Chapter 8 Forecasting Demand

- Qualitative Forecasting Methods
- Moving Averages and Smoothing
- Trend and Seasonal Factors


What is a Forecast?

A prediction of future events used for planning purposes.

- 國外推出新一代的產品，該不該爭取代理進口？
- 景氣逐漸轉好，何時該擴充產量？
- 下週有促銷活動，各分店各種款式應準備多少庫存？

Forecasts are critical inputs to business plans, annual plans, and budgets and affect decisions and activities throughout an organization:

Accounting, Finance, Human resources, Marketing, MIS, Operations, Product/service design, Customer service

Demand Patterns

noise

trend+noise

season+noise — Year 1, Year 2

cycle

PX mart
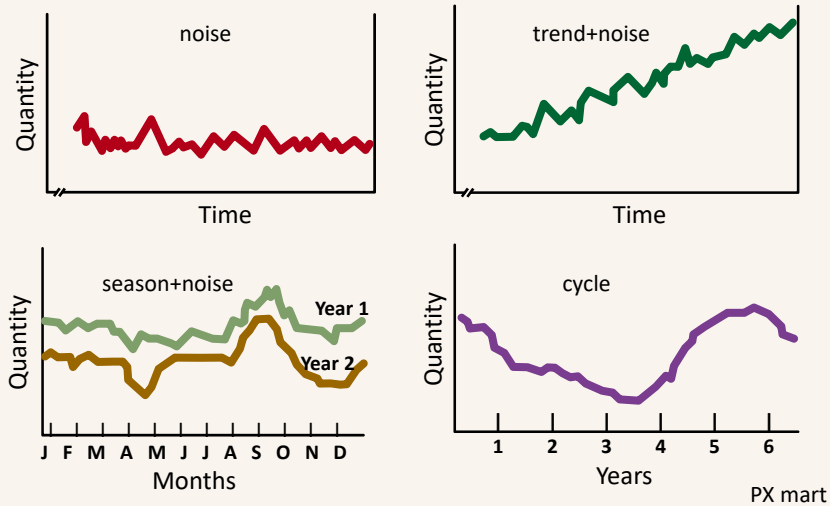
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Demand Management Options

- The process of changing demand patterns using one or more demand options 主動影響市場需求
  - Complementary Products
  - Promotional Pricing
  - Revenue Management
  - Prescheduled Appointments
  - Reservations
  - Backlogs
  - Backorders and Stockouts

supply   demand
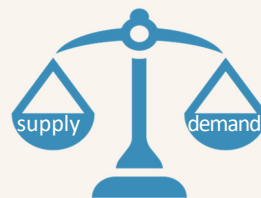
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Key Decisions on Making Forecasts

- Deciding What to Forecast
  - Level of aggregation: clustering several similar services or products so that forecasts are more accurate.
- Choosing the Type of Forecasting Technique
  - Judgment methods, Causal methods, Time-series analysis

Rules of Forecasting

- Forecasts are not perfect. 預測永遠是錯誤的
- Forecasts for groups of items tend to be more accurate 整體預測較準確
- Forecast accuracy decreases as the time horizon increases. 越久遠的預測越不準確

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Judgment (Qualitative) Methods

- Forecasts based on contextual knowledge gained through experience.
  - Salesforce estimates
  - Executive opinion
  - Market research
  - Delphi method

Strengths
- 可針對缺乏市場數據的新產品進行預測
- 可加入無法量化的資訊

Weaknesses
- 需要良好的問卷設計與調查方式
- 意見可能偏頗、分歧、或受到不當影響

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Forecast Error

- It is important to measure and monitor the accuracy of forecasts.
- Forecast error for a given period: $E_t = D_t - F_t$

F_t = forecast for period t, D_t = actual demand in period t

Mean **A**bsolute **D**eviation = $\dfrac{\sum\limits_{t=1}^{n}\left|D_t - F_t\right|}{n}$

Mean **A**bsolute **P**ercentage **E**rror = $\dfrac{\sum\limits_{t=1}^{n}\left|D_t - F_t\right|/D_t}{n} \times 100\%$

Causal Forecasting (using Linear Regression)

