Doc 8991
AT/722/3

# Manual on Air Traffic Forecasting

Approved by the Secretary General
and published under his authority

Third Edition — 2006

International Civil Aviation Organization

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# AMENDMENTS

The issue of amendments is announced regularly in the *ICAO Journal* and in the supplements to the *Catalogue of ICAO Publications and Audio-visual Training Aids*, which holders of this publication should consult. The space below is provided to keep a record of such amendments.

## RECORD OF AMENDMENTS AND CORRIGENDA

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# FOREWORD

1. The work of the Organization in the field of air traffic forecasting is governed by Appendix C of Assembly Resolution A35-18 *(Consolidated statement of continuing ICAO policies in the air transport field)*:

Appendix C — Forecasting and Economic Planning

> *Whereas* Contracting States require global and regional forecasts of future civil aviation developments for various purposes;
>
> *Whereas* the Council, in carrying out its continuing functions in the economic field, must foresee future developments likely to require action by the Organization and must initiate such action in good time; and
>
> *Whereas* the Organization requires specific forecasts and economic support for airports and air navigation systems planning and environmental planning purposes;
>
> *The Assembly:*
>
> 1. *Requests* the Council to prepare and maintain, as necessary, long-term and medium-term forecasts of future trends and developments in civil aviation of both a general and a specific kind, including, where possible, regional as well as global data, and to make these available to Contracting States;
>
> 2. *Requests* the Council to develop methodologies and procedures for the preparation of forecasts, the analysis of cost-benefit or cost-effectiveness, and the development of business cases, to meet the needs of the regional air navigation planning groups and, as required, other systems or environmental planning bodies of the Organization; and
>
> 3. *Requests* the Council to make arrangements to collect and develop material on current forecasting methods both for the purposes described in clauses 1 and 2 and for dissemination to Contracting States from time to time as guidance in their own forecasting and economic planning.

2. This manual represents a partial fulfilment of the requirement set out in the third resolving clause "to collect and develop material on current forecasting methods … for dissemination to Contracting States from time to time as guidance in their own forecasting and economic planning". The first edition of this manual was published in 1972. The second edition, published in 1985, took into account additional material received by ICAO and experience gained during the intervening period. This third edition takes into account new material developed by ICAO and additional experience gained since 1985.

3. This manual is addressed to civil aviation administration personnel, airline planners, planners of airports and air navigation systems and others actively engaged in practical forecasting work. It provides a survey of techniques currently used for air traffic forecasting, and practical guidance on the application of these techniques. The advantages and disadvantages of the techniques as well as the criteria for selection of a particular technique for the forecast concerned are discussed. These techniques can vary considerably in their usefulness and sophistication.

4. The manual is divided into three parts. Part I presents the techniques that are available for air traffic forecasting purposes. These are classified into three broad categories: quantitative, qualitative and

decision analysis. Within quantitative forecasting methods, time-series analysis using both trend projection and decomposition methods are presented. This is followed by a presentation of causal methods for traffic forecasting based on the formulation of cause and effect relationships between air traffic demand and the underlying causal factors. Econometric analysis methods, widely recognized for the development of air traffic forecasts, are described in detail, along with procedures to interpret and understand summary statistics and the pros and cons of estimation procedures. This is followed by a presentation of other causal methods. Part I also presents other methods of forecasting under "qualitative forecasting methods" and "decision analysis". A discussion of various forecasting time horizons and forecasting accuracy is included. This is followed by a set of illustrative examples from various regions of the world including an illustration of the development of a longer term (fifty-year) forecast.

5. Part II of this manual presents methods and procedures for forecasting for aviation planning, including forecasting for air navigation planning, airline planning and airport planning purposes. The methods developed by ICAO and its regional traffic forecasting groups (TFGs), including those required for the progressive implementation of the components of the communications, navigation, surveillance/air traffic management (CNS/ATM) systems, are included in this section.

6. Part III of this manual is devoted to case studies and methodologies developed by selected Contracting States and other organizations to develop forecasts for the requirements of civil aviation, including aviation forecasting methods used by the European Organisation for the Safety of Air Navigation (EUROCONTROL), Canada, India and Tunisia. This is followed by a presentation of methodologies used in forecasting for airports including methods applied by airports in India and Newark Airport in the United States.

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# INTRODUCTION

1. The air transport industry has experienced rapid growth with an average annual growth rate of almost 10 per cent over the past 55 years. This rate is just over three times the average growth of the gross domestic product (GDP) in real terms, the broadest available measure of world economic activity. This increase in air traffic has been achieved through technological advances, productivity improvements and increased consumer spending along with the progressive de-regulation of the air transport markets.

2. Civil aviation, through a complex interaction with other economic sectors, benefits from and contributes to the economic development of nations. Because of the increasing role of air transport in the economic development of nations and regions, it is important to take due account of the economic and social benefits that an efficient air transport system can offer and to ensure that future air transport needs are properly assessed, together with the associated resources that need to be provided.

3. With the change in dynamics of the air transport industry, the past three decades have seen a number of developments in the forecasting field applicable to various sectors of civil aviation planning. The ultimate test of any forecast is whether or not it is capable of predicting future outcome fairly accurately. Aviation forecasters and planners have a choice of ways to forecast, ranging from purely intuitive or judgemental approaches to highly structured and complex quantitative methods, including econometrics and simultaneous equations models.

4. Econometric theory has also progressed a great deal during the last three decades with the availability of personal computers and the infusion of new concepts. Economic theory applicable to forecasting work is becoming increasingly sophisticated. Sophistication, in turn, can obscure the fundamental difference between theoretical statistics and econometrics in their application in real-world examples. Even though one estimation procedure may be better than another on paper, the distinction may not be clear in practice.

5. In order to make efficient use of forecasts developed by quantitative methods, it is necessary that the results be easily understood by, and acceptable to, the decision maker or the end user. The degree of acceptability by the end user depends on the ability to explain and interpret the results of the forecasting methods and their characteristics. Different forecasting methods invariably can and do tend to produce different forecasts from the same set of historical time-series data. Such discrepancies between theoretical predictions and empirical results may be due to the inaccuracy of the assumptions of the major factors affecting traffic trends. It is therefore prudent to present the results of a forecasting task in the form of a range of forecasts associated with various assumptions.

6. This edition of the manual includes broader and more detailed coverage of methods that hold the greatest potential for aviation forecasters. Examples and case studies have been included, wherever possible, to clarify and expand on methods included in the previous edition. This manual also deals with forecasting methods that have gained widespread acceptance over the years and tries to present some questions frequently asked by aviation forecasters and suggest some answers. In doing so, the relevance of a particular tool to a given forecasting situation is emphasized rather than its theoretical properties under appropriate sets of assumptions. Other additions and significant revisions have also been made to this edition.

# PART I — FORECASTING METHODOLOGIES

1. Reliable forecasts of civil aviation activity play a critical role in the planning process of States, airports, airlines, engine and airframe manufacturers, suppliers, air navigation service providers and other relevant organizations.

2. The first consideration in terms of a forecast is its intended use. Forecasting has a short-term, medium-term or long-term time horizon depending on the intended use, the length of which can vary from industry to industry, as well as the particular application concerned. Forecasting is not an independent discipline but is a part of the overall aviation planning process. The form of the output, the level of the detail and the rigour of the method used will vary depending on the intended use of the forecast. In the civil aviation field, forecasts generally are used to:

a) assist States in facilitating the orderly development of civil aviation and to assist all levels of government in the planning of airspace and airport infrastructure such as air traffic control, terminal facilities, access roads, runways, taxiways and aprons;

b) assist airlines in the long-term planning of equipment and route structures; and

c) assist aircraft manufacturers in planning future types of aircraft (in terms of size and range) and when to develop them.

3. Forecasting methods in general can be divided into three broad categories: quantitative or mathematical, qualitative or judgemental, and decision analysis, which is a combination of the first two methods, as illustrated in Figure 1-1.

4. Forecasting techniques that start with historical data and develop a forecast based on a set of rules fall into the category of quantitative methods. Situations in which such data are not readily available or applicable and in which experience and judgement have to be used are generally best suited for the application of qualitative forecasting methods. Numerous methods exist for analysing time-series data. The methods, which are possible in particular circumstances, may be limited by a lack of data or resources. In general, however, a more reliable forecast may be obtained by employing more than one approach and consolidating differing results through judgement and knowledge of the markets concerned.

## QUANTITATIVE FORECASTING METHODS

5. Quantitative forecasting methods can be broadly classified into two major subcategories: time-series analysis and causal methods. Some of the more widely used techniques in these two subcategories include trend projections, decomposition methods and regression analysis.

### TIME-SERIES ANALYSIS

6. The time-series analysis methods are largely based on the assumption that historical patterns will continue, and they rely heavily on the availability of historical data.

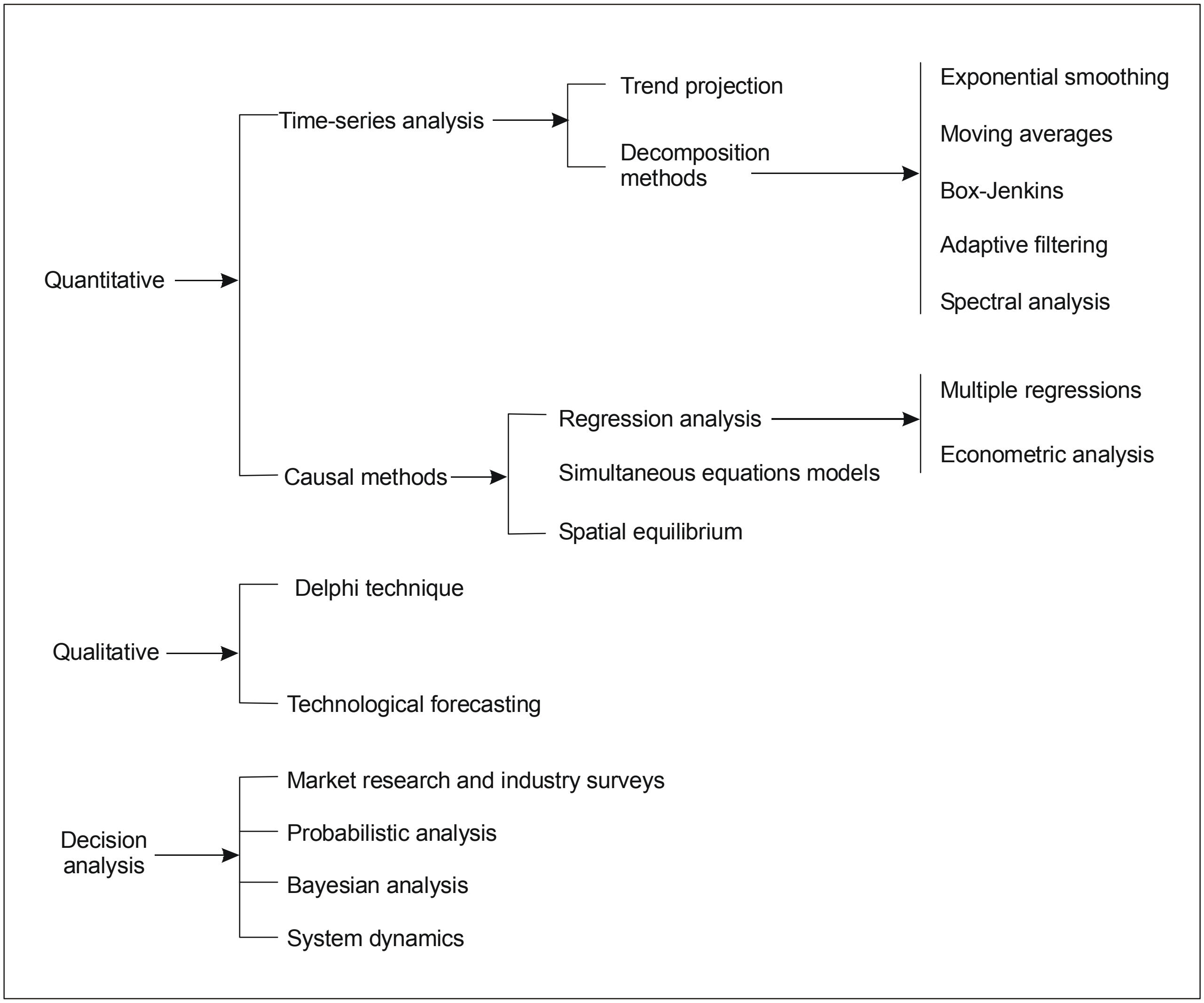


**Figure 1-1. Alternative forecasting techniques**

## TREND PROJECTION

7. A first step when forecasting air traffic activity is usually to study the historical data (time series) and determine the trend in traffic development. In the context of medium-term or long-term forecasting, a traffic trend represents the development in traffic over many years, isolated from short-term fluctuations in traffic levels. When deriving a medium-term or long-term forecast by extrapolating from the traffic trend, the forecaster assumes that the factors which determined the historical development of the traffic will continue to operate in the future as in the past, except that their impact may change gradually, and steady-state conditions will continue into the future. The appropriateness of using trend analysis in forecasting depends heavily on stability in past developments and the confidence of the forecaster that the assumption of continuing trends is appropriate to the particular operating environment.

8. In its simplest form, trend projection analysis is nothing more complicated than plotting the traffic data series on a graph. The traffic variable to be forecast (the dependent variable) is plotted on the vertical axis, and time (the explanatory or independent variable) is plotted on the horizontal axis. When each point in the time series is plotted, a smooth curve that seems to come close to all the points may then be drawn in freehand style, or a straight edge can be used to put a line through the data.

9. A trend may be stable in absolute terms (linear growth) or in percentage terms (exponential growth), but it can also suggest an ultimate limit to growth, particularly if the time span extends over several decades. The type of trend curve that best fits a given time series of traffic data may be determined by using different types of graph paper and different ways of plotting the data. Plotting the data on ordinary graph paper with even spacing (or arithmetic grid paper) will show a linear growth pattern as a straight line. An exponential growth pattern (constant percentage growth rate) will appear as a straight line on linear-logarithmic paper (linear timescale, logarithmic traffic scale), and the slope of the curve at any point will be proportional to the percentage rate of growth or decline at that point in time.

10. After the data are plotted on graph paper and a trend curve that appears to fit the data is established, the forecaster can then simply extend the visually fitted trend curve to the future period for which the forecast is desired. The forecast data can then be read from the graph and presented in a table. This is considered to be a simple linear extrapolation of the data.

11. Trend projection analysis methods use mathematical techniques to determine the best fit line through the data, just as is done by using graph paper and a straight edge. In the more sophisticated trend projection methods, the mathematics and the shape of the line being fitted to the data are more complex. Illustrative examples of the use of trend projection can be found in paragraphs 116 to 126 and 143 to 151 of this part of the manual.

**Specifications of trend curves**

12. The different types of trend curves can be represented by various mathematical relationships. The mathematical formulations, which correspond to the trend curves illustrated in Figure 1-2, are given below. In each case, the dependent variable $Y$ is traffic, the explanatory variable $T$ is time (normally measured in years) and $a$, $b$ and $c$ are all constants (sometimes called coefficients) whose values can be estimated from the data.

a) *Linear (or straight line):*

$$Y = a + bT$$

This implies a constant annual increment $b$ in the traffic level, and a declining rate of growth.

b) *Exponential:*

$$Y = a(1 + b)^T$$

$$\log Y = \log a + T \log (1 + b)$$

With $b$ positive and normally less than one, this implies a constant annual percentage increase in traffic at a rate $100b$. By taking logarithms, the exponential formulation can be converted to a linear formulation.

c) *Parabolic:*

$$Y = a + bT + cT^2$$

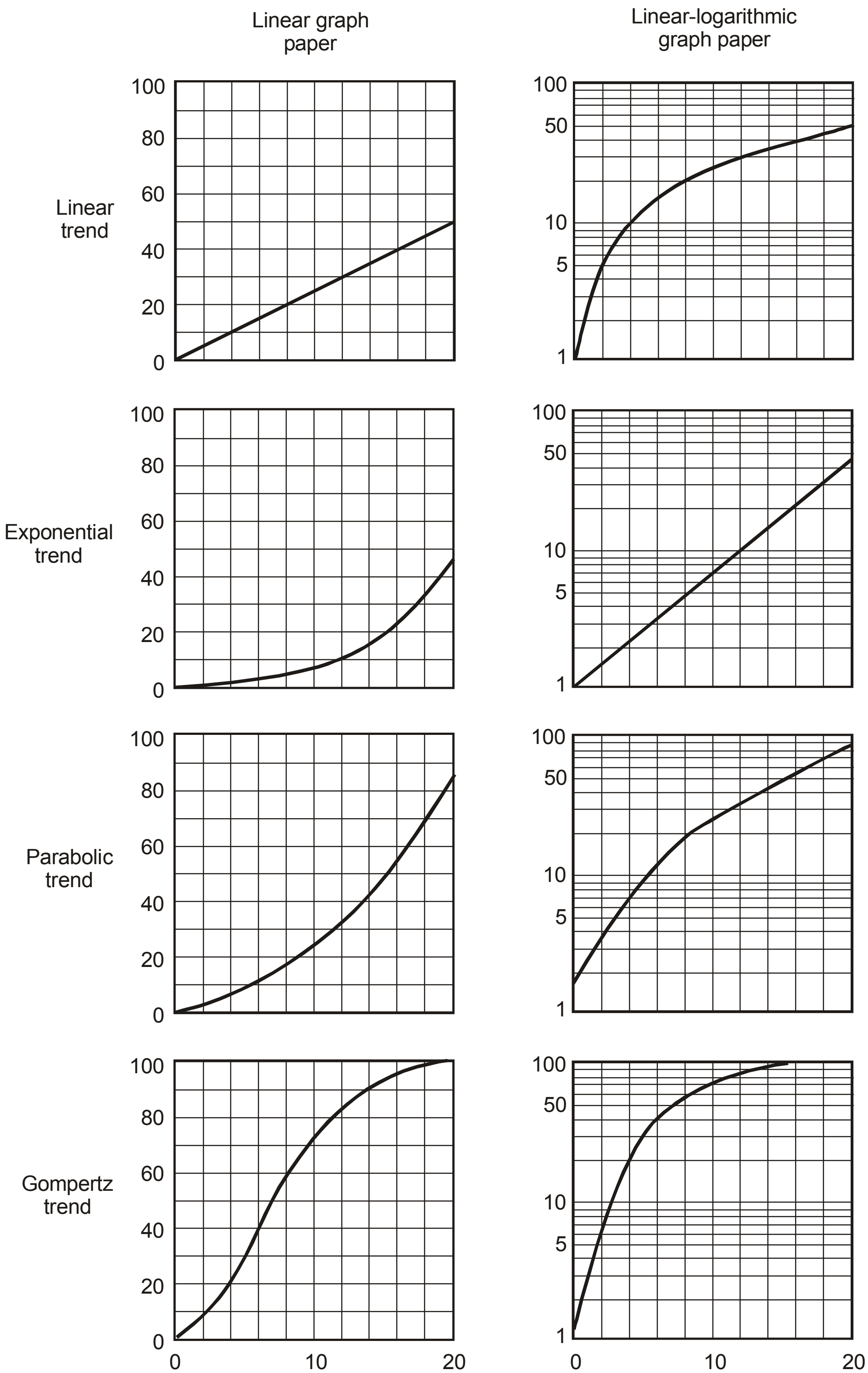


**Figure 1-2. Typical trend curves**

With three constants, this family of curves covers a wide variety of shapes (either concave or convex). For *c* greater than zero, growth curves of this type have the characteristics that growth in absolute terms per unit time increases linearly with time while the rate of growth decreases with time.

d) *Gompertz:*

$$Y = ab^{-c^T}$$

$\log Y = \log a - c^T \log b, \qquad 0 < c < 1$

This curve eventually approaches a saturation level *a* and may be found appropriate to represent traffic developments over very long time periods.

### Statistical estimation

13. One obvious difficulty with graphical extrapolation is the absence of any objective criteria for establishing which trend curve "best fits" the data. If visual inspection by the forecaster is to be the criterion, it is likely that different forecasters will come up with different curves, as best fit, for the same data. A more objective method of establishing a trend curve is to use statistical techniques. For each of the above mathematical formulations there is one particular set of values of the constant coefficients (*a*, *b* and *c*) that will provide a better fit of the equation to the data than all other sets of coefficients.

14. For example, if it has been found that a linear equation suitably represents the trend of the time-series data, the procedure of simple linear regression can be used to determine the values of coefficients *a* and *b* that provide the best fit to the data. This is done on the basis of the least squares criterion, which requires that the line that is fitted to the sample data be such that the sum of the squares of the vertical deviations (distances) from the data points to the line be a minimum.

## DECOMPOSITION METHODS

15. Decomposition methods involve the dissection of the problem into various components. These methods are particularly relevant when strong seasonality or cyclical patterns exist in the historical data. These methods can be used to identify three aspects of the underlying pattern of the data: the trend factor, the seasonal factor and any cyclical factor that may exist.

### Exponential smoothing

16. A general class of widely used forecasting techniques that attempts to deal with the causes of fluctuations in a time series (trend, seasonality and cyclical factors) is that of smoothing. The two most common smoothing techniques are moving averages and exponential smoothing. Exponential smoothing, in general, draws upon the philosophy of decomposition. The exponential smoothing approach to time series is similar to the moving averages approach. However, it places more emphasis on the most recent data, to increase their influence on the forecast. In doing so, it is important to recognize the seasonality inherent in the airline traffic data if monthly or quarterly forecasts are considered. In such cases, depending upon the month of the year, data would have to be de-seasonalized. A smoothing factor would determine how much weight is to be placed on, for example, various months of the year. The notion of giving greater weight to more recent data is one that has strong intuitive appeal to the analyst, depending on the particular circumstances, and is straightforward to apply.

**Moving averages**

17. As mentioned above, the moving averages technique is similar to exponential smoothing. The only conceptual difference is that each observation is weighted equally. For example, a moving average of four observations would be:

$$Y_{t+1} = \frac{Y_{t-3} + Y_{t-2} + Y_{t-1} + Y_t}{4}$$

Because of the equal weighting, moving averages tend to lag the current situation more than exponential smoothing. The advantage of the moving averages approach compared to exponential smoothing is that the former is much simpler. A disadvantage of the moving averages approach is that a longer data series is required for the analysis. Forecasts from moving averages can be used, as those from exponential smoothing, for short-term forecasts. This can be achieved by deviating from the standard formulation and assigning a relatively higher weight to the most recent observation, provided there is justification for doing so. A technique called auto regressive moving average (ARMA) can also be used, where the forecasts are expressed as a linear combination of past actual values and/or past computed error, since each new forecast based on a moving average is an adjustment of the preceding forecast.

**Box-Jenkins**

18. Another approach in the analysis of time series is the Box-Jenkins approach. This method is suited to handle complex time-series data in which a variety of patterns exist such as a continuation of a trend, a seasonal factor and a cyclical factor. Typically, it uses the most recent data point as the starting value and then analyses the recent forecasting errors to establish the adjustment factors for future time periods. For example, if the forecast was 10 per cent lower in the previous period, the forecast for the next period might be adjusted by some fraction of this error (say 5 to 7 per cent) for the next period. This description also suggests that the Box-Jenkins method is only appropriate for very short-term forecasts. The method allows for much flexibility; however, it also calls for much subjectivity.

**Adaptive filtering**

19. The method of forecasting with adaptive filtering is another approach for determining the appropriate set of weights for each of the time periods. This method takes an initial set of weights and computes a forecast for the next period or the most recent year for which data are available. The process is repeated by adjusting the weights to reduce the error. The weights are finalized to minimize the mean squared error. Thus, the technique of adaptive filtering states how the weights should be adjusted after the forecast error has been computed.

**Spectral analysis**

20. The spectral analysis method can be used to explain the variation of the data using different types of complex mathematical curves. It is an approach used to study the cyclical variation over time. The data can be decomposed, for example, into a series of sine waves of different frequencies and magnitudes. Such complex curves should only be used if prior knowledge exists or if the data clearly demonstrate that such a form could be adapted in the forecasting process.

## CAUSAL METHODS

21. Extensive use has been made of trend forecasting by basing judgement on past growth trends, which the analyst simply extrapolates, based on the historical values. In the short term, this approach appears to be reliable, especially when the extrapolation procedure is applied with modified growth rates to account for short-term disturbance in underlying trends. In the long term, this type of extrapolation is likely to be unreliable and is theoretically difficult to substantiate. Consequently, forecasts derived by taking into account how economic, social and operational conditions affect the development of traffic offer an alternative to time-series analysis.

22. Causal methods infer a cause-and-effect relationship, hence the name. When used successfully, causal methods can predict the ups and downs of the market. This mathematical process is actually a testing procedure. The procedure is designed to evaluate whether the relationship of the dependent variable (as expressed in the causal model) to the independent (explanatory) variables is significantly related to the movements of these variables.

## REGRESSION ANALYSIS

23. Of the causal methods described in Figure 1-1, regression analysis is by far the most popular method of forecasting civil aviation demand. In regression analysis, the forecast is based not only on the historical values of the item being forecast but also on other variables that are considered to have a causal relationship. Multiple regression analysis takes into account more than a single explanatory variable, in contrast to the one variable used in simple regression analysis.

### Econometric analysis

24. The use of multiple regression analysis with a price-income structure is generally referred to as econometric analysis or econometric modelling. The starting point for an econometric analysis is, in effect, a regression equation model that postulates a causal relationship between a dependent variable and one or more explanatory variables. Dependent variables in the analysis of traffic demand, in general, are historical traffic data measured in terms of passengers or revenue passenger-kilometres (RPK) and tonnes of freight or freight-tonne kilometres (FTK). The explanatory (or independent) variables are those variables which would have an influence on the demand for air travel. The econometric model attempts to explain the demand for air travel as being caused by the changes in the explanatory variables. Conceptually, the changes in the explanatory variables are observed independently of the causal relationship expressed by the model. Illustrative examples of the use of econometric analysis can be found in paragraphs 127 to 142.

25. Using econometric analysis, the analyst tries to estimate the change in demand from year (1) to year (2). Under such conditions, the change in demand can be explained by a change that occurs along the demand curve as well as a shift of the demand curve, as illustrated in Figure 1-3.

26. If a price decline and increased economic activity both occur, then demand will increase from $X_1$ to $X_4$. Therefore, the shift from $X_1$ to $X_4$ explains the combined increase in demand from period (1) to period (2) due to a decrease in average prices and an increase in economic activity as well as changes in demographics where applicable. Likewise, an increase in prices will reduce demand, and a decline in economic activity will shift the demand curve to the left rather than to the right.

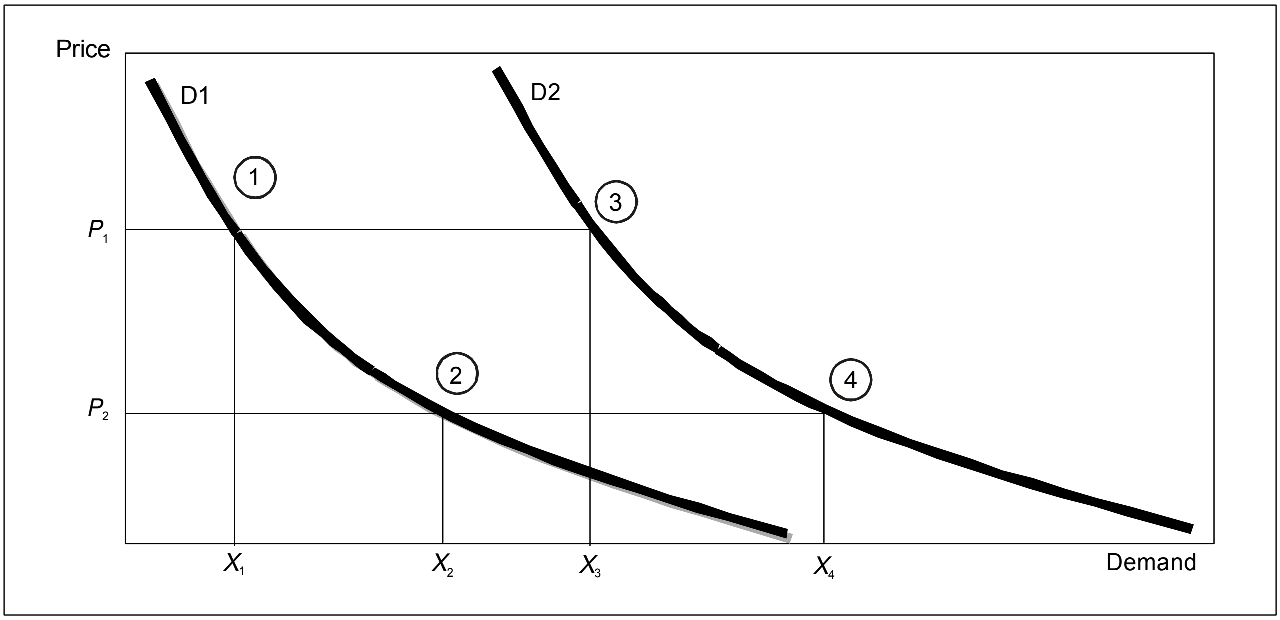


**Figure 1-3. Demand curve**

27. In economic terms, the increase in demand from $X_1$ to $X_2$ (change along the demand curve) can be explained as the price effect, while the increase in demand from $X_2$ to $X_4$ (shift of the demand curve) can be explained as the income effect. The magnitude of the change along the demand curve is a measure of the elasticity of price, while the magnitude of the shift of the curve is a measure of the elasticity of income.

28. The change along the demand curve from (1) to (2) is due to a decline in price (average fare), indicating a demand increase from $X_1$ to $X_2$. Likewise, the shift of the demand curve from (1) to (3) can be explained by a change in economic activity indicating a demand increase from $X_1$ to $X_3$ provided the average price remained the same. The change in demand from $X_1$ to $X_4$ provides the combined effect of changes in average fares and economic activity and possibly other related demographic factors.

### *Elasticity of demand*

29. Elasticity is an expression of the relationship between two variables. The concept of elasticity is widely used to describe the relationship between the dependent variable ($Y$), air traffic, and explanatory variables ($X$) such as income, price, etc. For some of the commonly used functional forms, the elasticity of demand can be derived as described below.

a) Consider an equation having a functional form:

$$\log Y = a + b_1 \log X_1 + b_2 \log X_2 + \ldots + b_n \log X_n$$

By differentiating the above equation with respect to $X_1$, keeping $X_2, X_3, \ldots, X_n$ constant:

$$1 / Y\, dY = b_1 \bullet 1/X_1\, dX_1$$

The left-hand side of the equation $1/Y\, dY$ is the rate of change of $Y$ resulting from a change in $X_1$.

