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SURVEY OF AIR CARGO FORECASTING TECHNIQUES

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Final Report
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A. Summary

Future technological developments in aircraft for the air cargo industry will be closely related to both the quantity and nature of the products best handled by the air mode. Thus, the ability to estimate or predict the demand for air cargo in various markets is an essential first step in planning research and development to improve the contributions to be realized from technology. This study has reviewed and summarized the various forecasting techniques currently in use in the field. The literature in both the air cargo and air passenger fields has been examined. A general discussion of the fundamentals of the various forecasting approaches is presented with references to specific studies as appropriate. An evaluation of the effectiveness of current methods is made and several prospects for future activities or approaches are suggested. Appendices contain summary type analyses of about 50 specific publications on forecasting, and selected bibliographies on air cargo forecasting, air passenger demand forecasting and general demand and modal-split modeling.

B. Introduction

There is no unanimity of opinion about the adequacy of current air cargo (or air freight) service and capabilities. Operators and users often have different objectives, purposes, and opinions on the nature of the service offered. The type of aircraft used is an extremely important factor which touches on many facets of the service such as costs, delays, loss and damage, and ability to serve a variety of markets.

For example, the use of "belly" space for cargo in regularly scheduled passenger aircraft limits the size and weight of individual shipments, and often makes the handling of these shipments awkward at many airports. On the other hand, the economics of operating the all-cargo versions of the normal passenger aircraft have restricted them to only the highest density routes at long stage lengths.

Thus it might be suspected that the air cargo industry suffers from the lack of one or more properly designed dedicated-freighter aircraft. Indeed there are many advanced concepts currently under development which perhaps could be applied to the design of such aircraft. However, in order to profitably initiate such design studies, forecasts from the market place will have to indicate the need for increased airlift capacity. Also, some indications of the gross design characteristics such as payload, range, speed, field length capability, etc. will be required.

The lead time for the development of new aircraft requires several years. Therefore, the future need for capacity and various operating characteristics must be based upon the forecasts of air-cargo activity during that time frame and beyond. There are several forecasting techniques which are currently being used and have been used in the recent past. When attempting to examine retrospectively the accuracy of the projections resulting from these techniques, the performance is not good. Thus their ability to provide realistic estimates in the future must also be suspect.

Nevertheless, forecasting is essential to decisions on the commitment of resources to new aircraft and so it's important to achieve the best possible understanding of the powers and limitations of current forecasting techniques. This is an essential first step to modifying and extending these current techniques in order to improve the accuracy of the forecasts necessary for sound design decisions.

Thus the present study was undertaken with the basic objectives of reviewing and summarizing the various forecasting techniques currently in use, and to suggest which techniques might be most suited to predict the future trends for air cargo.

In establishing the scope of the study, both near term (next five years) and long term (1990 - 2000) time periods were addressed, but considerations of mail and military freight were excluded. Also because the techniques are usually quite similar, forecasting in air passenger markets was also examined.

C. Approach

The obvious initial step in the study was to generate a reasonably comprehensive bibliography for air cargo forecasting, and then examine the documents involved, both to gain insight into the techniques and methods used, and to generate additional reference sources. It soon became apparent that there are many similarities between the methods and techniques of forecasting air cargo and forecasting air passenger traffic. Thus the work was expanded to include a survey of the latter field. The literature is much more voluminous with regard to passenger forecasting, primarily because of the existence of better data, and it was necessary to be quite selective in order to remain within the resource constraints prescribed for the study.

It was also clear from the preliminary literature survey that forecasting the demand for air cargo service was intimately involved with the nature of the service to be offered and the organizational aspects of providing that service. Thus the review was extended along the following lines

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- . the development and review of a selective bibliography of reports and papers relating to the entire air cargo system;
- . a review of the more general material contained in monographs and texts, or in conference proceedings, e.g., the International Forums for Air Cargo; and
- . an examination of the development of the major issues in air cargo from the viewpoint of the trade journals in the industry.

Thus, in essence the results, conclusions and recommendations presented later in this report are based on a relatively thorough study of selected material relating to the air cargo industry in general, and the forecasting of air cargo demand and air passenger traffic in particular. The many judgements required have been made within a reasonably extensive familiarity with the general fundamentals of forecasting methods and techniques and with the development and application of models for demand and modal split.

The material in the report is presented in the following format: A summary presentation of the present status of air cargo forecasting is presented in Section D. The various forecasting techniques are explained briefly and their advantages and disadvantages are discussed. Section D also contains a tabulation of some of the cargo and passenger forecasting work which is adaptable to this type of presentation. The summary is supplemented by Appendix A which contains brief critical reviews of a number of papers and reports.

Section E presents the results and conclusions of the evaluation of the current status of air cargo demand forecasting and some suggestions for the future are made in Section F.

With the anticipation that they might be of value to some of the readers of this report three additional appendices containing bibliographical material have been included as follows:

- B - Air Cargo Forecasting
- C - Air Passenger Demand Forecasts
- D - General Demand Models and Modal Split Analysis.

These are not intended to be complete bibliographies, but they are representative of the type of work which has been done.

D. Review of Forecasting Methods

1. General Comments on Forecasting

In this section the current methods and techniques used in forecasting will be reviewed and summarized. Forecasting is foretelling of the future and can either be a prediction or a projection. Cetron (1) says that prediction is an anticipation of future events without qualification. That is, when an event is predicted all if's and but's are considered. Nevertheless, a projection is made with qualification statements such as if this ... then that or statements of a similar nature that safeguard the forecaster from the complications involved in the prophetic nature of a forecast. According to Ayres (2), "most of the (forecasting) hazards--the uncertainty and unreliability of data, the complexity of "real world" feedback interactions, the temptations of wishful or emotional thinking, the fatal attraction of ideology or an idee fixe, the dangers of forcing soft and somewhat pliable "facts" into a preconceived pattern--apply to all forms of forecasting."

The presentation is focused on the structure of a variety of forecasting techniques that have appeared in the literature concerning forecasting in a variety of areas such as business, and economic indicators, stock-market, sales and marketing, weather, technology and travel demand, among others. These areas are typical of the many disciplines where forecasting techniques are being used with varying degrees of success.

As will be seen, the various techniques involve a wide range of processes and procedures, but they all have certain fundamental factors in common which are important in understanding their ability to be applied successfully.

In essence they represent extrapolations of some sort based on past experience. These extrapolations may be made on the basis of personal judgment, graphical or proportional techniques, or mathematical analysis of varying degrees of complexity, but in all cases they are extrapolations.

Being extrapolations, they must depend upon a data base, built on already-accomplished experience--past, present or both. These data can be obtained and used in a chronological sequence (time series) or by examining a variety of the factors which seem to exert control over the quantity to be forecast during a relatively brief time period (cross sectional)--or in some cases these techniques can be combined.

Either the forecasts contain the implicit assumption that the factors that were influential in controlling the system performance as the data were being obtained will (a) continue to be those that are influential, and exert similar influences in

the future, or (b) some method must be devised for predicting the changes which will occur and the manner and extent of their influences.

2. Classification of Forecasting Techniques

Forecasting techniques may be classified based on two schools of thought. According to the first school, a forecasting approach is either teleological (i.e., goal oriented), dialectical (i.e., conflict oriented), or phenomenological (i.e., analogy oriented).

A teleological approach, also called normative forecasting, is based on goals, purposes, objectives, or needs. Program plans are charted toward the goal, modifications are made as and when necessary, and strategies are planned and implemented as time progresses to achieve the goal. The proponents of this approach assert that the future is to be shaped according to the existing needs and so a forecast has to be normative. A typical technique in this area is the technical feasibility analysis which focuses on costs, benefits, social values, etc., of choosing various program plans. Once the program plans are chosen, techniques like PERT (Program Evaluation and Review Technique) and GERT (Graphic Evaluation and Review Technique) are used in the plan implementation phase.

The underlying philosophy of the dialectical approach is that "both history and the future are a sequence of conflicts, and the truth content of a system--or the events in the past and future--are the results of a highly complicated process". Such a process can be modeled only approximately after an honest conflict definition and resolution. Well-known techniques like the Delphi technique and scenario methods fall in this category.

The phenomenological approach is based on the premise that operational behavior is predictable from ad hoc relationships formed from evidence of natural phenomena. Analogy methods, where the phenomena are observed in an analogous field, and empirical methods, where the phenomena are observed from experience or experimentation in the same field, can be classified as belonging to this approach.

According to the second school of thought, forecasting approaches are either subjective or objective in nature. Objective methods are further classified as empirical methods and operational and analytical methods. In this section, forecasting techniques are presented and described according to the latter school of thought, primarily on the basis of intuitive appeal when viewed from the perspective of transportation forecasting. As will be seen, subjective and objective approaches can be combined.

3. Forecasting Methods

Table 1 presents a summary of the various methods to be discussed in this section. As indicated earlier, these discussions are concerned with basic structure of the method and not with applications. In Appendix A, almost 50 documents from the literature of transportation forecasting are reviewed briefly. Table 2 contains an outline of some of these in a ready-reference format which indicates the methods used. Also, in the text which follows references are given whenever possible to illustrate how the methods have been applied. In many cases these are in areas outside transportation, but the analogies should be apparent.

It should be noted that Ellison and Stafford, in an appendix to their book, The Dynamics of the Civil Aviation Industry (3) offer a presentation somewhat similar to Table 2. Most of their articles are prior to 1970, and include some rail forecasting studies for comparison. There is only a minimal overlap between the two tables.

a. Subjective Methods

Subjective forecasting methods consider the value judgments of individuals or groups in projecting future events. These methods are the most direct and simplest of all the forecasting techniques. The basic aspect of this approach is that the final conclusions reached are the result of the educated "guesses" or estimates by one or more individuals familiar with the field. These judgments may be rendered with or without any formal evaluation of economic, social or political forces which might apply to the matter at hand. They may be the work of individuals, or groups of small or medium size. The groups may meet informally or they may use structured techniques. Subjective methods are divided into four major groups, namely (i) genius forecasting, (ii) consensus forecasting, (iii) scenario forecasting, and (iv) curve fitting by judgment.

(1) Genius Forecasting

The simplest of all forecasting techniques is, as Lenz (4) calls, "genius forecasting." It is an undiluted vision of an expert who is openminded and takes a synoptical view of the area in which his/her expertise has direct application.

(2) Consensus Methods

The problem with genius forecasting is that it is the opinion of an individual and excludes any review process or at least averaging out multiple opinions. A method of overcoming the disadvantage inherent in genius forecasting is to seek

Table I - Outline of Forecasting Methods

1. Subjective Methods
 - a. Genius Forecasting
 - b. Consensus Methods
 - (1) Polls
 - (2) Committees
 - (3) Structured Group Interactions
 - c. Scenario Method
 - d. Curve Fitting by Judgement
2. Empirical Objective Methods
 - a. Naive Forecasting Models
 - (1) Same Level Models
 - (2) Simple Trend Models
 - (3) Average Trend Models
 - (4) Link Relative Models
 - b. Correlation Analysis
 - (1) Curve Fitting by Regression
 - (2) Trend Correlation Analysis
 - c. Time Series Analysis
 - (1) Classical Time Series Analysis
 - (a) Secular Trend
 - (b) Cyclical Fluctuations
 - (c) Seasonal Variations
 - (d) Irregular Movements
 - (2) Exponential and Adaptive Smoothing Models
 - (3) Mathematical Time Series Analysis
 - d. Cross Sectional Analysis
 - e. Category Analysis
3. Analytical Objective Methods
 - a. Simultaneous Equation Approach
 - b. Input-Output Analysis
 - c. Analogy Methods
 - d. Simulation
4. Combined Methods
 - a. Behavioral Modeling
 - b. Market Research.

TABLE II. SUMMARY OF SELECTED AIR TRANSPORT FORECASTING STUDIES

#	Ref	Class	Method	Variables	Data Sources		Base Period	Comments
					Calibration	Forecasting		
1	MAIO-76	Freight, Domestic	Time Series	(D) Total Rev Ton Miles GNP Yield (Rev/ton mile)	CAB - HAS ? CAB - HAS	-- Wharton EFA 3 Scenarios on Prices (1) avg. inc. 2%/yr (2) no change (3) avg. dec. 2%/yr	1965-74	Regression models developed for each case; int'l markets must be treated by nation-pair and by imports vs. exports. Although demand is recognized to be a function of quality of service, no data are available on this relationship.
		Freight, Int'l	Time Series	G.P. of US GNP of ith Region Yield	LOC - SCB UN - SY IMF - IFS CAB - ATFS	Wharton EFA	1965-74	
2	BOEI-73	Freight, US-Europe	Time Series	(D) Total Trade (\$) (D) Eastbound Tons (D) Westbound Tons US GNP Other National GNP Yield (Rev/ton mile)	-- -- -- Various Economic Forecasts are Studied	-- -- --	1962-72	Attempts were made to include per capita income and time as independent variables, but they were not significant.
3	ROEI-74	Freight, Domestic	Time Series	(D) Rev Ton Miles G.P. Yield	CAB Form 41 DOC - SCB CAB Form 41	-- Chase Econometrics Special Boeing Scenario	1962-73	Both short-term and long-term regression models were developed.
4	DEOS-77	Carrier Passengers	Extrapolation	Total Emplacements Income Economic Isolation Unit	(see FAA-76)	Based on Total Air Carrier Forecasts (see FAA-76)	1965-75	Developed separate procedures for hubs, non-hubs, special areas, small points and potential points. In each case total emplacements are predicted based on a fixed relationship to air carrier forecasts, then they are allocated to specific points.
5	MAIO-77	Freight, Domestic	Extrapolation			(see MAIO-76)		Allocates the domestic projections developed in MAIO-76 to the 25 leading hubs and translates them into aircraft activity.

Table II. Summary of Selected Air Transport Forecasting Studies (Cont.)

# Ref	Class	Method	Variables	Data Sources		Base Period	Comments
				Calibration	Forecasting		
6	SIWA-68 Freight, Domestic	Regression on Causal Variables	Fraction Moving by Air (D) Relative Cost Relative T. Inventory Costs	DOC - COT Various	DNA	1963	A very thorough analysis of data. Model is deduced to account for the fraction of a commodity in a given market that goes by air relative to by surface modes.
7	SIWA-69 Freight, Int'l	Regression on Causal Variables	Similar to #6				
8	FPA-67 Domestic Passenger	Simple Extrapolation	(D) Boardings (D) Rev Pax Miles	Past FPA Records	DNA	1958-67	Forecasts are revised annually; always under-estimate; good in short range; poor in long range.
9	CAB-65 Total US Passenger	Regression on Causal Variables	(D) Rev Pax Miles Consumer Price Index Disposable Personal Income Population Fares	Past Records from Various Sources	Various	Prior to 1965	Gave relatively poor forecasts when compared in retrospect with what actually happened.
10	AZA Total US Passenger	Simple Extrapolation	(C) Rev Pax Miles	Past Records from Member Airlines	--	Prior to 1966	Selected three possible figures for growth rates and then projected linearly.
11	ELLI-70 Domestic Passenger Incl. Modal Split	Projections + Judgments on Socioeconomic Variables; Modal Split by Models	(D) Zonal Person Trips Population Income Time Cost Propensity to Travel	CAB: FPA, NDCIP National Planning Association Judgment	--	1962 and 1967	Model split between auto, air, bus and rail (in corridors only); is estimated in 1975, 1970 and 1990 for person trips made between any of 490 zones covering the US.
12	WILS-76 Commuter Passenger	Regression on Socioeconomic Variables	(D) Trips Population Income Air Travel Time	Judgment APTIS	?	1967-74	$R^2 = .89$ for the regression which turns out to be essentially a gravity type model; value added and personal income were not significant.

Table II. Summary of Selected Air Transport Forecasting Studies (Cont.)

#	Ref	Class	Method	Variables	Data Sources		Base Period	Comments
					Calibration	Forecasting		
13	ROSE-75	Cargo, Domestic & Int'l Passenger	Market Analysis thru Simulation	Supply, Demand and Services Characteristics	DNA	DNA	Current	Specifically attempts to find specific market scenarios in which LTA vehicles might compete favorably.
14	BROW-73	Passenger	Cross Sectional	(D) Demand (D) Modal Split Cost Trip Time Access Cost Convenience Population Type of Travel	Not Calibrated	DNA	DNA	This is an attempt to correct for deficiencies in a gravity type model.
15	SLET-75	Domestic & Int'l Freight	Econometric	(D) Ton Miles GNP or Income IP Rates Yield	CAB - ATFS C/B - HAS ICAO - FD DOC - Statistical Abstracts	DNA	1947-72 (Period Varies)	Does regression on the independent variables to study their elasticities.
16	THOR-78	Commuter Air Passengers	Econometric	(D) Avg. Daily Enplanements Population Income Education Isolation Occupation	DOT - Air Carrier Service to Small Communities 1970 Census of Population	Same	1970	A nonlinear regression equation was found to be a poor "best"; only had $R^2 = .401$.

- ABBREVIATIONS:
- CAB - HAS Civil Aeronautics Board - Handbook of Airline Statistics
 - Wharton EPA Wharton Economic Forecasting Associates
 - CAB - ATFS Civil Aeronautics Board - Air Traffic and Financial Statistics
 - DOC - SCB Dept. of Commerce - Survey of Current Business
 - UN - SY United Nations - Statistical Yearbook
 - IMF - IFC International Monetary Fund - International Financial Statistics
 - DOC - COF Dept. of Commerce - Census of Transportation
 - NECTP Northeast Corridor Transportation Project
 - APTIS Atlantic Provinces Transportation Information System
 - ICAO - FD International Civil Aviation Organization - Financial Data

multiple opinions. The idea is that the interaction between several experts is more likely to insure consideration of aspects which any single individual might overlook. Furthermore, the chance that a hidden bias of one member will be offset by the counter bias of another member is relatively high. There are three varieties of consensus forecasting, namely (i) forecasts from polls, (ii) forecasts from committees in interpersonal interaction, and (iii) forecasts from the group judgments obtained in a structured manner.

a. Polls

Forecasting from polls consists of sampling a group of representative persons and drawing conclusions from the responses. However, extreme caution is to be exercised in designing "polls" as the individual responses might be composed of not only true values but the so-called "systematic and experimental errors" as well, if the polls are poorly designed. Therefore, to avoid systematic errors, it is vital in polling to insure that the target population is properly represented and the problem of nonresponse is adequately dealt with. The poll should represent the target population and measures must be taken to collect data from various strata of the sample size, that is, strata that are representative of the nonhomogeneity of the entire sample. In a mail survey, it is absolutely essential to obtain a high rate of return (>60%). Otherwise the risk of a bias toward those with beliefs on one or both extremes will be very high.

Experimental errors arise primarily in the actual process of collecting and analyzing data. A principal source of such error is a combination of inadequate understanding of a question by the responder and faulty interpretation of the response by the interrogator. To minimize this, all mail surveys should be pretested with follow-up interviews.

b. Committees

A common type of consensus forecast is that prepared by a committee of experts in an interpersonal interaction. "Project Seabed" of the Navy, and "Project Forecast" of the Air Force are two successful examples of committee forecasting. In "Project Forecast," representatives from 30 DOD organizations, 10 non-DOD organizations, 26 universities, 70 industrial corporations, and 10 not-for-profit organizations participated in the so-called "technology panels" and "capability panels". They met during a six-month period (in 1963) and produced forecasts of U.S. defense needs of the 1970's. The committee approach, despite its recognition as a successful forecasting technique, suffers from drawbacks which are typical of any interpersonal interactions. For example, the "bandwagon effect," that is, the tendency to join the majority, is a commonly observed phenomenon in committee approaches. Further, there are chances of arriving at a false

consensus due to fatigue and psychological factors or because of the domineering personalities of one or more of the participants. Several structured approaches to committee activity have been devised to help overcome these shortcomings.

(c) Structured Group Interactions

One of the most popular of the structured techniques is the Delphi method, conceived in 1964 by Olaf Helmer (5) (6), of the Rand Corporation. This technique requests independent and anonymous opinions on the principal topic and closely related issues by the submission of questionnaires to a panel of experts which has been selected to participate in the exercise. The returns from the questionnaires are analyzed, and some informational statements (not specifically related to the identity of any of the respondents) are prepared and circulated to the group. At the same time a second questionnaire is distributed seeking additional or revised opinions based upon the individual's assessment of the information presented. Again the responses are anonymous. The process is repeated until the range of opinions (or forecasts) obtained from the respondents tends to stabilize.

The Delphi method has the disadvantage of requiring a long period of time to implement. It also depends upon the judgment of the administering team in interpreting the questionnaires and formulating the informational feedback. However, it overcomes one major weakness of a regular committee approach to reaching judgmental decisions, viz., a bias which might be introduced by the persuasiveness of individual members who may not have valid arguments or who are not focused on the key issues computed from earlier parts of the program. There are a number of instances where variations of the Delphi technique were used. For example, the Naval Supply Systems Command (NAVSUP) used a variation of the Delphi Technique called SEER (System for Event Evaluation and Review) to produce a forecast of the information-processing industry. The SEER technique considers a number of Delphi drawbacks such as excessive consumption of time, possible false role playing, lack of benchmarks to stop iteration of the technique, lack of event interrelationships, lack of goal orientation, (7), etc.

Since this approach has many similarities to the general area of product, or service, acceptability, an area which is of extreme importance to the air cargo industry, it is appropriate to pause briefly to describe it in more detail. SEER consisted of two rounds. In the first round, top-level experts from industry participated in the evaluation of a pre-prepared list of potential events. This list was developed through a literature search and a series of interviews of users and producers of information processing equipment. The evaluator is permitted to include additional events in his area of expertise and then

evaluate the events based on three primary considerations:

User desirability--consider the need to make the results of a given event available as a usable product. In other words, is the output of the event needed desperately, or desirable, or undesirable?

Producer feasibility--consider technical, economic, and commercial feasibility of converting the event into a usable product. Is it highly feasible, or likely, or unlikely but possible?

Probable Timing--project a series of three dates for each event: a date of reasonable chance (probability, $p = 0.2$), a most likely date ($p = 0.5$), and an almost certain date ($p = 0.9$).

During round II, a group of outstanding individuals in the field of information processing was asked to evaluate the round I data base to refine and augment the data base, to identify events of importance, and to determine possible interrelationships between events. After receiving the inputs from the panel of round II experts, a refined list of potential events was produced. This list was used to develop a "menu" of alternative potential short-, mid-, and long-range goals; and identify supporting events which might be desirable or even necessary to make these goals achievable.

(3) Scenario Method

"A scenario is a logical and plausible (but not necessarily probable) set of events, both serial and simultaneous, with careful attention to timing and correlations wherever the latter are salient" (8). Kahn, et al. (9) cite two advantages of the scenario method:

(i) Scenarios are an effective tool to counteract "carry over" thinking, and to force the analyst to look at cases other than the straightforward "surprise-free" projections;

(ii) Scenarios are not amenable to abstracting generalizations overlooking crucial details and dynamics. A notable example of the scenario method is due to Kahn-Wiener (10). The authors, in their The Year 2000 construct a scenario which is essentially a sequential plotting of events as they could happen (but need not). The sequence of events is a projection of a "Standard World" in terms of political and cultural development. They pick three base variables and present projections of high, medium, and low as alternative scenarios. Kahn-Weiner's forecasts are extrapolations of straight-line trends coupled with a great deal of judgments about alternative scenarios.

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(4) Curve Fitting by Judgement

The structure of this method is exemplified by its application to what is known as technological forecasting. The technique is based upon the general observations that the rate of invention, diffusion of knowledge, obsolescence, and eventually replacement by a new technology follows a consistent pattern which appears to be a curve with an S-shaped dependence on time. It is, of course, a sincere attempt to correct for the dependence of extrapolations on maintaining the status-quo in many of the potential controlling factors. Experts are called upon to review the emerging technologies and attempt to establish the basic time frame for the various events which might affect normal extrapolations. Either the same group or different groups of experts can then attempt to develop scenarios which indicate the types of effects and the extent of each which these new events might have on the system under consideration.

