introduction of wide-body aircraft. Of course, they also depend on the prospects of controlled rises in fuel prices. If it is assumed that fuel prices will not rise faster than the rate of inflation, costs can be expected to decline. This decline, however, is associated with the use of larger aircraft and implies an increase in available capacity if level of service, as measured by flight frequency, is to be maintained. Therefore, whether fleet changes in any one market are feasible cannot be evaluated on the basis of the cost implications alone. The evaluation would require an integration of cost forecasting with the analysis of demand in the market in question, particularly with regard to price elasticity. It is a known fact in air transportation that larger aircraft bring about unit cost savings and a reduction in break-even load factors. But the use of such aircraft is feasible only if it does not cause more reduction in actual load factors, which is a possibility when larger aircraft are used. In other words, productivity alone must not be evaluated in the absolute sense but within the framework of a given market and socioeconomic environment.

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Forecasting Airport Traffic: Mexico City as a Case Study

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A procedure for preparing forecasts of airport traffic is presented, and its use is illustrated through application to Mexico City. The underlying objectives are to identify the principal factors that cause changes in airport traffic and then to develop a model of how these causes specifically influence growth. In view of the demonstrably poor overall performance of purely theoretical forecasts, a pragmatic approach is recommended in which much emphasis is placed on identifying key causes of growth. The procedure recommended involves four phases: a detailed examination of the data to determine unusual or particular events, identification of the principal causes of past and future changes, introduction of these causal factors into statistical analyses to extend recent patterns of activity into short-range forecasts, and, finally, creation of long-range forecasts with suitably wide margins of uncertainty by use of scenarios of possible developments. The case study illustrates each of these phases. The results suggest that much of future airport traffic will be caused by external influences, such as the total recreational expenditures of the United States, and is beyond the influence of airport planners.

This paper treats two topics simultaneously: (a) the question of how to forecast traffic, particularly for airports, and (b) the specific application of this methodology to the current situation in Mexico.

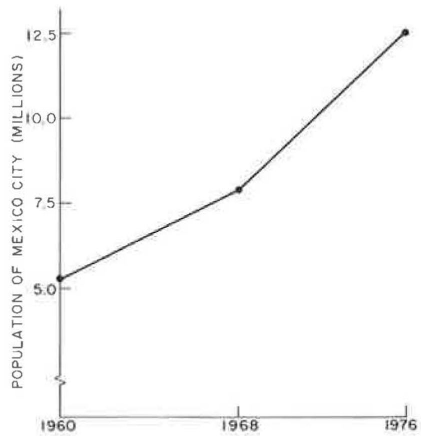
The general question of how best to forecast traffic is a troublesome one. Airport authorities typically spend a lot of money to obtain poor results. A traffic study for a major airport in the United States can easily cost about $250 000, yet the forecasts generated are notoriously inaccurate. An analysis of the five-year forecasts of total aviation traffic of the Federal Aviation Administration has shown that those forecasts were off by more than 20 percent half the time (1). And forecasts for any component of the aviation system, such as an airport, are necessarily more inaccurate since their errors do not cancel each other as they would in the aggregate. It does not take much to imagine that one might get equal value for less money by simply guessing at the future. It is easy to believe that the processes now used are highly cost-ineffective. The issue is, Can we deploy our engineering and analytic skills more productively to obtain reasonable, possibly better, results more cheaply?

This paper presents a suggestion as to how better forecasts of airport traffic might be obtained at less cost. The specific situation of Mexico City is used to illustrate the process. The discussion of Mexico City is also interesting as an example of how to prepare forecasts for nations similar to Mexico. The issue here is how to proceed when the kinds of data we are used to in the United States are unavailable and when the causes of growth are substantially different. This issue is particularly topical because most new airports are likely to be built in developing countries.

BACKGROUND

Essentially all of the participants in the planning, construction, and operation of the Mexico City International Airport were elements of the federal government of

Figure 1. Increase in population in Mexico City metropolitan area.



Mexico. This situation, which is typical of many countries similar to Mexico, is quite different from that prevailing in the United States.