This equation, therefore, expresses the rate of change of $Y$ with respect to the rate of change of $X_1$ and can be rewritten as:

$$\frac{dY/Y}{dX_1/X_1} = b_1$$

Similarly, it can be shown that:

$$\frac{dY/Y}{dX_i/X_i} = b_i, \ldots (i = 2, \ldots, \text{n})$$

The left-hand side of the equation $\frac{dY/Y}{dX/X_i}$ is the rate of change of $Y$ with respect to the rate of change of $X_i$.

Elasticity of $X_1$ ($EX_1$) = $\frac{\text{rate of change of } Y}{\text{rate of change of } X_1} = b_1$

Similarly:

Elasticity of $X_i$ ($EX_i$) = $\frac{\text{rate of change of } Y}{\text{rate of change of } X_i}$ = $b_i$ ($i$ = 2, …, n)

Thus, $b_i$ ($i$ = 1, …, n) represents the elasticity of the explanatory variable $X_i$ ($i$ = 1, …, n).

b) Consider an equation having a functional form as follows:

$\Delta Y = b_1 \, \Delta X_1 + b_2 \, \Delta X_2 + \ldots + b_n \, \Delta X_n$

where each observation to the equation is included as a per cent change from ($t$-1) to $t$:

i.e. $\Delta Y_t = \frac{Y_t - Y_{t-1}}{Y_{t-1}}$ and $\Delta X_{1t} = \frac{X_{1t} - X_{1t-1}}{X_{1t-1}}$

Such a functional form is usually called a per cent change or a Δ model, or first-difference model. In this particular case, since the functional form is specified as a first difference or per cent change, the regression coefficients $b_1$, $b_2$, etc., represent elasticities of the respective variables $X_1$, $X_2$, etc.

c) Consider an equation having a linear functional form as illustrated below:

$Y = a + b_1X_1 + b_2X_2 + \ldots + b_nX_n$

The elasticity in this particular case can be expressed as:

$EX_1 = b_1 \frac{X_1}{Y}$, $EX_2 = b_2 \frac{X_2}{Y}$, etc.

30. It is evident that in cases a) and b) above, the coefficients derived from the equation provide a measure of elasticity directly. This also implies that in cases a) and b), the elasticities are constant over the forecast horizons. In the case of equation c), the elasticities vary with the magnitude of the variable. This implies change in elasticity over the forecast horizon, i.e. smaller per cent growth in successive years.

### *Forecasting models — development procedures*

31. Advice is provided below on how to use econometric analysis to forecast air traffic demand as well as the procedures to be utilized in the development of traffic forecasting models using causal relationships.

32. Figure 1-4 illustrates the typical procedures to be followed and the steps involved in the development of a forecast using an econometric model.

33. As depicted in the figure, the main steps in the development of a forecast using an econometric model are:

a) Define the problem.

b) Select the relevant causal or explanatory variables.

c) After the relevant variables are selected, based on judgement or prior analysis, establish the availability of data or the selection of substitutes or proxy variables if such data are not available.

d) Once the data availability is established, formulate the model specifying the type of functional relationship between the dependent variable and the selected explanatory (causal) variables.

e) Carry out an analysis to test the relationship being hypothesized, including the estimation of the model coefficients, their magnitudes and signs and statistical measures.

f) When the foregoing criteria are achieved, establish the model in final form.

g) Develop forecasts of future scenarios for the explanatory variables from which the traffic forecast is subsequently derived.

34. It is important to keep in mind that the process is interactive and some of the later steps will have an impact on earlier steps and vice versa. For example, availability of data will influence the selection of causal variables.

#### *Problem definition*

35. Problem definition is related to the intended use of the forecast. It includes the geographical coverage, whether it is global, regional or a particular traffic flow. The type(s) of traffic being considered for analysis such as total traffic, scheduled traffic or any other segmentation should be clearly defined since this is the dependent variable of the model. The time horizon of the forecast should also be specified.

#### *Selection of explanatory variables*

36. In selecting the variables to be taken into account in a specific traffic forecast, the primary criterion is, of course, that they be expected to represent an important influence on demand in the particular circumstances. Traffic demand is normally affected by many factors, and the variables should be chosen so

that together they cover as many factors affecting demand as possible. In this context, there are two schools of thought. The first advocates the exploratory approach where the researcher identifies a long list of potentially useful causal variables. The second favours the selection of a small number of the most relevant variables. The explanatory variables should be chosen from those that are available from reliable sources. They should be measurable, quantifiable, continuous and predictable. Their magnitude should be on record so that their influence on the traffic can be quantified through statistical analysis. A continuous variable is a variable for which data are available over time with no missing periods. A predictable variable is a variable that can be independently predicted, either by a reliable independent source or by the forecaster as an "in-house" or internal prediction.

*Dummy variables*

37. The use of "dummy variables" is a technique to incorporate qualitative or categorical variables in a model. The modelling process, in general, implicitly assumes that the specified functional relationship is the same for all observations. This assumption does not take into account the possibility of segmentation of the data, seasonal factors, an airline strike or other special occurrences or events. The impact of such events can be measured through the use of the dummy variable technique.

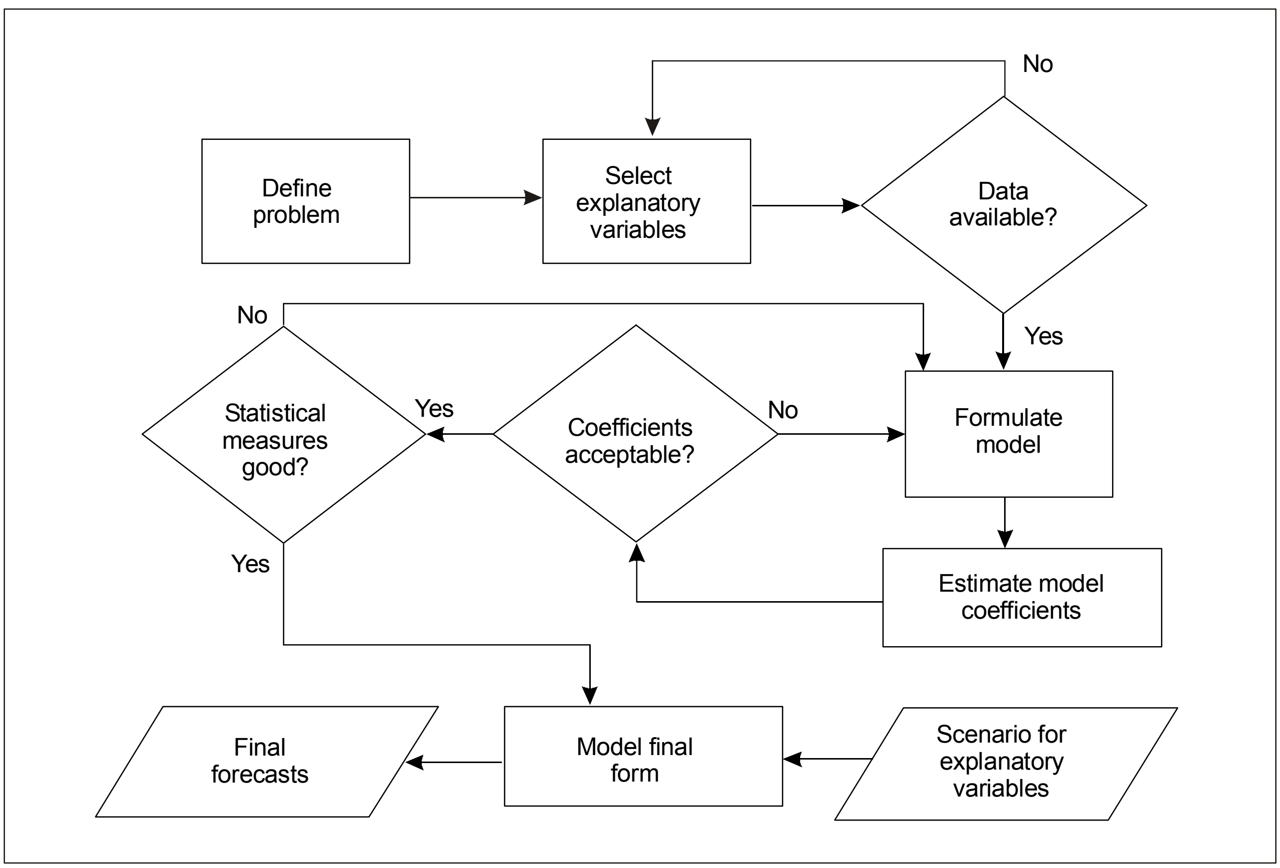


**Figure 1-4. Development of an econometric model**

38. The dummy variable is a causal variable that assumes only two values, zero and one. The coefficient of a dummy variable in an econometric model shows the average effect on air travel demand (the dependent variable) when the dummy variable assumes the value of one. In setting up the equation, the dummy variable has the value of one whenever the factor is present, and zero otherwise. If necessary, more than two categories can be handled by using additional dummy variables. The estimated coefficients corresponding to each of the dummy variables (if more than one is used) is a measure of the traffic demand level attributed to the presence of that particular event.

*Data availability*

39. The next step in the model-building process is the measurement of the variables chosen for inclusion in the model. As mentioned previously, it may become evident at this stage that certain variables can be rejected due to lack of available data. For some variables, the data may not be directly available in an appropriate form but can be derived from several sources or by careful estimation.

40. Data for the dependent variables, such as passenger traffic in terms of passengers or RPKs and freight traffic in terms of freight tonnes or FTKs, are normally available from the airline, airport or the State that needs the forecast. They are also normally available in the ICAO statistical databases. These data may be supplemented, as required, using International Air Transport Association (IATA), Airports Council International (ACI) or other sources. Data for the independent or explanatory variables related to airline operating economics are also available from the ICAO databases, supplemented as required, using other sources as mentioned earlier. Data for socio-economic variables and demographics may be available from the publications of the International Monetary Fund (IMF) and the United Nations national accounts and other economic services.

41. Accurate measurement of the price of air travel is complicated by the various fares that are available. A single measure of price may be calculated as an average of the various fares, weighted by the number of passengers using each fare. In general, passenger yield, i.e. passenger revenue per passenger-kilometre, can be used as a measure of price. Ideally, the average weighted fare for a particular route group or region concerned is more appropriate; however, the average yield can be considered as a suitable substitute or proxy variable to reflect the price of air travel.

42. A special problem with economic and financial data is whether to use current or constant money values to measure monetary quantities. The normal practice is to work with constant money values by adjusting the time series of financial data for simultaneous changes in the purchasing power of the currency. Consider, as an example, a model of the demand for passenger travel on a network of routes, which includes a measure of income (for example, GDP) of the country or region and the passenger yield as explanatory variables. The data for the variables in current values can be divided by consumer price indices for each of the years concerned to obtain a constant (or “real”) price series. The advantage of this approach is that it removes the effect of fluctuations in the inflation rate.

*Formulation of the model*

43. In order to establish the relationship between the selected independent (explanatory) variables and the dependent variable, i.e. traffic demand, it is necessary to specify the mathematical form of the relationship (model). The type of functional relationship to be used for an econometric traffic forecast must be developed through judgement and experimentation or through experience and prior knowledge of the market concerned. The validity of the relationship can be established empirically through tests against actual historical data. Several alternative forms, as suggested below, should be tested. In each case, $Y$ is traffic, $X_1$, $X_2$, …, $X_n$ are explanatory variables, and $a$, $b$, $c$, …, $z$ are constant coefficients.

a) *linear:*

$$Y = a + bX_1 + cX_2 + \ldots + zX_n$$

b) *multiplicative or log-log:*

$$Y = aX_1^{\,b}\, X_2^{\,c} \ldots X_n^{\,z}$$

$$\log Y = \log(a) + b \log X_1 + c \log X_2 + \ldots + z \log X_n$$

c) *linear-log:*

$$e^Y = aX_1^{\,b}\, X_2^{\,c} \ldots X_n^{\,z}$$

$$Y = \log(a) + b \log X_1 + c \log X_2 + \ldots + z \log X_n$$

d) *log-linear:*

$$\log Y = a + bX_1 + cX_2 + \ldots + zX_n$$

44. For estimation of traffic demand at an aggregate level such as global, regional or major traffic flows, the multiplicative (log-log) model is generally considered the most appropriate to use. However, a prior analysis of the traffic trends in a specific situation and a given market may lead to different choices.

*Model coefficients — estimation and statistical measures*

45. For each traffic demand model specification, in terms of a set of explanatory variables and a functional form, there is one set of values for the constant coefficients (*a, b, c,* etc.) that provides a better fit of the equation to the data than all other sets of coefficients.

46. Where the functional form of the model is either linear or is easily transformed into a linear relationship, the technique of multiple linear regression is used to determine the values of the coefficients.

47. It is important to establish, using the judgement of the analyst or other experts, whether the magnitude of the coefficients of the model is reasonable. It is likely that previous studies or prior analysis will also be useful in this context. The next step is to determine whether the coefficients have the correct sign. The coefficient can be positive or negative. When it is positive, the dependent variable tends to increase as the explanatory variable increases. When it is negative, the dependent variable tends to increase as the explanatory variable decreases.

48. The next step in this procedure is to estimate certain statistical parameters and examine their validity. The meaning and use of these statistical parameters are especially valuable in forecasting. They are usually referred to as summary statistics, and they are the basic tools of forecasters in working their way through an empirical problem. It is difficult to set up definite rules considering the uses of these summary statistics; however, the guidance provided here should help the forecaster to interpret these parameters.

49. In regression estimation, the residuals (i.e. the difference between observed and estimated values of $Y$) indicate the extent of the dependent variable that is not explained by the explanatory variables. If the residuals are small relative to the total movement in the dependent variable, this indicates that a major part of the variation has been explained and accounted for. Accordingly, the summary statistic, known as the multiple correlation coefficient *"R"*, is defined to measure the variation of the movements in the dependent variable explained by the explanatory variables used in the model. In practice, instead of the multiple

correlation coefficient, its square ($R^2$) is usually reported. The square of the multiple correlation coefficient is defined as:

$$R^2 = \frac{\text{variation explained by the model}}{\text{total variation of the dependent variable}}$$

$$R^2 = \frac{\sum\left(Y-\bar{Y}\right)^2 - \sum e^2}{\sum\left(Y-\bar{Y}\right)^2}$$

where:

$Y$ = the dependent variable

$\bar{Y}$ = the mean value of the dependent variable

$e$ = the residual that is not explained by the model.

The value of $R^2$ ranges between 0 and 1.

50. It is important to understand the validity of this measure. Although $R^2$ can be interpreted as the proportion of the variance explained by the model, it is not easy to translate this into decision-oriented terms. In the regression analysis procedure, whenever an additional variable is included in the equation, $R^2$ necessarily increases. Therefore, it is important to determine whether an incremental increase in $R^2$ justifies the inclusion of the particular variable. This can be explained by the loss in degrees of freedom in fitting the model. A high $R^2$ may imply the appropriateness of a model for explaining the movements of a dependent variable, but a low $R^2$ does not necessarily mean that the model is inappropriate.

51. For example, suppose two models are used to estimate traffic demand as a function of price and income, using two different functional forms, with the first model being a log-log model to estimate the level of traffic from 1 to 2, and the second model being a change in demand as a function of change in prices and income (per cent change from year to year).

52. The coefficients estimated by both models for income and price should be identical due to the specifications of the two models. They can be interpreted as the elasticity of price and income, respectively. However, the magnitude of $R^2$ will be much lower in the second case compared to that of the first. In relative terms, a low $R^2$ in this case does not necessarily mean that the second case is a poor fit; it is due more to the way $R^2$ is defined.

53. As a guideline, it is important to keep in mind that if $R^2$ is used as the criterion to compare the validity of two models, these models must have:

a) the same functional form; and

b) the same number of variables.

54. Having obtained the regression coefficients, one can also assess the precision of the estimation procedure by computing the standard error of the estimate (S.E.) of the dependent variable and the standard error or the *"t"* statistic associated with each of the estimated coefficients. Whenever the analysis provides the standard error of an estimate, it explicitly infers that the result is an estimate of the standard deviation of the coefficient and is not the standard deviation itself. Despite this distinction, most analysts overlook this point and use the standard error as if it were the standard deviation itself.

55. The *"t"* statistic corresponding to a particular coefficient estimate is a statistical measure of the confidence that can be placed in the estimate. Since regression coefficients are estimates of the expected value or the mean value from a normal distribution, they have "standard errors" that can themselves be estimated from the observed data. The *"t"* statistic is obtained by dividing the value of the coefficient by its standard error. The larger the magnitude of *"t"*, the greater is the statistical significance of the relationship between the explanatory variable and the dependent variable, and the greater is the confidence that can be placed in the estimated value of the corresponding coefficient. Likewise, the smaller the standard error of the coefficient, the greater is the confidence that can be placed in the validity of the model.

56. Most of the computer software packages available for statistical analysis provide the *"t"* values. The standard error can be easily calculated knowing the *"t"* value and the estimated value of the coefficient, and vice versa, since:

$$"t" \text{ value} = \frac{x}{S.E.}$$

where $x$ is the estimated value of the coefficient of the explanatory variable, and *S.E.* is the standard error of the estimated value of the coefficient.

57. A value of about 2 is usually considered as the critical value of *"t"*. A *"t"* value below 2 is considered not significant since not much confidence can be placed in the precision of the coefficient. However, it is conceivable that even with a *"t"* value below 2, the model may be able to provide a reasonable forecast provided other statistical criteria are satisfied.

58. It should also be noted that the estimated value of the coefficients from the econometric analysis are relative and not absolute. Explanatory variables are not always mutually independent. There is usually some correlation between explanatory variables. Hence, the coefficients themselves can have a certain amount of bias. In particular, when more than one explanatory variable is used, a certain amount of bias is involved in the estimated coefficients due to the intercorrelation of the explanatory variables.

59. When an explanatory variable is closely correlated with one or more of the other explanatory (or independent) variables, this can lead to greater bias in the estimated coefficients, thus reducing the reliability of the estimated coefficients. This situation, referred to as "multicollinearity", is often encountered in econometric estimation. A low *"t"* statistic or a larger standard error may be a symptom of multicollinearity.

60. The existence of multicollinearity can be recognized by looking at the simple correlation matrix and then choosing for inclusion in the econometric analysis, only those explanatory variables that are not highly correlated with each other. Ideally, the goal is to select explanatory variables that are highly correlated with traffic but are not correlated with each other. In reality, this is not always the case, particularly when using time-series data.

61. Various approaches may be developed for reducing the multicollinearity between explanatory variables. For example, if it is critical that both income and population variables be included in a model and they are highly correlated with each other, the analyst can combine these two variables into one by translating the data as income per capita (i.e. income for a given year divided by the population size for that year). As a general rule, the likelihood of encountering multicollinearity can be reduced by selecting the most relevant variables, combining variables (wherever feasible) and limiting the number of explanatory variables. It is also important to bear in mind that the analysis should include the most important variables. It is not advisable, however, to drop one of the key variables completely. This will reduce the standard error at the cost of introducing additional bias into the estimation of other coefficients. The ordinary least-square estimates of coefficients are unbiased only when theoretically specified variables are included in the regression analysis.

62. For various reasons, including measurement problems and to some degree multicollinearity, econometric models do not, as a rule, include all the variables that may have an effect on traffic demand. It is therefore always important to include a constant term in the model to account for some of the variables "left out" of the analysis. The constant term along with the residual error term will provide evidence to understand the impact of such "left-out" factors.

*Model — final form*

63. Once the model has satisfied all the criteria discussed so far and the statistical measures have been met, the econometric model will be established in its final form. The model provides the first step in producing a forecast but not necessarily the last.

*Explanatory variables — projection scenarios*

64. Future projections of the explanatory variables form an integral part of the development of the forecast. It is highly desirable to develop a scenario approach to better understand expectations of the explanatory variables. Scenario analysis also represents the acknowledgement that the forecaster must consider a range of possible outcomes. To some degree, the methods of projecting future movements of the explanatory variables will depend on the circumstances and on the type of variable concerned.

65. In constructing the scenarios, many important factors come into play, which will have an influence on the final forecasts. Although, the final form of the forecasting model may include only two to three variables, other factors may be considered in determining the values of the explanatory variables included in the model.

*Forecast*

66. The forecast can then be derived by incorporating the values of the explanatory variables into the model. The model can also be used for sensitivity analysis by examining alternative scenarios of the airline operating environment and assumptions of the explanatory variables to see the impact on air traffic demand (dependent variable).

67. It is important to recognize that the accuracy of an econometric traffic forecast depends on the accuracy of the forecast scenarios of the explanatory variables included in the forecasting model. At the same time, a virtue of this approach is that it offers the possibility of studying the sensitivity of air traffic development to alternative patterns of development of the underlying factors. Given ranges within which the various explanatory variables are likely to develop, it is possible to generate a range of traffic forecasts. That range will give an indication of the uncertainty or risk surrounding the prospects for traffic. While the planner may be primarily concerned with the "most likely" traffic forecast, it will usually be useful for him/her to consider the planning implications of "high" and "low" forecasts.

*Forecast error*

68. There are four potential forecast errors:

a) a specification error, which results when the incorrect functional form is chosen or a key explanatory variable is left out of the model, or if the model structure varies over time;

b) a conditional error, which occurs when predictions of the inputs to the model are not accurate;

c) a random error, which is due to sampling and randomness associated with the data; and

d) an exogenous error, which is unrelated to any of the inputs or specifications but is due to an external event of a unique character, such as a war or terrorist attack.

Also, the standard errors from a regression analysis assess the effects of errors in estimating the forecast coefficients, recognizing that they provide estimates of uncertainty near the mid point of the historical series.

69. The standard errors of the estimates of the parameters (regression coefficients) provide the validity of the "precision" of the estimate. It is important to keep in mind that the computed standard errors do not necessarily reflect the absolute precision of the estimates because the error terms of the coefficients are not distributed completely independent of each other. While the coefficients provide a relative precision, bias and trade-offs among the explanatory variables are universal.

*Autocorrelation*

70. In econometric models, it is common that errors are correlated over time (autocorrelation). In such cases, the estimation procedure does not yield the best linear unbiased estimates. Analysis of the residuals and their patterns may help detect the existence of autocorrelation. When error terms are serially correlated, they seem to be either always positive or negative, in successive periods.

71. Autocorrelation may also be detected by the Durbin-Watson statistic. The Durbin-Watson statistic is a measure of correlation between residuals over successive time intervals. The value of this statistic ranges from zero to four. If no autocorrelation is present, the expected value should be around two. In principle, values less than two and approaching zero indicate positive autocorrelation, while values greater than two and approaching four indicate negative autocorrelation.

72. In general, however, the estimates for air traffic demand itself are not affected much by autocorrelation, so it is seldom worth making any corrections unless the error term from the model appears to be either always positive or negative throughout the historical time period concerned.

73. A solution to autocorrelation, if it does exist, is to formulate the model in terms of first differences, i.e. period-to-period changes in the dependent variable are related to period-to-period changes in the explanatory variables. This can, however, be worse than the problem itself for long-range forecasting in that the first difference models are generally used to estimate short-term effects instead of long-range effects. When residuals are not independent, other implications can be that an important explanatory variable has been left out or the wrong functional form has been used in the model formulation.

## SIMULTANEOUS EQUATIONS MODELS

74. The specification of some economic models involves more than one equation. These models are called simultaneous equations models because their variables simultaneously satisfy all these equations. A simultaneous equations model usually includes several variables in its specification. The model is a case of demand and supply for the same product. It addresses the issue of supply-demand interactions. For example, suppose the demand (D) for air traffic can be expressed as a function of price, income and level of service offered (LOS), the level of service itself can be expressed as a function of lagged demand, airline competitive effects and network effects. Supply can be expressed as a function of lagged demand, price and operating costs. To represent simultaneous causality, econometricians have developed simultaneous equations models.

75. As with any regression analysis, the functional form of each equation has to be determined, the values of their parameters have to be estimated by solving them simultaneously, and the statistical

significance of the results and the validity of the assumptions have to be established. An advantage of a simultaneous equations model is that it provides the values of several explanatory variables from within the model itself. However, estimation of the parameters of the equations involves more complex issues than those encountered in a single equation model.

76. It is widely believed that whenever the model is of the form of simultaneous equations in nature, the use of a single equation procedure does not necessarily produce accurate results. This may not always be the case. In some cases, it may be that the single-equation procedure is better than the simultaneous equations procedure, even though the true model specification favours simultaneous equations. A topic all too frequently ignored in textbooks is when a simultaneous equations model should be used in preference to a single equation model. Simultaneous equations, while not used extensively, can be used under special circumstances. The following illustrations are provided to get a better understanding of the use of simultaneous equations models.

77. In an era of multiple-fare plans, deregulation, consolidation, and supply-side fluctuations, the standard demand model alone may not always provide reasonable estimates of income and price elasticities. In general, the demand model, D = *f* (income, price), works reasonably well provided the supply-side factors remain stable. But in the air transport environment, a complex interaction can occur between supply (S) and demand (D). In general, the demand models are not true demand curves but "reduced form" expressions for points of equilibrium.

78. A two-step approach may be essential in order to determine S and D interaction. The standard economic supply curve relates output to price. In air transportation, supply in general exceeds demand, as illustrated in Figure 1-5. Hence, this creates a market operation unlike the goods market models of classical economics. The form of the supply curve depends on the airline cost structure and the availability of seats.

79. The demand curve will shift due to price effect, income effect and other socio-demographic factors. The fares offered and market conditions can have an effect both on the "D" and "S" curves. An increase in fares will result in a reduction in demand (revenue passenger-kilometres (RPKs)), which may also have an impact on supply (available seat-kilometres (ASKs)) as illustrated in Figure 1-6. Similarly, an increase in income will also create a higher propensity to travel as illustrated in Figure 1-7. This can have an impact on the capacity offered (supply).

80. When a single equation econometric model, D = *f* (income, price), is used to estimate these relationships, the slopes of the curves give the respective values of the coefficients or weighting for these variables.

81. Such models are easy to conceptualize and they assume that income and price effects explain the changes in demand patterns but fail to recognize the impact of level of service on demand.

82. If a supply variable is incorporated in the model, D = *f* (income, price, supply), it recognizes that supply influences changes in demand but fails to account for the impact of demand on supply. Supply is incorporated in the model in terms of frequencies or ASKs or a combination of seats and frequencies, which could create all kinds of other problems. If the supply variable is left out of the model, an important determinant of demand is not properly addressed, especially in a deregulated environment. If, for example, low fares and other business expansion factors generate an increase in demand that exceeds the airlines' ability to provide a matching supply increase, demand could be affected. Such a case should be viewed as an external force that is affecting the demand curve. This condition would cause the econometrically determined demand curve to be invalid. If this were the case, under such conditions, the demand relationship would be heavily biased by the S and D interaction. These types of problems occur because a "reduced form" model is used when a multi-equation structural model appears to be more appropriate.

83. It should therefore be concluded that the price/income model can save a great deal of cost and effort provided that the supply-side factors are stable, supply is not constrained and demand is not overly sensitive to changes in supply-side factors.

