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Airport Curbside Planning and Design

PETER B. MANDLE, E.M. WHITLOCK, AND FRANK LaMAGNA

A method of estimating airport curbside demand and procedures for adjusting this demand for various service levels and operating conditions are discussed. Data are presented describing the effects of passenger and vehicular activity at the airport curb areas. Operational problems that typically occur at an airport curb are discussed. Factors influencing operational problems at the curb are addressed, as well as a means of determining curb frontage requirements, demands, and relating these to levels of service, based on observations at six major U.S. airports. This approach affords airport planners an opportunity to measure the degree of use of the curbside area and to correlate curbside requirements to the effective length of curb. Volumes of originating and terminating passengers were found to be of prime importance in forecasting demand as contrasted to total enplanements and deplanements. The enforcement level of parking regulations and corresponding vehicle dwell time was found to strongly influence curbside capacity. Design considerations such as roadway and sidewalk widths that affect the efficiency of the curb are presented, and criteria are recommended.

An airport terminal building's primary function is to facilitate the transfer of passengers and goods between ground and airborne transportation modes. Recognizing this, the importance of the terminal curb areas becomes evident. The actual transfer between ground and air transport occurs at two locations: the terminal curbs and the aircraft gates. Both areas must function properly, or the entire air/ground linkage will not operate in balance. It is at the curbside areas adjacent to the terminals that all arriving and departing air passengers (except those using nearby parking facilities) board or alight from ground transport vehicles. Unlike gate operations, tenant airlines share a common curbside area at most airports and, consequently, any resulting problems are felt by all users.

Factors influencing operational problems at the curb are addressed, as well as a means of determining curb frontage requirements, demands, and relating these to levels of service. This approach affords airport planners an opportunity to measure the degree of use of the curbside area and to correlate curbside requirements to the effective length of curb.

Observation of curb use at several major airports and related data collected for parts of prior and current ground transportation studies were used in the preparation of this paper. Data were derived from Miami International Airport, LaGuardia Airport, Dallas/Fort Worth Airport (D/FW), Lambert-St. Louis Field, Denver Stapleton International Airport, and, John F. Kennedy International Airport (selected terminals). The interrelationships of these parameters are presented, with emphasis on how the use characteristics of each airport, stemming from various studies, affect curbside operations. Alternative methods of balancing curb demand and supply are presented.

CAUSES OF AIRPORT CURBSIDE CONGESTION

Operational problems encountered at the airport curb are caused by behavior of arriving and departing passengers, operational restrictions occurring in the terminal area, and a variety of other contributing factors, such as the following:

1. Imbalances between the available capacity on the airside sector and the landside areas;
2. Surges due to the arrival or departure of passengers to and from high-capacity aircraft;
3. Uneven distribution of passenger loads along the curbs, due to the peaking patterns of individual airlines;
4. Activity concentrations on terminal doors, curbside and baggage check-in locations, resulting in imbalances in available space and demand;
5. Lack of strict enforcement of parking duration restrictions along the curb, resulting in vehicles remaining at the curbs for longer periods than desirable; and,
6. Perceived difficulties in recirculating from the curb back to parking, from parking to curb or, when unable to find a curb space, back again to the curb.

As each airport serves passengers who have different demands and exhibit individual seasonal and daily peaking patterns, the types of congestion problems will differ from airport to airport, and even among individual terminals. For example, Miami International serves a larger proportion of recreational or tourist passengers than does LaGuardia, where more air passengers are traveling on business-related purposes. At Miami International the passenger peaks occur at midday as they are related to hotel check-out times, while at LaGuardia peaking occurs at the start and end of the business day. Differences observed at these airports, including the number of bags per passenger, visitors accompanying air passengers, party size, and, accordingly, the average dwell time at the terminal curb, are all related to the proportion of passengers on business or vacation trips.

AIRPORT CURBSIDE DEMAND FACTORS

Factors that influence operations of the curb can be separated into those directly related to demand and those that influence supply as shown in Figure 1. Three basic groups of factors influence curbside demand. These are

1. Airport Activity Levels--Volume of originating/terminating passengers during peak periods, seasonal peaking characteristics, and short-term parking location, availability, and cost;
2. User Characteristics--Mode of travel to and from terminal, proportion of air passengers using curb, number of well-wishers and greeters accompanying air passengers, passenger trip purpose/arrival time before flight, and, number of bags per passenger; and
3. Vehicle Characteristics--Number of air passengers per vehicle, time vehicle remains at curb, and proportion of buses, taxis, and other commercial vehicles in traffic stream.

