



Forecasting aircraft movements – an unavoidable case of uncertainty

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Abstract:

Forecasting long-term aircraft movements for airport and air traffic control master planning has become more challenging in an era of deregulation and privatised airports. The demand for air travel has become more responsive to changes in prices and to income levels and assumptions about changes in these factors introduce a key source of error into forecasts. Further problems arise in working from passengers to aircraft movement forecasts. The need to incorporate judgements about the types of aircraft likely to become used over a 20 to 30 year horizon indicates the importance of understanding the long-term factors influencing airline competition. The paper considers a well-documented and thorough study undertaken 20 years ago to identify the sources of errors. We argue that a key area of improvement is in the combination of qualitative information about the future and statistical analyses of past trends. Furthermore, there is value in shifting the emphasis from prediction to management of uncertainty. Scenario methods are proposed as a form of participatory forecasting that allows managers and planners to learn how to deal with uncertainty and how to concentrate scarce forecasting resources on areas with the greatest payoffs.

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Long term forecasting and realistic expectations

There is ample evidence the airline market is strongly influenced by the business cycle and the challenge for the civil aviation sector is to predict turning points accurately. For example, in the period between 1985 and 1990, the number of aircraft operating in the USA's domestic market increased by more than 75% with only a 36% increase in demand. As the economy began to turn down in the early 1990's, the airlines were caught with excess capacity and the combined losses of large and small airlines alike mounted to billions of dollars. Morrison and Winston (1995) found that an inability to predict the business cycle could have been responsible for up to half of the total losses incurred by the US carriers in the recession of the early 1990's.

Airlines require forecasts for a variety of purposes, but the time horizons are likely to be up to one year ahead for schedule planning and between 2 to 5 years for fleet planning. Short-term and medium-term forecasts are needed as well for designing and managing air navigation systems (Forrester and Dean, 1997), but airport master plans typically require estimates of traffic levels for 20 to 25 years ahead. Lead times for significant increases of capacity can be between 3 and 7 years, while assets have long lives and little value in other uses. Failure to forecast accurately can result in costly, but unnecessary increments of capacity or they can constrain growth and add to user costs through congestion (D'Amato, 1997). Also, inadequate airport capacity can influence competitive outcomes.

Statistical analyses of past trends provide the foundation for most aviation forecasts, but quantitative methods rely heavily on the maintenance of the status quo. Models estimated on historical data are not able to foresee wars, terrorist attacks, and health risks (eg bird flu' in Hong Kong), yet future traffic levels can be dominated by these types of discrete events or by changes in key drivers such as consumer tastes. It is a challenge even to predict major turning points in the economy. This has been illustrated most recently with the economic crises in Asia and its immediate impact on travel markets.

The Tourism Forecasting Council produced a set of forecasts of international arrivals in Australia in November 1996 (TFC, 1996). These were revised downwards in December 1997 (TFC, 1997) and were adjusted again in March of 1998 (IFC, 1998) after economic conditions continued to deteriorate in several Asian countries. The unanticipated economic crisis has wiped out between 4 and 6 years of growth so that forecasts of visitors to Australia have been written down by between 20% and 36%. Furthermore, planning and financing risks have increased with such uncertain economic conditions and it has become accepted that forecasting in a dynamic setting requires continuing revision to take account of new information.

This raises several issues worthy of investigation. First, how much of the initial impact of the economic crisis on travel markets is going to be a result of reduced wealth and income and how much is due to low consumer confidence? Will the reduction in travel be short-

lived? What second-round effects are likely to occur that counter the economic downturn (eg hotels and airlines discounting)? However, it is inevitable that events such as this result in scepticism about the usefulness of long-term forecasts.

This is the key issue that has motivated this paper. We concentrate mainly on the particular problem of forecasting aircraft movements at airports because it introduces several sources of uncertainty. We argue that quantitative forecasting methods provide valuable inputs in forecasting aircraft movements, but better results will be gained by recognising that uncertainty is an inescapable feature of planning. With the benefit of hindsight, we revisit long-term forecasts of aircraft movements for Sydney produced in 1978 for the period to 2000 (Bureau of Transport Economics, 1978). Now that the forecast horizon is almost upon us, it is a sobering experience to compare the forecasts with outcomes. We can see that the forecasts of passenger movements were too optimistic, but wrong assumptions about the greater use of larger aircraft can have the effect of making the aircraft movement projections appear to be close to the actual level.