Technological forecasting is currently receiving much attention and is indeed a promising tool. However, Ayres, in his book on the subject, (11) lists the following difficulties as serious problems yet to be overcome:

- . lack of imagination (or nerve) on the part of the experts;
- . an inherent human tendency to overcompensate;
- . failure to anticipate converging developments and/or changes in competitive systems;
- . over concentration on specific configurational details at the expense of adequate consideration of large scale effects (macrovariables);
- . incorrect calculations; and
- . intrinsic uncertainties and misinterpretation of historical "accidents."

In the aviation field technological forecasting is often used to predict the characteristics of future aircraft performance characteristics, size, noise, etc. Such forecasts imply a relationship to demand, although in far too many cases this is not identified.

(5) Additional Comments

The work of Roberts (12) and Ellis and Rassam (13) involve scenario building.

One of the most popular uses of committee judgment is to apply it at the end of a forecasting methodology to temper and adjust the results obtained through extrapolation or more analytical approaches discussed later. These adjustments tend to include the effects of variables for which accurate data are not available, e.g., frequency of service, aircraft type, forthcoming economic developments in an area, shifting social trends, impending government support or restrictions.

This latter procedure is used with reasonable success by the Air Transport Association (ATA) (14). Various forecasts made by individual companies throughout all sectors of the industry are collected and analyzed by a special committee. Ensuing discussions among the committee members attempt to achieve an understanding of why various forecasts of similar activities differ and then reach a consensus as to the choices and adjustments which should be made to establish the official ATA position.

Professional judgment is also rendered on the basis of experience with certain economic indicators. These can either be individual indicators such as those used for econometric modeling or various measures of the individual indicators. For example, the term diffusion index is given to the process of monitoring the percentage of a group of indicators which are either going up or down. Another popular approach is the use of "leading" indicators, i.e., a time series of an economic activity whose movement in a given direction precedes the movement of some other time series in the same direction.

Finally, in reading the literature, one cannot escape the feeling that most authors who have worked in the field of transportation forecasting for some time temper, modify, or in some way massage the results of their special techniques, whatever they may be, with their own experience. This would seem to qualify as application of "genius" forecasting.

(b) Empirical Objective Methods

The objective methods are quantitative in nature and range from very simple-minded approaches to very complex methods involving a great deal of mathematical and statistical sophistication. These methods are broadly divided into two categories, viz., (i) empirical methods, and (ii) operational and analytical methods. Empirical methods are derived from experience and experimentation. Quantitative analyses developed in statistics, econometrics, and related fields are, for the most part, empirical in nature. The term "operational" merely connotes the use of operations research techniques such as simulation, whereas analytical implies the use of mathematical analysis to a certain degree. While both empirical and analytical methods use mathematical analysis, their classification as to whether they belong to the empirical class or the analytical class is mostly arbitrary

in nature and the extent to which they are based on existing data.

(1) Naive Forecasting Models

The naive forecasting models assume that recent past periods are the best predictors of the immediate future. Three types of models are presented below:

(a.) Same Level Models

The same level models assume that whatever is happening in the present or happened in the past will continue to happen in the future.

EX 1. $\hat{X}_{t+\Delta t} = X_t$

where

$\hat{X}_{t+\Delta t}$ = forecast value at time period (t+Δt)

X_t = observed value at time period t.

(b) Simple Trend Models

Simple trend models assume that the future is shaped based on specified trends such as absolute changes, rates of change, multiplicative changes, etc. Examples that are frequently used in the literature are as follows:

EX 1. $\hat{X}_{t+1} = X_t + (X_t - X_{t-1}),$

The forecast value at time period (t+1) is assumed to increase or decrease from the value at time period t by the same amount as the actual difference between the time periods t and (t-1).

EX 2. $\hat{X}_{t+1} = X_t \left(\frac{X_t}{X_{t-1}} \right).$

The forecast value at time period (t+1) is assumed to increase or decrease according to the ratio of the present value to the previous value of the given variable. Ratio methods can also be used to relate current or historical (time) trends in some local or component activity to equivalent experience in a larger sector. This relationship is then preserved and used to predict future activity in the component based on forecasts in the larger sector which may be readily available or easier to forecast.

(c) Averaged Trend Models

Slightly more complicated versions of naive forecasting models are based on the average of past absolute changes and the average of past rates of change.

$$\text{EX 3. } \hat{X}_{t+1} = X_t + \frac{\sum_{i=0}^n [X_{t-i} - X_{t-(i+1)}]}{(n+1)}$$

$$\text{EX 4. } \hat{X}_{t+1} = \frac{X_t}{(n+1)} \left[\sum_{i=0}^n \frac{X_{t-i}}{X_{t-(i+1)}} \right]$$

where

n is the number of time periods.

Bonini (15) describes an interesting forecasting procedure which considers monotone invariant functions and arithmetic averages. The author considers a hypothetical firm for which a sales forecast is to be made. The method proceeds as follows: "The sales forecast is made during the last period in a quarter for the forthcoming quarter (three periods). Each salesman bases his forecast upon actual sales over the past five periods (i.e., the two periods this quarter for which data are available and sales during the last quarter).

Let \bar{S} be the average sales for a product over the past five periods.

Let S_{t-1} and S_{t-2} be the sales of the product in the last period (month) and the month before last, respectively, and

Let \hat{S} be the sales forecast (average monthly sales for the forthcoming quarter) for a product by a salesman.

Then, if

$$S_{t-1} \geq \bar{S} \text{ and } S_{t-2} \geq \bar{S}'$$

$$\text{then } \hat{S} = \max (S_{t-1}, S_{t-2}).$$

Thus, if the sales in the last two months are both above "normal" (i.e., the average, \bar{S}), then the salesman interprets this as an indication of upward trend and makes his monthly estimate for the next quarter as the greater of the sales during the last two periods.

If

$$s_{t-1} \geq \bar{s} \geq s_{t-2} \quad \text{or if} \quad s_{t-2} \geq \bar{s} \geq s_{t-1}$$

then $\hat{y} = \bar{s}$.

Thus, if one of the past two months' sales is above average and the other below average, then the salesman takes this as evidence of continued "normal" conditions and uses this "normal" value (i.e., the average, \bar{s}) as his forecast:

If

$$s_{t-1} < \bar{s} \quad \text{and} \quad s_{t-2} < \bar{s}$$

then
$$\hat{y} = \frac{s_{t-1} + s_{t-2}}{2}$$
.

If both of the two most recent months are below "normal," then the salesman interprets this as an indication of downward trend and estimates sales as the average of the last two months."

The above is a typical example of how simple naive methods can be used to make efficient short-term forecasts--forecasts based on pure empirical evidence.

(d) Link Relative Models (16)

Link relative models are commonly employed to measure seasonality of a time series and forecast the seasonal component of a time series. The average relationship between successive time periods is used to describe the pattern of seasonality. Percentage or ratio change is the most widely used relationship in the link relative models. First, the ratio of month-to-month change is computed for all pairs of successive months, e.g.,

$$\frac{X_{\text{Feb}}}{X_{\text{Jan}}}, \frac{X_{\text{March}}}{X_{\text{Feb}}}, \frac{X_{\text{April}}}{X_{\text{March}}}, \frac{X_{\text{May}}}{X_{\text{April}}}, \text{ etc.}$$

Then a statistic which is the

most representative of all these ratios is iteratively decided, e.g., mean, mode, median, geometric mean, etc., and this statistic is used to compute the forecasts of forthcoming months. For example, if the decided statistic is, say Y, and if the forecaster is interested in the forecast for June, then

$$X_{\text{June}} = Y * X_{\text{May}}.$$

Once the actual X_{June} is available, Y is

updated. A variant of the general procedure outlined above is employed to compute "seasonal indices" of a time series. In this case, the standing of the second quarter relative to the first quarter is computed for each year. If a second quarter figure is higher than the corresponding first quarter figure, the link relative exceeds 100%. On the other hand, if the second quarter

figure is lower when compared to the corresponding first quarter figure, the link relative is less than 100%. An average link relative is then obtained for each quarter-to-quarter comparison. These four numbers, when adjusted to the total 400, constitute the seasonal indices.

(e) General Comments on Trend Models

Trend models or extrapolations are often used as checks on other methods. Any forecast which shows a large deviation from a trend extrapolation should be examined to justify the causes for such a deviation.

The reverse is also a common occurrence, i.e., the reasonableness of the trend extrapolations in the dependent variable representing some measure of air traffic activity is checked by comparing these predictions with the independent projections of various economic indicators (17), (18).

There are several problems with trend analysis.

- (i) The method does not provide any useful information as to why growth (or its opposite) is taking place, or what might be done to influence the trends.
- (ii) It implicitly assumes that the socio-economic factors which control the initial relationship will remain in force to a similar extent during the forecast period. This, of course, emphasizes the importance of having some understanding of these controlling factors at the time that the initial relationship is developed.
- (iii) It does not allow for market generation or results due to changes in product or service. Nutter discusses this problem very succinctly in terms of transportation demand as follows. (19)

Suppose one has determined a demand function for a given mode, k_1 , operating between i and j at some time, t . If this function is then used to project into the future, the demand is estimated at a future time, t' i.e., we have a projected value

$$D_{ijk_1t'}$$

Now, if a new mode, k_2 , is introduced and we use the above relation to estimate the portion of the demand that could be captured by the new mode at the same time t' , we are in effect splitting $D_{ijk_1t'}$ into two parts. The danger involved is that the service provided by mode k_1 may be very poor related to that to be offered by k_2 . Nevertheless, the demand for k_2 can never be greater than for k_1 by the above formulation. Thus there is no opportunity to allow for market generation by a new and appealing (to potential users) mode when the above strategy

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is used for forecasting demand. Nutter refers to this as the "half of nothing" problem.

(2) Correlation Analysis

Correlation analysis covers problems dealing with relationships between two or more variables. Two widely used correlation techniques in the field of forecasting are (i) curve fitting with regression, and (ii) trend correlation analysis.

(a). Curve Fitting with Regression

In this approach a dependent variable is characterized as a function of one or more independent variables and a random disturbance term, ϵ :

$$Y = f(X) + \epsilon.$$

$f(X)$ usually takes the form $a_0 + \sum_{i=1}^n a_i X_i$.

or,

$$f(X) = A \prod_{i=1}^n X_i^{b_i}$$

which becomes linear in its logarithmic form. If $n = 1$, the regression is a simple linear regression. If $n > 1$, the regression is called multiple linear regression. If $f(X)$ takes the form of a second or higher degree polynomial or a geometric growth function, the regression is called nonlinear regression. A widely-used technique to estimate the parameters of a regression equation is the method of least-squares, it is a "best fit"

in the sense that the sum of squared deviations, $\sum (Y - \hat{Y})^2$, where \hat{Y} is the estimated value, is less than it would be for any other possible straight line. The minimum condition criterion of calculus is applied to the expression obtained from the least-squares condition to get the so-called "normal equations" from which the expressions for the parameters are obtained. The validity of estimated regression equations is ascertained with statistics such as t , coefficient of determination, and also by simply observing if the signs of the parameters are in accordance with intuition.

The regression analysis can be performed quite easily with modern computer capabilities. Standard software packages exist (e.g. Statistical Package for the Social Sciences - (SPSS)) which are inexpensive and easy to use. Regression analysis is used extensively for forecasting purposes in various disciplines. For example, in macroeconomic literature, a number of authors have used the technique either directly or as a part of a simultaneous equation approach. In business forecasting, the technique was used to project sales of various industrial

products. In travel demand forecasting, regression analysis was widely employed to compute trip generation and trip attraction equations.

As illustrations of the application of correlation analysis, reference (20), (21) (22) are concerned with correlation studies in the domestic and international air cargo markets, while (23) examines the correlation between socio-economic variable and air commuter traffic .

(b) Trend Correlation Analysis

Trend correlation analysis is used to interpolate or extrapolate a time series based on the trend of a related series whose observed values or projections are readily available. Trend correlation analysis is sometimes used in estimating components of Gross National Product where annual time series data may have to be converted into quarterly data. In order to use two or more trends to determine the trend of the variable of interest, the forecaster must establish the relationship between the related series and the variable under consideration. The trends of the independent variables may then be obtained in order to compute the forecast of the dependent variable. There is a simple version of trend correlation analysis called "precursor events" forecasting. In this case, the progress trends between two developments, one of which leads the other, are observed. Lenz (4) uses the precursor events technique to forecast the trend of transport aircraft speed based on combat aircraft speed trends.

(c) General Comments on Correlation Analysis

There are several problems involved with correlation analysis and the regression techniques normally used.

(i) Choice of variables--One can, of course, examine the effect of an unlimited number of variables (their significance is determined by the regression technique) but this requires an extensive data base which becomes a costly and time consuming proposition. Hence a more restricted selection is usually made based, for air transportation work, on such factors as:

- population
- . disposable income
- . education level
- . gross national product
- . employment
- . time
- . cost

(ii) Accuracy of the data-- As pointed out repeatedly by the participants in the 1975 MIT Workshop on Transportation Demand, (24), accurate data, properly disaggregated and summarized, simply does not exist to the extent that economic models can be derived which are reliable.

(iii) Variable interdependence--There appears to be a high degree of interdependence or collinearity between the variables which affect transportation systems. Not only is it difficult to identify these relationships before considerable data analyses has been done, but there is also the risk of overlooking their existence and thus drawing erroneous conclusions from the derived models. Techniques are available for overcoming some of the difficulties, but their success seems to depend on increasing complexity, time and cost, as well as increasing demands in the data bank requirements. The smaller size of the data bank, the more serious the problem.

(iv) Transferability--There is not yet any conclusive indication that model coefficients and exponents derived on the basis of a data bank acquired in some specific locale or set of "institutional circumstance" are universally applicable with data acquired elsewhere. In fact the evidence is that they are not.

(v) Estimation of the independent variables--Perhaps the greatest problem of all, when using econometric models for forecasting, is that the job of predicting the future of some aviation activity is simply shifted to that of predicting the future trend of several socioeconomic variables which are believed to control the aviation activity. This implies that, as in the case of trend extrapolation, the extent to which these variables control the phenomenon of interest will remain constant with time--which is certainly questionable. It also implies that the forecaster expects that the future of these control variables can be predicted with much greater accuracy than the phenomenon of interest--or that with a sufficient number of variables, compensating errors in their future prediction can save the day. When engaging in this latter aspect, the large expenditure in data collection and analyses must be questioned when the results are little more than what might be obtained on the basis of using professional judgment.

(vi) Serial correlation--This refers to situations where the value of one error term is not independent of the next. Positive serial correlation occurs when an error term tends to be followed by another of the same sign. It may also occur when some kind of dynamic adjustment process takes place but the estimation is done in terms of a static model. Serial correlation may indicate the existence of missing variables that should be in the relationship.

One of the major values of econometric models seems to be the identification of the socioeconomic variables which in the past, under a set of carefully specified circumstances, have been proven to have a positive or negative influence on the aviation activity. This information is then of great value to forecasters who are operating on the basis of professional judgment, either in the direct postulation of forecasts or in the checking of the predictions of other devices such as time-series analysis or ratio methods.

(3) Time Series Analysis

A time series is a set of statistical observations arranged in chronological order. Time series analysis is concerned with data which are not independent, but serially correlated, and where the relations between consecutive observations are of interest. Examples of time series of this nature include stock prices, industrial production, and national income. In each of these series, the level at any point in time depends upon the levels achieved in preceding periods. The techniques of analyzing a time series may be categorized into three major subdivisions, namely (i) classical time series analysis, (ii) exponential and adaptive smoothing models, and (iii) mathematical time series analysis.

(a) Classical Time Series Analysis (25)

The traditional or classical method of time series analysis is descriptive in nature and does not provide any statements concerning the future. Essentially, the method attempts to break a time series into major components which represent the effects of the operation of groups of explanatory factors that are the primary determinants of the time series.

(i) Secular Trend

Secular trend refers to the smooth upward or downward movement over a long period of time. Secular trend movements are attributable to factors such as population change, technological progress, and large-scale shifts in consumer demands. Analytical techniques used with this type are usually quite simple ranging from free hand curve sketching to a simple "best fit" using regression analysis.

(ii) Cyclical Fluctuations

Cyclical fluctuations or business cycle movements are recurrent up and down movements around secular trend levels. In business cycles the period of expansion ends at the peak, or upper turning point, and then moves into contraction which terminates at the lower turning point, the trough. These phases repeat themselves, with a different

duration and amplitude. In this case analysis is usually done by what is known as the cyclical relative method (CR), which can be stated tersely as follows: If y is an annual time series with components trend, T , cyclical fluctuations, C , and irregular movements, I , and if Y_t is the trend value, then

$$CR = Y/Y_t = \frac{T \times C \times I}{T} = C \times I$$

(iii) Seasonal Variations

Seasonal variations are periodic patterns of movement in a time series. The movement completes itself within the period of a calendar year and continues in a repetition of the basic pattern. The major factors in producing these annually repetitive patterns of seasonal variations are weather and customs. Three methods are customarily used to determine this component.

. Ratio-to-moving point average:

If Y = original quarterly observations

MA = moving average figures (containing trend and cyclical components)

T = trend components

C = cyclical components

S = seasonal components

t = irregular components

then

$$Y/MA = T \times C \times S \times I / T \times C = S \times I.$$

averaging these values of Y/MA accomplishes elimination of the irregular component.

- . Link relative method (discussed above)
- . Percentage of annual averages method
Each quarter is expressed as a percentage of the average for the year. The averages of these figures for each quarter over all years are then the seasonal indices

(iv) Irregular Movements

Irregular movements are fluctuations in a time series which are erratic in nature, and follow no discernible pattern. These movements are sometimes referred to as residual variations, since, by definition, they are residuals in a time series after the trend, cyclical, and seasonal components are accounted for.

Classical time series analysis is based on the assumption that various time series components are independent of each other. Analyzing the time series after decomposing the same into components, though very useful for descriptive purposes, is grossly artificial. This is true especially in the case of forecasting. Hence, in forecasting with time series components, combination projections are used to reflect the interactions of the components. For instance, in short-term forecasting, a combined trend-seasonal projection is a common technique. In a company's forecast of next year's sales by months, a projection of the trend of annual sales might be distributed among months using seasonal indices. A comprehensive forecast might also involve adjusting with cyclical prediction. Cyclical movements are more difficult to forecast than trend and seasonal elements. The cyclical fluctuations in a specific time series are generally influenced by general business cycle movements characteristic of large sectors of the overall economy. Specifically, any economic series, while exhibiting a certain amount of commonality in business cycle fluctuations, displays differences in timing and amplitude. The National Bureau of Economic Research has studied these differences and classified the time series into three groups, namely, (i) leading series, (ii) coincident series, and (iii) lagging series. These statistical indicators are adjusted for seasonal movements and published monthly in "Business Conditions Digest," by the Bureau of the Census, and in "Economic Indicators," by the Council of Economic Advisors. For the most part, these indicators are useful in the prediction of cyclical turning points. For example, if most of the "leading indicators" move in an opposite direction from the prevailing phase of the cyclical activity of business interest, this is an indication of a possible turning point in the business cycle. A subsequent similar movement by a majority of "coincident indicators" would be considered a confirmation that a cyclical turn was in progress. A diffusion index is another type of cyclical prediction tool. This index utilizes the fact that various economic series attain their peak and trough levels at different points in time. The index is defined as the percentage of seasonally adjusted series which are expanding at a given point in time. When the percentage drops below 50, it may be taken that a peak has been reached and that contraction in the aggregate activity is beginning. Diffusion indices are generally regarded by economists as effective early warning signals of impending turning points in overall economic activity.

Several of the articles reviewed in Appendix A and included in Table 2 are based on classical time series analysis e.g. Maio (26) and the two Boeing articles on international and domestic freight (27) (28).

(b) Exponential and Adaptive Smoothing Models

Exponential smoothing uses a weighted moving average of past data as the basis for a forecast. The weights ($0 < \alpha < 1$) are a geometric progression with smaller weights assigned to observations in the more distant past. The smoothed value of X (variable of interest) is given by :

$$\bar{X}_t = \frac{X_t + (1-\alpha)X_{t-1} + \dots + (1-\alpha)^{n-1}X_{t-(n-1)}}{1 + (1-\alpha)^{n-1} + \dots + (1-\alpha)^{n-1}}$$

as $n \rightarrow \infty$, it can be shown that

$$\bar{X}_t = \alpha X_t + (1-\alpha)\bar{X}_{t-1}.$$

The forecast in time period $(t+1)$ is made equal to the latest smoothed value of X . The above smoothing procedure is applicable to series which do not exhibit trend and seasonality. The trend and seasonality adjustments are made with factors computed as exponentially smoothed estimates. Various types of adjustment procedures are described in the literature. For example, Winters (29) presents an exponential forecasting equation which incorporates both trend and seasonal adjustment factors. The smooth equation is given by

$$\hat{X}_t = \alpha \frac{X_t}{F_{t-L}} + (1-\alpha) (R_{t-1} + \bar{X}_{t-1})$$

where R_t , the trend adjustment factor, is given by

$$R_t = \gamma(\bar{X}_t - \bar{X}_{t-1}) + (1-\gamma)R_{t-1}$$

and F_t , the seasonality factor is given by

$$F_t = \beta(X_t/\bar{X}_{t-1}) + (1-\beta)F_{t-L}$$

where L is the number of periods in the seasonal cycle, and α, β , and γ are the forecasting parameters. The estimates of α, β , and γ are obtained by minimizing the sum of squares of forecast errors in an iterative procedure. The forecast errors are computed for combinations of α, β , and γ and the combination that gives the smallest error is taken as the estimate. Adam, et al. (30) describe a "grid search" procedure to estimate the value of a parameter in a single parameter equation as a two-step procedure. First, the smoothing constant is varied by 0.1 increments. Once the minimum error range is located, the smoothing constant is

varied by 0.01. The authors allude to a "pattern search" procedure in the case of two or more parameter estimates. In contrast to the procedures employed above, if the parameters are dynamically updated, the model is termed an adaptive smoothing model. The parameter values are determined each period using a tracking signal suggested by Trigg and Leach (31). A forecast error E_t is computed at the end of each period and the average

error \bar{E}_t and average absolute error $ABS(\bar{E}_t)$ are determined as follows:

$$\bar{E}_t = (1-\nu)\bar{E}_{t-1} + \nu E_t$$

$$ABS(\bar{E}_t) = (1-\nu)ABS(\bar{E}_{t-1}) + \nu ABS(E_t)$$

where ν is another smoothing constant ($0 < \nu < 1$). The tracking signal T is computed by taking the ratio of these two error terms, $T = E_t / ABS(\bar{E}_t)$. Finally, the estimates of the smoothing constants α, β , and γ are given by

$$\alpha = ABS(T)$$

$$\beta = K_1 ABS(T)$$

$$\gamma = K_2 ABS(T) \text{ where } 0 \leq K_1 \leq 1 \text{ and } 0 \leq K_2 \leq 1.$$

Adaptive smoothing models are sensitive to abrupt shifts in the demand pattern. For major changes in the demand, large forecast errors will result as compared to the period immediately before the major change, and the tracking signal reflects this change. Estimating the values of the parameters $\alpha, \beta, \gamma, \nu, K_1$, and K_2 is a combinatorial problem generally solved by means of simulation.

