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DEPARTMENT OF MECHANICAL ENGINEERING

Forecasting

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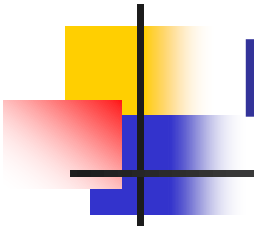
MECH IV – B.TECH (PRODUCTION PLANNING & CONTROL)

Decisions that Need Forecasts

- Which markets to pursue?
- What products to produce?
- How many people to hire?
- How many units to purchase?
- How many units to produce?
- And so on……

Common Characteristics of Forecasting



- Forecasts are rarely perfect
- Forecasts are more accurate for aggregated data than for individual items
- Forecast are more accurate for shorter than longer time periods

Forecasting Steps

- What needs to be forecast?
  - Level of detail, units of analysis & time horizon required
- What data is available to evaluate?
  - Identify needed data & whether it's available
- Select and test the forecasting model
  - Cost, ease of use & accuracy
- Generate the forecast
- Monitor forecast accuracy over time

Types of Forecasting Models

- Qualitative (technological) methods:
  - Forecasts generated subjectively by the forecaster
- Quantitative (statistical) methods:
  - Forecasts generated through mathematical modeling

Qualitative Methods

Type	Characteristics	Strengths	Weaknesses
Executive opinion	A group of managers meet & come up with a forecast	Good for strategic or new-product forecasting	One person's opinion can dominate the forecast
Market research	Uses surveys & interviews to identify customer preferences	Good determinant of customer preferences	It can be difficult to develop a good questionnaire
Delphi method	Seeks to develop a consensus among a group of experts	Excellent for forecasting long-term product demand, technological	Time consuming to develop