The physical and demographic setting is also remarkable. Population and wealth are concentrated in the capital, coincidentally in the center of the country. In 1976, 20 percent of the population of the republic lived in the metropolitan area of Mexico City; that level has risen steadily from 15 percent in 1960 and could easily reach 25 percent by the end of the century. In absolute numbers, the population of the Mexico City metropolitan area has grown, at a compound rate of 5 percent annually, from 5.2 million in 1960 to more than 13 million in 1979 (see Figure 1) (2-5). Mexico City is now the size of New York City. Relative to the rest of the country, it is even more important than New York: A comparable U.S. city would have 45 million inhabitants and be growing by 2 million people a year. This degree of rapid growth of the central capital city, not uncommon in developing countries, can certainly be expected to influence the nature of the growth of airport traffic.

APPROACHES TO FORECASTING

Two major approaches to forecasting can be distinguished: trend extrapolation and causal modeling. Trend extrapolation consists of fitting a line or a function to past observations and simply extending it into the future. Causal modeling consists of trying to identify the several causes that affect a situation and thus create a formula that might forecast the future for a wide variety of situations, some of which might occur naturally and others through explicit policies directed toward changing the environment.

Trend extrapolation is by far the easier and the most commonly used method. The calculations necessary can be carried out almost without effort, now that sophisticated statistical computer-based procedures are available. The method is especially attractive because it is essentially always possible to obtain formulas that fit the data well. One merely has to rearrange the expressions or add new variables. In fact, the mathematics guarantee that one will always obtain an equivalent or better fit to the data by adding any variable, regardless of how irrelevant it may be to the real situation. Gullible clients beware!

Trend extrapolation can be useful for short-range forecasts. Indeed, if the environment changes slowly and if the fundamental causes stay fairly constant, it is reasonable to believe that the past is a good indication of the immediate future. The irony of this argument is, however, that if one justifies a forecast on this basis one does away with the rationale for any sophisticated analysis. All one has to do is to observe that traffic has grown at X percent annually over the past few years and is likely to change similarly in the future.

The difficulty with trend extrapolation is that underlying causes may change. Fares might suddenly jump, for example, because of changes in the market or because of policy decisions either on the fares themselves or on the costs of inputs such as fuel. To the extent that such changes were not part of the past, the forecast based on the trend will not account for their effect and will be wrong.

Planners thus really need causal models to help them to forecast traffic. As this becomes more obvious, more analysts are presenting models that are identified as causal or, equivalently, as behavioral. The problem at this stage is that calling a model causal does not make it so. To the extent that a model is developed by purely analytic, statistical techniques, there is indeed little justification for calling the result causal, however good the statistical fit. Correlation is not causality. Spending money on presents does not bring Christmas.

Evidence abounds of the inability of statistical techniques to detect the underlying motivations of the demand for travel. Consider the set of 59 econometric analyses of North Atlantic passengers discussed by Moore (1, 6). Each study identifies, among other things, how fares influence traffic. The range of estimates for this fare elasticity spreads rather evenly from about 0 to almost -3—that is, from no effect to a significant effect. Whatever the influence of fares might be, these studies did not determine it.

The justification for a causal model must rest on one or more of the following factors:

1. Prior knowledge of how parts of the system function—for example, of how airlines might schedule flights to maintain a desired level of load factor;
2. Theory, which should be substantiated by additional evidence as to how particular factors influence traffic; and
3. Specific evidence on how individual factors have shifted traffic, as obtained by before-and-after studies of the effect of sudden changes in major factors, such as fares, while all else remains substantially the same.

PROCEDURE ADOPTED

To develop forecasts for airport traffic for Mexico City, we attempted to develop a causal model. We used the several ways of justifying the components of the model outlined above and then used statistical analyses to establish its correspondence with the data.

