COURSE MANUAL

C4: Operations Management

Module 2

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COL would also like to thank the many other people who have contributed to the writing of this course.

Contents

Module 2

Balancing supply with demand

Introduction

This module examines at a strategic level, the balancing of demand with supply. An economist would argue that prices adjust to balance supply with demand. This is great in theory, but the operations manager gains no comfort from this statement. Excess demand means lost revenue and excess supply means wasted resources. The balancing of supply with demand in the real world is very difficult. If organisations can (somehow) get it right, then they should be very effective and very successful.

Upon completion of this module you will be able to:

Outcomes

- *Explain* the nature of demand.
- *Understand* the strategic role of forecasting.
- *Distinguish* between qualitative and quantitative forecasting and perform basic quantitative calculations.
- *Outline* how capacity is measured and appreciate the dilemma faced by management in matching variable demand with variable capacity.
- *Calculate* various aggregate planning scenarios.
- *Identify* various strategies for balancing supply with demand.
- *Evaluate* the application of yield management.
- *Evaluate* queues and waiting lines.

Unit 3

Demand management and forecasting

Introduction

Operations managers spend money on the inputs to the transformation process. These inputs may be raw materials, human resources, buildings, machines, processes, energy and operating supplies, to name a few. A major decision is what to buy, but equally important decisions include when to buy and how much to buy. To answer these questions we need to know, with some level of accuracy, how much output from the transformation process we will need. That is where forecasting and demand management enter the picture.

Operations management personnel use forecasts to make decisions about process selection, capacity planning, facility layout, production planning, scheduling and inventory. Forecasting is essential in operations management.

One thing we can be reasonably certain about is that any forecast is most likely to be different from what eventually happens. Many managers are discouraged from making forecasts simply because they know they will be "wrong". The essence is to somehow agree on a set of numbers and plan around those numbers and to develop a contingency plan in case the real numbers are too high or too low.

This unit starts by defining demand management and distinguishing between short-range, medium-range and long-range forecasting. This leads to a discussion on the strategic role of forecasting and the differences between dependent and independent demand.

We perform some forecasting deviation calculations and interpret the answers. This is followed by some more calculations in quantitative forecasting. The intention is to show the types of calculations that can be performed and therefore the mathematics is quite basic.

We decompose a time series into components so we can understand where the data is coming from and this places us in a better position to determine future data. One of the demand components is seasonality, so we develop the seasonality index and perform detailed calculations using seasonal indices and regression analysis.

We conclude with a discussion on alternative approaches to forecasting.

Outcomes

Upon completion of this unit you will be able to:

- *Define* demand management.
- *Explain* the nature of demand.
- *Understand* the strategic role of forecasting.
- *Distinguish* between qualitative and quantitative forecasting.
- *Explain* forecast accuracy.
- *Define* forecast value added.
- *Perform* basic quantitative calculations on forecasting.
- *Define* and calculate seasonal indices.
- *Use* regression analysis to develop long-term trends.
- *Discuss* other approaches to forecasting.

Terminology

Cyclical component	A component of demand that occurs in a cycle greater than one year. Examples of cycles include economic, political and/or business.
Decomposition	A method of forecasting where the time series data is split into components of demand (trend, seasonal and cyclical). Trend measures the general upwards or downwards direction, seasonal indicates the effect of different seasons and cyclical shows the effect of a longer repeating non-seasonal period cycle. Each separate component is projected into the future and the sum of the projections becomes the new forecast.
Delphi method	A qualitative forecasting method that uses a group of experts to arrive at a consensus about the future.
Demand	A need for a particular product or service. At the finished-goods level demand may not equate to sales. Demand is what the customer wants, while sales represent the ability to deliver. In demand forecasting there are four components of demand: trend, seasonal, cyclical and random.
Dependent demand	The demand for all lower-level items calculated from the product structure of the end item. Dependent demand should be calculated and not forecast.

Forecast	An estimate of future demand. A forecast can be constructed using quantitative methods, qualitative methods or a combination of both. The four components of demand are: trend, seasonal, cyclical and random.
Forecast deviation	The difference between the actual (eventual) demand and the forecast value.
Independent demand	The demand for an item that is unrelated to the demand for other items. Examples include demand for finished items and spare parts.
Random component	Random component in demand forecasting has no predictable pattern. For example, sales data may vary around a forecast value with no specific pattern forming and no way of more accurately determining the actual demand other than by the forecast.
Seasonal component	A component of demand describing the variation that occurs because of the time of year, month or week. A seasonal component generally repeats itself at least once a year whereas a cyclical component usually takes longer than one year.
Seasonal index	A number used to adjust data to seasonal demand.
Trend component	A component of demand showing an increase or decrease of demand over time.

Terminology sourced from Gardiner (2010).

What is demand management?

Demand is the need for a particular product or service. When customers need a product or service they approach their supplier and demand sufficient quantity of that product or service to satisfy their demand.

Without a need to satisfy demand, firms and organisations have little reason to exist. Production firms make tangible products that can be consumed by customers and service firms deliver services that are experienced by customers. It is up to the organisation to decide how much of that demand they will deliver.

It is a strategic decision for organisations to decide how much of that demand they want to supply. When a production firm stores products in a warehouse, they are anticipating future demand. When a service organisation occupies a facility and employs and trains staff, they are anticipating future demand.

Demand occurs at all stages in a supply chain and at all stages in a service chain. Raw materials are demanded by the manufacturer, fabricated and component parts are demanded by the assembler, finished products are demanded by the wholesaler/distributor, finished products are also demanded by the retail customer, and services are demanded at all stages of the supply chain as well as the service chain.

Predicting the future is an art as well as a science. It does not really matter how specific firms and organisations arrive at their forecast. What does matter, however, is exactly what the organisation does with the forecast. The predictions are useful for organisations before they make decisions which may give them a competitive advantage in the market place.

A forecast is an estimate of future demand and it can be developed using quantitative methods, qualitative methods or a combination of both. The forecasting process is the business process that attempts to predict demand for products and services so that capacity, resources and materials are available in time to meet the need.

It will cost money to buy capacity; it will cost money to occupy a facility; it will cost money to buy raw materials and components; it will cost money to train and educate employees to perform production and service activities; and it will cost money to deliver products and services to customers.

Depending on how much money is spent and when it is spent will determine how well, or how poorly, the organisation is able to satisfy customer demand. If the organisation spends the right amount of money, the organisation will satisfy customer demand at the minimum cost. If the organisation spends too much, the organisation may find it has under-utilised resources.

Short-, medium- and long-range forecasting

Demand forecasting operates within three time horizons, short-, medium- and long-range.

Long-range forecasting

Long-range forecasting generally covers the period required to replace major resources. These forecasts are strategic in nature and cover applications such as facility and capacity planning, technology and design planning, research and development, and process planning.

Forecasting is aggregated into total groups of similar products and should indicate trends and resource imbalances. So a steel producer might forecast tonnes of output per year, an airline might forecast the number of passengers and tonnes of freight per route per month and an electricity producer might forecast megawatt hours ($MW \cdot h = 10^6$ watt hours) of electricity per month.

Forecast data for long-range forecasting should be bracketed in months, quarters or even years. If you were planning the electricity generation requirements for a significant region you might examine closely the peak seasons for the next 10 or 20 years. Daily requirements would not be important, but possible daily peak loads would be important. The actual day that the peak load will occur will not be considered, but the year that the new peak level is achieved would be important.

The forecasts at this level need to be in the "ballpark". In other words, absolute accuracy is not relevant as long as it is relatively close and clearly provides the trend data and resource requirements that will be required.

Medium-range forecasting

Medium-range forecasting applications include sales planning, operations planning, budgeting, yield management and aggregate staffing plans.

Medium-range forecasting models use some aggregation. A hospital, might group all patients into the type of care they are to receive, for example: maternity, paediatric, psychiatric, elective surgery or accident and emergency.

The level of detail is greater than with long-range forecasting and the required accuracy is also greater. An organisation planning in this time frame usually will not have the capability of acquiring additional resources in time to meet any significant changes in demand. This should have been highlighted in the long-term plans.

Peak periods such as holidays, special events and changes in shift capacity will, however, need to be considered.

Short-range forecasting

Short-range forecasting usually involves detailed planning and scheduling for purchasing, job scheduling and staffing rosters as well as production allocations.

Planners and operators working with short-range data will be endeavouring to resolve short-term demand and capacity issues. These issues will be current and have to be resolved immediately.

Planning is performed by named personnel for individual tasks at specific times on given days. This can become very detailed and this level of detail is required to make the tactical decisions of the organisation.

Strategic role of forecasting

Forecasting demand for some products is more difficult than forecasting the demand for others. New products do not have established patterns of demand; fashion items are influenced by intangible forces such as perceived desirability; and commodity products are sold on a regular basis. This, however, does not make forecasting any less worthwhile.

One thing certain about forecasting is that it will almost always be wrong. It may deviate from actual performance by only a small margin, but it will be different. This is enough to put some organisations off the concept of forecasting. They wonder why they should put valuable resources into an activity that is always wrong.

In a strategic sense, each organisation should understand the dynamics of the demand patterns and be prepared for whatever happens. Sudden demand changes may occur because of external factors such as natural disasters, terrorist activities, weather patterns, major events and accidents. Gradual changes may occur as a result of social, demographic, political, legal and environmental change.

