ *Q*) = critical fractile

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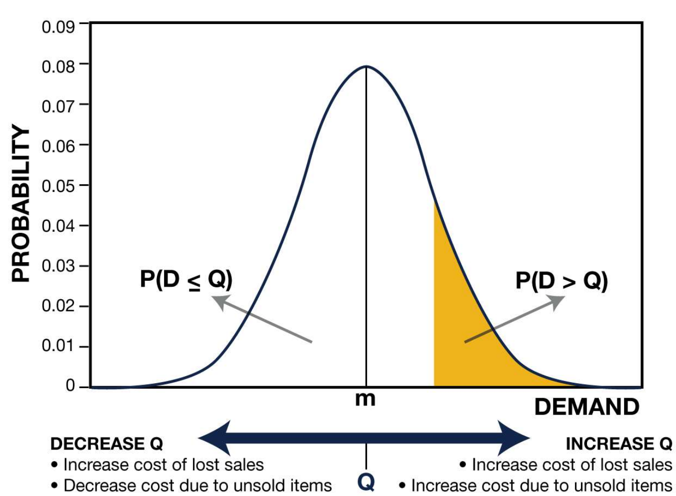
For a Normal Distribution of Demand

Let F(Q) = G(z) to find z: $F(Q) = P(D \le Q) = \dfrac{c_u}{c_u + c_o}$



Q = μ + z * σ

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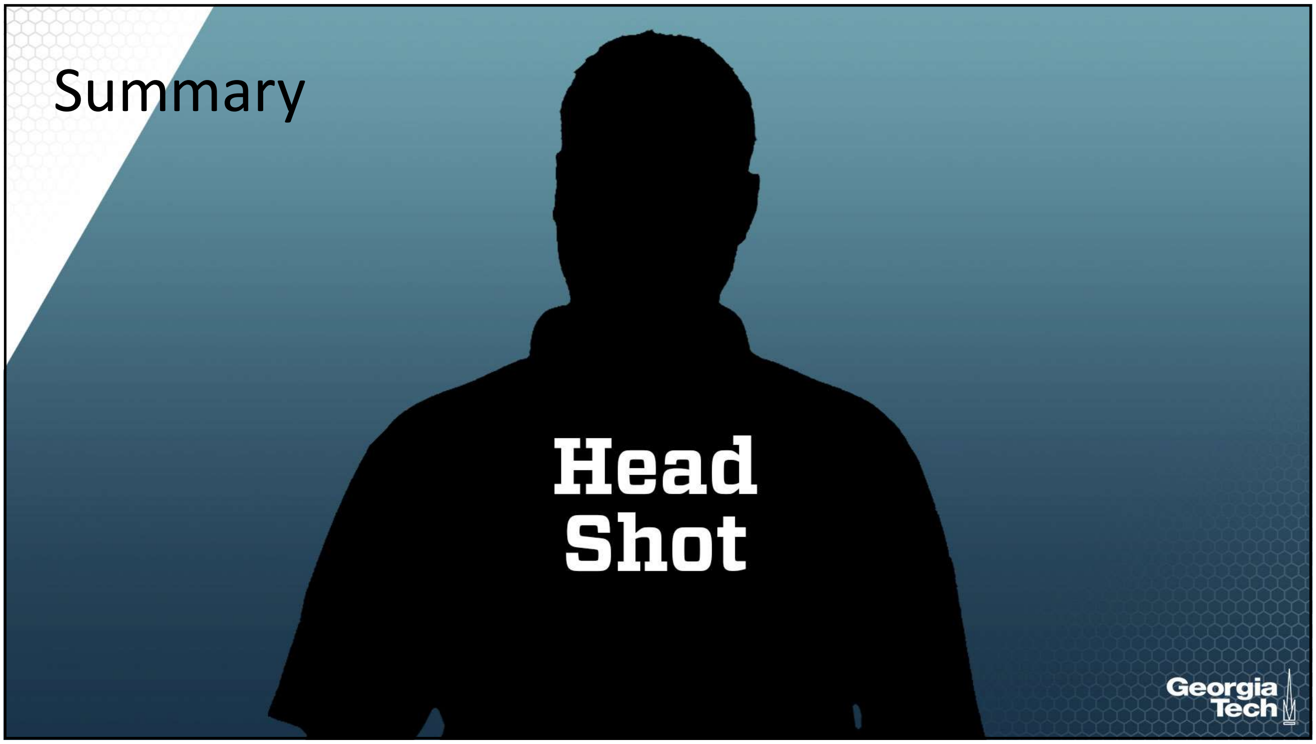
Summary
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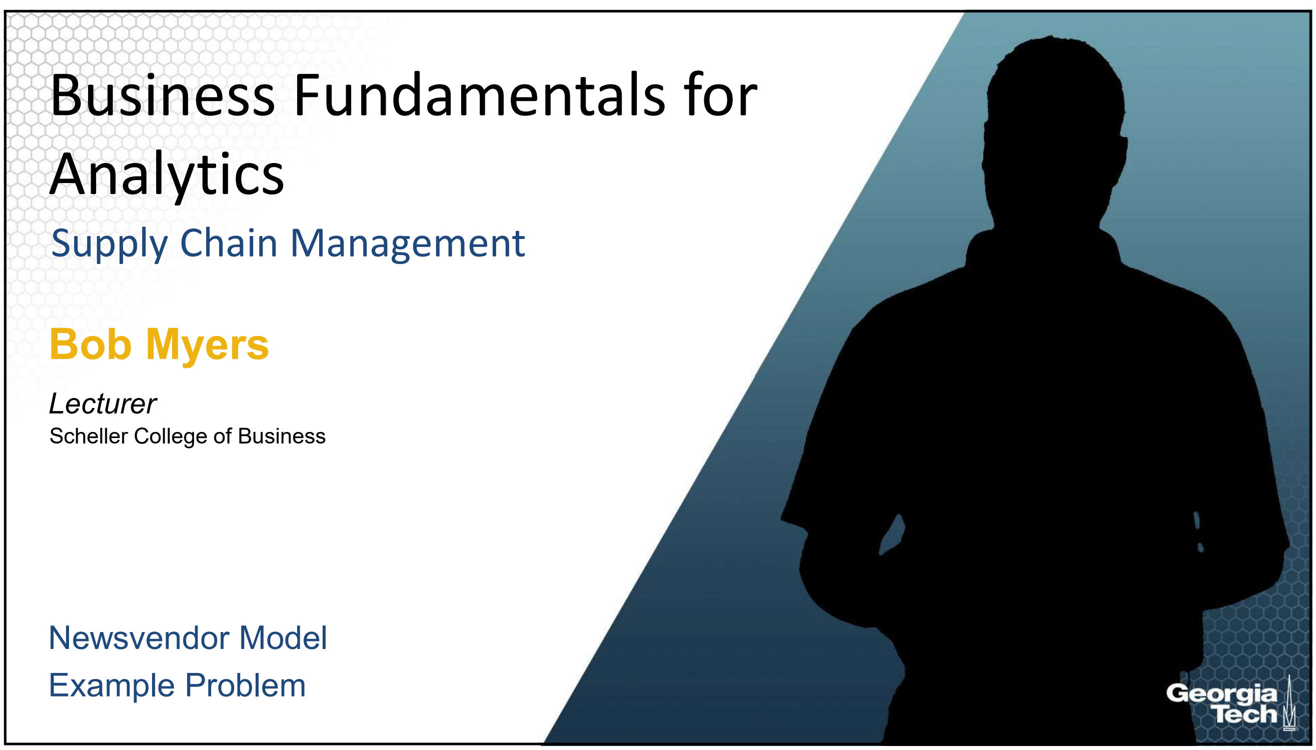
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Newsvendor Model
Example Problem
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Learning Objectives

Use the critical fractile and newsvendor model in an example problem

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Merchandise Buyer

- You work for the University Bookstore.
- Georgia Tech Football is going to play in the Sun Bowl.
- You need to decide on a T-shirt order from your supplier.
- Order too many and costs go up.
- Order too few and miss out on sales.

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Data

- T-shirt vendor charges \$6.50 per shirt.
- You sell t-shirts for \$8.95 each.
- After the bowl game, demand will go away but Big Lots will buy any leftover t-shirts for \$1.00 each.
- From past orders, you estimate demand to be normally distributed with a mean of 20,000 t-shirts and a standard deviation of 1,000.

How many t-shirts should you order?