The procedure adopted to develop the causal model consists of four steps:

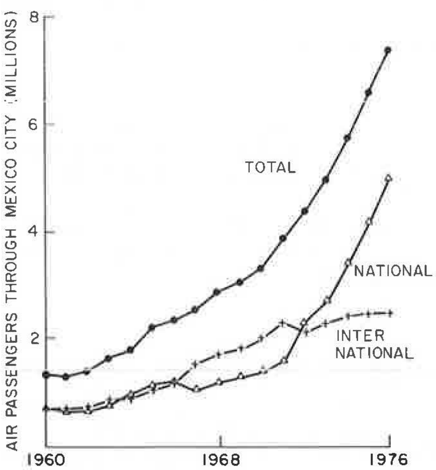
1. Examination of the data,
2. Search for major causes,
3. Statistical analyses to develop short-range forecasts, and
4. Use of scenarios to create long-range forecasts.

Our recommendation to start with a detailed examination of the data is based on our experience, which indicates that the available data—however reputable the source—are often full of errors, inconsistencies, changes of definition, and other factors that introduce spurious jogs and jiggles into past trends. What we have in mind here is not a mathematical analysis but a

Table 1. Official data on passenger traffic through Mexico City International Airport.

	Passengers by Category (000s)			
Year	National	International	Transit	Total
1960	682	610		1292
1961	640	643		1283
1962	666	706		1373
1963	799	815		1684
1964	899	861		1761
1965	1112	1054		2176
1966	1167	1154		2321
1967	1027	1515	190	2732
1968	1164	1683	196	3042
1969	1258	1767	181	3207
1970	1329	1967	158	3454
1971	1576	2250	135	3961
1972	2264	2059	142	4465
1973	2697	2231	236	5165
1974	3383	2376	295	6064
1975	4145	2416	207	6767
1976	4966	2433	195	7594

Figure 2. Official statistics on passengers through Mexico City International Airport.

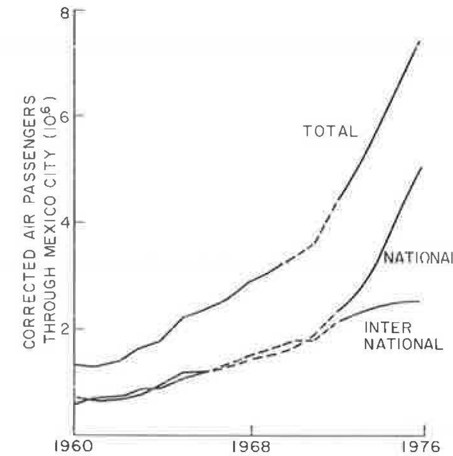


careful look at the data by someone who is knowledgeable about the field and is thus capable of detecting anomalies in the reported data. The case study illustrates the advantages of this approach.

A search for major causes for changes in traffic is then appropriate. The question here is whether there are any factors peculiar to the situation—factors that would ordinarily not be included—that should be entered into the model. For Mexico City, the investigation of secondary sources revealed at least one major factor that should be considered but would not ordinarily be part of a theoretical model as typically developed in the United States. The statistical analysis then follows, focusing on the specific, presumably causal, factors identified both through theory and in the previous phase. At this point we find out which elements of the model are correlated significantly with traffic and whether the overall model fits the data. If it does, we have of course not proved that the model is correct but that it is at least plausible. For short-range forecasts, in which matters cannot change drastically, this justification is sufficient. And so we prepare a short-range forecast by using the model.

Finally, it is probably not reasonable to expect that the statistical model will provide reasonable forecasts for the long range, over which the situation may change drastically. Our approach, then, is to develop sce-

Figure 3. Corrected statistics on passengers through Mexico City International Airport.



narios that describe how the major causes of airport traffic might change and use them to prepare order-of-magnitude forecasts of traffic. This is not elegant but, in our opinion, it provides an honest projection of likely and possible high and low levels of traffic.

The procedure adopted appears to have several advantages. The hope is that, by emphasizing the active use of the intelligence rather than the mechanical procedures of a computer, more insight into the problem can be gained. Since the results are consequently simpler, they are easier for airport planners to understand. Finally, of course, the total cost of the effort may be relatively low.

EXAMINATION OF THE DATA

The official statistics on national, international, and transit passengers through Mexico City International Airport are given in Table 1 and shown in Figure 2 (7, 8). Before our effort got under way, a number of econometric analyses had been run in an effort to model the data. From the standpoint of usual practice, these looked like good models—both theoretically, in that they included obvious factors such as fares, frequency, and gross national product, and statistically, in that the fit was excellent. Ultimately, however, these preliminary models were worthless because the data were, subtly but significantly, wrong.