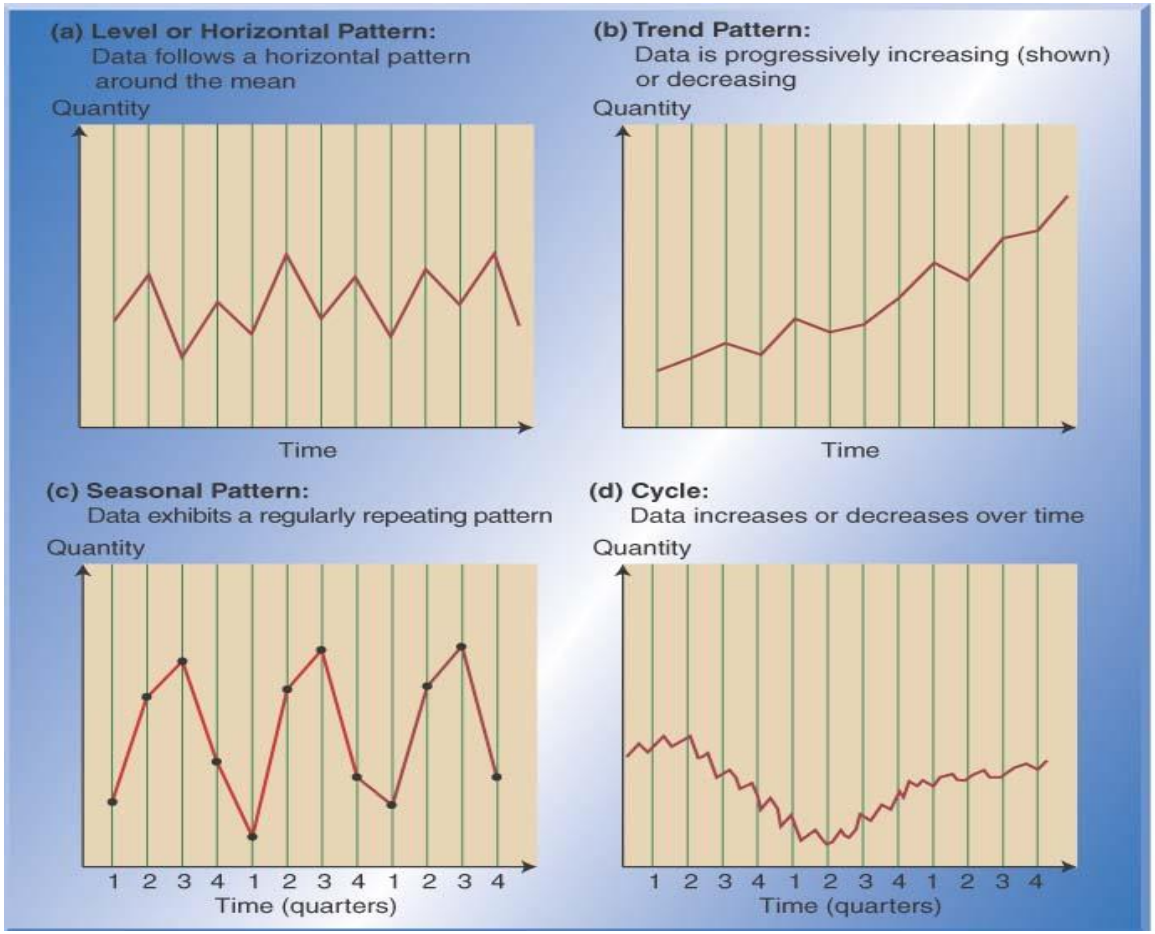
Statistical Forecasting

- **Time Series Models:**
  - Assumes the future will follow same patterns as the past
- **Causal Models:**
  - Explores cause-and-effect relationships
  - Uses leading indicators to predict the future
  - E.g. housing starts and appliance sales

Composition of Time Series Data

- Data = historic pattern + random variation
- Historic pattern may include:
  - Level (long-term average)
  - Trend
  - Seasonality
  - Cycle

Time Series Patterns



Methods of Forecasting the Level

- Naïve Forecasting
- Simple Mean
- Moving Average
- Weighted Moving Average
- Exponential Smoothing

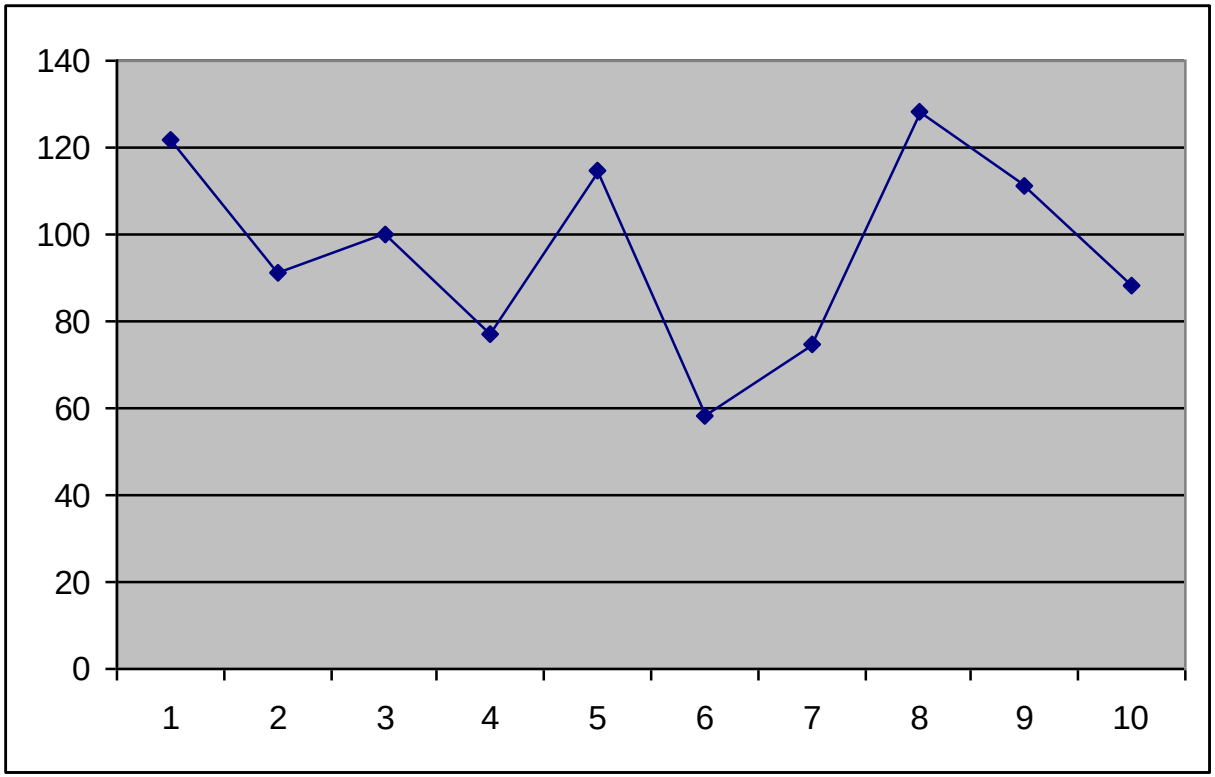
Time Series Problem

Determine forecast for periods 11

- **Naïve forecast**
- **Simple average**
- **3- and 5-period moving average**
- **3-period weighted moving average with weights 0.5, 0.3, and 0.2**
- **Exponential smoothing with alpha=0.2 and 0.5**