估計可事先觀察的因素對於需求或銷售的影響程度

$(x_1, …, x_n)$ $\qquad$ $(y_1, …, y_n)$

可事先觀察的數值
如房地產銷售

要預測的數值
如家電銷售

假設兩者的因果關係為線性變化 $\Rightarrow Y = a + b \cdot X$

影響程度(斜率)

$b = \dfrac{\sum\limits_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{\sum\limits_{i=1}^{n} x_i^{\,2} - n\bar{x}^2}$ $\qquad a = \bar{y} - b\bar{x}$

Linear Regression

Regression equation:
$$Y = a + b \cdot X$$

Forecast error

Forecast of y from regression equation

Actual Value of y

Value of x used to forecast y

Dependent variable

Independent variable
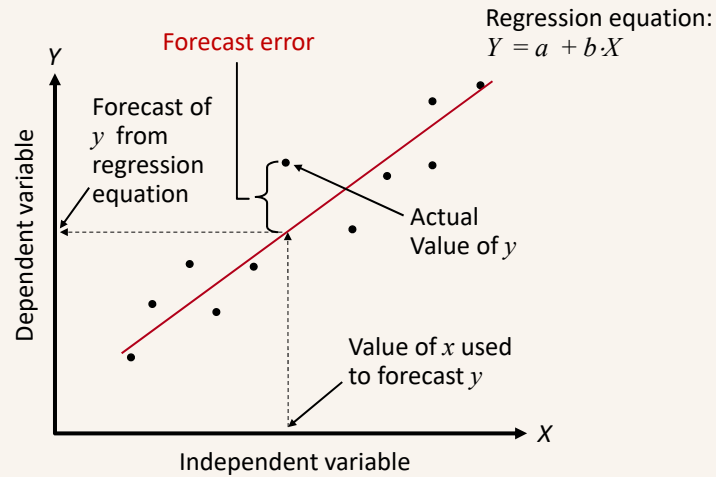
Example 8.2

A manager seeks to forecast the demand for door hinges and believes that the demand is related to advertising expenditures.

Month	Sales (thousands of units)	Advertising (thousands of $)
1	264	2.5
2	116	1.3
3	165	1.4
4	101	1.0
5	209	2.0

The company will spend $1,750 next month on advertising for the product. Use causal method to develop a forecast for this product.

Example 8.2

$$b = \frac{1560.8 - 5 \cdot 1.64 \cdot 171}{14.9 - 5 \cdot (1.64)^2} = 109.229$$

