

Chapter 2

Forecasting

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I. Introduction

Forecasts are a basic input in the decision processes of operations management because they provide information on future demand. The primary goal of operations management is to **match supply to demand**. Having a forecast of demand is essential for determining how much capacity or supply will be needed to meet demand. For instance, operations needs to know what **capacity** will be needed to make **staffing** and **equipment** decisions, **budgets** must be prepared, **purchasing** needs information for ordering from suppliers, and **supply chain partners** need to make their plans.

Two aspects of forecasts are important. One is **the expected level of demand**; the other is **the degree of accuracy** that can be assigned to a forecast (i.e., the potential size of forecast error). The expected level of demand can be a function of some structural variation, such as a trend or seasonal variation. Forecast accuracy is a function of the ability of forecasters to correctly model demand, random variation, and sometimes unforeseen events.



Forecasts are made with reference to a specific **time horizon**. The time horizon may be fairly short (e.g., an hour, day, week, or month), or somewhat longer (e.g., the next six months, the next year, the next five years, or the life of a product or service). Short-term forecasts pertain to ongoing operations. Long-range forecasts can be an important strategic planning tool. Long-term forecasts pertain to new products or services, new equipment, new facilities, or something else that will require a somewhat long lead time to develop, construct, or otherwise implement.

Forecasts are the basis for budgeting, planning capacity, sales, production and inventory, personnel, purchasing, and more. Forecasts play an important role in the planning process because they enable managers to anticipate the future so they can plan accordingly.



II. Features common to all forecasts

A wide variety of **forecasting techniques** are in use. In many aspects, they are quite different from each other. Nonetheless, certain features are common to all, and it is important to recognize them.

1. Forecasting techniques generally assume that the same underlying causal system that existed in the past will continue to exist in the future.
2. Forecasts are not perfect; actual results usually differ from predicted values. Allowances should be made for forecast errors.
3. Forecast accuracy decreases as the time period covered by the forecast - the *time horizon* - increases. Generally speaking, short-range forecasts must contend with fewer uncertainties than longer-range forecasts, so they tend to be more accurate.



III. Elements of a good forecast

A properly prepared forecast should fulfill certain requirements:

1. The forecast should be **timely**. Usually, a certain amount of time is needed to respond to the information contained in a forecast. For example, capacity cannot be expanded overnight, nor can inventory levels be changed immediately. Hence, the forecasting horizon must cover the time necessary to implement possible changes.
2. The forecast should be **accurate**, and the degree of accuracy should be stated. This will enable users to plan for possible errors and will provide a basis for comparing alternative forecasts.
3. The forecast should be **reliable**; it should work consistently. A technique that sometimes provides a good forecast and sometimes a poor one will leave users with the uneasy feeling that they may get burned every time a new forecast is issued.
4. The forecast should be expressed in **meaningful units**. Financial planners need to know how many *dollars* will be needed, production planners need to know how many *units* will be needed, and schedulers need to know what *machines* and *skills* will be required. The choice of units depends on user needs.



IV. Steps in the forecasting process

There are **six basic steps** in the forecasting process:

1. Determine the purpose of the forecast. How will it be used and when will it be needed? This step will provide an indication of the level of detail required in the forecast, the amount of resources that can be justified, and the level of accuracy necessary.

2. Establish a time horizon. The forecast must indicate a time interval, keeping in mind that accuracy decreases as the time horizon increases.

3. Obtain, clean, and analyze appropriate data. Obtaining the data can involve significant effort. Once obtained, the data may need to be “cleaned” to get rid of outliers and obviously incorrect data before analysis.

4. Select a forecasting technique.

5. Make the forecast.

6. Monitor the forecast. A forecast has to be monitored to determine whether it is performing in a satisfactory manner. If it is not, reexamine the method, assumptions, validity of data, and so on; modify as needed; and prepare a revised forecast.



V. Forecast accuracy

Accuracy is a vital aspect of forecasting, so forecasters want to minimize forecast errors. However, the complex nature of most real-world variables makes it almost impossible to correctly predict future values of those variables on a regular basis. Moreover, because random variation is always present, there will always be some residual error, even if all other factors have been accounted for. Consequently, it is important to include an indication of the extent to which the forecast might deviate from the value of the variable that actually occurs. This will provide the forecast user with a better perspective on how far off a forecast might be.

Decision makers will want to include accuracy as a factor when choosing among different techniques, along with cost. Accurate forecasts are necessary for the success of daily activities of every business organization. Forecasts are the basis for an organization's schedules, and unless the forecasts are accurate, schedules will be generated that may provide for too few or too many resources, too little or too much output, the wrong output, or the wrong timing of output, all of which can lead to additional costs, dissatisfied customers, and headaches for managers.



