Operations & Supply Planning
PGDM 2018-20

Demand Forecasting

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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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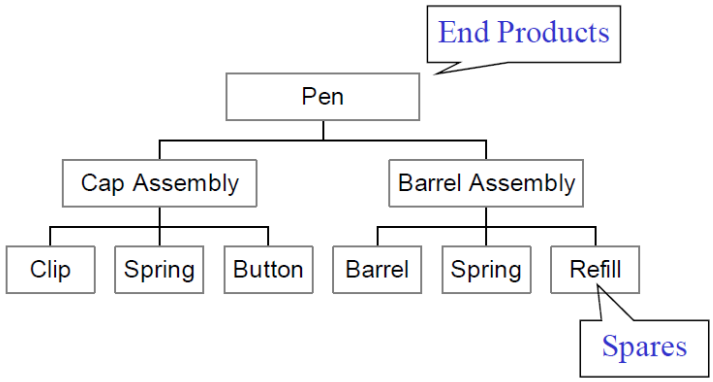
Independent – Dependent Demand



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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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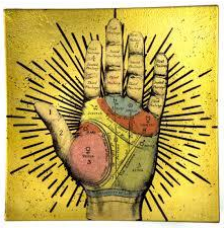
Understanding Independent demand!

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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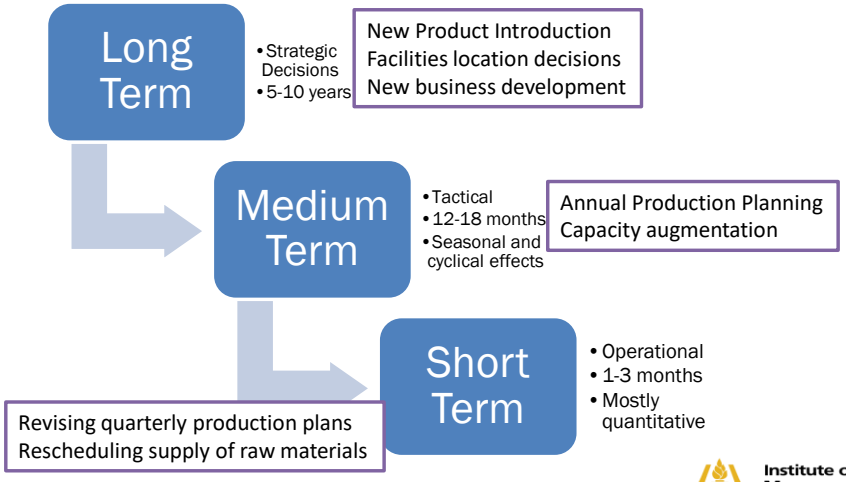
What is forecasting?

Predicting the future based on past data!!

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?

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

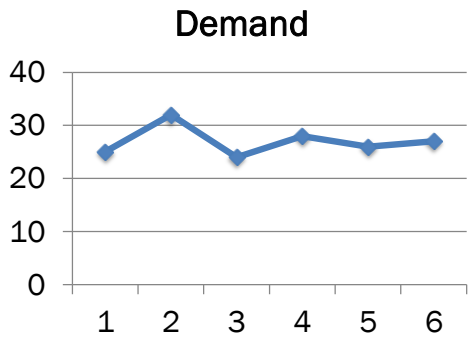
- Inconsistency
  - Applying different decision criteria in similar situations
- Conservatism; Recency
- Anchoring; Confirmation bias
- Uncertainty underestimation
- Reputation effect

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



What is the likely sale during month 7?

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:

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

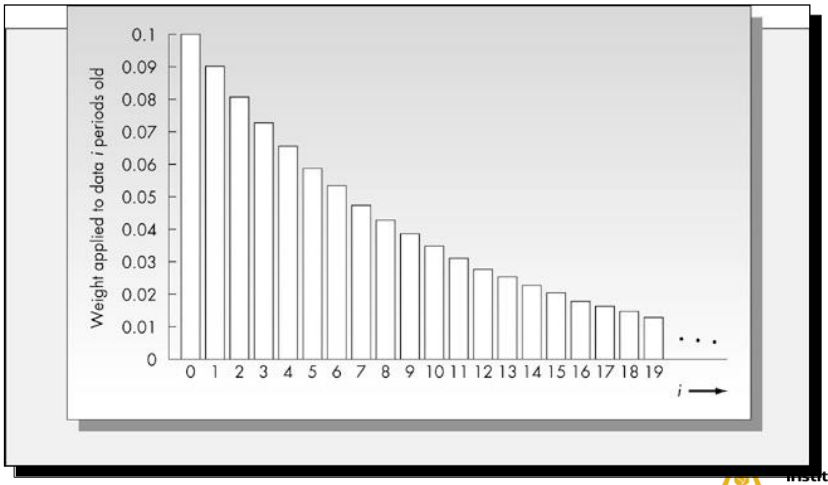
$= \alpha A_t + (1 - \alpha)(\alpha A_{t-1} + (1 - \alpha) F_{t-1})$