Some of these changes can be expected and some are unexpected. One could argue that the unexpected should, in fact, be expected and that it is the magnitude and timing of the occurrence that is in doubt. Organisations should be prepared for whatever happens to their demand patterns. This does not mean that they should be able to react satisfactorily to all changes in demand. They may, for instance, elect as a matter of policy not to service demand. They may have in their planning a statement suggesting that should demand exceed a certain value then they will choose to reject it and not attempt to satisfy it. This is not a statement that says that all demand must be satisfied. Rather, it is a statement that says that the firm can handle certain deviations from expected demand but only up to a limit, at which point the excess is unsatisfied.

Organisations should consider the consequences of the forecast being too optimistic or too pessimistic. What would happen to the business if the forecast figures were not achieved? Or the forecast figures were exceeded? What are the choices of action?

Reflection 1

Reflection

Excluding the changing behaviours demonstrated by the customer, what factors would influence demand?

Activity feedback can be found at the end of this module.

Dependent and independent demand

Dependent demand is the demand for all lower-level items calculated from the product structure of the end item. Dependent demand should be calculated and not forecast. Independent demand is the demand for an item that is unrelated to the demand for other items. Examples include demand for finished items and spare parts.

Demand forecasting processes should be applied to independent demand items and groups of independent demand items. Most products and services sold exhibit independent demand as these can be sold independently of all other sales. Occasionally, an item is sold in association with another item. For example, bread and butter, socks and shoes, motor vehicles and petrol, fish and chips, and paint and a paint brush. The demand for these types of items is still considered to be independent since the quantity of each is not directly related to the other item in the pairing.

Dependent demand relates to the component items of a product structure where the component items are in relatively fixed quantities of the parent item. For example, the meat and vegetables of a restaurant meal, the purchased and fabricated items of a refrigerator and the quantity of steel and concrete in a building. Dependent demand should be calculated by multiplying the quantity per parent by the number of parent items being demanded.

Forecast deviation calculations

Forecast deviation is the difference between the actual (eventual) demand and the forecast value. Organisations use the output of forecasting for spending decisions. It must be obvious that if the actual demand differs from the forecast values then spending will not be at the optimum level. A forecast deviation would suggest the firm is about to either spend too much and have excess products and capacity available, or not spend enough and be unable to satisfy demand for its products and services.

Most organisations plan their supply chains assuming forecasts will actually happen. They start with this assumption and express regret, or blame market conditions, when they end up with product shortages or surpluses. Instead, they should start with a range that represents the likely upper and lower bounds and plan the demand and supply risk of those limits.

While it is not necessary (or even practical in all cases) for the forecast to be 100 per cent accurate, it would benefit the whole forecasting process if the reasons for the variation were understood and if a learning process took place. This allows the forecasting process to improve and, in turn, allows the organisation to aim for the optimum expenditure of resources.

Reflection 2

Reflection

Think of three or four reasons why a forecast value would be inaccurate.

Activity feedback can be found at the end of this module.

There are two types of forecast deviation, bias and random. Bias deviations occur when a consistent mistake such as always too high or always too low is made. Random deviations simply cannot be explained; they just happen and are sometimes referred to as “noise”.

We can measure forecast deviation in various ways. Most measurements examine the difference between the actual demand and the forecast value. Sometimes we look at the algebraic difference which allows for high values to cancel out low values with a net summation of close to zero. It is possible to have wildly fluctuating forecast values and still conclude that a good forecast model is being used.

An absolute difference allows the magnitude of the over- or under-forecast to be measured. Whether the forecast value is over or under does not matter; the absolute measurement examines the relative distance of the actual demand from the forecast value.

The algebraic deviation and the absolute deviation are very popular measurements but the significance of the deviation relative to the actual observation quantity is required. A deviation of 50 when forecasting demand in hundreds is significantly different from a deviation of 50 when forecasting demand in millions.

Mean absolute deviation (MAD)

The mean absolute deviation (MAD) measures the absolute dispersion of the deviation. It is calculated as the mean of the sum of the absolute differences between the actual demand values and the forecast values. An absolute value does not have any sign. If the difference is negative, it is written just as a number; similarly, if it is positive it is written just as a number. The mean absolute deviation measures the average distance of demand values from forecast values. The formula for mean absolute deviation (MAD) is:

mean absolute deviation

$$\text{MAD} = \frac{\sum |D - F|}{n}$$

where D is the actual demand value for each period

F is the forecast value for each period

n is the number of periods or observations

Activity 2.1

Activity

Use the data in the following table to calculate mean absolute deviation MAD.

Month	Demand D	Forecast F	Deviation $(D-F)$	Abs deviation $\lvert D-F \rvert$
Jan	500	550	-50	50
Feb	550	600	-50	50
Mar	420	490	-70	70
Apr	500	530	-30	30
May	610	530	80	80
Jun	600	550	50	50
Jul	680	610	70	70
Aug	670	670	0	0
Sep	720	690	30	30
Oct	750	730	20	20
Sum	**6000**	**5950**	**50**	**450**
Ave	**600**	**595**	**5**	**45**

Activity feedback can be found at the end of this module.

Bias

Bias indicates whether a method of forecasting tends to favour a higher or lower value. It is calculated as the sum of the algebraic differences between the actual demand values and the forecast values divided by the sum of the demand values. Thus, the pluses may offset the minuses. It is a useful measure especially when expressed as a percentage of actual demand.

The formula for bias is:

$$\text{bias} = \frac{\sum (D - F)\text{x}100}{\sum D}$$

where D is the actual demand for each period

F is the forecast for each period

Activity 2.2

Activity

Use the data in the following table to calculate bias.

Month	Demand D	Forecast F	Deviation $(D\text{-}F)$	Abs deviation $\lvert D\text{-}F \rvert$
Jan	500	550	-50	50
Feb	550	600	-50	50
Mar	420	490	-70	70
Apr	500	530	-30	30
May	610	530	80	80
Jun	600	550	50	50
Jul	680	610	70	70
Aug	670	670	0	0
Sep	720	690	30	30
Oct	750	730	20	20
Sum	**6000**	**5950**	**50**	**450**
Ave	**600**	**595**	**5**	**45**

Activity feedback can be found at the end of this module.

Mean absolute percentage deviation (MAPD)

Mean absolute percentage deviation (MAPD) is the mean of the absolute deviation between actual demand value and forecast value divided by the mean of the demand values expressed as a percentage. This is similar to mean absolute deviation (MAD) but considers the significance by dividing by mean demand.

The MAPD is described as a mean value but the formula does not divide by the number of observations. This is simply because *n*, the number of observations, is the divisor for both numerator and denominator and cancels itself out. The formula could be written as mean absolute deviation divided by mean demand.

The formula for mean absolute percentage deviation MAPD is:

mean absolute percentage deviation

$$\text{MAPD} = \frac{\sum |D\text{-}F| \text{x}100}{\sum D}$$

where D is the actual demand value for each period

F is the forecast value for each period

Mean absolute percentage variation (MAPV)

Mean absolute percentage variation (MAPV) is the average of the absolute deviation between actual demand value and mean demand value divided by the mean demand expressed as a percentage. The MAPV is described as a mean value, but the formula in total does not divide by *n*, the number of observations. This is simply because *n*, the number of observations, is the divisor for both numerator and denominator and cancels itself out. MAPV measures the variability in the demand.

The formula for mean absolute percentage variation (MAPV) is:

mean absolute percentage variation

$$\text{MAPV} = \frac{\sum \left| D - \frac{\sum D}{n} \right| \text{x}100}{\sum D}$$

where D is the actual demand value for each period

n is the number of periods or observations

Mean absolute percentage deviation (MAPV), on its own, is not strictly a forecasting measure. The usefulness of MAPV comes when comparing the forecast deviation with the volatility of the actual demand. A dynamic demand pattern is considerably more difficult to forecast than a stable commodity demand pattern.

Activity 2.3

Activity

Use the data in the following table to calculate mean absolute percentage deviation MAPD and mean absolute percentage variation MAPV.

Month	Demand D	Forecast F	Abs deviation $\lvert D-F \rvert$	$\Sigma D/n$	Abs variance $\lvert D-(\Sigma D/n) \rvert$
Jan	500	550	50	600	100
Feb	550	600	50	600	50
Mar	420	490	70	600	180
Apr	500	530	30	600	100
May	610	530	80	600	10
Jun	600	550	50	600	0
Jul	680	610	70	600	80
Aug	670	670	0	600	70
Sep	720	690	30	600	120
Oct	750	730	20	600	150
Sum	**6000**	**5950**	**450**		**860**
Average	**600**	**595**	**45**		**86**

Activity feedback can be found at the end of this module.

Forecast value added

Forecast value added is the change in forecast accuracy due to an activity in the forecasting process. The forecasting process starts with demand history. This is usually quite difficult to obtain since most organisations have sales history but not demand history. The difference is in the detail of quantities, products and timings. The customer demands products in certain quantities and certain times, and the organisation supplies quantities of products at certain times. The demand may not equal the supply, but it is the supply that is measured. Supply is the firm's ability to deliver.

The quantitative forecast is now examined by various functions and individuals in the organisation for their qualitative inputs. These functions and individuals may represent sales, marketing, product development, finance, production and anyone else who can make a meaningful contribution to the forecast output. Additionally, executive management would almost certainly want to have some inputs.

This is where the forecast value added analysis becomes effective. All the inputs supplied by these functions and individuals are noted and a consensus forecast is developed by a consensus process.

Power, influence, hierarchy, knowledge, lack of knowledge, history, experience and politics all play their part in developing the consensus forecast. Often, in power politics, it is the chief executive that has the strongest voice, since few employees reporting below the chief executive actually stand up and argue strongly against the chief executive. Yet, it could conceivably be that the inputs from the chief executive are making the forecast worse.