$$a = -8.135$$
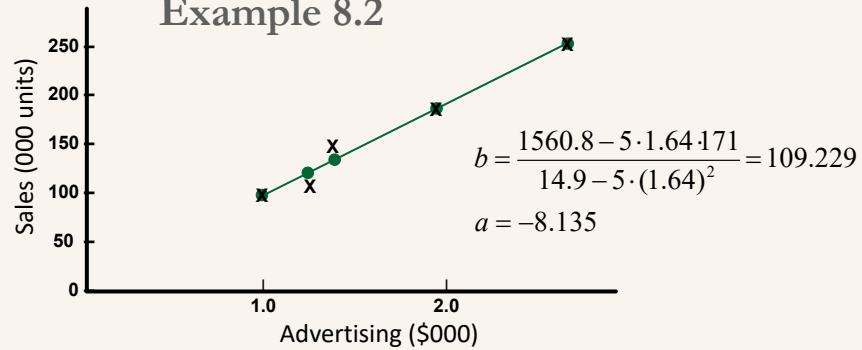
$Y = -8.135 + 109.229X$

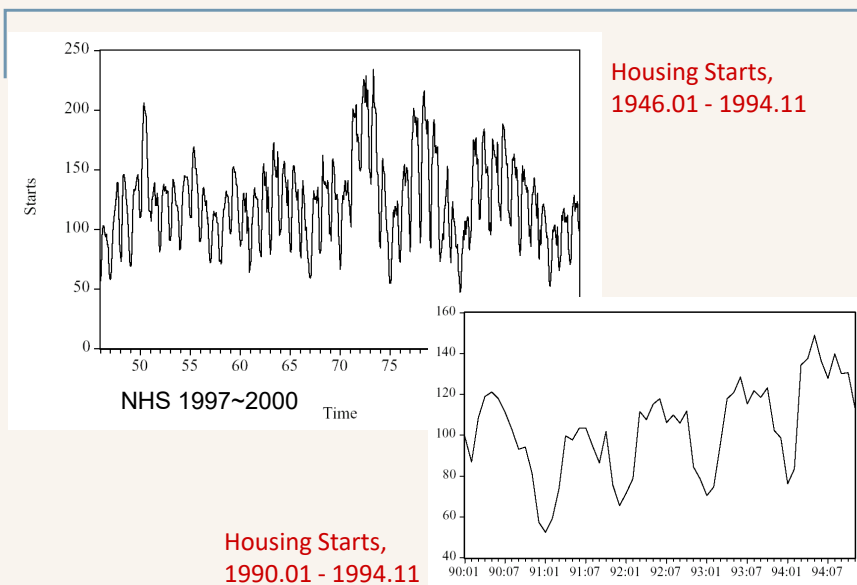Forecast for next month : $Y = -8.135 + 109.229(1.75) = 183.016$

Time Series Forecasting

These methods assume that the past demand pattern will continue in the future. 過去的銷售變化型態會持續到未來

Time-series analysis identifies underlying patterns of demand that combine to a model to forecast future demands.

Housing Starts,
1946.01 - 1994.11

NHS 1997~2000

Housing Starts,
1990.01 - 1994.11
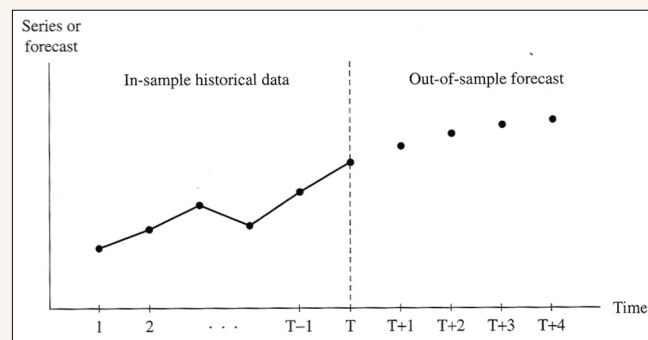
Naïve Forecast

The forecast for the next period equals the demand for the current period.

- Stable time series data
  $F(t+1) = D(t)$

- Seasonal variations
  $F(t+1) = D(t+1-n)$

- Data with trends
  $F(t+1) = D(t) + (D(t) − D(t-1))$ 外插法

Works best when the horizontal, trend, or seasonal patterns are stable and random variation is small.
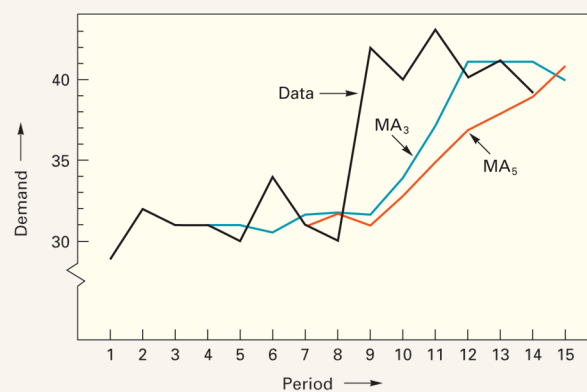
Horizontal Patterns: Simple Moving Averages

$$F_{t+1} = \frac{\text{Sum of last } n \text{ demands}}{n} = \frac{D_t + D_{t-1} + D_{t-2} + \ldots + D_{t-n+1}}{n}$$

Example 8.3

Week	Patient Arrivals
1	400
2	380
3	411

a. Compute a three-week moving average forecast for week 4.

c. If the actual number of patient arrivals in week 4 is 415, what is the forecast for week 5?

Large values of n should be used for demand series that are stable, and small values of n should be used for those that are susceptible to changes in the underlying average.