(c) Mathematical Time Series Analysis

Like classical analysis, the formal or mathematical time series analysis is concerned with data which are not independent, but serially correlated. Recently, mathematical time series analysis has received much attention as evidenced by research and literature. A notable procedure of analyzing time series mathematically is that of Box and Jenkins (32). The Box-Jenkins approach is so involved and complex that it is perhaps not fitting to include it in an exposition of basic nature. However, an attempt is made below to present the fundamental concepts of the approach and introduce the reader to more sophisticated material as presented in references (32), (33), and (34).

First Box and Jenkins describe a class of stable linear statistical models called AR(p) class, MA(q) class, and ARMA(p,q) class. The general form of the AR(p) class, i.e.,

"autoregressive process of order p," is given by

$$z_i = \phi_1 z_{i-1} + \dots + \phi_p z_{i-p} + a_i$$

where the current value of the process is expressed as a weighted sum of past values plus the current shock. z_i can be considered to be regressed on its own previous values, hence the name. The general form of the MA(q) class, i.e., "moving average process of order q," is given by

$$z_i = a_i + \theta_1 a_{i-1} + \dots + \theta_q a_{i-q}.$$

The general form of the ARMA (p,q) class, which contains both AR(p) and MA(q) classes is given by

$$z_i = \phi_1 z_{i-1} + \dots + \phi_p z_{i-p} + a_i + \theta_1 a_{i-1} + \dots + \theta_q a_{i-q}.$$

Box-Jenkins' approach then proceeds to describe an identification procedure whereby a given time series can be identified as belonging to a certain class. The identification phase consists of computing series mean, variance, autocorrelation function $\{\gamma_k\}$, and partial autocorrelation function $\{\hat{\phi}_{kk}\}$ to ascertain the class of the model. This is done by considering where the cutoffs, if any, occur in the $\{e_k\}$, the population autocorrelation function and $\{\phi_{kk}\}$, the population partial autocorrelation function, by comparing the estimated functions with their large-lag standard errors, and then seeing whether the results fit any of the theoretical patterns. Values of p and q are thus obtained. Having identified a tentative model, the next stage is to estimate the parameters using the rough values calculated in the identification stage as initial values. Box and Jenkins describe a nonlinear least squares procedure to obtain the vector of parameter estimates $(\hat{\phi}, \hat{\theta}) = (\hat{\phi}_1, \dots, \hat{\phi}_p, \hat{\theta}_1, \dots, \hat{\theta}_q)$ which minimizes the error

sum of squares

$$S(\phi, \theta) = \sum_{i=1}^N (z_i - \hat{z}_i)^2.$$

The next step in the Box-Jenkins approach is to verify the estimated model for its adequacy. In the AR(p), MA(q), and ARMA(p,q) models mentioned above, the order of the operators p and q is important as unnecessary increases in the order may lead to parameter redundancy and inadequate order may under-identify a model. One approach is to identify and estimate various models (i.e., models with different orders of operators)

which seem to fit the series and apply a χ^2 -test. Once the model is identified, estimated, and verified, it is ready for

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forecasting purposes. Anderson (33) presents two variants of the ARMA model, namely the ARIMA (p,q) (autoregressive integrated moving average) model and the IMA (p,q) (autoregressive integrated moving average) model, and proves that the IMA (1,1) model is the same as the famous exponential smoothing formula used by many forecasts in forecasting sales of industrial products (exponential smoothing is described in the preceding pages).

(d) General Comments on Time Series Analyses

Most of the advantages and disadvantages of time series analyses have already been discussed. However it is well to emphasize that the major drawbacks are probably the requirements for accurate data, and the assumption that what has happened in the past will continue into the future. The data requirement is particularly severe, especially since historical information is needed. In many cases it simply does not exist in a useful form, and the reliability is doubtful. This infers that most time series studies are done using data from standard government collection source. However, there is no guarantee that these data represent the factors which are most important in controlling the phenomenon under study.

(4) Cross Sectional Analysis

Generically, these models are constructed such that calibration can be based on a mass of data about demand between different O-D pairs taken at a single point in time, although they can also be constructed to permit inclusions of time dependent projections of zonal properties (i.e., properties at O or D).

One of the major model types included under this category is the "gravity model," so named because its form is similar to the two-body equation for gravitational attraction. Although there are a variety of gravity models with varying degrees of sophistication, they all stem from the basic concept that transportation demand depends primarily on two factors: (a) the desire for travel between two points (called a mutual attractiveness term) denoted as $P_i P_j$ where the P's represent some function of properties of the zones; and (b) a term which represents the capability for travel between i and j which can be expressed either as an impedance I_{ijk} or a conductance K_{ijk} (note that they are specific to a given mode k).

Hence the demand for travel between i and j on a given mode k is

$$D_{ijk} = \frac{(P_i P_j)^A}{(I_{ijk})^B} = (P_i P_j)^A (K_{ijk})^B .$$

The forecaster must choose the properties, P, and the mode characteristics, I. It can be noted that in format these models are, in effect, a special case of the general econometric models discussed in another section. However, they are treated separately because the general econometric models are not usually applied in the modal context.

The above equation can also be used in a modal split form by simply dividing D_{ijk} by the total demand, i.e., by

$$\sum_k D_{ijk}$$

Although in even its simplest form the gravity model solves the "half of nothing" problem referred to earlier (it does so by introducing the I or K terms which are dependent on the modes selected), it is subject to other problems. Indeed the variety of forms of the gravity model have often been developed in the hope of overcoming some of these problems.

The most fundamental of the problems is that the gravity model is hyperbolic in form and, as such, it is open-ended. That is, it is obviously incorrect at the end points. To illustrate, if the impedance term is taken to be fare, then a zero fare will induce an unlimited number of riders, and at the other end, there will always be riders no matter how high the fare. Thus, unless a major effort is undertaken to obtain calibration data, the function cannot be properly bounded. This leaves the forecaster in the position of having a limited range calibration curve which must be assumed correct, although in considering possible extensions of the ranges of the variables, the result is obviously incorrect at large values. The question is, when does it stop being correct and how quickly does it deviate once it has started?

Another troublesome problem arises if one wishes to subdivide the zones represented in the numerator. To illustrate, if P is taken to be population, as it often is, then the population of zone i should be obtainable by adding up all the populations from subzones i_1 to i_n , i.e.,

$$P_i = P_{i1} + P_{i2} + \dots + P_{in}$$

now forming $P_i P_j = (P_{i1} + P_{in}) P_j = P_{i1} P_j + P_{i2} P_j + P_{in} P_j$

and then raising this to the A power we have

$$(P_i P_j)^A = (P_{i1} P_j + P_{i2} P_j + \dots + P_{in} P_j)^A$$

These two expressions are obviously different for most all values of A resulting in the fact that by calculating the demand from each zone separately and then adding them, we get a larger demand than if we just added populations and then computed demand.

There are also problems associated with the conductance or impedance term. These are generally related to the fact that the calibration data must depend upon user perception, and when new modes or changes in modal characteristics are introduced, it is difficult to forecast how this will be perceived by the user.

Finally, one encounters a universal-type problem, viz., in trying to "fix" the models to overcome deficiencies like those indicated above, one generally risks introducing one or more new problems which are equal to or worse than the one solved.

The work of Melvin Brown of Mitre Corp. (35) typifies some of the most advanced work done with gravity models; that of Thorsen and Brewer (36) and Wilson and Stevens (37) illustrates how many attempts at analyzing cross sectional data ultimately end up in the gravity form; and the paper by Brown and Watkins (38) is interesting in that it compares the results of forecasting in the same market using both time series and cross sectional data. Finally, the Northeast Corridor Transportation Project has done extensive work in the modeling and modal split analysis of transportation demand. See for example Mclynn (39) Systems Analysis and Research Corporation (40) and National Analysts, Inc. (41)

(5) Category Analysis (42)

Category analysis or cross-classification analysis is a technique for estimating the characteristics of entities which have been sorted into a number of separate categories. Category analysis is used in travel demand forecasting where the number of trips produced by a specific category of travellers in a zone is of interest. With reference to travel demand forecasting, the characteristic is the number of trips and the entities are the households who travel. Entities may be categorized by subdividing them into smaller groups such as 1-person households, 2 person households, etc., and each subdivision of households is further subdivided according to car ownership rates. For example, the 1-, 2-person households mentioned above may be divided according to 1-person, 0-car households, 1-person, 1-car households, etc. In the general case, if $p_i(c)$ is the number of characteristics (of the same type) observed in the category c entity in spatial unit i, $h_i(c)$ is the number of entities in spatial unit i in category c, and $tp(c)$ is the characteristic observance rate of entities in category c, then the characteristic observance rate during the base year is given by

$$tp(c) = p_i(c)/h_i(c)$$

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and the forecast for the horizon year is given by

$$\hat{tp}(c) = tp(c) \times H_i(c)$$

where $H_i(c)$ are the number of entities during the horizon year.

The category models are generally tested for significance by means of a statistical technique called analysis of variance. In category analysis the characteristic of interest is categorized and subcategorized into various levels which is reminiscent of the factorial designs used in statistics. In factorial designs both qualitative and quantitative factors can be used and the designs do not require linearity of relationship between variables, thus eliminating need for any transformation of variables. The data for factorial analysis are presented in matrix form in the same way category models are developed. From the standpoint of format, category models seem to be natural candidates for factorial analysis for significance testing.

C. Analytical Objective Methods

(1) Simultaneous Equation Approach

Contrary to the approach taken in least-squares regression where the parameters in regression equations are determined independently, the simultaneous equation approach determines the parameter values of constituent equations from what are called "reduced-form equations." The essential difference between the least-squares regression method and the simultaneous equation method is illustrated by means of an example (43). The example consists of a system of two equations depicting the relationships between disposable income and consumer expenditures:

$$Y_t = C_t + Z_t \dots (1)$$

$$C_t = \alpha Y_t + \beta + u_t \dots (2)$$

where

Y_t = disposable income per capita

C_t = consumer expenditures per capita

Z_t = investment expenditures per capita, autonomous

α = marginal propensity to consume

β = C-intercept of the consumption function, and

u_t = the random element in consumers' behavior.

In the least-squares method, regression of consumers' expenditures (C_t) on disposable income (y_t) is taken directly. To take the least-squares regression of C_t on y_t as the true consumption function, however, is to assume that y_t is completely independent of C_t , i.e., to assume that random deviations in consumers' expenditures about the consumption function can take place independent of the disposable income. However, this is not possible as long as Z_t in the equation $y_t = C_t + Z_t$ is considered as autonomous. Z_t is regarded as autonomous in this example and so y_t cannot be completely independent of C_t . The least-squares approach, if applied to such an equation system, yields inconsistent estimators. The simultaneous-equation approach draws attention to this inconsistency bias of the least-squares approach, where the independent variable(s) are not completely independent of the dependent variable. The first step in the simultaneous equation approach is to reduce equations (in this case, equations (1) and (2)) to equations showing nothing on the right side but the autonomous variable, Z_t , as shown below:

$$C_t = \alpha y_t + \beta + u_t$$

$$C_t = \alpha(C_t + Z_t) + \beta + u_t$$

$$C_t(1-\alpha) = \alpha Z_t + \beta + u_t$$

$$C_t = \frac{\alpha}{(1-\alpha)} Z_t + \frac{\beta}{(1-\alpha)} + \frac{u_t}{(1-\alpha)} \dots (1.1)$$

$$y_t = \frac{1}{(1-\alpha)} Z_t + \frac{\beta}{(1-\alpha)} + \frac{u_t}{(1-\alpha)} \dots (2.1)$$

Equations (1.1) and (2.1) are called reduced-form equations. Since the investment is considered autonomous (i.e., completely independent of consumers' expenditures and disposable income), the least-squares method if applied on (1.1) and (2.1) will yield consistent estimators. The simultaneous equation approach is extensively used in the forecasting of many areas, especially where complex interrelationships will have to be portrayed in the form of a system of equations. The method is amenable to sophisticated statistical techniques and tests, and is taken for granted by many analysts, economists, and other forecasting professionals as a reasonable way of making some probability statements about the future.

(2) Input-Output Analysis

Input-output analysis (44) was initially developed as a tool for analyzing the structure of the national economy. However, by virtue of its specific character, this powerful technique found a place in such fields as energy, pollution, transportation, etc. Input-output analysis, as a forecasting

technique, can best be explained by means of an example. In the example, the economy is disaggregated into various sectors with intersector transactions, measured in monetary terms. It is assumed that a part of the sector outputs are transferred to final consumer demands also. These transactions are represented by means of a matrix of the form shown below.

To From	1	2	3	....	n	Final Demand	Total Output
1	x_{11}	x_{12}	x_{13}	....	x_{1n}	Y_1	X_1
2	x_{21}	x_{22}	x_{23}	....	x_{2n}	Y_2	X_2
.
.
.
n	x_{n1}	x_{n2}	x_{n3}	....	x_{nn}	Y_n	X_n

If a_{ij} is defined as the ratio x_{ij}/X_j , then

$$X_1 = a_{11}X_1 + a_{12}X_2 + \dots + a_{1n}X_n + Y_1$$

$$X_2 = a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n + Y_2$$

$$\vdots$$

$$\vdots$$

$$X_n = a_{n1}X_1 + a_{n2}X_2 + \dots + a_{nn}X_n + Y_n$$

Rearranging the terms, we get

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ \vdots \\ Y_n \end{bmatrix} = \begin{bmatrix} 1-a_{11} & -a_{12} & & -a_{1n} \\ -a_{21} & 1-a_{22} & \dots & -a_{2n} \\ \vdots & \vdots & & \vdots \\ \vdots & \vdots & & \vdots \\ -a_{n1} & -a_{n2} & \dots & 1-a_{nn} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ \vdots \\ X_n \end{bmatrix}$$

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and $\bar{X} = [I-A]^{-1} \bar{Y}$ where \bar{X} is a vector of projected output and \bar{Y} is a vector of projected final demands. In economic forecasting, input-output analysis is used as an extension of general equilibrium analysis. General equilibrium analysis helps us to under-

stand the reasons why change in one market will create change in many other markets. But this analysis is not suitable to predict the extent of future change. Input-output analysis helps to quantify changes in general equilibrium in a convenient manner so as to enable one to forecast future output once the future demands are projected.

(3) Analogy Methods

Methods of forecasting which are analogous to biological growth models are developed by a number of authors. A majority of analogy models are developed to forecast technological progress. According to Lenz, (4) attempts to develop a theory explaining why technological progress should proceed in an exponential manner date back to the early twentieth century with the theory advanced by Henry Adams (45). Adams relates the technological progress to the force of attraction between masses. Derek de Solla Price (46) proposes a logistic growth curve of the form

$$f(x) \propto \frac{1}{1 + A \exp(-kx)}$$

to explain technological progress. This is similar to Pearl's (47) biological growth formula

$$P = \frac{P_0}{1 + A \exp(-kt)}$$

where P is the population at time t, P_0 was the population at the beginning of the experiment, and A and k are parameters. Apart from convenience, logistic functions of the above type are preferred by some technological forecasters due to the reason that logistic functions exhibit deviations of the actual trend from idealized exponentials.

Logistic growth formulae of the type described by Pearl and utilized by others in the area of technological forecasting are based on the superficial resemblance between the actual processes involved, i.e., biological growth and technological growth processes. But the questions are:

- a. Is a technological growth process really similar to a biological growth process? For example, is an increase in knowledge the same as an increase in population?
- b. An exponential growth assumes a constant rate of change. Why should one assume a constant rate of change, say, in technological forecasting?

Ridenour (48) and a few others took a fresh look at mechanisms which would explain the behavior of technological trends, rather than accepting a biological growth process as an equivalent of the technological growth process. However, an exponential increase was accepted as a general "law of

social change" (49). Ridenour assumes that the rate of acceptance of a technology is a function of potential users who have been exposed to such technology. If N is the number of potential users and K is a proportionality constant

$$\frac{dN}{dt} = KN.$$

However, the author suggests that K is a function of the type $K = k(1 - \frac{N}{L})$ where L is the upper limit of potential users. Thus

the rate of change will approach zero as L approaches N . When the expression for K is substituted in dN/dt and integrated, we have

$$N(t) = \frac{L}{1 + (\frac{L}{N_0} - 1) \exp(-kt)}$$

which is equivalent to the logistic growth curve presented above. The author, despite his intentions not to accept a biological growth process, ends up with the same to explain the technological growth process. Furthermore, the link between the author's formula and technological change seems to be quite subtle.

Hartman (50) considers information gain as a prelude to technological gain and suggests that

$$\frac{dI(t)}{dt} = KNI$$

where I is the information in bits, N is the number of scientists, and K is the probability that a scientist encountering a bit of information will add another bit of information. In disciplines which are not yet saturated, $N(t) = N_0 \exp k_1 t$. Then,

$$\frac{dI(t)}{dt} = (KN_0 \exp k_1 t) I(t)$$

which results in an exponential of the form

$$I = I_0 \left[\exp\left(\frac{KN_0}{k_1} \exp k_1 t\right) - 1 \right].$$

If I has an upper limit, say J , the constant K may take the form $K = k(1 - I/J)$ in which case

$$I = \frac{J I_0}{1 + (\frac{J}{I_0} - 1) \exp(-kNt)}$$

Hartman's model assumes that creation of significant new information is a function of the average amount of information encountered by the scientist. Further, the author assumes that no extraneous factors limit the addition of new knowledge.

Isenson (51) suggests that the rate of increase of information follows a polynomial trend of the form

$$\frac{dI(t)}{dt} = K [N(t) + \lambda N^2(t)]$$

where $I(t)$ is the amount of information at time t and $N(t)$ is the number of scientists. The term $N^2(t)$ is called "interscientist communication factor" and K is an important weight indicating the scientists' productivity. For $\lambda = 1/2$ and assuming that I in the equation $K = k(1 - \frac{I}{J})$ is minute compared to J , $dI(t)/dt$ is approximately equal to $\frac{K}{2} N^2(t)$. If $N = N_0 \exp(k_1 t)$, $dI(t)/dt$ can be integrated to yield

$$I = \frac{K}{4K_1} N^2 \left[\exp(2k_1 t) - 1 \right]$$

Floyd (52) describes a mathematical model which begins with a Bernoulli process of binomial distribution. The author assumes that two values (f , the given value and F , the upper limit value) of a figure of merit are given. The author further assumes that out of a total of M possible technologies (or technologies) X technologies would lead to an increase in the value of f , the figure of merit. Then, the probability of "success" per attempt is given by

$$P(f, 1) = \frac{X}{M}$$

If there are N scientists with W trials each, the total number of trials = NW , and the probability of success in time Δt is unity minus the cumulative probability of failure, that is,

$$P(f, \Delta t) = 1 - \left(1 - \frac{X}{M} \right)^{NW \Delta t}$$

In order to evaluate the expression in the right parenthesis, the author forms a relationship based on an analogy with absorption phenomena and then derives a relationship

$$\left(1 - \frac{X}{M} \right) = \exp^{-K [(F - f)]}$$

Substituting in the expression for $P(f, \Delta_i t)$

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$$P(f, \Delta_i t) = 1 - \exp - \left[(F-f) K_i(t) N_i(t) W_i(t) \Delta_i t \right]$$

$$P(f, t) = 1 - \exp \left[- (F-f) \int_i K_i(t) N_i(t) W_i(t) \Delta_i t \right]$$

$$= 1 - \exp \left[- (F-f) \int_{-\infty}^t K N W dt \right] .$$

The number of scientists N is a function of technological progress in a given field. Floyd suggests an expression of the type $N = N_0(t) (f-f_c)^P$ to reflect the change in the number of scientists, where f_c is the figure of merit of some competitive technology. Then

$$P(f, t) = 1 - \exp \left[- (F-f) \int_{-\infty}^t K(t) \cdot N_0(t) (f-f_c)^P W(t) dt \right] .$$

If $T(t) = K(t) N_0(t) W(t)$

then $P(f, t) = 1 - \exp \left[- (F-f) \int_{-\infty}^t (f-f_c)^P T(t) dt \right]$.

Further analysis is facilitated by specifying values of $P(f, t)$. Floyd considers $P(f, t) = 0.5$, in which case,

$$\ln \frac{1}{2} = - (F-f) \int_{-\infty}^t (f-f_c)^P T(t') dt'$$

or

$$\frac{1}{F-f} = \frac{1}{\ln 2} \int_{-\infty}^t (f-f_c)^P T(t') dt' .$$

Differentiating both sides with respect to t

$$\frac{\frac{df}{dt}}{(F-f)^2} = (f-f_c)^P \frac{T(t)}{\ln 2} ,$$

then

$$\int_j^f \frac{df}{(F-f)^2 (f-f_c)^P} = \int^t \frac{T(t)}{\ln 2} = g(t) .$$

Making the substitution, $Y = (F-f_c)/(F-f)$, and $p = 1$, the integrals may be evaluated to yield

$$Y + \ln(Y - 1) + c = (F - f_c)^2 g(t) .$$

Floyd approximates the right-hand side to a linear form $A(t) + c$ and computes a nomogram from which f can be determined. Any trend can be projected along the 0.50 probability trajectory once f_c , F , A , and c are known. Using this approach, the author fits data pertaining to crude oil supplies, speed trends of mechanically powered vehicles, and efficiency of fuel burning plants--all fitted closely to historical time series--and makes projections for the future.

(4) Simulation

Simulation is an operations research technique which is sometimes used for forecasting purposes. Broadly speaking, in the "simulation" approach, we construct a model of an existing or hypothetical system and examine the behavior of the system in an artificially created static or dynamic environment. Dynamic simulation models are of interest in our case as such models specify the time period explicitly. The advantage of a simulation approach is that it makes no specific attempt to isolate the relationships between any particular variables; instead, it observes the way in which variables of the model vary with time. Once the relationships are derived from the available data, these relationships are projected into the future. Two commonly employed simulation approaches to forecasting are the simultaneous recursive equation approach where a system of equations are interconnected temporarily and the so-called "industrial dynamics" approach (53). In the simultaneous equation system, a number of dependent variables are postulated as autoregressive functions with any number of exogenous variables and the parameters are estimated. The resulting equations are then used recursively for any number of future time periods, provided the exogenous variables are completely specified over the period of interest.

An industrial dynamics view of a system concentrates on the rates at which various quantities change and expresses the rates as continuous variables. The industrial dynamics framework consists of levels, rates, and rate equations. The levels represent the accumulation of various entities in the system such as inventories of goods, capital stock, etc. The current value of a level at any time represents the accumulated difference between the input and output flow for that level. Rates are defined to represent the instantaneous flow to or from a level. Decision functions or rate equations determine how the flow rates depend upon the levels. Decision functions depend upon the system's prevailing conditions.

A highly debated example which used the industrial dynamics approach to technological forecasting is "The Limits to Growth" (54). This project, which aroused worldwide attention, is an ambitious effort to forecast complex phenomena. It assumed that five variables: population, industrial output, food production,

depletion of non-renewable resources, and pollution of the environment were the "triggering" variables. The "Limits to Growth" projects the trends of these variables into the future on a globally-aggregated basis and concludes that a continuation of current trends will lead inevitably to catastrophic malfunctioning of the world system within the next century. The model consists essentially of a large number of difference equations expressing causal links. Projections are based on the assumptions on which the equations rest and thus, as in any forecasting approach, their credibility is dependent on the validity of assumptions. Some economists and other professionals are critical of "The Limits to Growth" alleging that some of the authors' assumptions are misrepresentations of reality and so are invalid. In any case, "The Limits to Growth" is a bold venture into the future and simulation as an instrument made that possible.

(5) General Comments

Specific applications of the analytical objective methods to transportation demand forecasting are not numerous - undoubtedly because of the complexity involved. Although the simultaneous equation approach is a standard technique for handling expressions containing interdependent variables, the use of such variables is usually avoided by most workers in the field. This may be unfortunate since there is no fundamental reason to suspect that demand processes are controlled by variables that are independent. In addition to the reference cited above, the subject is also discussed by Eriksen et al in a study of the relationship between air transportation demand and level of service (55).