Forecast error is the difference between the value that occurs and the value that was predicted for a given time period. Hence, **Error = Actual – Forecast** :

$$e_t = A_t - F_t$$

Positive errors result when the forecast is too low, negative errors when the forecast is too high.

Forecast errors influence decisions in two somewhat different ways. One is in making a choice between various forecasting alternatives, and the other is in evaluating the success or failure of a technique in use.



Summarizing Forecast Accuracy

Forecast accuracy is a significant factor when deciding among forecasting alternatives. Accuracy is based on the historical error performance of a forecast.

Three commonly used measures for summarizing historical errors are:

- ❑ the **mean absolute deviation (MAD)** : average absolute error,
- ❑ the **mean squared error (MSE)** : average of squared errors,
- ❑ and the **mean absolute percent error (MAPE)** : average absolute percent error

$$MAD = \frac{\sum |Actual_t - Forecast_t|}{n}$$

$$MSE = \frac{\sum (Actual_t - Forecast_t)^2}{n-1}$$

$$MAPE = \frac{\sum \frac{|Actual_t - Forecast_t|}{Actual_t} \times 100}{n}$$



Example

Compute MAD, MSE, and MAPE for the following data, showing actual and forecasted numbers of accounts serviced

Period	Actual	Forecast
1	217	215
2	213	216
3	216	215
4	210	214
5	213	211
6	219	214



VI. Approaches to forecasting

There are **two general approaches** to forecasting: **qualitative** and **quantitative**.

- ❑ **Qualitative methods** consist mainly of subjective inputs, which often defy precise numerical description.
- ❑ **Quantitative methods** involve either the projection of historical data or the development of associative models that attempt to utilize causal (explanatory) variables to make a forecast.

Qualitative techniques permit inclusion of soft information (e.g., human factors, personal opinions, hunches) in the forecasting process. Those factors are often omitted or downplayed when quantitative techniques are used because they are difficult or impossible to quantify.

Quantitative techniques consist mainly of analyzing objective, or hard, data. They usually avoid personal biases that sometimes contaminate qualitative methods. In practice, either approach or a combination of both approaches might be used to develop a forecast.



Forecasting techniques that are classified as **judgmental**, **time-series**, or **associative**.

- ❑ **Judgmental forecasts** rely on analysis of subjective inputs obtained from various sources, such as consumer surveys, the sales staff, managers and executives, and panels of experts. Quite frequently, these sources provide insights that are not otherwise available.
- ❑ **Time-series forecasts** simply attempt to project past experience into the future. These techniques use historical data with the assumption that the future will be like the past. Some models merely attempt to smooth out random variations in historical data; others attempt to identify specific patterns in the data and project or extrapolate those patterns into the future, without trying to identify causes of the patterns.
- ❑ **Associative models** use equations that consist of one or more explanatory variables that can be used to predict demand. For example, demand for paint might be related to variables such as the price per gallon and the amount spent on advertising, as well as to specific characteristics of the paint (e.g., drying time, ease of cleanup).

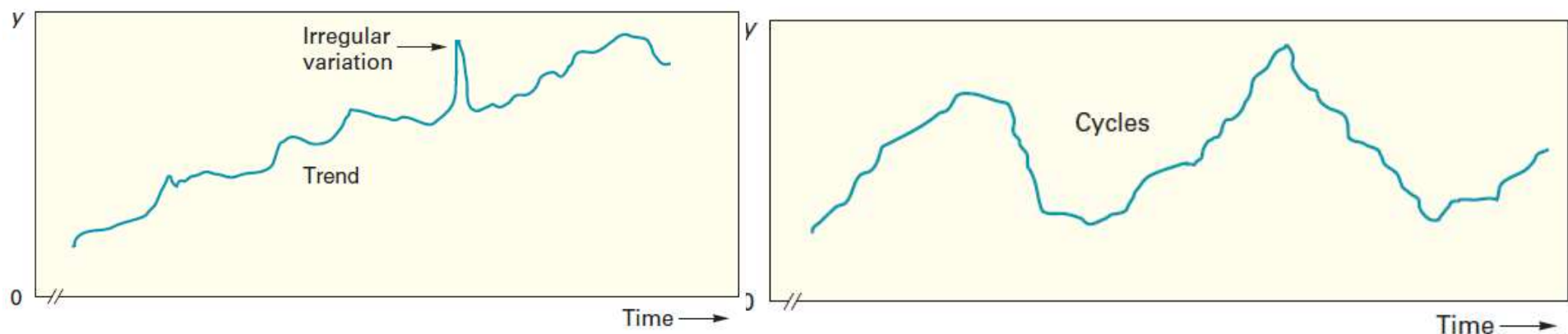


VII. Forecasts based on time-series data

A **time series** is a time-ordered sequence of observations taken at regular intervals (hourly, daily, weekly, monthly, quarterly, annually). The data may be measurements of demand, earnings, profits, shipments, accidents, output, precipitation, productivity, or the consumer price index.