Our suspicions concerning the data were aroused by peculiarities in the data. For instance, the level of transit passengers shifts dramatically between 1972 and 1973. In addition, the ratio of national and international passengers jumps suddenly in 1967 from about 1:1, which it had been for years, to about 1:1.5. These kinds of shifts are highly unlikely to be realistic, since patterns of travel are typically stable over the short term.

In looking at some of the supportive data on airport operations, we noticed that the numbers of passengers per airline operation also jumped anomalously in 1966 and 1973. Somehow the data did not reflect what our experience with airline operations indicated must be happening.

These operations prompted us to cross check the official statistics with all available airline sources (9-11), federal sources (12-15), and international sources such as the International Civil Aviation Organization (16). Not surprisingly, given our experience with comparable American and international data, we found a number of inconsistencies that seemed to deserve correction.

A major source of potential error was traced to institutional changes of the kind that occur everywhere. Specifically,

1. In 1966, the collection of airport statistics passed from the Ministry of Public Works to the newly created office, Aeropuertos y Servicios Auxiliares (ASA), which established the category of transit passengers and apparently subtracted them from what had previously been counted as national passengers.
2. In 1972, at the start of the next presidential term, a new administration altered the way in which international passengers were counted. Previously, a passenger was considered international if the ultimate destination of his or her flight was outside the country; afterwards, this same traveler was considered part of the national traffic if his or her flight made an intermediate stop in Mexico.

In addition, there appear to be a few mistakes that are attributable to typographical errors. For example, the official 1971 figure for total traffic seems too high by 300 000 passengers, both in comparison with other totals and with the sum of the parts reported by airlines and immigration officials. These conclusions thus led us to adjust the data to obtain the patterns shown in Figure 3 (17). These adjustments, justified in detail because of specific factors in the process for collecting the data, resulted in elimination of anomalies and jumps in the data that would be difficult to explain. It is our contention that there is usually a need for this kind of correction.

SEARCH FOR MAJOR CAUSES

The trends in traffic shown in Figure 3 indicate that the causal model must explain two phases: a period of steady growth in both national and international traffic, followed after 1972 by much more rapid increases in national traffic while international traffic tapered off. In looking for causes, we must therefore identify plausible reasons both for the shift in trends around 1972 and for the subsequent divergence between national and international travel.

The basic structure of the shift in trends is actually fairly obvious. Mexico discovered vast quantities of oil, estimated by some to equal the reserves of Saudi Arabia, and this domestic prosperity increased the ability of Mexicans to travel. Simultaneously, the fuel crisis depressed the economy of the United States and thus dampened the international traffic that, in fact, represents the influx of American tourists.

The preceding period of steady growth in traffic, on the other hand, is the expected pattern associated with steady demographic and economic expansion. Any of a number of variables would represent this effect.

In general, many variables might stand for the underlying causes we have described. To select likely factors, a wide variety of candidates were examined. By category, these included

1. Demographics—the population of the nation and the city and their ratio, the adult population, and the number of people gainfully employed (2-5, 18);
2. Economics—the distribution of income and the percentage of families earning enough to afford to fly, price indices for Mexico and the United States, the gross national product, real national investment and total capital, the expenditures on infrastructure in the nation and the capital, the level of imports and exports, and foreign economic factors, specifically the U.S. gross national product and recreational expenditures as reported by the U.S. Department of Commerce (5, 18-22);
3. Transport—airline tariffs, frequencies, and routes and levels of traffic on competitive modes such as highways and railroads (7, 9, 10); and
4. Tourism—the availability of accommodations for tourists (15).