When actual observations are available they are compared to the consensus forecast. Ideally, the consensus forecast should mirror the actual observations. If it does not, and this outcome would normally be expected, then each of the inputs to the consensus process is examined to see the effect each input had in modifying the statistical forecast. In other words, each modification to the quantitative forecast is noted and analysed to see if it added value to the forecast or made it worse.

If, for example, the marketing function is able to exert pressure during the consensus process and this results in a positive contribution to the consensus, then marketing will assume a stronger position in the next consensus round. If a function, or an individual, contributed to the consensus and made it worse, their inputs will be discounted in future and may even be ignored.

Quantitative forecasting

Quantitative forecasting assumes the history of past data about the item being forecast can, in some way, be used to predict the future. Quantitative techniques include time series models such as simple moving average, weighted moving average, exponential smoothing, decomposition of a time series and regression analysis.

When using past data one assumes the demand pattern will be repeated. If it is known that the demand patterns will not be repeated, then the historical data must be changed. This may occur, for example, when a supplier is unable to deliver raw materials resulting in no sales of finished products. In this example, demand is occurring but the sales are not and most firms record sales (and not demand). Other examples of when past data becomes unreliable include changes in legislation and known changes in the environment.

Firms often struggle with this concept of changing the actual data to reach a better forecast. They argue that the past data is history and the forecast should be based on history. The analyst response should be that it does not matter how the forecast is developed. What does matter is that the forecasting process is improved.

Simple moving average

The simple moving average forecast is a forecasting method that adds together the most recent actual observations and divides by the number of observations.

The formula to calculate the forecast using simple moving average is:

$$F_t = \frac{\text{sum of actual demand values for the chosen number of periods}}{\text{chosen number of periods}}$$

$$F_t = \frac{D_{t-n} + \ldots\ldots + D_{t-2} + D_{t-1}}{n} = \frac{\sum D}{n}$$

where F is the forecast

D is the demand value for each period

t is the period number

n is the chosen number of periods

Using simple moving average, the forecast for a period is the average of the actual demand for the n most recent periods. The choice for the number of periods, n, is arbitrary and is usually an odd number of periods such as 3, 5, 7 or 9. Greater numbers of periods makes the forecast less responsive as this tends to smooth out any temporary ups and downs in the demand pattern.

Activity 2.4

Activity

Calculate the forecast for month six using a three-month simple moving average given historical demand for months one to five as follows: 120, 130, 110, 135 and 145.

Activity feedback can be found at the end of this module.

Activity 2.5

Activity

Calculate the forecast for month six using a five-month simple moving average given historical demand for months one to five as follows: 120, 130, 110, 13, and 145.

Activity feedback can be found at the end of this module.

Weighted moving average

The weighted moving average is an averaging technique that assigns varying weights according to their significance to selected data values.

The formula for weighted moving average is:

$$F_t = \frac{\text{sum of (each period's demand value x each period's weight)}}{\text{sum of the weights}}$$

$$F_t = \frac{D_{t-n}w_{t-n} + \ldots.. + D_{t-2}w_{t-2} + D_{t-1}w_{t-1}}{w_{t-n} + \ldots.. + w_{t-2} + w_{t-1}}$$

where F is the forecast

D is the demand value for each period

w is the weight applied to each period

t is the period number

n is the chosen number of periods

A weighted moving average allows any weighting (or influence) to be placed on the demand for each of the *n* most recent periods. This method recognises that all periods should not be treated equally. Assume, for example, that the forecast covers nine months. It might be unreasonable to allow the same emphasis (weight) to be applied to the first period (most distant) as is used with the last period (most recent).

The simple moving average treats all periods equally and applies an even weighting to each period. Weighted moving average does not treat all periods equally. The sum of all weights usually adds up to one.

Activity 2.6

Activity

Calculate the forecast for month six using a three-month weighted moving average given historical demand for months one to five as follows: 120, 130, 110, 135 and 145. Apply weights of 0.2, 0.3 and 0.5. (In other words, apply weights of 20 per cent, 30 per cent and 50 per cent.)

Activity feedback can be found at the end of this module.

Exponential smoothing

Exponential smoothing is a time series forecast that adjusts a previous forecast by a percentage of the forecast deviation. The method is called exponential because data points are weighted in accordance with an exponential function of their age.

The formula for exponential smoothing is:

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

where F is the forecast

D is the demand value for each period

t is the period number

α is the smoothing constant $0 < \alpha < 1$

For this method, only three pieces of data are required — namely the most recent forecast, the actual demand that occurred for that period, and a smoothing constant, alpha (α). Alpha is given a value between 0 and 1. This method gives the weight of α to the demand of the most recent period; $\alpha(1- \alpha)$ to the demand one time period older; $\alpha(1- \alpha)^2$ to the demand two time periods older; and so on. Thus the method applies exponential weighting such that each increment in the past is decreased by $(1- \alpha)$.

For stable demand, a small alpha is desirable for lessening the effects of random changes. For increasing or decreasing demand, a large alpha is desirable. Adaptive smoothing refers to approaches for controlling the value of alpha.

Activity 2.7

Activity

Calculate the forecast for month six using exponential smoothing given historical demand for months one to five as follows: 120, 130, 110, 135 and 145. Use an alpha factor α equal to 0.2 and you are given a forecast for month five equal to 130.

Activity feedback can be found at the end of this module.

Regression analysis

Regression analysis enables us to determine the relationship between a variable of interest, called a dependent variable, and one or more independent variables. The equation that describes a straight line, or linear function, takes the form $\hat{y} = a + bx$.

$\hat{y}$ is the best estimate of $y = a + bx$

$$b = \frac{n\sum xy - (\sum x \sum y)}{n\sum x^2 - (\sum x)^2}$$

$$a = \frac{\sum y}{n} - b\frac{\sum x}{n}$$

where y is the dependent variable

x is the independent variable

a is a constant where the line on the graph cuts the y - axis (the y intercept)

b is a constant giving the gradient, or slope, of the line

Simple linear regression provides a mathematical way of estimating a and b. It is also known as the line of best fit or least squares linear regression.

Simple linear regression defines the trend line by determining the values of a and b from the past data such that the sum of squares of the vertical differences between actual values ($\boldsymbol{y}$) and values obtained from the line ($\hat{\boldsymbol{y}}$) is a minimum.

In demand forecasting, a trend line using linear regression is derived by fitting a straight line through the time series demand data, with time on the ***x***-axis and demand on the ***y***-axis.

Activity 2.8

Activity

Given the six months sales data in the following table, develop a trend line using least squares regression analysis. Use the trend line to forecast the next three months.

Month	Demand	x	y	xy	x^2
January	115	1	115	115	1
February	123	2	123	246	4
March	132	3	132	396	9
April	130	4	130	520	16
May	140	5	140	700	25
June	150	6	150	900	36
Sum		**21**	**790**	**2877**	**91**
Average		**3.5**	**131.6667**		

Activity feedback can be found at the end of this module.

Decomposition of a time series

Decomposition of a time series occurs when the time series data is split into the components of demand (trend, seasonal and cyclical). The trend component measures the general upwards or downwards direction, the seasonal component shows the effect of different seasons, and the cyclical component shows the effect of a longer repeating non-seasonal period cycle. Each separate component is projected into the future and the sum of the projections becomes the new forecast.

Seasonal index

The seasonal index is a number used to adjust data to seasonal demand.

The seasonal index for each season is derived as the average of all the demands for that period divided by the average demand for all periods.

The formula to calculate the seasonal index is:

$$\text{seasonal index} = \frac{\text{period average demand}}{\text{average demand for all periods}}$$

The deseasonalised demand is calculated by dividing the observed demand for the period by the seasonal index for the period.

The formula for deseasonalised demand is:

$$\text{deseasonalised demand} = \frac{\text{observed demand for the period}}{\text{seasonal index for the period}}$$

Activity 2.9

Activity

Using the observed demand data for two years is shown in the following table; perform a regression analysis on deseasonalised demand to forecast demand for the winter season in year three.

Year	Season	Observed demand
1	autumn	205
	winter	140
	spring	375
	summer	570
2	autumn	475
	winter	270
	spring	685
	summer	960
Sum of demand		3680
Average demand		460

Activity feedback can be found at the end of this module.

Alternative approaches to forecasting

Modern technology allows firms to improve their internal and external processes, to change behaviours and subsequently arrive at a better forecast of future demand. Most forecasting systems accept the customer demand as given when it is quite feasible for firms to be proactive and influence demand.

Four very effective alternative approaches to forecasting are:

1. customer collaboration
2. supply chain engineering
3. demand smoothing
4. proactive collaboration.

With customer collaboration, it is possible for suppliers and customers to work together and share information relating to demand. If a customer is planning on increasing demand for a short period by promoting and advertising a product, then it would make sense to have sufficient supply arrangements in place before the demand increases.

Supply chain engineering uses standard operations management techniques to improve the effectiveness of the supply chain.

Techniques such as building flexibility into processes, shortening set-up times, minimising lead time, minimising safety stock, using pull replenishment systems and postponement tend to reduce the reliance on forecasts by shortening the forecast horizon.

Demand smoothing is a proactive approach that recognises the volatility of inherent demand caused by normal consumption of the product or service and the artificial volatility created by the organisation's own policies and procedures. End-of-period push, sales contests, trade promotions, channel-stuffing, bulk discounts, trading terms favouring start-of-month orders and pricing changes all contribute to a pattern of demand variability beyond the normal variability of consumption. This is artificial and is all within the managerial control of the organisation.