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Solution

p = \$8.95, c = \$6.50, s = \$1.00

c_u = \$8.95 - \$6.50 = \$2.45

c_o = \$6.50 - \$1.00 = \$5.50

m = 20,000, s = 1,000

$$F(Q) = (P(D \leq Q) = \frac{c_u}{c_u + c_o} = \frac{2.45}{2.45 + 5.50} = .308$$

Look at the standard normal table and find the z that corresponds to F(Q): z = -0.5

$$Q = \mu + z\sigma = 20{,}000 - .5 * 1{,}000 = \mathbf{19{,}500\ t - shirts}$$

Since the overage costs were more than the underage costs, you order fewer than the expected demand

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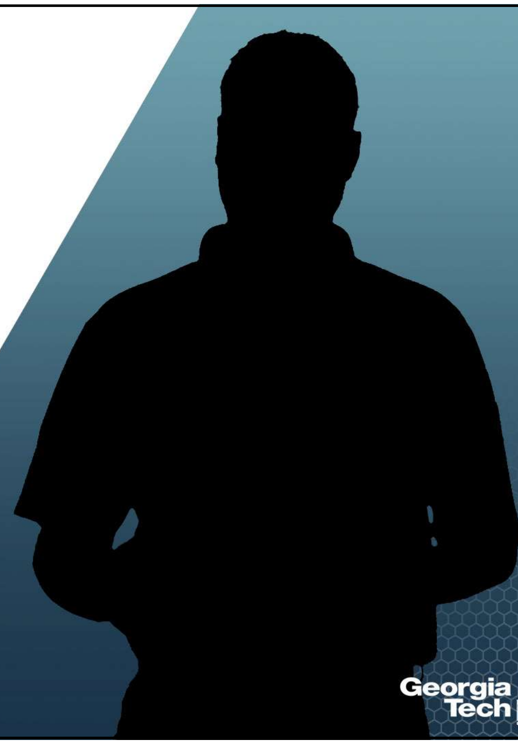
Forecasting 1



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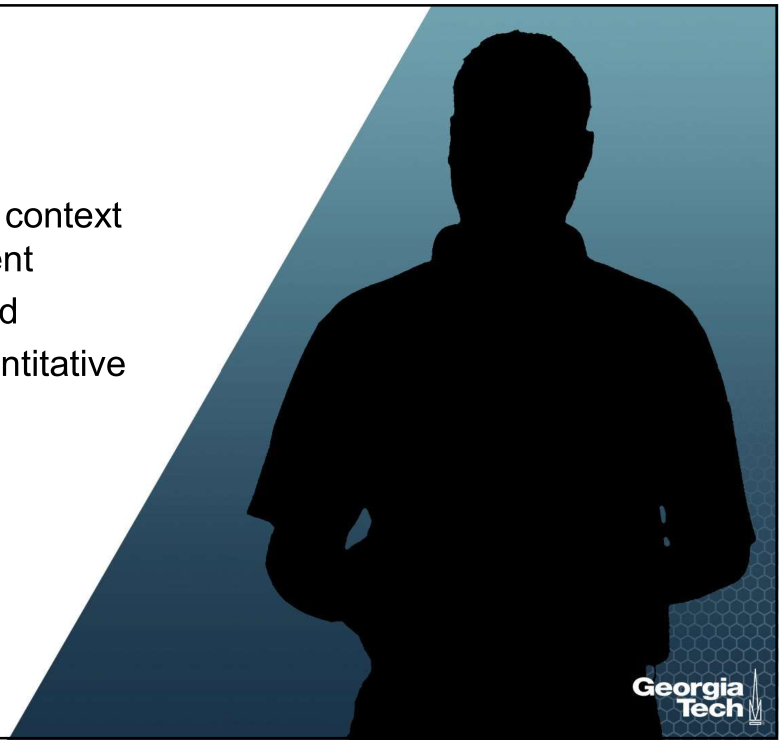
Learning Objectives

- Discuss Forecasting in the context of supply chain management
- Discuss patterns of demand
- Identify qualitative and quantitative forecasting methods



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What is Forecasting?

Forecasting – **prediction of future events used for planning purposes**.

Used for:

- Strategic planning (long term capacity decisions)
- Finance and Accounting (budgeting and cost control)
- Marketing (future sales trends, new product introduction)
- Production and Operations (staffing and supplier relations)

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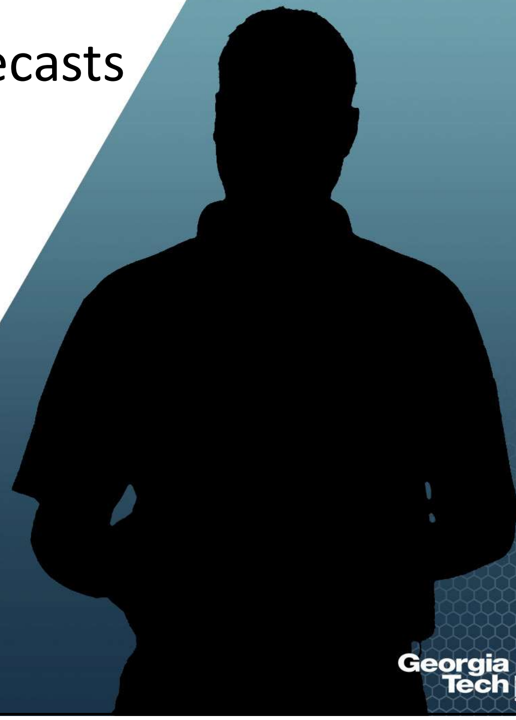
General Characteristics of Forecasts

- Forecasts are almost always wrong!
- Forecasts are more accurate from groups or families of items
- Forecasts are more accurate for shorter periods of time
- Every forecast should include an error estimate
- Forecasts are no substitute for actual demand



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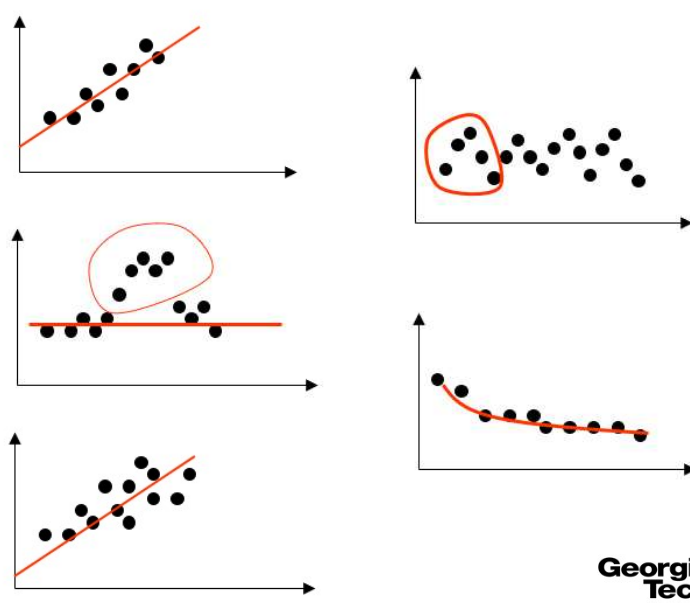
Patterns of Demand

- Trends
- Seasonality
- Cyclical elements
- Autocorrelation
- Random variation



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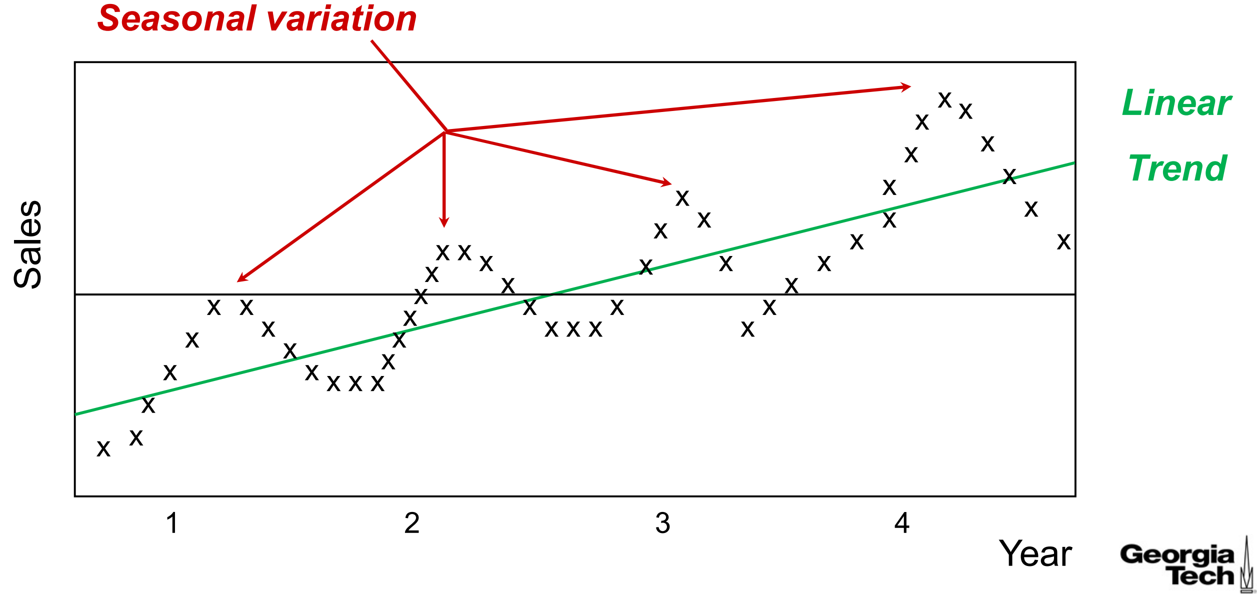
Data can exhibit multiple patterns