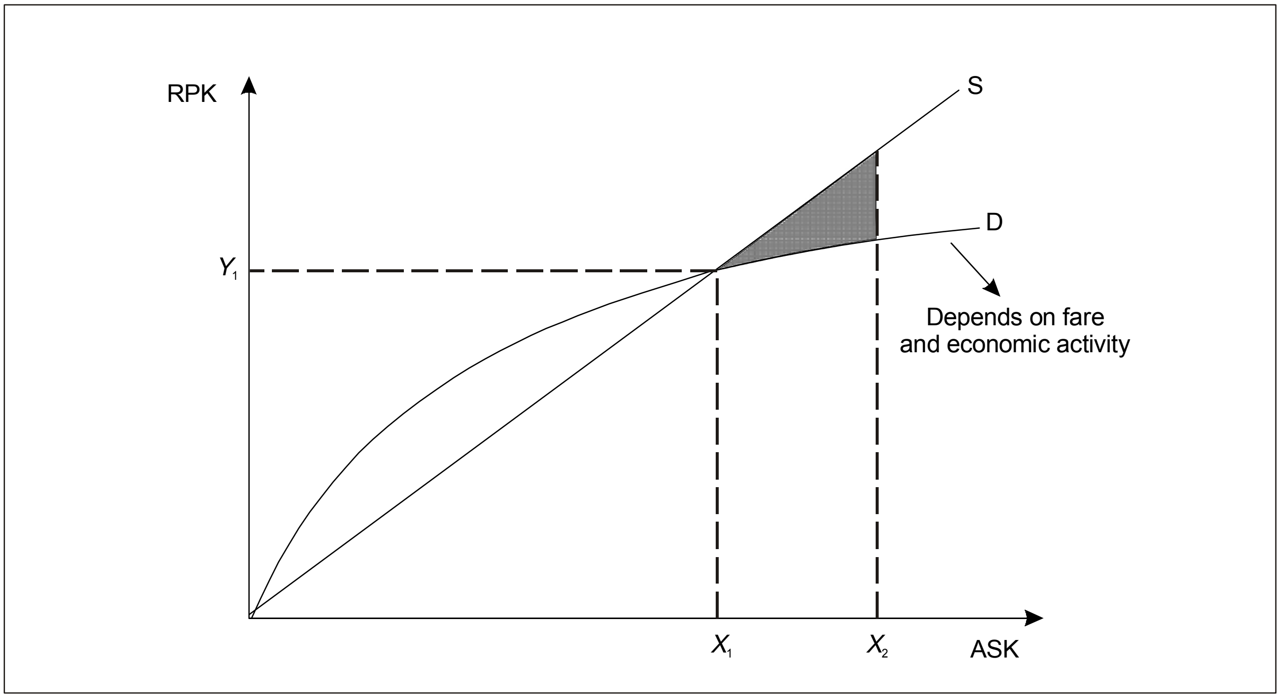


**Figure 1-5. Supply and demand interactions**

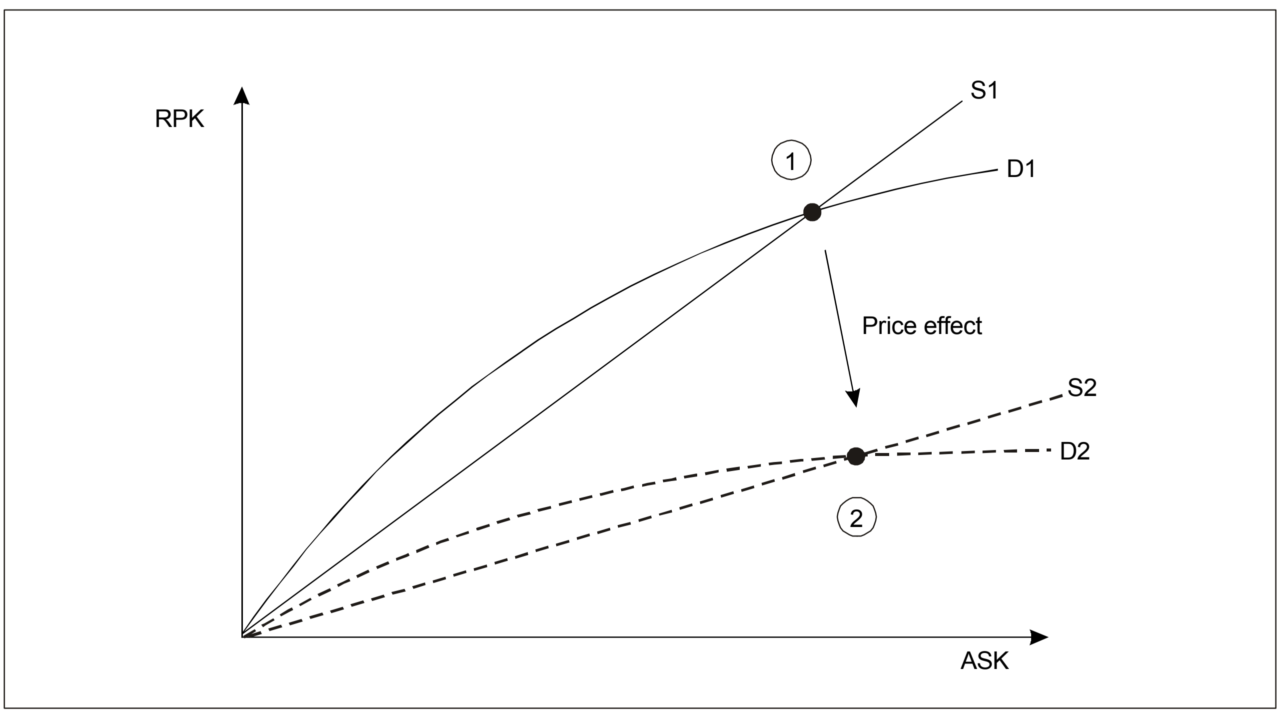


**Figure 1-6. Effect of price increase**

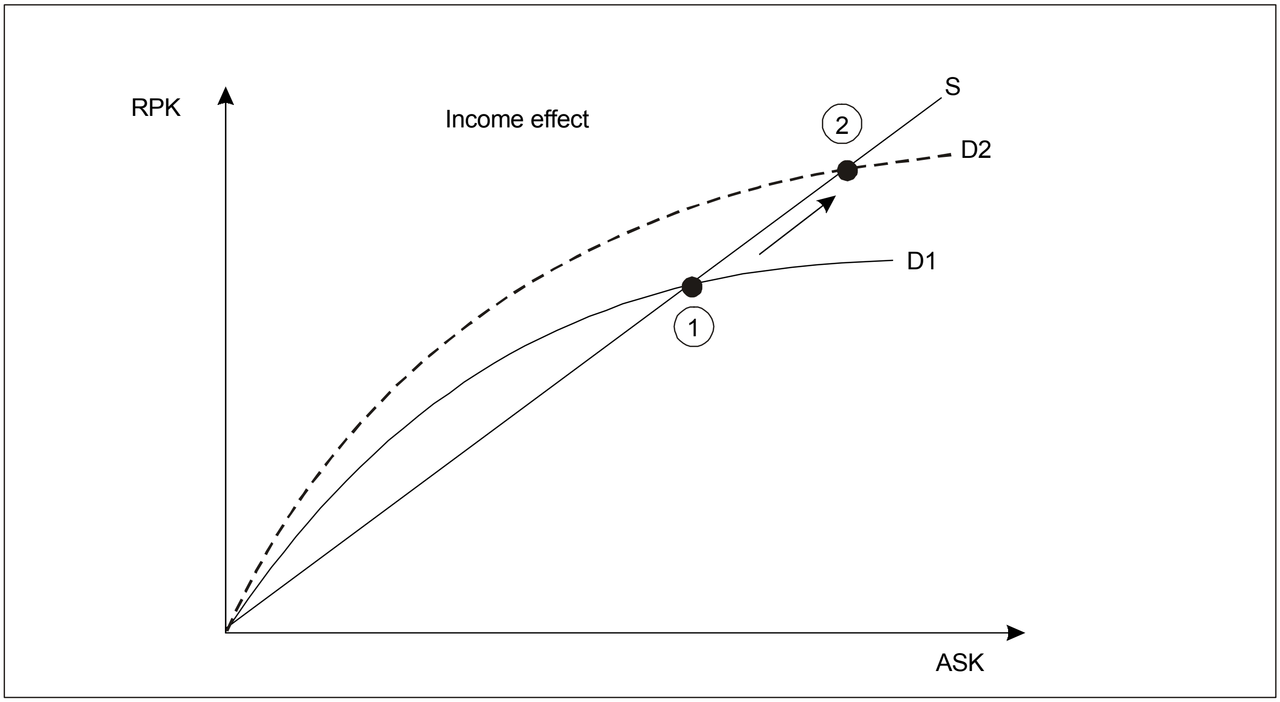


**Figure 1-7. Effect of increase in economic activity**

84. Adding supply (capacity ASKs) to a model will improve the statistical measures ($R^2$) but not necessarily the model as a forecasting tool unless supply is constrained to such a point that capacity changes could have an overwhelming influence on demand and the capacity may be forecast easily and independently. When both these conditions prevail, some form of simultaneous equations model as described earlier (in paragraph 74) is applicable.

### SPATIAL EQUILIBRIUM MODELS

85. Spatial equilibrium models establish a relationship for the movement of traffic between any two traffic centres or regions. In the basic form of this relationship, the traffic between each two points is directly proportional to some characteristic of the size of the region and inversely proportional to the distance between regions. These types of analysis are discussed in more detail under the air traffic distribution models section.

## OTHER VARIATIONS OF CAUSAL METHODS

### LAGGED VARIABLES AND DISTRIBUTED LAGS

86. The standard linear regression model specifies a causal relationship between the dependent and explanatory variables. This specification implies that a change in one of the explanatory variables causes a

change in the dependent variable during that time period alone. However, this specification may be restrictive in some cases. For example, traffic demand may take a year or several years to respond to changes in underlying causal factors such as GDP, disposable income and fares, particularly if such changes are sudden and substantial. An airline ticket can be purchased this year for use in the coming year. A causal relationship where the influence of a change in an explanatory variable is expected to spread over a longer time period is called the “distributed lag effect”. The modelling procedure may be tailored to incorporate such effects so that a specific profile of the distributed lag and its effect over time can be estimated. In some cases, particularly for short-term forecasts, a lagged dependent variable can be included in a model as an explanatory variable.

## STEPWISE REGRESSION

87. The stepwise regression procedure has been developed to enable the analyst to search through a list of possible explanatory variables in order to select those which provide the best regression model. This procedure can be used in two ways: “step-up” and “step-down”. In the “step-up” version, the explanatory variable with the highest correlation to the dependent variable is entered first, followed by the one with the highest partial correlation, and so on, in order to maximize the adjusted coefficient of determination ($R^2$). The “step-down” version starts with all the variables initially and then removes the one that contributes least to the $R^2$, and so on. This procedure is not recommended for air traffic forecasting unless a situation occurs where the analyst is not sure which causal variable should be included in the model.

## AIR TRAFFIC DISTRIBUTION MODELS

88. Air traffic distribution models can be used to forecast traffic demand between designated airport pairs, city pairs and/or country pairs. The socio-economic factors, demographics and other relevant factors including the economic characteristics of the cities themselves for the market concerned should be taken into consideration. Also, supply-side factors such as the level of service available between origin and destination can also come into play.

89. The early application of predicting demand between given airport pairs or city pairs used a gravity model concept. Gravity models, in general, estimate demand in terms of travel between discrete points as opposed to global or system-wide demand. The basic form of the model used for traffic demand between city pairs took the following form:

$$D_{AB} = f(C, P_A, P_B, S_{AB})$$

where:

$D_{AB}$ = traffic demand between the city pair A-B

$P_A$ = population of city A

$P_B$ = population of city B

$S_{AB}$ = distance between the two points A and B

$C$ = constant of proportionality.

90. Demand between the two cities is directly proportional to the population of the two cities concerned and inversely proportional to the square of the distance between them. Population is used here as a measure of attractiveness of the cities, and the distance as a measure of impedance (resistance). This is a very simplistic approach, and the gravity model in its simplest form implies that if there is a two-fold increase in population, this will result in a four-fold increase in demand.

91. These models have been refined further using air fare, time and other factors to allow for the impedance effect and using truncated population above a predetermined income level to represent those who would be potential candidates for air travel.

92. A variation in gravity models is also used in the developing phase of specific models. These models try to estimate a relationship between air traffic demand and relative shares of other modes when accessibility of service by different modes is available for the route concerned. Multi-modal models attempt to predict simultaneously the demand for each of the modes. The modes are usually defined in the abstract to account for hypothetical or undeveloped modes. For air transport demand, variables such as distance, travel time, level of service, and accessibility of service by other modes of transportation have been used. The advantage of using the abstract mode is its ability to assess the demand for a non-existent service. The models developed in this manner are somewhat simplistic in nature, and it would be difficult to justify their use in long-term forecasting. However, such models can be useful to predict demand for new city pairs where services do not exist.

93. Another procedure to develop route group or city-pair forecasts is to express the traffic flow concerned as a share of the total market and to use the market share and historical growth patterns to ensure consistency between the city pair and the total market forecast. The underlying assumption of this procedure is that each city pair's share of the total approaches its eventual share of the market asymptotically, taking into account the concept of market maturity, where applicable. For example, mature markets tend to have a declining share approaching an asymptotic value, whereas developing markets tend to increase their share as illustrated in Figure 1-8.

94. The rate at which different markets tend to approach the asymptotic value depends on the characteristics of the market concerned.

95. An exponential function in terms of $e^{-\alpha t}$ provides the best estimate for most traffic flows within a given market. The coefficient "$\alpha$", as illustrated in Figure 1-9, determines the rate at which the city-pair or traffic-flow share approaches its asymptotic value.

96. This method provides a procedure to disaggregate a total market forecast into its components, having established the total market forecast as the basis, and the rate of variation among traffic flows within the market. In other words, the aggregate of all the component traffic flows must equal the total market forecast.

## QUALITATIVE FORECASTING METHODS

97. The forecasting techniques discussed so far are based on the assumption that a number of historical observations are available and they represent some underlying pattern. Qualitative forecasting methods are used when such data are sparse or not available. These methods can also be used in an assessment of how new technological or other developments would affect the forecast. The state-of-the-art in qualitative forecasting methods is not nearly as well-defined as in quantitative analysis. These methods are largely intuitive. They rely heavily on the judgement of experts and may be used to predict a significant change in historical patterns or, due to lack of sufficient historical data, for a quantitative analysis. Therefore, judgement plays an important part in qualitative analysis.

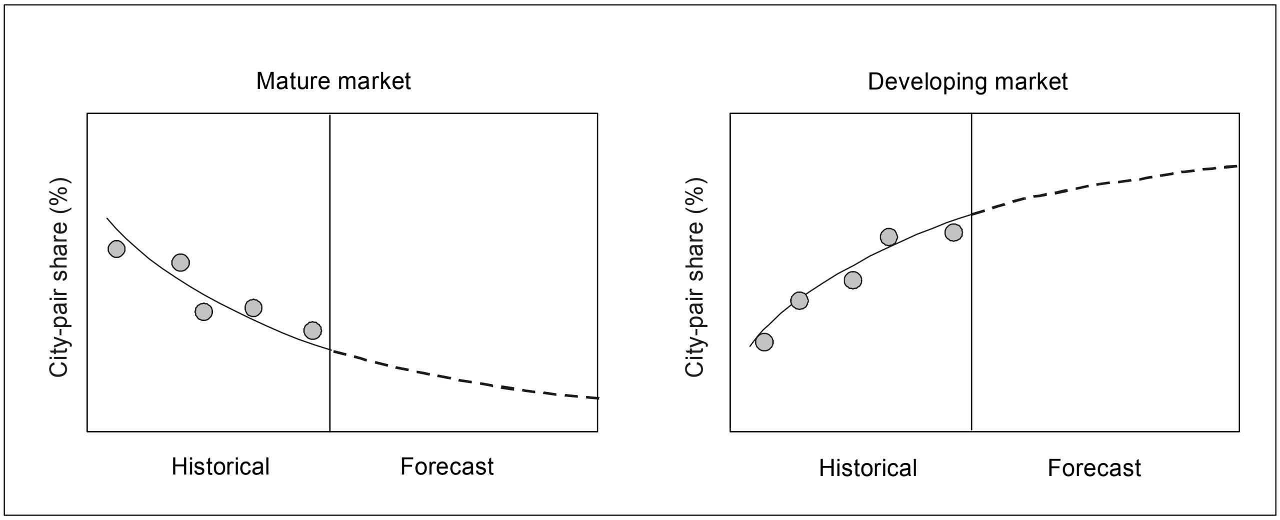


**Figure 1-8. City-pair categories**

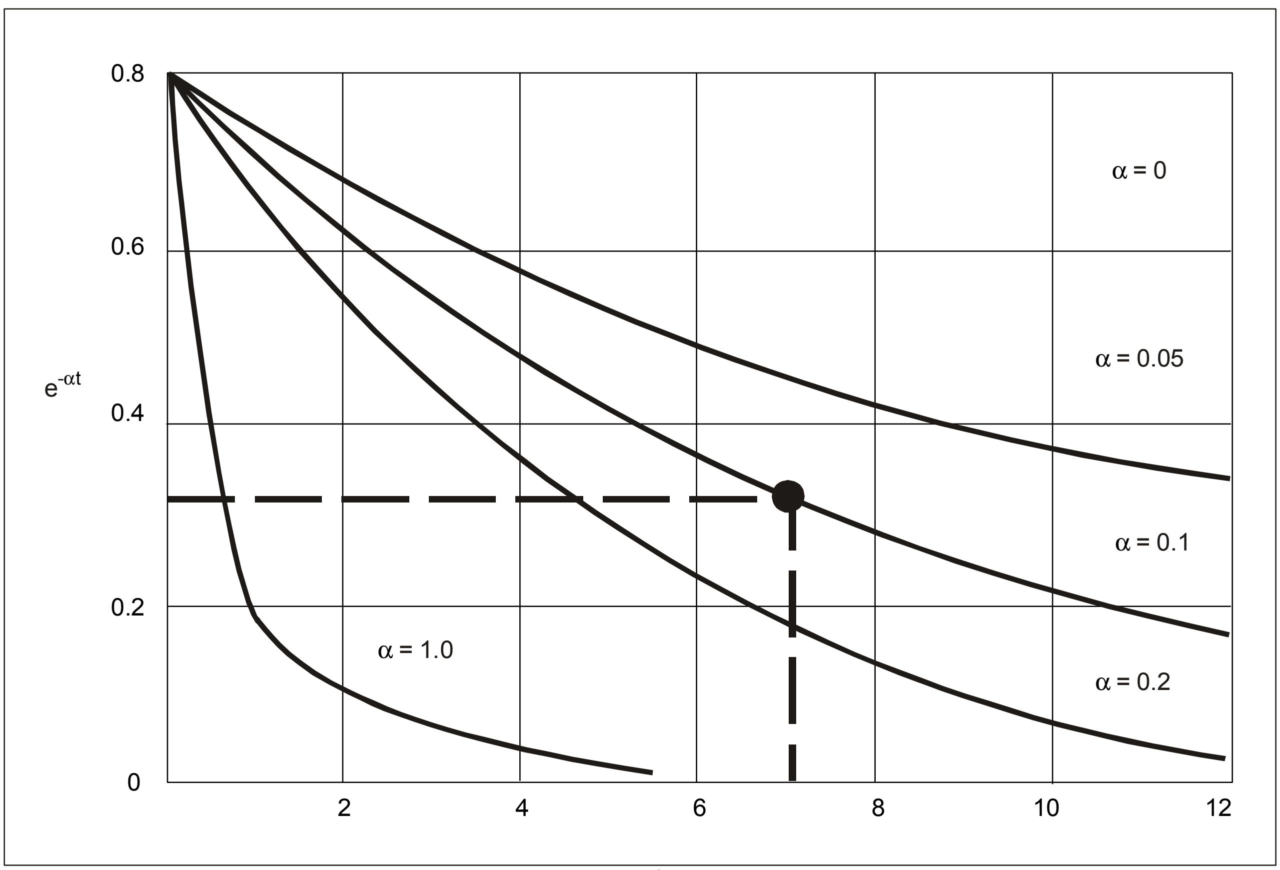


**Figure 1-9. Behaviour of $e^{-\alpha t}$ for parametric values of $\alpha$**

### DELPHI TECHNIQUE

98. The Delphi technique is a special procedure for forecasting by consolidation of opinions on the future. It has two steps. A selected group of qualified people are first presented with a questionnaire in which they are requested to indicate a most probable course of development in the activity being forecast. The initial returns are then consolidated and the composite response returned to all contributors giving them the opportunity to revise their original assessments in light of prevailing opinions among other experts. The Delphi technique is a practical means of bringing together information from many experts and moving towards a consensus among them.

### TECHNOLOGICAL FORECASTING

99. Technological forecasting is another method of qualitative forecasting. The term “technological forecasting” is somewhat misleading since this approach can be used to forecast many things other than technological developments. Technological forecasting attempts to generate new information about future systems and performance. This information can be either explanatory or speculative in terms of what new developments will take place in certain areas and is used to obtain a better understanding of future expectations. The logistic or the S-curve concept falls into this category. Technological forecasting can be classified into two categories: explorative and normative. Explorative techniques use the current basis of knowledge to broadly assess future conditions. Normative techniques start with assessing future goals and objectives and work backwards to determine the necessary developments in order to achieve the desired goals.

## DECISION ANALYSIS

100. Decision analysis should be considered as a combination of both quantitative and qualitative analysis methods. In decision analysis, the analyst’s judgement is used in preparing forecasts for a particular area of expertise in combination with some statistical or mathematical techniques including subjective inputs of probabilities. Decision analysis is helpful in the assessment of uncertainty and in risk analysis. Examples of forecasting methods within this category are market research and industry surveys, Bayesian analysis, probabilistic analysis and system dynamics.

### MARKET RESEARCH AND INDUSTRY SURVEYS

101. Traffic forecasting through market research surveys aims at analysing the characteristics of the air transport market in order to examine empirically how the use of air transport varies between different sectors of the population and different industries. Such results, in combination with forecasts of socio-economic changes, may indicate the likely future development of air transport.

102. Special air transport market situations, in which an empirical market research and industry survey approach to forecasting is appropriate, may frequently prevail in developing countries where a majority of the consumers of air transport services can be identified as belonging to a limited number of well-defined

sectors of society, perhaps supplemented by foreign travellers on holiday. Market research and industry surveys can be useful tools in identifying those segments of the population that generate most of the air travel and potential passengers. In small developing countries, for example, it may be that government agencies, a few industries or one or more tourist resorts account for an overwhelming proportion of all air travellers. If this can be expected to remain the case, a forecast of future air travel can be derived by studying the likely future traffic generation for each sector separately.

103. With respect to air freight in developing countries, the bulk of outgoing air freight may frequently be confined to one or a few commodities that the country exports, while incoming freight essentially consists of entirely different types of goods. In such cases, it would usually be preferable to base air freight forecasts on studies of the development of the structure of economic activity in the country and its trade pattern.

104. Market research and industry surveys are also used in situations where the markets are more developed and complex, the studies becoming correspondingly more detailed. Based on national travel market surveys, information can be obtained on the air travel propensities of various socio-economic groups. For example, in a study to analyse personal air travel at the national level in the United States, the population was divided into a large number of “cells”, each characterized by a certain combination of occupation, income and education. Each cell had a trip rate per head of population associated with it. Projections of the trip rates for each of the cells were based on trends in percentages of people with flying experience and in the trip frequency of the travellers. Trip rate projections were combined with forecasts of the cell populations (obtained from various government agencies) in order to obtain forecasts of air travel. To analyse the business air travel market, the employed population was divided into cells defined by occupation, industry affiliation and income. Business travel forecasts were then based on projections of trip rates and cell populations. In another example, for the development of forecasts for New York airports, in-flight surveys of passengers departing from New York’s airports were used to obtain more detailed information on the New York market, including local origin of traffic in the area, mode of ground access, duration of stay, etc.

## PROBABILISTIC ANALYSIS

105. The notion of forecasting the value of some variable in the future is based on the fact that there is some uncertainty associated with that variable. In cases where the amount of uncertainty is large, it would be desirable to have a range of values associated with that variable and to assign probabilities to the outcome of a variable or the forecast itself. The probability assigned to any outcome must be between zero and one, while the sum of the assigned probabilities must equal one. If an outcome is assigned a probability of zero, it implies that the outcome is impossible. Likewise, assigning a probability of one implies that the outcome is certain to occur.

106. Within the decision analysis process, having a distribution of possible outcomes for a variable can provide a more realistic outcome, and the range of the forecast can be assessed based on subjective probabilities. However, application of either heuristic or probabilistic methods to forecast air traffic demand is limited.

## BAYESIAN ANALYSIS

107. Forecasts based on subjective probability estimates require the use of an analytical model. Generally a model of this type is referred to as a Bayesian analysis. Bayesian analysis can be described as

a procedure to improve a prior estimate using new data or using conditional regression, a method for using objective data to refine prior estimates of the regression coefficients. In this method, coefficients of one of the explanatory variables can be assigned based on an *a priori* basis and the coefficients of the other variables can then be re-estimated. This process can be repeated until all relationships have been estimated.

### SYSTEM DYNAMICS

108. System dynamics techniques use large-scale computer models of integrated mathematical formulas and algorithms. Such methods can be used to simulate the behaviour of the system concerned in response to certain variables. For example, an increase in demand increases the load factor when the supply remains stable and, in turn, increases airline revenues. This increase in demand reduces unit cost, which is a condition to reduce average fares and further stimulate demand, which in turn will increase the supply offered. At this point, the process may reverse itself. Such models may be used to evaluate alternative policy scenarios and their impact on aviation activity.

## FORECASTING TIME HORIZONS

109. Forecasting time horizons can generally be classified into short-term, medium-term and long-term. The length of time used to describe each of these three categories may vary from industry to industry and for the particular type of application concerned. One of the useful criteria for matching a specific forecasting situation with the appropriate methodology also depends on the time horizon involved. For the aviation industry, the following time horizons are generally used:

| | |
|---|---|
| Short-term: | up to 1 year |
| Medium-term: | 1 to 5 years |
| Long-term: | more than 5 years. |

110. Short-term forecasts generally involve some form of scheduling, which may include for example the seasons of the year, for planning purposes. The cyclical and seasonal factors are more important in these situations. Such forecasts are prepared every six months or on a more frequent basis.

111. Medium-term forecasts are generally prepared for planning, scheduling, budgeting and resource requirement purposes. The trend factor as well as the cyclical component plays a key role in the medium-term forecast because the year-to-year variations in traffic growth are an important element in the planning process.

112. Long-term forecasts are used mostly in connection with strategic planning to determine the level and direction of capital expenditures and to decide on ways in which goals can be accomplished. The trend element generally dominates long-term situations and must be considered in the determination of any long-run decisions. Since the time span of the forecast horizon is long, it is also important that forecasts are calibrated and revised at periodic intervals (every two or three years depending on the situation). The methods generally found to be most appropriate in long-term situations are econometric analysis and life-cycle analysis.

## FORECASTING ACCURACY

113. The validity of a forecasting method depends on how accurately predictions can be made using that method. One approach to estimate accuracy is to compare the actual results with those predicted by the model. An alternative way is to fit the model only to part of the data (truncated analysis) and apply the model to the rest of the available data to test its accuracy. Since the second subset is not used to determine these parameters, this is equivalent to an ex-post testing of the accuracy of the method or model as well as the functional form selected. For example, the validity of the constant elasticity concept of a multiplicative model can be tested by using this method.

114. To measure the effectiveness of a forecasting application, it is necessary to compare the actual results with those which were forecast. This can be done through a periodic review process. The forecaster must analyse the errors in the forecast and any trends that may be apparent in the errors.

## ILLUSTRATIVE EXAMPLES

115. Some illustrative examples based on ICAO forecasting experience are provided below as guidance to the forecaster. They include examples of the application of trend projection methods using traffic from the North Atlantic market, causal methods to forecast world traffic and the trans-Pacific market, and the application of logistic curves for global traffic forecasting scenarios for a fifty-year horizon. The pros and cons of the various methods involved and the most appropriate technique for the particular application are discussed. The interpretation of the statistical parameters are also included, where applicable.

### TREND PROJECTION (NORTH ATLANTIC MARKET)

116. Figure 1-10 shows the actual North Atlantic passenger traffic for the period 1960–1975, as indicated by the solid line. Traffic data for the period 1960–1970 was utilized to establish a relationship between traffic *(Y)* over time (*t*). Mathematically, this can be written as $Y = f(t)$. Using simple regression, this is a straight line relationship and therefore the mathematical form can be expressed as $Y = a + bt$, where *a* and *b* are coefficients derived from the regression analysis. Using the ten-year traffic data for the period 1960–1970 resulted in the following relationship:

$$Y = -33\,953 + 589.38(t)$$

117. Having estimated the coefficients of the equation and concluding that the formula traces the historical trends in the data reasonably well, the formula can then be used to forecast future traffic by specifying the time (*t*) in the mathematical formulation and calculating the corresponding traffic *Y*.

118. The dotted line illustrates the model estimate of traffic for the period 1960–1970 as well as for the period 1970–1975. While the model underestimated traffic for 1970, it overestimated traffic for the period 1972–1975.

119. Figure 1-11 shows a similar analysis using the same data but a different functional relationship of the form $Y = ab^t$. This form can also be expressed as:

$$\log(Y) = \log(a) + \log(b)t$$

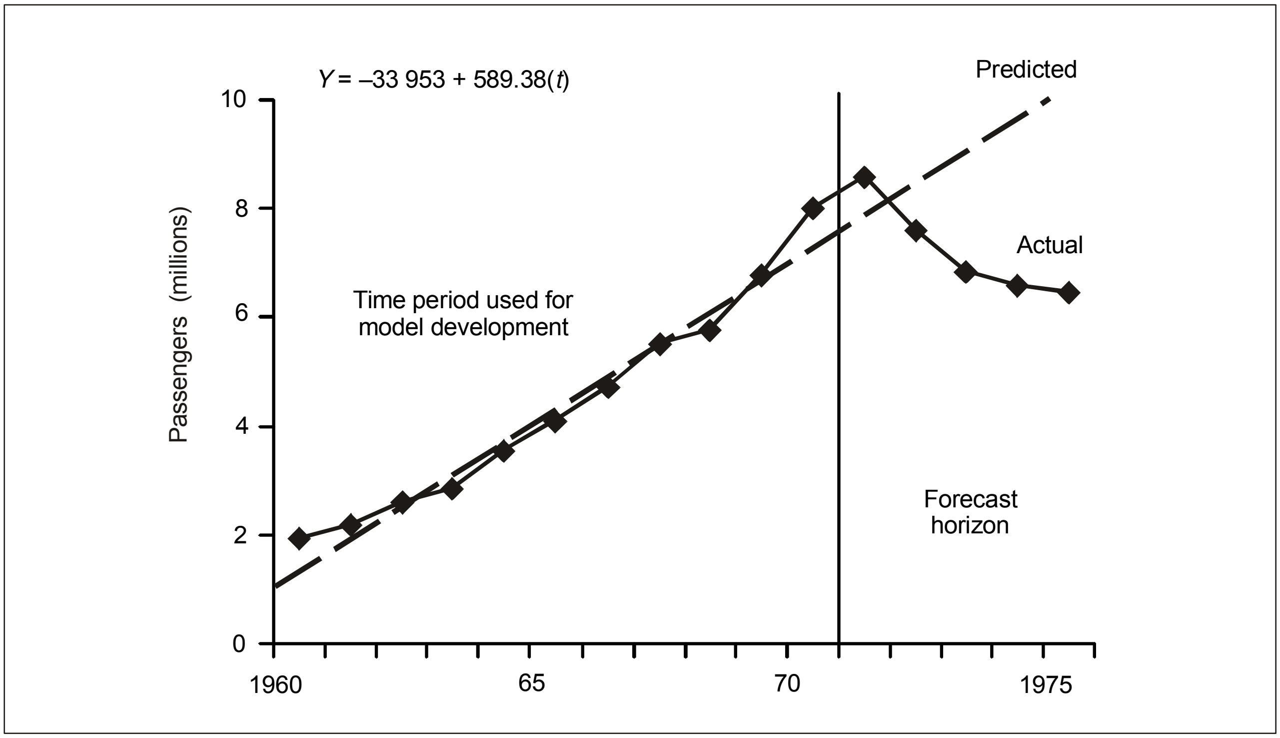


**Figure 1-10. An example of trend projection of linear form, 10-year period — North Atlantic passenger traffic (all services)**

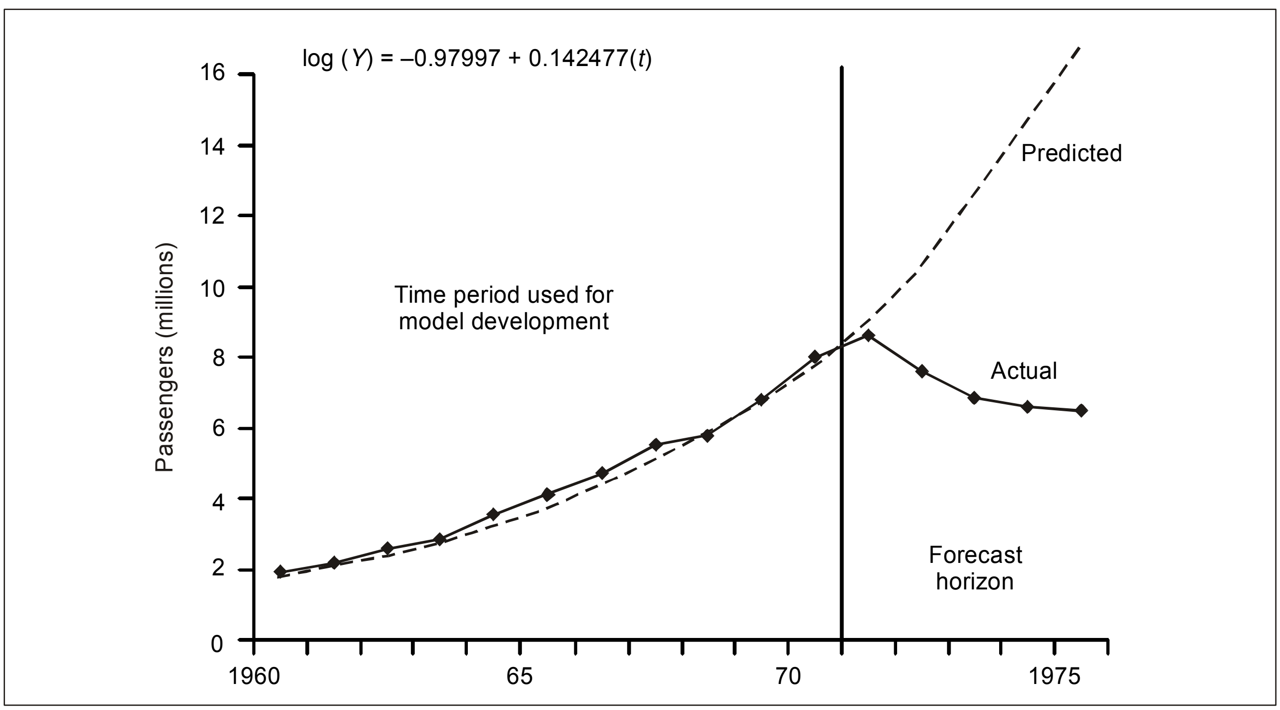


**Figure 1-11. An example of trend projection of multiplicative form, 10-year period — North Atlantic passenger traffic (all services)**

Using the same ten-year traffic data resulted in the following relationship:

$$\log(Y) = -0.97997 + 0.14277(t)$$

120. The graphical illustration shows how the model estimated the traffic for the period concerned. While it tracked the period 1960–1971 fairly accurately, the gap between the actual value versus the predicted value in the multiplicative form is much greater than in the previous case, the linear form.