The inherent volatility of demand can be measured using the coefficient of demand variation (CDV). This is the standard deviation of demand divided by the mean demand. The value calculated for both supplier and customer should be the same. If they are not the same then artificial volatility exists.

Proactive collaboration is similar to customer collaboration but operates proactively. Business partners work together to smooth demand and make demand patterns predictable. This results in an effective supply chain which should lower total supply chain costs.

Activity 2.10

Activity

Work through the following questions. You may need to go back and reread the unit to help you.

1. Describe the four components of demand.
2. Explain the difference between qualitative and quantitative forecasting.
3. Describe the strategic importance of forecasting.
4. Describe the use of MAPD and MAPV.
5. Explain how forecasting performance might be measured.
6. Explain the expression, "Forecasting is about understanding variation".
7. What is the difference between seasonal variation and cyclical variation?

8. Discuss seasonal variation of demand and how an organisation can respond.
9. Explain how the seasonal index is calculated.
10. What strategies are used by airlines, hotels and rental car companies to influence demand?

Unit summary

Summary

In this unit you learned how to define demand management, to explain the nature of demand, to understand the strategic role of forecasting, to distinguish between qualitative and quantitative forecasting, to explain forecast accuracy, to define forecast value added, to perform basic quantitative calculations on forecasting, to define and calculate seasonal indices, to use regression analysis to develop long-term trends and to discuss other approaches to forecasting.

Readings for further study

Reading

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Unit 4

Capacity planning and management

Introduction

Today, providing service in a competitive world has uncovered issues relating to what service actually is and how to measure it in the minds of most managers, how service is perceived by the customer and how the customer's future purchasing decisions may be affected by the service experiences they currently encounter.

To provide a service, management must first anticipate the level and nature of customer demand. For instance, airlines must anticipate the level of demand in order to purchase aircraft and support staff. If customer demand is low, profits will be lower because expensive resources such as aircraft are not utilised. If demand is high it may be that customers will be dissatisfied by not getting the seats advertised and may opt for a competitor's offering. There is a need to anticipate demand and provide resources and — at the same time — maximise profit. This requires management to take decisions. How many customers a day can a restaurant service? How long should a customer wait before being answered by a telephone hotline? How many firefighters and appliances should a city employ?

Manufacturing companies may create inventory buffers in order to supply goods from stock even if the factory is idle. This is not so with service products which are intangible and often consumed and supplied simultaneously. Service can rarely be inventoried although there are exceptions such as in emergency services where fire engines are essentially inventoried in case they are required. Also, most product offerings come bundled with services. When you purchased a car, was it presented in a showroom? Did you require finance to pay for the car? Was your old car traded in as part of the new purchase arrangement?

Manufactured products are often sold “off the shelf”, which means customer demand had been anticipated and resources organised to make, assemble, ship and store the product. Services cannot be managed in a similar fashion. Errors or the mismatches between actual demand for services and the resources needed to provide those services must be managed without the ability to keep stock. Hence better managerial approaches are necessary. How well competing companies manage resources may have a significant impact on both their competitive position in the market and their profitability.

This unit focuses on answering difficult, often strategic resource questions and explains the significance of managing capacity and providing customer service. It begins by considering the problems facing both manufacturing and service organisations in meeting their respective customer demand. It considers the nature of variability and the significance of different resources and their part in balancing supply with demand. The study unit then investigates yield management (or revenue maximisation) which attempts to maximise revenue from (relatively) fixed capacity and is practised by airlines, hotels and rental companies.

This is followed by a short discussion on flexibility and an analysis of queues and waiting lines.

Outcomes

Upon completion of this unit you will be able to:

- *Outline* how capacity is measured and appreciate the dilemma faced by management in matching variable demand with variable capacity.
- *Calculate* various aggregate planning scenarios.
- *Discuss* the strategic planning process.
- *Identify* various strategies for balancing supply with demand.
- *Evaluate* the application of yield management.
- *Discuss* flexibility.
- *Appreciate* the customers psychology in relation to queuing.
- *Discuss* queues and waiting lines.

Terminology

Aggregate planning Aggregate planning is the process used to develop tactical plans to support the organisation’s business plan. In the capacity planning process hierarchy, aggregate planning follows strategic capacity planning and is performed before short-term capacity planning. Aggregate planning is performed for families or groups of products and usually includes an analysis of the plans for total sales, total production, targeted inventory and targeted customer backlog. The result of the process is the production plan.

Capacity Capacity is the capability to produce output for a time period. Capacity required represents the process capability needed to make a given

	product mix or deliver a given service mix (assuming technology, product specification and so on). The capacity available and the capacity required can be measured in the short, medium and long term.
Capacity planning	Capacity planning is the process of determining the amount of capacity required to meet market demand for products and services.
Chase capacity strategy	Chase capacity strategy is a production planning method that varies production to meet demand. Production resources are added and removed as required and this maintains a stable inventory level or a stable backlog (queue). This suits firms that experience significant changes in demand and can add and remove resources easily and effectively.
Demand management strategy	Demand management strategy is a production planning strategy that attempts to modify demand to meet available capacity. It is used in conjunction with either a level capacity strategy or a chase capacity strategy. Methods employed include pricing to promote “off-peak”, restricted service at peak times, advertising, promotion, reservations and appointments.
Diseconomies of scale	Diseconomies of scale refer to the situation when this reduction in average unit cost is no longer possible through further increases in facility size because co-ordination of material flows and personnel becomes so expensive that new sources of capacity must be found.
Economies of scale	Economies of scale refer to the drop in the average cost for each unit of output as a plant gets larger and each succeeding unit absorbs part of the fixed costs. Economies of scale are important to capacity decisions. The best operating level is the capacity for which the average unit cost is a minimum.
Level production strategy	Level production strategy is a production planning method that maintains resources at a constant level resulting in a relatively level production rate. This strategy suits a firm with

	scarce or expensive resources or when steadily building up stock levels in anticipation of seasonal demand.
Master production schedule	Master production schedule is a line on the master schedule grid that reflects the anticipated build schedule for items assigned to the master scheduler. The master scheduler maintains this schedule, and in turn, it becomes a set of planning numbers that drives the material requirements planning. It represents what the company can build and will build expressed in specific product configurations, quantities and dates.
Master schedule	Master schedule is a report that shows by time period the forecast, customer orders, projected available balances, available to promise and the master production schedule. It takes into account the forecast, the production plan and other things such as backlog, capacity, material availability and management policies.
Production plan	Production plan is the agreed plan that comes from the aggregate planning process, specifically the overall level of production output planned to be produced, usually stated as a monthly rate for each product family (group of products).
Sales and operations planning	Sales and operations planning is a business process that helps companies keep demand and supply in balance. It does that by focusing on aggregate volumes (product families and groups) so that mix issues (individual products and customer orders) can be handled more readily.
Supply	Supply is the actual or planned replenishment quantity created in response to a demand for a product or a component in anticipation of such demand.
Yield management or revenue management	Yield management is the application of discriminatory pricing to various market segments so that relatively fixed capacity can be utilised to satisfy customer requirements and simultaneously maximise revenue.

Terminology sourced from Gardiner (2010).

Capacity and capacity planning

Capacity is the capability to produce output over a time period. Capacity required represents the process capability needed to make a given product mix or deliver a given service mix (assuming technology, product specification and so on.). The capacity available and the capacity required can be measured in the short-, medium- and long-term.

Capacity planning is the process of determining the amount of capacity required to meet market demand for products and services.

The term *capacity planning* has traditionally been used in production industries where the capacity requirements of open manufacturing orders were calculated at a very detailed level. Production scheduling attempted to schedule jobs through the factory at minimum cost and minimum lead time.

More recently, the term *capacity planning* has been used by information and communications technology organisations since they need to have sufficient resources available to meet current and future demand.

Forecast demand is not completely predictable and available capacity is not completely predictable. There are elements of predictability in demand and capacity but the summation includes variation and unpredictability. The real significance of capacity planning is realised when organisations appreciate the variations of demand and capacity.

Set-up time variations, production rate variables, unavailability of resources at planned times, unexpected machine breakdowns and transport disruptions all contribute to the variations of output that govern capacity decisions.

The importance of capacity

Long-range capacity planning ensures that sufficient resources are available to meet the long-range demand. For most organisations this is 18 months and beyond.

Medium-range capacity planning uses aggregate sales and operations plans. The time horizon can range from six months to a year and a half depending on the organisation. Capacity increments (or decrements) have to be in place to meet the medium-range demand.

Short-range capacity planning determines the required capacity from current time out to about six months but can extend up to a year. Twenty or 30 years ago, capacity requirements were planned in great detail at this level. Today's business systems do not require that level of detailed capacity planning since modern methods of lean thinking and flexibility reduce the need for intense detailed reports, provided the capacity planning has been performed at the long-range (resource) level and at the medium-range (aggregate) level.

Strategic capacity planning

The objective of strategic capacity planning is to specify the overall capacity level of resources — facilities, equipment and labour — that best supports the organisation's long-range competitive strategy.

If capacity is inadequate, the organisation may lose customers through slow service or by allowing competitors to enter the market.

If capacity is excessive, the organisation may have to reduce prices to stimulate demand or else underutilise its workforce, carry excess inventory, or seek additional, less-profitable products to stay in business.

Reflection 3

Reflection

Imagine you are about to launch a new venture. It may be a factory, a restaurant, a medical centre, a retail store, a transport company, a school or a hospital (to name a few examples).

All production and service organisations usually occupy one or more facilities at one or more locations. For this new venture, the following strategic decisions need to be resolved:

1. Where will each facility be located?
2. How large, or small, will each facility need to be?
3. What process technology will be installed at each location?
4. Will the physical size of the facility be sufficient in the short-, medium- and long-term?
5. When should capacity increments be installed?
6. What happens if the available capacity is too much?
7. What happens if it is too small?