Simulation is becoming more popular, but it suffers from requirements for extensive computer software and enormous amounts of data. One interesting study in the air cargo field using simulation was that done by Roberts et al. in analyzing the potential for lighter-than-air vehicles (56)

(d) Combined Methods

(1) Behavioral Modeling

The choice of a transport mode is a human decision, regardless of whether it is for the transport of passengers or freight. Thus it seems logical that the factors which have a major influence on human preferences under a given set of circumstances would be expected to exert an important degree of control over this mode selection process. In order to approach the subject from this point of view, it is necessary to combine the subjective and objective methods. The important variables must be determined and the data relating to those variables obtained on a subjective basis from those affected by the system. Using these data objective methods, usually empirical in nature, are applied to develop models from which forecasts can be obtained.

These factors have received much more attention of late in the forecasting of passenger traffic, but are rarely used in air cargo forecasting. There is no questioning the difficulties involved in defining and quantifying the behavioral variables and the situation is probably an order of magnitude worse for cargo than for passengers.

In the first place it is difficult to define the variables which are significant. The list of potential candidates is long, but an extensive amount of work is now underway to try to make order out of this complex problem. To say the least, behavioral modeling is a problem of the first degree in disaggregate analysis.

Generally the variables can be classified under four very broad headings:

Demographic--Who are the trip originators and where are they located? Usually classified here are such things as age, sex, race, religion, location, population density, etc.

Motivational--To where are the trips going and why are they being made. Typical variables involved are: trip purpose, past experiences with modes, impressions formed through advertising or communication with others, etc.

Socioeconomic--To what extent is the freedom of modal choice available to the trip originator? This is often governed by education, income, type of employment, family size, home ownership, health and others.

System Characteristics--What is it about the system that the trip originator must react to in making a final selection? This category is particularly complex, with major variables such as: safety, dependability, time, convenience, cost, comfort, aesthetics, ability to use time, etc. Many of these have subsets of descriptors. For example, comfort involves all possible degrees of freedom of motion (their rates, accelerations, and changes in accelerations), noise, temperature, humidity, air quality and seat accommodations. Furthermore, all of these variables must be applied to a variety of possible trip components which can all be grouped into three major categories: access to the main vehicle, use of the main vehicle, and egress from the main vehicle.

The next problem is that of obtaining data. Fortunately the fundamentals of statistical science, are available to assist in the planning and analysis and these principles are adhered to very carefully by those who have made significant contributions to the field. Nevertheless, execution of the techniques is not simple, and this combined with the large number of variables and their many inter-relations makes the tasks difficult and progress slow and relatively costly.

(2) Market Research

In its broadest sense behavioral modeling must be considered as a form of what the business community loosely calls market research. There are many forms of market research and it means different things to different people. Thus care must be used in any discussion of such a universal topic. Part of the problem is illustrated by a typical definition of the process as presented by Chambers, et al (57): "The systematic formal and conscious procedure for evolving and testing hypotheses about real markets". However, upon examining most of the effort discussed in this paper, it is found that the emphasis is on the marketing of products. Unfortunately there are significant differences between product sales and the offering of services such as transportation. Some of these may be outlined as follows:

First, the process of marketing services has four unique characteristics when compared to marketing products:

- a. The service cannot be inventoried to match fluctuations in demand;
- b. The service is personalized--each individual wants the service to match their own perception;
- c. There is no equivalent of the "replacement of bad product" concept; and
- d. It is difficult to check quality prior to the final sale.

Next, air transportation is different from most other service in one or more of the following ways:

- a. It is a demand derived from a need other than that of simply taking a journey for its own sake;
- b. It is under considerable government control (although this is now being relaxed somewhat, particularly in the air cargo field);
- c. Delivery aspects cannot be guaranteed (e.g., bad weather); and
- d. It is only producible in batches, i.e. once a vehicle has been scheduled only a certain amount of space is available, and it is difficult to change this on short notice.

The implications of these factors in air transportation result in three principal areas. First, constraints are imposed on the selection of variables which can be used as subjective measures. Second, the sources of data are more limited and most

of the essential information must be obtained through direct contact with the groups of individuals involved. Finally, care must be exercised in identifying subject populations and sample groups within those populations.

Actually the market research techniques in the transportation field take on several forms depending on the type of transportation service involved. In air transportation, they range from records of vehicle activities or head counts (e.g. FAA statistics on the number of aircraft operations at various airports (58), or CAB origin - destination statistics (59), to behavioral and attitudinal surveys done by questionnaires or interviews (60) (61), to evaluations made by trained test subjects (e.g. as used by the University of Virginia in their work on the modeling of vehicle ride comfort (61))

Perhaps the Port Authority of New York and New Jersey can be regarded as the most sophisticated practitioner of market analysis in the air transportation field, although most airlines also conduct surveys of their passengers on a regular periodic basis. The PANYNJ work strives to take full advantage of disaggregate data and segments its samples into many categories based on one or more variables from each of the four major groups presented above. There is no doubt that this detailed type of analysis can provide more accurate information than an aggregated approach, but it is certainly more costly both in terms of time and money.

E. Evaluation

In attempting to conduct an evaluation of the present state of forecasting there are three main aspects to be addressed. The criteria which should be used to select a method for a specific purpose is one concern. Another concern is the ability of the method to produce accurate and reliable forecasts. Intuitively this predictive ability should indeed constitute one of the selection criteria. However, when considering air cargo forecasting there are not sufficient documented differences between the accuracy of the various approaches to make this the prime criteria. Others are often equally important. Finally,

there are several specific issues relating to the individual methods, or the means for their implementation, which should receive consideration. Each of these aspects will be discussed separately, preceded by a brief summary of the techniques currently in use by some of the organizations most actively concerned with air transportation forecasting.

1. Techniques Currently in Use

Over the past ten years there have been three major reviews of current practices in air travel forecasting by Calderone in 1967, (62) by Kiernan in 1970 (63), and by Haney in 1975 (64). These studies are all done from different perspectives, but it is clear that the techniques used by the various organizations have remained essentially the same over the years. Thus the following excerpt taken from Calderone (62) summarizes the practices as concisely as is possible.

"Airline Companies. Generally, airline companies have taken a relatively simple approach to forecasting future passenger traffic, employing one or a combination of three methods: (1) executive judgment, (2) trend and cycle analysis, and (3) correlation analysis. Of these, the first two are used most frequently and, of the two, judgment plays the most prominent role. While the airlines consider a number of factors in preparing their forecasts, they seem to consider that current and anticipated levels of economic activity are of primary importance. They statistically analyze only a few indices, however, and of these the most commonly chosen is GNP.

Government, Trade, and Aircraft Manufacturing Organizations. These organizations usually employ the following techniques: (1) linear or curvilinear projections of historic trends, (2) simple or multiple correlation analysis (3) executive judgment, (4) economic models, (5) statistical and mathematical formulas, and (6) marketing surveys.

Demand studies made by airlines or aircraft manufacturers fall within distinguishable classifications according to the length of the forecast period.

- (1) Short-range predictions of up to one year periods are generally the product of trend projections of passenger and/or revenue growth. Such predictions are made either for a segment of the industry, or for the entire industry, or for some specific airline.
- (2) Longer-range predictions always include behavioral analyses of one or a number of general economic activity indices (most frequently GNP, national income, disposable personal income, consumer price level, retail sales, or industrial production). It is

assumed that there are some relatively stable relationships between the general economic activity growth and that of transportation (general or air), and therefore population and employment trends are studied. The number and relationship of variables vary, but what is generally used is a combination of traffic trend projections in conjunction with or modified by expected traffic as a function of exogenous national economic indices. The forecasts are usually made for the entire national air travel market. Divisions of total projected traffic among the various airlines are generally predicted or anticipated market shares which are assumed to be functions of pricing, equipment plans, etc."

2. Selection Criteria

At the outset of the study it was hoped that it would be possible to make a clearcut evaluation of various forecasting techniques based on some set of criteria to be determined. Ideally these criteria would emerge from the review of the literature in a clearly defined state of existence, and a potential user could then score each method against the criteria as viewed from the particular purpose of that user - much in the same way in which one might reach an objective decision about purchasing a car or home, or locating a plant. Unfortunately, it soon became apparent that such would not be the case. The complexities, options, redundancies, interdependencies, etc. among the various techniques as evidenced by the reviews presented in section D, and the lack of definitive experience with the results of their past applications indicated the difficulties to be encountered with this approach. While there are undoubtedly techniques of decision analysis which could be applied to achieve the initial objective to some extent, their use would be well beyond the scope and resources of this study.

One of the major problems in considering criteria is that the one criterion which might be expected to be foremost on almost any list, viz accuracy, is difficult to determine. In fact there have been surprisingly few studies that have tried to assess accuracy in any detail. This subject will be addressed in more detail in subsection 4. Also it is very difficult if not impossible to define criteria which are mutually independent. Thus perhaps the most useful way to treat criteria at this time is to simply list in a terse taxonomical format those items to which thought should be given by anyone concerned with the selection of a forecasting method for air cargo. This is done in Table III.

Table III

Criteria for Selection of a Forecasting Method

<u>Criterion</u>	<u>Typical Descriptors</u>
1. Purpose of Forecast	1- Commitment of capital expenditures. - Changes in routing or scheduling - Assignment of equipment types
2. Effective Time Period	2- Very long range $t > 10$ years - Long range; 5 years $< t < 10$ years - Intermediate range; 1 year $\leq t < 5$ yrs. - Short range; $t \leq 1$ year
3. Variables to be used	3- Number - Type - Independence
4. Type of Data Required	4- Historical or current - Subjective or objective
5. Sources of Data	5- Corporate records - Literature - Government Statistics - Personal information
6. Data Acquisition Methods	6- Search - Questionnaires - Interviews
7. Quantity of Data Required	7- Amount
8. Cost (both dollars and Time) Note: With due respect to the old saying "Time is money", there are cases where time represents a cost which is more or less important than cash outlay	8- Availability of data - Data acquisition Procedures - Data Processing . capital investment . operating expense - Personnel . type . training . experience
9. Accuracy	9- Standard duration of predictions - Sensitivity to change in variables - Commonality - Transferability . geographical . Time . commercial sector . range of calibration
10. Confidence Factor	10- Overall subjective judgment of user based on experience.

3. General Comments on Forecasting Methods

At the present time the ability to forecast the demand for transportation services is very poor. This is true not only for air cargo, where there is a paucity of data available, but also for air passenger transportation where the availability of data is perhaps an order of magnitude better. Furthermore, the same statement can be made for modes other than air, and for urban transportation. Thus it appears to be a "generic" problem, and indeed, the literature does provide insight into some of the problems.

In his book on airport systems planning, DeNeufville summarizes some of the basic problems so well that they merit repeating (65)

"Ultimately, all forecasts are in fact themselves based on trend extrapolations. The use of a sophisticated statistical model to develop a formula giving the amount of air travel as a function of factors such as national product, average income and the like does not eliminate judgment from our estimates of future conditions. The procedure merely shifts it from air travel to those other quantities whose future may be equally difficult to guess".

" So far there is no compelling evidence that sophisticated statistical techniques provide better forecasts of air traffic than simpler approaches. Although the amount of detail involved in computerized statistical analysis could possibly provide us with an accurate estimate (of transportation demand), it usually does not. One reason is that, in these analyses involving hundreds of different factors, we lose the ability to apply judgment and common sense to each element. We must instead allow the computer to apply mechanical rules to determine the influence of each factor on future trends."

"A further difficulty with statistical analysis is that the predictions are sensitive to the form of the mathematical model used. Analysts who happen to choose to work with different equations may thus obtain quite different results using the same basic statistics and overall procedure. Although different specialists are often adamant about the peculiar merits of their particular approach, no compelling logical grounds exist to discriminate between conflicting, often arrogant claims. This situation puts authorities responsible for making a choice in a difficult situation: as experts do not agree among themselves, the decision-makers cannot rely upon a single analysis or develop a firm test of which analyses may be best."

One particularly difficult problem is that of preparing forecasts for new systems, or systems which are to incorporate untried operational characteristics. This situation requires

an estimate of demand at some future time and place for a transportation system for which there is no information available concerning user or community acceptance. All results under these circumstances can be little better than educated guesses. Certainly time series projections are not possible unless there is prior experience. The only approach is to attempt to draw analogies with other systems in other areas. We have recently concluded a study (as yet unpublished) of a variety of demand forecasts used in the development of state airport system plans around the country. We find that in essence the forecasting methods are not applicable outside the region in which they were developed.

Another problem with mathematical and econometric forecasting models developed with statistical techniques is that they are totally dependent upon the stability of the data trends in time. Thus they are of minimal value in estimating elasticities of the causal variables. The statistical variance of such forecasts is also open to question as the simple ordinary least squares regression frequently introduces a downward bias in standard errors when applied to time series.

Because of the factors indicated above, the reliability of forecasts decreases with the length of time period for which the forecasts are to apply. Beyond 10 years there is little value in attempting anything more sophisticated than expert judgment.

As a final set of comments, Nutter (19) presents a very lucid and concise account of the difficulties inherent in modeling air passenger demand. Because it is so well done and equally applicable to the air cargo field, the following extract from his article is presented.

"In the broad sense, a mathematical model can be any set of rules or procedures which represent some significant aspect of a real process. A transportation demand forecasting model, in particular a passenger demand model, represents the aggregate actions of people. Since travel is a voluntary action, each individual presumably makes a rational decision on whether, when, where and how to go, based on his perception of the situation. We do not know the details of psychological decision process and certainly do not know each individual's perception of the real situation. Most efforts at constructing passenger demand models are based on the observed actions of people (i.e., the external results of the internal decision process, when that process led to action) and on the investigator's perception of reality.

Two points about passenger demand models should be recognized at the outset: (1) the data base is usually bad and (2) the model is frequently applied to some situation not in the data base. As to the data base, it is extremely difficult to run an experiment with all significant factors controlled or

or even to make measurements without disturbing the system being measured. Travel data collection efforts are expensive and the investigator usually finds that past surveys are limited in scope and spotty in location. As to the application of the model, if it is to be used as part of a planning effort, the concern must be for a new location, a new time, a new service, or a new vehicle. The most critical application comes when the new situation requires extrapolation of the model variables to levels completely beyond the calibration range.

The investigator developing a demand model must select a model "form" (i.e., equations, procedures, logic) which he can calibrate against his data base. Because of the scatter of the data, he may be able to get an acceptable fit for several forms. For the application to the real problem, he must rely on the "behavior" of the model outside the calibration. He can never truly validate his model against the future to test the accuracy of his predictions. At best he can test its ability to predict the past and since the past is much more likely to be limited to points inside his calibration range, he cannot rigorously test the model behavior."

4. Accuracy of Forecasts

To summarize what has been said above is to reiterate the initial statement of the last section, viz. the ability to forecast the demand for transportation services is very poor. The summary report of the 1975 multiagency workshop on air transportation demand (24) explains the situation as follows: "Past forecasting methods have become inadequate for at least two reasons. First, the trend extrapolations method of forecasting is no longer appropriate due to significant changes in both the economic and operating environments in recent years. Second, the more sophisticated econometric forecasting models are only as good as our understanding of the total air transportation system on the one hand, and the availability of data on the other."

The results of this state of affairs can be shown graphically in Figures 1 through 4, which have been borrowed from Haney's survey article (64). Figure 1 shows the history of FAA forecasting over the years. The solid line is what actually happened and the various dashed lines represent what FAA was forecasting at various periods in time. This illustrates very well the problems with simple trend extrapolation. They do reasonably well in the short term, but fail badly at long range. The influence of external factors is clearly observable, e.g., the industry activity seemed relatively easy to predict in the period from 1950-1962, but since then the gyrations have been extensive.

Figure 2 examines the history of CAB forecasts. These use more sophisticated techniques, but on a relative basis, are

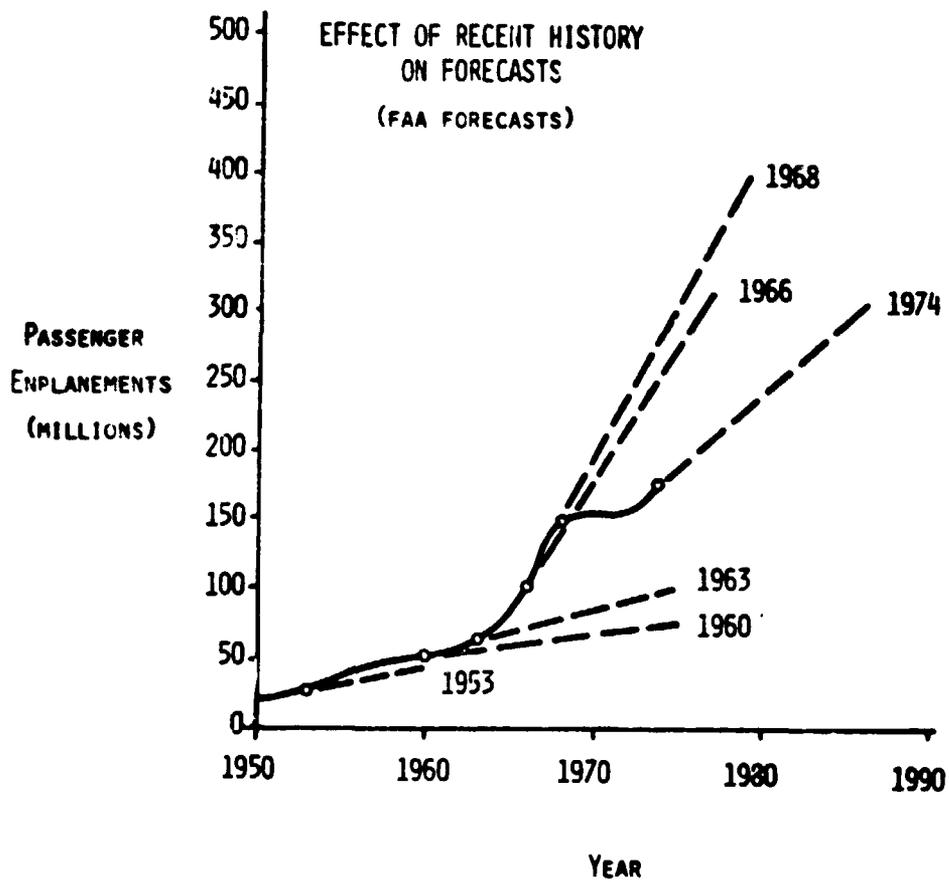


Figure 1. History of FAA Forecasting

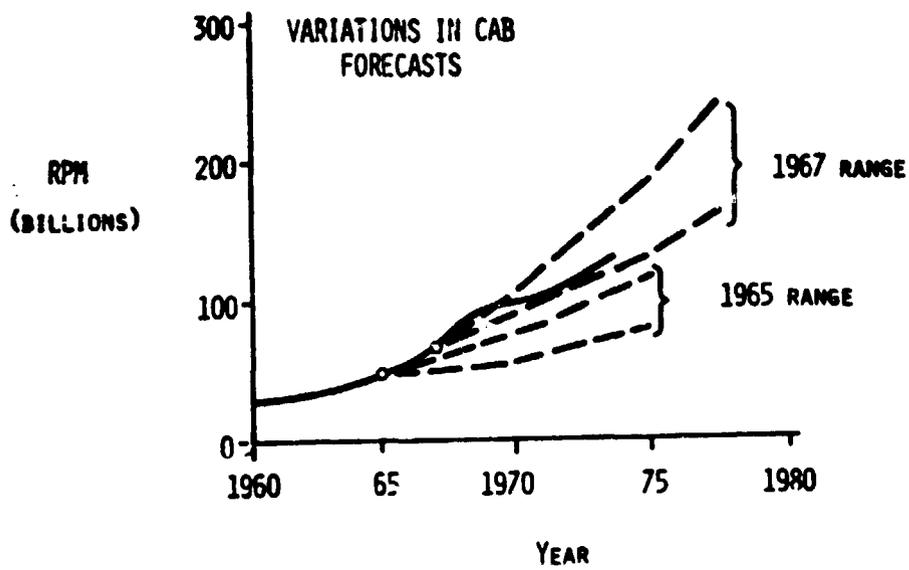


Figure 2. History of CAB Forecasts

actually little better than those of the FAA. Note that these are in terms of Revenue Passenger Miles instead of emplanements. This parameter has remained somewhat more stable over the years, but the same inflections in the two curves at corresponding time frames are clearly recognizable.

Figure 3 looks at world traffic as analyzed by a major airframe manufacturer. Again, the methods used were unable to cope with the factors that influenced the markets since 1965.

Finally, Figure 4 looks at the range of forecasts made by the various sources at different time periods. With tongue in cheek, one can conclude that we are approaching the state-of-the-art where some forecast will be correct--but only because almost every imaginable value is being forecast by someone. It is interesting to note that the trend in forecasts since the late 1960's has always been to the high side. This suggests that the best method of forecasting might be to examine all the forecasts you can find as done by others and then choose the most pessimistic value.

Certainly the data-crunching approach has been used to its ultimate sophistication in several past studies, (13) (21) (22) (26). Since there does not seem to be anything particularly exceptional resulting from these analyses, one must question the value of these relatively expensive methods. The difficulty must be with the data base-- probably both its inadequacy for documenting what has happened in the past and its inability to account for future shifts in the social and economic factors that exert major controls over the use of air transportation (i.e., those factors which caused the major inflections noted in the preceding figures).

F. Recommendations

One of the threads that can be picked up from a careful study of the field is that sound judgment is probably as important an asset as any other tool or technique in making a realistic forecast. Similarly, in attempting to make any recommendations for the future in a field which currently enjoys such a deplorable state of affairs, judgment must necessarily be the predominant factor. Thus what is offered below is the result of our judgment based on our past experience in work related to many aspects of user acceptance of transportation systems and our rather detailed review of the literature regarding air cargo. Unfortunately, this judgment indicates that there is no easy way out of the present dilemma. The process of determining how to produce better forecasts will undoubtedly be slow. It will require the introduction of some new concepts and approaches as well as a marked improvement in items of fundamental importance to any techniques such as good data bases. Listed below are a few thoughts which seem to merit further consideration by those concerned with attempting to improve forecasting accuracy in the air cargo field.