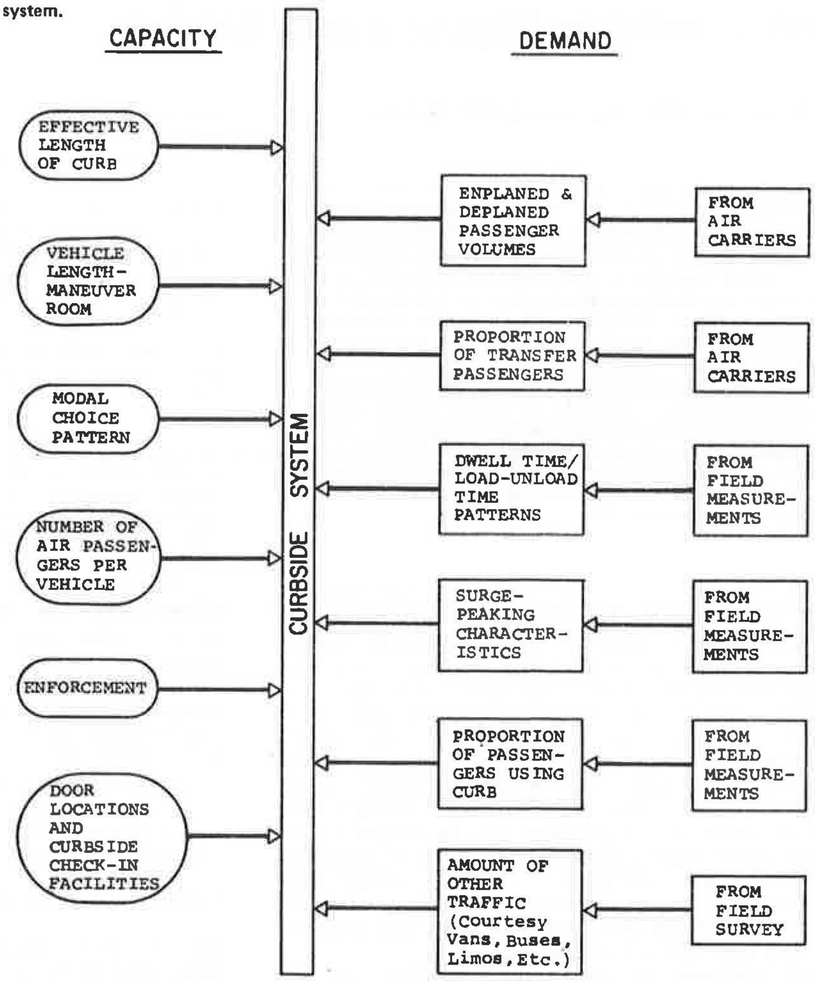
Although these characteristics all influence demand for curb space, curb demand in actuality is sensitive to fluctuations in only a few. Specifically, curb length demand changes significantly when the average vehicular dwell time varies by as little as 30 s, is sensitive to changes in the proportion of vehicles and passengers using curb and vehicle occupancy, is relatively insensitive to modal choice, and is relatively insensitive to changes in party size and trip purposes.

AIRPORT CURBSIDE CAPACITY FACTORS

Several factors determine the capacity of airport curb frontage areas. These include the following:

1. Effective Length of Curb--The length of curb

Figure 1. Elements that influence airport curbside system.



available for use, excluding nonusable space such as areas adjacent to columns or other physical barriers.

2. Vehicle Length and Maneuvering Room--The vehicle length plus the necessary maneuvering room. Larger, less maneuverable vehicles require more time to enter and exit a curb space and, as they carry more passengers, occupy these spaces for a longer time period. The average curb space per vehicle needed is 25 ft for an average size automobile, 20 ft for a taxi, 30 ft for a limousine, 40 ft for a courtesy van or car rental van, and 55 ft for a bus. Adequate travel lanes must be provided to assure the continuous flow of vehicles and to enable motorists to bypass vehicles stopped at the curb.

3. Enforcement--Vehicle dwell time is directly related to the enforcement of curbside parking and vehicle standing regulations. Strict enforcement encourages reduced curbside dwell times, thereby increasing curbside capacity, while lax enforcement tends to result in longer vehicle dwell times and necessitates a greater amount of curb space for equivalent quality of operations.