Activity feedback can be found at the end of this module.

Aggregate planning – matching capacity and demand

Aggregate planning seeks to find the combination of sales, production, labour requirements, inventory levels (production) and customer backlog (services) that minimises total production-related costs over the planning period. An aggregate plan could be a formal report in one company and an informal directive in another.

Capacity policy decisions could also limit demand requests which, for example, are in excess of current capacity limits.

The planning process at the aggregate level considers families or groups of products. Typically, a firm should have 6–12 families or groups of products. This number is quite significant. A number less than six suggests that the firm is approaching a full consolidation of the total plans for the business and this would suit a business planning exercise. A number greater than 12 would make the evaluation of the aggregate plans a very lengthy exercise. Assume aggregate plans are discussed at a senior executive meeting and 30 minutes is allocated to discuss each family or group. If the organisation has, say, 20 groups, then the meeting has a 10-hour duration and the whole purpose of the meeting may be lost and irrelevant.

Sales are matched with the overall level of production output to best meet general business objectives of profitability, productivity and competitive customer lead times consistent with the overall business plan. The sales and production capabilities are evaluated and a sales plan, production plan, financial budget statements, and supporting plans for materials and workforce requirements are developed.

This plan affects most functions of the firm and requires inputs from marketing, sales, production, finance, new product and service development, service and distribution.

The master production schedule disaggregates the aggregate production plan and specifies the amount and need dates for the production of specific end products. It is a statement of *what can and will be built*.

Facilities and capacity

Design capacity is the amount a firm would like to produce under normal circumstances and for which the system was designed. It is the rate of production the facility was designed to accommodate over the long-term.

Best operating level is the level for which the process was designed and is thus the volume of output at which the average unit cost is at a minimum.

Economies of scale refer to the drop in the average cost for units of output as a plant gets larger and each succeeding unit absorbs part of the fixed costs. Economies of scale are important to capacity decisions. The best operating level is the capacity for which the average unit cost is a minimum.

Diseconomies of scale refer to the situation when this reduction in average unit cost is no longer possible through further increases in facility size because co-ordination of material flows and personnel becomes so expensive that new sources of capacity must be found.

Economies of scale occur as the average cost per unit decreases and diseconomies of scale occur as the average cost per unit increases. The best operating level occurs at the transition from decreasing unit cost to increasing unit cost.

Having sufficient capacity available is a strategic decision for any organisation. For manufacturing industries, capacity can be stored in inventory. Service organisations do not have that option. Some assessment of the required capacity has to be made in advance of requirements.

Finding the right capacity in service industries has more cost implications simply because the output cannot be stored. Underutilised resources, including staff, do not generate as much incoming revenue and become a serious cost to the firm. Over-utilised resources also increase costs and impact on flexibility and lead time.

Strategic capacity planning process

Master planning of resources

Master planning of resources is the group of business processes that includes demand management (forecasting sales, planning distribution, servicing customer orders) sales and operations planning (sales planning, production planning, inventory planning, backlog planning and resource planning), master scheduling (preparation of master production schedule and rough-cut planning).

Sales and operations planning

Sales and operations planning is a business process that helps companies keep demand and supply in balance. It focuses on aggregate volumes (product families and groups) so that mix issues (individual products and customer orders) can be handled more readily.

It usually occurs on a monthly cycle and displays information in quantity and monetary units. The organisation's strategic plan is linked to its detailed processes. When this process is used properly it enables the organisation's managers to view the organisation holistically and gives them a window into the future.

Master schedule

The master schedule is a report that shows by time period the forecast, customer orders, projected available balances, available to promise and the master production schedule. It takes into account the forecast, the production plan and other things such as backlog, capacity, material availability and management policies.

Once the preliminary demand numbers have been presented, the capacity choices are balanced to arrive at what is achievable in terms of capacity. This may result in agreeing that the planned demand can be produced with existing resources or it may require a modification of demand to create the rate of sales consistent with existing capacity.

If there is a shortfall in available capacity, the organisation may increase capacity, to obtain temporary resources, to outsource production capacity or simply to not deliver the forecast demand.

If there is an excess of capacity, the organisation may decide to sell excess capacity or close down some resource.

Strategies for balancing supply with demand

It is difficult to say which should come first — supply or demand. An organisation that can look forward and visualise a demand pattern based on history or their perception of what is about to happen is in a strong position to determine the required capacity or supply. This can be determined on the basis of the quantity and the timing required.

Organisations use production planning strategies to develop the overall production output to meet customer demand by setting production levels, inventory levels and backlog levels. The main methods used are chase capacity strategy, level production strategy and demand management strategy.

The chase capacity strategy varies production to meet demand. Production resources are added and removed as required and this maintains a stable inventory level or a stable backlog (queue). This strategy would suit firms that experience significant changes in demand and can add and remove resources easily and effectively.

The level production strategy maintains resources at a constant level, resulting in a relatively level production rate. This would suit a firm with scarce or expensive resources or when steadily building stock levels in anticipation of seasonal demand.

Demand management strategy attempts to modify demand to meet available capacity. It is used in conjunction with either a level capacity strategy or a chase capacity strategy. Methods employed include pricing to promote “off-peak”, restricted service at peak times, advertising, promotion, reservations and appointments.

Reflection 4

Reflection

For the most part, the production planner is given a sales forecast and has to use a pure strategy or a combination of strategies.

Think of three or four capacity or supply planning decisions that the production planner could use to increase/decrease the available capacity.

Activity feedback can be found at the end of this module.

Level production strategy

A level production schedule focuses on holding production and the work force constant over a period of time. Any difference between the constant rate of production and the varying rate of demand is made up by allowing inventory levels to rise or fall, increasing or decreasing the number of orders in the backlog, or changing the length of the queue of customers.

Operations managers often prefer this method since production rates are usually dependable, quality of outputs tend to be consistently high, and operating costs tend to be low. The emphasis is on production efficiency and service goals are secondary. Staff levels can be kept constant and supply lines can be arranged to deliver at a steady rate.

The disadvantage is that inventory levels do change and this requires substantial warehousing arrangements to handle periods of low demand. If a queue of customers is being managed, a process for handling lengthy queues has to be implemented.

Examples of a level production strategy can be found in electronics and home appliance assembly plants when high volumes of common products are produced.

Packaging companies will often build up packaging supplies before the season for which the packaging is required. This applies to seasonal produce such as apples, pears, kiwifruit and some vegetables where the seasonal demand of the product is higher than the production capability at the time for the packaging. Therefore the companies manufacture the packaging before it is needed and are able to meet demand when it happens.

Chase capacity strategy

The chase capacity strategy allows the production capacity to vary each period to exactly match the forecast aggregate demand in that time period. Workers are employed and terminated to adjust the level of the workforce. Overtime and temporary staff are used to fill short periods of high demand. Often a subcontractor is used to add additional capacity during peak periods.

The main advantage of this method is that the level of finished goods inventory can be maintained at a relatively low level. Customer queues, if present, are held at a constant length.

However, labour and material costs are much higher because of the disruptions caused by frequently scaling the work force up and down and adjusting capacity of materials suppliers. Essentially, the demand is being matched with available supply.

Examples of this strategy occur in most agricultural and horticultural seasonal harvesting activities where the production requirement occurs for a very short time. To have staff permanently on the payroll just for the seasonal activity would be an ineffective use of resources.

Demand management strategy

Some organisations have the ability to modify demand to suit their available capacity.

One obvious way is to alter prices. A firm that increases the price would normally expect demand to fall; likewise a firm that decreases the price would normally expect demand to rise. Pricing can be an effective tool to promote off-peak demand.

Telephone companies, airlines, hotels and rental car companies all practise changing the price of their service to promote off-peak demand. The net effect, though, is to level the supply.

Restaurants may offer a restricted service at peak periods. This is not presented as a negative offering on their part. Rather they usually promote the restriction as a positive. They may offer, for example, a special low-priced breakfast menu until 10:30 am each day allowing the restaurant to focus production activities on a narrow range of choices rather than the full range. The customer benefits by having a cheaper breakfast option prepared in a very short lead time. Other restaurants may display a “specials” board which sounds like it is offering something extra and “special” when in fact it just means that the chefs have sufficient quantities of those food items and can prepare them quickly and easily.

Production planning model

Production planning considers the forecast demand, the available capacity, the required capacity, cost of production, cost of regular and overtime labour, cost of hiring and training new staff, cost of making employees redundant or laying off, cost of holding inventory, cost of backlogging, cost of managing the queue and subcontracting costs.

Activity 2.11

Activity

The data in the following table represents the demand forecast for 12 months commencing January for an organisation.

Month	Demand forecast
Jan	4400
Feb	3200
Mar	4000
Apr	5400
May	6600
Jun	5000
Jul	4000
Aug	3000
Sep	4800
Oct	6400
Nov	7000
Dec	6200
	60000

The organisation currently employs 25 employees. For planning purposes, each employee is capable of making 200 units a month. The cost of hiring additional staff is $600 per employee and the cost of making an employee redundant is $300. A storage charge of $1 per unit is made for inventory on hand at the end of each month. This is to cover the cost of warehousing.

(Please note that the dollar amounts are nominal amounts for planning purposes and no attempt has been made to quantify the actual costs in this example.)

Plan 1: Develop a production plan using a level production strategy.

Plan 2: Develop a production plan using a chase capacity strategy.

Plan 3: Develop a production plan using six months at 4800 and six months at 5200.