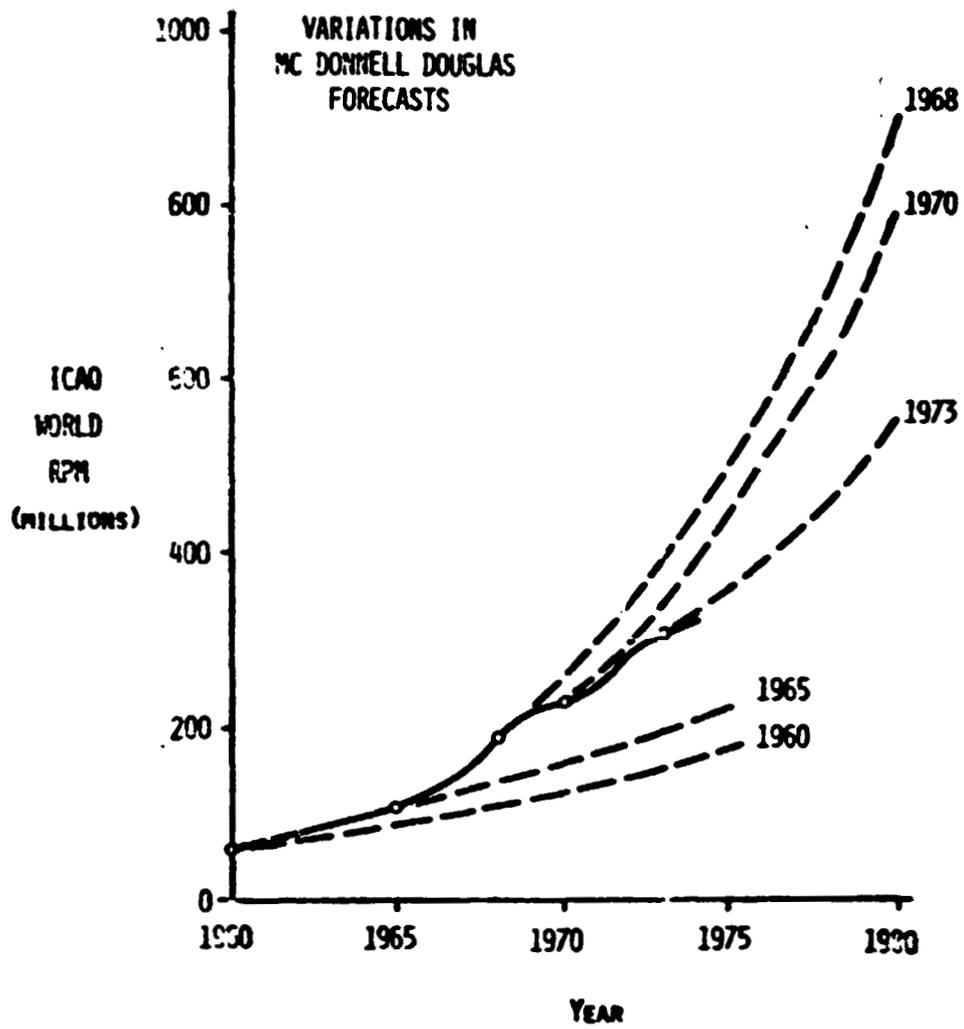
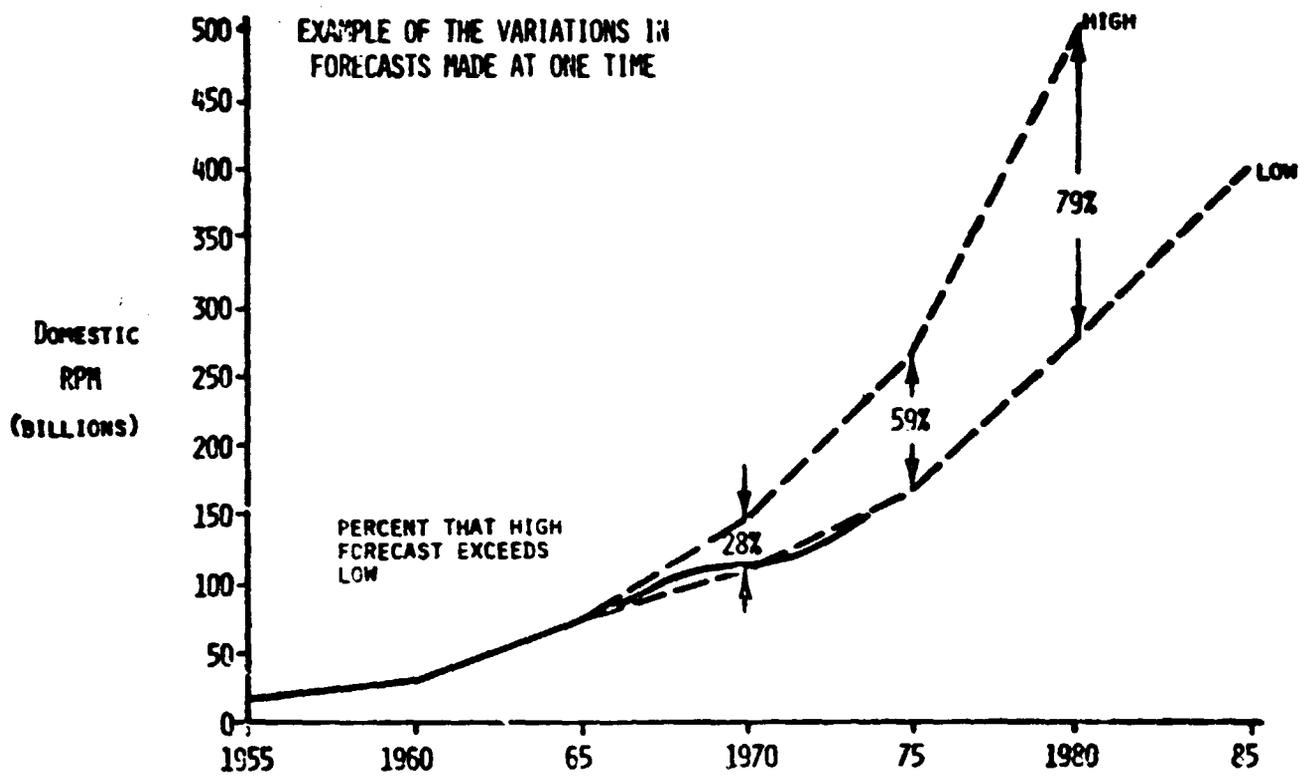


Figure 3. History of Mc Donnell Douglas Forecasts



SOURCES: ATA, BOEING, CAB, DOUGLAS, FAA, GE, LOCKHEED, NORTH AMERICAN

Figure 4. Comparison of Air Transportation Forecasting

1. More emphasis should be placed on behavioral modeling. As pointed out earlier in this report, the decision as to how to move cargo is made by human beings, taking many things into consideration. It is not at all clear that these decisions are controlled by gross economic, demographic and geographical indicators. While such factors do undoubtedly influence the magnitudes of total goods movements, they may be a poor second to the service concepts of the overall systems when the final choice is made as to what goes where by which mode. The recent successes of such concepts as Federal Express and the Emery "Air Force" illustrate the importance of operational parameters such as convenience, dependability, special handling, coordinated movements, small community service, etc.
2. There should be a trend toward a more disaggregate approach to cargo forecasting. Such is indeed implied in a behavioral analysis. It does not appear that an accurate forecast may ever be possible on the basis of gross quantities such as tons of cargo, or revenue ton-miles, etc. The disaggregation will probably have to be done both on the basis of product or commodity, and geography, i.e. market segmentation. Research has been underway along these lines for some time now in the passenger demand area. An example is the construction of models such as the gravity type which can be calibrated on a zone-to-zone basis. It should be possible to extend such a zone concept to include product class or type as one of the zonal descriptors.
3. The previous two statements, when taken together, imply that improved market analysis is a primary requirement for better forecasting. A product-by-product examination needs to be undertaken to identify the transport properties most important to each class of products. With this understanding, the required properties which an air transportation system must exhibit in order to be competitive in each market can be determined. This type of approach was illustrated by the work of Roberts (56) in examining the potential of lighter-than-air vehicles as cargo movers, and was also implied in Sletmo's studies (22).
4. More attention should be paid to the role of modal split analysis in cargo forecasting. This fact is, of course, implied in #3 above. In pursuing such studies, it is important to be able to allow for the introduction of new concepts evolving in any of the modes, and the effect that they might have on the parameters which control the mode selection process.

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5. One possibility, which is done only in the most primitive manner at the present time, is to introduce probability estimates into the forecasting art. The best that is offered at present is to describe a series of scenarios and then to provide an estimate for each of the scenarios. This is extremely crude. Certainly the state-of-the-art of probability analysis is such that the large amount of past data which exist could provide information for the construction of probability relationships between the independent and dependent variables. We have been very successful in doing this for another type of behavioral decision issue in transportation, viz., using a given set of variables which describe the motion of a vehicle to predict the probability of the passengers being satisfied with the performance of the vehicle to the point where they will use it (61), an analogy with predicting the probability of a shipper selecting a particular transportation service, given the properties of the service seems reasonable.
6. More effort needs to be done to select the proper quantities to be used as the independent variables in any forecasting models. As indicated earlier, the key issue in forecasting is to predict what the future values of these variables will be. It would seem that there are ample data available now to examine the accuracy of past performances for predicting what would happen to factors used as independent variables. Perhaps a good bit of this does exist in the literature of the general business community. However, the scope of our effort did not allow us to pursue this.
7. Finally, it is recommended that a continuing effort be maintained to examine the validity of all past predictions of air cargo forecasting. The reviews of Appendix A contain mention of several articles (the latest based on data of about 1970) which have done this for air passengers. However, there is no evidence of any serious studies in the air cargo field even though a variety of air cargo forecasts have been made ever since the early 60's. To maintain an analysis of the success and failures of air cargo forecasts would be a relatively simple thing to do once the initial backlog is overcome. Furthermore, it should provide insight into the process that could well lead to major improvements. At the least, it will provide estimates of the reliability of the various forecast figures as they appear from time to time.

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APPENDIX A
BRIEF REVIEWS OF SELECTED ARTICLES ON
TRANSPORTATION FORECASTING

These articles are a representative sample of those reviewed which had a major impact on the evaluations and recommendations made in this report. In a few cases the article was not directly obtainable and the review is based on a digest of a previous review by other authors.

The reviews are presented alphabetically by author, either personal or corporate as the case may be. A coding system is used for the convenience of the reader. The code consists of

- (a) 4 letters - representing the first four letters in the author's name
- (b) 2 numbers-indicating the year of publication

AIRT-66
Air Transport Association
"Air Transport Facts and Figures"
Washington, D.C., 1966

These sources, issued annually, for many types of data relative to the air transportation industry also include traffic forecasts for future years. The 1966 year is referenced here for comparison to several other forecasts prepared about this time. The ATA approach is the most simple-minded kind of extrapolation. They simply presented projections of current levels based on three different possible growth rates: A "low" rate of 10.8% per year; and a "high" rate of 16.2% per year; resulting in an "average" growth rate of 13.5% per year. In retrospect applying something between the average and high values would give the best comparison against actual fact than any of several other more sophisticated projections done during the same time frame.

Presumably the three rates were determined by an "experienced judgment" of what the future held in store for the air transportation industry.

ARIZ-67
Arizona State University
(National Program for Training Skilled Aviation Personnel)
A Technical Assistance Project Sponsored by the Economic Development Administration of the Dept. of Commerce, 1967

The study concluded that the key to employment in the aviation industry was the number of aircraft to be required and the extent to which they would be operated. Thus they became interested in demand forecasts in the air transportation industry and reviewed the work that had been done to date in this area. They focused their attention on several major forecasting studies*, adjusted them for comparability, and then formulated a composite

projection based on a judgmental review of the results.

It is impossible to give any results since at this writing the original report has not been located. The above comments were made from the summary report of Kiernan (KIER-70).

*
Boeing Company
Douglas Aircraft
FAA
CAB

ATA
Lockheed Aircraft
General Electric
North American

BOEI-7

Boeing Company
"Boeing Traffic Forecasts"
Commercial Airplane Division, Report S-637, 30 January 1967

This summary is taken from KIER-70 since it has not been possible to obtain a copy of this document thus far.

The forecast was divided into U.S. domestic and international to arrive at the total civil air carrier traffic. Two projections were made for each of these segments on the basis of different forecast growth rates. A "probable" forecast used growth rates that start at approximately 15% in 1966 to 1967 and drop to about 6% in the late 1970's. A "possible" forecast was based upon growth rates that vary from approximately 17% in 1966 to a little over 8% by 1980. To get the total Free World traffic, Boeing added non-U.S. forecasts to these totals. These were based upon growth rates that vary from about 14% to 6% for the "probable" level and 18% to 8% for the "possible" level.

Boeing checked the consistency of their forecasts with other economic indicators. Specifically, the economic growth rates of the U.S. and those countries represented in the non-U.S. forecasts were evaluated to determine their ability to support the projected traffic growth. A further check on consistency was made by evaluating the compatibility of the air carrier forecasts with projections for the transportation sector of the overall economy. Although demand elasticities were not used directly in the forecasts, an underlying assumption of moderate fare decreases and continued use of promotional fares was used. They felt that this would be necessary to support even the "possible" level of growth.

The potential market population was checked against the passengers represented in the forecasts and the results were determined to be consistent with a continued increase in the propensity to travel.

BOEI-73

Boeing Commercial Airplane Company
Cargo Analysis and Development Unit
"U.S.-Europe Econometric Forecasts of Trade and Air Freight
to 1980"
June 1973

Note: Europe consists of 15 Western European nations.

A regression-type econometric model is used, with the model in the exponential form:

$$Y = aX_i^{b_i} X_j^{b_j} . \quad (1)$$

Three dependent variables are used:

- (1) total trade in dollars;
- (2) air freight tonnage eastbound; and
- (3) air freight tonnage westbound.

Four causative (or independent) variables were studied:

- (1) Gross National Product \equiv GNP;
- (2) per capita income;
- (3) time; and
- (4) yield in cents per ton mile \equiv \bar{Y} .

In developing the actual model, the following actions or assumptions were made:

- (a) transform equation (1) to a log form;
- (b) all dollar values are to be constant 1969 values;
- (c) the independent variables are expressed as indices with the 1962 data assigned the value of 100.

Hence, if

1962 GNP = 679.2 billions
1963 GNP = 706.4 billions

then

1962 \rightarrow 100
1963 = 706.4/679.2 = 1.04 x 100 = 104.

The regression studies yielded the following three models:

Total Trade \equiv (TT)

\log (TT) = -1.494 + 1.7425 \log (composite US + Europe GNP)

$$R^2 = .98$$

Eastbound Air Freight Tons = (EAFT)

$$\log (\text{EAFT}) = -2.0843 + 3.466 \log (\text{EGNP}) - 1.4309 \log \bar{T}$$

$$R^2 = .96$$

Westbound Air Freight Tons = (WAFT)

$$\log (\text{WAFT}) = .655 + 2.73 \log (\text{USGNP}) - 2.05 \log \bar{Y}$$

$$R^2 = .99$$

The EAFT model has the highest standard error (.068) and the TT model the lowest (.011); WAFT has standard error of .034.

Thus the procedure for forecasting the future performance of the independent variables becomes that of forecasting the future values of the dependent variables:

USGNP - Based on the study of the reports of a variety of economic forecasting groups scattered throughout the country.

Results are as follows:

	<u>Year</u>	<u>GNP*</u>	<u>% Change in GNP</u>	<u>Index (1962 = 100)</u>
(actual)	1962	679.2	-	100
	1972	1,012.3	-	149
	1973	1,073.4	6.0	158
	1974	1,112.9	3.7	164
	1975	1,157.4	4.0	170
	1976	1,206.0	4.2	178
	1977	1,251.8	4.0	184
	-----	-----	-----	-----
	1980	1,435.0	4.6 (avg)/yr	211

*in billions of constant 1969 dollars.

EGNP - The GNP's of 15 European nations (all Western Europe) are used to form this variable. Again economic reports are studied and annual forecasts made for each country (annual percentage increase). The final value for all Europe is obtained by taking the average % increase for these 15 countries. This average appears to be unweighted. Thus it does not account for future shifts among countries. However, it is weighted in the sense that it is applied to the 1972 actual value figure which is the sum of all the individual actual values.

<u>Year</u>	<u>% Increase</u>
1973	5.3
1974	5.1
1975	5.0
1976	5.7
1977	4.9
1978-1980	4.5/yr

Combined USGNP + EGNP - Obtained by simply adding the two previous values:

<u>Year</u>	<u>GNP</u>	<u>Index</u>	<u>Avg. Annual Growth</u>
1973	1,876	161	5.7%
1974	1,951	168	4.3
1975	2,037	175	4.4
1976	2,136	184	4.9
1977	2,227	191	4.3
1980	2,547	219	4.6

Yields, \bar{Y}

Westbound yields are generally known to be higher than east-bound yields. Yield is also an implicit indicator of the commodity mix and the quantity per shipment involved.

Anticipating no general rate increase in excess of that required by inflation, and being conservative in the estimate of productivity gains and regulatory changes favorable to air freight, produces the following forecasts:

<u>Year</u>	<u>Current Prices</u>	<u>Constant 1969 Prices</u>
1962	24.5¢/ton mile	28.3
1973	19.6	16.5
1974	20.4	16.4
1975	21.1	16.3
1976	21.3	16.3
1977	22.5	16.1
1980	25.0	15.0

BOEI-74

Boeing Commercial Airplane Company
 Cargo Analysis and Development Unit
 "U.S. Domestic Air Freight-- An Econometric Forecast"
 June 1974: A1748

A regression-type econometric model is used with the model in the exponential form:

$$Y = aX_1^{b_1} X_2^{b_2} \dots X_j^{b_j} \quad (1)$$

The dependent variable is always Revenue Ton Miles (RTM).

Two models were formulated:

(1) Short term

RTM's on a quarterly basis:

X_i → annualized quarterly GNP

X_j → annualized quarterly yield.

(2) Long Term

RTM's on an annual basis:

X_i → annual GNP

X_j → average annual yield

All data used in the regression analyses came from CAB Form 41 and U.S. Dept. of Commerce National Economic Statistics.

The short-term forecasts are done on a quarterly basis to allow for the definite seasonal variation which exists for air freight.

Aggregate economic activity, measured by the U.S. GNP, is a better explanatory variable of change in industry basic demand than any of the individual components of GNP, e.g., personal consumption, capital or government expenditures, and industrial production. These variations influence the air freight market less as individual factors than as an aggregate.

Average yield in real terms is a reflection of many interacting variables of the industry. These include rates, route structures, shipment sizes, modes of handling, commodity mixes, quantities, densities of individual shipments, and changes in productivity of the airline industry.

Models

(1) Short Term

\log (quarterly RTM's) = $-1.349 + 1.83 \log$ (annualized quarterly USGNP) - $0.9 \log$ (annualized quarterly yield)

$R^2 = .96$; standard error = 0.42

RTM's in millions

GNP in billions in constant 1958 price levels

Yield in ¢/ton mile in constant 1958 price levels.

(2) Long Term

\log (RTM's) = $-0.558 + 1.852 \log$ (USGNP) - $1.084 \log$

(average annual yield)

$$R^2 = .97; \text{ standard error} = 0.036$$

Units same as in (1) above.

Thus, as was the case in BOEING-1973, the problem of forecasting air freight demand becomes one of forecasting GNP and average yield.

GNP

Reports of many economic forecasting agencies are studied, but the work in this document is based entirely on the forecasts of Chase Econometrics. It seemed to perform well during recent periods of economic turbulence and its scenario is well adapted to the long-term/short-term approach.

Average Yield

This is based on a scenario constructed by Boeing which apparently reflects the experience of their economists.

A slow rise in yield through 1975 is predicted, caused by inflation and increased rates. In the long-term, technological advantages resulting from the wide bodies and improved ground handling equipment should bring the yield down to about its current level.

Forecasts

Air freight demand will increase an average of 10.4% per year and exceed 6.1 billion RTM's by 1980.

Revenue growth is expected to average 13% per year and exceed 1.6 billion in 1980.

BROW-68

Brown, Samuel L. and Waynes S. Watkins

"The Demand for Air Travel: A Regression Study of Time Series and Cross Sectional Data in the U.S. Domestic Market

Paper given at the 47th Annual Meeting of the Highway Research Board, National Research Council, Washington, D.C.,

January 16, 1968

Two separate approaches to air traffic demand were investigated. First, a regression analysis using time series data and, second, a regression analysis using cross-sectional data. The results for both analyses were comparable. The variables used in the time series analysis were: 1) average fares per miles; 2) net disposable income per capita; and 3) clock time--a proxy. Those variables used in the cross-sectional analysis were:

1) fares per mile; 2) quality of service (number of stops); 3) distance; 4) community of interest (business calls); 5) income products (product of aggregate incomes); and 6) sales promotion resulting from competition (index). All variables proved to be significant with variables 1 through 3 being inversely related and 4 through 6 directly related.

Fare elasticities proved to be low or insignificant in the shortest distance trips, however, lengthening the interval does change the picture considerably. For fairly long distances (1,100) miles, fare elasticities are high and then decline to insignificance at the longest distances. Elasticities with respect to journey time appear to increase (numerically) fairly steadily as the length of trip increases.

BROW-73

Brown, Melvin

"A Transportation Demand Forecasting Model"
Mitre Corp., Report MTP-377, May 1973

This is a rather analytical summary of the theoretical development of a model to forecast the demand for transportation in a network of cities, connected by a number of competing travel modes. Although of a type which might be classified as a cross-sectional modal split demand model with time dependence incorporated as needed, it is not the usual "gravity" type. It was developed in such a way as to make a conscious attempt to avoid the inconsistencies and characteristics of unreasonable behavior that is exhibited by many of the currently used models. Many of these problems were analyzed and summarized in an earlier Mitre report by Nutter (NUTT-72).

The model derived is quite complex when used to all of its power, and at the time of the report no calibration had yet been attempted. It may, indeed, be difficult to find or extremely expensive to generate data banks adequate for calibration of the full model.

Some of the factors taken into consideration are:

- (1) effective cost of travel
- (2) single mode conductivity;
- (3) competing mode conductivity;
- (4) intrinsic attractiveness;
- (5) effect of competing destinations;
- (6) complex itineraries; and
- (7) effective attractiveness.

The model provides both total demand and modal split.

CAB-65

CAB

"Forecasts of Passenger Traffic of Domestic Trunk Air Carriers--
Domestic Operations, Scheduled Service, 1965-1975"
Bureau of Accounts and Statistics, Research and Statistics
Division, Staff Research Report #5, September 1965

This brief summary is extracted from Kiernan's analysis (KIER-70) as it has not been possible to obtain the original report in the given time frame.

The methodology was based upon econometric modeling with revenue passenger miles regressed on such independent variables as consumer price index, disposable personal income, population, and fares. An estimated value of fare elasticity was also used. Projections for the independent variables were obtained from a variety of sources, most of them outside of the CAB.

Forecasts were developed for each of the years of the 10 year period and resulted in a growth rate during the early years of 9.3% per year declining in later years to about 7.6% per year. In retrospect, it is interesting to note that although this was one of the most sophisticated forecasts done in the mid to late 60's, the results were among the poorest when compared with what actually transpired.

CHAM-71

Chambers, John C., Satinder K. Mullick, and Donald D. Smith
"How to Choose the Right Forecasting Technique"
Harvard Business Review, July-August 1971, pp. 45-74.

This is a very interesting and informative survey article on how forecasting can be done in the business community. However, the reader interested in forecasting from the point of view of transportation must be careful in interpretation since many of the techniques discussed are applicable to the marketing of physical products and goods, but not to services. For example, the marketer of goods has types of information available which are extremely useful to him for forecasting, but which do not even exist in the transportation field, e.g., inventory control, order backlogs, customer reordering cycles, replacement sales, warranty returns, etc.

Nevertheless, this is a very useful document. It is easily readable and indeed should be read subject to the above cautions by everyone not thoroughly familiar with forecasting methodology. One of the major features of the article is the presentation in tabular form of a summary of the principal features of a large number of techniques. Rather than review these here, pertinent comments from this article are incorporated in the general sections of the final project report dealing with forecasting techniques.

DEEM-76

Deemer, Robert L. and Donald A. Orr
"Over-Ocean Cargo Forecasting"
DRC Inventory Research Office, IRO Report 244, November 1976

This article is concerned with improved logistics planning for the scheduling of both sea and air shipments of military material of all kinds. It talks in terms of long-range (1 year) and short-range (3 months) forecasts.

All material to be moved is for a strict military market, and there are essentially two inputs into the forecasting process: (1) the requirements as stated by the overseas base commander based on his plans, budgets and orders; and (2) data on the past history of activity vs. plans for each base.

The report recommends an operations analysis computer-type activity at a central Logistics Control Agency which will process these inputs in conjunction with a Kalman-type smoothing algorithm to provide updated forecasts to the MAC and MSC planners as to what the most likely demands for O-D service might be during the short - and long-range periods. A manual review and override function is provided to accommodate or adjust for large-scale events due to unusual circumstances.