This degree of forecasting error is disturbing for those people responsible for preparing airport master plans, but is not surprising. Yet the BTE's 1978 study was very thorough and, by using it as an initial reference point, we have a sound basis for commenting upon methods in current use. A more important objective, though, is to emphasise the uncertain nature of long-term forecasting of aircraft movements. We can learn about key contributions to errors from this case study and we can appreciate ways to improve forecasting in the future. In part this is occurring through the combination of quantitative information and qualitative assessments. However, it is important to incorporate assessments of risks into the forecasting process and to integrate forecasting more closely with managerial processes. Recognising this is a first step in managing risk and this paper examines ways to use long-term forecasts in flexible, adaptive planning processes.

Assessing forecasts with the benefit of hindsight

In 1978, the Bureau of Transport Economics prepared forecasts of passenger and aircraft movements for the Sydney region for the Major Airport Needs of Sydney (MANS) study (BTE, 1978). In particular, this study used quantitative methods to analyse passenger and aircraft movement data for the previous decade to develop forecasts of passenger and aircraft movements, including busy-hour forecasts, for the period 1976 to 2000. Tables 1 and 2 illustrate the extent and nature of the forecast errors when compared with actual traffic levels.

For example, the actual number of international passengers in 1995/96 fell between the low and median forecasts predicted by the BTE. For a long-term forecast, this might seem to be a relatively good result, but the strong growth in the international visitor market dating from

the mid-1980's brought the actual level closer to the forecast. The BTE had been overly optimistic for the first ten years of its forecasts and this is borne out by the mean absolute percentage error (MAPE) of 34% for the low forecast and 52% for the high forecast for the 20-year period from 1976/77. The BTE's median forecasts of domestic plus regional passengers tracked actual levels reasonably well until a sluggish market resulted in error rates of up to 37%. The pilot's dispute compounded the problems, but the percentage error in 1995/96 was only 19%. The MAPE for total passenger movements for the 20 years was 32%.

However, the forecasts of aircraft movements were predicted with even less accuracy. This is immediately apparent for the international aircraft movements with the actual level being twice the BTE's low forecast for 1995/96. The forecasts for domestic plus regional do fall within the bounds predicted by the BTE, and since these dominate total aircraft movements, the overall forecast for 1995/96 fell short of the BTE's upper bound. However, the tables reveal that this result occurred because of a combination of an optimistic estimate of the number of passenger movements and a high load per aircraft movement. In the case of international services, the BTE's upper bound for passengers per aircraft movement is almost twice the actual level in 1995/96. The MAPE for passengers per aircraft movement over the 20 years was in excess of 70% for international services, a disturbingly high error rate that was evident even in the BTE's short-term forecasts.

Table 1 Comparison of BTE forecasts with actual levels in 1995/96

| | Actual Traffic | Forecast Level | | |
|----------------------------------|-------------------|----------------|--------|-------|
| | | High | Median | Low |
| Passenger movements | | | | |
| International | 6.2 | 7.2 | 6.7 | 5.9 |
| Domestic plus regional | 13.7 | 21.9 | 16.3 | 14.4 |
| Total passengers | 19.9 | 29.1 | 22.9 | 20.3 |
| Aircraft movements | | | | |
| International | 40.8 | 24.6 | 23.0 | 20.4 |
| Domestic plus regional | 195.3 | 221.9 | 163.2 | 129.0 |
| Total aircraft | 236.1 | 246.4 | 186.1 | 149.4 |
| Passengers per aircraft movement | | | | |
| International | 152.5 | 293.8 | 290.3 | 288.1 |
| Domestic plus regional | 70.1 | 98.8 | 99.7 | 111.7 |
| All markets | 84.3 | 118.3 | 123.2 | 135.7 |

Note: The BTE (1994) distinguished between "interstate", "intrastate" and "commuter". These have been combined here as "domestic" and compared with "domestic" plus "regional" reported by the Department of Transport and Communications in its *Avstats* series.