Activity feedback can be found at the end of this module.

Yield management

Yield management is the application of discriminatory pricing to various market segments so relatively fixed capacity can be used to satisfy customer requirements and simultaneously maximise revenue.

The objective of yield management (also known as revenue management) is to increase revenues for organisations that operate with relatively fixed capacity.

The concept of yield management was first applied in the airline industry during the late 1970s but has since been applied across a number of industries including hotels, rental cars, retail, advertising, electricity generation and transmission, tour operators, passenger transport and freight carrying. Even restaurants are learning how to use yield management to their advantage.

The application of yield management is well practised in the airline industry with airlines offering flights for as low as one dollar. Airlines may offer discounted fares on lightly loaded sectors and these bookings usually have to be paid in full, are non-transferrable to another person, and non-refundable. In some cases they are changeable but with the payment of a change penalty fee and by paying any applicable fare adjustment. Peak-hour flights are unlikely to have many fares at lower rates since the airlines have little trouble selling these at higher rates.

Hotels practise yield management by offering lower rates at weekends and during an off-season. They have to be aware of both predictable, seasonal factors and unpredictable, individual customer demand by using a systematic approach with a combination of knowledge, experience, understanding and forecasting. This combines predictability and uncertainty.

Yield management is most effective when the following exist:

- **Relatively fixed capacity and the same unit of capacity can be used in variety of ways.** There would be no need to manage yield when capacity is flexible. With relatively fixed capacity such as an airline seat or a hotel room, the organisation cannot easily change the capacity and yet demand fluctuates widely.
- **Demand can be segmented by market and each segment has varying needs, behaviour and willingness to pay.** Airlines segment their market into general classifications of

business class, full economy fares and discount fares. Business travellers are time sensitive and are likely to book late and require maximum flexibility. For that flexibility they pay a higher-priced fare.

- **Demand is highly variable (seasonal fluctuations) and uncertain.** In periods of low demand (winter for the tourism industry), demand needs to be stimulated and in periods of high demand (summer in the tourism industry), revenues need to be maximised.
- **Inventory is perishable (hotel room by night, airline seat by flight).** If an airline seat is not sold by the time the flight departs, the revenue from that seat is lost and can never be recovered. Similarly, the revenue from an empty hotel room for the night can never be obtained.
- **Product can be sold in advance.** Customers choose to buy at different times, either well in advance or at the last minute. Suppliers can take advantage of this buyer behaviour and they also have an opportunity to influence that buyer behaviour. When the same price applies regardless of booking time, the only driver that would encourage customers to buy earlier would be a fear of unavailability of supply.
- **Product can be forecast with relatively high accuracy**. The organisation will dynamically adjust pricing and will hold back on some capacity to be sold at the last minute at a premium. The company needs to know how much to hold back. If it holds back too much, it may miss out on any revenue. If it holds back too few, it misses out on the high revenue-generating last-minute sales.
- **Fixed costs are high and marginal costs of selling one extra unit are low.** The cost of adding an additional aircraft with additional seats to the fleet is high. The cost of adding an additional hotel room requires a new hotel to be constructed and this is relatively expensive. The cost of adding one more passenger to the passenger list is relatively low. The airline has to handle the reservation, handle the check-in, carry the luggage and make sure the passenger arrives at their destination.
- **Price is not an indicator of quality.** Price should not be seen as a status symbol and should not be an indicator of quality. Using airline pricing as an example, most customers realise that if they pay a high price for their seat they will not get a higher quality flight when compared to a discount purchaser who purchases the same class of seat.

The difference is in the timing of the purchase, not the delivery of the service.

- **Producers are profit-oriented and have freedom of action**. Yield management assumes that the supplier of the service is profit-oriented. A hotel can charge different rates for each room and can hold back some rooms in anticipation of receiving higher revenue later. This approach would not be feasible in an emergency ward of a public hospital.

Yield management process

The yield management process starts by determining how far in advance the system will look ahead. Airlines typically use 300 days.

The market is segmented, based on future purchasing behaviour. Airlines have a clear segmentation between leisure and business travellers. Hotels have short-term, long-term, leisure, business and conference guests. Rental car firms have similar segments to hotels.

The supplier predicts customer demand based on forecast demand and capacity at each product/price level and attempts to optimise the price by mathematically determining capacity availability and price that maximises expected profit.

This attempts to allocate the right capacity to the right customer at the right time and simultaneously maximises revenue or yield. It relies on being able to predict the expected behaviour of specific market segments within the overall market demand. Successful implementation of yield management requires the organisation to be capable of continually monitoring and forecasting changes in demand patterns.

The supplier dynamically recalibrates and continually monitors performance and reacts to the updated market response. It is a continuous process keeping surveillance on response to the pricing, competitor reactions and making adjustments.

The management of demand attempts to influence buyer behaviour so that it fits in with available capacity. Options to influence demand include:

- **Partitioning demand or segmenting the market based on purchasing behaviour, not just current or past classifications**. The most common example is the partitioning of business and leisure travel and accommodation.
- **Offering off-peak pricing incentives**. When off-peak services are priced at a lower rate than full-peak services,

customers will deliberately delay their demand for the service until the price incentive takes effect.

- **Promoting off-peak demand**. This is similar to the off-peak option but relates to promoting activities and advertising that promotes off-peak demand almost to the exclusion of promoting on-peak activities.
- **Developing reservation systems**. Customers know that they have to make a reservation or an appointment so they are encouraged to book early to avoid disappointment. This has an added effect of controlling demand to the capacity limit.

The options to manage supply are:

- **Share capacity with another supplier**. This capacity sharing occurs with airline companies when they fly one aircraft on a particular route and it carries two or more airline flight numbers.
- **Increase customer participation**. This may occur at all times or just in peak periods or off-peak periods. On-line banking and automatic teller machines allow customers to conduct banking business without the need for bank personnel to be present while the transaction is occurring. This allows the fixed capacity of the banking system to be used for longer periods without needing additional staff.
- **Cross-train employees**. If demand shifts from one area of the business to another, trained staff can be directed to meet that demand. If cross-training were not in place the organisation may not be able to offer the full range of services at all times.
- **Employ part-time**. This allows staff numbers to be increased and decreased almost at will to meet whatever demand is placed on the organisation.
- **Create adjustable capacity**. This occurs when organisations do not normally use all available capacity and they open up the additional capacity only in peak periods and close it in quiet times. Tourist destinations often operate in this manner with some hotels closing completely for the off-season.

Capacity flexibility

Capacity flexibility essentially means having the capability to deliver what the customer wants within a shorter lead time than competitors can offer. Such flexibility is achieved through flexible plants, processes, workers and through strategies that use the capacity of other organisations.

The actual capacity is the level of output for a process or activity over a period of time. The effective capacity is the output rate that managers expect for a given activity or process. The demonstrated capacity is the proven capacity calculated from actual performance data.

Capacity control is the process of measuring production output and comparing it with the capacity plan, determining if the variance exceeds pre-established limits, and taking corrective action to get back on plan if the limits are exceeded.

Set-up time is one of the determinants of capacity flexibility. Set-up occurs at the start of a production run and total set-up time is a function of the number of production runs executed. A machine is set up and the run size quantity is produced. The machine is then set up for the next product. Organisations often look at the production rate to determine capacity. Capacity, though, needs to consider set-up time as a non-productive period as well as the processing speed to determine capacity of a machine.

A production facility works best when it focuses on a fairly limited set of production objectives because a firm should not expect to excel in every aspect of production performance — cost, quality, flexibility, new product introductions, reliability, short lead times, and low investment.

Service capacity must be available to produce a service at the time it is needed. Empty airline seats, for example, cannot be transferred from an off-peak flight to a full-peak flight.

Service capacity must be located near the customer or at least be available to the customer before the service can be delivered. Having empty hotel rooms in one city does not help a shortage of hotel rooms in another city.

Customers interact with the service production system and as a result the processing time required for each delivery may vary. Services experience off-peak and on-peak as well as in-season and off-season demands and this is caused by customer behaviour influencing demand.

Service providers must consider the day-to-day relationship between service utilisation and service quality. A good operating point is near 70 per cent of the maximum. This is enough to keep servers busy but allows time to serve customers individually and keep enough capacity in reserve so as not to create too many managerial headaches.

Low rates are appropriate when both the degree of uncertainty and the stakes are high, such as an accident and emergency department at a hospital and fire services. Sporting events and concerts prefer sell-out crowds that use the maximum capacity.

Queues and waiting lines

Queues are a natural consequence of service delivery. In many ways a queue in a services environment is equivalent to buffer inventory in manufacturing.

In production industries, the inventory acts as a buffer to allow the rate of inputs to be different from the rate of outputs.

In services, the queue acts as the buffer between the arrival rate of customers and the supply and delivery rate of the actual service.

Activity 2.12

Activity

When you are waiting in a queue, it often feels like you are waiting for a very long time. Make a list of possible reasons why a customer perceives the wait time is longer than it actually is.

Activity feedback can be found at the end of this module.

Queuing theory

Queuing theory is used to manage processes. A queue can be studied in terms of the source of each customer, how frequently customers arrive, how long they can or should wait, whether some customers should jump ahead in the queue, how multiple queues might be formed and managed, and the number of servers required.

The design of a call centre provides an excellent example of queuing theory in practice. Call centre performance is typically measured by the cost per call, the resolution rate or fulfilment rate and customer satisfaction.

When customers are in the queue they may leave and be lost to the system. They may call back or they may hold one line and use another telephone to join the queue again. An increase in the average call duration increases the queue.