Period	Orders
1	122
2	91
3	100
4	77
5	115
6	58
7	75
8	128
9	111
10	88
11	

Time Chart of Orders Data



Naïve Forecasting

Next period forecast = Last Period's actual:

$$F_{t+1} = A_t$$

Simple Average (Mean)

Next period's forecast = average of all historical data

$$F_{t+1} = \frac{A_t + A_{t-1} + A_{t-2} + \ldots\ldots\ldots\ldots}{n}$$

Moving Average

Next period's forecast = simple average of the last N periods

$$F_{t+1} = \frac{A_t + A_{t-1} + \ldots\ldots\ldots + A_{t-N+1}}{N}$$

The Effect of the Parameter N

- A smaller N makes the forecast more

  responsive

- A larger N makes the forecast more

  stable

Weighted Moving Average

$$F_{t+1} = C_1 A_t + C_2 A_{t-1} + \ldots\ldots\ldots + C_N A_{t-N+1}$$

where

$$C_1 + C_2 + \ldots\ldots\ldots C_N = 1$$

Exponential Smoothing

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

where

$$0 \le \alpha \le 1$$

The Effect of the Parameter α

- A smaller α makes the forecast more

  stable

- A larger α makes the forecast more

  responsive

Time Series Problem Solution

				Simple	Simple	Weighted	Exponential	Exponential
		Naïve	Simple	Moving	Moving	Moving	Smoothing	Smoothing
Period	Orders (A)	Forecast	Average	Average (N=3)	Average(N=5)	Average (N=3)	(α = 0.2)	(α = 0.5)
1	122						122	122
2	91	122	122				122	122
3	100	91	107				116	107
4	77	100	104	104		102	113	104
5	115	77	98	89		87	106	91
6	58	115	101	97	101	101	108	103
7	75	58	94	83	88	79	98	81
8	128	75	91	83	85	78	93	78
9	111	128	96	87	91	98	100	103
10	88	111	97	105	97	109	102	107
11		88	97	109	92	103	99	98

Forecast Accuracy

- Forecasts are rarely perfect
- Need to know how much we should rely on our chosen forecasting method
- Measuring forecast error:

$$E_t = A_t - F_t$$

- Note that over-forecasts = negative errors and under-forecasts = positive errors

Tracking Forecast Error Over Time

- Mean Absolute Deviation (MAD):
  - A good measure of the actual error in a forecast

$$MAD = \frac{\sum |actual - forecast|}{n}$$

- Mean Square Error (MSE):
  - Penalizes extreme errors

$$MSE = \frac{\sum (\text{actual - forecast})^2}{n}$$

- Tracking Signal
  - Exposes bias (positive or negative)

$$TS = \frac{\sum (\text{actual - forecast})}{MAD}$$

Accuracy & Tracking Signal Problem: A company is comparing the accuracy of two forecasting methods. Forecasts using both methods are shown below along with the actual values for January through May. The company also uses a tracking signal with ±4 limits to decide when a forecast should be reviewed. Which forecasting method is best?

Month	Actual sales	Method A				Method B			
		F'cast	Error	Cum. Error	Tracking Signal	F'cast	Error	Cum. Error	Tracking Signal
Jan.	**30**	**28**	**2**	**2**	**2**	**28**	**2**	**2**	**1**
Feb.	**26**	**25**	**1**	**3**	**3**	**25**	**1**	**3**	**1.5**
March	**32**	**32**	**0**	**3**	**3**	**29**	**3**	**6**	**3**
April	**29**	**30**	**-1**	**2**	**2**	**27**	**2**	**8**	**4**
May	**31**	**30**	**1**	**3**	**3**	**29**	**2**	**10**	**5**
MAD			**1**				**2**		
MSE			**1.4**				**4.4**		

Forecasting Trends

- Trend-adjusted exponential smoothing
- Three step process:
  - Smooth the level of the series:

$$S_t = \alpha A_t + (1-\alpha)(S_{t-1} + T_{t-1})$$

  - Smooth the trend:

$$T_t = \beta(S_t - S_{t-1}) + (1+\beta)T_{t-1}$$

  - Calculate the forecast including trend:

$$FIT_{t+1} = S_t + T_t$$

Forecasting trend problem: a company uses exponential smoothing with trend to forecast usage of its lawn care products. At the end of July the company wishes to forecast sales for August. July demand was 62. The trend through June has been 15 additional gallons of product sold per month. Average sales have been 57 gallons per month. The company uses alpha+0.2 and beta +0.10. Forecast for August.