This illustrates how incorrect assumptions about aircraft size and/or load factors can dampen the effect of inaccurate passenger forecasts. Statistical texts often suggest a MAPE of less than 10% is an excellent forecast performance for a long-term forecast. The MAPE for the BTE's median forecast of total aircraft movements for Sydney Airport over a 20-year period was only 9.4%. But the predictions of the number of landed tonnes and the

number of passengers passing through domestic and international terminals proved to be unreliable. In presenting this information it has to be said that the planning process for Sydney International Airport has made use of updated information and there have been numerous revisions to these forecasts (for example, BTCE, 1994).

Table 2 Mean absolute percentage error (MAPE) for BTE forecasts in comparison with actual levels 1976/77 to 1995/96

| | Forecast | | |
|----------------------------------|----------|--------|------|
| | High | Median | Low |
| Passenger movements | | | |
| International | 51.7 | 43.7 | 34.4 |
| Domestic plus regional | 60.1 | 27.9 | 17.5 |
| Total passengers | 56.7 | 32.3 | 21.8 |
| Aircraft movements | | | |
| International | 22.0 | 20.7 | 22.5 |
| Domestic plus regional | 29.2 | 9.9 | 13.6 |
| Total aircraft | 22.7 | 9.4 | 14.5 |
| Passengers per aircraft movement | | | |
| International | 70.4 | 71.2 | 70.6 |
| Domestic plus regional | 24.0 | 24.2 | 35.6 |
| All markets | 27.7 | 31.9 | 42.1 |

Sources: BTE (1994) and Department of Transport and Communications. *Avstats* series.

Econometric analyses of passenger markets provided the foundation for the BTE's estimates of aircraft movements. The passenger markets were disaggregated according to geographic scope (international, interstate, intrastate and commuter) and by purpose of travel (business and leisure) where possible. Within these broad categories, the traffic data provided information for individual routes on a quarterly basis over a period of 10 years. The role of variables such as income, fares, exchange rates and population were tested and a set of forecasts was produced based on assumptions about how these variables would change over time. For example, the number of interstate passenger movements model was estimated on the time-series of a cross-section of origin-destination markets and took the form:

$$\frac{D}{P} = 0.446 \ln(RI) - 0.137 \ln(P) - 0.284 \ln(RF) - 0.144 \ln\left(\frac{RF}{CC}\right)$$

(6.0)
(-7.7)
(-9.2)
(-1.4)

$$R^2 = 0.90$$

Where

- D = total passenger movements
- P = the product of the populations of the origins and destinations
- RI = real disposable income per person
- RF = real air fares plus access and egress costs
- CC = perceived cost of car travel in real terms (price of petrol)

One of the interesting features of the BTE's models was that they allowed the influence of the variables to change over time in a systematic way as traffic levels built up. In later years for example, a given percentage increase in income levels (or reduction in fares) would have less impact on demand than in earlier periods as the market matures. However, the actual outcome was that the BTE over-predicted the strength of demand early in the forecast period and under-predicted stronger growth in later periods. This raises the question that, if similar methods continue to be used to forecast passenger movements, can we expect to see error rates like those reported in Tables 1 and 2? Over the past two decades numerous model specifications have been tested and there have been significant improvements in forecasting software. As a result, today's forecasters can more easily test a variety of models and they can draw on a wide body of empirical research to help them assess the validity of their models.

One particular problem, though, is that the quantitative analysis is very much dependent on data inputs. The BTE used quarterly data for a decade. Under "normal" circumstances this would have covered a full economic cycle and would have contained sufficient variation to provide a reliable base for forecasting. However, the particular decade in question exhibited strong growth. As new aircraft types were introduced, the airlines were able to reduce the real cost of travel and service standards improved. With a buoyant economy, there was a strong underlying growth trend until rises in real air fares in the late 1970's put a brake on expansion. Essentially, the models were being called upon to make predictions in conditions unlike those experienced within the period covered by the analysis. This is a problem all models face and a partial solution is to use as long a series of data as possible. However, changes in definitions of variables in recent years and structural changes in the market such as deregulation make this difficult.