The work may be best described as strategic logistics planning. Although the data analysis techniques could perhaps be used to advantage in performing the same function for commercial air cargo data, the input forecasts from the "market" areas would cause a problem in the commercial arena. The article certainly contributes nothing in this area which is the key commercial problem. In the military version, these forecasts are based on operational plans and commitments, and are not subject to the control of the normal demographic, economic and sociological forces which govern forecasting in civilian markets.

DEOS-77

Deosaran, Gerald, Henry Sweezy and Regina Van Duzee
"Forecast of Commuter Airlines Activity"
FAA, Report FAA-AVP-77-28, July 1977
(authors a & b are with SARC; author c with FAA)

The approach of using straightforward regression techniques on a variety of the usual population and economic explanatory variables with past years' traffic statistics was rejected. This was because the six-year period (1970-75) for which commuter airline statistics are available represents a period of unusual growth. Thus the basic assumption of time-series modeling, viz., that the interrelationships between variables will remain stable through the periods of model formulation and application, does not seem to be valid.

As an alternative it was decided to seek models which would relate commuter traffic to both economic or demographic variables and the operational factors which are likely to affect it. This led to grouping the potential markets into the following basic categories:

1. Hubs (CAB/FAA classifications were used);
2. Non-hubs (over 1000 emplanements in 1975);
3. Special areas (water, mountains, resorts, etc.);
4. Small points (under 1000 emplanements).

A. Total Emplanements

The first step was to forecast the total commuter emplanements anticipated in the target forecast year. This was done by tying the forecast directly to that made for emplanements of certificated carriers that year. The rationale for this decision was that a study of the historical development of the commuter industry showed that the large majority of commuter passengers connected with certificated carriers. Also since the industry seemed to be reaching maturity, the present data on the relative emplanements of the two types (viz., 25.5/1000) would continue to hold. Thus the actual data is based on the FAA Aviation forecasts for certificated carriers (FAA-76). The result is a forecast of 10 million commuter emplanements from certificated points. A separate estimate using a different approach was made for the traffic to be generated from points not now served (see section entitled "Potential Commuter Points"). This added 2.2 million-- the actual total figure being 12,183,600 emplanements.

B. Allocation to Groups

Methods were next devised to allocate these emplanements to the various basic groups, and then to service areas within the groups. Each of the groups must be examined separately.

1. Hubs

The hub category was allocated its share of emplanements using total personal income as the indicator (total personal income is representative of population and per capita income which historically "seem to be the most significant explanatory factors in developing a demand forecast for air travel"); the share was weighted for the ratio of its percentage share of traffic to income for the base year. This gives the following relationship:

$$\left(\frac{E_{g/N}}{I_{g/N}}\right)_B = \left(\frac{E_{g/N}}{I_{g/N}}\right)_F$$

where $E_{g/N}$ = ratio of emplanements of group to the national figure

$I_{g/N}$ = ratio of total personal income of group to the national figure

B = base year

F = forecast year

From this expression the forecasted emplanements for the group could be written as:

$$E_{gF} = E_{NF} \cdot \left(\frac{I_g}{I_n} \right)_F \cdot \left(\frac{E_g/E_N}{I_g/I_n} \right)_B$$

The data used to obtain values for I were obtained from the Dept. of Commerce BEA area data and projections.

Once the total allocation for the hubs as a group was obtained, it was distributed among the individual hubs using the same weighted formula, simply replacing g by the local hub, and N by g.

On this basis the forecasts call for 58.1% of the commuter traffic (emplanements) to occur at 84 hub airports.

2. Non-hubs (over 1000 emplanements in 1975)

A wide variety of straightforward regressions did not work, and so an approach focusing on service characteristics was used.

The overall group was divided into four sub-groups based upon the character of their operations:

- Sub-1. Institutional;
- Sub-2. Agricultural and Distributive;
- Sub-3. Industrial and Mining;
- Sub-4. Recreational

A further stratification was effected by dividing each of these sub-groups into two classes: (a) those having joint service with a certified carrier; and (b) those having only commuter service.

Each sub-group was allocated its share of the total projected commuter market using the same proportional basis as for the hubs.

Then each point (P) in a given sub-group was allocated its share in a similar fashion, but with a major change in the variable. Instead of using total income, an index called the Economic/Isolation Unit was used (see below). Thus the allocation formula for each point became:

$$E_{PF} = E_{GF} \cdot \left(\frac{U_P}{U_G} \right)_F \cdot \left(\frac{E_P/E_G}{U_P/U_G} \right)_B$$

where U = Economic/Isolation Units

U = total personal income x driving time to alternate.

As before the total personal income comes from Dept. of Commerce BEA statistics. The driving time to alternate points must be estimated in each case.

After these projections at each point were computed, it was possible to analyze them as a function of U for the various sub-groups given above and develop the following regression equations:

Service by Commuters Exclusively

Institutional $E_1 = -7.425 + 0.1413U$

Agricultural $E_1 = -3.615 + 0.0812U$

Industrial $E_1 = -0.099 + 0.0498U$

Recreational $E_1 = -0.038 + 0.1080U$

Service by Commuters and Certificated Carriers

Institutional $E_2 = 21.897 + 0.0414U$

Agricultural $E_2 = 5.540 + 0.0802U$

Industrial $E_2 = -2.666 + 0.1025U$

where E_1 = commuter passenger emplaned

E_2 = total passenger emplaned (commuter and certificated)

3. Special Areas

No model was found. The allocation was on the same basis as hubs.

4. Small Points

The forecasts for these points are based on the same methodology used for hubs.

5. Potential Commuter Points

Based on an analysis of traffic trends and CAB activities, a group of 124 points not now having cummuter service, but likely to acquire it by 1988 were identified:

74 are currently certificated points, which would shift to commuter

50 currently have no service.

The traffic forecasts for this group were handled in a manner similar to non-hubs, using the same sub-group divisions.

DOUG-56

Douglas Aircraft Company
"Measuring the 70's-- An Air Travel Market Analysis"
Report CI-12/66-423, November 1966

The following summary is taken from Kiernan (KIER-70) since it has not been possible to obtain the Douglas document.

The Douglas forecast is for U.S. domestic air passenger traffic only. Their validations of their forecasts involved the same economic factors as those used by Boeing (BOEI-67). In addition they looked at the U.S. Intercity common carrier traffic. They compared their forecast for the air share of intercity travel with projections of total common carrier domestic intercity travel to check for consistency. They also looked at personal income and corporate profits as key factors in the support of continued growth of air travel.

ELLI-70

Ellis, Raymond H. and Paul R. Rassam
"National Intercity Travel: Development and Implementation of a Demand Forecasting Framework"
Peat, Marwick and Livingston, Washington, D.C., Report T8-542, Mod. 1, Final Report, PB 192 455, March 1970

This is a very intense assimilation and computerized analysis of large amounts of data done under extreme time pressure (the entire job was accomplished in one month). Quite obviously (even to the authors of the report) this time pressure detracted from the ability to consider the results as definitive. The reason for the time pressure is not clear.

All modes were considered, but several strategic decisions and constraints were applied. First of all this was for passenger transportation only. The idea was to estimate the demand between any of a series of zones covering the U.S. At the request of DOT, the zonal pattern was one previously established for them by the Service Bureau Corporation and which divided the U.S. into 490 zones. It was decided that rail was only a serious competitor between those zones which involved major population corridors (N.E., California, etc.) and so the corridor areas were done separately from the other zones. Next, it was found that intercity bus data were so sparse that it was impossible to treat bus in any analytical way, and so the bus contribution was forecast separately at the end of the study. Hence, the major portions of the study were concerned with highway and air.

The first task was to prepare current trip tables between the zones using whatever data were available and making projections when necessary. For example, the Bureau of Public Roads had prepared auto trip tables for 3,076 zones for 1962; this had been compressed to the 490 zone structure by Service Bureau Corp. and it was then extended to the 1967 base year using population projections and a Fratar Model technique; finally it was adjusted judgmentally to reflect changes in propensity to travel based on personal income, life style, etc. Air travel was based upon the 1967 CAB Domestic Origin-Destination Survey of Airline Passenger Traffic. This information provided airport-to-airport statistics that could be arranged according to the 490 zones. However, it was felt necessary to redistribute these trips to the true origin and destination points of the travelers which are often not in the same zone as the airport used.. This was accomplished using a gravity model with the "production" terms being the airport-to-airport trip tables, and the "friction" terms based upon time and distance factors obtained from a number of airport access studies. It is interesting to note that about 29% of the trips had final origin-destinations in zones different from those in which the airports were located. Combining the air and auto data produced total person-trip tables for all interchanges between the 490 zones.

The next step is to calculate trip impedances based upon those factors which tend to effect travel. For auto these were based on distance in the highway network, costs of operating autos and overnight times and costs where applicable. Air network impedances were estimated on the basis of distance, time, cost and frequency, including access and egress times and costs.

In the projection phase of the work the air-auto portion involved a two-step process. The first was to project the total trip tables. This was done by upgrading the 1967 trip tables using the Fratar Model technique and future population forecasts. The results were again adjusted for the additional growth (potentially positive or negative) due to projected changes in income and travel propensity. Total zonal trip tables were prepared for 1975, 1980 and 1990.

These trips then had to be distributed between the air and auto modes. Initially it had been hoped to accomplish this through the use of a gravity-type model similar to the McLynn model developed for the Northeast Corridor project. However, this did not work, probably due to collinearity between the time and cost variables used in the friction terms. Instead, an approach involving a diversion curve between air and auto based on a decision made on the basis of comparing cost and time was developed. The resulting equation was similar to that which results from the discriminant analysis method.

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Bus projections were made on the basis of a proportional extrapolation of what meager data were available. The projections probably had poor accuracy, but represented an insignificant portion of the total.

Finally the projections for high-density corridor travel were obtained by adapting the results of travel studies made earlier by a variety of investigators for about 20 different corridors.

ELLI-71

Ellison, A.P.
"Forecasting Passenger Air Demand"
Flight International, July 8, 1971, p. 58

Ellison is a lecturer in Economics at Queen Mary College at the University of London.

The article appears to be a popularized version of another article entitled "Air Transport Demand Elasticities for U.K. Domestic and International Routes"--although the source of this latter paper is not given.

Discusses econometric forecasting models. Stresses the importance of evaluating the demand elasticities on a route by route basis. However, available data are meager, and so this aspect is still in its infancy. Unfortunately, rate making procedures do not use this approach. The across-the-board changes usually made in rates imply either uniform price elasticity or that the demand-price relationship is inelastic, neither of which is true.

The major problems with econometric modeling are:

- (1) specifying the proper variables which exhibit the important elasticities on a given route;
- (2) choosing the type of equation to properly reflect the elasticity;
- (3) neglecting variables which are difficult to specify, e.g., safety, speed, social characteristics, etc. (this usually causes an upward bias in the demand);
- (4) forecasting the trends in the independent variables, the variables with the high elasticities are often the most difficult to forecast, e.g., income;
- (5) accounting for effects of competing modes, often regulated by totally different agencies;
- (6) cut-off or cut-on values in many of the variables.

Frequency of service is an important variable, but difficult to include in the demand equation. The problem can be partially overcome by appreciating that the airlines often adjust their frequencies at a given period of time in response to the output sold during the corresponding period of the previous year. Substituting in the lagged demand variable produces a means of representing frequency changes, and of obtaining estimable coefficients for them.

"Econometric models have the advantage over other techniques of forecasting in that they attempt to explain the causes of changes in demand. They can be altered and improved by empirical testing. In revealing the structure of demand, they allow administrative decisions to take place within an informed framework."

To use the models to the best advantage, the forecaster should have control over as many of the variables as possible. Thus the airlines could produce better forecasts if, for example, control over price and capacity was not exercised by an outside regulatory agency.

FAA-67

FAA

"Aviation Demand and Airport Facility Requirement Forecasts for Large Air Transportation Hubs Through 1980"
1967

This report and those prior to it in this series dating back to 1958 are analyzed in detail by Kiernan of IDA in a 1970 report (KIER-70). The information is analyzed in terms of passenger boardings and revenue passenger miles for domestic air traffic, but does not include cargo.

The methodology used involves a two-step procedure. First the total domestic figures are projected on a simple extrapolation of past trends. Then the share of each hub is determined, again by trend extrapolation based on the history of the percentage of the total enjoyed by that hub in the past.

Analysis of the results of these forecasts for the 9-year period shows the following:

1. They are reasonably accurate, within 1%, for the next year.
2. They become increasingly inaccurate in the longer range being off by as much as 20% with a standard deviation of + 20% in six years.
3. In spite of the fact that the projections were revised annually, they constantly underpredicted the growth in this period.

FAA-67a

FAA

"Aviation Forecasts, Fiscal Years 1967-1977"
Office of Policy Development, Economics Division, January 1967

The forecast was undertaken in support of the SST development program. The actual forecasting was based on the U.S. domestic traffic adjusted to total traffic by simply scaling up according to the historical relationship between domestic and international traffic.

It was unique among the forecasts done during the period in that the projected growth rates, which start at about 14% per year, decline to around 10% per year in 1970 and then increase again to 12%. The latter increase is due to an estimate of lower fares in the 70's because of technological advances which would lower operating costs.

Other factors taken into account are the GNP (estimated to grow 2-3% per year) and continued availability of promotional and reduced fares.

GOOD-73

Goodnight, John C.

"Model for Estimating Regional Air Passenger Travel Demands"
Highway Research Record #472, 1973

The purpose of this paper is to develop a model to estimate the level of air traffic volume which would be generated given a specific set of conditions. The conditions are relative prices, transportation system configuration, and regional socioeconomic activity. The model developed is primarily concerned with estimating demand in communities which have no air service or only low levels of service.

The operation of the model is in three phases. The first phase computes the estimated magnitude and distribution of all intercity travel within the region under consideration. The second phase estimates the modal split on the basis of comparative costs. The third phase estimates the number of flights produced by the regional air network.

Total trip distribution is estimated on the basis of three socioeconomic variables: 1) trip purpose--business, visitation of friends and relatives, and recreation; 2) associated attractiveness factor (i.e., associated with trip purpose)--total taxable payrolls, total population, and total hotel and motel payrolls; and 3) family income level--less than \$000, \$6000-\$9999, more than \$9999. Modal split between air and auto transportation is estimated on the basis of comparative costs which include out-of-pocket costs and value of travel time.

The author has presented none of the standard statistical tests for the explanatory power of his model. He does, however, present a bar graph comparison between estimated and observed air trips for 1967 in Texas. The author concludes that the model gives reasonable estimates of total air demand. However, the presentation of the graphs on a logarithmic scale tends to shrink the apparent size of errors. The author admits that the model tends to underestimate travel into special counties such as those containing universities and the state capitol. One attractive feature of the model is its ability to make estimates of demand on the basis of a hypothesized air transportation network. Thus, the effects of changing the level of service to a community can be studied.

This model would appear to be appropriate for use in studies of regional air transportation demand. However, the heart of the model is a gravity type equation which estimates the magnitude and distribution of trips generated by a region. This gravity equation requires the production of extensive trip tables for each county or similar zone in the region. The trip tables must include total trips, regardless of mode, of 100-199 miles, 200-499 miles, 500-999 miles, and greater than 1000 miles. Presently trip tables such as this are difficult to find for very many regions. Therefore, data collection requirements for this model are enormous.

HANE-75

Haney, D.G.

"Review of Aviation Forecasts and Forecasting Methodology"
Peat, Marwick and Mitchell, Inc., Report DOT-40176-6, 1975

This is a relatively general summary of the status of air transport forecasting (passengers primarily) prepared as a summary briefing for a special task force reviewing FAA activities.

The approaches and experience (success or failure) of the general forecasting activities of FAA, ATA, CAB, and McDonnell Douglas are summarized and compared. The problems encountered in various types of forecasts are discussed briefly with the major point being that an overall review such as this clearly demonstrates the vulnerability of all types of forecasting to sudden changes in the social, technological, economic or political factors upon which these forecasts depend.

This points out the extreme importance of including rather complete sensitivity analyses with forecasts. The forecasts should always be tested to determine the changes which would occur under various scenarios which might have an impact on the trends for the independent variables used in the forecasting process. Also the author laments the fact that most papers and reports on forecasting tend to stress the results and provide insufficient documentation of the information and methodologies used in deriving these forecasts.

A detailed analysis of the various forecasting done in connection with the St. Louis airport expansion case is presented to illustrate the problems. Also a bibliography of 119 articles is presented.

KANA-74

Kanafani, Adib K. and Shing-Leung Fan
"Estimating the Demand for Short-Haul Air Transport Systems"
Highway Research Record #526, 1974

The authors developed a method for estimating short-haul demand in the Los Angeles-San Francisco corridor. The methodology consists of two stages. The first stage estimates the total demand for air travel within the corridor. The second stage then estimates the choice between the available routes. The authors recognize the significance of competing ground systems on short-haul air transportation, but choose to ignore this interaction because adequate ground transportation in the subject corridor is confined to a 500-miles auto journey.

Three alternative models for total demand are postulated. All are of the production function form with socioeconomic variables: 1) population; 2) median income; and 3) employment and transportation variables: 1) best available schedule frequency; 2) lowest travel time; and 3) lowest travel cost.

Multiple regression analysis proved that population and median income were significant variables. However, the explanatory power of each model was low ($R^2 = 0.26 + 0.36$), and the authors conclude that they are not suitable for demand forecasting.

In order to avoid the difficulties caused by low R^2 values, the authors shifted to a procedure, shown in the equations below, involving projected growth rates rather than predictions from the regression models:

$$T_{ij} = \prod_n X_n^{\alpha_n}$$
$$dT_{ij} = \sum \alpha_n \frac{dX_n}{X_n}$$

where

T_{ij} = total traffic between i and j

X_n = independent variables

α_n = demand elasticity with respect to each variable.

Using the significant α_n 's for population, income, and travel time, the authors postulate that increases in total air demand can be predicted from changes in the significant variables. The

authors used this analysis to make predictions concerning increases in air travel five, ten and twenty years in the future. No reproduction of historical data or other validation technique is presented.

KESS-65

Kessler, David S.

"Relationships Between Intercity Air Passengers and Economic and Demographic Factors--A Multiple Linear Regression Analysis"
MSE Thesis, Princeton University, 1965

The author has developed a gravity type model for predicting the level of air traffic volume between various cities. Variables included in the model were: 1) population; 2) distance; 3) wealth (as measured by percent of national retail sales divided by percent of national population); 4) proximity factors (population of the nearest larger city divided by population, distance to the nearest larger city divided by distance); 5) city classification (as measured by the percent employed in manufacturing and mining); 6) welfare (as measured by percent of households with income over \$10K); and 7) transient factor (as measured by per capita hotel sales).

Multiple regressions were run on the basis of groupings by population size (50-99K, 100-250K, 250-499K, 500-999K, over 1000K); regional geographic location (northeast, central, southern, southwest, northwest, west coast); and city classification (marketing centers, industrial centers, institutional centers, and balanced cities). On the basis of the regression analysis all variables with the exception of the transient factor proved to be significant. The explanatory power of the model showed a wide range of variability. Values of R^2 tended to be high for regressions based on economic classification, but much lower on the population group regressions.

The ability of the model to reproduce historical data was shown to be poor. The results of the multiple regression analysis indicated that the explanatory power of the variables became higher as the characteristics of the city pairs become more similar. This result tends to support the contentions of later authors that gravity models may produce satisfactory results when applied to homogeneous city pairs.

KIER-70

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Kiernan, Janet D.

"A Survey and Assessment of Air Travel Forecasting"
Institute for Defense Analysis, Research Paper P-540, April 1970

This survey was conducted under a special program at JDA sponsored by UMTA. Since, at the time frame of this report, there were many agencies placing heavy reliance for a variety of uses on

FAA forecasts, the historical effort of FAA forecasting is examined in some detail. It was found that the basic method used by FAA is to project current experience on an extrapolated basis and then update them annually. Over the period from 1957 to 1970 they were found to be reasonable on a short-term basis, but highly inaccurate for the long term (5-10 years). The error was found to be consistently one of underestimation, even after the updating.

Eight other major forecasting efforts were also studied.* They used a variety of methodologies but their results showed little or no consensus. The projections diverge over a wide range of expectations and in recent years all have proven to be too low when compared with the actual. Also there does not seem to be any rationale for favoring one methodology over the other, in spite of the fact that they vary from ultra-simple to rather complex.

<u>*Boeing</u>	North American	CAB
Douglas	General Electric	ATA
Lockheed	FAA	

LOCK-66

Lockheed Aircraft Corporation
"Air Traffic Demand 1967-1990"
Burbank, California, Report OEA/SST/22, November 1966

Since the original was not available, the following comments are derived from a review by Kiernan (KIER-70).

The Lockheed approach was to handle the U.S. domestic and international traffic separately. For the domestic market, three methods were used: (1) a market analysis technique; (2) a city pair analysis; and (3) relation to GNP. The international traffic forecast was based upon an analysis of the relationship between the U.S. forecast and the transatlantic traffic, plus a trend extrapolation for major market areas of the world.

The basic underlying assumptions of all three approaches in forecasting the domestic traffic include continued growth in the GNP, continued downward pressure on air fares, increasing propensity to fly, and no major economic or political changes in the world situation. Lockheed's overall forecast is a composite of the three techniques.

LONG-68

Long, Wesley
"City Characteristics and the Demand for Interurban Air Travel"
Land Economics, May 1968, p. 197.

The model presented in this paper attempts to assess the effects of city characteristics on air travel. The typical

gravity model approach is used in developing the analytical framework for the model. For the most part the paper is concerned with weighing characteristics of the K factors in the gravity model: "Different people in a city have different potentials for air travel according to their economic and demographic characteristics. Thus it seems reasonable to give people who have more than one characteristic that is related to air travel more weight than others by including a number of these gravity form variables which use the product of the number of people in the two cities having a given characteristic. The assumption is that like characteristics indicate community of interest." The theory proposed that the number of persons going a given distance is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities. The basic components of the model include city effect, population, income, education, size of employing business, location, and region. The results of Long's work showed "that population is the dominant explanatory city characteristic. The regional location of city pairs and the size of the businesses residing in them are other factors of importance. The negative effects of city-pair population relative to surrounding cities are surprising results, and these surprises point the way to further investigation."

LONG-59

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Long, Wesley

"Airline Service and the Demand for Intercity Air Travel"
Journal of Transport Economics and Policy, Vol. 3, September
1969, p. 287.

This paper attempts to quantify consumer reactions to changes in a few aspects of airline service: changes in the number of airlines serving a given city pair, changes in non-stop service, and the changes in the class of flight (and consequently the minimum price of an air trip) between city pairs. Usually, one perceives an increase in the number of rivals in a city pair market to give rise to an increase in the number of scheduled flights and a struggle for market shares. This paper uses a model of the demand for air travel in large city pair markets and multiple regression analysis to measure the effects of regulatory variables while controlling the other variables.

The paper is divided into three major sections: 1) an explanation of the model of air travel used; 2) a display of the statistical results; and 3) a discussion of some of the resulting implications.

Basically, the equation representing the model hypothesizes that the year to year traffic change experienced by any pair is determined by changes in the types of service offered between the cities, adjusted for the confounding effects of the distance between cities, the characteristics of cities, and events connected with the statistical methodology employed. The results of the study are presented in tables giving the effect of variables on traffic change by traffic level class, representing data taken

from over thirty major cities in the United States. Also, estimates of price elasticity of air travel by traffic level class are presented.