4. Facility Locations--Motorists try to park near terminal doorways, curbside baggage check-in facilities and skycap services, which can disperse vehicles along the curb frontage roadways. Similarly, motorists tend to park near the signs identifying their airlines rather than proceed to available curb space located elsewhere along the curb.

Service Levels

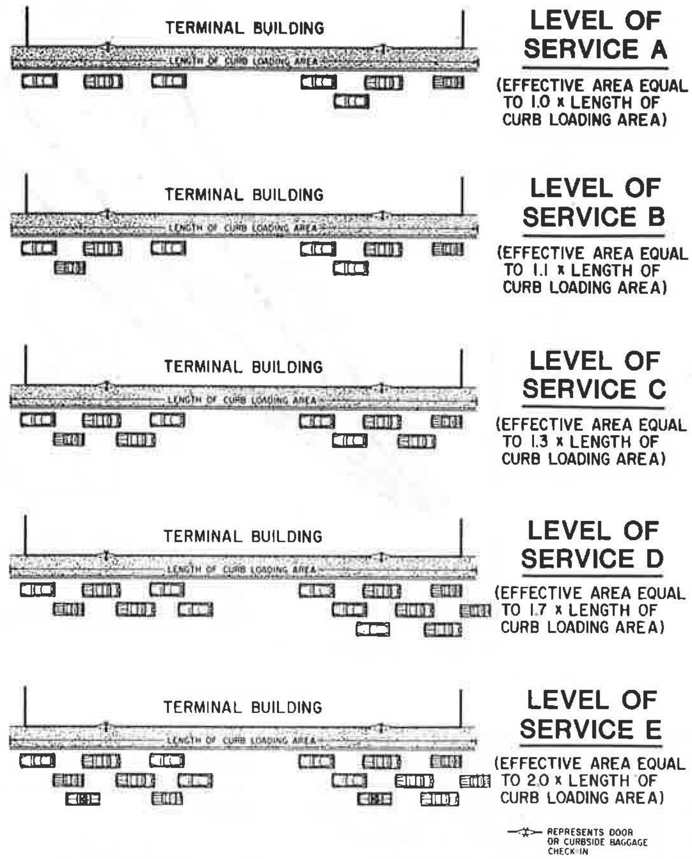
For a given physical arrangement, the capacity is constant, but the service level (or quality of operation) may fluctuate. At the airport terminal curb, service levels are considered to be related to the amount of double to triple parking (congestion) that occurs. Level of service is generally defined as a qualitative measure describing user (i.e., motorist) satisfaction with a number of factors influencing the degree of traffic congestion (1). Figure 2 illustrates these service levels at the airport curbside.

Level of service A represents vehicular operations at the curb where motorists experience free flow (no interference from other vehicles or pedestrians) conditions. Arriving drivers can stop immediately adjacent to the curb at a location they select. It is unrealistic to design for this service level during peak periods at major airports.

Level of service B, like level A, describes relatively free flow conditions; however, with level B, limited double parking can be observed at primary demand locations (baggage check-in or major entrance and exit points) along the curb frontage. The effective curb length is equal to 1.1 times the linear dimension of usable curb space.

Level of service C is indicative of activity observed at most major airports during peak hours. It is suggested that level C is appropriate for peak-period design conditions at major airports. Level of service C represents operating conditions where double parking near doors is common, and some intermittent triple parking occurs. The effective curb length for level C is equivalent to 1.3 times the usable curb length.

Figure 2. Airport curbside levels of service.



Level of service D exhibits conditions where triple parking becomes more prominent and where vehicle maneuverability is somewhat restricted. Queues of vehicles form both along the curb roadway and at the entrance to the curb frontage road. The effective length of curb for level of service D is equal to 1.7 times the usable curb area.

Level of service E occurs at a curb when motorists experience significant delays and queues. Both congestion and multiple parking are evident throughout the entire terminal curb frontage area. Momentary breakdowns in operation occur as the flow of vehicles comes virtually to a halt. The effective length of curb under these conditions is equal to at least 2.0 times the actual linear footage of usable curb. Where unusually wide curb frontage roadways exist, between 50 and 60 ft (curb-to-curb width), this value can be increased to 2.5.