- **Smooth the level of the series:**

$$S_{July} = \alpha A_t + (1-\alpha)(S_{t-1} + T_{t-1}) = (0.2)(62) + (0.8)(57+15) = 70$$

- **Smooth the trend:**

$$T_{July} = \beta(S_t - S_{t-1}) + (1-\beta)T_{t-1} = (0.1)(70-57) + (0.9)(15) = 14.8$$

- **Forecast including trend:**

$$FIT_{August} = S_t + T_t = 70 + 14.8 = 84.8 \text{ gallons}$$

Adjusting for Seasonality

- Calculate the average demand per season
  - *E.g.:* average quarterly demand
- Calculate a seasonal index for each season of each year:
  - Divide the actual demand of each season by the average demand per season for that year
- Average the indexes by season
  - *E.g.*: take the average of all Spring indexes, then of all Summer indexes, ...

Adjusting for Seasonality

- Forecast demand for the next year & divide by the number of seasons
  - Use regular forecasting method & divide by four for average quarterly demand
- Multiply next year's average seasonal demand by each average seasonal index
  - Result is a forecast of demand for each season of next year

Seasonality problem: a university wants to develop forecasts for the next year's quarterly enrollments. It has collected quarterly enrollments for the past two years. It has also forecast total enrollment for next year to be 90,000 students. What is the forecast for each quarter of next year?

Quarter	Year 1	Seasonal Index	Year 2	Seasonal Index	Avg. Index	Year3
Fall	24000		26000			
Winter	23000		22000			
Spring	19000		19000			
Summer	14000		17000			
Total						90000
Average						

Seasonality Problem: Solution

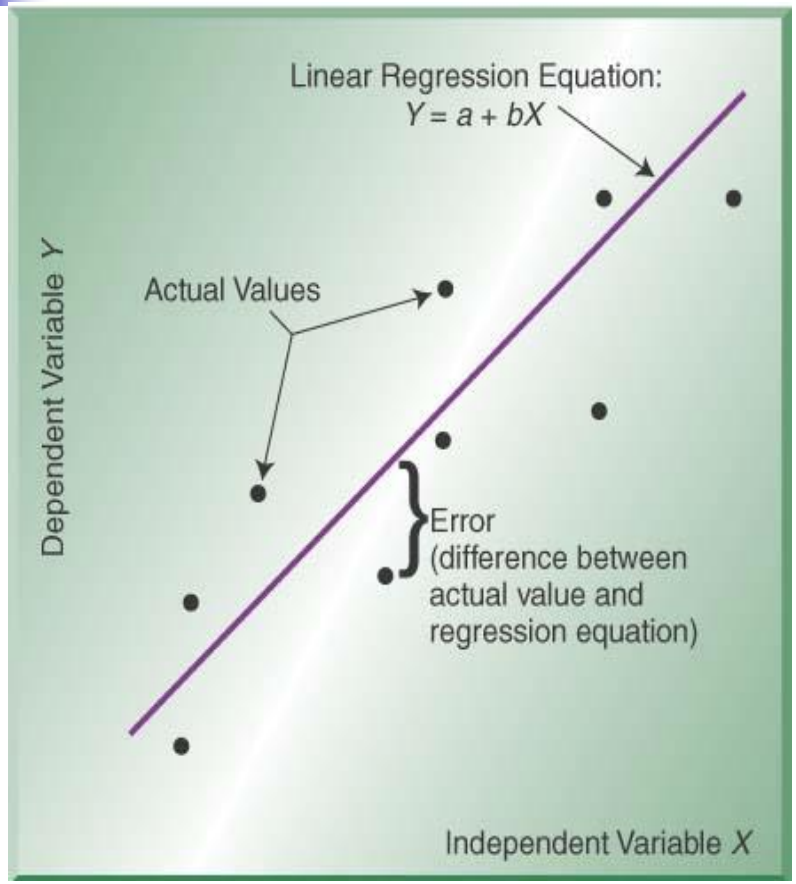
Quarter	Year 1	Seasonal Index	Year 2	Seasonal Index	Avg. Index	Year3
Fall	24000	**1.20**	26000	**1.24**	**1.22**	**27450**
Winter	23000	**1.15**	22000	**1.05**	**1.10**	**24750**
Spring	19000	**0.95**	19000	**0.90**	**0.93**	**20925**
Summer	14000	**0.70**	17000	**0.81**	**0.76**	**17100**
Total	80000	**4.00**	84000	**4.00**	**4.01**	90000
Average	**20000**		**21000**			**22500**