Forecasting techniques based on time-series data are made on the assumption that future values of the series can be estimated from past values. Although no attempt is made to identify variables that influence the series.

Analysis of time-series data requires the analyst to identify the underlying behavior of the series. This can often be accomplished by merely *plotting the data* and visually examining the plot. One or more patterns might appear: **trends**, **seasonal variations**, **cycles**, or **variations around an average**. In addition, there will be **random** and perhaps **irregular variations**.



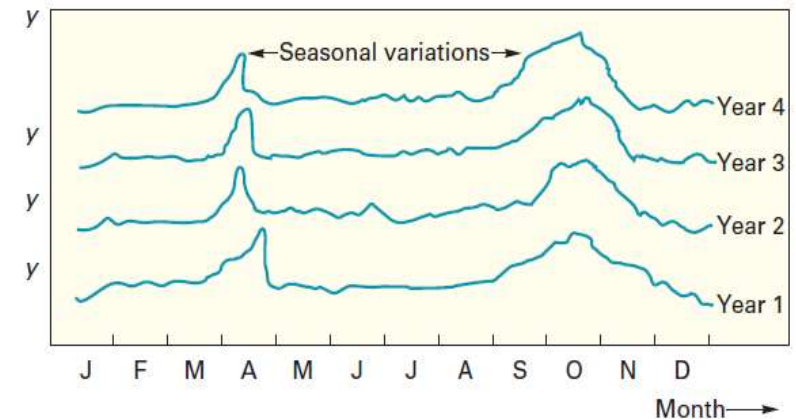
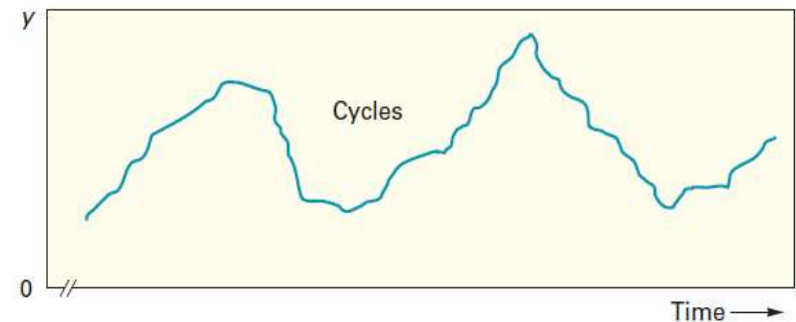
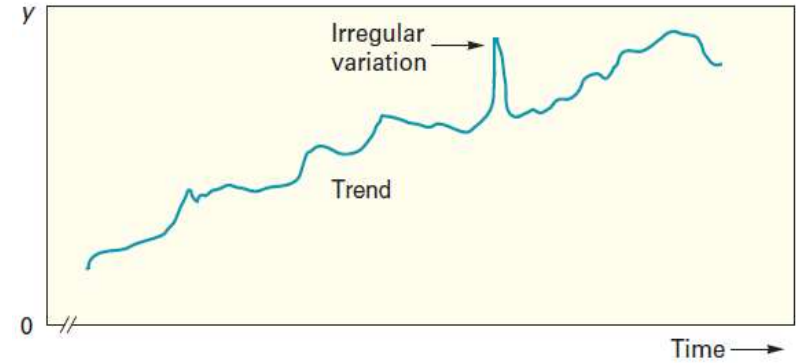
Trend refers to a long-term upward or downward movement in the data. Population shifts, changing incomes, and cultural changes often account for such movements.

Seasonality refers to short-term, fairly regular variations generally related to factors such as the calendar or time of day. Restaurants, supermarkets, and theaters experience weekly and even daily “seasonal” variations.

Cycles are wavelike variations of more than one year’s duration. These are often related to a variety of economic, political, and even agricultural conditions.

Irregular variations are due to unusual circumstances such as severe weather conditions, strikes, or a major change in a product or service. They do not reflect typical behavior, and their inclusion in the series can distort the overall picture. Whenever possible, these should be identified and removed from the data.

Random variations are residual variations that remain after all other behaviors have been accounted for.