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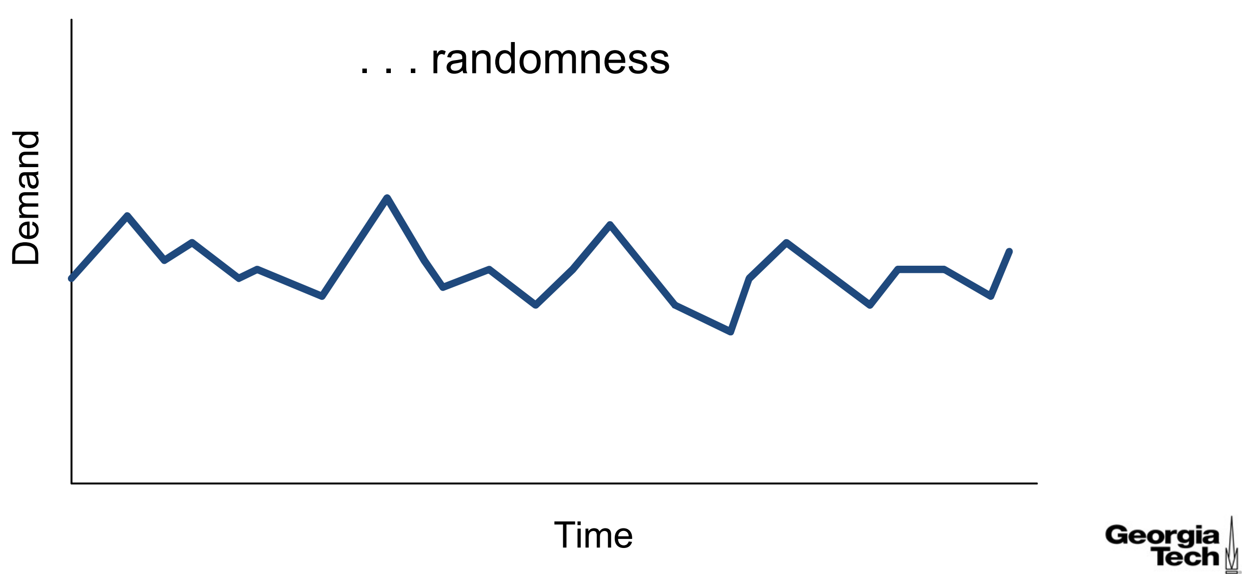
Time series Components of Demand



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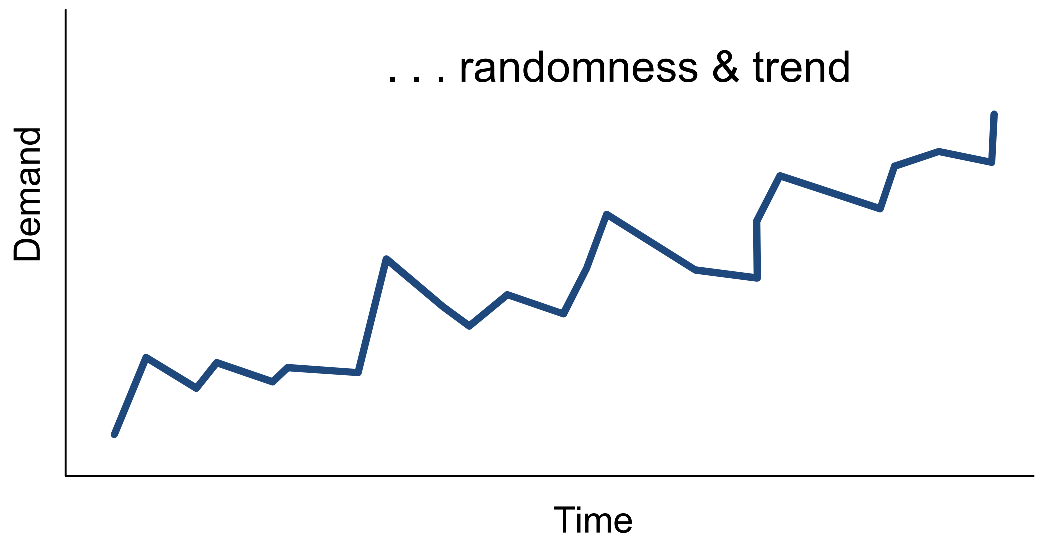
Time Series with..



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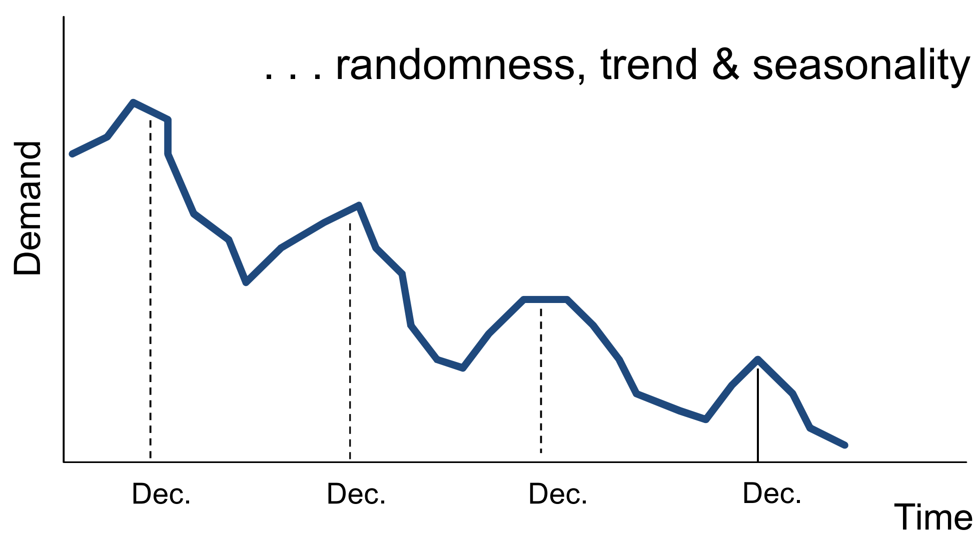
Time Series with..



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Some Important Questions

- What is the purpose of the forecast?
- Which systems will use the forecast?
- How important is the past in predicting the future?

Answers will help determine the time horizons, techniques, and level of detail in the forecast.

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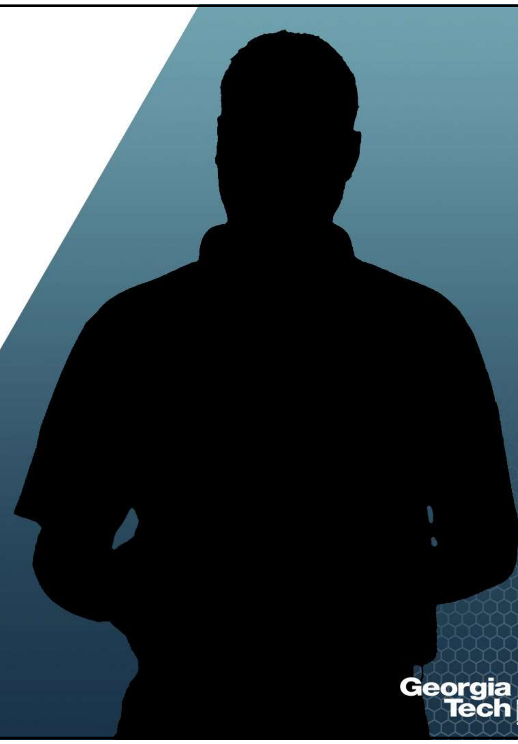
Type of Forecasting Methods

Qualitative

- Rely on subjective opinions from one or more experts

Quantitative

- Relay on data and analytical techniques



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Quantitative Forecasting Methods

Time Series: models that predict future demand based on past history trends

Casual Relationships: models that use statistical techniques to establish relationships between various items and demand (Ex: Linear Regression)

Simulation: models that can incorporate some randomness and non-linear effects

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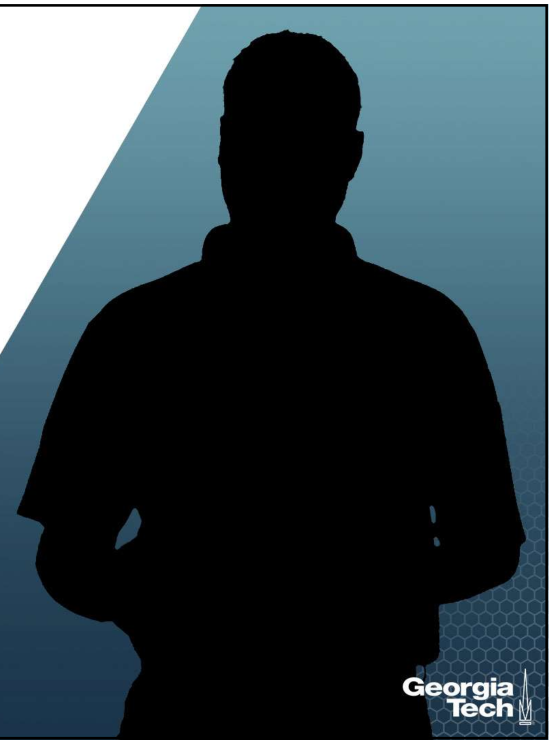
Forecasting 2



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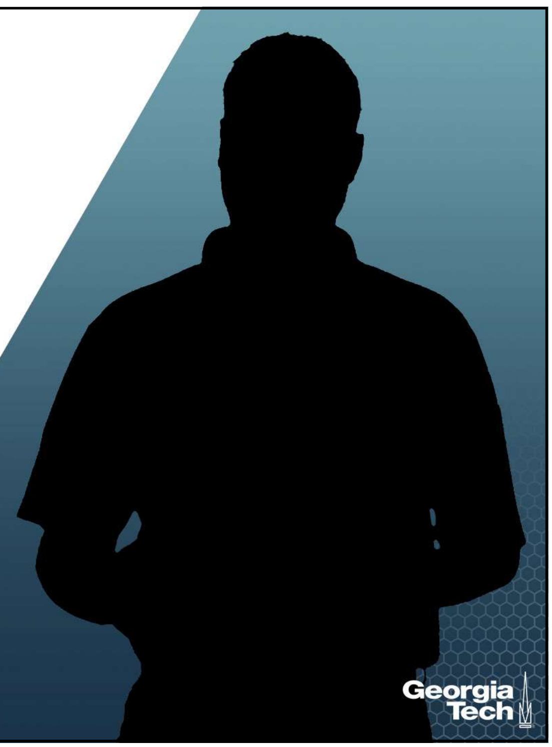
Learning Objectives

- Explain time series forecasting methods
- Outline simple moving average



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Time Series: Moving Average

- The moving average model uses the last *n* periods in order to predict demand in period *t+1*.
- There are two types of moving average models: simple moving average and weighted moving average.
- The moving average model assumption is that the most accurate prediction of future demand is a simple (linear) combination of past demand.