121. The accuracy of trend extrapolation over time depends on whether steady-state conditions prevail over the time being forecast. There are other factors that had an impact over this time period. The slowdown in the economy and a four-fold increase in fuel prices that occurred in the 1973–1974 period had a strong negative impact on traffic in this most travelled international traffic flow.

122. The analysis can be further extended using the time-series data for the 1960–1985 period to cover the variation in traffic over a longer 25-year time horizon, compared to the ten-year horizon used earlier. The following relationships were established for the linear and multiplicative functional forms respectively:

*linear form:*

$$Y = -1\,681\,654 + 857.95(t)$$

*multiplicative form:*

$$\log Y = -183.36 + 0.098(t)$$

123. The results are summarized graphically in Figures 1-12 and 1-13. In this case, the linear relationships tracked the period 1960–1985 reasonably well. However, the estimates for the 1985–1995 period are much lower than the actual values (see Figure 1-12).

124. The prediction from the multiplicative form model is greater than the actual traffic (see Figure 1-13). The disparity between the predicted and the actual values increases as the time span of the forecast horizon increases.

125. With the 25-year time horizon, the actual values lie between the linear and the multiplicative functions. Given this situation, it appears that neither the linear nor the multiplicative form performs well. However, an average of the two methods appears to provide a good forecast in this case, particularly in the short term such as a period of one to two years. It is also evident that using the longer historical data stream (1960–1985), instead of the much shorter data stream (1960–1970), absorbed the cyclical variations of the data over the volatile time period of 1973–1974 and again in the 1975–1980 period. Cyclical variations are the result of a combination of many positive and negative factors over the time period concerned. It is evident from the above analysis that industry would have continually underestimated the growth in traffic throughout the 1985–1995 period if a linear extrapolation method had been used for this time period.

126. The above illustrations clearly demonstrate that an air traffic forecast arrived at by projection of past trends does not explicitly take into account the way in which various economic, social and operational conditions affect the development of the traffic. As these underlying causal factors change, it is important to attempt to take these changes into account in order to develop more reliable forecasts.

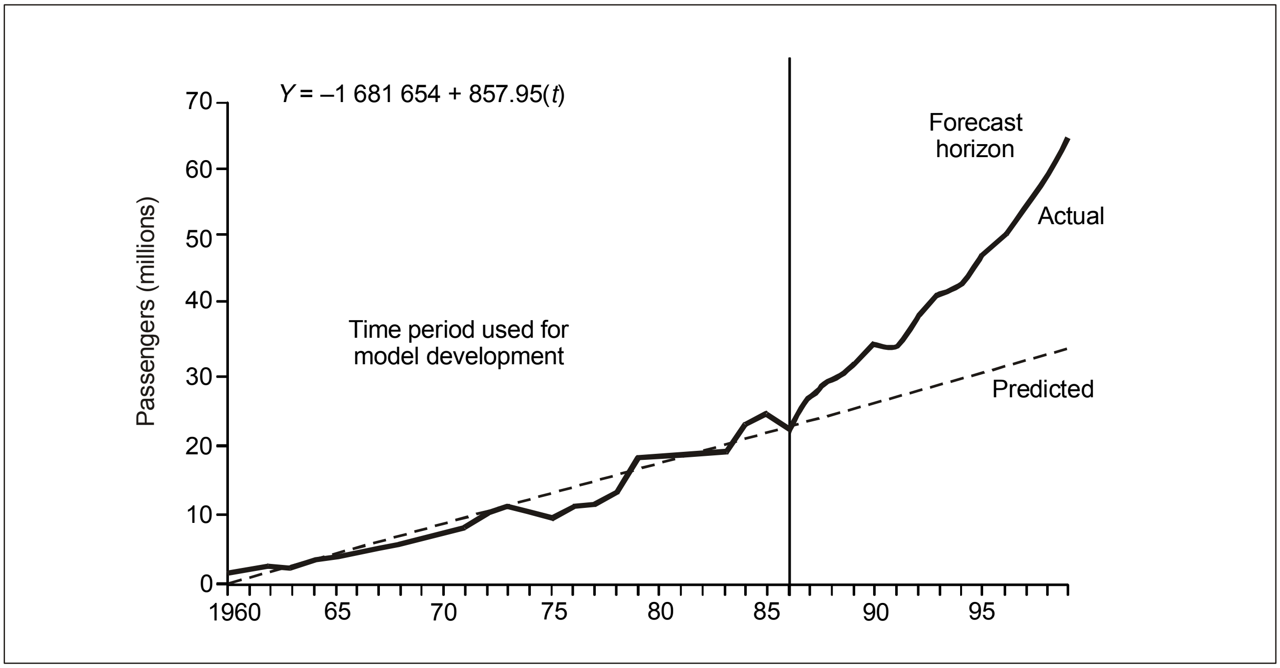


**Figure 1-12. An example of trend projection of linear form, 25-year period — North Atlantic passenger traffic (all services)**

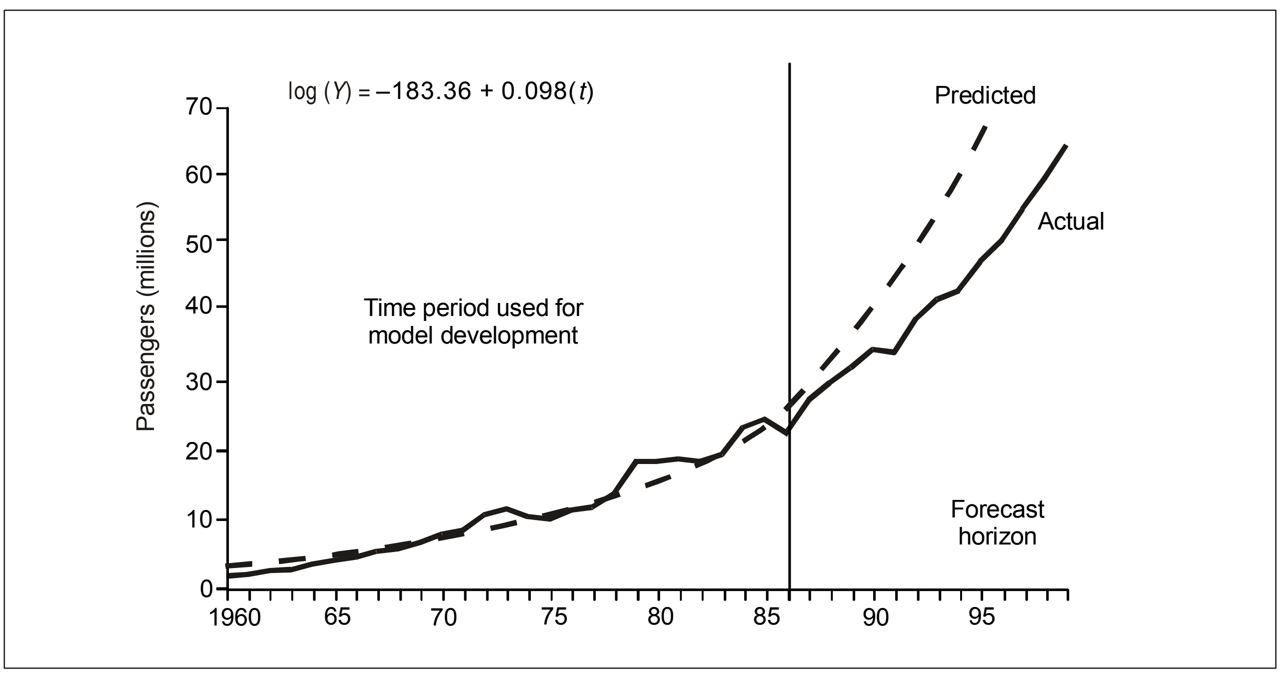


**Figure 1-13. An example of trend projection of multiplicative form, 25-year period — North Atlantic passenger traffic (all services)**

## ECONOMETRIC ANALYSIS

### ICAO'S GLOBAL AIR TRAFFIC FORECAST

127. It has been found that the demand for air travel is primarily determined by socio-economic variables such as income, demographics and the cost of air travel. World energy demand, supply and prices are critically important to both economic progress and the cost of air travel.

128. Analysis of historical data for world airline scheduled traffic indicates that air transport has exhibited high growth rates since its inception in the 1940s. The average annual growth rate in the 1960–1970 decade was 13.3 per cent, and the growth rate subsequently declined to 9.3, 5.9 and 5.7 per cent for the next three decades, respectively (see Table 1-1). The corresponding growth of GDP for the ten-year periods concerned indicate that traffic, in general, has grown in parallel with prevailing economic activity. Likewise, reduction in airline yields (average prices) has influenced the stimulation of traffic growth.

129. World GDP, the broadest available economic indicator, is used in this model to estimate the impact of economic, demographic and income factors. Airline yields are used as a proxy for average airline fares, but the average fare would be more appropriate or ideal. Measurement of the price of air travel is complicated due to the structure of fares and both the types of service available and the varying fares available for each type. The current fare structure is a complex set of service pricing schemes that have evolved as a result of less government involvement in price setting and of various market developments, such as airline alliances and new low-cost carriers. Therefore, it is difficult to develop an accurate average fare index. In these circumstances, the use of airline yields, i.e. revenue per passenger-kilometre, appears to be an excellent proxy for average weighted airline fares.

130. Airline yields are dependent on a number of factors such as productivity gains, operational expenses and level of competition. Major developments related to these factors include efficiencies achieved in fuel and labour costs as well as the continued introduction of new, more efficient aircraft types. Airline yields for future periods are analysed by taking into account expected trends in aircraft productivity, fuel prices, load factor and other relevant factors affecting airline economics.

131. Once the values for the explanatory variables (GDP and yield in this case) have been determined for each of the years of the forecast horizon, they can be inserted into the model to estimate the traffic forecast.

132. The result of an econometric analysis process is illustrated applying a model for the world airline traffic and using historical data for the period 1960–2000 (Table 1-1). The dependent variable is the total world scheduled traffic, excluding that of the Commonwealth of Independent States (CIS), expressed in RPKs. The explanatory variables chosen for this particular model are world gross domestic product (GDP) as a measure of economic activity, and airline yields expressed as revenue per passenger kilometre, which is used as a proxy for weighted average airline fares. The explanatory variables are expressed in real terms (1980 dollars) to remove the effect of inflation.

133. After examining the data and their growth patterns, a multiplicative functional form was chosen as the most suitable:

$$Y = aX_1^b X_2^c$$

As discussed earlier, this form can be made linear in its parameters:

$$\log(Y) = \log(a) + b\log(X_1) + c\log(X_2)$$

On the basis of this data, the following equation was estimated:

$$\log(\text{RPK}) = -1.52 + 2.31 \log(\text{GDP}) - 0.35 \log(\text{yield})$$

$R^2$ = .998 (29.5) (4.1)
*S.E.* = 0.033

where $R^2$ is the coefficient of correlation, and *S.E.* is the standard error associated with the estimate of RPK. The *"t"* statistics for the GDP and yield coefficients are given in brackets under the coefficients.

134 These statistical measures indicate that 99.8 per cent of the variations are explained by the model with a very small standard error. The high *"t"* values (29.5 and 4.1) for the coefficients indicate that they are stable; therefore, a high degree of confidence can be placed in the validity and accuracy of the model.

135. Since a multiplicative form is used, the coefficients of the model reflect elasticity as described in the section "Elasticity of demand" (paragraphs 29 and 30) and the elasticities are assumed to remain constant for the forecast horizon; hence, the coefficients of the explanatory (or independent) variables can be interpreted as follows:

a) A one per cent increase in real GDP will increase traffic demand (RPK) by 2.31 per cent.

b) Likewise, a one per cent decline in real yield (average prices) will increase traffic by 0.35 per cent.

c) The results from this analysis also imply that at the aggregate level for the world, approximately 85 per cent of the traffic growth can be attributed to economic factors whereas about 15 per cent can be attributed to the cost of travel.

d) These factors, of course, can vary for different regions of the world as well as for major domestic and international traffic flows.

e) Also, it is important to keep in mind that the elasticity values are relative and not absolute, and there is some bias associated with the coefficients.

136. The graph in Figure 1-14 simulates the historical period using the econometric model. The dotted line indicates the model prediction compared to that of the actual value indicated by the solid line. The error term, which is the variation between the actual and the predicted value, provides the analyst with additional information to understand the accuracy of the model and reasons for under- or over-prediction. A sudden shift in demand due to airline strikes, special events, terrorist attacks or other disturbances requires analysis using special variables. The error term becomes an important parameter to analyse these effects as well as the impact of variables that have been "left out" of the model and to determine whether the autocorrelation in the error term is evident.

137. The ICAO Secretariat has considerable experience using income-price (GDP-yield) econometric models to forecast demand for air travel, and the results have generally been good.

138. As an illustration, suppose the real GDP of the world is expected to grow at an average annual rate of 2.5 per cent and that the yield (real revenue per passenger kilometre) is estimated to increase at 1.5 per cent per annum. The average annual growth rate for traffic for the period can be estimated by inserting these values into the model, which results in an average annual growth rate of 5.2 per cent for the period 2000–2010, as illustrated in Figure 1-15. This is a long-term trend. Year-to-year changes in traffic growth can be estimated by incorporating the appropriate values for GDP and yield on an annual basis.

**Table 1-1. World airline traffic and GDP**

| Year | RPK (excluding CIS States) | Real GDP index | Real passenger yield index |
|---|---|---|---|
| 1960 | 109 | 43.0 | 165.9 |
| 1961 | 117 | 44.5 | 170.3 |
| 1962 | 130 | 46.8 | 161.3 |
| 1963 | 147 | 49.2 | 153.5 |
| 1964 | 171 | 52.2 | 146.8 |
| 1965 | 198 | 55.1 | 140.8 |
| 1966 | 229 | 58.1 | 134.0 |
| 1967 | 273 | 60.2 | 125.6 |
| 1968 | 309 | 63.4 | 119.1 |
| 1969 | 351 | 66.9 | 117.2 |
| 1970 | 382 | 69.2 | 113.2 |
| 1971 | 406 | 72.0 | 113.9 |
| 1972 | 465 | 75.9 | 109.5 |
| 1973 | 520 | 80.6 | 106.5 |
| 1974 | 548 | 81.9 | 106.7 |
| 1975 | 575 | 82.7 | 106.9 |
| 1976 | 633 | 86.8 | 100.0 |
| 1977 | 691 | 90.6 | 99.5 |
| 1978 | 797 | 94.5 | 94.4 |
| 1979 | 910 | 97.9 | 92.5 |
| 1980 | 929 | 100.0 | 100.0 |
| 1981 | 948 | 101.6 | 94.7 |
| 1982 | 970 | 101.7 | 86.9 |
| 1983 | 1 013 | 103.7 | 84.8 |
| 1984 | 1 095 | 105.8 | 82.3 |
| 1985 | 1 180 | 107.9 | 79.9 |
| 1986 | 1 258 | 110.1 | 77.9 |
| 1987 | 1 388 | 112.8 | 75.1 |
| 1988 | 1 492 | 115.6 | 72.8 |
| 1989 | 1 556 | 119.2 | 71.9 |
| 1990 | 1 653 | 121.8 | 72.1 |
| 1991 | 1 618 | 121.9 | 71.3 |
| 1992 | 1 786 | 123.9 | 66.0 |
| 1993 | 1 852 | 126.1 | 63.9 |
| 1994 | 2 029 | 129.7 | 63.2 |
| 1995 | 2 172 | 133.7 | 63.5 |
| 1996 | 2 360 | 138.5 | 59.8 |
| 1997 | 2 534 | 143.1 | 55.9 |
| 1998 | 2 598 | 145.6 | 54.1 |
| 1999 | 2 742 | 149.9 | 51.9 |
| 2000 | 2 964 | 156.8 | 51.4 |
| Traffic growth (average annual per cent growth rates) | | | |
| 1960–1970 | 13.3 | | |
| 1970–1980 | 9.3 | | |
| 1980–1990 | 5.9 | | |
| 1990–2000 | 5.7 | | |

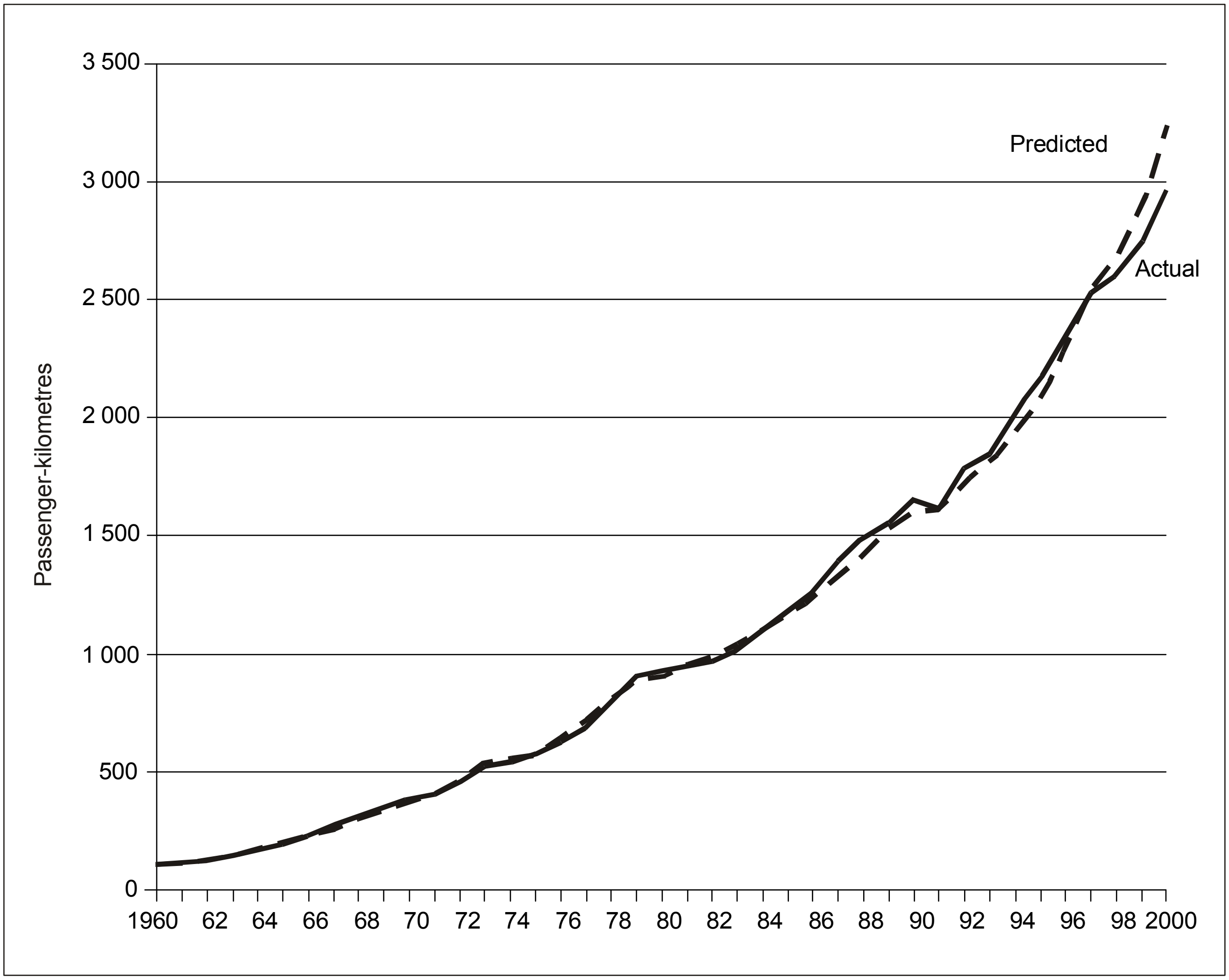


**Figure 1-14. Actual versus predicted world data, 1960–2000**

139. Taking into account the impact of the events of 11 September 2001, the war in Iraq and other unforeseen events such as the severe acute respiratory syndrome (SARS) outbreak, the predictions of the explanatory variables should be adjusted to reflect the lower growth rates experienced for the years 2001, 2002 and 2003. In addition, "the dummy variables technique" should be introduced into the model to account for such events.

## ICAO'S TRANS-PACIFIC MARKET FORECAST (APPLICATION OF DUMMY VARIABLES)

140. The following example from the trans-Pacific market illustrates the use of dummy variables to account for the impact of the events of 11 September 2001 on traffic demand in the year 2001 and to assess the impact of the traffic downturn due to the financial crisis that occurred in the Asia/Pacific region in 1998.

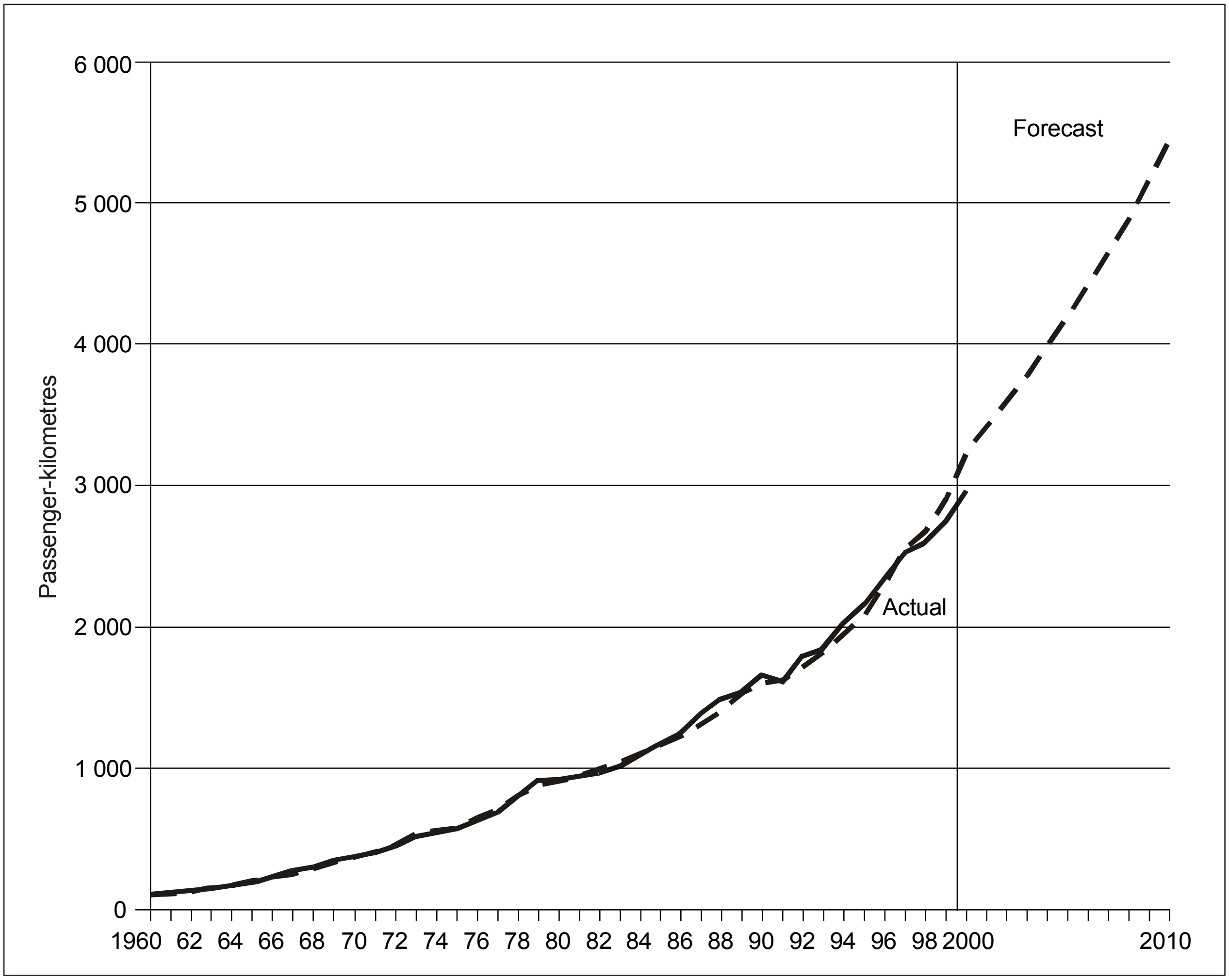


**Figure 1-15. Actual versus predicted and forecast to 2010**

141. Two dummy variables were introduced into the model to assess the impact of the respective events. The variable $dummy_1$ was introduced into the model to capture the impact of traffic downturns that occurred in 1998, and $dummy_2$ was introduced to capture the impact of the events of 11 September 2001. Traffic data, GDP and yield given in Table 1-2 were used in the analysis.

142. The analysis using the above data and dummy variables resulted in the following forecasting model:

$$\log(\text{passengers}) = -4.82 + 1.90 \log(\text{GDP}) - 0.69 \log(\text{yield}) - 0.20\,(\text{dummy}_1) - 0.13\,(\text{dummy}_2)$$

$R^2 = 0.99$ "$t$" GDP = 5.67

*S.E.* = 0.03 "$t$" yield = 2.01.

The introduction of the "dummy variable" for the years 1998 and 2001 provided a more accurate representation of the traffic forecast and improved the predicting capability of the model.

**Table 1-2. Trends in trans-Pacific traffic, GDP and yields**

| Year | Total traffic | Real GDP U.S.$ (billions) (1990 prices) | Yield index | $Dummy_1$ | $Dummy_2$ |
|---|---|---|---|---|---|
| 1980 | 6 845 | 7 688 | 139.48 | | |
| 1981 | 6 845 | 7 907 | 145.67 | | |
| 1982 | 7 036 | 7 908 | 134.53 | | |
| 1983 | 7 058 | 8 217 | 132.10 | | |
| 1984 | 8 296 | 8 704 | 127.37 | | |
| 1985 | 8 889 | 9 057 | 119.26 | | |
| 1986 | 10 044 | 9 363 | 126.11 | | |
| 1987 | 11 517 | 9 750 | 115.58 | | |
| 1988 | 13 363 | 10 269 | 108.42 | | |
| 1989 | 14 729 | 10 642 | 103.16 | | |
| 1990 | 16 033 | 10 937 | 100.00 | | |
| 1991 | 16 363 | 11 109 | 100.77 | | |
| 1992 | 18 121 | 11 494 | 93.63 | | |
| 1993 | 18 967 | 11 727 | 93.96 | | |
| 1994 | 20 266 | 12 185 | 93.68 | | |
| 1995 | 22 567 | 12 732 | 87.96 | | |
| 1996 | 24 816 | 13 241 | 83.88 | | |
| 1997 | 26 779 | 13 739 | 80.43 | | |
| 1998 | 25 184 | 13 941 | 80.43 | 1 | |
| 1999 | 26 681 | 14 482 | 78.82 | | |
| 2000 | 28 846 | 15 184 | 78.43 | | |
| 2001 | 25 945 | 15 380 | 76.07 | | 1 |
| | | Average annual growth rate (per cent) | | | |
| | 6.9 | 3.4 | –2.8 | | |

## LONGER-TERM FORECASTS (25 TO 50-YEAR HORIZON)

143. In many instances, the aviation industry forecasts call for much longer time horizons, up to 25 to 50 years. This is particularly relevant for aviation environmental issues, for example, when considering possible future effects of aviation activity on the atmosphere as a result of greenhouse gas emissions from aircraft engines.

144. Early trend forecasts were straight-line extrapolations that were almost always too low in the rapid growth years of the 1950s and early 1960s. Forecasts made in the 1960s were exponential. Over the longer term, taking into account the moderation of growth that is likely to occur, the growth of the curve is more likely to be an S-curve. The problem in using the S-curve is to find the most appropriate type. It depends on the technology of the product cycle that is under consideration. The analysis of a long, historical data stream along with expert judgement plays a crucial role in selecting the appropriate form. S-curves can take a logistic, gompertz, exponential or logarithmic form.

145. When looking at a fifty-year horizon, it is advisable to consider a forecast scenario, rather than a forecast itself, because of the uncertainty associated with such a longer-term forecast. Such longer-term outlooks should take into account mega trends and the market maturity likely to occur over the period. As mentioned before, a logistic curve approach is considered more appropriate for this type of application. Logistic curves have the shape of a symmetrical S-curve, where the percentage growth accelerates initially and subsequently slows over time. A logistic model of the following form was utilized in the development of the fifty-year scenario for the demand for air transport, as illustrated in Figure 1-16. This classic growth model exhibits initial slow growth, starting from the point $K/(1+a)$ at $t = 0$, then demonstrates accelerated growth (a function of $b$, the growth rate) and eventually tapers off to the asymptote $K$. The model takes the form:

$$Y = \frac{K}{1 + a\exp(-bt)}$$

where:

$Y$ = dependent variable

$K$ = coefficient to be estimated

$b$ = growth factor ($b$ is less than 1)

$t$ = time

$a$ = constant factor.

146. It was recognized that different markets would achieve different rates of maturity over the forecast horizon. Member countries of the Organisation for Economic Co-operation and Development (OECD) may be approaching relative maturity, while in other markets in the developing world this process is only beginning. However, the market maturity concept would be of critical importance in the development of longer-term scenarios. The implicit assumption here is that, in the aggregate, global traffic should eventually level off at a rate equal to that of the world GDP growth rate as markets reach maturity. Therefore, RPK/GDP was used as the dependent variable in the model formulation:

$$\frac{\text{RPK}}{\text{GDP}} = \frac{K}{1 + a\exp(-bt)}$$

where:

RPK = total global traffic measured in revenue passenger-kilometres

GDP = world GDP in real terms

$K, a, b$ = parameter values

$t$ = time.