Horizontal Patterns: Weighted Moving Averages

Assumption: 近期的數據有較高的參考價值

$$F_{t+1} = W_1 D_t + W_2 D_{t-1} + \ldots + W_n D_{t-n+1}$$

$$\Sigma W_i = 1 \quad W_1 > W_2 > \ldots > W_n$$

Example 3:

Week	Patient Arrivals
1	400
2	380
3	411

$F_t = 0.5\ D_{t-1} + 0.3\ D_{t-2} + 0.2\ D_{t-3}$

$\Rightarrow F_4 = 0.50(411) + 0.30(380) + 0.20(400)$

$= 399.5$

$W_1 = 0.5,\ W_2 = 0.3,\ W_3 = 0.2$

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Horizontal Patterns: Exponential Smoothing

- A sophisticated weighted moving average that calculates the average of a time series by implicitly giving recent demands more weight than earlier demands 由複雜的加權平均演化而成
- Requires only three items of data
  - The last period's forecast
  - The demand for the last period
  - A smoothing parameter, alpha (α), where $0 \leq \alpha \leq 1.0$

$F_{t+1} = \alpha$ (Demand this period) $+ (1-\alpha)$(Forecast calculated last period)

$\quad = \alpha D_t + (1 - \alpha)F_t = F_t + \alpha\ (\ D_t - F_t\ )$

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Example 8.4

Week	Patient Arrivals
1	400
2	380
3	411

Calculate the exponential smoothing forecast (α = 0.10) for week 4.

Assume $F_3 = (D_1 + D_2)/2 = 390$

$$F_4 = \alpha D_3 + (1 - \alpha)F_3 = 0.10(411) + 0.90(390) = 392.1$$

If the actual demand for week 4 turned out to be 415,
what is the forecast for week 5?

$$F_5 = 0.10(415) + 0.90(392.1) = 394.4$$
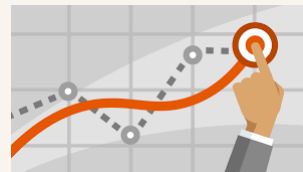
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Using Exponential Smoothing

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

Approaches to obtain an initial forecast

F_1=前一期的銷售量

F_1=先前幾期的平均銷售量

F_1=a subjective estimate

smoothing constant α

- Larger α values emphasize recent levels of demand and result in forecasts more responsive to changes in the underlying average.
- Smaller α values treat past demand more uniformly and result in more stable forecasts.

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Trend Patterns using Linear Regression

A *trend* in a time series is a systematic increase or decrease in the average of the series over time.

Indep. variable X (time) $\Rightarrow$ dependent variable Y (demand)

Regression估計市場需求(Y)隨著時間(X)演進的線性關係

$$Y = a + b \cdot X$$

該期的產品
需求預測

要預測之未來
的時期編號

趨勢(斜率)

$$b = \frac{\sum_{i=1}^{n} x_i y_i - n\overline{x}\,\overline{y}}{\sum_{i=1}^{n} x_i^2 - n\overline{x}^2} \qquad a = \overline{y} - b\overline{x}$$

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Example 8.5 Arrivals at Medanalysis

Week	Arrivals	Week	Arrivals
1	28	9	61
2	27	10	39
3	44	11	55
4	37	12	54
5	35	13	52
6	53	14	60
7	38	15	60
8	57	16	75

What is the forecasted demand for the next three periods?

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Seasonal Patterns: Using Seasonal Factors

Seasonal patterns are regularly repeating upward or downward movements in demand measured in periods of less than one year (hours, days, weeks, months, or quarters).

Additive seasonal method
  Add a constant to the estimate of average demand per season.

Multiplicative seasonal method
  Seasonal factors are multiplied by an estimate of average demand

Additive model
Demand = Trend + Seasonality

Multiplicative model
Demand = Trend × Seasonality

Time
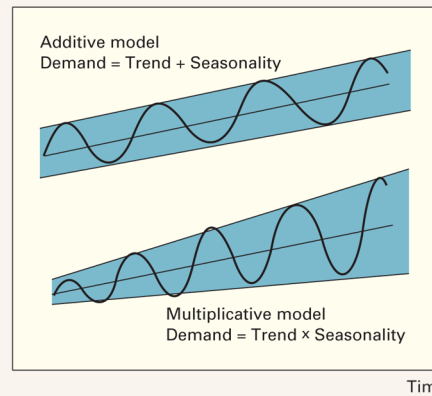
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Multiplicative Seasonal Method

1. For each year, calculate the average demand for each season by dividing annual demand by the number of seasons per year.
2. For each year, divide the actual demand for each season by the average demand per season, resulting in a seasonal factor for each season.
3. Calculate the average seasonal factor for each season using the results from Step 2.
4. Calculate each season's forecast for next year.

