Operations & Supply Planning
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Demand Forecasting

Vinay Kumar Kalakbandi
Assistant Professor
Operations Management

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Agenda

- Understanding Demand: nature and components
- Forecasting - motivation
- Forecasting techniques
  - Stationary series
  - Error measures
  - Trend
  - Seasonality
- Forecasting in the real world

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Opening question

What is the key role of an operations manager?

Making the right product/service available at the right place at the right time for the right customer at the right price

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Matching Supply with Demand

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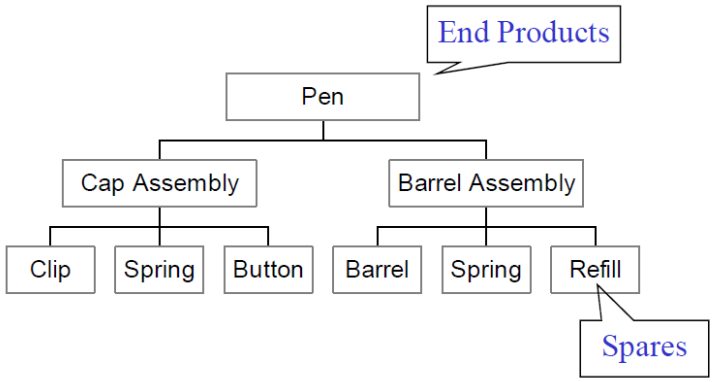
Independent – Dependent Demand



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Demand Management

- Not much a firm can do about dependent demand
  - It is demand that must be met
- There is a lot a firm can do about independent demand
  1. Take an active role to influence demand
  2. Take a passive role and respond to demand

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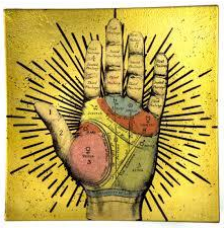
Understanding Independent demand!

Independent Demand – Nuances

- What are the characteristics of demand?
  - Demand is not the same as sales.
  - It's random and uncertain
  - Depends several factors
    - Time of the year
    - Economic environment
    - Weather
    - Price fluctuation – upward or downward
    - Sales Promotion
    - Other product demand

What Forecasting is not…



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What is Forecasting?

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What is forecasting?

Predicting the future based on past data!!

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Questions to ponder

- Why forecast?
  - It's expensive not to. Why?
- What to forecast?
  - Level of aggregation.
  - What use is a forecast to you?
- How to forecast?
  - What methodology are you going to follow?
  - What data do you need?

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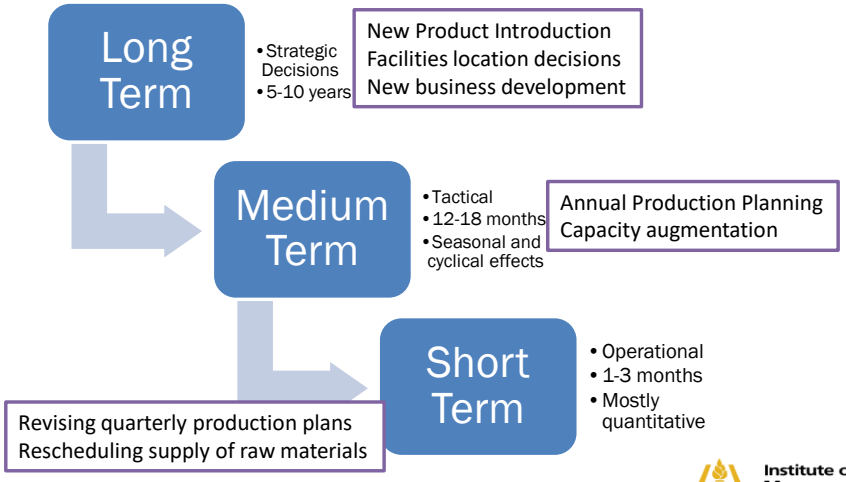
Forecasting time horizon