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Time Series: Simple Moving Average (Cont'd)

In the simple moving average models the forecast value is

$$F_{t+1} = \frac{A_t + A_{t-1} + \cdots + A_{t-n+1}}{n}$$

t	is the current period
Ft+1	is the forecast for the next period
n	is the number of periods
A	is the Actual demand for a given period

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Example: 4 Period Simple Moving Average

Week	Demand
1	650
2	678
3	720
4	785
5	859
6	920
7	850
8	758
9	892
10	920
11	789
12	844

What is the Forecast for Week 13 using a 4 period Simple Moving Average?

$$F_{13} = \frac{A_t + A_{t-1} + \cdots + A_{t-n+1}}{n} = \frac{A_{12} + A_{11} + A_{10} + A_9}{4}$$

$$F_{13} = \frac{844 + 789 + 920 + 892}{4} = 861.25$$

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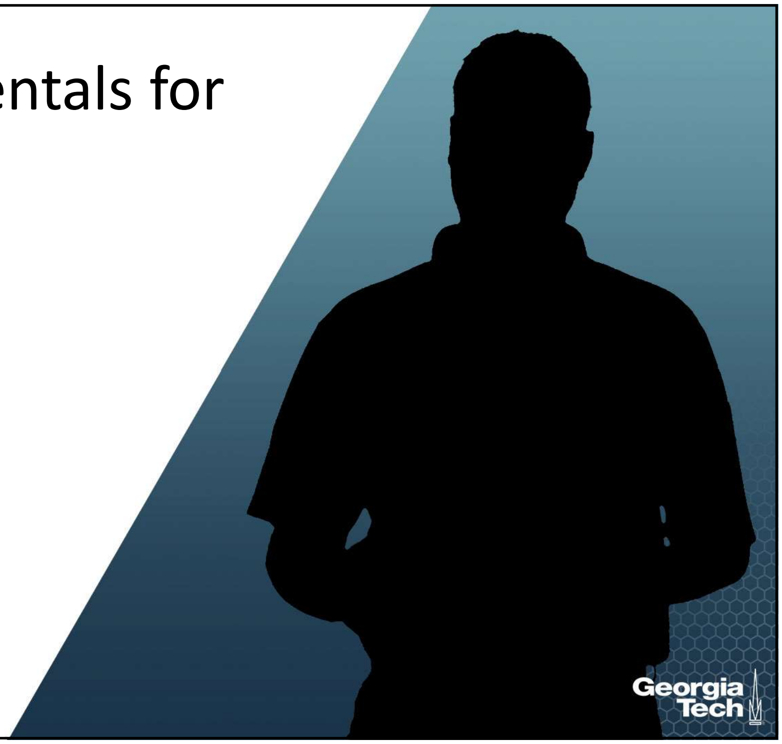
Forecasting 3



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Learning Objectives

- Outline weighted moving average

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Time Series: Weighted Moving Average (WMA)

We may want to give more importance to some of the data…

$$F_{t+1} = w_1 A_t + w_{t-1} A_{t-1} + \cdots + w_{t-n} A_{t-n}$$

$$w_t + w_{t-1} + \cdots + w_{t-n} = 1$$

t is the current period

Ft+1 is the forecast for the next period

n is the number of periods

A is the Actual demand for a given period

w is the importance (weight) for a given period

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Example: 3 Period Weighted Moving Average

Week	Demand
1	650
2	678
3	720
4	785
5	859
6	920
7	850
8	758
9	892
10	920
11	789
12	844

What is the Forecast for Week 110 using a 3 period Weighted Moving Average with weights .7,.2,.1?

$$F_{t+1} = W_t A_t + W_{t-1} A_{t-1} + \cdots + W_{t-n+1} A_{t-n+1}$$

F_{10}=.7A_9 +.2A_8 +.1A_7

$$F_{10} = .7 * 892 + .2 * 758 + .1 * 850 = 861$$

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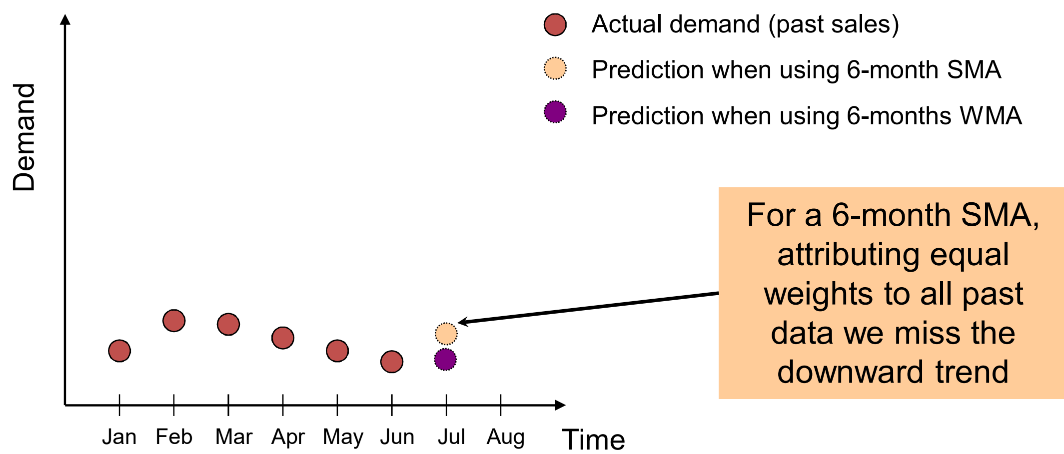
Why do we need WMA models?

Because of the ability to give more importance to more recent data without losing the impact of the past.



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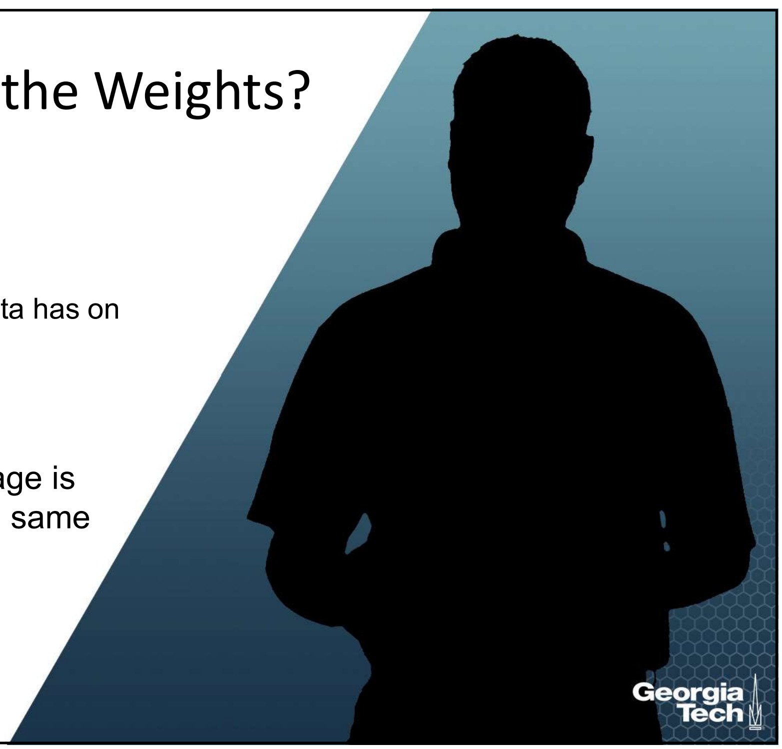
How Do We Choose the Weights?