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

- 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

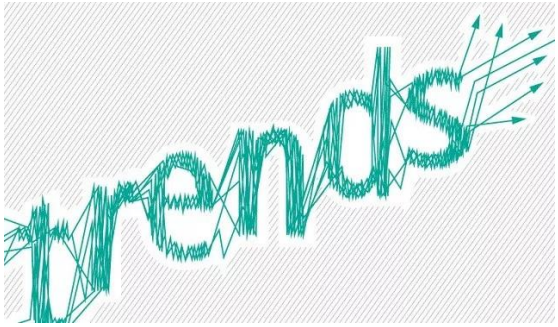
Accuracy of Forecasts

- 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

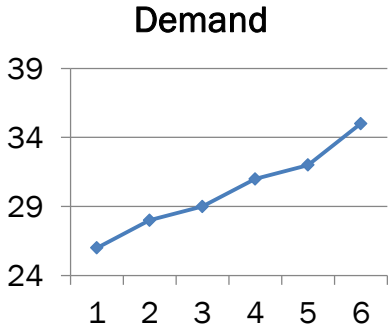
$$TS = \frac{RSFE}{MAD} = \frac{\text{Running sum of forecast errors}}{\text{Mean absolute deviation}}$$



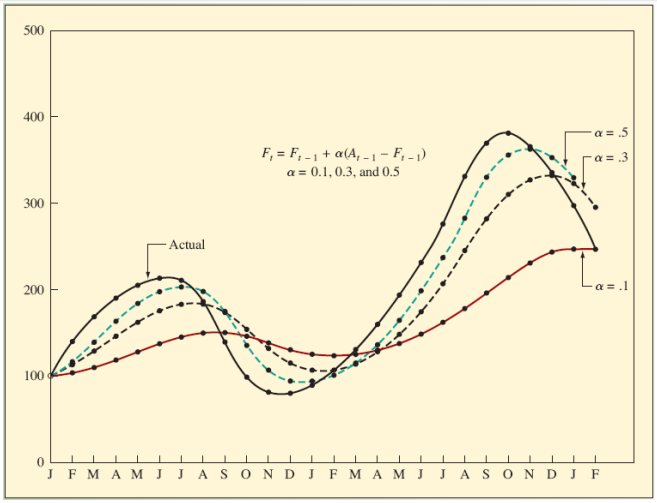
WHEN THERE IS A TREND

When there is a trend

- Period 1 – 26
- Period 2 - 28
- Period 3 - 29
- Period 4 - 31
- Period 5 - 32
- Period 6 - 35



Exponential Forecasts versus Actual Demand over Time Showing the Forecast Lag



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Trend Effects in Exponential Smoothing

- An trend in data causes the exponential forecast to always lag the actual data
- Can be corrected somewhat by adding in a trend adjustment
- To correct the trend, we need two smoothing constants
  - Smoothing constant alpha (α)
  - Trend smoothing constant delta (δ)

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Trend Effects Equations

$$\text{FIT}_t = F_t + T_t$$
$$F_t = FIT_{t-1} + \alpha(A_{t-1} - FIT_{t-1})$$
$$T_t = T_{t-1} + \delta(F_t - FIT_{t-1})$$