From all of these possibilities, we selected the following causal variables:

1. To represent the overall level of activity in Mexico City, we took its population in thousands by year ($POBDF_t$), which is closely correlated with other exponentially growing factors, such as gross national product, and stands for them statistically.
2. To capture the actual market of Mexican passengers, we chose the number of families able to travel—that is, families with incomes greater than 10 000 (1968) pesos (1 peso = U.S. $0.08), by year and in thousands (FPV_t).
3. To represent the amount of international tourism, we selected U.S. recreational expenditures by year, expressed in 1967 dollars per person ($RECUS_t$). Figure 4 shows the recent evolution of this variable. Studies of North Atlantic air traffic indicate that this is a powerful explanatory variable (23-25).
4. The effect of the oil crisis was expressed by a dummy variable, equal to zero until 1973 and to one thereafter (DUMMY).
5. The cost of transportation for national traffic was represented by an index of fares expressed in constant pesos, by year ($TARN_t$). As Figure 5 shows, this measure fluctuated within a narrow range until the 1970s, when rapid inflation and prosperity sent the real prices tumbling. This is closely associated with the more rapid increase in traffic during this period.
6. Conversely, however, there is little point in including a figure for international fares, which are, as Figure 6 shows, so closely correlated—although inversely—with the trend of U.S. recreational expenditures. One could not distinguish statistically between these measures.
7. A final factor considered was the shift from rail to air for intercity travel in Mexico. As Figure 7 shows, this has been quite dramatic for the railroads. But, considering the small fraction of national air travelers this represents and the close correlation of this variable with Mexican air tariffs, it was not included.

These variables, three each for national and international traffic, completed the set of presumed major causes of change in air traffic for Mexico. More variables could easily be justified theoretically, but they would not make sense statistically. After all, the available data comprise only 16 independent points; more variables would severely restrict the ability to estimate the coefficients of the model.

SHORT-RANGE FORECASTS

The causal models were calibrated by ordinary least squares to obtain the following results. For national passenger traffic, by year,

$$PN_t = e^{-7.45} FPY_t^{3.32} TARN_t^{-0.95} POBDF_t \quad R^2 = 0.98$$

$$(5.02) \quad (17.0) \quad (6.13) \qquad F = 289$$

$$d = 2.40 \qquad (1)$$

Figure 4. Evolution of U.S. recreational expenditures per person.

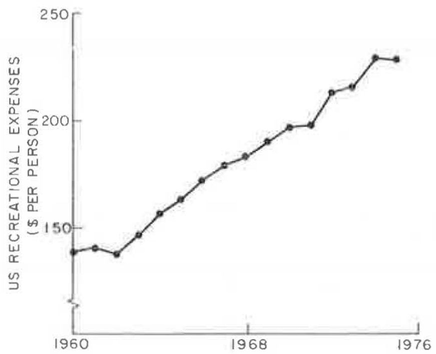


Figure 5. Trend of air fares within Mexico in constant pesos.

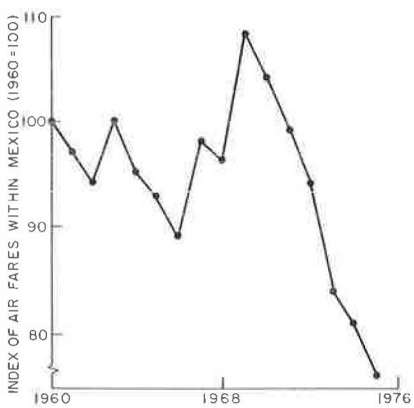


Figure 6. Trend of international air fares at constant prices.

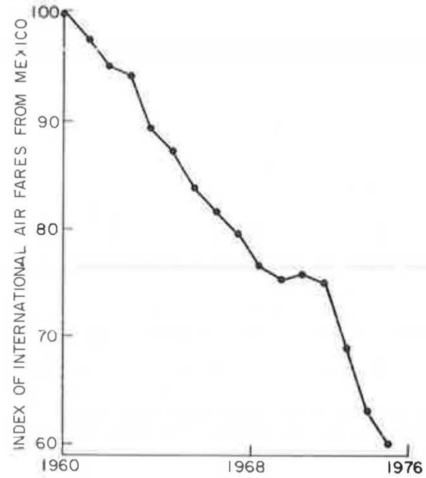
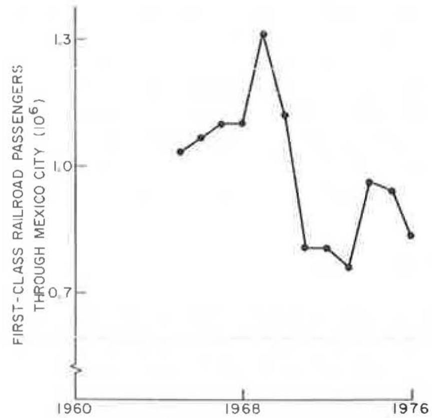


Figure 7. Decrease in first-class intercity rail travel in Mexico.