147. Thirty-seven years of data from 1960–1996, as shown in Table 1-3, were used in the model. Rather than make explicit assumptions as to the ultimate traffic level (*K*) or when it would be reached (*t*), no constraints were imposed on any of the parameters, and the data were allowed to determine the best fit for these values. Additional checks were made, by varying the starting year of the data and modelling subsets of the data, to ensure the stability and precision of the model.

148. The analysis resulted in the formulation as illustrated in Table 1-4.

149. Most of the statistical parameters, as indicated in Table 1-4, were found to be excellent. The model simulation is illustrated in Figure 1-17 for the historical period 1960–1995.

150. This model could then be used in the development of a range of possible (low-high) longer-term scenarios based on the expected growth scenarios of GDP over the fifty-year horizon. Global traffic scenarios were developed from the model by first projecting the estimated functional form of the model to the year 2050. GDP growth rates were then applied to transform the RPK/GDP projection into traffic scenarios in RPK. An illustration of one scenario to the year 2050 is given in Figure 1-18.

151. The example above demonstrates a successful application of logistic curves to assess the longer-term scenarios of the development of air transport from its early development phase, to a high growth phase and then to its maturity phase. The maturity phase usually exhibits gradually decreasing per cent growth in yearly growth increments.

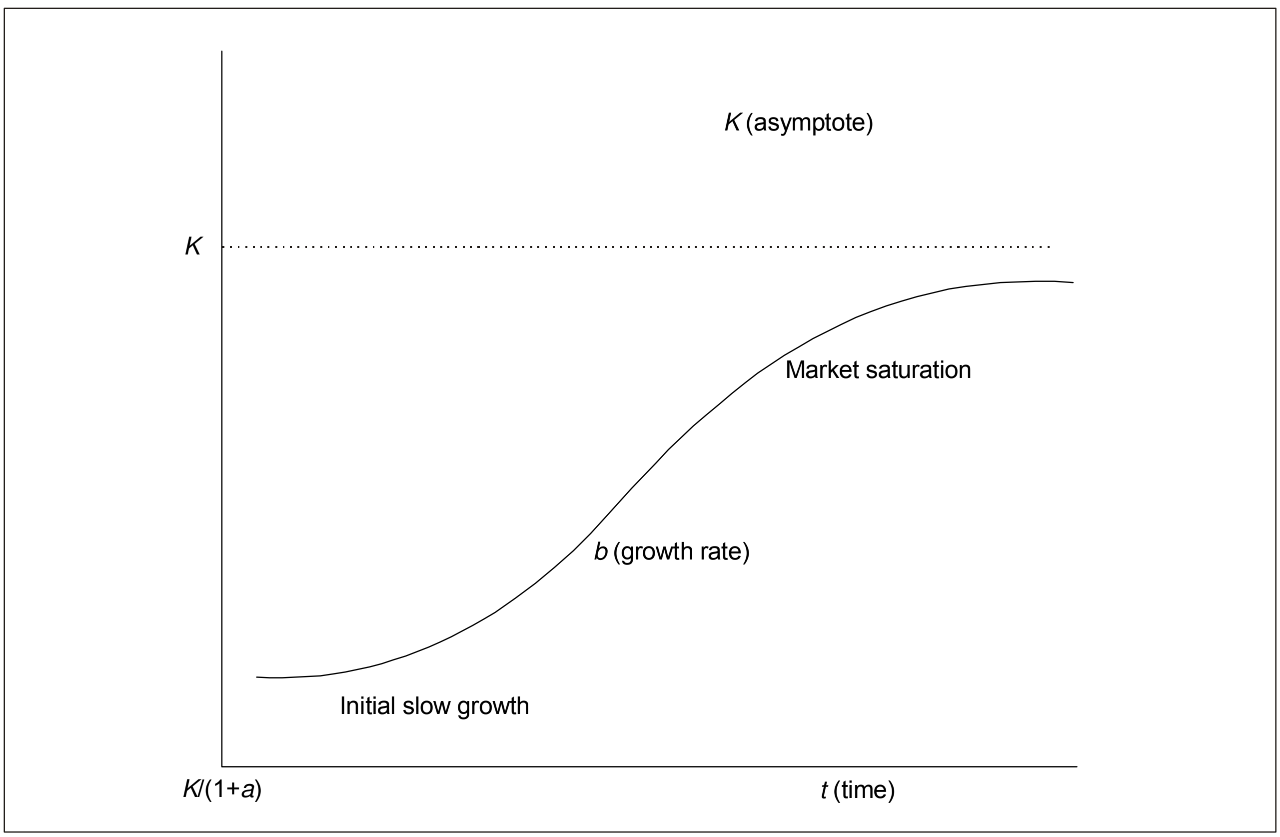


**Figure 1-16. Logistic curve**

**Table 1-3. RPK/GDP — Actual versus predicted results**

| Year | RPK (excluding CIS States) (billions) | GDP index (1980 = 100) | Actual RPK/GDP | Predicted |
|---|---|---|---|---|
| 1960 | 109 | 43.0 | 2.535 | 2.791 |
| 1961 | 117 | 44.5 | 2.629 | 2.979 |
| 1962 | 130 | 46.8 | 2.778 | 3.178 |
| 1963 | 147 | 49.2 | 2.988 | 3.389 |
| 1964 | 171 | 52.2 | 3.276 | 3.611 |
| 1965 | 198 | 55.1 | 3.593 | 3.845 |
| 1966 | 229 | 58.1 | 3.941 | 4.092 |
| 1967 | 273 | 60.2 | 4.535 | 4.352 |
| 1968 | 309 | 63.4 | 4.874 | 4.625 |
| 1969 | 351 | 66.9 | 5.247 | 4.911 |
| 1970 | 382 | 69.2 | 5.520 | 5.21 |
| 1971 | 406 | 72.0 | 5.639 | 5.523 |
| 1972 | 465 | 75.9 | 6.126 | 5.85 |
| 1973 | 520 | 80.6 | 6.451 | 6.19 |
| 1974 | 548 | 81.9 | 6.691 | 6.543 |
| 1975 | 575 | 82.7 | 6.953 | 6.91 |
| 1976 | 633 | 86.8 | 7.293 | 7.29 |
| 1977 | 691 | 90.6 | 7.627 | 7.682 |
| 1978 | 797 | 94.5 | 8.434 | 8.087 |
| 1979 | 910 | 97.9 | 9.295 | 8.502 |
| 1980 | 929 | 100.0 | 9.290 | 8.929 |
| 1981 | 948 | 101.6 | 9.331 | 9.366 |
| 1982 | 970 | 101.7 | 9.538 | 9.812 |
| 1983 | 1 013 | 103.7 | 9.769 | 10.267 |
| 1984 | 1 095 | 105.8 | 10.350 | 10.729 |
| 1985 | 1 180 | 107.9 | 10.936 | 11.197 |
| 1986 | 1 258 | 110.1 | 11.426 | 11.67 |
| 1987 | 1 388 | 112.8 | 12.305 | 12.147 |
| 1988 | 1 492 | 115.6 | 12.907 | 12.626 |
| 1989 | 1 556 | 119.2 | 13.054 | 13.107 |
| 1990 | 1 653 | 121.8 | 13.571 | 13.588 |
| 1991 | 1 618 | 121.9 | 13.273 | 14.067 |
| 1992 | 1 786 | 123.9 | 14.415 | 14.544 |
| 1993 | 1 852 | 126.1 | 14.683 | 15.018 |
| 1994 | 2 029 | 129.7 | 15.648 | 15.486 |
| 1995 | 2 172 | 133.7 | 16.248 | 15.948 |
| 1996 | 2 344 | 138.4 | 16.941 | 16.403 |

**Table 1-4. Logistic model regression statistics**

| | Coefficient | Standard error | t-statistic | 2-tail significance |
|---|---|---|---|---|
| *K* | 26.24 | 2.05 | 12.81 | 0.000 |
| *a* | 9.04 | 0.55 | 16.32 | 0.000 |
| *b* | –0.073 | 0.003 | 19.67 | 0.000 |

| | | | |
|---|---|---|---|
| R-squared | 0.994041 | Mean dependent variable | 8.65139 |
| Adjusted R-squared | 0.99369 | Standard deviation dependent variable | 4.281283 |
| Standard error of regression | 0.340082 | Sum of squared residuals | 3.932307 |
| Log likelihood | 11.02943 | F-statistic | 835.672 |
| Durbin-Watson statistic | 0.706985 | Probability (F-statistic) | 0.000 |

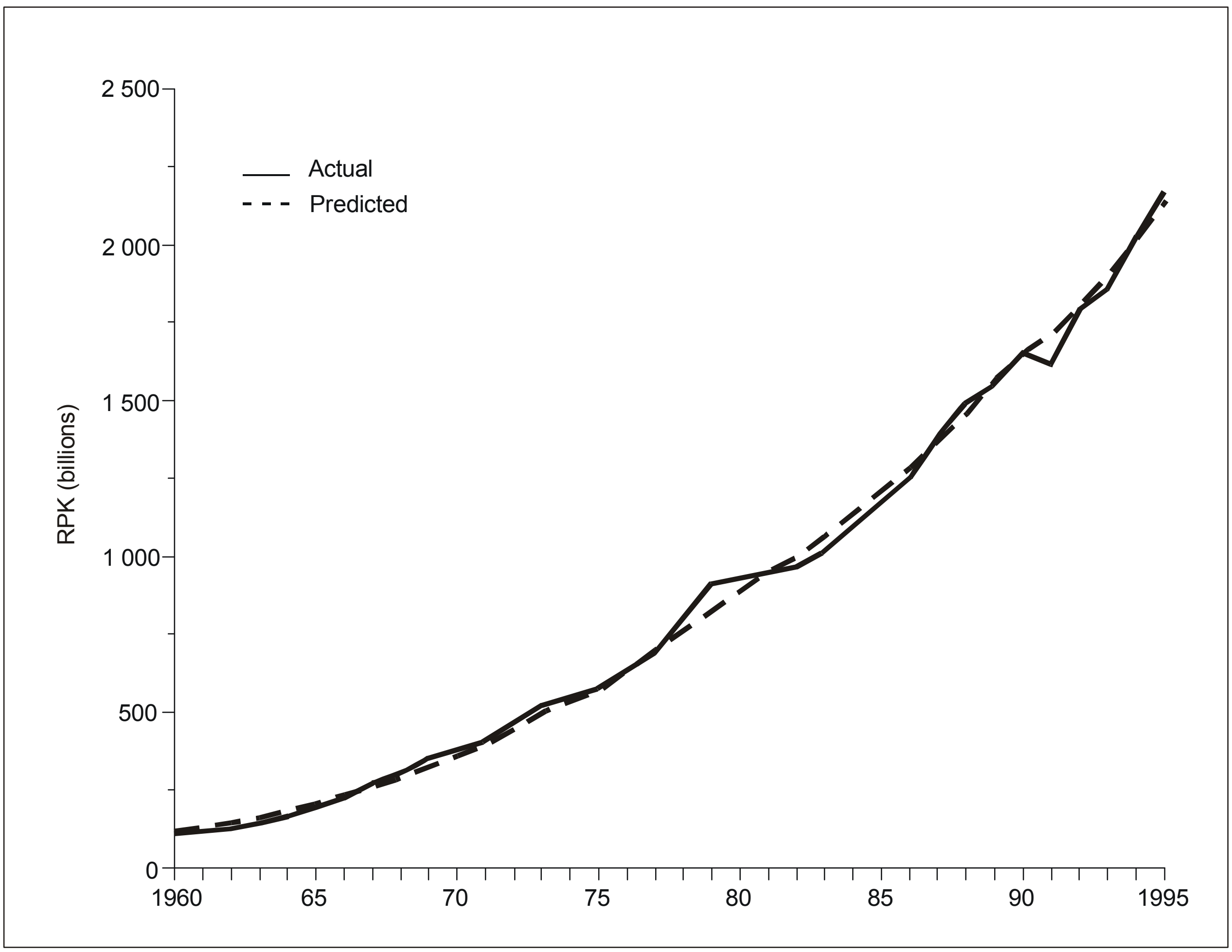


**Figure 1-17. Traffic — actual versus predicted**

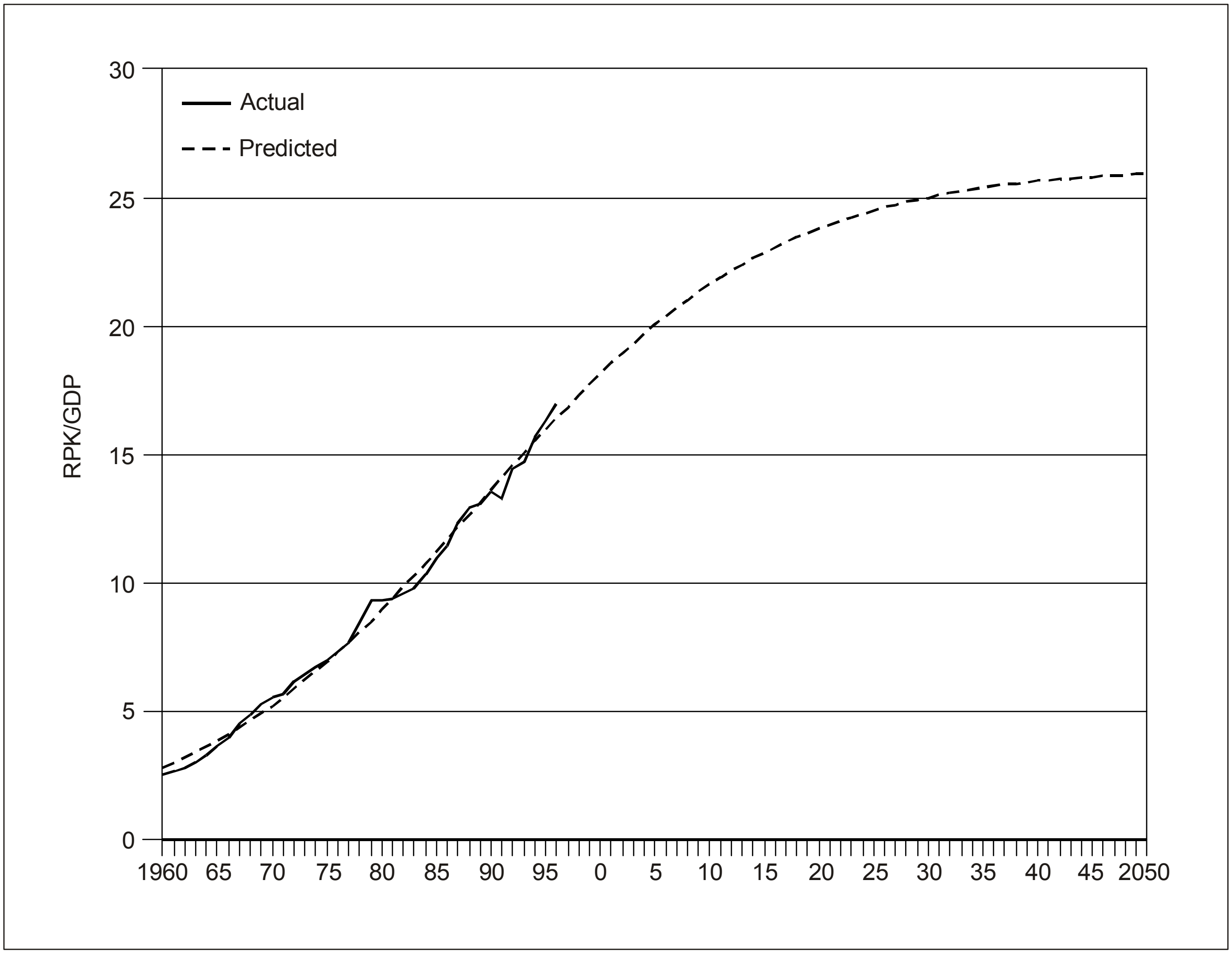


**Figure 1-18. Plot of actual versus predicted, with projection**

# PART II — FORECASTING FOR AVIATION PLANNING

1. Part II of this manual presents methods and procedures for forecasting for aviation planning, including forecasting for air navigation planning, airport planning and airline planning purposes. The methods developed by ICAO and its regional traffic forecasting groups (TFGs), including those required for the progressive implementation of the components of communications, navigation, surveillance/air traffic management (CNS/ATM) systems are also presented.

## AIR NAVIGATION SYSTEMS PLANNING

2. Traffic forecasts and peak-period parameters are important for air navigation systems planners in anticipating where and when congestion occurs. Traffic forecasts are required by ICAO's regional planning and implementation groups for air navigation systems planning including the implementation of CNS/ATM systems across the regions. A uniform strategy has been adopted by ICAO for the purpose of developing traffic forecasts and peak-period parameters in support of the regional planning process. This section provides an overview of the methodology developed by ICAO and its regional traffic forecasting groups in the generation of these forecasts.

3. Some of the key planning parameters required for air navigation systems planning include annual aircraft movements and an assessment of aircraft movements during peak periods. The peak-period parameters are further disaggregated into average-day movements, peak-day movements as well as average-hour and peak-hour aircraft movements for a given airspace.

### ESTIMATES OF AIRCRAFT MOVEMENTS

4. Estimates of aircraft movements may be obtained by simple trend projection techniques, discussed in Part I of this manual, using historical aircraft movement data. However, such forecasts are valid only for a very short term.

5. The methodology described here starts with the air passenger demand forecast developed from the modelling procedures described in Part I. The primary relationship between aircraft movements and passenger demand hinges on the load factor and fleet mix. Passenger forecasts are therefore converted into aircraft movements taking into account fleet mix and average load factors. The load factor can be defined as the ratio of total passengers carried to total seats offered or the ratio of passenger-kilometres performed to available seat-kilometres.

6. The procedure developed for forecasts of aircraft movements is illustrated in the flow chart in Figure 2-1.

7. Historical trends in total seats offered, average aircraft size, average load factor as well as aircraft movements (departures) are established for each of the route groups concerned by utilizing the traffic by flight stage (TFS) data compiled by ICAO.

8. For each of the major route groups concerned, a detailed traffic flow matrix can be developed using data from the Official Airline Guide (OAG) as the basis. A relationship between the TFS data and the aircraft movement data from the OAG is then established.

9. As mentioned above, forecasts of aircraft movements in a particular route group can be derived from forecasts of passengers, and assumptions about future trends in load factors and average aircraft size. The link between these variables is given by:

$$\text{Aircraft movement} = \frac{\text{passenger numbers}}{(\text{load factor}) \bullet (\text{aircraft size})}$$

where:

load factor = number of passengers carried/total seats offered

aircraft size = total seats offered/total number of aircraft.

10. A judgement is necessary about whether or not gradual improvements in load factors can be expected from marketing initiatives and yield management programmes (the allocation of seats on particular flights to passengers using various types of fares). Assumptions can be made about future trends in average aircraft size based on expectations about the types of aircraft that may be introduced on the route over the forecast period. Historical trends as well as data concerning aircraft orders are also factored into the development of future trends.

11. The route group aircraft movement forecasts are then allocated to each of the city pairs within that particular matrix, taking into account traffic service patterns, types of aircraft, demographics and other pertinent factors. The aggregate of all the traffic flow within the matrix is adjusted, as necessary, so that the aggregate of all intermediate traffic flows within the matrix matches the average growth of the total flow of the route groups concerned.

12. The information from the OAG data can be used in grouping the in-service aircraft into different generic seat categories. The evolution of historical frequency and capacity and its future trends, based on the current in-service fleet and planned deliveries, as well as new aircraft types, should be taken into consideration.

## PEAK-PERIOD PLANNING PARAMETERS

13. Because of the seasonality patterns in the aviation industry, there are high variations in demand by month throughout the year. These variations will occur not only by month of the year, but also by day of the month. The daily traffic distribution will also vary by hour of the day. In markets with high seasonality patterns, peak-period patterns provide the planner with key information to determine areas of congestion that might occur in the airspace as well as in the airports and also help in the design of facilities.

14. ICAO regional traffic forecasting groups have developed system analysis modules to analyse all flight records for a given airspace for a sample week. Such analysis provides a summary, by aircraft type, of movements by route and day of the week. The analysis can also provide the busiest hour for each route and the corresponding traffic for the other routes during that busiest hour.

15. The following examples from the ICAO Asia/Pacific Area Traffic Forecasting Group (Tables 2-1 to 2-3) illustrate the application of the methodology described above.

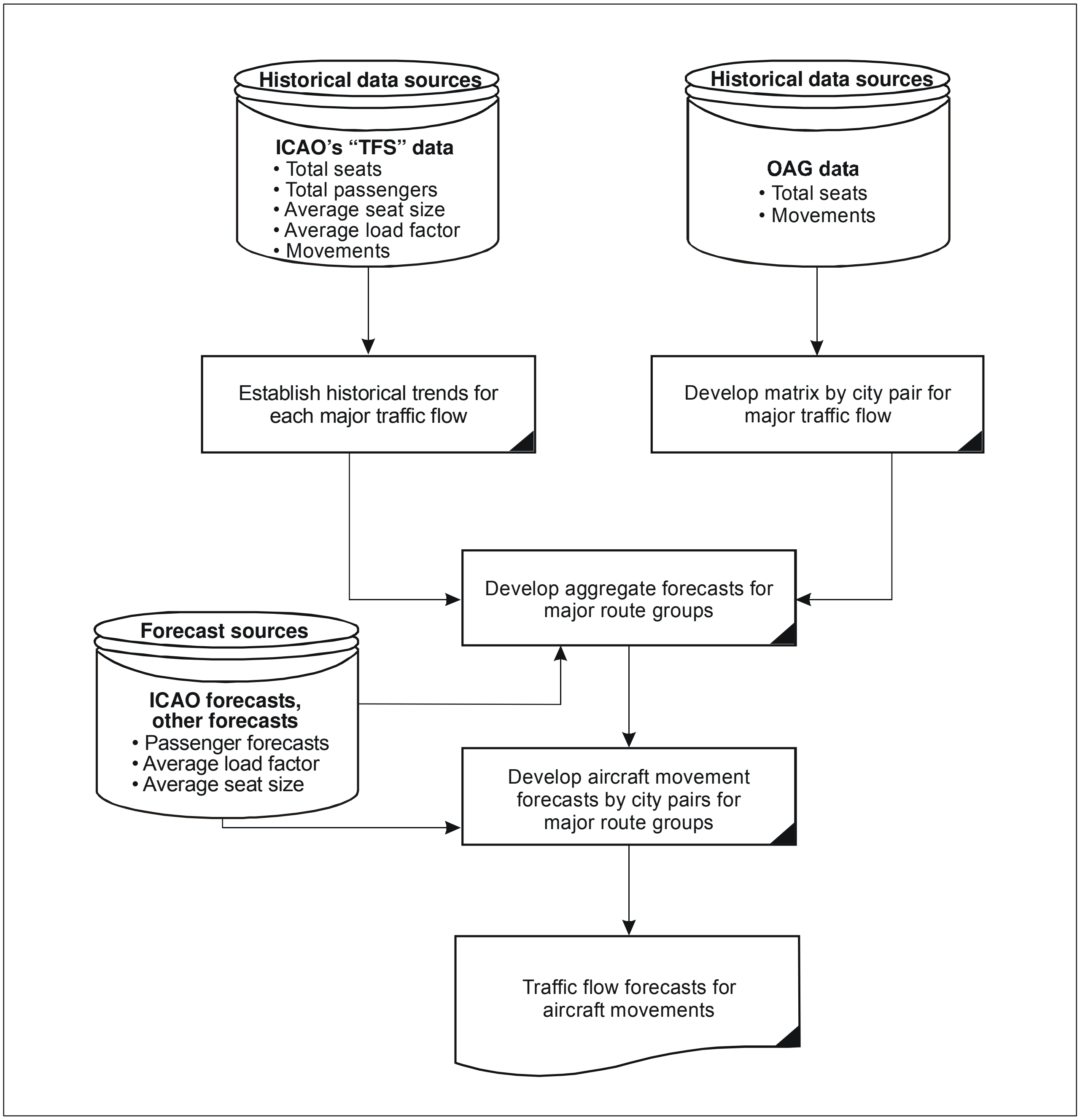


**Figure 2-1. Methodology for the development of traffic-flow forecasts for aircraft movements**

**Table 2-1. Pacific daily traffic summary**
(Week beginning Sunday, 1 July 2001)

| No. | Route | Sun. | Mon. | Tue. | Wed. | Thu. | Fri. | Sat. | Total | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ALASKA–ASIA PAC NO | 20 | 33 | 21 | 18 | 26 | 35 | 31 | 184 | 26.3 |
| 2 | ALASKA–ASIA PAC CE | 1 | 4 | 2 | 3 | 3 | 3 | 2 | 18 | 2.6 |
| 3 | HONOLULU–ASIA PAC NO | 20 | 19 | 19 | 21 | 19 | 20 | 18 | 136 | 19.4 |
| 4 | HONOLULU–ASIA PAC CE | 2 | 2 | 2 | 0 | 1 | 0 | 2 | 9 | 1.3 |
| 6 | US WEST–ASIA PAC NO | 40 | 40 | 39 | 40 | 41 | 42 | 43 | 285 | 40.7 |
| 7 | US WEST–ASIA PAC CE | 7 | 7 | 6 | 7 | 8 | 7 | 3 | 45 | 6.4 |
| 9 | US OTHER–ASIA PAC NO | 26 | 23 | 26 | 22 | 23 | 26 | 22 | 168 | 24.0 |
| 10 | CANADA–ASIA PAC NO | 11 | 10 | 9 | 9 | 10 | 9 | 9 | 67 | 9.6 |
| 11 | CANADA–ASIA PAC CE | 6 | 4 | 5 | 4 | 3 | 5 | 3 | 30 | 4.3 |
| 15 | ASIA PAC NO–ALASKA | 39 | 18 | 18 | 31 | 34 | 30 | 27 | 197 | 28.1 |
| 16 | ASIA PAC CE–ALASKA | 6 | 4 | 4 | 6 | 3 | 4 | 8 | 35 | 5.0 |
| 17 | ASIA PAC NO–HONOLULU | 17 | 20 | 20 | 20 | 17 | 20 | 18 | 132 | 18.9 |
| 18 | ASIA PAC CE–HONOLULU | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0.3 |
| 20 | ASIA PAC NO–US WEST | 44 | 40 | 41 | 48 | 44 | 44 | 44 | 305 | 43.6 |
| 21 | ASIA PAC CE–US WEST | 8 | 8 | 9 | 8 | 8 | 8 | 7 | 56 | 8.0 |
| 23 | ASIA PAC NO–US OTHER | 30 | 22 | 24 | 28 | 27 | 26 | 22 | 179 | 25.6 |
| 24 | ASIA PAC NO–CANADA | 10 | 9 | 10 | 8 | 10 | 9 | 8 | 64 | 9.1 |
| 25 | ASIA PAC CE–CANADA | 4 | 4 | 5 | 4 | 4 | 1 | 5 | 27 | 3.9 |
| WESTBOUND TOTALS | | 133 | 142 | 129 | 124 | 134 | 147 | 133 | 942 | 134.6 |
| EASTBOUND TOTALS | | 158 | 125 | 131 | 154 | 147 | 143 | 139 | 997 | 142.4 |

## AIRPORT PLANNING

16. Traffic forecasts provide criteria for both facility planning and financial planning. Traffic forecasts are required in order to determine future airport capacity requirements. Peak demand (rather than annual demand) must be determined in order to evaluate facility requirements since airport capacity becomes most critical during daily and hourly traffic peaks. The expected number of aircraft movements is the most important determinant of runway, taxiway and apron requirements, while the number of various categories of passengers (e.g. arriving, departing and transit) affects passenger terminal capacity requirements. Other planning parameters are required for other components of airport infrastructure such as cargo facilities, aeronautical and non-aeronautical activities and surface access. Airport development is generally planned on the basis of forecast activity during typical “peak” or “busy” periods because of the hourly, daily and monthly variations inherent in air transport. Airport forecasts are also required for assessing the environmental impact (analysis of noise contours and emissions) and assisting in the implementation of CNS/ATM systems.