F_t = The exponentially smoothed forecast for period t

T_t = The exponentially smoothed trend for period t

FIT_t = The forecast including trend for period t

FIT_{t-1} = The forecast including trend made for the prior period

A_{t-1} = The actual demand for the prior period

α = Smoothing constant

δ = Smoothing constant

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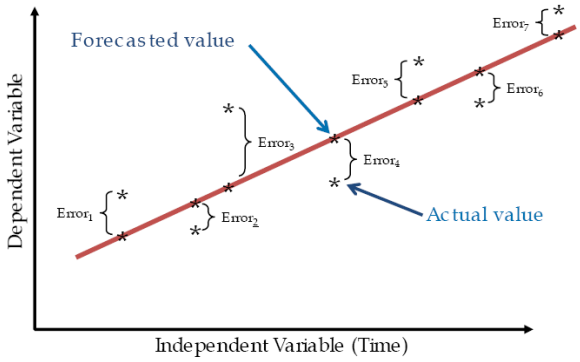
Linear Regression



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Estimating Trend

Method of Least Squares

- Treat the time periods as independent variable and the actual demand as dependant variable.
- Linear regression of the form Y = a + bX could be constructed to predict the demand Y for any value of X

X_i = Time periods
Y_i = Actual demand during period X_i
a = Intercept (at period 0)
b = Slope of the line
n = Number of periods

The coefficients of the regression equation are as follows:

$$b = \frac{\sum_i X_i Y_i - n\bar{X}\bar{Y}}{\sum_i X_i^2 - n\bar{X}^2} \qquad a = \bar{Y} - b\bar{X} \qquad \bar{X} = \frac{\sum X}{n} \qquad \bar{Y} = \frac{\sum Y}{n}$$

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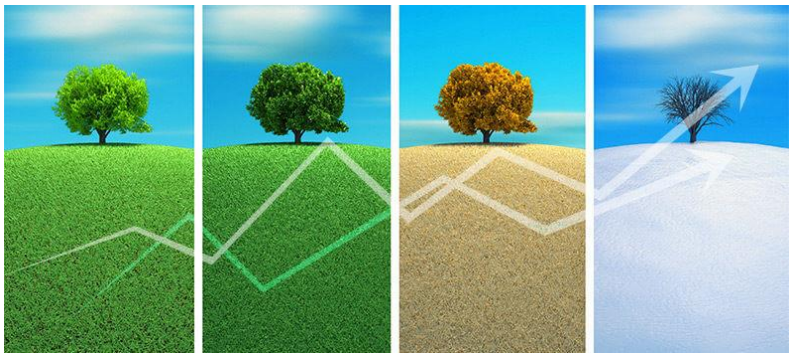

WHEN THERE IS SEASONALITY

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When there is seasonality

- Need to de-seasonalize data before using any standard forecasting techniques
  - Use average demand for entire series
  - Use average demand for same period across seasons
  - Use moving average based on length of season

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Extracting the components of Time Series

If A_i is the demand during a period *i* and

$\bar{D}_i$ is the average demand for the corresponding period

Then the seasonality index Si is given by: $S_i = \frac{D_i}{\bar{D}_i}$

Period	Actual Demand	4 Qtr Moving Average of Demand	Average Demand for period	Seasonality index
Year 1 - Q1	360			
Year 1 - Q2	438	390.75		
Year 1 - Q3	359	399.00	394.875	0.909
Year 1 - Q4	406	405.75	402.375	1.009
Year 2 - Q1	393	412.75	409.250	0.960
Year 2 - Q2	465	427.25	420.000	1.107
Year 2 - Q3	387	455.00	441.125	0.877
Year 2 - Q4	464	493.25	474.125	0.979
Year 3 - Q1	504	507.25	500.250	1.007
Year 3 - Q2	618	526.25	516.750	1.196
Year 3 - Q3	443			
Year 3 - Q4	540			

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Extracting the components of Time Series

Normalised Seasonality Indices

	Year 1	Year 2	Year 3	Average
Quarter 1		0.960	1.007	0.984
Quarter 2		1.107	1.196	1.152
Quarter 3	0.909	0.877		0.893
Quarter 4	1.009	0.979		0.994

Forecast adjusted for Trend & Seasonality

Forecast for Year 4 – Q1 = 0.984*(324.26 + 18.55*13) =536.01
Forecast for Year 4 – Q2 = 1.152*(324.26 + 18.55*14) =
Forecast for Year 4 – Q3 = 0.893*(324.26 + 18.55*15)=
Forecast for Year 4 – Q4 = 0.994*(324.26 + 18.55*16)=