For international passenger traffic, by year,

$$PI_t = e^{-1.71}\,RECUS_t^{2.06}\,FPY_t - 76\,900\ DUMMY \qquad R^2 = 0.99$$
$$(4.92) \quad (31.0) \qquad F = 959$$
$$d = 1.90 \qquad (2)$$

Both models have reasonable coefficients, fit the data well, and are free from autocorrelation. Given our prior reasons for believing that these models make sense, the statistical tests encouraged us to use them for short-range forecasts.

It is easy to suggest more sophisticated—and more expensive—mathematical analyses that might lead to statistically more satisfying models. But would such extensions be worthwhile? And would they be cost effective?

We believe that further analyses would not be productive. Indeed, the creation of a formula for airport traffic does not solve the problem of generating a forecast. The development of the model merely displaces the forecasting problem: Instead of having to forecast traffic, we now have to forecast many other variables. It is hoped that the future trajectory of these variables will be reasonably obvious. But uncertainty still exists and is, in our opinion, bound to overwhelm any marginal improvements that might be made in the models.

In the event, we obtained short-term forecasts by using low, medium, and high estimates of each of our explanatory variables. The results are shown in Figures 8 and 9.

Fairly obviously, forecasts similar to ours could have been obtained at essentially no cost at all simply by drawing in lines freehand. How much is this, or any, analysis worth? We feel that the analysis is useful as a discipline to force us to examine the data, to think about the possible causes, and to develop a true understanding of the reasons why low or high levels of traffic might occur. We do not believe that this or any procedure can provide precise predictions. Consequently, we also believe that relatively modest efforts, such as the one described here, are most reasonable for airport planning.

LONG-RANGE FORECASTS

Given the uncertainties of past data, the fact that econometric models are valid only over a relatively short term, and the possibility of major technical and even political developments, long-range forecasts of airport traffic can at best be only estimates of the general magnitude of future traffic.

Our estimates are based on scenarios of how air traffic through Mexico might develop. The results are validated (to the extent that this is possible) by comparing the forecasts with the evolution of passenger traffic at other major airports that have already passed beyond the current level of traffic at the Mexico City airport. We prepared estimates of the level of population in Mexico, its spatial distribution, and the financial

Figure 8. Short-range forecasts of national passengers through Mexico City International Airport.

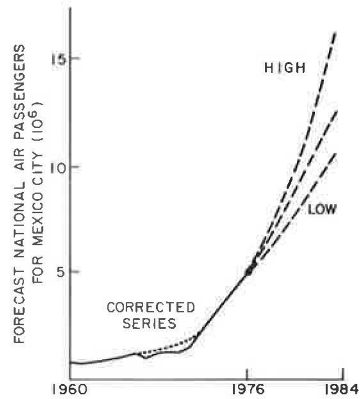


Figure 9. Short-range forecasts of international passengers through Mexico City International Airport.