第1季	第2季	第3季	第4季
200	350	300	150
0.8	1.4	1.2	0.6

設次年的全年
預測=1100

第1季	275×0.8=220
第2季	275×1.4=385
第3季	275×1.2=330
第4季	275×0.6=165

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Example 8.6

The carpet cleaning business is seasonal, with a peak in the third quarter and a trough in the first quarter.

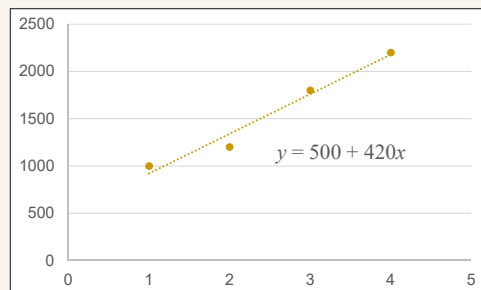|	YEAR 1	YEAR 2	YEAR 3	YEAR 4
Q1	45	70	100	100
Q2	335	370	585	725
Q3	520	590	830	1160
Q4	100	170	285	215
Total	1,000	1,200	1,800	2,200

The manager wants to forecast demand for each quarter of year 5.

Example 8.6

使用其他預測方法對全年的總需求進行預測

Year	Total Demand
1	1000
2	1200
3	1800
4	2200

$y = 500 + 420x$

Total Demand for Year 5 = 500 + 420×5 = 2600

Example 8.6

Average Seasonal Factor

Quarter	Average Seasonal Factor
1	0.2043
2	1.2979
3	2.0001
4	0.4977

Quarterly Forecasts for Year 5

Quarter	Forecast
1	650 x 0.2043 = 132.795
2	650 x 1.2979 = 843.635
3	650 x 2.001 = 1,300.06
4	650 x 0.4977 = 323.505

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Criteria for Selecting Time-Series Method

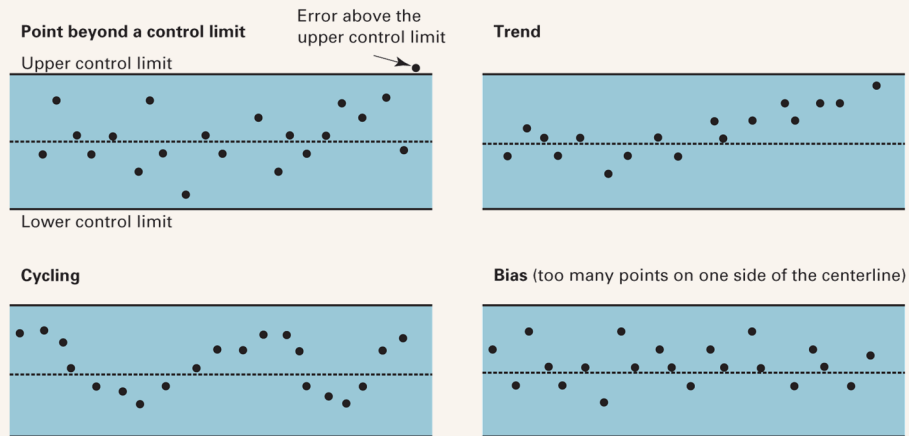- Minimizing MAPE/MAD in recent periods.
- Using a holdout sample: use actual demands from more recent time periods to test models developed from earlier time periods.
- Monitor forecast errors.
- Better forecasts result in better customer service.
- Bias is the worst kind of forecast error.

"A good forecaster is not smarter than everyone else, he merely has his ignorance better organized" – **Anonymous**

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Monitoring the Forecast

Point beyond a control limit

Error above the upper control limit

Upper control limit

Lower control limit

Trend

Cycling

Bias (too many points on one side of the centerline)

Practical Approaches to Demand Forecasting

- Combination forecasts: averaging independent forecasts based on different methods, different sources, or different data. 多種預測

- Judgmental adjustments: an adjustment made to forecasts from quantitative models that takes into account contextual information. 參考其他資訊

- Focus forecasting: A method of forecasting that selects the best forecast from a group of forecasts based on ... 利用軟體選擇最信任的

- Collaborative Forecasting: part of Collaborative Planning, Forecasting, & Replenishment (CPFR) that allows a supplier and its customers to collaborate on making the forecast. 供應鏈協同預測