Assuming for the moment that a model does provide a sound understanding of the roles of all of the key determinants of travel, the forecasting process then requires independent estimates of the way these variable will change in the future. The BTE believed there would be no change in real air fares on interstate routes for its high forecast up until 1985 while its "median" forecast assumed fares would rise by 2% per annum as a result of cost pressures, especially in relation to labour and fuel inputs. Beyond 1985, it was expected productivity improvements would result in real fares falling at an average rate of -0.7%

Comparisons of air fares over time are difficult because of the lack of published data and changes in airline pricing practices, especially since deregulation in 1990. However, it appears that real air fares were increasing in the early part of the forecast period by at least 5% per annum (May et al, 1986). During this period, the Independent Air Fares Committee allowed the airlines to recoup re-equipment costs in the presence of weak demand conditions, but price increases in the latter part of the 1980's tended to track changes in the consumer price index (BTCE, 1993). Since deregulation, the airlines have made greater use of promotional fares and the entry of Compass Airlines stimulated intense rivalry. In the first year of deregulation average air fares fell by 35% on the longest routes

and, despite an increase in real average fares in 1994, the average fare was 22% lower than it was prior to deregulation (Prices Surveillance Authority, 1994)

As important as air fares are in competitive airline markets, much of the long-term increase in travel is stimulated by growth in real per capita incomes. The BTE assumed its income variable would change by 3.0% (high), 2.25% (median) and 1.5% (low) per annum over the entire forecast period. What in fact has happened has been that GDP per capita averaged 1.7% per annum over the period 1976/77 to 1996/97. But this average figure does not account for cycles in GDP per capita. The rate of annual growth ranged from -3% up to +4.9% during the period examined. It is possible that the long-run traffic forecasts can cope with variation of income around an average level provided the desired information is the long-run trend in passenger and aircraft numbers. From the point of view of managing, financing and planning, though, it does matter that there are shortfalls in some periods and larger flows in other periods. Furthermore, it is possible the short-term variations in income can be so significant they can shift the long-term trend. In these circumstances, there is a need to continue revising forecasts as new information becomes available.

Clearly, the accuracy of long-term air passenger forecasts depends very largely on the independent forecasts of the variables entering the models. Unanticipated variations in income levels can dominate trends in travel markets, but additional assumptions are required about the way airlines introduce new aircraft into their fleets. The BTE's understanding of supply relationships was based on developments in the period 1960 to 1975. The Boeing 727 was introduced into service in the USA in 1963 and the B737 followed in 1968. The DC-10 and the B747 had such a large impact on international travel markets in the early 1970's that liner shipping services to Australia disappeared almost overnight. Airlines were reaping major productivity gains by introducing larger aircraft in line with traffic growth.

In 1976, the fleet operated by Australia's two domestic airlines consisted of Boeing 727-100 (108 seats) and -200 series (137 seats), DC-9-30 (97 seats) and F27 (36-44 seats) aircraft. Larger aircraft were replacing F27 services and the BTE, acting on the advice of the airlines, understood this process would continue. In international markets, it was expected that supersonic aircraft (Concorde) would capture a large share of the business travel market to Europe and North America via Melbourne. Furthermore, it was believed that the airframe manufacturers would introduce larger aircraft including a stretched version of the B747 (630 passengers) and a two-deck version of the same aircraft (800 passengers). Additionally, the BTE assumed load factors would increase.

The approach to modelling domestic aircraft movements took the total airline fleet as a function of the total market requirements and aircraft fleet planning. Aircraft then were assigned to routes using a linear programming technique that took minimisation of costs as the objective function. The relevant constraints were technical requirements, origin-destination demand, acceptable load factors and minimum frequency. The airlines indicated

to the BTE at the time that they intended to introduce wide bodied aircraft carrying 240 passengers and intermediate aircraft carrying 180-200 seats during the early 1980's.

The gross inaccuracy introduced into the analysis with these assumptions is evident in Tables 1 and 2. Moreover, the error rates were large even in the short-term despite consultation with airlines about their fleet plans and despite the relative stability of a highly regulated industry. The problematic issue is that frequency has a value to consumers and airlines have to strike a balance between frequency of flights and lower operating costs. The BTE's assessment of technological possibilities was not so much in error as its assumptions about the competitive forces driving airlines. Clearly this is a key area where forecasting can improve.

Finally, we note that the historical profile of aircraft movements taken over the day was expected to continue into the future with allowance for the addition of new flights and the effects of curfews at Sydney and other international airports. The procedure for domestic aircraft movements assigned time slots based on the historical pattern of demand constrained by the availability of aircraft. These assumptions provided the basis for busy-hour forecasts determining peak requirements.