Activity 2.13

Activity

1. What does the term "capacity" mean?
2. How does capacity differ from capability?
3. Why is capacity management strategically important?
4. The management of capacity for services is more difficult than for manufacturing. Why?
5. Describe the capacity considerations for a hospital and identify how this is different from a manufacturing unit.
6. What are the possible consequences of demand rate being different from design capacity rate?
7. What is yield management?
8. What industries use yield management and why?
9. Describe three strategies for expanding capacity.

Unit summary

Summary

In this unit you learned how capacity is measured, and appreciated the dilemma faced by management in matching variable demand with variable capacity. We developed various aggregate planning scenarios and discussed the strategic planning process and developed various strategies for balancing supply with demand

We explored the application of yield management (or revenue management) and discussed flexibility.

We concluded with a section on the customers' psychology in relation to queuing, queues and waiting lines.

Assignment

Assignment

There are three questions in this assignment**.**

Question 1 40 marks

a. Lowering prices can increase demand for products or services, but it also reduces profit margins if the product or service cannot be produced at lower cost. Briefly discuss how an operations manager should approach his or her job when **competing on cost.**

b. Quality is a dimension of a product or service that is defined by the customer. Today, more than ever, quality has important market implications. Briefly discuss how an operations manager should approach his or her job when **competing on quality**.

c. As the saying goes, "time is money." Some companies do business at "Internet speed," while others thrive on consistently meeting delivery promises. Briefly discuss how an operations manager should approach his or her job when **competing on time.**

d. Flexibility is a characteristic of a firm's operations that enables it to react to customer needs quickly and efficiently. Some firms give top priority to flexibility. Briefly discuss how an operations manager should approach his or her job when **competing on flexibility.**

Question 2. 30 marks

a. Provide three questions that should be considered when developing the objectives of a forecast.

b. Name three different models that could be developed and tested during the forecasting process.

c. What does "applying the model" mean?

d. Explain, using an example, the forecasting step "considering real-world constraints on the model's application".

e. Explain how one might "revise and evaluate the forecast".

f. What is the most important rule of forecasting and what should we be trying to achieve?

Question 3: **30 marks**

The number of guests staying at an exclusive lodge has been:

Quarter	Year	Actual
Summer	1	73
Autumn	1	104
Winter	1	168
Spring	1	74
Summer	2	65
Autumn	2	82
Winter	2	144
Spring	2	52
Summer	3	89
Autumn	3	146
Winter	3	205
Spring	3	98
Total		**1300**

a. Calculate seasonal indices using the above data.

b. Deseasonalise the above data, and determine the regression equation.

c. Using the regression equation, determine the forecasts for year four.

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Johnson, R. & Clark, G. (2008). *Service operations management: Improving customer service* (3rd ed.). Harlow, England: Prentice Hall.

Further Readings

Reading

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Activity feedback

Reflective activities

Reflection 1

A number of factors influence demand such as changes in technology, competitor initiatives or pricing levels. Forecasting helps firms to focus on the factors that influence demand and establish a relationship between those factors and actual demand.

Reflection 2

Forecast inaccuracy can be attributed to the following causes:

- The forecasting model or method employed may not be suitable for the demand being monitored.
- The information in the forecasting process may arrive too late to be of significant value.
- True demand is not being captured and it is being confused with sales data.
- Appropriate data is not being used. This feature develops when individuals are left to source information for themselves and then this data is consolidated in some way at an organisational level.
- Forecasts are calculated from the past data that may not hold for projected data points.

Reflection 3

All of these questions have a major bearing on the success, or otherwise, of the organisation. If you are capable of getting it right, you will find yourself in an enviable position of being able to capitalise on every opportunity that comes your way (assuming you want to take it) and thus maximise revenues and profits. If you get it wrong, you may find yourself searching for additional capacity at a premium price or being left with excess capacity that you are unable to sell.

Reflection 4

- Hiring additional staff and making staff redundant.
- Working variable days per week.
- Working overtime.
- Varying the level of inventory.
- Varying the number of orders in the backlog.

- Varying the length of the queue of customers.
- Using subcontractors to supply additional capacity.
- Outsourcing parts of the business to free up resources.
- Adding or removing temporary capacity.
- Adding or removing permanent capacity.

These are reactive measures and the controllability of these factors depends on union agreements, employment contracts, employment legislation, short-term constraints on physical capacity levels, customer requirements and preferences, and the amount of money that can be tied up in inventories.

Activities

Activity 2.1

Calculate the absolute deviation between demand values and forecast values for each month. Add them up and find the average (mean) value. This is the mean absolute deviation (MAD).

$$\text{MAD} = \frac{\sum |D - F|}{n} = \frac{450}{10} = 45$$

Thus the actual demand is, on average, 45 units from the forecast value.

Activity 2.2

Bias is found by calculating the algebraic difference between demand value and forecast value for each period. To make sure that the algebraic sign is correct, ensure you subtract forecast from demand ($D - F$). The sum of the algebraic differences is divided by the sum of the demand values and expressed as a percentage.

$$\begin{aligned}\text{bias} &= \frac{\sum (D - F)\text{x}100}{\sum D}\\ &= \frac{(6000 - 5950)\text{x}100}{6000}\\ &= 0.833\%\end{aligned}$$

Thus the forecasting model has a bias in favour of demand of 0.833 per cent.

Activity 2.3

MAPD is the mean of the absolute deviation between actual demand value and forecast value divided by the mean of the demand values expressed as a percentage. In this formula description, both numerator and denominator calculate average values using the number of observations. In the formula, the number of observations, *n*, could appear in numerator and denominator and cancels each other out.

$$\text{MAPD} = \frac{\sum |D\text{-}F| \text{x}100}{\sum D} = \frac{450\text{x}100}{6000} = 7.5\%$$

Mean absolute percentage variation (MAPV) is the average of the absolute deviation between actual demand value and mean demand value divided by the mean demand expressed as a percentage.

$$\text{MAPV} = \frac{\sum \left| D - \frac{\sum D}{n} \right| \text{x}100}{\sum D} = \frac{860\text{x}100}{6000} = 14.33\%$$

Thus the mean absolute deviation is 7.5 per cent of the mean demand (MAPD) and the variability of demand (MAPV) is 14.33 per cent.

Activity 2.4

In this example $n = 3$ and $t = 6$.

$$n = 3, \; t = 6$$

$$F_t = \frac{\text{sum of actual demand values for the chosen number of periods}}{\text{chosen number of periods}}$$

$$= \frac{D_{t-n} + \ldots\ldots + D_{t-2} + D_{t-1}}{n}$$

$$= \frac{D_3 + D_4 + D_5}{3}$$

$$= \frac{110 + 135 + 145}{3}$$

$$= 130$$

Thus, the forecast for month six using a three-month simple moving average is 130.

Activity 2.5

In this example n = 5 and t = 6.

$$n = 5, \ \ t = 6$$

$$F_t = \frac{\text{sum of actual demand values for chosen number of periods}}{\text{chosen number of periods}}$$

$$= \frac{D_{t-n} + ... + D_{t-2} + D_{t-1}}{n}$$

$$= \frac{D_1 + D_2 + D_3 + D_4 + D_5}{5}$$

$$= \frac{120 + 130 + 110 + 135 + 145}{5}$$

$$= 128$$

Thus, the forecast for month six using a five-month simple moving average is 128.

Activity 2.6

In this example n = 3, t = 6.

$$n = 3, \ \ t = 6, \ \ w_3 = 0.2, w_4 = 0.3, \ \ w_5 = 0.5, \ \text{sum of the weights} \ = \ 1$$

$$F_t = \frac{\text{sum of (each period's demand value x each period's weight)}}{\text{sum of the weights}}$$

$$F_t = \frac{D_{t-n}w_{t-n} + ... + D_{t-2}w_{t-2} + D_{t-1}w_{t-1}}{w_{t-n} + ... + w_{t-2} + w_{t-1}}$$

$$F_6 = (D_3 \text{ x } W_3) + (D_4 \text{ x } W_4) + (D_5 \text{ x } W_5)$$

$$F_6 = (110 \text{ x } 0.2) + (135 \text{ x } 0.3) + (145 \text{ x } 0.5)$$

$$= 135$$

In this example, the sum of the weights adds up to 1. Thus, the forecast for month six using a three-month weighted moving average is 135 units.

Activity 2.7

$$t = 6, F_5 = 130, \; D_5 = 145, \; \alpha = 0.2$$
$$\begin{aligned} F_t &= F_{t-1} + \alpha (D_{t-1} - F_{t-1}) \\ &= 130 + 0.2 \text{ x } (145 - 130) \\ &= 133 \end{aligned}$$

Thus, the forecast for month six using exponential smoothing with α equal to 0.2 is 133.

Activity 2.8

The data as supplied has demand data for six months. The monthly demand is the independent variable and is assigned to the ***x***-axis. The months in the ***x***-axis are numbered 1 through 6. The ***y***-axis is for the dependent variable and this is the observed demand.

In order to calculate *a, b* and the trend line, the values for ***xy*** and $\boldsymbol{x^2}$ are required as shown in the table above.

$$n = 6, \sum xy = 2877, \sum x = 21, \sum y = 790, \sum x^2 = 91$$
$$\begin{aligned} b &= \frac{n\sum xy - (\sum x \sum y)}{n\sum x^2 - (\sum x)^2} \\ &= \frac{6\text{x}2877 - 21\text{x}790}{6\text{x}91 - 21^2} \\ &= 6.4 \end{aligned}$$

$$n = 6, \sum xy = 2877, \sum x = 21, \sum y = 790, \sum x^2 = 91$$
$$\begin{aligned} a &= \frac{\sum y}{n} - b\frac{\sum x}{n} \\ &= 131.67 - 6.4\text{x}3.5 \\ &= 109.27 \end{aligned}$$

$\hat{y} = 109.27 + 6.4x$ trend line equation

By using Excel the calculations can be automated. The Excel software requires the data analysis add-in and the calculation is initiated using the Data menu followed by Data Analysis and then Regression. For the Input Y Range select the column of ***y***-values and for the Input X Range select the column of ***x***-values. The output report contains more data than is immediately required and the pertinent values are shown below.