Averaging techniques generate forecasts that reflect recent values of a time series (e.g., the average value over the last several periods). These techniques work best when a series tends to vary around an average, although they also can handle step changes or gradual changes in the level of the series. Three techniques for averaging are described:

1. Moving average.

2. Weighted moving average.

3. Exponential smoothing.



VII.1. Moving average

A **moving average** forecast uses a number of the most recent actual data values in generating a forecast. The moving average forecast can be computed using the following equation:

$$F_t = MA_n = \frac{\sum_{i=1}^n A_{t-i}}{n} = \frac{A_{t-n} + \dots + A_{t-2} + A_{t-1}}{n}$$

where

$$\left\{ \begin{array}{l} F_t = \text{Forecast for time period } t \\ MA_n = \text{n period moving average} \\ A_{t-1} = \text{Actual value in period } t-1 \\ n = \text{Number of periods in the moving average} \end{array} \right.$$

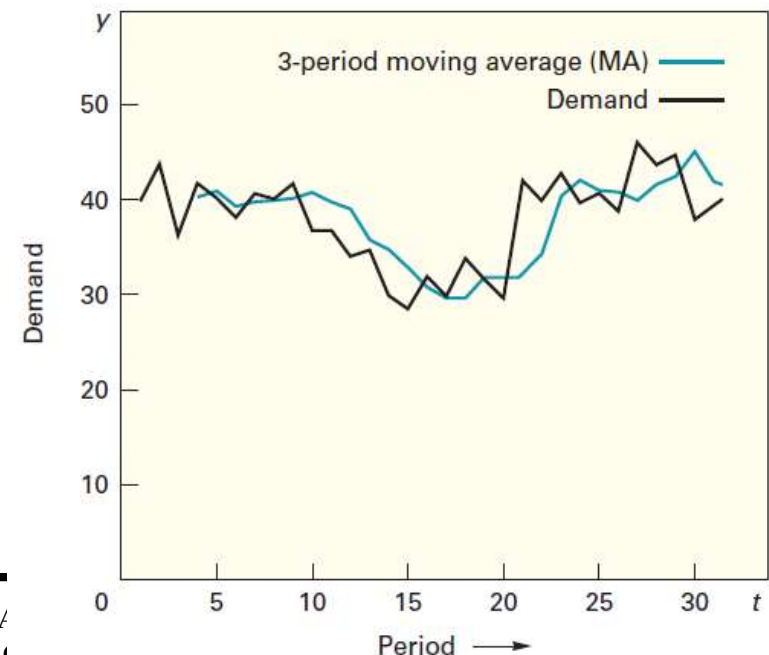


Example

Compute a three-period moving average forecast given demand for shopping carts for the last five periods.

Period	Demand
1	42
2	40
3	43
4	40
5	41

Note that in a moving average, as each new actual value becomes available, the forecast is updated by adding the newest value and dropping the oldest and then recomputing the average. Consequently, the forecast “moves” by reflecting only the most recent values.



VII.2. Weighted moving average

A **weighted average** is similar to a moving average, except that it assigns more weight to the most recent values in a time series. For instance, the most recent value might be assigned a weight of .40, the next most recent value a weight of .30, the next after that a weight of .20, and the next after that a weight of .10.

Note that the weights must sum to 1.00, and that the heaviest weights are assigned to the most recent values.

$$F_t = w_t(A_t) + w_{t-1}(A_{t-1}) + \dots + w_{t-n}(A_{t-n})$$

$$\text{where } \begin{cases} w_t = \text{Weight for the period } t \\ A_t = \text{Actual value in period } t \end{cases}$$



Example

Given the following demand data,

- ❑ Compute a weighted average forecast using a weight of .40 for the most recent period, .30 for the next most recent, .20 for the next, and .10 for the next.
- ❑ If the actual demand for period 6 is 39, forecast demand for period 7 using the same weights as in part a.

Period	Demand
1	42
2	40
3	43
4	40
5	41

The advantage of a weighted average over a simple moving average is that the weighted average is more reflective of the most recent occurrences. However, the choice of weights is somewhat arbitrary and generally involves the use of trial and error to find a suitable weighting scheme.



VII.3. Exponential smoothing

Exponential smoothing is a sophisticated weighted averaging method that is still relatively easy to use and understand. Each new forecast is based on the previous forecast plus a percentage of the difference between that forecast and the actual value of the series at that point. That is:

$$\text{Next forecast} = \text{Previous forecast} + \alpha \cdot (\text{Actual} - \text{Previous forecast})$$

where

- (Actual - Previous forecast) represents the forecast error
- α is a percentage of the error.

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

$$\text{where} \left\{ \begin{array}{l} F_t = \text{Forecast for period } t \\ F_{t-1} = \text{Forecast for the previous period } t-1 \\ \alpha = \text{Smoothing constant} \\ A_{t-1} = \text{Actual demand or sales for the previous period} \end{array} \right.$$



Example

Compare the error performance of the two forecasting techniques using MAD, MSE, and MAPE : a two-period moving average, and exponential smoothing with $\alpha = 0.10$ for periods 3 through 11.

Period	Demand
1	42
2	40
3	43
4	40
5	41
6	39
7	46
8	44
9	45
10	38
11	40