Some lessons for current practice

It has become common practice to base air traffic forecasts on quantitative analyses of past trends in passenger movements even if the results of these models are modified subsequently by expert judgements. The passenger forecasts are of considerable interest in their own right, but there also is some justification for using them to develop forecasts of aircraft movements. Consumer demand is the force driving aviation activity and a large body of research testifies to the importance of income, fares and exchange rates as determining factors. Nevertheless, it is well known that consumers prefer direct flights and that an airline's market share of traffic at a particular airport is a function of the frequency of its services. In so far as the aggregate market demand is concerned, there is a limited amount of research on these matters. Logically, the fleet and aircraft allocation decisions of the airlines affect total demand, but the two-step, sequential model continues to dominate most practical studies. That is, passenger demand is estimated independent of aircraft size and passenger demand enters into the aircraft movements model as an exogenous variable.

As a practical matter, this has been most important in relation to international routes. New markets can grow rapidly once direct airline services are introduced but historical analyses of aggregate demand relationships have provided little guidance to forecasters in dealing with this matter. Quantitative methods have the desirable properties that they draw upon an established body of statistical theory and they provide a systematic framework (Taneja, 1978), but they are open to the criticism that they provide a guide to the future by looking

backwards in time. In practice, it is necessary to incorporate experiential or judgemental information in combination with quantitative forecasts (Cain, 1995). Delphi survey methods can be used, for example, to build a consensus. Such an approach is being used by the Tourism Forecasting Council to gauge the impact of the 2000 Olympics (TFC, 1998). "Technological forecasting" makes use of exploratory techniques to investigate the implications of future events, perhaps using simulation models within an input-output analysis, scenario-writing or cross-impact analysis framework (Taneja, 1978)

For the present, several observations about passenger demand modelling practices need to be made. The first is that econometric models, by their very nature, produce erroneous forecasts. A deterministic model would predict exactly the number of passenger movements at an airport for particular levels of the income and fare variables. In contrast, the econometric models assume there is a host of other influences having some impact, but that the net effect appears to be random "white noise". The choice of an appropriate modelling technique very largely depends upon the assumptions about how these unexplained factors vary. The output of the models, though, is a best "point" estimate of passenger demand – the most likely value under a set of conditions. Alternatively we can make statements such as "we can be confident that the true level of demand will lie in this interval in 95% of cases". It is this theory of error structures that provides the justification for using econometric methods and the basis for statistical bounds of confidence.

It is important to understand that the width of the statistical bounds on a forecast can vary depending upon our ability to estimate a robust model. In practice, there are numerous problems to overcome. Meaningful information about air fares is almost impossible to obtain in deregulated airline markets. It is even difficult to construct a consistent series of passenger movements given changes in the definitions used in reported statistics over the past decade. In modelling international visitor traffic, there is little specific information about air fares and services to competing destinations.

The problem is most severe in relation to air fares. The practical significance of this, however, is not so great. There is a consensus amongst forecasters and industry practitioners that the contribution of lower fares to future growth is likely to be less than 1% per annum. Variations in exchange rates and incomes and improvements in airline services are much more important. The qualification to this is that price competition between airlines can stimulate strong market growth in the short term.

An obvious fact is that if there is less variation in traffic levels to explain then it will appear that the models are more robust. For example, the national network of airline services consists of a set of individual routes. On each there will be a host of local conditions that affect traffic levels and there will be differences in growth rates across the network. Models of passenger numbers for individual routes have to explain more variation and invariably appear to be less robust than models at the national network level.

One approach is to use a national model and to assume that individual airport shares move according to some predictable pattern, perhaps identified in an airport share model (Caves 1993). Even then, we should note that many textbooks regard an average forecast error of 10% as being "very good". One benchmark of the degree of accuracy possible at the national level in the world's most developed airline market has been provided by the Federal Aviation Administration of the USA (FAA, 1996). Using econometric models, the FAA predicted domestic revenue passenger kilometres for the USA in 1995 within 0.2% on the basis of its analyses in 1994. However, its forecasts of the 1995 level prepared ten years ahead were out by almost 12%.