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Subjective Forecasts

- Sales force composites
  - Salesforce provides optimistic, pessimistic and most likely forecasts
- Jury of executive opinions
  - Top executives from different functional areas
- Customer surveys
  - Select a sample population of customers
- The Delphi method

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Subjective forecasts

- Form group of experts – anonymous
- Send questionnaires
- Collect and tabulate findings
- Redistribute and seek justification of outer quartiles
- Re-collect and tabulate findings
- Repeat until consensus is reached

Common biases in subjective forecasting

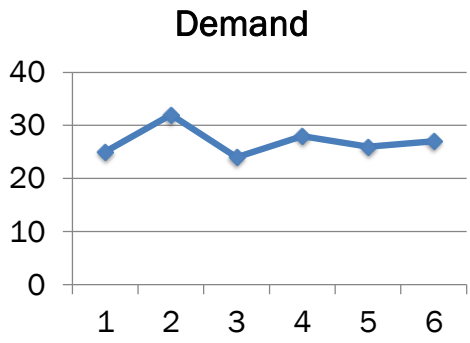
- Inconsistency
  - Applying different decision criteria in similar situations
- Conservatism; Recency
- Anchoring; Confirmation bias
- Uncertainty underestimation
- Reputation effect

Objective forecasting methods

- Extrapolative methods or time series models
  - Using past data of same metric to predict future
- Causal models
  - Using cause effect relationship

Demand for Diapers at a local store

- Month 1 – 25
- Month 2 – 32
- Month 3 – 24
- Month 4 – 28
- Month 5 – 26
- Month 6 – 27



How much should the store keep in stock for the next month?

Next month demand

- Average
- Average of last four periods
- Last period demand
- Weighted average of last five periods
- Up down up down
- Remove outliers, find average

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Components of Demand

1. Average demand for a period of time
2. Trend
3. Seasonal element
4. Cyclical elements
5. Random variation
6. Autocorrelation

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Notation Conventions

- Let A_1, A_2, . . . A_n, . . . be the past values of the series to be predicted (demands?). If we are making a forecast during period t (for the future), assume we have observed A_t , A_{t-1} etc.
  - Let $F_{t, t+\tau}$ = forecast made in period t for the demand in period t + τ where τ = 1, 2, 3, ...
  - Then $F_{t-1, t}$ is the forecast made in t-1 for t and
  - $F_{t, t+1}$ is the forecast made in t for t+1. (one step ahead) Use shorthand notation $F_t = F_{t-1, t}$

Simple averages

- The arithmetic average of the n most recent observations. For a one-step-ahead forecast:

$$F_t = (1/N)\,(A_{t-1} + A_{t-2} + \ldots + A_1)$$

Moving Averages

- The arithmetic average of the n most recent observations. For a one-step-ahead forecast:

$$F_t = (1/N)\,(A_{t-1} + A_{t-2} + \ldots + A_{t-n})$$

Summary of Moving Averages

- *Advantages of Moving Average Method*
  - Easily understood
  - Easily computed
  - Provides stable forecasts
- *Disadvantages of Moving Average Method*
  - Requires saving lots of past data points: at least the N periods used in the moving average computation
  - Lags behind a trend
  - Ignores complex relationships in data

What about Weighted Moving Averages?

- This method looks at past data and tries to logically attach importance to certain data over other data
- Weighting factors must add to one
- Can weight recent higher than older or specific data above others
  - If forecasting staffing, we could use data from the last four weeks where Tuesdays are to be forecast.
  - Weighting on Tuesdays is: T_{-1} is .25; T_{-2} is .20; T_{-3} is .15; T_{-4} is .10 and Average of all other days is weighed .30.

Exponential Smoothing Method

- A type of weighted moving average that applies declining weights to past data.