- Trial and error
- Depends upon:
  - Importance we feel past data has on future data
  - Known seasonality

***Note that Simple Moving Average is actually WMA with all weights the same



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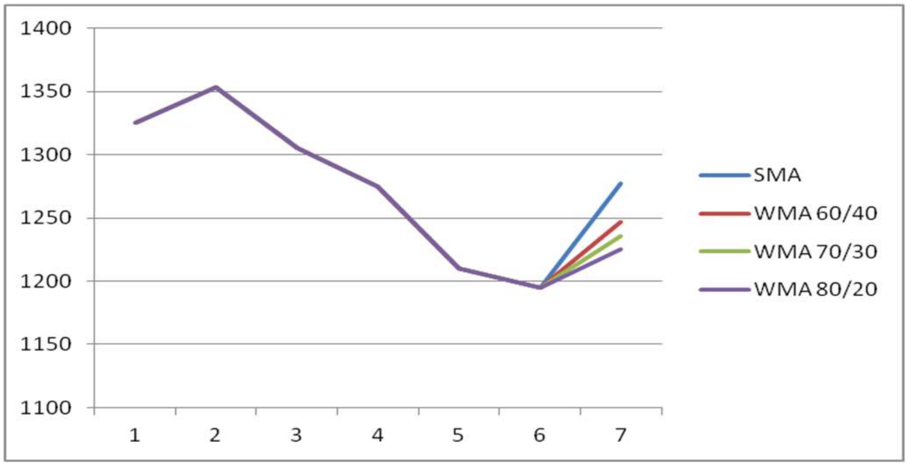
Plotting Weighted Moving Averages



The higher the importance we give to recent data, the more we pick up the most recent trend in our forecast.

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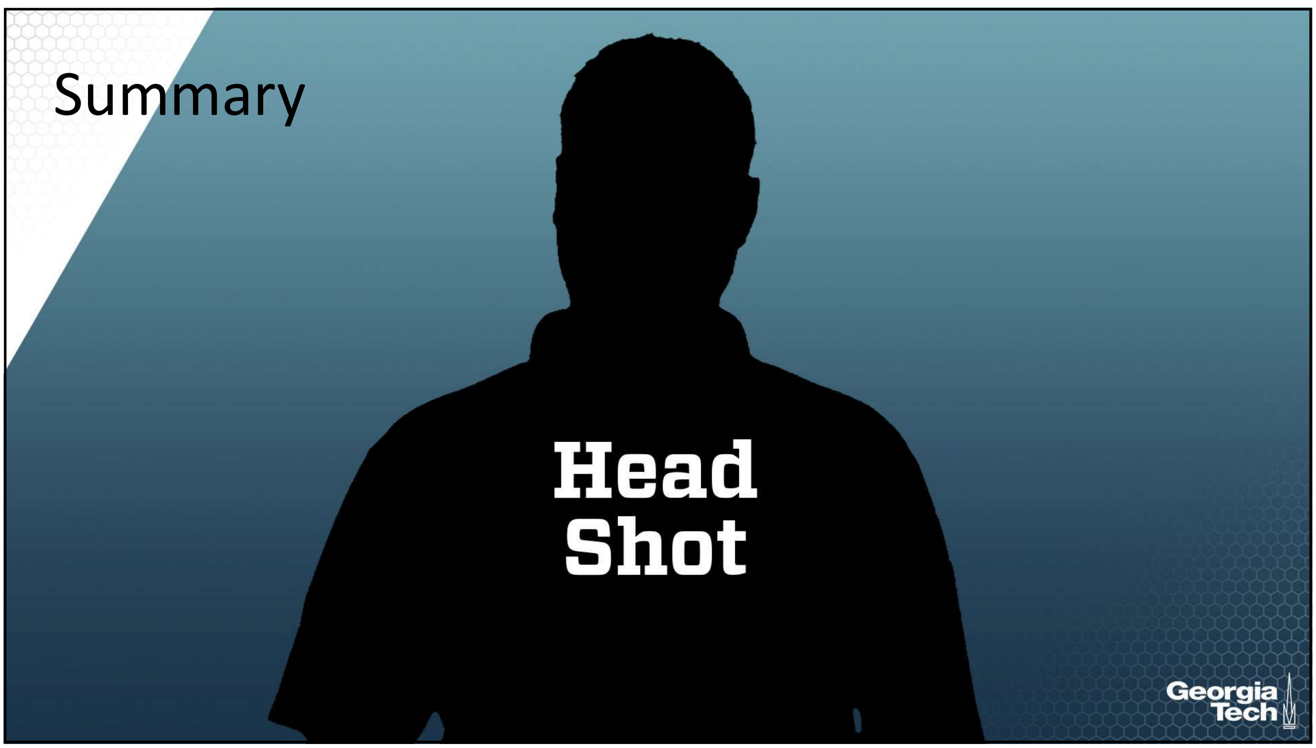

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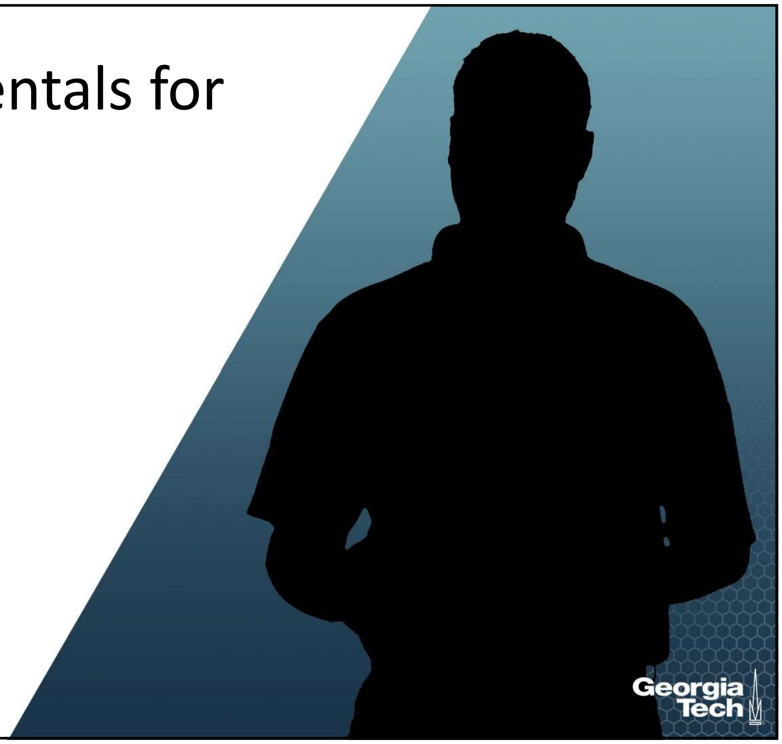
Forecasting 4



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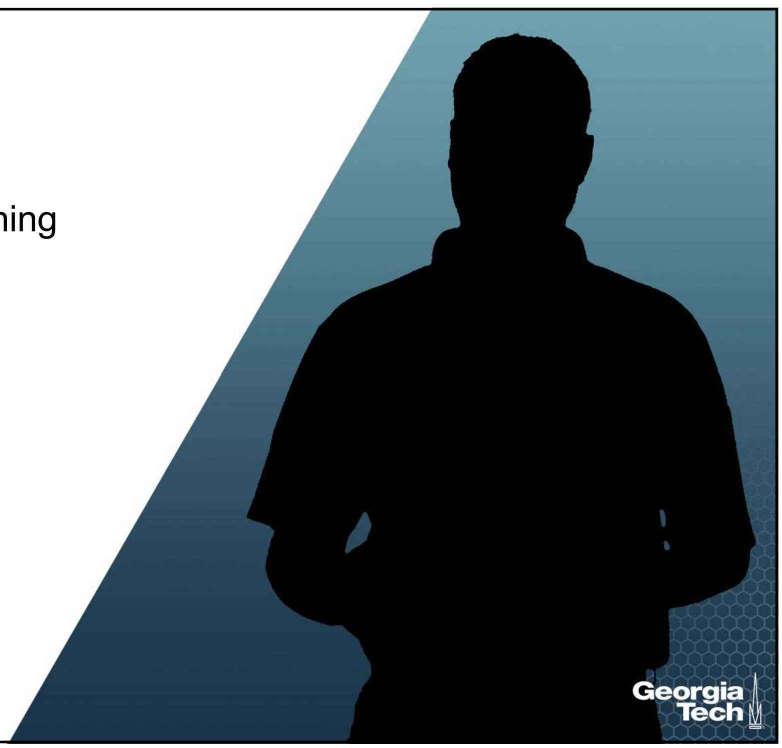
Learning Objectives

- Outline exponential smoothing



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Time Series: Exponential Smoothing

The Prediction of the future depends mostly on the most recent observation and on the error for the latest forecast

Smoothing constant alpha α → Denotes the importance of the past error

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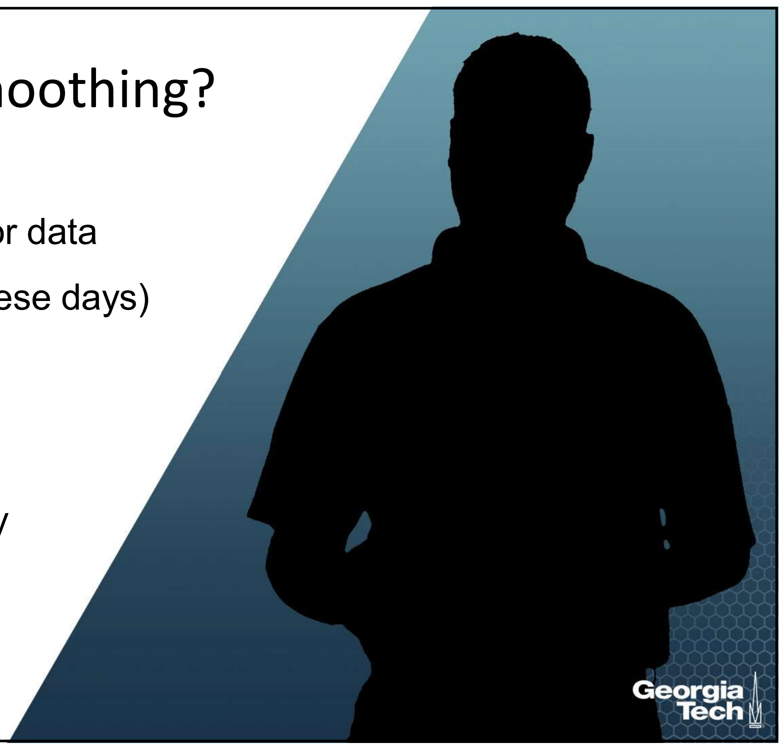
Why Exponential Smoothing?