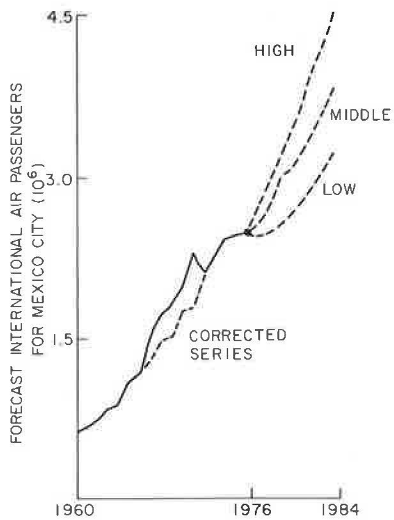
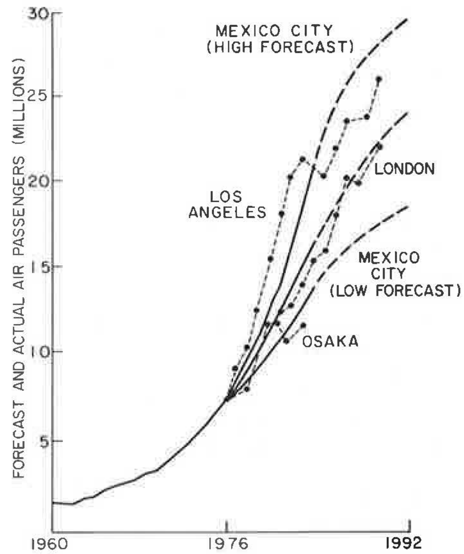


Figure 10. Long-term forecasts of total passengers through Mexico City International Airport and other major airports.



or touristic attractiveness of each city linked by air to Mexico City. Subjective estimates of the probability distributions of air passengers on each route were made and then merged to obtain a joint probability distribution. This led to a median forecast of 25 million passengers for Mexico City in 1992 and 80 percent confidence limits of about ±25 percent. Figure 10 shows these results.

These long-range forecasts turn out to be close to what has already happened at other major international airports that have grown beyond the 7.5 million passengers/year who currently use the Mexico City International Airport. That these airports either grew faster or slower than the upper and lower bounds of our forecasts does suggest, however, that our range of uncertainty may need to be even wider than ±25 percent.

CONCLUSIONS

This paper presents a procedure for forecasting traffic at airports and applies it to Mexico City. The validity of the process, for the purpose of airport planning and design, depends on how well it informs the decisions that must be made about how much and when to expand airport capacity. We believe that the procedure fulfills the needs inexpensively.

ACKNOWLEDGMENT

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Proposed Technique for Identification of Market Potential for Low-Cost Air Travel

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A mail-back survey conducted by the Maryland State Aviation Administration to assess the interest of Maryland residents in a low-fare, no-frills air service from the Baltimore-Washington region to the West Coast is described. The questionnaire used was designed to determine whether or not respondents had traveled by air from the Baltimore-Washington area to California during the past 24 months and whether they would have traveled more often to California (or for the first time) if a $99 one-way fare had been in effect between the Baltimore-Washington region and the Los Angeles and San Francisco areas. Results were tabulated and analyzed on a computer by using the Statistical Package for the Social Sciences. In addition to analysis based on statewide population data, tabulations were developed at the zip code, county, and regional levels for more detailed analysis of potential markets. The proposed technique shows how the use of existing computerized data on area population can be conveniently converted to a representative sample for public policy purposes.

The diversion of air passenger traffic from one market to another was an important factor in the economic regulatory environment of the Civil Aeronautics Board (CAB) prior to the recent passage of legislation deregulating the airline industry. The more diversion there was, the less likely the CAB would be to award the new authority. By attempting to show that additional air passenger demand could be produced by the new service, an argument could be made for allowing additional air carrier supply without apparent diversion of traffic from existing services. Such an argument removes one of the principal grounds for CAB disapproval of low-fare proposals.

With the evolution of a more procompetitive regulatory policy, the need for carriers (and communities) to argue the absence of diversion for new service has been eliminated. Moreover, communities are now in a position to seek to convince suitable air carriers, rather than the CAB, that their market would be the most advantageous for a carrier to commit its limited equipment and resources.

In an effort to demonstrate that new air passenger travel would be generated by low-fare, transcontinental service, the Maryland State Aviation Administration conducted a mail-back survey designed to measure objectively the additional traffic that would be produced by new service. The survey had, as a major constraint, the need to produce a mailing list that was representative of the entire geographic area under question—in this case, the state of Maryland.

In the design of surveys to elicit the general opinion of this potential market, it is inappropriate to use commonly "manufactured" mailing sources that may tend to be biased toward higher-income groups or to concentrate geographically on urban areas. In addition, it is