SUMMARY OUTPUT	
	Coefficients
Intercept	109.27
x	6.4

Substituting x=7, x=8 and x=9 into the trend line equation provides the forecast values as shown below.

Month	*x*	Forecast
July	7	154
August	8	160
September	9	167

Activity 2.9

Start by calculating the seasonal indices for autumn, winter, spring and summer.

The period average demand for autumn is (205 + 475) / 2 = 340

The period average demand for winter is (140 + 270) / 2 = 205

The period average demand for spring is (375 + 685) / 2 = 530

The period average demand for summer is (570 + 960) /2 = 765

The average demand for all periods can be calculated as 3680/8 and is given as 460.

$$\text{seasonal index} = \frac{\text{period average demand}}{\text{average demand for all periods}}$$

$$\text{seasonal index for autumn} = \frac{340}{460} = 0.7391$$

$$\text{seasonal index for winter} = \frac{205}{460} = 0.4457$$

$$\text{seasonal index for spring} = \frac{530}{460} = 1.1522$$

$$\text{seasonal index for summer} = \frac{765}{460} = 1.6630$$

Calculate the deseasonalised demand for each season by dividing the observed demand by the seasonal index for that period as shown in the following table. Then calculate the extended fields for xy and x^2 as shown in the following table.

Year	Season	Observed demand	x	Seasonal index	Deseasonalised demand y	xy	x^2
1	autumn	205	1	0.7391	277.3644	277.3644	1
	winter	140	2	0.4457	314.1126	628.2252	4
	spring	375	3	1.1522	325.4643	976.3929	9
	summer	570	4	1.6630	342.7541	1371.0164	16
2	autumn	475	5	0.7391	642.6735	3213.3675	25
	winter	270	6	0.4457	605.7886	3634.7316	36
	spring	685	7	1.1522	594.5148	4161.6036	49
	summer	960	8	1.6630	577.2700	4618.1600	64
		3680	36	8	3679.9423	18880.8616	204

$$n = 8,\ \sum xy = 18880.8616,\ \sum x = 36,\ \sum y = 3679.9423,\ \sum x^2 = 204$$

$$b = \frac{n\sum xy - (\sum x \sum y)}{n\sum x^2 - (\sum x)^2}$$
$$= \frac{8\ \text{x}\ 18880.8616 - 36\ \text{x}\ 3679.9423}{8\ \text{x}\ 204 - 36^2}$$
$$= 55.2648$$

$$a = \frac{\sum y}{n} - b\frac{\sum x}{n}$$
$$= 460 - 55.2648\ \text{x}\ 4.5$$
$$= 211.308 \qquad \therefore \hat{y} = 211.308 + 55.2648x$$

Now calculate *b, a* and the best estimate of $\hat{y} = a + bx$.

Thus the trend line for deseasonalised data is $\hat{y} = a + bx = 211.308 + 55.2648x$.

Now substitute $\boldsymbol{x} = 10$ corresponding to winter in the third year to get the deseasonalised value for that period.

when $x = 10$, the deseasonalised value for winter in the third year is

$$\hat{y} = 211.308 + 55.2648x$$
$$= 211.308 + 55.2648\text{x}10$$
$$= 763.956$$

By using a program such as Excel, the calculations to get the regression line can be automated. The Excel software requires the data analysis add-in and the calculation is initiated using the Data menu followed by Data Analysis and then Regression.

For the Input Y Range select the column of y-values and for the Input X Range select the column of x-values. The output report contains more data than is immediately required and the pertinent values are shown in the following table.

SUMMARY OUTPUT	
	Coefficients
Intercept	211.308
x	55.2648

The deseasonalised forecast for winter in the third year is:

$$\hat{y} = 211.308 + 55.2648x = 763.956$$

Now multiply the deseasonalised forecast by the seasonal index to calculate the seasonalised forecast for winter in the third year:

763.956 x 0.4457 = 340.4952 = 340 (0 dp)

Activity 2.10

All answers are in the learning material.

Activity 2.11

Plan 1: Develop a production plan using a level production strategy.

Start this plan by calculating the level production rate. The annual demand is 60,000 and there are 12 monthly periods so that makes 5000 units a month.

In January, the beginning inventory is zero, the production is 5000 and demand is 4400, therefore the ending inventory is 600 units.

In February, the beginning inventory (following on from January) is 600, the production is 5000 and demand is 3200, therefore the ending inventory is 2400 units.

In March, the beginning inventory (following on from February) is 2400, the production is 5000 and demand is 4000, therefore the ending inventory is 3400 units.

Continue like this for the rest of the year.

Month	Beginning inventory on hand	Production	Demand forecast	Ending inventory on hand	Number of employees	New staff	Redundant staff
Jan	0	5000	4400	600	25		
Feb	600	5000	3200	2400	25		
Mar	2400	5000	4000	3400	25		
Apr	3400	5000	5400	3000	25		
May	3000	5000	6600	1400	25		
Jun	1400	5000	5000	1400	25		
Jul	1400	5000	4000	2400	25		
Aug	2400	5000	3000	4400	25		
Sep	4400	5000	4800	4600	25		
Oct	4600	5000	6400	3200	25		
Nov	3200	5000	7000	1200	25		
Dec	1200	5000	6200	0	25		
		60000	**60000**	**28000**			

The inventory storage cost is $28,000, the cost of employing new staff is zero, and the cost of terminating staff is zero to give a total cost for this plan of $28,000.

Plan 2: Develop a production plan using a chase capacity strategy

In this plan the production rate varies to match the demand pattern and the number of employees is increased or decreased to match the production rate.

In January, the demand forecast is 4400, so production is set to match that rate. Beginning inventory on hand is zero, production matches demand forecast, so the ending inventory on hand is zero. To produce 4400 we need 22 staff (200 units per employee per month) so three employees are made redundant. Their employment contract would specify the temporary nature of their employment.

In February, the demand forecast is 3200, so production is set to match that rate. Beginning inventory on hand is zero, production matches demand forecast, so the ending inventory on hand is zero. To produce 3200 we need 16 staff (200 units per employee per month) so six employees are made redundant.

In March, the demand forecast is 4000, so production is set to match that rate. Beginning inventory on hand is zero, production matches demand forecast, so the ending inventory on hand is zero. To produce 4000 we need 20 staff (200 units per employee per month) so four employees are hired.

The remaining months are calculated in a similar fashion.

Month	Beginning inventory on hand	Production	Demand forecast	Ending inventory on hand	Number of employees	New staff	Redundant staff
Jan	0	4400	4400	0	22		3
Feb	0	3200	3200	0	16		6
Mar	0	4000	4000	0	20	4	
Apr	0	5400	5400	0	27	7	
May	0	6600	6600	0	33	6	
Jun	0	5000	5000	0	25		8
Jul	0	4000	4000	0	20		5
Aug	0	3000	3000	0	15		5
Sep	0	4800	4800	0	24	9	
Oct	0	6400	6400	0	32	8	
Nov	0	7000	7000	0	35	3	
Dec	0	6200	6200	0	31		4
		60000	60000	0		37	31

The inventory storage cost is zero, the cost of employing new staff is $22,200, the cost of terminating staff is $9,300 to give a total cost for this plan of $31,500.

Plan 3: Develop a production plan using six months at 4800 and six months at 5200.

The calculations for this strategy follow the same pattern as plan one and two except that the production rate is set at 4800 for the first six months, then increases to 5200 for the rest of the year. This represents a starting position in trying to optimise the plan. The number of employees is increased or decreased to match the production rate.

Month	Beginning inventory on hand	Production	Demand forecast	Ending inventory on hand	Number of employees	New employees	Redundant employees
Jan	0	4800	4400	400	24		1
Feb	400	4800	3200	2000	24		
Mar	2000	4800	4000	2800	24		
Apr	2800	4800	5400	2200	24		
May	2200	4800	6600	400	24		
Jun	400	4800	5000	200	24		
Jul	200	5200	4000	1400	26	2	
Aug	1400	5200	3000	3600	26		
Sep	3600	5200	4800	4000	26		
Oct	4000	5200	6400	2800	26		
Nov	2800	5200	7000	1000	26		
Dec	1000	5200	6200	0	26		
		60000	60000	20800		2	1

The inventory storage cost is $20,800, the cost of employing new staff is $1,200, the cost of terminating staff is $300 to give a total cost for this plan of $22,300.

Activity 2.12

Johnson and Clark (2008) identified that the customer often perceives that the time in the queue is longer than it really is. They observed the following:

- Unoccupied time feels longer than occupied time.
- Pre-process waits feel longer than in-process waits.
- Anxiety makes the wait seem longer.
- Uncertain waits are longer than known, finite waits.
- Unexplained waits seem longer than explained waits.
- Unfair waits are longer than equitable waits.
- The more valuable the service, the longer the customer waits.
- Solo waiting feels longer than group waiting.
- Uncomfortable waits feel longer than comfortable waits.
- New or infrequent users feel they wait longer.

Activity 2.13

All answers are in the learning material.