Casual Models

- Often, leading indicators hint can help predict changes in demand
- Causal models build on these cause-and-effect relationships
- A common tool of causal modeling is linear regression:

$$Y = a + bx$$

Linear Regression



- Identify dependent **(y)** and independent **(x)** variables
- Solve for the slope of the line

$$\mathbf{b} = \frac{\sum \mathbf{XY} - \mathbf{n}\overline{\mathbf{X}}\,\overline{\mathbf{Y}}}{\sum \mathbf{X}^2 - \mathbf{n}\overline{\mathbf{X}}^2}$$

- Solve for the y intercept

$$\mathbf{a} = \overline{\mathbf{Y}} - \mathbf{b}\overline{\mathbf{X}}$$

- Develop your equation for the trend line

Y=a + bX

Linear Regression Problem: A maker of golf shirts has been tracking the relationship between sales and advertising dollars. Use linear regression to find out what sales might be if the company invested $53,000 in advertising next year.

	Sales $ (Y)	Adv.$ (X)	XY	X^2	Y^2
1	130	48	4240	2304	16,900
2	151	52	7852	2704	22,801
3	150	50	7500	2500	22,500
4	158	55	8690	3025	24964
5	**153.85**	53			
Tot	589	205	30282	10533	87165
Avg	**147.25**	**51.25**			

$$\mathbf{b} = \frac{\sum \mathbf{XY} - \mathbf{n}\overline{\mathbf{X}}\,\overline{\mathbf{Y}}}{\sum \mathbf{X}^2 - \mathbf{n}\overline{\mathbf{X}}^2}$$

$$b = \frac{30282 - 4(51.25)(147.25)}{10533 - 4(51.25)^2} = 3.58$$

$$a = \overline{Y} - b\overline{X} = 147.25 - 3.58(51.25)$$

$$a = -36.20$$

$$Y = a + bX = -36.20 + 3.58x$$

$$Y_5 = -36.20 + 3.58(53) = 153.54$$

How Good is the Fit?

- Correlation coefficient **(r)** measures the direction and strength of the linear relationship between two variables. The closer the r value is to 1.0 the better the regression line fits the data points.

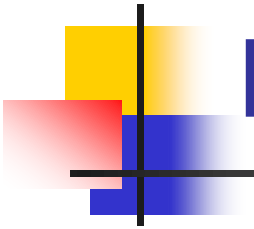
$$r = \frac{n\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{n\left(\sum X^2\right) - \left(\sum X\right)^2} * \sqrt{n\left(\sum Y^2\right) - \sum (Y)^2}}$$

$$r = \frac{(4)(30{,}282) - (205)(589)}{\sqrt{4(10{,}533) - (205)^2} * \sqrt{4(87{,}165) - (589)^2}} = .888$$

$$r^2 = (.982)^2 = .788$$

- Coefficient of determination (r^2) measures the amount of variation in the dependent variable about its mean that is explained by the regression line. Values of (r^2) close to 1.0 are desirable.

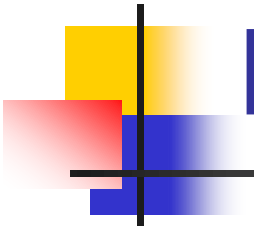
Factors for Selecting a Forecasting Model



- The amount & type of available data
- Degree of accuracy required
- Length of forecast horizon
- Presence of data patterns

Forecasting Software

- Spreadsheets
  - Microsoft Excel, Quattro Pro, Lotus 1-2-3
  - Limited statistical analysis of forecast data
- Statistical packages
  - SPSS, SAS, NCSS, Minitab
  - Forecasting plus statistical and graphics
- Specialty forecasting packages
  - Forecast Master, Forecast Pro, Autobox, SCA



Homework

Ch. 8 Problems: 2, 3, 5, 8, 9, 14, 16, 17, 18.