MAIO-76

Maio, Domenic J. and George H. Wang

"Forecasting Models and Forecasts of U.S. Domestic and U.S. International Air Freight Demand"

U.S. DOT/TSC, Report SS-211-UI-5, September 1976 (also included as part of FAA-AVP-77-2, January 1977)

The approach is to develop a model by regression on time series data using GNP (an aggregate measure of economic activity) and average revenue yield in \$/ton-mile (a surrogate for air service prices) as the explanatory variables. It is recognized that the demand for air freight should be a function of the quality of air freight services, and of the cost and quality of competing modes, but no adequate time series data are available on these variables.

The authors make the following statement which indicates their appraisal of the state of air cargo forecasting; It is assumed "that no dramatic technological or socio/political changes will occur in the forecast time frame. ... The shipper/consignee mode choice determinants are economic, will essentially remain unchanged in the aggregate, and are adequately reflected by the equation variables. ... Given available data, the limits of this approach to air cargo forecasting have been reached. Significant improvements in the accuracy or precision of the forecasts requires individual forecasts of specific commodity flows, credible mode split models, and more precise modeling of the price and service differentials between the surface and air options."

I. Domestic Air Freight

A. Model Forms

1. Linear Model

$$Y_t = \alpha_0 + \alpha_1 \nabla X_{1t} + \alpha_2 X_{1t-1} + \alpha_3 X_{2t} + \alpha_4 X_{3t} + \alpha_5 Y_{t-1} + U_6$$

where Y_t = total (freight plus express) Domestic revenue ton-miles (all services scheduled plus non-scheduled) in year t

X_{1t} = Gross National Product measured in 1958 constant dollars

X_{2t} = yield per revenue ton-mile deflated by implicit GNP price deflator (1958 = 100)

$$X_{3t} = \begin{matrix} 0, & t < 1969 \\ \text{dummy} & \\ 1, & t \geq 1969 \end{matrix} \quad \text{reflects change in}$$

reporting data to include Alaska and Hawaii as domestic

$$\nabla X_{1t} = X_{1t} - X_{1t-1}$$

X_{1t-1} = real GNP lagged one period

Y_{t-1} = RTM lagged one period

U_t = residual

Note: It was necessary to go to the lagged term in order to avoid difficulties caused by intercorrelation between X_1 and X_2 .

2. Log Linear Model

$$\ln Y_t = \alpha_0 + \alpha_1 \ln X_{1t} + \alpha_2 \ln X_{2t}$$

B. Data

In doing the regression, the following data sources were used:

GNP = not given

Y = CAB Handbook of Airline Statistics (RTM's were chosen since this was what was available--would have preferred emplaned tons)

Yield = $\frac{\text{total revenue of scheduled air freight \& air expense}}{\text{scheduled revenue ton miles}}$

C. Models

After the regression based on annual data from 1950-1974, the following relations were obtained, all satisfactorily tested for significance ($R^2 = 0.99$; all coefficients significant at 10% except intercept term):

$$Y_t = 776.33 + 4.85\nabla X_{1t} + 1.79X_{1t-1} - 54.22X_{2t} \\ + 187.09X_{3t} + 0.44Y_{t-1}$$

$$\ln Y_t = 0.91 + 1.84 \ln X_{1t} - 1.99 \ln X_{2t}$$

(all significant @ 5% except intercept)

D. Forecasts

Data

GNP from Wharton Economic Forecasting Associates.

Future Air Revenue Yields--based on three separate and arbitrarily chosen scenarios:

Aggregate air freight prices will increase an average of 2%/yr., remain constant, and decrease by 2% /yr.

II International Air Freight

In the international case the data must be stratified in two ways, specific nation pairs, and whether it is U.S. export or import traffic.

A. Model Forms

Conceptually the models should take the following functional forms:

Demand for U.S. air export services to the i^{th} world region $\equiv Z_i$

$$Z_i = f(Y_i, P_{1i}, P_{2i}, X_{1i}, X_{2i})$$

Y_i = real GNP of the i^{th} world region
(in constant 1958 U.S. dollars)

P_{1i} = real air freight rate from U.S. to i^{th} region (in constant 1958 dollars)

P_{2i} = real average surface freight rates from U.S. to i^{th} region

X_{1i} = measures of the quality of air freight services

X_{2i} = measures of the quality of surface freight services.

Demand for U.S. air import services $\equiv I_i$

$$I_i = f(Y_{US}, \bar{P}_{1i}, \bar{P}_{2i}, X_{1i}, X_{2i})$$

Y_{US} = GNP of U.S. in 1958 dollars

$\bar{P}_{1i}, \bar{P}_{2i}$ = real average air and surface freight rates from the i^{th} region to U.S.

B. Models

The models had to be simplified since good data are not available for the X's or for surface rates. The linear form was used as it was found to best represent the data:

$$Z_i = \alpha_0 + \alpha_1 P_{1i} + \alpha_2 Y_i + U_i$$

U is error term

$$I_i = \beta_0 + \beta_1 \bar{P}_{1i} + \beta_2 Y_{US} + U_n$$

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C. Data

Regressions were performed using data from the 1965-1974 period obtained as follows:

Y_{US} = Dept. of Commerce, Survey of Current Business

P_i = yield/ton-mile obtained from CAB, Air Traffic and Financial Statistics, and the GNP implicit price deflator (1958 = 100) from Survey of Current Business

Y_i = the approximate real gross domestic product of the i^{th} world region, calculated in four steps:

- (1) Value of GDP for each country obtained from the Statistical Yearbook published by the United Nations;
- (2) conversion from local currencies to U.S. dollars by the annual foreign exchange rate reported in International Financial Statistics published by International Monetary Fund;
- (3) normal GDP in U.S. Dollars for the i^{th} world region is obtained by summing over all individual countries assigned to that region;
- (4) real GDP is obtained by deflating the normal GDP by the U.S. price deflator.

D. Forecasts

Regressions are performed and forecasts made for the following world regions:

North America
South America
Europe
Asia
Australia and Oceania
Africa

MAIO-77

Maio, Domenic J. and Neil Maltzer
"Projection of Cargo Activity at U.S. Air Hubs"
U.S. DOT/TSC, Report SS-211-UI-4 (also included as part of
FAA-AVP-77-2, January 1977)

This work consists of a rather intricate massaging of data and projections in an attempt to allocate the forecasts of air

freight made by Maio and Wang (MAIO-76) plus those for air mail made by Washington Data Processing) to the 25 large air hubs as classified by the CAB, and translate them into aircraft activity.

The task is not straightforward, and involves a rather intricate procedure requiring several significant assumptions. A brief summary of the methodology is as follows:

1. Allocation of the National Demand for Cargo Tonnage to Each of the Hubs

This is done by straight projection based on current percentage of the total handled at each hub. This of course assumes that nothing will happen to change this situation and requires close monitoring of operations as they unfold to check the validity of this assumption. The current domestic data for the projections are obtained from CAB Airline Service Segment Data, and international data from the Dept. of Commerce data on exports by air.

2. Estimate the "Usable" Lower Hold Capacity of the Passenger Fleet by Hub

The basic assumption made here is that the nature of the air cargo industry will remain pretty much as it currently exists, with 85% of the domestic market and 63% of the international market held by combination passenger/cargo carriers who will continue to emphasize the cargo-carrying capacity of their wide-body fleets. Thus it is assumed that as much of the demand as possible will be met by "belly" cargo with dedicated air-freighters being used only for the residuals.

- a. Projection of Passenger Aircraft Size

Projections can be made on the basis of the analyses of the present fleets showing a direct (nonlinear) relationship between available seats per departure and the tonnage of available cargo capacity. Trends in the national aircraft fleet mix are developed, and thus a projection of the available seats per departure (and hence tonnage), can be made. This projection of course depends on the accuracy of predicting what the aircraft fleet mix will look like in periods up to 1990.

- b. Allocation of the Available Tonnage into Specific Market Sizes

Since different types of aircraft are used in different types of markets, the mix of aircraft cannot be assumed to be homogeneous at each hub. The basis for this allocation is the ratio of emplaned cargo pounds to emplaned passengers for each on-flight origin destination pair. Using this index, all destinations served from a given hub are classified into two groups, depending upon whether this index is greater or smaller than unity.

c. Estimation of the Number of Departures of the Average Passenger Airplane to Each Market Group at Each Hub

This is essentially computed as follows:

Projected passenger emplanements

(avg seats/departure) (avg load factor)

Again, estimates need to be made of the numerator (obtained from the latest FAA terminal area forecasts) and the second term in the denominator. Little is said about how the latter is obtained.

d. Estimation of the Total Lower Hold Capacity

As the final step in this subsequence, the "potential usable" lower hold capacity in a hub market is the product of (b) and (c).

3. Allocate the Hub Demand to the "Usable" Lower Hold Capacity and Determine the Residual Demand to be Satisfied by Freight Service

a. Determine the "Actual Usable" Lower Hold Capacity

The "potential usable" hold capacity must be discounted to allow for mismatches between passenger and cargo scheduling and dead space caused by multistop routes. The CAB data permit the computation of a current hub lower hold emplanement load factor, and this is projected by extrapolation into the future.

b. Match the Hub/Market Demand to the Actual Lower Hold Capacity

This is a straightforward problem in accounting-- with the end result being either:

- (1) All demand satisfied by actual usable capacity;
- (2) All actual usable capacity filled and a residual demand identified.

4. Translate the Residual Cargo Demand into Freight Departures

To do this it is necessary to know the aircraft mix at the various hubs where the residual demand exists. This is done on the basis of an analysis of past trends and a simple projection.

MILL-65

Miller, Ronald E.
"Forecasting Air Traffic"

Journal of the Aero-Space Transport Div., Proc. ASCE, October 1965

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Miller compares the results of forecasting air passenger traffic between selected city pairs by using a simple linear

regression model with the results obtained from a simple gravity-type model.

The regression model was developed from an observed historical series of traffic data on each route as a proportion of total national traffic, using CAB data. The analysis dealt entirely with the air traffic statistics, without any consideration being given to other modal choices which might be available to travelers in each market.

This linear model was then extrapolated to a given time period --5 years ahead. Predictions are also made for the same time frame based on a gravity model. They are then both compared with the actual data for the 5-year period. The results are not very satisfactory, but if anything, the extrapolation is a little better than the gravity model.

MILL-69

Miller, Ronald E. et al. .
"Studies in Travel Demand" Vol. 5
Mathematica, Princeton, New Jersey, Sept. 1969 pp. 173-499

The authors review the various fundamental approaches for conducting travel demand studies; and then discuss some of the basic problems in forecasting transportation demand. These may be stated tersely as:

1. The degree of detail needed to specify the model.
2. The problem of the interdependence & identifiability of the supply of and demand for transportation.
3. The data problems .
4. The problem involved when introducing new modes .
5. The problem of forecasting error .

Next some recommendations are offered to improve the models.

1. Keep the number of variables to a minimum .
2. Do not expect to deduce the "correct" model specification by trying out alternative regressions, since multicollinearity may make standard errors sufficiently large in most alternative formulations of the model as to render statistical discrimination among them difficult. It is probably better to rely on a priori judgment and theory for this.
3. Do not be over-concerned about applying the most sophisticated estimating techniques. The paucity of data makes their desirable asymptotic properties irrelevant.

4. Try, instead, for efficient estimates. In this regard, it may be desirable to investigate recursive models which allow for equation-by-equation least squares estimation. Efficiency frequently may be further increased by regressing subject to a priori restrictions on the size of parameters. These methods usually require the application of Lagrange multipliers, linear programming, or quadratic programming, depending on whether the restriction is an equality or inequality and whether absolute or squared deviations are to be minimized.

NUTT-72

Nutter, Robert D.

"Form and Behavior of a Transportation Demand Forecasting Model"
Mitre Corporation, Report MTP-370, April 1972

This is a tutorial-type article dealing with the problems encountered in using "gravity" - type demand. It summarizes the general philosophy and approach behind this type of model and then examines in detail the various errors or inaccuracies to which the model is prone. The material is well written and should be read by anyone interested in analytical approaches to demand modeling.

The textual material is not summarized here since most of it is incorporated into other portions of this final report.

PULL-65

Pulling, Ronald W.

"Intercity Travel Characteristics"
Journal of Aerospace Transport Division, Proceedings of ASCE,
April 1965

In this paper the author discusses the validity of the gravity model, $T_{TAF} = K_{AT} \frac{P_1 P_2}{D^*}$ where T_{TAF} equals air passengers, K_{AT} is a constant developed for air travel, P_1 denotes population of origin, and P_2 represents population of destination, D refers to distance between 1 and 2, and $*$ is an exponential value of distance. Pulling also suggests that the following variables are important in determining air travel demand: 1) relative size of city; 2) proximity to a larger city (transportation characteristics); 3) density of population; 4) economic classification (marketing center, industrial city, balanced city, institutional city); 5) wealth distribution; 6) geographical surroundings; and 7) selected market indices.

QUAN-69

Quandt, Richard and William Baumol
"The Demand for Abstract Transport Modes: Some Hope"
Journal of Regional Science, Vol. 9, No. 1, 1969

The essence of the abstract mode approach is that the demand for a commodity is taken to be a function not only of its price but also of its other attributes such as speed, comfort, convenience, etc., which one hopes are quantifiable. Most standard econometric procedures realize the necessity for placing a cost on such attributes. What differentiates this approach from the many others already formulated is that when the observed attributes of a given demand commodity appear to be the same as the attributes of another commodity, then for the same homogeneity, the two commodities are considered to be the same.

The authors are quick to point out that one should distinguish the abstract mode approach as an analytical method or a theoretical model from some specific set of functional forms which are selected for econometric estimation.

The analytical work presented is an offshoot of the original formulation of the abstract mode model developed by Alcala and Gronau. Quandt and Baumol expose the inherent weaknesses in the previous modelling technique and offer what they feel are the major structural changes which give their model greater validity.

ROBE-75

Roberts, F.O., H.S. Marcus and J. Pollock
"An Approach to Market Analysis for Lighter than Air Transport of Freight"
in: MIT, Proc. of the Interagency Workshop on LTA Vehicles,
January 1975, pp. 87-110

This is a quantitative approach to market analysis using computerized simulation routines as the analytical tool. The objective is to introduce quantitative values for all facets of the modal choice decisions for selected situations and use the simulation program to compare costs and benefits of the LTA mode with competitors. With these results, a judgment can be made about the probability for choosing the LTA mode.

Briefly, the strategy is as follows:

1. Proscribe attributes for the three principal aspects of modal choice.
 - a. Those pertaining to the supply of the commodity to be shipped;
 - . volume in tons;
 - . consolidation and deconsolidation possibilities;
 - . shipment size distribution;

- . required frequency of service;
- . seasonality; and
- . directionality.

b. Those pertaining to the performance of the mode:

- . waiting time;
- . travel time;
- . time reliability;
- . probability of loss and damage;
- . special services such as refrigeration or in-transit privileges; and
- . transport cost or tariff

c. Those related to the economics of the shipper/receiver (demand):

- . value per pound;
- . density;
- . shelf life;
- . inventory stock-out characteristics;
- . annual use volume and variability; and
- . need for special environment, handling or services.

2. A three-phase approach to the analysis of market potential is then carried out:

Phase I is a simple overview of comparative line-haul operations, which provides an estimate of those commodities for which LTA might compete favorably in this simplest aspect of the transport process;

Phase II is a computer simulation of the total origin to destination costs and times for the competing modes; and

Phase III addresses the shipper's demand side of the market analysis with another computer simulation model which reflects shipper's concerns in choosing a transport mode.

The report then proceeds to carry out this analysis using a modification of a simulation program developed by Planning Research Corporation. The results indicate that for the cases studied, which represented fairly wide ranges of the variables involved, it was not obvious that LTA would be an overwhelming choice in any of the markets. If clear advantages had been determined, then certainly judgmental forecasts of the size and time development of that market could be made.

SCHO-69

Schoennauer, A.W.

"Airline Schedules and Their Impact Upon Passenger Traffic"
Transportation Research, Vol. 3, 1969, pp. 69-73

Airline management is concerned with scheduling flights to meet demand as well as to influence demand. Chief considerations are: 1) departure and arrival times; 2) number and duration of stops en route; 3) speed of equipment. This analysis concerns the question of whether or not airlines can anticipate changes in passenger traffic by manipulating schedules either through changes in the short-or the long-run factors.

The mathematical models used to isolate the scheduling factor from other passenger traffic determinants were composed of the ability-to-pay factor, scheduling penalties, and a distance factor. The specific models to be tested took the following forms:

- (1) under 450 miles
passenger traffic = f (sum of household + distance - sum of penalties)
- (2) over 450 miles
passenger traffic = f (origin households - distance - sum of penalties)

The penalty effect had a negligible effect upon passenger traffic for city pairs separated by more than 450 miles while distances less than 450 miles were affected with respect to penalty levels assessed to schedules.

From this analysis, the results showed that 1) there existed some significant association between schedules and passenger traffic up to about 450 miles; and 2) the travel market could be segmented. But it did not appear logical to infer from these findings that long-distance travelers were not concerned with schedules.

A number of conceivable marketing alternatives for airline management were derived from these findings.

SIMA-68

Simat, Helliesen and Eichner

"A study of the Potential Air Freight Market--Phases I and II"
Prepared for Lockheed-Georgia Company, October 1968

This is a fairly hasty (60 days), but intense, effort to determine that segment of the domestic U.S. truck market that is most susceptible to air freight, and to develop a method (or model) for estimating this potential diversion based upon distribution costs and competitive transportation factors.

A major effort went into the development of a data bank. On the dependent variable side, the effort was to provide O-D information on the movement of manufactured and agricultural commodities.

Among the principal data sources used are:

1. Dept. of Commerce, Bureau of the Census, Census of Transportation for 1963 (manufactured commodities);
2. Ibid., Special Airline Tape for 1963 (manufactured commodities);
3. Dept. of Agriculture, Unload Reports (fruit and vegetable shipments);
4. Dept. of Commerce, Import/Export Statistics;
5. Interstate Commerce Commission, Motor Carrier Freight Commodity Statistics;
6. Ibid., Role of Regulated Motor Carriers in Handling Small Shipments, November, 1967;
7. Ibid., Carload Waybill Statistics.

Even so, the data were not complete and some projections of time dependence (e.g., source #1 from 1963 - 1967) had to be developed.

In order to provide information on possible independent variables, information was identified for a number of commodity and movement characteristics:

e.g., Commodity:	shipment size
	shipment value
	shipment density
Movement:	distance
	number of interchanges (trans-shipments)
	costs
	transit time

In formulating the model, it was decided to calibrate on 1963 data only. Since no domestic value data were available, it was assumed that the international value data were applicable.

Information on the above factors were researched in great detail. Costs, for example, included all door-to-door costs, including such non-transportation costs as depreciation, insurance, deterioration in value, and packaging. Data were obtained for all pertinent modes.

The regressions were performed by looking at each variable and various combinations of variables independently and selecting the result which gave the best correlation. Two models were proposed, one including depreciation/deterioration costs, and the other omitting them.

Transportation Cost and Time Only

Proportion of a commodity moving by air = 1.0886

$$-0.2273 T_A/T_S - 0.1971 C_A/C_S .$$

Five expressions involving three independent variables were tested with over 5,000 observations and the above was the best with $R^2 = 0.6778$.

Including Depreciation/Deterioration

Twelve expressions with six independent variables alone or in combination were tested, again on 5,000 observations. The best, having an $R^2 = 0.8162$, is:

Proportion of a commodity moving by air = 1.31557

$$-0.23132 T_A/T_S - 0.25131 C_A/C_S - 0.00008 I_A/I_S .$$

The model was validated on two domestic routes (to about 10% accuracy) and one international route (much more difficult to do, primarily because of data problems).

SIMA-69

Simat, Helliesen and Eichner, Inc.

"A Method for Estimating International Air Freight Potential"

Vol. I, Development of Data Base and Estimating Model

Vol. II, Projections of International Air Freight 1975

(report not dated)

The forecasts are based on a causal-type equation developed from an immense computerized regression on existing data.

The data were obtained from a variety of sources. The dependent variable was to be related to the amount or fraction of a given commodity which went by air. This information was obtained from the two main sources of international trade data produced by the Census Bureau of the Department of Commerce, viz.,

Schedule A - Statistical Classification of Commodities Imported into the United States

Schedule B - Statistical Classification of Domestic and Foreign Commodities Exported from the United States

Based on earlier work of a similar nature (but relating entirely to domestic shipments) for Lockheed-Georgia, it was decided that the independent variables generating a proper causal relationship would involve some grouping of specific entities within the broad classifications of cost, time, and value of service. It is to be noted that these classes are by no means mutually independent--indeed they are highly interrelated. No less than 38 separate variables were defined to be tested. Many of these were composite, and involved ratios for air/surface.

Numerical identification of these variables, and their many detailed component parts, was a major undertaking. Many sources of data were used including CAB, IATA, Dept. of Commerce, etc. Much of the data for ocean shipping came from a report "Selected Commodity Unit Costs for Oceanborne Shipments via Common Carriers (Berth Lines)" produced by Ernst and Ernst for the Dept. of Commerce in 1967.

It seems clear that an enormous amount of labor and effort went into documenting values of the variables, as well as into computer analyses to establish the final regression model. The work should certainly be regarded as a definitive effort for this type of approach to forecasting.

The final analysis produced two equations, one for imports and one for exports:

Imports (based on 23,020 observations)

$$\frac{WA}{WA + WO} = 0.5165 - 0.8520 \frac{CA}{CA + CO} + 0.03932 \log e \frac{VA + VO}{WA + WO}$$

where

CA = total cost by air
 CO = total cost by water
 VA = value by air from census tapes
 VO = value by water from census tapes

$$R^2 = 0.3872$$

Exports (~ 32,000 observations)

$$\frac{WA}{WA + WO} = -0.5776 + 0.1049 \log e \frac{VA + VO}{WA + WO} - 0.0554 \frac{CA}{CA + CO}$$

$$R^2 = 0.2787$$

The only comment to be made at this point is that it is surprising that the R^2 values are not somewhat larger, given the thoroughness of the analysis. It would also seem that a few more independent variables might have been helpful.

In Vol. II, these models are used to forecast the potential air share of the 1975 market for a variety of commodities (the models must be applied repeatedly for various commodities and O-D pairs). However, at this forecasting stage the process once again became involved with dependency upon projecting the independent variables into the future. Estimates on times came from the technology experts in both air and sea. Cost estimates were partially involved with technology, but also had to contend with that old bugaboo of forecasters, inflation.

There is one additional complication. The model depends upon knowing the total trade projections for the year desired since the model itself only gives an indication of the modal split potential.

Once again a careful analysis is done to obtain the most accurate values possible for all that is needed to make the forecasts. With the data sources that exist, it is difficult to see how any more careful work can be done using this method.

SLET-75

Sletmo, Gunnar K.

"Air Freight Forecasting and Pricing"

The Logistics and Transportation Review, Vol. 11, No. 1,
pp. 7-29, 1975

This paper analyzes several sets of data relating to air freight traffic, obtained from CAB, ICAO, and Bureau of the Census, using the econometric modeling concept. After indicating some of the classical problems involved in performing linear regressions on log-log type equations (e.g., multicollinearity and serial correlation), additional equations are constructed using techniques designed to protect against these difficulties. Thus the data sets are used to calibrate three types of relations--double logarithmic (DL), a first difference logarithmic (FDL), and a double log with search (DLS).

Various groupings of the data sets and portions thereof are examined with air freight ton-miles being regressed in terms which are effective in representing yield (revenue per ton mile) and income (for U.S. data either industrial production or GNP was substituted for income). The elasticities and indicators of statistical reliability were examined in each case in an attempt to understand the physical significance of what was indicated by the values of the elasticities.

For the most part the statistical tests show that problems exist even though the R^2 correlation coefficients are reasonably high. Nevertheless, the following general conclusions seem reasonable even though the reliability of the quantitative predictions leaves a lot to be desired:

1. The demand for air freight appears to be sensitive to the

level of industrial production, but not to changes in this level. This would tend to make short-range forecasting difficult.