Even with "uncontroversial" national models, it is impossible to avoid uncertainty and the challenging task of translating the forecast to individual airports remains. In a world of privatised airports and deregulated airline markets there is increasing scope for airport market shares to vary (De Neufville and Barber, 1991; Ashley et al., 1995). It is an inescapable fact that even the best econometric models provide, at best, a probabilistic foundation for the aircraft movements models.

But it is at this point that we have to deal with the problem of predicting the behaviour of airlines, and we have to recognise that the airlines themselves are not always able to provide sound short to medium term advice on this matter. Many studies opt for a simple approach in this situation. All that is required is to fit a trend line of passenger movements for aircraft over a period of time. This can be based on assumptions about the likely sizes of aircraft in use at some future point in time combined with further assumptions about load factors, and a transition path. However, the Bureau of Transport and Communications Economics has undertaken more formal analyses (BTCE, 1988).

Specifically, the BTCE focused its attention on load factors. These are identified with the seating capacity of aircraft, the number of passengers to be carried and the number of aircraft movements. In the long-term it was expected the load factor would vary around an average or trend level, but this variation would occur mostly in a predictable manner. For example, load factors are likely to fall as larger aircraft are being introduced at an airport. Additionally, load factors change in response to short-term fluctuations in passenger demand. It is possible as well that airlines cut back on flights in response to increases in fuel costs. Time series models incorporating these variables were estimated for six of Australia's major domestic airports including Sydney. Broadly, the hypotheses about load factor variations were confirmed and the models produced statistically significant coefficients, validating the model for forecasting purposes. A separate time-series regression model was used to predict the annual change in passenger movements in future years. The advantage of this approach is that it yields a forecast of variations in load factor that has a theoretical justification, but it is still necessary to make assumptions about the way average aircraft seating capacity changes.

Another shortcoming of the approach is that it does not show how the pattern of arrivals and departures will be spread over the day. It is necessary to fall back on projections of current scheduling practices even though aircraft sizes and network service strategies change. An alternative approach was investigated in which the fleet composition and total passenger volume was taken as given and a simulation model was developed in which simple decision rules were used to allocate aircraft to routes. This incorporated three time bands so that the issue of peak demands on the airport could be analysed directly. The inputs to the model are details about the network configuration, the aircraft fleet chosen to service demands, passenger loads on the individual routes and the proportion of passenger demand in each time period. The decision rules that assign aircraft, for example, ensure that aircraft end their day at the airport where they are needed to start the next day and include a set of "allowable" flight sequences between airports in each time period. Whilst the model does not optimise the fleet assignment it does incorporate preferences for using the largest possible aircraft in the fleet while meeting the assignment constraints. In validating the models, the BTCE considered they provided a reasonable degree of accuracy in reproducing peak patterns and the total number of aircraft movements. The time-series and simulation models could be used to complement each other.

Simulation modelling of airline network strategies has been investigated by a number of researchers. For example, Gordon and De Neufville (1973) present a model to optimise the level of service of a given air transport network for a given budget. Kanafani (1981) has modelled the relationship between technology of aircraft and network structure for a region of the USA. Aircraft technology is defined in terms of size (number of seats), stage length (design stage length or payload-range function), and unit operating cost while total origin-demand is assumed to be inelastic. Kanafani assumes the break-even load factor operates as a constraint (lower bound) for each route and then proceeds to iterate towards a network equilibrium by adjusting link frequencies for a given aircraft size.

Simulation models can provide valuable information for detailed financial and operational planning, the time distribution of aircraft movements over the period of a day for example. However, there is a trade-off to be made in any simulation model between complexity to deal with the multitude of factors influencing real-world decisions and the simplicity required for a manageable and understandable model. Moerz (1991) provides an example of an approach that models both passenger and aircraft movements at a single airport, taking account of the links between increasing congestion, increases in congestion charges, and consumer and airline behaviour. However, the model incorporates only the single hub and is not able to account for the demands placed on the airlines by other services on their networks. Ashley Hanson and Veldhuis (1995) have developed a policy-sensitive model that predicts the likelihood of an aircraft of a given size being used on a particular route. The model allocates aircraft to six size ranges and classifies routes according to their density and range. However, the model continues to require independent assessments of aircraft types.