**Table 2-2. Pacific aircraft category summary**
(Week beginning Sunday, 1 July 2001)

| No. | Route | B747 | A340 | MD11 | DC10 | B777 | B767 | Other | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ALASKA–ASIA PAC NO | 167 | 0 | 48 | 18 | 0 | 5 | 4 | 242 |
| 2 | ALASKA–ASIA PAC CE | 14 | 7 | 3 | 0 | 0 | 1 | 0 | 25 |
| 3 | HONOLULU–ASIA PAC NO | 105 | 0 | 4 | 19 | 0 | 10 | 6 | 144 |
| 4 | HONOLULU–ASIA PAC CE | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 7 |
| 5 | HONOLULU–ASIA PAC SO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | US WEST–ASIA PAC NO | 265 | 3 | 41 | 7 | 28 | 0 | 0 | 344 |
| 7 | US WEST–ASIA PAC CE | 37 | 7 | 0 | 0 | 0 | 0 | 0 | 44 |
| 8 | US WEST–ASIA PAC SO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | US OTHER–ASIA PAC NO | 117 | 0 | 13 | 0 | 42 | 0 | 1 | 173 |
| 10 | CANADA–ASIA PAC NO | 38 | 18 | 0 | 0 | 0 | 14 | 0 | 70 |
| 11 | CANADA–ASIA PAC CE | 22 | 7 | 0 | 0 | 0 | 0 | 0 | 29 |
| 12 | CANADA–HONOLULU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | US MAINLAND–HONOLULU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | CSA–HONOLULU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | ASIA PAC NO–ALASKA | 177 | 0 | 58 | 20 | 0 | 9 | 1 | 265 |
| 16 | ASIA PAC CE–ALASKA | 13 | 5 | 6 | 0 | 0 | 0 | 0 | 24 |
| 17 | ASIA PAC NO–HONOLULU | 99 | 0 | 4 | 18 | 0 | 10 | 5 | 136 |
| 18 | ASIA PAC CE–HONOLULU | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 7 |
| 19 | ASIA PAC SO–HONOLULU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | ASIA PAC NO–US WEST | 268 | 0 | 47 | 7 | 33 | 0 | 0 | 355 |
| 21 | ASIA PAC CE–US WEST | 44 | 10 | 0 | 0 | 0 | 0 | 0 | 54 |
| 22 | ASIA PAC SO–US WEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | ASIA PAC NO–US OTHER | 143 | 0 | 18 | 0 | 42 | 0 | 0 | 203 |
| 24 | ASIA PAC NO–CANADA | 39 | 19 | 0 | 0 | 0 | 14 | 0 | 72 |
| 25 | ASIA PAC CE–CANADA | 20 | 7 | 0 | 0 | 0 | 0 | 0 | 27 |
| 26 | HONOLULU–CANADA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | HONOLULU–US MAINLAND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | HONOLULU–CSA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | WESTBOUND TOTALS | 770 | 44 | 109 | 44 | 70 | 30 | 11 | 1 078 |
|  | EASTBOUND TOTALS | 803 | 48 | 133 | 45 | 75 | 33 | 6 | 1 143 |

## Table 2-3. Pacific busy hour report
(Week beginning Sunday, 1 July 2001)

| No. | Route | Hour | Day | Flights | Busiest hour and corresponding traffic by route | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | Sum |
| 1 | ALASKA–ASIA PAC NO | 6 | Saturday, 7 July 2001 | 10 | 10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 12 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 34 |
| 2 | ALASKA–ASIA PAC CE | 20 | Sunday, 1 July 2001 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| 3 | HONOLULU–ASIA PAC NO | 10 | Wednesday, 4 July 2001 | 6 | 1 | 0 | 6 | 0 | 0 | 10 | 0 | 0 | 7 | 3 | 0 | 0 | 0 | 0 | 9 | 0 | 2 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 |
| 4 | HONOLULU–ASIA PAC CE | 19 | Sunday, 1 July 2001 | 2 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 5 | HONOLULU–ASIA PAC SO | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | US WEST–ASIA PAC NO | 10 | Wednesday, 4 July 2001 | 10 | 1 | 0 | 6 | 0 | 0 | 10 | 0 | 0 | 7 | 3 | 0 | 0 | 0 | 0 | 9 | 0 | 2 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 |
| 7 | US WEST–ASIA PAC CE | 16 | Wednesday, 4 July 2001 | 3 | 1 | 0 | 0 | 0 | 0 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 8 | US WEST–ASIA PAC SO | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | US OTHER–ASIA PAC NO | 10 | Tuesday, 3 July 2001 | 8 | 1 | 0 | 5 | 0 | 0 | 8 | 0 | 0 | 8 | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 33 |
| 10 | CANADA–ASIA PAC NO | 6 | Sunday, 1 July 2001 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 8 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 18 |
| 11 | CANADA–ASIA PAC CE | 7 | Tuesday, 3 July 2001 | 2 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 1 | 3 | 5 | 0 | 0 | 6 | 0 | 0 | 4 | 1 | 1 | 0 | 0 | 0 | 31 |
| 12 | CANADA–HONOLULU | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | US MAINLAND–HONOLULU | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | CSA–HONOLULU | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | ASIA PAC NO–ALASKA | 10 | Sunday, 1 July 2001 | 10 | 0 | 0 | 5 | 0 | 0 | 7 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 10 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 34 |
| 16 | ASIA PAC CE–ALASKA | 7 | Tuesday, 3 July 2001 | 3 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 1 | 3 | 5 | 0 | 0 | 6 | 0 | 0 | 4 | 1 | 1 | 0 | 0 | 0 | 31 |
| 17 | ASIA PAC NO–HONOLULU | 7 | Monday, 2 July 2001 | 7 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 7 | 0 | 0 | 4 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 28 |
| 18 | ASIA PAC CE–HONOLULU | 10 | Wednesday, 4 July 2001 | 1 | 1 | 0 | 6 | 0 | 0 | 10 | 0 | 0 | 7 | 3 | 0 | 0 | 0 | 0 | 9 | 0 | 2 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 |
| 19 | ASIA PAC SO–HONOLULU | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | ASIA PAC NO–US WEST | 6 | Friday, 6 July 2001 | 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 12 | 2 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 25 |
| 21 | ASIA PAC CE–US WEST | 14 | Tuesday, 3 July 2001 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 22 | ASIA PAC SO–US WEST | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | ASIA PAC NO–US OTHER | 4 | Sunday, 1 July 2001 | 7 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 7 | 2 | 0 | 0 | 0 | 0 | 22 |
| 24 | ASIA PAC NO–CANADA | 7 | Saturday, 7 July 2001 | 3 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 7 | 0 | 0 | 6 | 2 | 0 | 7 | 3 | 0 | 0 | 0 | 0 | 33 |
| 25 | ASIA PAC CE–CANADA | 6 | Saturday, 7 July 2001 | 2 | 10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 12 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 34 |
| 26 | HONOLULU–CANADA | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | HONOLULU–US MAINLAND | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | HONOLULU–CSA | 0 | Sunday, 1 July 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | WESTBOUND | 10 | Wednesday, 4 July 2001 | 27 | 1 | 0 | 6 | 0 | 0 | 10 | 0 | 0 | 7 | 3 | 0 | 0 | 0 | 0 | 9 | 0 | 2 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 |
| | EASTBOUND | 7 | Saturday, 7 July 2001 | 29 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 7 | 0 | 0 | 6 | 2 | 0 | 7 | 3 | 0 | 0 | 0 | 0 | 33 |

## IDENTIFICATION OF AIRPORT PLANNING PARAMETERS

17. The availability of data required for airport forecasting and planning varies considerably from case to case. Where the available data is inadequate, a significant part of the forecasting task may be to supplement the data, for example, by means of special surveys.

18. The airport facilities to be considered and the nature of the planning decisions to be taken will determine the range of items to be forecast. Planning parameters commonly required are the following:

a) annual airport passengers categorized as international (scheduled or non-scheduled) or domestic, originating or terminating, and transiting or transferring;

b) annual aircraft movements by type of operations (international commercial, domestic commercial, general aviation, military);

c) peak-hour passengers by various categories;

d) peak-hour aircraft movements by size/type;

e) number of airlines serving the airport;

f) number and type of aircraft requiring maintenance and overhaul services at the airport;

g) number of visitors to the airport;

h) number of employees at the airport; and

i) freight and mail traffic.

## AIRPORT PASSENGERS

19. Terminal planning is assisted by breaking down passenger forecasts into passengers using the arrival and departure facilities (e.g. check-in, baggage collection, customs and immigration) and passengers using transfer or transit facilities (e.g. cafeterias and transit lounges). The factors that influence the number of originating/terminating passengers at an airport will differ from those affecting the number of direct transit and transfer passengers. It is therefore preferable to analyse and forecast these traffic categories separately. Forecasts of transit and transfer passengers at an airport are particularly sensitive to the structure of airline services in the region, which in turn is influenced by many factors, including the geographical pattern of demand, aircraft size, constraints on service frequency, number of competing airlines and government regulation of air services.

## AIRCRAFT MOVEMENTS

20. Aircraft movements can generally be grouped into commercial air transport movements (for carriage of passenger and freight traffic), general aviation movements (flying training, private and business

flying, aerial work, etc.) and military movements. Accommodation of passenger aircraft movements is generally the major reason for airport development.

21. The simplest method of forecasting future aircraft movements is to extrapolate the historic trend. However, although it is prudent to take historic trends in movements into account, a common approach is to derive forecasts of aircraft movements from passenger traffic forecasts and assumptions about future load factors and aircraft sizes. Using this approach, care is needed in the interpretation of the terms and concepts involved. For example, it is important to distinguish between "embarked/disembarked" load factors (i.e. the proportion of seats occupied by embarking passengers and those occupied by disembarking passengers) and "on-board" load factors. In some cases, transit passengers may not be included in airport data, and historic embarked/disembarked load factors observed at an airport may be much lower than on-board load factors. A low observed load factor may encourage the forecaster to predict a substantial build-up of the load factor during the forecast period when, in fact, this may be impossible because of the presence of large numbers of transit passengers.

22. A critical assumption affecting the forecasts of aircraft movements and the planning of airport facilities concerns the sizes (including seating capacity) of aircraft that will be using the airport over the forecast period. Also important are the proportion of movements by aircraft of different sizes. An indication of likely changes in the mix of aircraft types using the airport may be obtained from consultations with airlines and from judgements of the likely future suitability of new aircraft types for use on routes connecting the airport.

23. Instead of determining aircraft movements from an aggregate analysis of all routes serving the airport, it may be possible, depending on the resources available, to carry out a more detailed analysis by various submarkets, e.g. long haul, short haul, regional route groups or even individual routes. In a study of member airports of the former Western European Airports Association, aircraft movements by route were forecast for the busiest month. On routes dominated by pleasure travel, which tend to be operated at low frequencies by relatively large aircraft, forecast traffic growth was accommodated by increasing the aircraft load until an upper limit was reached, and thereafter by increasing the frequency. Future traffic growth on business-oriented routes, on the other hand, was accommodated by increasing the frequency until the routes reached a level of maturity specified by an upper limit on the frequency. Further anticipated growth was then accommodated by increasing the aircraft load.

## TRAFFIC IN PEAK PERIODS

24. There is no single universally accepted definition of typical peak periods. The typical peak hour is sometimes defined as the thirtieth or fortieth busy hour in a year, or traffic in a typical peak hour or peak day may be measured as an average over a specified period such as the peak month. The IATA airport forecasting programme defines an average week in the busiest month of the year (taking into account each of the Mondays in the peak month, each of the Tuesdays, etc.). The selected "busy day" is the second busiest day of that week.

25. Forecasts of peak-period passengers and aircraft movements can be obtained directly from annual forecasts by applying ratios of busy period traffic to annual traffic derived from recent historic data. However, time profiles of aviation activity are unlikely to remain constant. There is usually a trend in the ratio of peak to annual traffic which can be projected into the future, taking into account the factors which influence it, such as changes in the mix of business and holiday traffic, curfews at other airports and changing route patterns.

### OTHER PARAMETERS

26. As mentioned earlier, numerous other parameters need to be forecast for planning purposes. For example, the number of visitors to the airport in the peak period can be calculated on the basis of an assumed relationship to the number of originating and terminating passengers. Also, the number of employees can be forecast on the assumption of specific relationships to the number of air passengers or aircraft movements (depending on the job classification). These parameters are used in the estimation of parking requirements and the impact on airport surface access and transport.

27. The planning of freight handling facilities at an airport requires forecasts of the freight tonnage passing through the airport. Requirements for handling and clearance facilities often vary according to the type of freight so that a breakdown of the forecasts into various types of freight (e.g. perishables, live cargo, manufactured goods) may be needed.

### ALTERNATIVE DEVELOPMENT STRATEGIES

28. The planning parameters indicate possible future capacity requirements for various airport facilities. However, there are usually alternative ways of providing this capacity. For example, the design of new passenger facilities will depend on the relative emphasis given to spaciousness on the one hand and economy of design on the other. Airport capacity is also affected by various operating constraints and procedures such as curfews, scheduling activities to ease congestion, and priorities assigned to types of traffic. Although flexibility in these procedures is often severely limited, the planning process may sometimes involve changes to them, which may reduce the need for capacity expansion.

## AIRLINE PLANNING

29. The airline planning process is influenced by the results of planning in other civil aviation sectors, particularly as reflected in the capacity of the aviation infrastructure, the products of the equipment manufacturers, and government policy. In some measure, all of these in turn respond to traffic growth and the requirements for air services. Airline planning decisions are therefore important not only to airlines, but also to aircraft manufacturers, airport facility planners, regulatory bodies and the investment community. Airline planning involves the planning of routes and services, fare structures, fleet development and the estimation of market share. These various activities are interrelated and require close coordination.

### PLANNING OF ROUTES AND SERVICES

30. Econometric analysis and other quantitative forecasting techniques can be used to develop an airline’s total market outlook both for domestic and international markets. The airline’s share of a given market depends on several factors that are discussed below.

31. A carrier’s route system is essentially the key to all planning. Internationally, the traffic rights granted by governments in bilateral agreements provide the basis for the operation of an airline’s scheduled

route system, the expansion of operations and the serving of new routes. The degree of flexibility accorded by such rights, including the authority to pick up or carry traffic to various points, varies considerably.

32. The demand for air travel on particular routes is largely a function of traffic generating factors (e.g. population and economic conditions), price and service levels as discussed in Part I. This demand may also be influenced by the price and relative attractiveness of competing destinations and other transport modes. Moreover, demand for travel between two points usually represents only part of the total traffic between the two airports concerned since it also includes traffic coming from, or destined for, other points. This further broadens the range of factors to be considered in the preparation of route traffic forecasts and the planning of services.

33. Competition between carriers or airline alliances remains one of the most important elements in route and service planning. Such planning determines where and how the airline or alliance can compete effectively and what must be done to build up competitive strength to enter or defend markets. Various alternatives are explored, markets are researched in varying degrees, and opportunities and risks are evaluated, leading to the establishment of priorities. This activity is related to the efforts of marketing, scheduling and fleet planning.

34. Traffic shares of competing carriers or airline alliances serving a route can be influenced by a variety of factors such as price, service frequency, aircraft type and number of stops. Governments may exert a strong influence on airline traffic shares through traffic rights, including any capacity arrangements and, to some limited extent, regulations relating to fares and rates. This influence is, however, diminishing in most States as progressive liberalization alleviates capacity restrictions and deregulates fares and rates. Other factors may also play a role, such as the quality of customer service provided or traveller perceptions of the carriers.

## IMPACT OF FARE STRUCTURES

35. Fare structures have become very complex, with a variety of promotional fares offered on many routes in addition to first class, business class and normal economy class fares. In many markets, fares are often adjusted or introduced to meet competition. In some markets, circumstances may permit more careful evaluation of changes to fares, including predictions of the traffic and revenue shares of the various fare types, which mainly depend on the characteristics of the markets served, price differences and ticket restrictions (e.g. advance purchase, limitations on stopovers, or trip duration).

36. In any event, the fares offered will influence the traffic carried on individual routes as well as revenues generated and financial results. With fares established, yield management has become, for many airlines, an important means of influencing these results. Fare developments will thus influence planning decisions concerning the capacity to be offered on various routes.

## FLEET PLANNING

37. Fleet planning can be described as the act of determining future fleet requirements and the timing of aircraft acquisitions. Fleet planning is an important part of the development of an overall operating plan for the airline, which takes into account the airline's objectives, operating constraints and financial position.

38. The fleet planning process must consider the following:

a) airline goals and objectives;

b) passenger and cargo traffic demand;

c) service pattern impact on market share;

d) aeroplane performance;

e) operating economics; and

f) operational and other system constraints.

39. The nature of the fleet planning process is complex due to the following reasons:

a) Passenger and cargo traffic continue to increase.

b) Available aircraft types and configurations change.

c) Route structure, traffic rights and airline competition change.

d) There is a strong emphasis on financial results.

40. Three approaches are commonly used in airline fleet planning efforts. They can be categorized as the macro-evaluation method, the schedule-evaluation method and the aircraft-assignment method.

41. The macro-evaluation method is a multi-year system analysis wherein the number of various types of aircraft required is determined based on a macro-traffic forecast. There are several steps in the macro-evaluation method:

a) Forecast aggregate passenger/freight traffic.

b) Convert traffic forecast to a capacity forecast based on load factor assumptions.

c) Project the capacity available from the current fleet.

d) Calculate the additional requirements for growth and replacement, considering the fleet mix, aircraft productivity and system characteristics.

42. The macro-evaluation method is a reasonably quick method of estimating future fleet requirements. Several alternatives can be analysed, including different assumptions concerning seating capacity, average stage length and anticipated restrictions, taking into account the summary of the results of the various evaluation steps listed in paragraph 38. This technique places heavy emphasis on historical seat trends and average stage length, which may not be good indicators of future aircraft requirements. No attention is given to the airline’s route structure, and the analyst is limited to information aggregated over the whole system.

43. The schedule-evaluation method examines the quality of a previously determined schedule. After traffic demand is allocated to aircraft assigned to itineraries, the analyst examines the resulting load factor for direction. If it appears unreasonably high or low, adjustments are made to frequency, previously assigned aircraft, itinerary structure and connect opportunities. Operating economics are considered, and finally, fleet requirements are determined after several iterations of the approach.

44. In the aircraft-assignment method, total origin-destination traffic demand, aircraft performance, operating economics, financial limits and system constraints are initially defined. A computer programme is then used to select and assign aircraft that meet the service and operating requirements of the total system while satisfying some objective function such as operating profit. The system may be represented by individual itineraries or cells constructed by market segmentation techniques.

45. Each of these methods enters the airline planning process at a different point in the analysis, and each has a contribution to make. The planning requirements dictate when each technique is more appropriate. In summary, the planning process must be a system-level approach considering traffic demand, aircraft performance, operating economics and system constraints. The final results of the fleet-planning process will usually determine the major portion of future capital and other resource needs forming part of the total airline corporate plan.

## ESTIMATION OF AN AIRLINE'S MARKET SHARE

46. Having established the total market based on techniques discussed in Part I, an airline can estimate its market share using the analytical procedures described below:

$$(\text{M.S.})_x = \frac{\text{frequency offered by airline } x \ (F_x)}{\text{total frequency offered } (F_t) \text{ by all airlines serving the market}}$$

$(\text{M.S.})_x$ is a function of the frequency offered by airline $x$, assuming that all other factors (such as aircraft size) are equal. Such an estimate can be derived fairly easily from airline schedule data. However, there are several other relevant factors that must be taken into account in estimating the market share since they will have a direct impact. They can be categorized into two groups.

| Service offered by the airlines | Consumer preferences |
|---|---|
| Schedule | Schedule convenience — frequency |
| Equipment | Airline preference |
| Passenger service | Non-stop versus number of stops |
| Routing | Available fare plans |
| Fares | Frequent-flyer programmes |

These factors can then be broadly categorized into schedule-related factors and airline-related factors.

47. The schedule-related factors include airline flight frequency, number of stops and time preference. The latter two are more applicable in short-range and business-oriented markets than long-range markets. As the trip distance increases, the importance of non-stop flights and flight frequency decreases as illustrated in Figures 2-2 and 2-3, respectively.

48. Airline-related factors include the airline's position in the market, consumer preference for the airline due to its frequent-flyer programmes, its passenger service and its own image. These factors come into play primarily in long-range markets. The schedule and the time of day are considered less important as the trip distance increases.

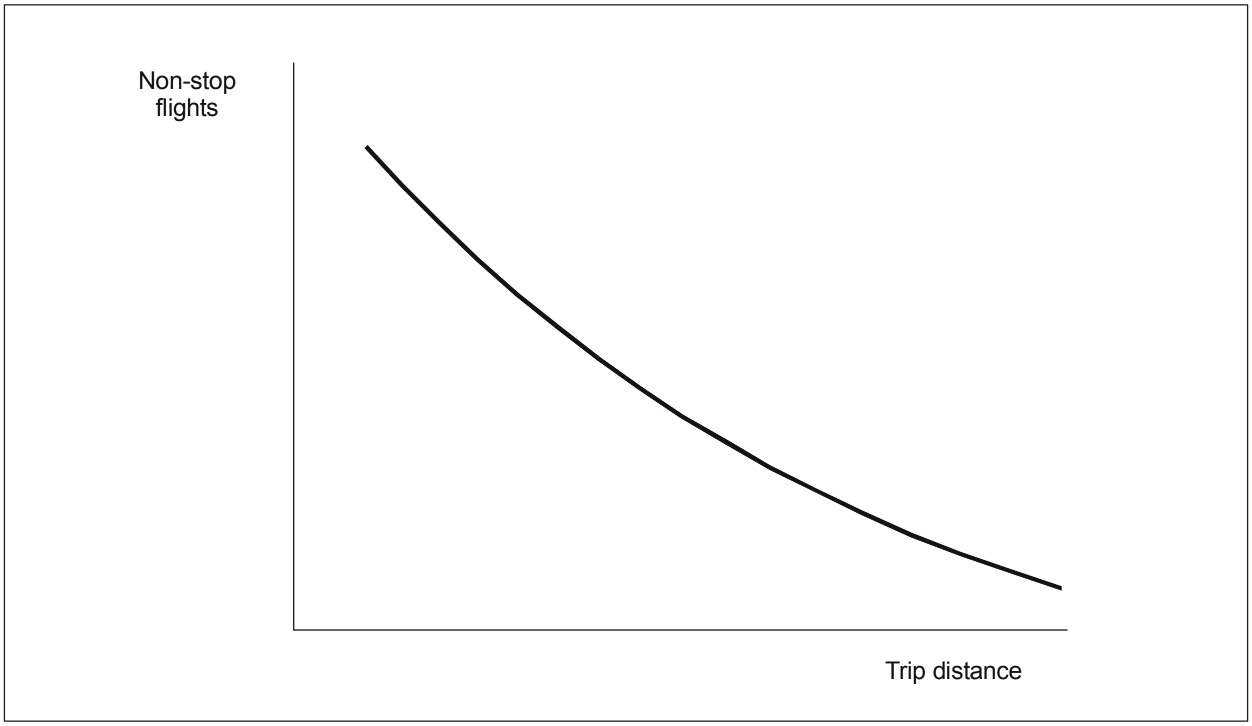


**Figure 2-2. Preference for non-stop flights**

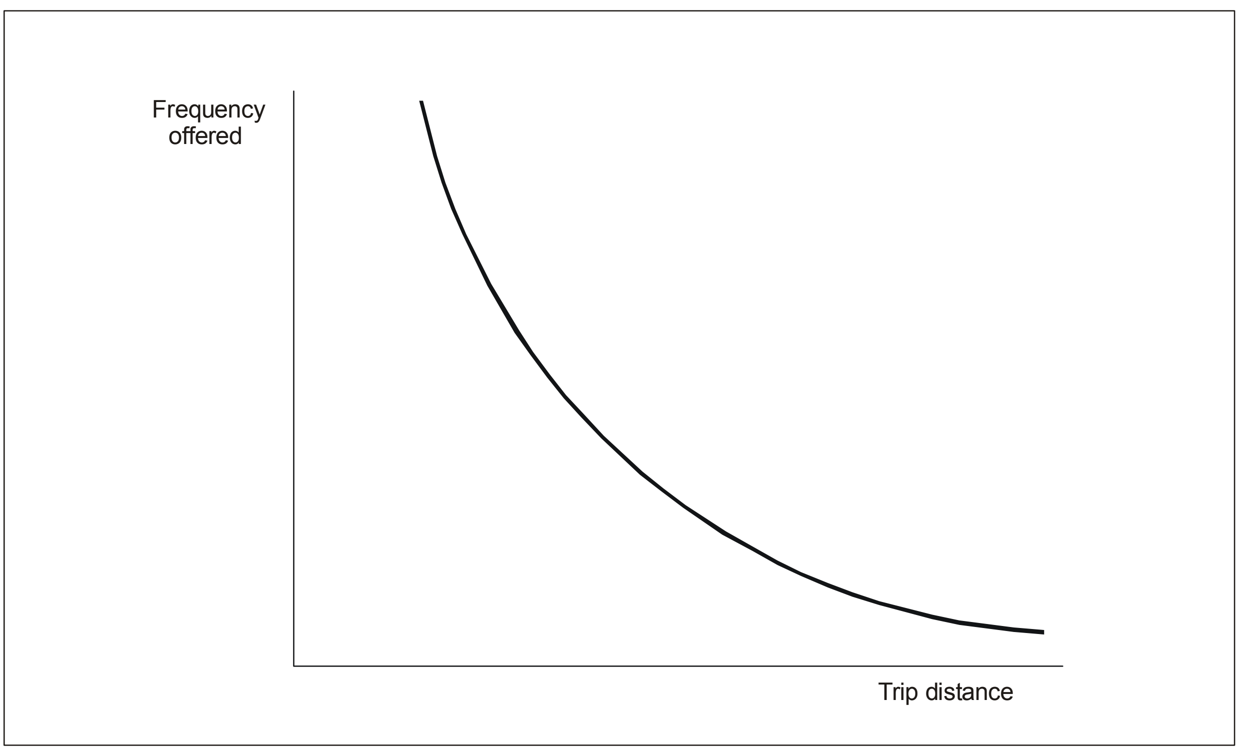


**Figure 2-3. Preference for frequency**

49. It should be noted that the proliferation of airline alliances and code-share systems further complicates the assessment of the market share of a given airline.

50. Taking the above factors into account, the market share for a given airline can be estimated using the following formula:

$$(\text{M.S.})_x = \frac{F_x C_x S_x P_x A_x}{\sum F_t C_t S_t P_t A_t}$$

where:

$F$ = airline flight frequency

$C$ = capacity offered

$S$ = stop factor

$P$ = average price

$A$ = airline's market appeal

$x$ = airline x

$t$ = airline servicing the market; $t$ takes values 1, …, n.

These factors have to be quantified taking into account the particular market and the airlines servicing that market. The formula can be simplified to take into account only the most relevant factors for the market concerned. For example, a long-range market does not need to include the stop factor because its effect diminishes with stage length.

# PART III — CASE STUDIES AND METHODOLOGIES FOR FORECASTING

1. Part III contains case studies of forecasting methods and approaches used by a selected set of ICAO Contracting States and other organizations to develop forecasts for the requirements of civil aviation. General air traffic forecasting methods used by the European Organisation for the Safety of Air Navigation (EUROCONTROL), Canada, India and Tunisia are presented. This is followed by a presentation of methodologies used in forecasting for airports including methods applied by airports of India and Newark Airport (United States). These case studies were provided by the States and Organizations concerned and were reviewed by the ICAO Secretariat.

## GENERAL AIR TRAFFIC FORECASTING

### EUROCONTROL FORECASTING METHODOLOGY

2. This is a summary of the air traffic forecast method used by the Statistics and Forecast Service (STATFOR) of EUROCONTROL.[1]

3. STATFOR produces air traffic forecasts for Europe and for a number of individual States and regions at the level of major flow (e.g. transatlantic). These forecasts are produced to support planning and monitoring of the air traffic management system, so they are focused on flights rather than passenger numbers or freight volumes.

4. STATFOR has three forecast horizons: short (24 months), medium (7 years) and long (typically 20 years). Each has its own method of forecasting.

#### SHORT-TERM FORECAST

5. The short-term forecast is produced by time-series methods. The steps involved are:

a) Take historical time series that are to be forecast, by month. Typically ten years are available, but in some cases only two or three years.

b) Adjust the series for errors (e.g. data recording), abnormal events (e.g. 1999 Kosovo Crisis), length of the month, moveable holidays such as Easter, etc.

c) Forecast each series using a pre-selected auto regressive integrated moving average (ARIMA) model or, if necessary, a simpler model (Holt-Winters or simple exponential smoothing). These models have been selected on out-of-sample performance at horizons of 1 to 24 months.

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1. EUROCONTROL/STATFOR/Doc 55, 30 July 2003.

d) Create forecast intervals by calculating how accurate this model would have been at each forecast horizon if used in earlier months.

e) Impose consistency within hierarchies of series (e.g. the forecast of total traffic should equal the forecasts for international arrivals and departures, domestic flights and overflights).

## MEDIUM-TERM FORECAST

6. The medium-term forecast (MTF) has, at its core, a forecast of traffic between airport pairs for each of a set of scenarios. This "core forecast" provides the consistent foundation for a number of different, more specific forecasts, e.g.:

a) traffic volume by origin-destination zone pair, assuming current routing patterns;

b) traffic volume by origin-destination zone pair, assuming the shortest route in the route network; and

c) flight hours by area control centre.

7. The MTF process also generates and applies supporting or explanatory information, e.g. aircraft size or the impact of airport capacity constraints.

8. Figure 3-1 gives more details on the MTF, focusing on the analysis processes and the related data. Each of the five processes has a similar form, taking one description of demand and then applying growth or supply data to develop a different description of demand. In more detail, the five processes are:

a) *Forecast demand.* The baseline demand is in terms of flights between area pairs (one or more areas per State, one or more airports per area). For passenger flights, convert this into passenger numbers in a number of categories. Using the socio-economic and supply data such as GDP, expand this baseline to give future demand (passenger numbers or flight numbers, depending on the type of flight).

b) *Forecast demand behaviour*: For passenger flights, convert the passenger demand into mode and station-pair[2] choices, taking into account the available connections between station pairs and other factors such as cost.

c) *Forecast schedules.* Using passenger demand and other information, such as information on airport capacity and fleets, refine the structure of connections between station pairs (and the structure of the fleet). Iterate these first three processes, as necessary.

d) *Forecast flights.* Combine the passenger flights and the other flight forecasts to produce a complete airport-pair forecast. This result is the "core" of the forecast for a particular scenario.

e) *Forecast flight details.* Use a given air route network and a routing rule (e.g. shortest route) to convert the airport-pair forecast of flights to a set of flight details. Measure the impact of these flight details (international arrivals and departures, domestic flights and overflights) for all reporting regions.

2. "Station" means either an airport or a railway station (for high-speed trains).

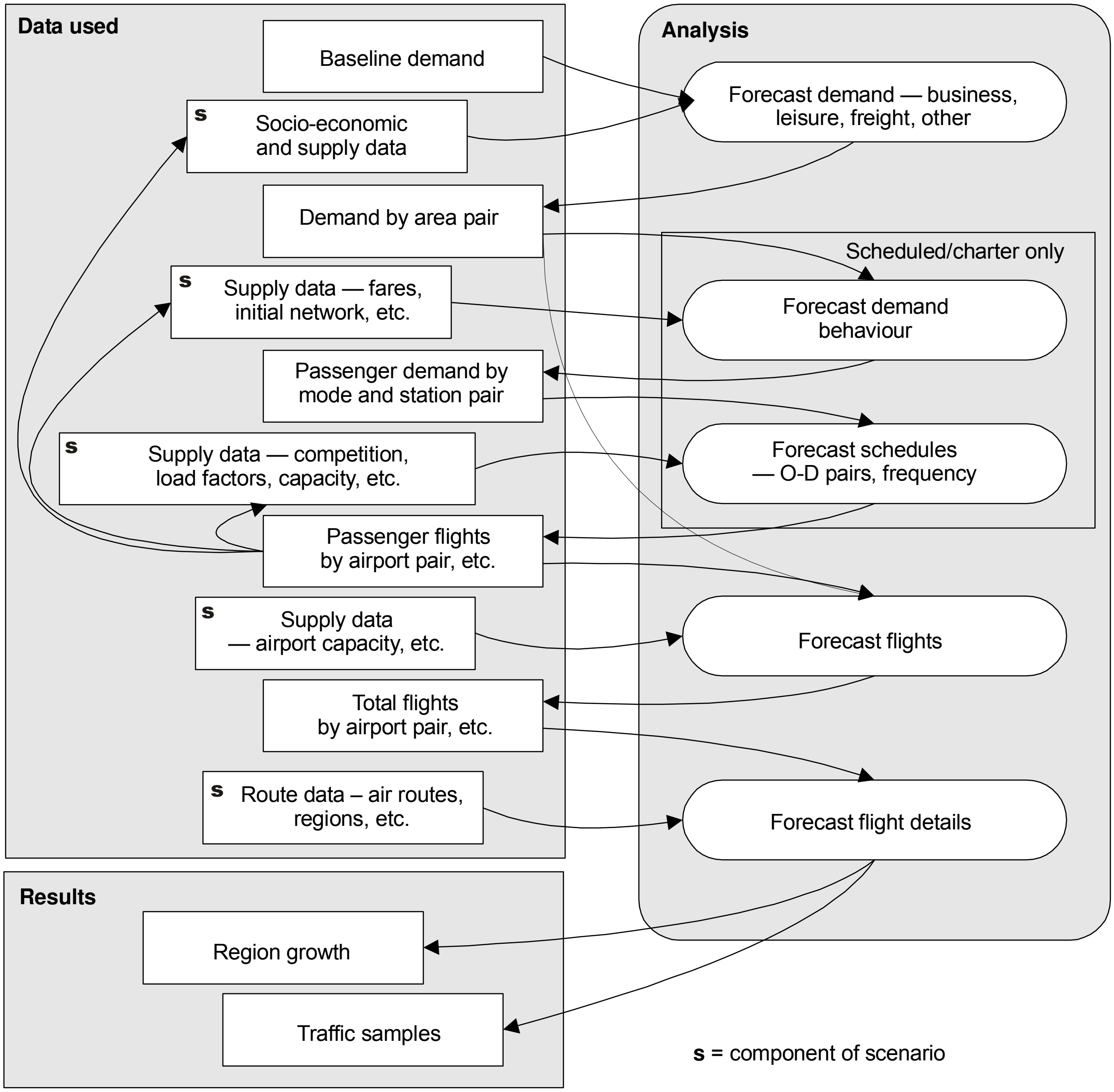


**Figure 3-1. Overview of medium-term forecast analysis components**

## LONG-TERM FORECAST

9. Currently, the long-term forecast is produced by extrapolating growth in the later years of the medium-term forecast. Plans have been made to use instead a method more closely based on the medium-term forecast.