- Uses less storage space for data (although not a problem these days)
- Extremely accurate
- Easy to understand
- Little calculation complexity

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Exponential Smoothing (ES)

Assume that we are currently in period t. We calculated the forecast for the last period (Ft-1) and we know the actual demand last period (A_{t-1})…

$$F_{t+1} = F_t + \propto (A_t - F_t)$$

$$where\ 0 \leq \propto \leq 1$$

The smoothing constant a expresses how much our forecast will react to observed differences..

- If a is **low,** there is little reaction to difference
- If a is **high,** there is a lot of reaction to differences

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Example

Week	Demand	Forecast
1	820	820
2	775	820
3	680	811
4	655	785
5	750	759
6	802	757
7	798	766
8	689	772
9	775	756
10		760

$F_2 = F_1 + \alpha(A_1 - F_1)$ =820 + 0.2(820-820)

$F_4 = F_3 + \alpha(A_3 - F_3)$ =811+ 0.2(680-811)

$F_6 = F_5 + \alpha(A_5 - F_5)$ =759+ 0.2(750-759)

$F_8 = F_7 + \alpha(A_7 - F_7)$ =766+ 0.2(798-766)

$F_{10} = F_9 + \alpha(A_9 - F_9)$ =756+ 0.2(775-756)

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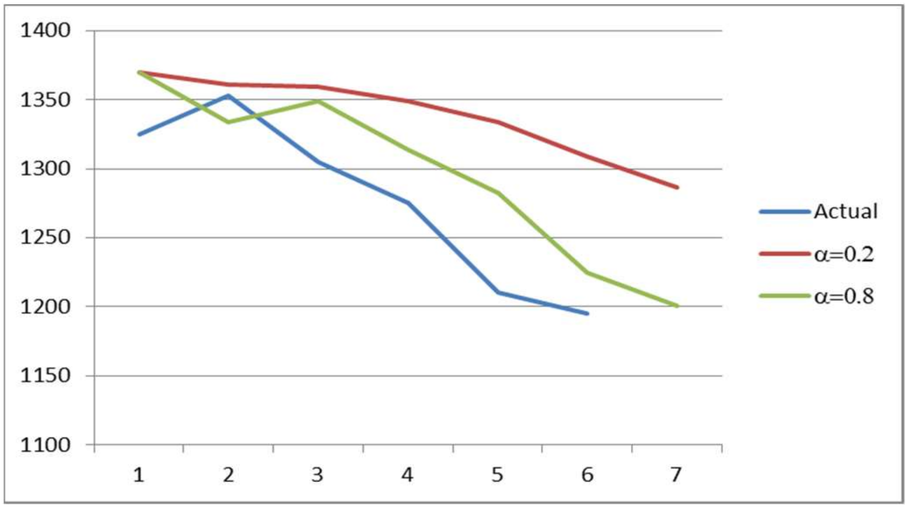
Plotting Exponential Smoothing Forecasts



Small α– Stable

Large α - Responsive

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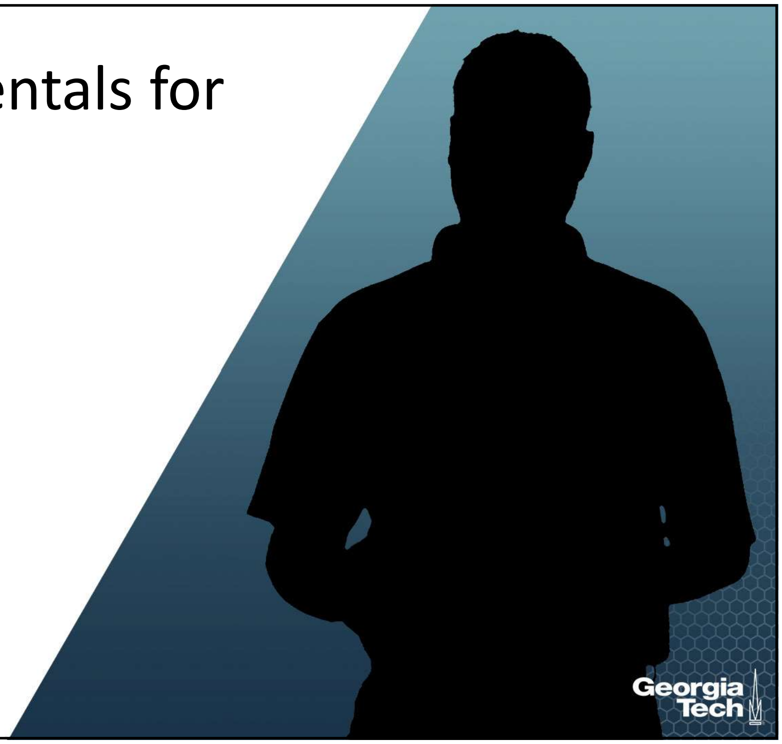
Forecasting 5



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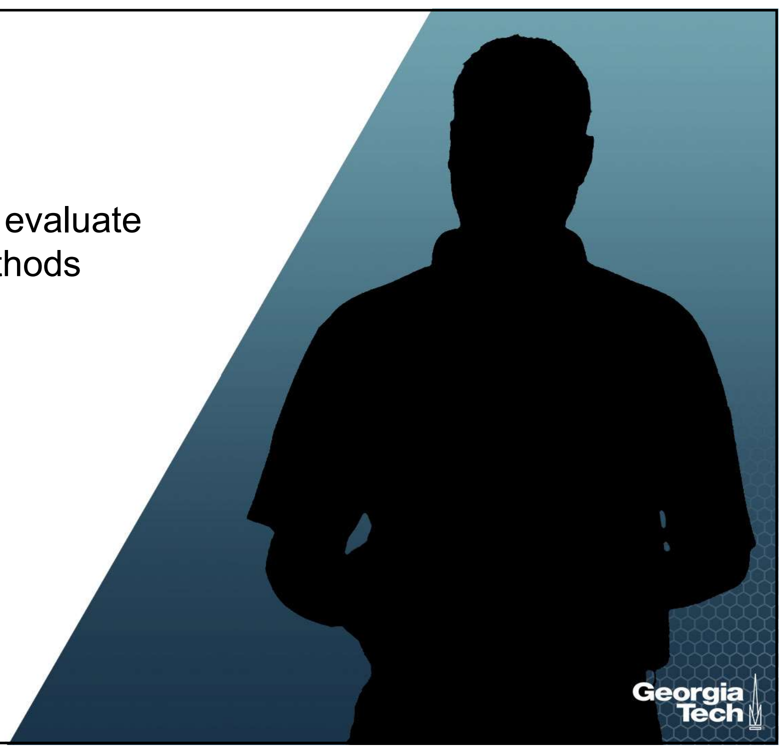
Learning Objectives

- Explain the use of errors to evaluate accuracy of time series methods



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How can we compare/evaluate different methods?

- **Bias** – when a consistent mistake is made
- **Random** – errors that are not explained by the model being used

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Measure of Forecast Accuracy

$$E_t = A_t - F_t$$

- E_t can be positive or negative
- Positive E_t means the forecast was too low
- Negative E_t means the forecast was too high

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Measures of Forecast Error

- RSFE – Running Sum of Forecast Error $RSFE = \sum (A_i - F_i)$
- MFE – Mean Forecast Error (Bias) $MFE = \frac{\sum (A_i - F_i)}{N} = \frac{RSFE}{N}$
- MAD – Mean Absolute Deviation $MFE = \frac{\sum |A_i - F_i|}{N}$
- TS – Tracking Signal $TS = \frac{RSFE}{MAD}$

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Computing Forecast Error

RSFE = $\sum (A_i - F_i) = 200$

Bias = MFE = $\frac{\sum (A_i - F_i)}{N} = \frac{200}{10} = 20$

Mean Absolute Deviation (MAD) =

$$\frac{\sum |A_i - F_i|}{N} = \frac{1600}{10} = 160$$

PD	Forecast	Actual Sales	(Sales – Forecast)	Absolute Error
1	1,000	1,200	200	200
2	1,000	1,000	0	0
3	1,000	800	-200	200
4	1,000	900	-100	100
5	1,000	1,400	400	400
6	1,000	1,200	200	200
7	1,000	1,100	100	100
8	1,000	700	-300	300
9	1,000	1,000	0	0
10	1,000	900	-100	100
	10,000	10,200	200	1,600

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Measuring Accuracy: Tracking Signal

- TS = Tracking Signal
- Measure of how often our estimations have been above or below the actual value. It is used to decide when to re-evaluate the model

$$TS = \frac{RSFE}{MAD}$$

- Positive tracking signal – most of the time, the actual values are above the forecasted values.
- Negative tracking signal – most of the time, the actual values are below the forecasted values.
- If TS < -4 or TS > 4, **investigate!**