A framework for dealing with uncertainty

The preceding discussion indicates what can be achieved with quantitative methods and the degrees and sources of uncertainty associated with even the best models. However, consider a sample of the discrete events and continuing environmental changes listed in Table 3. For example, the earthquake that devastated Kobe (Japan) in 1995 had implications for the world's financial markets. The forest fires in Indonesia and the bird flu' scare in Hong Kong in 1997 had significant impacts on Asian travel markets. The world wide web is accelerating the spread of electronic commerce, but there is on-going speculation about the potential for economic disaster with the "millennium bug". World trade has been outstripping national income growth as large and small firms alike respond to the opportunities and threats in global markets. The implications of global warming are only beginning to be understood.

Long-term forecasting requires an assessment of these types of factors. Systematic analyses of past experiences can yield some insights. For example, it has been shown that changes in the age distribution in the USA make little impact on long-term air traffic forecasts (Mayer, 1989). Concerns that the air travel market is reaching maturity have been investigated (Pilarski and Thomas, 1995). There is a growing literature on the strategies of airlines in competitive markets that can help guide our predictions in a less predictable market environment. Experienced managers and forecasters understand the need to combine quantitative forecasts with qualitative assessments about major events and trends such as those listed above.

Furthermore, it is understood that forecasts are guidelines that affect the *wishes and aspirations of management* with consequences for *goals, objectives and decisions through resource commitments and implementation* (Makridakis et. al., 1983). Greatest value from the forecasting process can be gained by integrating forecasting more closely into planning and managerial decision-making. Viewed in this light, the challenge for forecasting long-term activity at airports is to pose questions that yield the greatest pay-offs, to ensure organisations continue to learn about the future, and that strategies are robust enough to cope with future challenges.

Techniques for dealing with risky projects are well established. Decision theory focuses on combinations of possible states of nature and outcomes within a probabilistic framework. This approach builds upon system dynamics to investigate interactions between a potentially large set of influences. Pay-off matrixes can be constructed and we could adopt a decision rule to choose the course of action with the highest expected gain. However, this and other decision rules can be shown to lead to sub-optimal and inconsistent solutions in a variety of situations. There is no way to reduce an uncertain situation to a uni-dimensional decision factor. Having recognised this fact, greater value is placed on structuring decisions so that uncertainty can be reduced. For example, increments in capacity can be designed so that their timing can be accelerated or deferred as the situation requires.

Table 3 Major events affecting travel markets in past two decades

| Factors | Events |
|-------------------------|--|
| Society | Emergence of the middle income class as a global economic force Changing composition of households |
| Political | Ageing of the population Breakdown of former Soviet Union Civil and regional conflict |
| Natural environment | Acts of terrorism Earthquakes Floods |
| Economic environment | Cyclones, typhoons and storms World trade growing at twice the rate of GDP The transition from GATT and GATS to WTO The spread of regional free trade agreements Asia's economic growth and its sudden decline in 1997 |
| Competitive environment | Growth in services sector Deregulation and privatisation New entrant airlines Network strategies built on hub and spoke systems Alliance formation |
| Technology | Globalisation Information technology (eg CRS and yield management) Communications technology Electronic commerce |

In addition, it often is the case that some decisions are relatively insensitive to a wide range of forecasts, or a large amount of resources devoted to the forecasting task cannot yield sufficiently reliable information to assist with the decision. At the same time, it might be more useful to concentrate on questions such as "which countries will be most important?" and "which markets have the greatest impact on busy hour forecasts?". Greater confidence may be placed in some specific forecasts than in others. Highlighting the importance of different components of the forecasts may yield additional value in decision making. Closer interactions between forecasters and planners/managers can ensure scarce resources are used most productively (Cain, 1995).

Curve fitting, catastrophe theory, analogues and social physics are fields that can contribute to long-range forecasting where technology, consumer tastes and social structures are changing (Taneja, 1978; Makridakis et al., 1983), but the types of factors listed in Table 3 often are more readily dealt with using scenario techniques. Scenario development combines some elements of quantitative and qualitative assessments and recognises that there are several realistic forecasts (Cain, 1995). The scenario approach also allows us to establish a logical structure for including variables such as changes in tastes and lifestyle preferences and the impact of ongoing strategy development by industry players. Perrottet and Foster (1996) have argued that airlines should adopt scenario-based planning because it

is an outside-in approach that allows airlines to manage uncertainty by identifying strategic elements that will be resilient to a number of possible scenarios.