## TRANSPORT CANADA FORECASTING MODEL[3]

10. Since 1976, the Statistics and Forecasts Branch of Transport Canada has used the passenger origin-destination model (PODM) to generate air traffic forecasts. This econometric model is one of the cornerstones of the forecasting system as it is used to predict passenger air-transportation demand in Canada. The model has recently been revised (PODM-V2) based on a theoretical analysis of the forecasts and the suitability of the explanatory variables, and an empirical analysis of the forecasts by city pairs and by market segment to indicate the relative strengths and potential limits.

### PODM-V2 MODEL: A FORMAL FRAMEWORK

11. PODM-V2 attempts to explain passenger origin-destination demand in Canada using econometric techniques. The patterns of origin-destination trips during one year are related to several variables: socio-economic conditions of cities (e.g. population, economic activities), air transport attributes (e.g., fare, direct flights) and measures of mode competition (e.g. travel time by car). Once identified and understood, those relationships allow the analyst to produce air traffic demand forecasts by airport based on clear assumptions of a set of variables.

12. PODM-V2 is defined by equations (1), (2) and (3).

$$T_{odm}^{(\lambda_{mT})} = \sum_{k} X_{odmk}^{(\lambda_{mk})} \beta_{mk} + \varepsilon_{odm} \qquad (1)$$

where:

$$T_{odm}^{(\lambda_{mT})} = \begin{cases} T_{odk}^{\lambda_{mT}} - 1/\lambda_{mT}, \text{ if } \lambda_{mT} \neq 0 \\ \ln(T_{odm}), \text{ as } \lambda_{mT} \rightarrow 0 \end{cases} \qquad (2)$$

$$X_{odmk}^{(\lambda_{mT})} = \begin{cases} X_{odmk}^{\lambda_{mT}} - 1/\lambda_{mk}, \text{ if } \lambda_{mk} \neq 0 \\ \ln(X_{odmk}), \text{ as } \lambda_{mk} \rightarrow 0. \end{cases} \qquad (3)$$

where:

$T_{odm}$ = the number of passenger air trips from zone *o* to zone *d* for market segment *m*

$X_{odm}$ = a vector of explanatory variables associated with zone *o* and zone *d* for market segment *m*

$\epsilon_{odm}$ = the random error associated with zones *o* and *d* for market segment *m*

$\beta$ = a vector of parameters to be estimated

$\lambda$ = a set of parameters to be estimated.

3. Transport Canada, *Presentation and Discussion of the PODM-V2 Model*, June 2003.

13. Once the regression equations are calibrated and *ß* and $\lambda$ parameters estimated, it becomes possible to measure the impact of a specific explanatory variable by its elasticity on origin-destination trips.

14. Conceptually, elasticity ($\eta$) is defined as the percentage change in demand resulting from a one per cent change in the explanatory variable. Mathematically, the elasticity of explanatory variable *k* associated with zones *o* and *d* for market segment *m* ($\eta_{odmk}$) of the PODM-V2 is expressed as follows:

$$\eta_{odmk} = \beta_{mk}\left(X_{odmk}^{\lambda_{mk}} / T_{odm}^{\lambda_{mT}}\right) \tag{4}$$

15. PODM-V2 has been estimated using four market segments: domestic "economy" fare class, domestic "discount" fare class, trans-border (Canada-United States) "economy" fare class and transborder "discount" fare class. This market segmentation arises mainly because the interpretation of socio-economic variables is not entirely compatible across countries.

## PODM-V2 CALIBRATION

### Database and explanatory variables

#### *Zonal system and data used*

16. A special statistical procedure called "Econometric Approach to Merging Observations" (EAMO) was employed to define the airport catchment area. The EAMO procedure ascertains, within a certain confidence level, that the aggregation of two airports does not affect the calibration of the econometric demand model. The procedure uses an econometric demand model to measure the impacts of amalgamating say, airport A with B. Based on this procedure, PODM-V2 zonal system has 36 domestic zones and 20 transborder zones.

17. Data used in the PODM-V2 are for the period 1995-2001. All air passenger data were obtained from Statistics Canada. This includes directional origin-destination data (DOD) (defined as the origin-destination directionality from zones where tickets were bought) and air fare data. All socio-economic data were provided by the Conference Board of Canada and other sources.

#### *Level of service*

18. The level of service variable ($DFLIGHT_{od}$) indicates the availability of direct flights between two city pairs. It is defined in the Official Airline Guide as a nominal variable having a value of one if there are at least five daily direct flights for a domestic market and three daily direct flights for a transborder market. Otherwise, the variable is equal to zero.

#### *Travel time by car*

19. Competition to the air mode by the surface mode is represented by the amount of time ($TIMECAR_{od}$) required to travel by car between city pairs. This variable is defined as the road distance between city pairs divided by an average speed.

***Socio-economic variables***

20. The general form of the PODM-V2 is similar to Newton's gravity model. This model stipulates that the number of trips between two zones is directly proportional to origin and destination sizes and inversely proportional to impedance between zones. "Impedance" variables are air fare, level of direct flights and travel time by car.

21. Socio-economic variables represent the factors that account for air trip generation by zones at origin and for air trip attraction by zones at destination.

22. Factors influencing air trip generation are assumed to be:

a) origin zone adult population (20 years and over) of zone *o* ($POPAD_o$);

b) origin zone real gross domestic product ($GDP_o$), measured in 1996 Canadian dollars; and

c) origin zone per capita real personal disposable income (PDI), measured in 1996 Canadian dollars.

The factor influencing air trip attraction is destination zone real gross domestic product ($GDP_d$), measured in 1996 Canadian dollars.

23. In addition to attraction and generation factors between Canadian cities, linguistic similarity of origin and destination zones ($LINGSIM_{od}$) is also an important factor in explaining inter-urban trips; everything else being constant, fewer inter-urban trips are made between cities with different linguistic compositions. The index of linguistic similarity between the origin zone *o* and the destination zone *d* is defined as follows: $LINGSIM_{od} = 1 - | L_o - L_d |$, where $L_o$ ($L_d$) is the proportion of the population of zone *o* (*d*) whose mother tongue is English.

***Dummy variables***

24. Two dummy variables are included to reflect specific conditions of a time period: one for trips done during the year 2000 (AUX2000) and the other for trips done in 2001 (AUX2001). Also included are seven dummy variables to reflect specific geographic conditions of zones.

**Calibration**

25. The TRIO-Model[4] computer programme developed by the Centre for Research on Transportation at the University of Montreal was used to jointly estimate $\lambda$ parameters of the dependent and explanatory variables and $\beta$ parameters included in the regression. Those parameters are estimated with the maximum likelihood procedure, which has a number of desirable properties:

a) estimators are consistent, i.e. they get closer to the true unknown parameter as sample size increases;

b) estimators are asymptotically efficient, i.e. variance of each estimator is smaller than that of any other estimator; and

4. Gaudry, M., Dagenais, M., Laferrière, R. and Liem, T., *Trio Model Types, Version 1.0*, Centre for Research on Transportation, University of Montreal, (CRT-904), 1993.

c) estimates of the variances can be determined as a by-product of the estimation process.

26. Assuming that the error terms in equation (1) are normally distributed (0, $\sigma^2$), then the log-likelihood function corresponding to the market segment *m* ($L_m$) to be maximized is given by equation (5):

$$L_m = -\left(T/2\right) \ln \left(\sigma^2\right) - \left(1/2\sigma^2\right) \sum_t \left( Y_{tm}^{(\lambda_{mT})} - \sum_k X_{tk}^{(\lambda_{mk})} \beta_{mk} \right)^2 + \left(\lambda_{mT} - 1\right) \sum_t \left(Y_{tm}\right) \qquad (5)^{5}$$

The estimation of equation (5) has been carried out for each market: domestic economy, domestic discount, transborder economy and transborder discount. For illustrative purposes, the estimation for the domestic-economy fare market is discussed below.

### Domestic-economy fare model

27. The "economy" fare category may be viewed as being similar to the "business" purpose. However, it differs in that an "economy" fare trip is substitutable with a "discount" fare trip. Conceptually, a trip for a specific purpose is not substitutable with another purpose. Table 3-1 presents elasticities and other parameters of the domestic-economy fare model.

28. The results of the model estimate "economy" fare elasticity to be -0.88. Another way of interpreting the "economy" fare effect on air travel demand is that increasing "economy" fare by one dollar reduces the number of trips by 28.01 per year.

**Table 3-1. Parameters of the domestic-economy fare model**

| Variable | Code | $\beta$ | $\lambda$ | Elasticity | Partial derivative |
|---|---|---|---|---|---|
| "Economy" fare | $FECO_{od}$ | –2.86 | 0 | –0.88 | –28.01 |
| "Discount" fare | $FDISC_{od}$ | 9.43 | -0.5 | 0.18 | 15.3 |
| Direct flights | $DFLIGHT_{od}$ | 4.43 | | 1.14 | 46 806.48 |
| Car travel time | $TIMECAR_{od}$ | 1.59 | 0 | 0.41 | 5.39 |
| Gross domestic product at origin | $GDP_o$ | 0.14 | 0.25 | 0.54 | 0.17 |
| Gross domestic product at destination | $GDP_d$ | 0.13 | 0.25 | 0.52 | 0.16 |
| Linguistic similarity | $LINGSIM_{od}$ | 1.7 | 0 | 0.44 | 84.19 |
| Year 2000 | AUX2000 | –0.41 | | –0.11 | –11 467.83 |
| Year 2001 | AUX2001 | –1.14 | | –0.29 | –37 387.79 |
| Dependent variable | $T_{odm}$ | | 0.1375 | | |
| $R^2$ | | | | 0.47 | |
| Number of observations | | | | 1 791 | |

5. To ease the notation, the dependent variable has been replaced by the letter "Y".

29. Increasing the "discount" fare has a direct impact on a "discount" trip by reducing it, and a proportion of that reduction is shifted to "economy" trips. On average, increasing the "discount" fare by one per cent increases "economy" trips by 0.18 per cent.

30. Everything else being constant, the availability of direct flights between two city pairs increases the number of trips by 46 806 over a year.

31. PODM-V2 also estimates that, everything else being constant, a one-minute increase of travel time by car contributes to an increase of 5.39 air trips a year. Economic growth of city pairs has a direct impact on "economy" trips. Results show that a one per cent increase of $GDP_o$ and $GDP_d$ would increase "economy" trips by 0.53 per cent on average.

32. Although the variable "linguistic similarity" is very statistically significant, its impact on actual number of trips is modest: an increase of one per cent in the linguistic index increases the number of "economy" trips per year by 84.19.

33. Finally, PODM-V2 implies that, on average, the number of "economy" fare trips for each city pair is 11 467 smaller during year 2000 than during each year over the period 1995 to 1999. The reduction is more important for the year 2001 with 37 387 less trips than each year over the period 1995 to 1999.

34. The $R^2$ coefficient, representing the proportion of the dependent variance explained by the model, is reasonably high, i.e. 47 per cent. The $R^2$ coefficient from a cross-section sample regression is much smaller than the $R^2$ coefficient from a time-series sample regression.

35. All explanatory variables are significant at the one per cent probability level or higher.

36. Table 3-2 presents the elasticities and other parameters of the domestic discount fare model.

## FORECASTING WITH PODM-V2

37. Once the PODM-V2 has been calibrated for a specific market segment, then forecasts are produced using equation (6), which includes the computed error term $(\hat{\varepsilon})$. This is done using an approach known as the Pivot Approach.

$$\hat{T}_m = \left( \left( \hat{\lambda}_{mT} \right) * \left( \sum_k X_{mk}^{\left( \hat{\lambda}_{mk} \right)} \hat{\beta}_{mk} + \hat{\varepsilon}_m \right) + 1 \right)^{1/\hat{\lambda}_{mT}} \tag{6}$$

## SENSITIVITY ANALYSIS

38. An econometric model with a flexible functional form allows elasticities of explanatory variables to vary from one market to another. The model shows how the elasticities of domestic and transborder markets vary as distance and market size change. Indeed, elasticities would vary depending upon specific conditions present in each market: the presence of specific industries, the strength or the absence of ground-mode competition, the type of air service, etc. For example, for the domestic-economy fare class, elasticities were computed with different market sizes and distances. The sample regression has been segmented into nine groups with approximately the same number of observations.

**Table 3-2. Parameters of the domestic-discount fare model**

| Variable | Code | β | λ | Elasticity | Partial derivative |
|---|---|---|---|---|---|
| "Economy" fare | $FECO_{od}$ | 0.34 | 0 | 0.07 | 6.64 |
| "Discount" fare | $FDISC_{od}$ | –1.86 | –0.9 | –0.96 | –223 |
| Direct flights | $DFLIGHT_{od}$ | 5.28 | | 1.14 | 130 896.06 |
| Car travel time | $TIMECAR_{od}$ | 3.1 | 0 | 0.67 | 24.6 |
| Personal disposable income at origin | $PDI_o$ | 0.04 | 0.5 | 1.09 | 2.57 |
| Gross domestic product at destination | $GDP_d$ | 0.32 | 0.18 | 0.47 | 0.4 |
| Linguistic similarity | $LINGSIM_{od}$ | 2.55 | 0 | 0.55 | 295.76 |
| Population at origin (20 years and more) | $POPAD_o$ | 0.09 | 0.23 | 0.47 | 0.02 |
| Maritime zone | AUXMAR | –1.13 | | –0.24 | –34 690.93 |
| Alberta, Saskatchewan, Manitoba zone | AUXWES | –0.35 | | –0.08 | –7 162.72 |
| Year 2000 | AUX2000 | 1.37 | | 0.3 | 89 325.13 |
| Year 2001 | AUX2001 | 1.69 | | 0.37 | 129 821.98 |
| Dependent variable | $T_{odm}$ | | 0.1402 | | |
| $R^2$ | | | | 0.68 | |
| Number of observations | | | | 1 790 | |

39. Results of the sensitivity tests, for the domestic-economy fare class, show that:

a) elasticities of explanatory variables (FECO, FDISC, TIMECAR and LINGSIM) decrease substantially (in absolute term) as market size increases; and

b) except for the elasticity of FDISC, elasticities do not vary substantially with respect to distance.

40. Table 3-3 shows that the specifics of each market are not revealed by the distance factor but by the size of the market.[6]

41. Fare elasticity ranges from –0.6 to –1.14. Interestingly enough, this range coincides with the lower and upper domestic business fare elasticities suggested by other studies. However, this study shows that the fare elasticity varies mainly because of the different market size instead of the trip distance. The expectation that fare elasticity should decrease as trip distance increases is based on the fact that trip diversion to ground modes then becomes smaller. This rationale is perfectly valid and without a ground mode variable in the PODM-V2 model, air fare elasticity might be more influenced by trip distance.

42. Further analysis of elasticities, for the domestic-economy fare class, shows a clear pattern of generation ($GDP_o$) and attraction ($GDP_d$) elasticities. The impact of GDP variations is more important for zones that have a larger GDP. This is perhaps due to the fact that larger economic zones are a synonym of more diversified economic sectors, which lead to more interactions (or transportation needs) with other zones.

6. This finding may be rationalized as follows: for a given distance, a larger market would tend to favour lower air fares; thus the "X" variable decreases and the "T" variable increases; therefore, the elasticity is smaller. See equation (4).

**Table 3-3. Elasticity sensitivity with respect to distance and market size (domestic-economy fare model)**

| Market size | FECO | FDISC | $GDP_o$ | $GDP_d$ | LINGSIM | TIMECAR |
|---|---|---|---|---|---|---|
| Short haul | | | | | | |
| Light traffic | –1.06 | 0.33 | 0.5 | 0.46 | 0.63 | 0.59 |
| Average traffic | –0.73 | 0.26 | 0.5 | 0.46 | 0.43 | 0.4 |
| Heavy traffic | –0.61 | 0.2 | 0.59 | 0.55 | 0.36 | 0.34 |
| Medium haul | | | | | | |
| Market size | FECO | FDISC | $GDP_o$ | $GDP_d$ | LINGSIM | TIMECAR |
| Light traffic | –1.14 | 0.27 | 0.55 | 0.51 | 0.68 | 0.63 |
| Average traffic | –0.75 | 0.21 | 0.51 | 0.45 | 0.45 | 0.42 |
| Heavy traffic | –0.66 | 0.19 | 0.5 | 0.49 | 0.39 | 0.37 |
| Long haul | | | | | | |
| Market size | FECO | FDISC | $GDP_o$ | $GDP_d$ | LINGSIM | TIMECAR |
| Light traffic | –1.12 | 0.2 | 0.54 | 0.5 | 0.67 | 0.62 |
| Average traffic | –0.78 | 0.17 | 0.62 | 0.55 | 0.47 | 0.44 |
| Heavy traffic | –0.6 | 0.13 | 0.56 | 0.51 | 0.36 | 0.33 |

## MODEL ACCURACY

43. The accuracy of the forecasting methodology was assessed by doing a back-cast analysis. This analysis evaluates how well the model fits the historic data series. However, it is generally observed that a model that back-casts accurately does not guarantee that it will forecast accurately, but it will give the user more confidence than using a model that does not. In PODM-V2, the results indicate that forecasts are reasonably accurate for origin-destination (O-D) pairs and produce only a small sampling error.

## CONCLUSION

44. One of the main advantages of PODM-V2 is that it allows the elasticities to vary from one O-D pair to another. As expected, the domestic discount model is more elastic (–0.96) than the domestic economy model (–0.88). Another significant result is in the estimation of air fare substitution. For instance, following an increase of “economy” air fare, the model estimates that 23.7 per cent of the “economy” air passenger reduction would be diverted to the “discount” category. As expected, a lower proportion (6.9 per cent) would divert to the “economy” category following an increase of the “discount” air fare.

45. A back-cast analysis shows that PODM-V2 forecasts are reasonably accurate for O-D pairs having a small sampling error:

a) over the 1996–2001 period, the PODM-V2 forecast error for major Canadian airports is, on average, 3.3 per cent and 2.0 per cent for domestic and transborder traffic, respectively;

b) forecast error is smaller than 20 per cent (in absolute terms) for 80 per cent of domestic O-D pairs; and

c) forecast error is smaller than 20 per cent (in absolute terms) for 85 per cent of transborder O-D pairs.

46. Obviously, although the back-cast method provides good results, PODM-V2 remains an econometric model to be used in conjuncture with professional judgement. As with any other forecasting model, professional judgement has to be incorporated because it:

a) allows for adjustments based upon judgement during the time that the forecasting model is being developed;

b) provides interpretation of the forecasts within the conceptual framework of the model and the data used to calibrate the model; and

c) takes into account events or recent trends that could not be considered in the calibration.

## AIR TRAFFIC FORECASTING FOR INDIA

47. This part provides the highlights of forecasting methods developed by the Government of India for its aviation planning purposes.

48. The study conducted by a committee constituted by the Government of India in 1999[7] to forecast domestic passenger traffic for the country is based on an approach that involves quantitative, qualitative and decision analysis taken together. The traffic growth rate for the period 1999–2008 was forecast based on the results of all three methods.

49. Multiple regression models of various functional forms were tested with step-by-step inclusion of different combinations of independent variables. These models were considered for three different historical periods: 1975 to 1998 (24 years), 1975 to 1998 (excluding the abnormal time period from 1988 to 1992) and 1984 to 1998 (latest 15 years). The models developed used the following functional form:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

where:

$Y$ = passengers carried (in thousands)

$\alpha$ = constant

$X_1$ = year with values 1 = year 1975, …, 24 = year 1998

$X_2$ = yield in Rupees at financial year 1980–1981 prices

$X_3$ = index of industrial production (IIP) at financial year 1980–1981 prices

7. *Growth of Air Traffic in India — Committee Report*, December 1999.

$X_4$ = gross domestic product (GDP) at financial year 1980–1981 prices

$X_5$ = foreign tourist arrivals (FTA) (in thousands)

$\varepsilon$ = random error

$\beta$ = regression coefficient vector.

50. Numerous significant econometric models using different data sets and independent variables were developed and examined in terms of their statistical validity and their ability to arrive at reasonable forecasts. The selection of an independent variable followed the criteria that:

a) it must significantly contribute to the explanation of historical fluctuations in air traffic growth;

b) its data must be readily available in a meaningful and measurable form; and

c) it must be capable of being forecast and have a forecast behaviour not markedly different from historical behaviour.

51. Out of some 17 models of various functional forms tested, the following model was selected as the most suitable, although the model does not satisfy Durbin-Watson (DW) test criterion for autocorrelation.

$$\ln \text{pax} = 6.82 + 0.33 \ln (t) + 0.27 \ln \text{IIP}$$

($t$-values) (4.76) (2.08)

$R^2 = 0.92$ DW = 0.78

where:

pax = domestic passenger traffic

$t$ = time

IIP = index of industrial production.

52. Based on the above model, the average annual growth rate for domestic passenger traffic under the most likely scenario was estimated at 3.5 per cent for the first five-year period and 3.2 per cent for the next five-year period. Because of the deficiencies in the econometric model, due to the fact that it does not satisfy the Durbin-Watson test criterion, other techniques such as trend projection and decision analysis were also used to supplement the results provided by the econometric models. The resulting forecast growth rates were as follows:

| Model type | Growth rate per annum (per cent) |
|---|---|
| Econometric model | 3.3 |
| Linear trend projection | 5.5 |
| Exponential trend projection | 5.4 |

The forecasts developed by other sources, primarily ICAO and ACI for the Asia/Pacific region, were also taken into consideration. Considering the above information, as well as inputs from the latest review of the

Indian economic and aviation system, historical growth patterns of the domestic market and previous work on forecasting carried out by various committees, the future average annual growth rate of 5 per cent was established as the most likely scenario for the 10-year period 1999-2008. The forecast growth rate was calibrated with that of actual traffic carried in the year 2002, and results indicated 13.6 million passengers in 2002 versus a forecast of 13.8 million for that year. Since the forecast involved analysis and the judgement of the experts, as well as information from other sources, a 92 per cent confidence was placed on the results in their application for planning purposes.

## AIR TRAFFIC FORECASTING FOR TUNISIA

53. This section describes a traffic forecast study[8] developed by the Tunisian Civil Aviation Authority in preparation of a master plan for the airports of Tunisia for the period up to the year 2020.

54. In general, the methodology used is a combination of both quantitative and qualitative techniques and consists of the following steps:

a) identification of the explanatory variables;

b) structural analysis of the explanatory variables;

c) morphological analysis of the explanatory variables; and

d) modelling and forecast development.

55. This analysis takes into account total air traffic to, from and within Tunisia. It is estimated that international traffic accounts for almost 90 per cent of the total traffic, and the remaining 10 per cent is domestic traffic. Based on surveys, it is estimated that business traffic accounts for some 18 per cent of the total international traffic and just over 16 per cent of the total traffic.

56. Because of the different characteristics of the traffic sectors concerned, each of the three sectors, i.e. international tourist traffic, international business traffic and domestic traffic within Tunisia, was analysed separately.

### IDENTIFICATION OF EXPLANATORY VARIABLES

57. In order to conduct the analysis, several explanatory or causal variables that would have an impact on traffic generation were considered. The following explanatory variables were identified as having the most potential, based on a preliminary analysis and the judgement of a group of experts:

a) economic growth in Western Europe;

b) the propensity of Western European citizens to travel (the major originating region of tourist traffic to Tunisia);

8. *Presentation of Traffic Forecasts for the Airports of Tunisia up to the Year 2020*, December 1997.

c) socio-economic developments in Eastern Europe and the Middle East;

d) economic growth in Tunisia;

e) demographic developments in Tunisia;

f) economic relations and partnership between Tunisia and the European Union;

g) open-sky policies between Tunisia and Europe;

h) geopolitical developments in the Mediterranean and the Middle East;

i) oil price trends;

j) air fare evolution;

k) evolution of the Tunisian tourist product;

l) competitiveness of other Mediterranean tourist destinations;

m) investments in the hotel infrastructure in Tunisia;

n) cost of tourist services; and

o) creation of free-trade zones.

## STRUCTURAL ANALYSIS OF THE EXPLANATORY VARIABLES

58. The aim of this step is to estimate the impact that each explanatory variable has on traffic as well as the interrelationships between them, in order to group them into different categories and to identify the variables to be used in the modelling step.

59. The explanatory variables identified above were analysed for each of the three traffic segments. Each of the variables was assigned a weighting based on subjective evaluation of its impact on the traffic concerned.

60. Since international tourist traffic is the major component of the traffic to, from and within Tunisia, the description of the steps leading to the development of forecasts focuses on that segment of traffic. Table 3-4 depicts the weight assigned to each of the explanatory variables based on the particular contribution each of the variables is expected to have on international tourist traffic.

61. The explanatory variables were then correlated with each other in order to identify the most influential components among them. The correlation matrix provides the level of impact each one of the variables would have on all other variables. These impacts were classified subjectively into four levels, and each of the levels was assigned a weighting as illustrated in Table 3-5.

62. The intercorrelation matrix developed for international tourist traffic is illustrated in Table 3-6.

63. This matrix provides the direct impact of one variable on all other variables as well as the combined impact all other variables would have on that one particular variable. Each row in the matrix provides the impact that variable would have on each of the other variables. The total of each of the rows

provides the combined impact of that particular variable on all other variables. For example, row 6 shows what the geopolitical developments in the Mediterranean and the Middle East would have on all other variables, and their combined impact is estimated to be 17 points. Similarly, each column provides the combined effect of what all other variables would have on a particular variable. For example, column 9 provides the combined effect that all other variables would have on explanatory variable 9, this variable being the investment in the hotel infrastructure in Tunisia, as specified in Table 3-4. The combined impact that all other variables would have on investment in the hotel infrastructure in Tunisia is estimated to be 10 points. The direct impact of each of the variables from Table 3-6 is summarized in Table 3-7.

**Table 3-4. Ranking of explanatory variables for international tourist traffic**

| | Variable description | Weighting for the impact on traffic |
|---|---|---|
| 1. | Economic growth in Western Europe | 12 |
| 2. | Competitiveness of other Mediterranean tourist destinations | 12 |
| 3. | Cost of tourist services in Tunisia | 10 |
| 4. | Propensity of Western European citizens (the major originating region of tourist traffic to Tunisia) to travel to sunny destinations | 9 |
| 5. | Socio-economic developments in Eastern Europe and the Middle East | 9 |
| 6. | Geopolitical developments in the Mediterranean and the Middle East | 8 |
| 7. | Evolution of the Tunisian tourist product | 8 |
| 8. | Economic relations and partnership between Tunisia and the European Union | 6 |
| 9. | Investments in the hotel infrastructure in Tunisia | 6 |
| 10. | Air fare evolution | 5 |
| 11. | Economic growth in Tunisia | 4 |
| 12. | Oil price trends | 4 |
| 13. | Creation of free-trade zones | 3 |
| 14. | Demographic developments in Tunisia | 2 |
| 15. | Open sky policies between Tunisia and Europe | 2 |

**Table 3-5. Impact among explanatory variables**

| Group | Weighting for the impact among explanatory variables |
|---|---|
| No impact | 0 |
| Weak impact | 1 |
| Moderate impact | 2 |
| Strong impact | 3 |

**Table 3-6. Inter-correlation matrix for international tourist traffic**

| Variable* i/j | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 2 | 0 | 2 | 1 | 1 | 0 | 0 | 9 |
| 2 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 9 |
| 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 4 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 5 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |
| 6 | 1 | 3 | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 2 | 3 | 2 | 0 | 0 | 17 |
| 7 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 |
| 8 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 2 | 0 | 2 | 12 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 4 |
| 10 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 11 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 3 |
| 14 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 |
| 15 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 3 |
| Total | 1 | 12 | 7 | 0 | 5 | 0 | 8 | 3 | 10 | 3 | 17 | 4 | 7 | 0 | 2 | 79 |

*As listed in Table 3-4.

64. Having established the direct impact, the next step is to analyse the indirect impact, which represents the impact that one variable has on another variable through one or more of the 13 remaining variables. For example, variable 6 has a direct impact on variable 2, which in turn has a direct impact on variable 7. Therefore, variable 6 has an indirect impact on variable 7, even though it has no direct impact. In order to estimate the first order indirect impact (only one intermediary variable is involved), the direct impact matrix is multiplied by itself. The values of this indirect impact matrix are then normalized (multiplied by a proportionality ratio) in order to obtain values comparable to those of the direct impact matrix. This process is repeated until the variation among the variables reaches a stable level. In other words, further multiplication of the matrix would not change the effects further. The indirect effect resulting from this analysis is summarized in Table 3-8. These impacts, i.e. the direct and indirect impacts, are then combined.

65. On the basis of the above analysis and the experts' judgements, the explanatory variables were grouped into four major categories described as follows:

a) *Category I.* economic developments in the tourist originating countries and geopolitical situation;

b) *Category II.* demographic and economic developments in Tunisia, the destination country;

c) *Category III.* competitiveness of the tourism sector in Tunisia with respect to other destinations; and

d) *Category IV.* the propensity of Western European citizens to travel to sunny destinations.

Figure 3-2 illustrates the four categories and the explanatory variables associated with them.