1. $F_t = \alpha (A_{t-1}) + (1 - \alpha)(F_{t-1})$

   Forecast = α (most recent demand) + (1- α) (last forecast)

   - OR -

2. $F_t = F_{t-1} + \alpha (A_{t-1} - F_{t-1})$

   Forecast = last forecast + α (last forecast error)

where $0 < \alpha < 1$ and generally is small for stability of forecasts (around .1 to .2)

Exponential Smoothing (cont.)

In symbols:

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

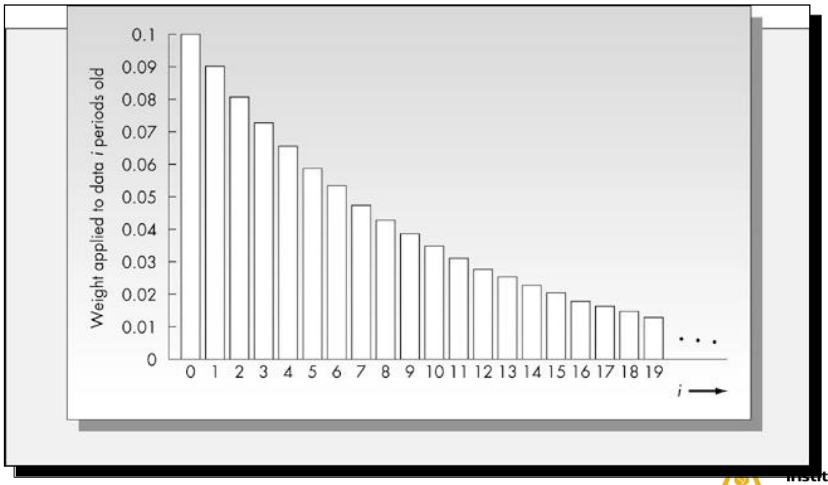
$= \alpha A_t + (1 - \alpha)(\alpha A_{t-1} + (1 - \alpha) F_{t-1})$

$= \alpha A_t + (1 - \alpha)(\alpha) A_{t-1} + (1 - \alpha)^2 (\alpha) A_{t-2} + \ldots$

- Hence the method applies a set of exponentially declining weights to past data. It is easy to show that the *sum of the weights* is exactly one.

$\{Or: F_{t+1} = F_t - \alpha (F_t - A_t)\}$

Weights in Exponential Smoothing:



Effect of seed forecast on the overall forecasting

- What should be the value of the forecast of the first period?
- Does it really matter which value is taken?

Effect of α value on the Forecast

- Small values of α means that the forecasted value will be stable (show low variability)
  - Low α increases the lag of the forecast to the actual data if a trend is present
- Large values of α mean that the forecast will more closely track the actual time series

Comparison of MA and ES

- Similarities
  - Both methods are appropriate for stationary series
  - Both methods depend on a single parameter
  - Both methods lag behind a trend

Comparison of MA and ES

- Differences
  - ES carries all past history (forever!)
  - MA eliminates "bad" data after N periods
  - MA requires all N past data points to compute new forecast estimate while ES only requires last forecast and last observation of 'demand' to continue

Accuracy of Forecasts

- Forecast error
  - $SFE = \sum_{i=1}^{t}(D_t - F_t)$
- Mean Absolute Deviation (MAD)
  - $MAD = \frac{1}{t} \times \sum_{i=1}^{t}|D_t - F_t|$
- Mean Absolute Percentage error (MAPE)
  - $MAPE = \frac{1}{t} \times \sum_{i=1}^{t}\frac{|D_t - F_t|}{D_t} \times 100$
- Mean Squared error
  - $MSE = \frac{1}{t} \times \sum_{i=1}^{t}(D_t - F_t)^2$

Tracking Signal

- The tracking signal (TS) is a measure that indicates whether the forecast average is keeping pace with any genuine upward or downward changes in demand
- Depending on the number of MAD's selected, the TS can be used like a quality control chart indicating when the model is generating too much error in its forecasts

$$TS = \frac{RSFE}{MAD} = \frac{\text{Running sum of forecast errors}}{\text{Mean absolute deviation}}$$