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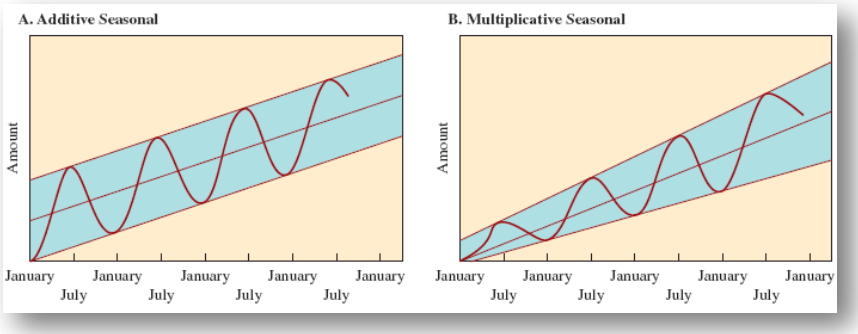
Patterns of demand with seasonality



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Winter's model

- How do we make this adaptive?
- A.k.a. Triple exponential smoothing
- Model could also be conceptualized to be additive or multiplicative (refer spreadsheet)
- Multiplicative
  - Forecast = (estimated level + estimated trend)*estimated seasonality

Winter's Model

$$\text{Revised Level} = L_{t+1} = \alpha\,(D_{t+1}/S_{t+1}) + (1-\alpha)(L_t + T_t)$$

$$\text{Revised Trend} = T_{t+1} = \beta(L_{t+1} - L_t) + (1-\beta)T_t$$

$$\text{Revised S. F} = S_{t+p+1} = \gamma(D_{t+1}/L_{t+1}) + (1-\gamma)S_{t+1}$$

Where,

- α = smoothing constant for level
- β = smoothing constant for trend
- γ = smoothing constant for seasonal factor

Practical considerations

Good forecasting practices

FORECASTING IN REAL LIFE

Characteristics of good forecasts

- Good forecasts
  - Would have to suggest specific actions
  - Would have to be better than a guess
- They are almost always wrong
  - And should always be coupled by an error measure

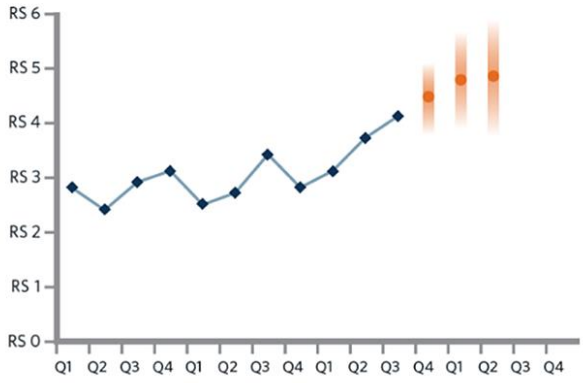
Characteristic of a good forecast

Note that in these figures the probability distribution of forecast values is symmetric. This isn't always the case.

Ways to reduce uncertainty of forecasts

- Collect more data
- When possible, do aggregate forecasts
  - Aggregate forecasts have lesser error than disaggregate forecasts
- Keep updating previous forecasts based on new information
  - Forecasts made farther out into the future are less accurate

Forecasts made farther out into the future are less accurate



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Steps for forecasting

1. Define the metric being forecast.
   - Make sure you have a clear definition
2. Collect data that matches your metric
   - Should be unbiased and complete
   - If info not available, use expert group opinions
3. Identify a suitable forecasting method and complete the forecast
   - Evaluate the precision based your estimated level of uncertainty

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Steps for forecasting

4. After a few weeks or months, evaluate the quality of the forecast by comparing it to actual values.
   - If necessary, adjust your method going forward.
5. Evaluate the usefulness of the forecast.
   - Did it influence management decisions in a valuable way?

Practical Considerations

- Forecasts are always wrong.
- Correct forecasts are not proof that the forecast method is correct.
- All trends eventually end.
- Complicated forecast methodologies can be dangerous.
- The underlying data in the forecast are nearly always wrong to some degree.

- Data that has not been regularly used is almost useless for forecasting
- Most forecasts are biased in some way -- usually accidentally.
- Technology will not make up for a bad forecasting strategy.
- Adding sophisticated technology to a bad model makes it worse.
- Large numbers are easier to forecast than small ones.

Forecasting is an exercise in projecting past into future – …like steering car by looking into rear view mirror!

THANK YOU

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