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For Prior Problem…

$$TS = \frac{RSFE}{MAD} = \frac{200}{160} = 1.25$$

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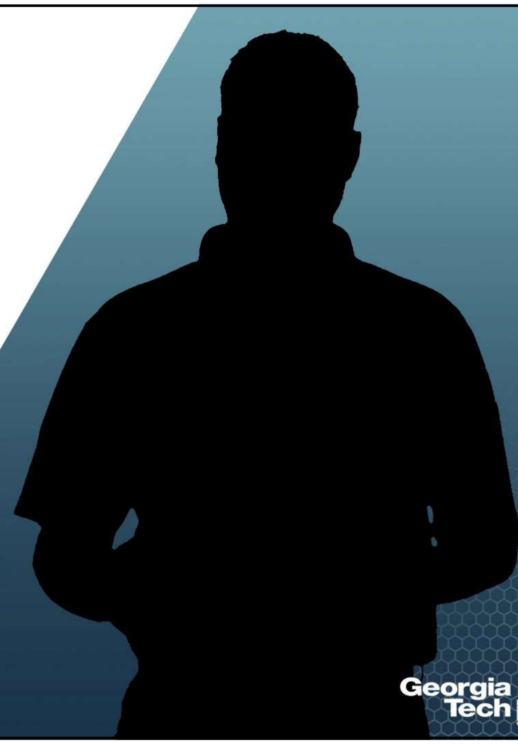
Forecasting Example Problem



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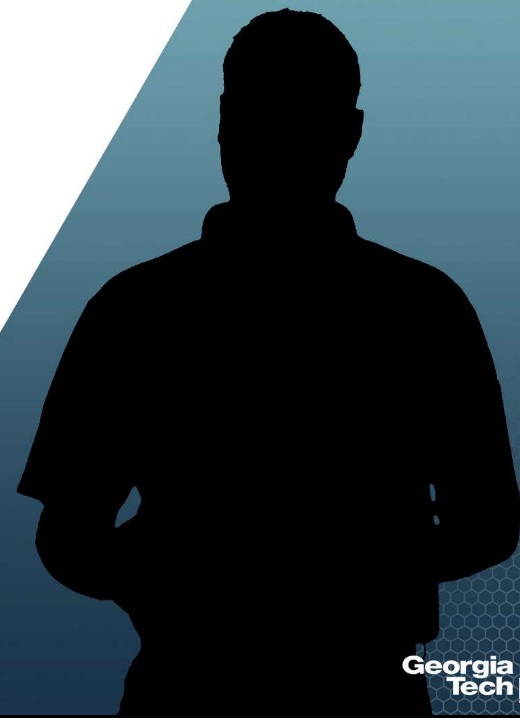
Learning Objectives

- Use simple moving average, weighted moving average and exponential smoothing to forecast a series of demand values
- Assess each method based on a variety of error values



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Example

Harrys Hardware has the following demand data for a new multipurpose hammer:

	Demand
1	289
2	296
3	354
4	287
5	301
6	281
7	294
8	318

Evaluate the following models:

1. SMA (2 period, 3 period, 4 period)
2. WMA (.5,.3,.2 and .7,.2.1)
3. ES (alpha =.9 and alpha=.2. for both take F_1=289)

Using these Error methods:

1. RSFE
2. MSE
3. MAD
4. TS

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Use Excel and when done, continue on..

- Next slide will have solutions!

	RSFE	MFE	MAD	TS
2 month SMA				
3 month SMA				
4 month SMA				
ES aplha=.9				
ES aplha=.2				
WMA (.5,.3,.2)				
WMA (.7,.2,.1)				

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Thoughts? Insights?

	RSFE	MFE	MAD	TS
2 month SMA	24.50	4.08	27.58	0.89
3 month SMA	-40.00	-8.00	20.13	-1.99
4 month SMA	-18.50	-4.63	18.25	-1.01
ES aplha=.9	29.43	4.20	27.16	1.08
ES aplha=.2	56.34	8.05	18.77	3.00
WMA (.5,.3,.2)	-38.60	-7.72	20.64	-1.87
WMA (.7,.2,.1)	-37.40	-7.48	21.20	-1.76

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Summary

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Business Fundamentals for Analytics

Supply Chain Management

Bob Myers

Lecturer
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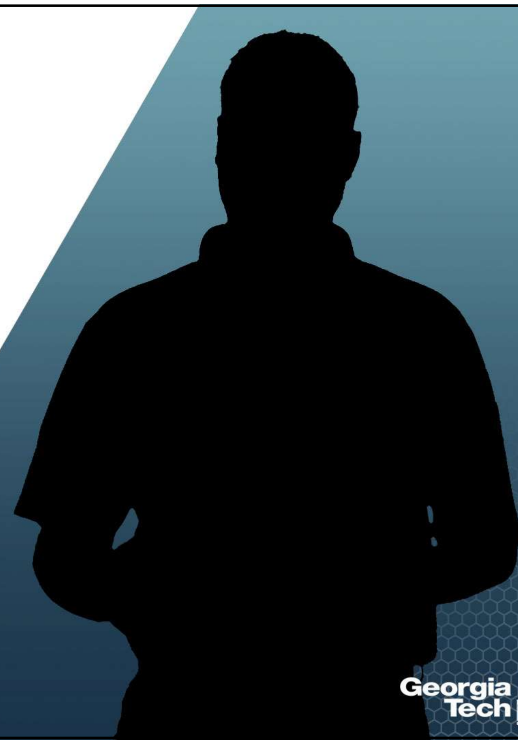
Trends



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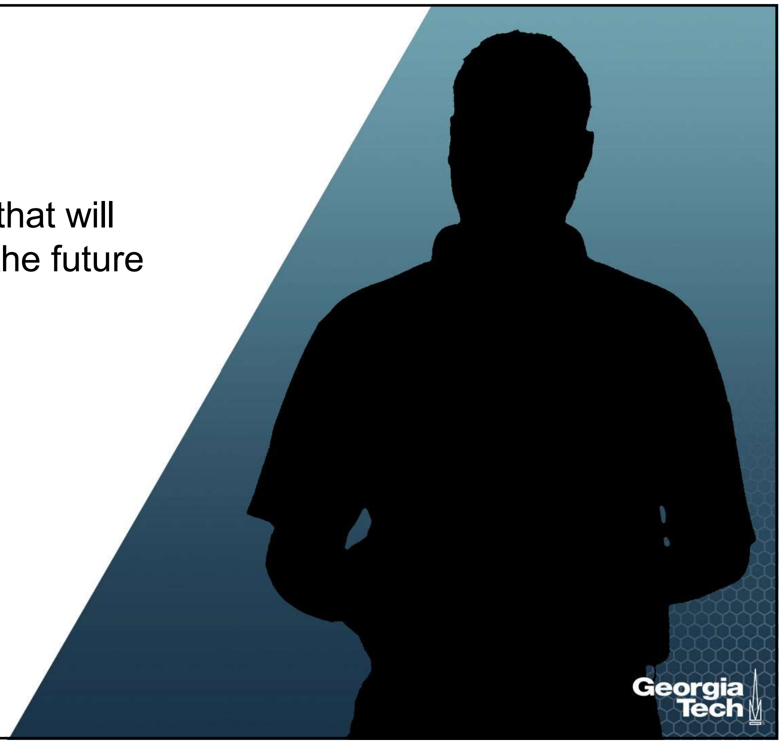
Learning Objectives

- Discuss technology trends that will impact the supply chain of the future



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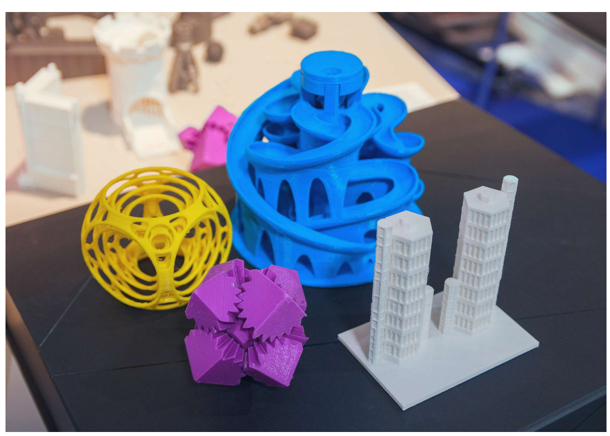
3D Printing



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Artificial Intelligence

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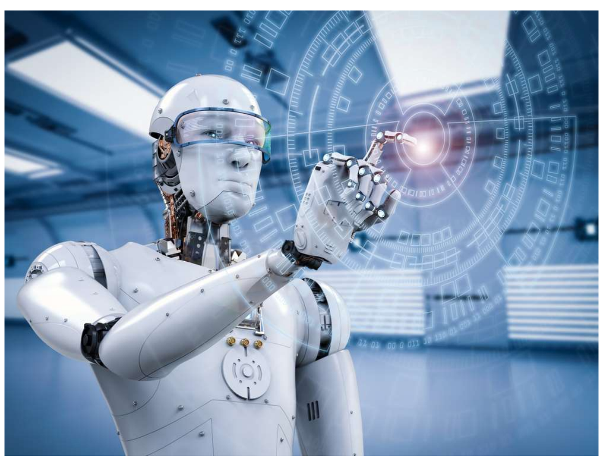
Robotics



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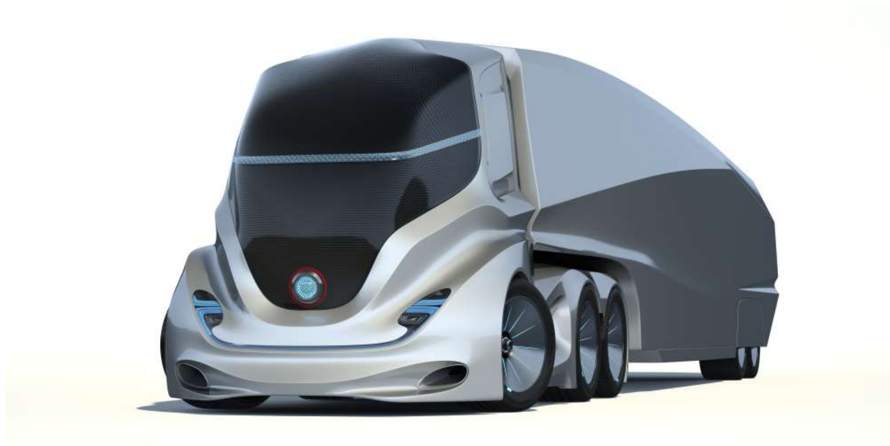
Autonomous Vehicles



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See Some Similarities?