**Table 3-7. Direct impact among explanatory variables**

| Variable description | Variables | Points | |
|---|---|---|---|
| | | Impact of a variable (1 to 15) on all other variables | Impact of all other variables on a variable (1 to 15) |
| Economic growth in Western Europe | 1 | 9 | 1 |
| Competitiveness of other Mediterranean tourist destinations | 2 | 9 | 12 |
| Cost of tourist services in Tunisia | 3 | 2 | 7 |
| Propensity of Western European citizens (the major originating region of tourist traffic to Tunisia) to travel to sunny destinations | 4 | 3 | 0 |
| Socio-economic developments in Eastern Europe and the Middle East | 5 | 4 | 5 |
| Geopolitical developments in the Mediterranean and the Middle East | 6 | 17 | 0 |
| Evolution of the Tunisian tourist product | 7 | 5 | 8 |
| Economic relations and partnership between Tunisia and the European Union | 8 | 12 | 3 |
| Investments in the hotel infrastructure in Tunisia | 9 | 4 | 10 |
| Air fare evolution | 10 | 2 | 3 |
| Economic growth in Tunisia | 11 | 1 | 17 |
| Oil price trends | 12 | 2 | 4 |
| Creation of free-trade zones | 13 | 3 | 7 |
| Demographic developments in Tunisia | 14 | 3 | 0 |
| Open sky policies between Tunisia and Europe | 15 | 3 | 2 |

66. Each variable within Category I is weakly dependent on the other 14 variables, but the combined impact that each variable of this category has on the other variables varies. Economic growth in Western Europe, geopolitical developments in the Mediterranean and the Middle East, and the economic relations and partnership between Tunisia and the European Union are strong drivers for the other variables. It can therefore be assumed that these variables are among the most appropriate for the modelling of international tourist traffic. At the same time, economic growth in Western Europe has the most impact on international tourist traffic while the other two variables have a moderate impact (see Table 3-4). This confirms the importance of such variables for modelling purposes.

67. Each variable within Category II has a very limited impact on the other variables and, at the same time, has a minor impact on international tourist traffic. These variables are deemed unimportant for international tourist traffic. However, they might be used for other types of traffic models.

68. Variables within Category III are moderately dependent on other variables. Competitiveness of other Mediterranean tourist destinations has a strong impact on tourist traffic and seems to have a moderate impact on other variables.

**Table 3-8. Indirect impact among explanatory variables**

| Variable description | Variables | Points: Impact of a variable (1 to 15) on all other variables | Points: Impact of all other variables on a variable (1 to 15) |
|---|---|---|---|
| Economic growth in Western Europe | 1 | 8.0 | 0 |
| Competitiveness of other Mediterranean tourist destinations | 2 | 7.4 | 13.3 |
| Cost of tourist services in Tunisia | 3 | 4.0 | 24.5 |
| Propensity of Western European citizens (the major originating region of tourist traffic to Tunisia) to travel to sunny destinations | 4 | 4.1 | 0 |
| Socio-economic developments in Eastern Europe and the Middle East | 5 | 4.2 | 0 |
| Geopolitical developments in the Mediterranean and the Middle East | 6 | 20.6 | 0 |
| Evolution of the Tunisian tourist product | 7 | 3.9 | 14.8 |
| Economic relations and partnership between Tunisia and the European Union | 8 | 10.1 | 0 |
| Investments in the hotel infrastructure in Tunisia | 9 | 2.7 | 7.2 |
| Air fare evolution | 10 | 4.0 | 0 |
| Economic growth in Tunisia | 11 | 1.1 | 19.2 |
| Oil price trends | 12 | 2.2 | 0 |
| Creation of free-trade zones | 13 | 1.3 | 0 |
| Demographic developments in Tunisia | 14 | 1.7 | 0 |
| Open sky policies between Tunisia and Europe | 15 | 3.5 | 0 |

69. Category IV includes only one variable: the propensity of Western European citizens (the major originating region of tourist traffic to Tunisia) to travel to sunny destinations. This variable has a notable impact on international tourist traffic and does not depend on any other variable. Therefore, it would be appropriate to include it in the potential models for international tourist traffic.

70. The characteristics of each of the explanatory variables assigned to the four categories were further examined under a number of alternative conditions. Under each alternative, the variables in each of the categories were assigned a status and a value, where applicable. Tables 3-9, 3-10 and 3-11 describe the assignments for each of the first three categories. The only variable in Category IV, the propensity of Western European citizens to travel to sunny destinations (variable 4), was assigned a status of increasing propensity to travel under alternative 1 and declining or stagnant propensity to travel under alternative 2.

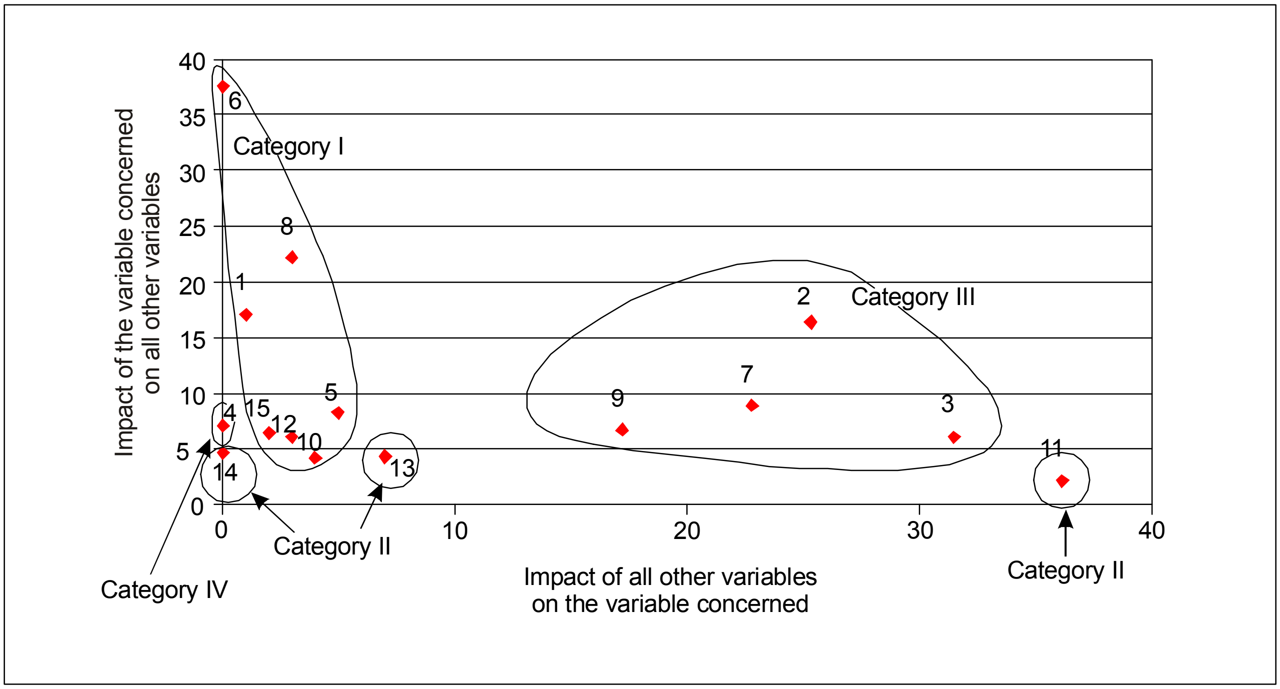


**Figure 3-2. Combined direct and indirect impacts of the explanatory variables and their groupings**

## MORPHOLOGICAL ANALYSIS OF THE EXPLANATORY VARIABLES

71. Morphological analysis can be defined as a systematic approach to identify possible future scenarios for the explanatory variables, taking into consideration the interrelationships between them (how each variable can have an impact on the other) and their classification into categories as performed in the structural analysis. Since it is not practical or economically feasible to analyse all the possible combinations of alternative status of the explanatory variables, the aim of using morphological analysis is to reduce the number of alternatives to be evaluated under each of the possible scenarios.

72. Using a morphological analysis of the possible status of each of the categories of explanatory variables led to the establishment of four scenarios as follows:

a) growth scenario;

b) trend scenario 1;

c) trend scenario 2; and

d) recessionary scenario.

73. These four scenarios are defined by assigning the most appropriate alternative condition to each of the four categories, as illustrated in Table 3-12. For example, the growth scenario was best represented by alternative 1 for Categories I, II and IV, and by alternative 2 for Category III. Trend scenarios 1 and 2 differ by the fact that Categories III and IV take different alternatives under each scenario.

**Table 3-9. Category I: Economic developments in the originating countries and geopolitical situation**

| Variable | Alternative conditions | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Geopolitical developments in the Mediterranean and the Middle East (Variable 6) | Favourable | Favourable | Non-favourable |
| Economic growth in Western Europe (Variable 1) | High (3%) up to 2020 | Moderate (2.5%) up to 2020 | Moderate (2%) up to 2020 |
| Economic relations and partnership between Tunisia and the European Union (Variable 8) | Association agreement extended to services by 2010 | Association agreement extended to services by 2010 | Association agreement extended to services by 2010 |
| Socio-economic developments in Eastern Europe and the Middle East (Variable 5) | Integration of the Eastern European States into the European Union and socio-economic development in the Middle East | Integration of the Eastern European States into the European Union and socio-economic development in the Middle East | Limited socio-economic development in Eastern Europe and the Middle East |
| Open sky policies between Tunisia and Europe (Variable 15) | Implemented | Implemented | Not implemented |
| Oil price developments (Variable 12) | Average price/barrel increases progressively to U.S.$35 by 2020 | Prices stable up to 2020 | Unstable prices until 2020 |
| Air fare evolution (Variable 10) | Directly affected by the increase in oil prices | Constant | Tendency to go higher |

74. The results of the structural and morphological analysis were used in the modelling and forecast development process.

## MODELLING AND FORECAST DEVELOPMENT

75. In view of the importance of international tourist traffic to Tunisia, the forecast for international tourist traffic was developed for its three major components, i.e.:

a) traffic from Western Europe to Tunisia;

b) traffic from Eastern Europe and the Middle East to Tunisia; and

c) all other traffic to Tunisia.

**Table 3-10. Category II: Demographic and economic developments in Tunisia**

| Variable | Alternative conditions | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Economic growth in Tunisia (Variable 11) | Strong growth: Average annual growth rates of 6.7 per cent from 1997 to 2007 7.8 per cent from 2008 to 2011 and 6.5 per cent thereafter | Moderate but sustained: Average annual growth rates of 6 per cent from 1997 to 2002 6.5 per cent from 2003 to 2007 7.3 per cent from 2008 to 2011 and 6 per cent thereafter | Deceleration of growth: Average annual growth rates of 4.5 per cent from 1997 to 2007 6 per cent from 2008 to 2011 and 4.5 per cent thereafter |
| Demographic developments in Tunisia (Variable 14) | Stable development | Stable development | Stable development |
| Creation of free-trade zones (Variable 13) | Success of the free-trade zones | Success of the free-trade zones | Weak development of the free-trade zones |

**Table 3-11. Category III: Competitiveness of the Tunisian tourism industry**

| Variable | Alternative conditions | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Investments in the hotel infrastructure in Tunisia (Variable 9) | Implementation of 80 per cent of the probable investment up to 2020, i.e. a capacity of 300 000 beds (or an average of more than 6 000 beds per year) | Implementation of 80 per cent of the probable investment up to 2020, i.e. a capacity of 300 000 beds (or an average of more than 6 000 beds per year) | Implementation of the investment projects already underway and part of the other projects, i.e. a capacity of 260 000 beds (or an average of less than 5 000 beds per year) |
| Evolution of the Tunisian tourist product (Variable 7) | Successful diversification | Successful diversification | Partial diversification |
| Cost of tourist services in Tunisia (Variable 3) | Costs maintained at the same level as the competition | Average increase of costs by 0.5 per cent in comparison to the competition | Average increase of costs by 0.5 per cent in comparison to the competition |
| Competitiveness of other Mediterranean tourist destinations (Variable 2) | No emergence of new competing markets | Emergence of new competing markets and strong development of the current ones (Egypt, Turkey, Middle East) | Emergence of new competing markets and strong development of the current ones (Egypt, Turkey, Middle East) |

76. Tourist traffic for each of the sectors was analysed using a set of selected economic, price and demographic variables. For example, traffic from Western Europe to Tunisia was deducted from traffic from Western Europe to the Mediterranean, which was analysed using a causal relationship as illustrated below:

$$Y_t = f\,(\mathrm{GDP}_t, \text{ air fares}_t, \text{ lifestyle}_t, Y_{t-1})$$

where:

| | | |
|---|---|---|
| $Y_t$ | = | traffic between Western Europe and the Mediterranean in year *t* |
| $\mathrm{GDP}_t$, | = | gross domestic product for Western Europe in year *t* |
| Air $\text{fares}_t$ | = | average air fare in year *t* |
| *$\text{Lifestyle}_t$* | = | propensity to travel and frequency of travel to sunny destinations in year *t* |
| $Y_{t-1}$ | = | traffic between Western Europe and the Mediterranean in the preceding year. |

77. Traffic between Western Europe and Tunisia was arrived at using the predicted market share of Tunisia in the forecast traffic $Y_t$, after making the necessary adjustments for the geopolitical developments in the Mediterranean and the Middle East, the competitiveness of other Mediterranean tourist destinations, the evolution of the Tunisian tourist product and the cost of tourist services in Tunisia.

78. Table 3-13 provides the forecasts for international tourist traffic between Western Europe and Tunisia. It shows that results for the growth scenario and trend scenario 1 are almost identical. This can be explained mainly by the fact that tourist traffic is not sensitive to economic growth in Tunisia. Table 3-13 also shows that trend scenario 2 leads to lower traffic levels and growth rates than trend scenario 1, which can be explained by the lower propensity of Western European citizens to travel under trend scenario 2. Results for the recessionary scenario are significantly lower than those for the other scenarios due to the combination of mediocre economic performance both in Western Europe and in Tunisia and the lower propensity of Western European citizens to travel.

79. A similar analysis was carried out for each of the other tourist traffic segments. Table 3-14 provides the forecasts for total international tourist traffic.

80. Table 3-15 provides the forecasts for the total traffic to, from and within Tunisia including international tourist traffic, international business traffic and domestic traffic.

## FORECASTING FOR AIRPORTS

### FORECASTING FOR AIRPORTS IN INDIA

81. Different approaches have been used to forecast airport traffic depending on whether forecasts are required for:

a) an airport in operation or an existing airport;

**Table 3-12. Assignment of alternative conditions to categories under four scenarios**

| Scenario | Category I | Category II | Category III | Category IV |
|---|---|---|---|---|
| Growth scenario | Alternative conditions 1 | Alternative conditions 1 | Alternative conditions 2 | Alternative conditions 1 |
| Trend scenario 1 | Alternative conditions 2 | Alternative conditions 2 | Alternative conditions 1 | Alternative conditions 1 |
| Trend scenario 2 | Alternative conditions 2 | Alternative conditions 2 | Alternative conditions 3 | Alternative conditions 2 |
| Recessionary scenario | Alternative conditions 3 | Alternative conditions 3 | Alternative conditions 2 | Alternative conditions 2 |

**Table 3-13. Forecast of international tourist traffic between Western Europe and Tunisia**

| Scenario | 1996 | 2001 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Growth scenario | | | | | | |
| Passenger traffic (millions) | 4.9 | 6.3 | 7.4 | 8.9 | 10.3 | 11.9 |
| Average annual growth rate (per cent) | | 5.2 | 4.1 | 3.8 | 3.0 | 2.9 |
| Trend scenario 1 | | | | | | |
| Passenger traffic (millions) | 4.9 | 6.2 | 7.3 | 8.7 | 10.3 | 11.9 |
| Average annual growth rate (per cent) | | 4.8 | 4.2 | 3.6 | 3.4 | 2.9 |
| Trend scenario 2 | | | | | | |
| Passenger traffic (millions) | 4.9 | 6.1 | 7.1 | 8.4 | 9.7 | 11.0 |
| Average annual growth rate (per cent) | | 4.5 | 3.9 | 3.4 | 2.9 | 2.5 |
| Recessionary scenario | | | | | | |
| Passenger traffic (millions) | 4.9 | 5.5 | 6.0 | 6.7 | 7.3 | 7.9 |
| Average annual growth rate (per cent) | | 2.3 | 2.2 | 2.2 | 1.7 | 1.6 |

**Table 3-14. Forecast of total international tourist traffic to/from Tunisia**

| Scenario | 1996 | 2001 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Growth scenario | | | | | | |
| Passenger traffic (millions) | 5.4 | 7.1 | 8.5 | 10.3 | 12.2 | 14.1 |
| Average annual growth rate (per cent) | | 5.6 | 4.6 | 3.9 | 3.4 | 2.9 |
| Trend scenario 1 | | | | | | |
| Passenger traffic (millions) | 5.4 | 7.0 | 8.3 | 10.1 | 12.0 | 14.0 |
| Average annual growth rate (per cent) | | 5.3 | 4.4 | 4.0 | 3.5 | 3.1 |
| Trend scenario 2 | | | | | | |
| Passenger traffic (millions) | 5.4 | 6.9 | 8.1 | 9.7 | 11.3 | 13.0 |
| Average annual growth rate (per cent) | | 5.0 | 4.1 | 3.7 | 3.1 | 2.8 |
| Recessionary scenario | | | | | | |
| Passenger traffic (millions) | 5.4 | 6.2 | 6.8 | 7.6 | 8.4 | 9.1 |
| Average annual growth rate (per cent) | | 2.8 | 2.3 | 2.2 | 2.0 | 1.6 |

**Table 3-15. Forecast of total traffic to/from and within Tunisia**

| Scenario | 1996 | 2001 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Growth scenario | | | | | | |
| Passenger traffic (millions) | 7.4 | 10.0 | 12.1 | 15.4 | 19.3 | 23.1 |
| Average annual growth rate (per cent) | | 6.2 | 5.6 | 5.4 | 5.2 | 4.9 |
| Trend scenario 1 | | | | | | |
| Passenger traffic (millions) | 7.4 | 9.8 | 11.7 | 14.8 | 18.4 | 22.1 |
| Average annual growth rate (per cent) | | 5.7 | 5.3 | 5.1 | 4.9 | 4.7 |
| Trend scenario 2 | | | | | | |
| Passenger traffic (millions) | 7.4 | 9.6 | 11.5 | 14.3 | 17.6 | 20.9 |
| Average annual growth rate (per cent) | | 5.4 | 5.0 | 4.8 | 4.7 | 4.4 |
| Recessionary scenario | | | | | | |
| Passenger traffic (millions) | 7.4 | 8.7 | 9.7 | 11.3 | 13.0 | 14.7 |
| Average annual growth rate (per cent) | | 3.3 | 3.1 | 3.0 | 3.0 | 2.9 |

b) an airport to be upgraded from domestic to international; and

c) a new airport to be constructed.

A brief description of the approaches used is presented below.

## PASSENGER TRAFFIC FORECAST FOR AN EXISTING AIRPORT[9]

82. The total passenger traffic handled during 2002 at all the 122 airports in India was 42 million. The top 5, 10, 20, 30 and 45 airports account for 72 per cent, 85 per cent, 92 per cent, 96 per cent and 99 per cent of the total passenger traffic in India, respectively. The airport's share in total traffic is one of the determinants in deciding the forecasting methodology to be used for that airport. The traffic forecasts are based on:

a) trend projection;

b) econometric models using a combination of various economic indices such as GDP, index of industrial production and net national disposable income;

c) air traffic projections developed by the national administration for the system as a whole, airlines, aircraft manufacturers, IATA, ICAO and ACI for the Asia/Pacific region;

d) tourism forecasts; and

e) other factors.

9. *Corporate Plan of Airports Authority of India*, April 1996.

## PASSENGER TRAFFIC FORECAST FOR AN AIRPORT TO BE UPGRADED FROM DOMESTIC TO INTERNATIONAL[10]

83. Prior to the nineties, there were four international airports in India, although some international passenger traffic potential did exist at domestic airports. Of the 12 international airports currently in existence, Mumbai Airport, located in the heart of the city with little capability of further expansion, is the busiest. In order to alleviate congestion at Mumbai Airport, the government policy has been to look at other airports for possible diversion of traffic. Accordingly, studies were conducted to:

a) assess the international passenger traffic potential of key selected domestic airports to which traffic diversion from Mumbai could be possible according to passenger preferences;

b) develop long-term forecasts of international and domestic passenger traffic at these domestic airports; and

c) assess the long-term effect on traffic congestion at Mumbai Airport.

The origin-destination surveys were conducted at hubs (Mumbai, Delhi, Calcutta) and seven other domestic airports. The results of these surveys were used to assess the traffic potential of various airports.

84. The origin-destination surveys were also used in the strategic decisions for the infrastructure planning of international airports and planning of new international airports. The last survey was conducted at Delhi Airport for a one-week period in 1999. Because the response from passengers was voluntary, coverage was some 57 per cent of the total embarking and disembarking passengers (39 487 passengers responded) on all international flights. The survey was conducted to assess the origin, destination, nationality, place of residence, purpose of travel and the airline.

85. Separate survey questionnaires were used for embarking and disembarking passengers. As an example, in the case of embarking passengers, in addition to the date and flight number, the following questions were included:

"(i) In India, which was the starting point of your journey [i.e., last city (from a given list) where you stayed more than 24 hours]?

(ii) What is your next destination (Where do you intend to stay for more than 24 hours — specified by international airport and country)?

(iii) What is your nationality (Indian/non-Indian of Indian origin/non-Indian)?

(iv) What is your permanent place of residence (Delhi/in India — other than Delhi/outside India)?

(v) What is the purpose of your travel (government duty/business/holiday — tourism/employment/ any other — to be specified)."

86. To assess the international traffic potential of a given domestic airport under study, such surveys were conducted at that airport and at the international hub airports where traffic diversion to the airport under study would be possible. The estimated proportion of the potential traffic diversion from the hub airport(s), in addition to any prevalent international traffic due to international flights operated by national carriers, formed the total international traffic potential in the base year for that airport.

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10. Reports on Origin-Destination Survey of International Passengers at: a) Indira Gandhi Delhi International Airport, 1999; b) Mumbai Airport, 1998; Report on Amritsar Airport to Assess International Passenger and Cargo Traffic Potential; Traffic Surveys at Domestic Airports, 1985.

87. The existing international traffic potential was assessed based on two sources, viz., the Origin-Destination Survey (1999) at Indira Gandhi International Airport, Delhi, and the Origin-Destination Survey (1999) at Amritsar Airport (in Punjab province of India).

88. Amritsar Airport handled 19 979 international passengers during 1998-99 because the national carrier operates some international flights to and from this airport. It has been estimated from the Origin-Destination Survey at Delhi Airport that 5.2 per cent of the traffic at Delhi Airport is bound for Amritsar.

89. Based on the analysis of the survey results, the traffic potential of Amritsar Airport for the next 15 years is summarized in Table 3-16.

## PASSENGER TRAFFIC FORECAST METHODOLOGY FOR A NEW AIRPORT

90. The following is the summarized methodology of long-term forecasting of international passenger traffic used for Cochin Airport and the new Bangalore Airport. Cochin Airport was commissioned in 1999 as a new international airport in the private sector. The new Bangalore Airport is currently under proposal.

91. Historical data in respect of dependent variables and explanatory variables relevant to the selected forecasting methodology are necessary. In the case of construction of a new airport at a site in the vicinity of which no airport exists, various traffic surveys are needed to prepare a valid database. Before a traffic forecasting technique is applied, it is necessary to gather information, in as much detail as possible, on the following aspects:

a) assessment of the strength of the region (to be served by the new airport) covering the economic and geographical aspects (description of connectivity to important locations, rail/road transportation, natural factor endowment, spatial advantage, etc.) and socio-political necessities (national interest in civilian and military terms, international strategic considerations in terms of business and trade, etc.); and

b) assessment of traffic potential through an origin-destination analysis, a traffic profile, and a demographic analysis of the region. Information on the first two issues can be obtained/ generated from the available survey reports or by conducting surveys of nearby airports, railway passengers, private cars on connecting highways, hotels, etc. Demographic analysis is possible from the data available in population census reports.

92. Broadly, historical data on the following items are necessary:

a) traffic at and traffic profiles of nearby airports in the region;

b) traffic at all hub airports in the nation;

c) traffic at all airports (taken together) in the nation;

d) traffic on significant flight sectors (trunk routes and those sectors from where diversion to a new airport is possible);

e) airline traffic (and future intentions);

**Table 3-16. International passenger traffic potential at Amritsar Airport**

| Year | Passengers in number | | | |
|---|---|---|---|---|
| | Delhi Airport International passenger traffic (excluding transit) | Estimated traffic diversion of 5.2 per cent from Delhi Airport to Amritsar Airport (as per O/D Survey 1999 at Delhi Airport) | International passenger traffic at Amritsar Airport | Total passenger traffic potential at Amritsar Airport |
| 1998–99 | 3 437 216 | 178 735 | 19 979 | 198 714 |
| Forecast | | | | |
| Average annual growth* (per cent) | 6 | 6 | 12 | 6.9 |
| 1999–2000 | 3 643 449 | 189 459 | 22 376 | 211 836 |
| 2003–2004 | 4 599 770 | 239 188 | 35 210 | 274 398 |
| 2008–2009 | 6 155 530 | 320 088 | 62 052 | 382 139 |
| 2013–2014 | 8 237 488 | 428 349 | 109 356 | 537 706 |

*Computed growth rate from traffic volume of 1998–1999 through 2013–2014.

f) explanatory variables (region's GDP, nation's GDP, number of tourists, trade volume, index of industrial production and yield, etc.); and

g) origin-destination analysis.

93. Assumptions are inevitable in any forecasting process because of uncertainty. Efforts to develop a valid information base and careful analysis can minimize the extent of uncertainty. While it is difficult to enumerate and state all the assumptions, a list of broad assumptions is desirable.

94. Since each of the alternative forecasting techniques has its own limitations and suitability, it is desirable to develop a forecast based on information available from all sources. The following inputs are considered useful in the development of the forecast:

a) overview of the national economy with reference to the subcontinent and the world economies;

b) economic overview of the region (State/city) to be served by the new airport; a comparative picture of the regional economy versus the national economy; other considerations in terms of the strength of the region;

c) national airport system including airport development plans;

d) airline forecasts and future plans (available from airlines);

e) international aviation organizations' forecasts for the subcontinent;

f) forecast by airport authority/civil aviation authority of the nation;

g) traffic trend analysis at national, regional and nearby airport(s) levels (regression, compound growth rates for three-, five-, ten-, fifteen-, twenty-year periods; annual growth rates for each year in the last five-year period);

h) econometric modelling at the national and regional level; and

i) any other information source relevant to the exercise.

95. The trend projection and econometric models developed at the regional level (catchment area of a new airport) provide guidelines for traffic growth projections in the case of a new airport. The most likely projected growth rate developed for a new airport should be consistent with the factors outlined above.

96. In general, traffic at any airport is composed of three factors:

a) normal traffic, i.e. existing traffic already using the airport;

b) diverted traffic, i.e. traffic diverted from nearby airports; and

c) induced (or generated) traffic, i.e. traffic that materializes from the catchment area of an airport after the investments are made and depends upon the regional economy, tourism, foreign trade, business and facilitated employment of people abroad or other types of motivation due to better transport facilities. In the case of a new (proposed) airport, the traffic component mentioned in a) would be non-existent. Diverted traffic would depend upon several factors such as airport facilities, time savings and increased convenience.

97. A new airport would mainly depend upon the "diverted traffic" component because it could materialize immediately, while the "induced traffic" component is expected to contribute at a slow pace. In general, components of the diverted traffic from nearby airport(s) and hub airport(s) form the base level of the traffic of the new airport. Origin-destination surveys conducted at the nearby airport(s) and the hub airport(s) are utilized by the Airports Authority of India and some consultants to estimate traffic diversion to Cochin and Bangalore airports.

## FORECASTING FOR NEWARK AIRPORT (UNITED STATES)

98. Examples of the translation of a passenger traffic forecast into various airport planning parameters were provided in a study for Newark Airport,[11] which was included in the previous edition of this manual. It was decided to retain this case study in this edition because of its usefulness in illustrating airport peak-period analysis. Annual passenger aircraft movements in a forecast year were determined by dividing the forecast annual passenger volume (10.9 million) by the average number of passengers per aircraft for the forecast year, which was itself the product of the assumed average aircraft seating capacity (97.5 seats) and average load factor (60 per cent).

$$\text{i.e. passenger aircraft movements} = \frac{10\,900\,000}{97.5 \times 0.60} = 186\,300$$

This figure was increased by 5 per cent to include non-revenue movements.

11. Paper by N.L. Johnson, presented to the American Society of Civil Engineers, April 1964.

99. Forecasts for the peak hour of the average Friday, normally the busiest day in the week, were derived from the annual traffic forecasts. A factor of 1.26 was used to convert average-day traffic into peak-day traffic, and a factor of 2.2 was used to convert average-hour traffic on the peak day into peak-hour traffic. These factors were determined after analysis of daily and hourly variations in traffic flows, taking into account the expectation that traffic would build up more in the off-peak hours. Applications of these factors resulted in converting a forecast for annual traffic of 10.9 million passengers into a peak-hour forecast of 3 400 passengers.

100. Forecasts of peak-hour aircraft movements were derived from peak-hour passengers and assumptions about the average aircraft seating capacity (97.5) and load factor (75 per cent) in the peak hour in the forecast year.

$$\text{peak aircraft movements} = \frac{3\,400}{97.5 \times 0.75} = 47$$

The assumed peak-hour load factor was considerably higher than the average load factor.

101. Forecasts of the population of passengers and visitors in the terminal building in the peak hour were developed. The total number of passengers was broken down into originating, terminating and transfer passengers, and the number of visitors was assumed to bear fixed relationships to the number of originating and terminating passengers (e.g. 31 visitors per 100 originating passengers). Assumptions were made regarding the average time spent in the terminal building for each of the categories. The average number of occupants in each category during the peak hour was then calculated by multiplying the passenger or visitor flow per minute by the average number of minutes spent in the terminal.

102. The number of various categories of airport employees was also forecast. For some categories, such as airline ground workers and staff of commercial enterprises at the airport, fixed relationships to air passengers were assumed (e.g. 425 airline ground employees per million annual passengers). For other groups, including airline flight employees and providers of various aviation services, fixed relationships to aircraft movements were assumed (e.g. 8 airline flight employees per 1 000 annual movements). Yet another group had a fixed relationship to the annual volume of cargo.

103. Other planning parameters, which were derived from the forecasts of traffic flows and aircraft movements, included short-term and long-term public parking spaces, passenger building curb space for loading and unloading, aircraft gate position requirements and aircraft fuel requirements.

**— END —**

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