2. Air freight is more highly correlated with GNP than with industrial production. This is probably because GNP is more representative of the type of products carried by air.
3. The demand for air freight over international routes shows very little rate elasticity.
4. In the domestic market, the cross-price elasticity with respect to trucks is positive and significant. Thus there appears to be a measurable degree of competition between Class I intercity common motor carrier service and air freight.
5. The effect of time trends was introduced in one set and showed up as highly significant. This may be caused by the fact that the normal economic indicators do not reflect the effect of technology changes nor the increasing familiarity with and acceptance of air freight by shippers.
6. The demand for air express is essentially inelastic with fare. This seems consistent with the emergency, or goods-of-high-value, nature of air express.

A version of a dynamic model due to Chow is then examined. In this model, available ton miles/hr (transport productivity) is used to represent advances in technology. The result is again only a very weak rate elasticity at best.

Based on all these analyses, the author concludes that:

1. There is overwhelming evidence that the demand for air freight is inelastic.
2. The road to profitability in air freight lies in a more rational rate structure and especially in providing improved service.
3. Forecasting efforts based on aggregate quantity of demand are not likely to be as valuable as those concerned with estimating specific trade flows.
4. As a prelude to developing quantitative forecasts it is first necessary to do considerable market analyses to determine the types of traffic which can be expected to be carried profitably.

SPEA-74

Speas, R. Dixon, Associates
"Scheduled Air Transportation for Outstate Areas"
Executive Summary, Part of Minnesota State Aviation System
Plan, May 1974

This study examines 15 variables which describe 18 urban areas in outstate Minnesota where use of air service was known. The variables used are: 1) population; 2) land area in square miles; 3) total wholesale trade; 4) employment in manufacturing; 5) passenger car registration; 6) college student enrollment; 7) number of households; 8) effective buying income; 9) effective buying income per household; 10) percentage of households with income of \$10,000 or more; 11) number of hotels and/or motels; 12) approximate distance to St. Paul, Minnesota; 13) miles to closest service point; 14) quality of service index; and 15) value added from manufacturing. It was concluded that five of the variables were significant in the following order: 1) total wholesale trade (directly); 2) quality of service index (directly); 3) value added for manufacturing (directly); 4) auto registrations (inversely); and 5) population (directly).

SU-75

Su, Vincent and Lucy Huffman
"Demand for Air Travel between New York City and Other Large
Cities"
Highway Research Record #529, 1975

The authors hypothesize that the theoretical structure of demand for air travel is based on three decisions: time period, city destination, and airline. A three-way classification analysis of variance is then used to breakdown total demand for air travel along the lines of the effects of the decisions to be made. The variables proposed are time effect, city effect, airline effect, and the cross interactions time/city, time/airline, and city/airline. The time, city, airline, and city/airline variables were found to be significant at the 99% level. Total variation in demand explained was 88.3%. Regression analysis was then used to explain the significant variables.

From the results of the regression analysis, the authors conclude:

- (1) Time effects are well explained by air travel price, proxied by yield per passenger-mile, and a trend variable, proxied essentially by increased income.
- (2) City effects are explained well by population and income. Distance between cities was found to show little effect on demand. However, demand is affected by competitive transportation modes.

(3) City/airline effects are explained basically by the average number of daily flights.

The model presented has been specifically developed to analyze demand between New York City and other large cities. Two of the significant variables, airline effect and city/airline effect, basically reflect the high levels of service expected in large, highly competitive metropolitan markets. The use of this model in analyzing demand in small communities with limited service is considered inappropriate.

SUSS-69

Sussex House

"Executive Aviation Report, No. 1807"
Wimbledon, England, March 18, 1969

This report reviews the same eight passenger demand forecasting models as Kiernan (KIER-70). It emphasizes the wide variation in the various methodologies used and the enormous variation in results which they produce, and concludes that there is little or no meaning or significance that can be attached to forecasting.

The wide discrepancy in results is demonstrated by the attached tables and figure. The report concludes that since none of the different methods applied in 1965 could predict the near-term upward growth (1967), it is obvious that the current art of forecasting is in trouble, and studies to establish relationships between air transport and published economic diagnostic parameters are needed.

TANE-75

Taneja, Nawal K. and James T. Kneafsey

"The State-of-the-Art in Air Transportation Demand and Systems Analysis"

MIT, Flight Transportation Laboratory, Report R75-7, August 1975

This entire report is a summary of a workshop managed by MIT/FTL, and held in Washington, D.C., in June 1975 under the joint sponsorship of CAB, DOT, and NASA. The workshop consisted of formal presentations by six different invited panels (as listed below) and subsequent discussion. Apparently no effort was made to have the participants form a consensus of opinion in the various problem areas. Rather, the MIT staff digested and analyzed the various papers and opinions and attempted to reflect the dominating attitudes toward the various issues. These were presented succinctly in the report and further condensation would not do justice to the material.

Ringling loud and clear throughout all the presentations was a lament for the gross inadequacy of existing data sources which can be used for accurate forecasting of all types of aviation activity. With regard to the area of estimating demand, the following issues emerged as important:

SUSS-69 (continued)

TABLE 9. COMPARISON OF EIGHT MAJOR U.S. FORECASTING EFFORTS-- PROJECTIONS FOR TOTAL CIVIL AIR CARRIER REVENUE PASSENGER-MILES (DOMESTIC AND FOREIGN SCHEDULED SERVICE), IN BILLIONS*

Cal. Year	ATA	Boeing "Probable"	CAB	Douglas	FAA	G. E.	Lockheed	North American	Composite	Actual
1965	76	76	76	76	76	76	76	76	70	
1966		88			87				87	
1967		103		99	98				99	111.7
1968		118			108				110	
1969		133		121	119				123	
1970	143	144	118		132	144	134	122	138	
1971		165		145	148				152	
1972		181			165				167	
1973		198		170	184				184	
1974		215							200	
1975	269	232	169	200		224	204	195	218	
1976		250							236	
1977		269		230	268				255	
1978		284							275	
1979		307		262					295	
1980	507	327			379	323	283	314	315	
1985		428			450		400			

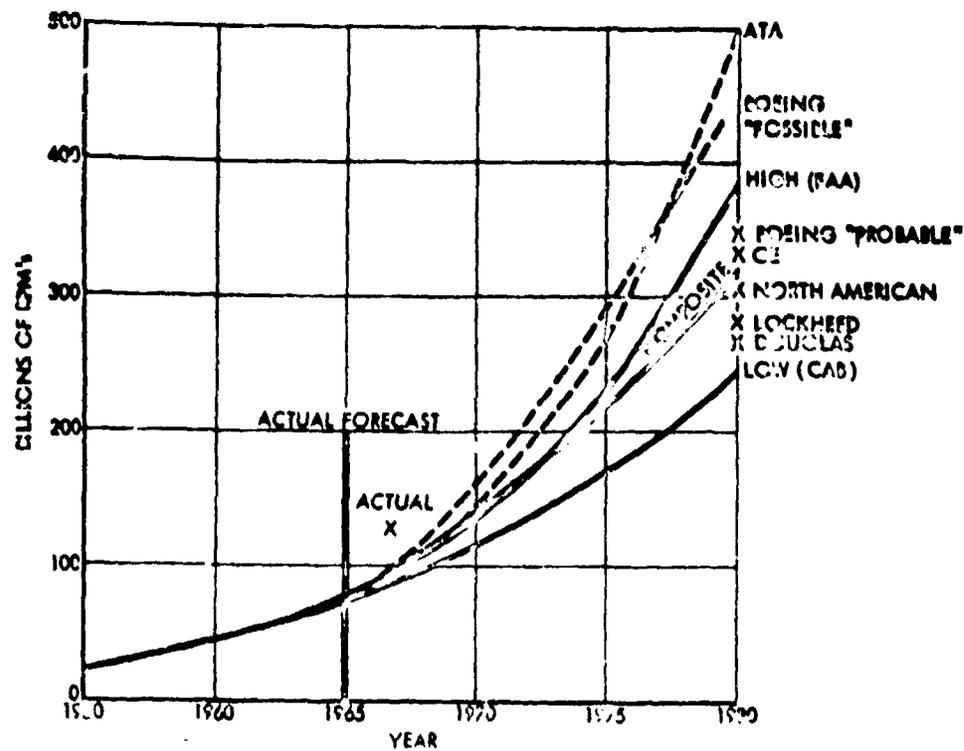


FIGURE 4. Comparison of Eight Major U.S. Forecasting Efforts--Projections for Total Civil Air Carrier Revenue Passenger-Miles (Domestic and Foreign Scheduled Service)

- . More information and better forecasts are required to estimate the price elasticity of demand (for both passenger and cargo).
- . More information is desired on the impacts of the special-fare plan packages presently in use.
- . The largest unknown area of airline operations is cargo, a situation which needs to be remedied in the future in view of the sizable annual growth rate anticipated (no information on how these growth rates were determined).
- . More detailed demand models reflecting disaggregate behavioral characteristics of both travelers and shippers need to be developed.
- . A more consistent pattern of data collection from the airline companies is desired. A major data gathering activity involving in-flight surveys and sharing of this information needs to be investigated.
- . Information on trip purpose and travel by fare type is needed.
- . Specific O-D segment data should be collected, in particular for cargo operations.
- . International data comparable to domestic U.S. data sets need to be developed.

The panels which functioned during the workshop were the following:

1. The Role of Government Agencies on Aviation;
2. Issues of Concern to Airport Authorities;
3. Forecasting as Perceived by the Airline Industry;
4. The Activities of the Financial Community in the Airline Industry;
5. Issues in the Quantity and Quality of Air Transportation Data; and
6. The Role of Aircraft Manufacturers in the Forecasting Process.

THOR-78

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Thorson, Bruce A. and Kenneth A. Brewer
 "A Model to Estimate Commuter Airline Demand in Small Cities"
 Paper presented at the Annual Meeting of the Transportation
 Research Board, January 1978

This paper summarizes some of the attempts at modeling

demand for commuter air transportation which occurred during a study of improvements in intercity passenger transportation in Iowa. The objective of the work described by this particular study was to check the possibility of developing a forecast model for use throughout Iowa based upon regressing average daily passenger enplanements (ADPE) with community or traveler characteristics.

After an extensive review of previous literature, the following variables were chosen to be tested:

- POPL = 1970 community population
- INCOME = percentage of the families in the community with annual incomes of at least \$15,000
- OCCUP = percentage of persons in the community employed in professional, technical, or managerial positions
- EDUC = percentage of persons in the community over 25 years of age with four or more years of college education
- ISOLATE = miles to the nearest FAA hub airport

The calibration data bank involved 56 cities in a 6-state area selected because they were deemed to have characteristics similar to those of Iowa cities having commuter air carrier service (also included in the 56). ADPE values were obtained from the U.S. DOT study Air Service to Small Communities, and the dependent variable data came from the 1970 Census of Population.

The SPSS stepwise variable inclusion multiple regression procedure was used. Eleven linear equations were attempted using combinations of the independent variables and stratifications of the data based on level of passenger enplanements and community populations. There were no really satisfactory models obtained as all showed one or more of the characteristics of poor correlation, poor t value or unreasonable or illogical values of coefficients.

Next, a nonlinear regression procedure was attempted. Six different stepwise analyses were conducted resulting in 26 different nonlinear regression models. Multiple correlations between the independent variables were found to be abundant, with the result that only about four of these nonlinear models were useful. The best one (which was also better than any of the linear models) was:

$$ADPE = 2.81694 + 0.09372 (ISOLATE) (POPL)$$

$$R^2 = .401 \text{ and } t = 6.01.$$

The implications of this model bear a striking resemblance to a gravity model. However, the low value of R^2 makes any values obtained by using this model in a forecasting mode highly doubtful.

VERL-72

Verleger, Phillip K. Jr.
"Models of the Demand for Air Transportation"
The Bell Journal of Economics and Management Science, Vol. 3,
No. 2, Autumn 1972

This paper presents an analysis of three different empirical approaches to the analysis of air transportation demand.

The first model discussed is the standard cross-sectional gravity type model which has the form of a production function. The variables used in this particular model include: 1) price; 2) product of aggregate income; 3) telephone calls between the city pairs; 4) distance; and 5) elapsed flying time. Parameters for the model were estimated for 500 city pairs classified on the basis of distance: 0-500 miles, 500-1000 miles, 1000-1500 miles, 1500-2000 miles, and over 2000 miles. R^2 values for the six classes ranged from .64 to .83 with the highest value associated with flights greater than 2000 miles. Short haul, 0-500 miles, obtained an R^2 of 0.72. The estimated values of the coefficient likewise experienced large variations across the models. From this analysis the author concludes that cross-sectional techniques are unsuited for demand analysis of the entire market. However, he asserts that the gravity type model can produce satisfactory results for homogeneous sets of city pairs.

The second model discussed is the aggregate travel model which treats air travel, as measured in revenue passenger miles, as a homogeneous commodity. In this model aggregate demand is postulated to be a function of some measure of price, a measure of average national income and, sometimes, some measure of alternative travel forms. The variables most often used are: 1) per capita disposable income and 2) average revenue per passenger mile. The author asserts that the use of average revenue as a proxy for price prevents the model from being a true demand model. The author concludes from the analysis of this model that aggregate equations can predict demand accurately only if demands between city pairs remain relatively uniform.

The third model considered is the city pair model of demand for air transportation. The purpose of the model is to indicate whether differences in demand exist across city pairs in order to determine if cross-sectional or aggregate models are theoretically feasible. The model is basically a modification of the gravity model with the variables being 1) price, 2) distance, and 3) mass variables. The mass variables selected are functions of the population and income distributions of the city pairs. Results of the specification of the model indicated that the special construction of the mass variable is significant. The major conclusion of the city pair analysis is that large differences in air travel demand exist between cities because of regional fluctuations. The author asserts that because cross-sectional and aggregate models ignore

the differences in demand between cities, the results obtained by these techniques are questionable.

WILS-76

Wilson, F. R. and A. M. Stevens

"Estimating Passenger Demand for Local Air Services in the Maritime Provinces"

Paper presented at the Annual General Meeting of the Canadian Aeronautics and Space Institute, Toronto, May 10-12, 1976

Although the affiliation of the authors is not given, this appears to be a part of a study prepared for the Maritime Provinces Transportation Committee, Fredericton, N.B., in August 1975 entitled "Maritime Provinces Local Air Service Study, 1975." It reports on the first two phases of a five-phase study:

1. Analysis of the study area;
2. Market evaluation and traffic forecasts;
3. Identification and evaluation of suitable aircraft for service on the system;
4. System economic analysis; and
5. System selection.

Analysis of the Study Area

This analysis focused mainly on potential time saving as the dominant modal choice factor. Auto trip length is translated into equivalent airline statute miles, and it is shown that the cross over point is about 60-80 miles or 1:15 min. to 1:45 min. time (on the average, a one-hour auto trip in a private auto can be equated to about 1.5 airline statute miles).

The influence of existing route structure including probable changes with the advent of an improved commuter system is also examined.

The basic approach was to define potential service areas by analyzing the population of "catchment areas." The criteria used to identify additional potential service centers were:

1. generation of a minimum of 4-6 passengers/day (on the basis of existing per capita trends);
2. extent of surface connections to the nearest convenient airport in an adjacent catchment area;
3. existing and proposed development programs for the area; the types of industry in the region and the spatial relationships of those industries to customers, head offices, related plants, etc.;
4. historic travel pattern by all modes and business community preference;
5. times and costs by competitive mode between regional communities and between communities and major transportation hubs; and

6. special factors, e.g., community isolation, resort areas, etc.

After screening the entire region by these characteristics, 23 potential service areas were identified, 13 of which currently had no air service of any kind.

Model Development and Traffic Forecasts

Seven variables were identified for which data were available and hence could be considered as possible air travel demand indicators:

1. catchment area total population;
2. number of persons with incomes > \$10,000 before tax in catchment area;
3. activity index of catchment area as measured by manufacturing value added;
4. special sector employment of catchment area (public service, defense, and higher education);
5. link preference index (value from 1 to 10 based on historic travel patterns);
6. link auto trip times (town center to town center); and
7. link air trip times (including terminal allowances).

Data used for model calibration were available for 1967-74 from a special Atlantic Province Transportation Information System maintained at the University of New Brunswick, and from Federal sources. A standard SPSS regression analysis produced the following model:

$$\text{link air trips} = e^{5.0} (X_1^{0.388}) (X_2^{0.582}) (X_3^{-1.818}) (X_4^{0.732}) \\ (X_5^{0.411}) (X_6^{-1.07})$$

where

- X_1 = sector employment at origin catchment area/100
- X_2 = sector employment at destination catchment area/100
- X_3 = total trip time by air in minutes
- X_4 = population of origin catchment area /1000
- X_5 = population of destination catchment area/1000
- X_6 = calibration constant obtained from ratio of primitive predicted trips to actual trips

$$R^2 = 0.89.$$

Actually this turns out to be pretty much of a gravity model with population and employment as the attractors and time as the friction term. To use the model in the forecasting mode, it is necessary to predict all the X's.

YOUN-69

Young, Kan Hua

"An Abstract Mode Approach to the Demand for Travel"
Transportation Research, Vol. 3, 1969, p. 443

As a result of the tendency in transportation economics to study one mode of transportation at a time, very little consideration has been given to the forecast of a future new mode which may be drastically different from any of the existing modes. The abstract mode approach originally presented by Quandt and Baumol was one such exception. Young's approach is also designed for such a purpose. The major intent of this article is to formulate an appropriate abstract mode model for forecasting inter-city travel in the Northeast Corridor of the United States.

The general plan of this paper is as follows: an examination of the theoretical foundations of the abstract mode model where such a model is discussed in terms of the theory of consumer behavior; a formulation of the statistical demand function where several alternative versions will be proposed; consideration of the appropriate estimation procedures and the forecasting formulas; and finally a presentation of the empirical results of various formulations of the abstract mode models which have been selected for examination including a summary of the major findings and conclusions.

While Young's primary concern is the application of the abstract mode approach to the study of travel demand, he is quick to point out that a similar approach can be adopted for much wider applications. The advantage of the abstract mode approach is of particular importance when the major objective is to forecast future travel volumes for some transportation facility which may be drastically different from the present and past ones. The major argument of this approach is that the demand for travel, like the demand for any other commodity, is a function of various attributes of the commodity in question. These attributes include various modal characteristics, such as money cost, journey time and departure frequency, etc. Therefore, as Young points out, the demand for travel by air, by bus, or by any other transport mode is actually determined by the same demand function. Young spends twenty pages doodling with an empirical interpretation of a nonlinear model to drive this point home.

YOUN-72

Young, Kan Hua

"A Synthesis of Time-Series and Cross-Section Analyses: Demand
for Air Transportation"
Journal of the American Statistical Association, Vol. 67, Sept.
1972

This paper is primarily a comparison of time series and cross-sectional analyses with a proposed methodology for pooling

both types of data. The author uses the results of the analysis to test various hypotheses concerning macro- and micro-economic parameters.

The author has applied the study to an empirical analysis of the demand for air transportation. It should be noted, however, that the author is not so much concerned with air transportation as he is with economic analysis. The results of the analysis appear to be excellent. In most cases the coefficients which have been estimated are statistically highly significant. The general case time series model postulates variables: 1) ticket price, 2) journey time, and 3) per capita income. The coefficients of the model are postulated to be indicative of short-run and long-run price and income effects. The explanatory power of the model was high with $R^2 = .9937$. The general case cross-sectional model postulates variables: 1) per capita disposable income of an income group, 2) reference income of the other income groups (as measured by a weighted average), and 3) reference demand (the average demand of the immediately higher and lower income groups). The explanatory power of the model was high with $R^2 = .9346$.

The author asserts that the general pooled model, which incorporates both time series and cross sectional data, has the best results of all. As might be expected, the complexity of this model is considerably increased over the other general case models.

The author had used time series data from the CAB and Commerce Department from 1937-1966, and cross-sectional data (same sources) for 1955, 1957, 1959, 1960, 1963, and 1964 in computing the parameters of the model. The time series model treats the entire nation as a consumption unit while the cross-sectional model treats groups of individuals, e.g., income classes, as consumption units. Since no data tables are included in the paper, it is not immediately apparent how either of the models should be used.

Finally, the paper is intended to predict demand for air transportation from a total demand point of view. The models appear to be inappropriate for use in predicting on an intercity basis.

YU-70

Yu, Jason C.

"Demand Model for Intercity Multimode Travel"
Transportation Engrg. Journal (ASCE), May 1970, pp. 203-218

This article suggests some modification to the abstract mode models which are tested on data collected from pairs of cities in West Virginia.

The results of the study are:

1. The usual exogenous motivations for business travel differ from those which influence personal travel. Although there exist some variables commonly attracting both business and personal travelers, the degree of influence relies, to a great extent, on the reasons for travel. Accordingly, in order to more effectively estimate travel demand, it is desirable to analyze business and personal travel separately.

2. In deriving the best predictions of travel demand, the mathematical forms of the variables entering the model must be both logical and meaningful. On the other hand, since data availability often plays an important role in limiting the number of variables that may be modeled, it becomes even more important to make the best possible use of the available variables in terms of their logical forms.

3. A travel demand model derived by a time series analysis offers superior ability for forecasting purposes, especially for study, dramatic changes of demand elasticities of relevant variables over two years indicate that the cross-section model derived from one single time period will not be appropriate to predict the travel demand during another period of time.

4. The frequently used transportation variables, travel time, travel cost, and service frequency, are obviously not the all-inclusive determinants which influence the travelers' modal choices. In this respect, the dummy variable technique is considered desirable in order to characterize the effect of other potential variables on modal-split."

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APPENDIX B
BIBLIOGRAPHY ON AIR CARGO FORECASTING

This is not intended to be an exhaustive bibliography, but rather a record of the documents and references encountered during this study. Additional references on forecasting, demand modeling, and modal split analysis are contained in Appendices C and D. Appendix E contains those citations which are either exclusively concerned with air cargo (or air freight) or have a considerable portion of their effort so directed.

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APPENDIX C
AIR PASSENGER DEMAND FORECASTING
A GENERAL BIBLIOGRAPHY

This bibliography contains a number of references acquired over the last few years which are directly involved with the forecasting of the demand for or use of air transportation by passengers. Work which emphasizes cargo, but contains some passenger data, is included in Appendix B and that which is primarily devoted to the fundamental aspects of model development and use is contained in Appendix D.

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APPENDIX D
FUNDAMENTALS OF DEMAND MODELING AND MODAL
SPLIT ANALYSIS: A GENERAL BIBLIOGRAPHY

This bibliography is compiled by selecting those references which illustrate the rather voluminous literature which documents the extensive effort which is underway throughout the world in attempting to understand how to account for and predict the choice and use of transport. The emphasis is on fundamentals although many of the articles are concerned with specific system studies as a means for checking the hypotheses or concepts under study. A conscious effort has been made to avoid the work in urban transportation, although this is the most active area. Nevertheless, some articles in this area are included because of their fundamental importance.

Work which emphasizes applications in air cargo are not included here, but appear in Appendix B. Similarly, those articles which pertain chiefly to air passenger transportation are in Appendix C.

The bibliography is divided into four sections. Section 1 (51 entries) contains those articles which stress achieving the ability to predict demand. Section 2 (55 entries) is comprised of citations that particularly address the issues of modal choice analysis. In Section 3, (73 entries), the principal concern is with techniques for model development. Finally, Section 4 contains a few key references (15) to technological forecasting which we have found to be particularly useful.

In each section the entries are alphabetical by author, personal when known, other corporate.

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Section D-1, Demand for Transportation

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