- All of these have large amounts of data and calculations underlying them. Meaning the need for Analytics!

  These will fundamentally, radically change how companies do business.

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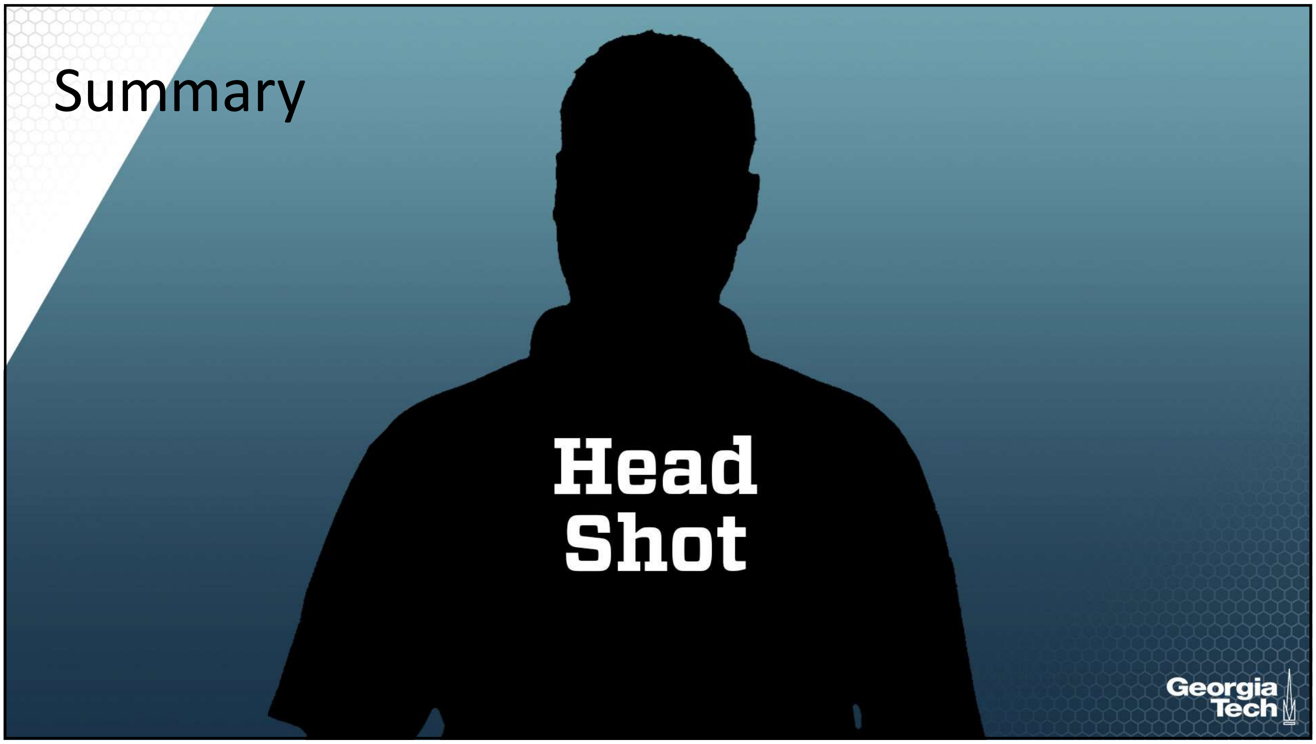
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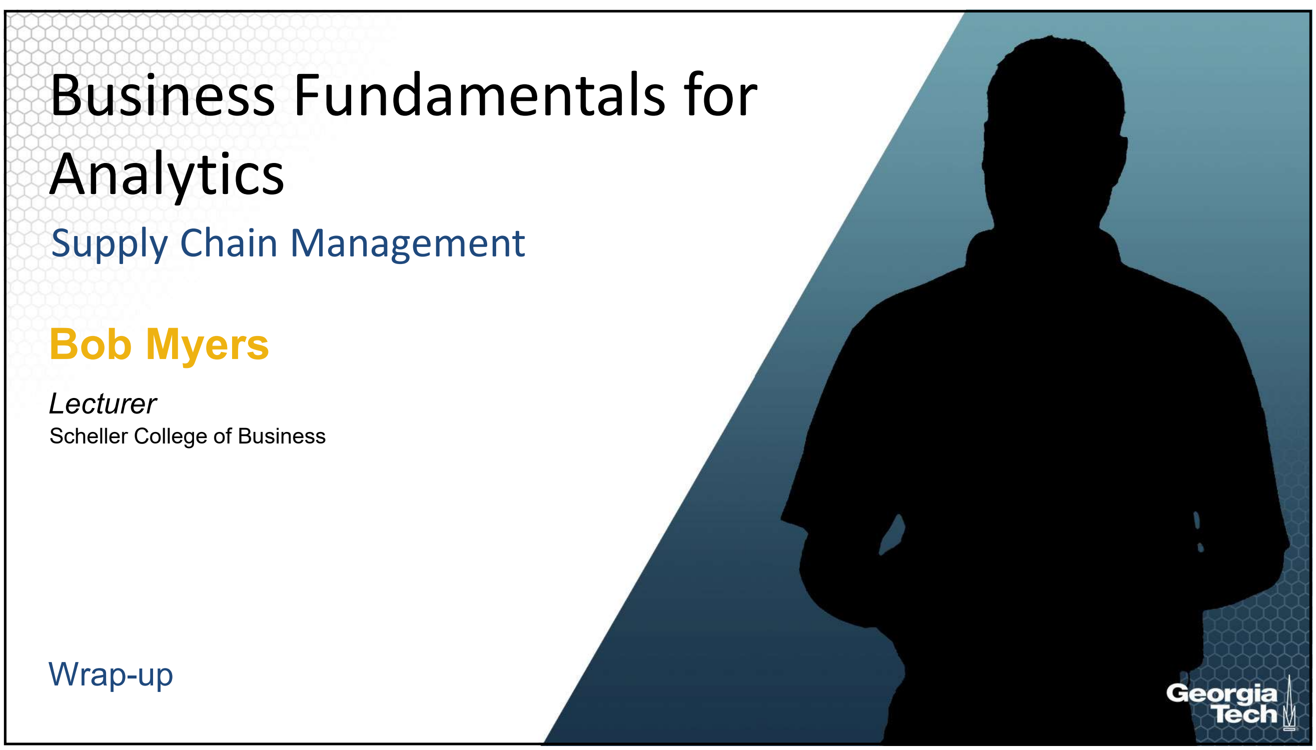
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Supply Chain Management
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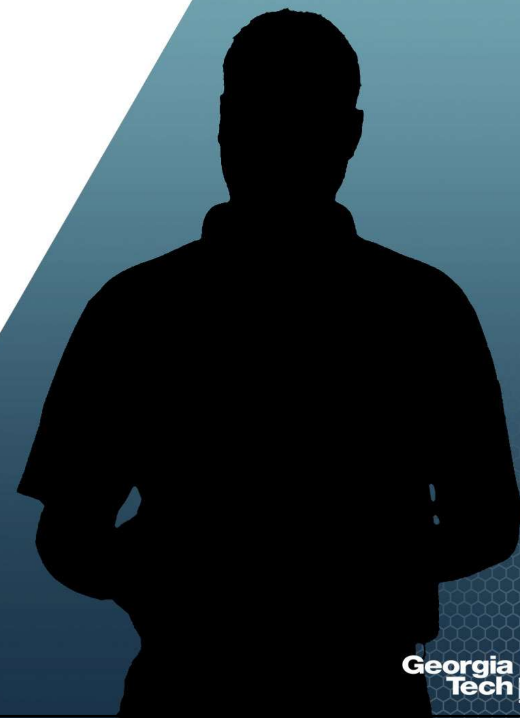
It is an Incredible Time for Operations and Supply Chain!

- Operations managers focus on how to **develop capabilities to design, produce, and deliver** products and services in a competitive market.
- Discipline going thru radical changes due to several maturing technologies.
- Data and Analytics will play a KEY role. Most new technology relies upon it.



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