Hardison et al. (1990) describe an application of scenario planning in an airport context in which they identify individual factors contributing to uncertainty and then attach probabilities to them. In this way they make explicit statements about the factors underlying the forecasts and they specify a probability distribution rather than a single, point estimate. These authors set out to encourage debate about forecasts by documenting assumptions ensuring stakeholders understand and agree on the process and the methods used. Moreover, these authors believed the scenario approach lent itself to presenting forecasting information in a way that can be easily understood. Within this framework, the implications of changing some of the key assumptions on the degree of confidence can be appreciated.

Concluding comments

This paper has taken a thorough, documented study produced 20 years ago and compared its forecasts of aviation activity at Sydney International Airport with actual performance. A key feature of the BTE's study was the central role of quantitative models. These allowed systematic analysis of past trends within a sound theoretical structure. A variety of tests can be used to confirm whether the methods used are justified given the patterns of variation in the data, whether the results conform to theoretical expectations about the demand relationships, and whether the effects of interest can be distinguished from random variation. The BTE was thorough in its econometric work but there were large error rates in its forecasts. The value of this retrospective analysis is that we can identify key sources of error and that we can learn how to improve forecasting practices.

One lesson is that quantitative models provide a valuable contribution, but even the best econometric model cannot eliminate uncertainty. Statistical tests can determine whether the model allows accurate prediction within the set of data used to estimate the model, but the true test for a forecasting model is whether it can be applied under a future set of conditions. This is a difficult matter to decide in advance, but it is clear that the economic and operating environments changed considerably over the two decades following the BTE's study. We have no reason to expect stability in the future and it is likely that the accuracy of forecasts derived from statistical models alone will suffer.

The magnitude of the errors can be increased when we translate passenger forecasts into aircraft movements. Certain aspects of the aircraft fleet assignment and route development modelling have improved over the past 20 years, though these approaches are less applicable in today's deregulated airline industry. The key issue is that there is no way to avoid making long-term predictions about the aircraft types that will be in use over the forecast period. Another of the lessons from the BTE's study is that this particular area

forecasting requires more attention. Even when it acted on the advice of the airlines in a regulated environment, the BTE's assumptions about short-term changes in fleet composition proved wrong. Not surprisingly, the long-term assumptions were well wide of the mark. Possibly the BTE's views about airline technology were subject to conditioning bias resulting from the introduction of new aircraft types in the 1960's and 1970's, and perhaps we can argue the nature of airline competition and the technological possibilities are better appreciated now. Even so, we argue this is a weak point in forecasting aircraft movements and that there is a need to understand the long-term strategic forces shaping competition in the airline industry.

Further difficulties are introduced when we try to account for a host of discrete events and continuing environmental changes that can have such large impacts on travel markets that they dominate the underlying trends. In some cases, events such as wars can wipe several years of growth from the market while in other cases they can shift the trend and change its pattern. Forecasters recognise these difficulties and there is greater acceptance of the need for continual up-dating of forecasts. Also, most practical work makes use of qualitative information about the future along with statistical analyses of trends and demand relationships.

Uncertainty surrounding the impact of events in a globalised and competitive airline sector is an inescapable fact. There is value in shifting the emphasis from making predictions about the future to management of uncertainty. This leads us to focus on the value of scenario based approaches that integrate quantitative and qualitative information. Within scenario planning, imaginative inputs can be channelled into a framework that accounts for probabilistic events and combines them in a meaningful format. We believe that scenario planning is a suitable framework that allows managers, planners and forecasters to work more closely. A desirable aim is to ensure decisions are structured in such a way to allow for adaptation where uncertainty is greatest. Scarce forecasting resources need to be directed to those questions where there is a good chance of providing information relevant to decisions-making. Participatory forecasting processes allow managers greater scope to understand the key contributions to uncertainty and allow them to test the implications of several future states for their strategies and plans. A useful point on which to conclude is to heed the advice of the authors of an influential text on forecasting techniques.

Concentrating on accuracy is like trying to melt an iceberg by heating the tip: when forecasting accuracy is slightly improved, other managerial problems of implementation rise to the surface to prevent the full realization of forecasting's promise.

(Makridakis et. al, 1983, page 803)

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