Analysis Method

In the past, several criteria have been published for determining curb frontage requirements. Among these methods are

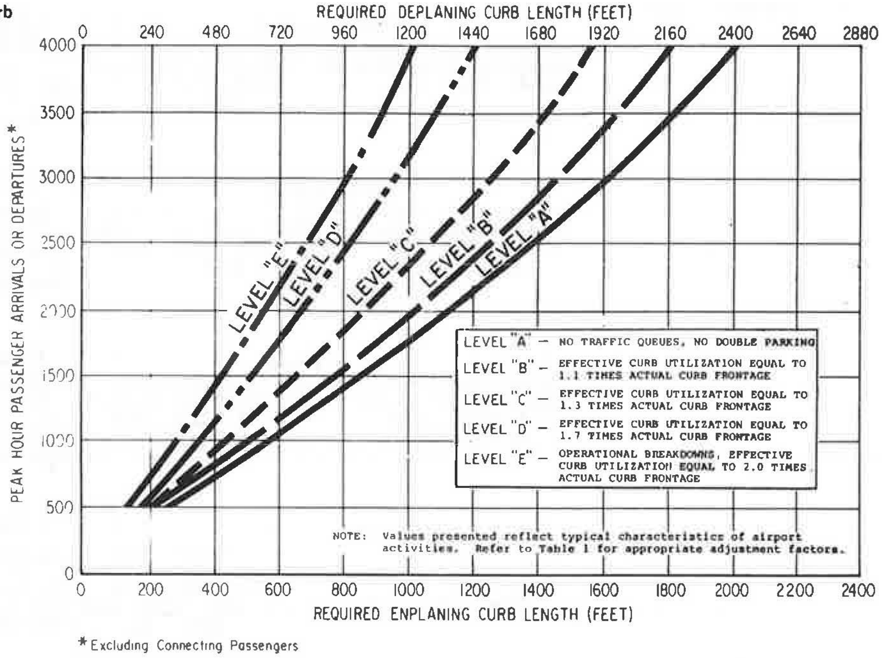
1. General rules of thumb relating curb space demand to annual passengers [for example, see DeNeufville (2)] or to peak-hour passengers [for example, see DeNeufville (2) and Whitlock and Cleary (3)];
2. Procedures requiring data that describe various curbside demand characteristics [for example, see Parsons (4)] and mathematical models of various forms [for example, see Tilles (5)]; and
3. Computer models that simulate curbside vehicular activities [see Hall and Dare (6) for an example of a simulation model].

Suggested Analysis Method

Curb frontage requirements should be calculated solely for originating or terminating air passenger volumes. By using data obtained during peak-period surveys at six major airports, curb frontage needs were ascertained, based on the number of peak hour vehicles using the curb. A review of these data indicated little variation between airports in the various factors influencing demand. Observations at airports throughout the United States indicate the combined proportion of private vehicles and taxis is relatively constant and revealed that the volume of other traffic (commercial vehicles) varied considerably. The volume of commercial vehicles had a greater influence on curb frontage needs than fluctuations in the percentage of private vehicles versus the percentage of taxis (7). For analysis purposes, the following average values, which are representative of most U.S. airports, were used:

1. Mode of arrival (private vehicles and taxis combined), 75 percent;
2. Percentage of private vehicles and taxis using the curb, 80 percent;
3. Vehicle occupancy, private vehicles and taxis combined, 1.5 air passengers/vehicle;
4. Percentage of passengers (excluding transfer) arriving at the terminal via people mover and fixed rail, 0 percent;
5. Ratio of all other vehicles to automobiles and taxis, 1:5 for up to 3000 peak-hour passengers and 1:6 for more than 4000 peak-hour passengers;
6. Vehicle dwell time (private vehicles and taxis combined), 2.0 min.; and
7. Vehicle dwell time (all other vehicles), 2.5 min.

Figure 3. Suggested method for estimating curb frontage needs.



The method presented in this paper includes a constant rate of other (non-automobile and taxi) vehicles on the curb. The analysis also revealed that the peak hour of curb activity depends on the arrival and departure patterns of air passengers. Thus, the curb frontage requirements are based on the following formulas:

$$C = C_1 + C_2$$

$$C_1 = (P \cdot M/V) \cdot F \div (60/D_1) \cdot L_1$$

$$C_2 = (P \cdot M/V) \cdot A \div (60/D_2) \cdot L_2$$

where

- C = curb frontage needs in linear feet for all vehicles,
- C_1 = curb frontage needs in linear feet for private vehicles and taxis,
- C_2 = curb frontage needs in linear feet for all other vehicles,
- P = equivalent peak hour of air passengers arriving at curb (based on an assumed arrival distribution rate),
- M = percentage of passengers using private vehicles and taxis,
- V = vehicle occupancy of private vehicles and taxis (combined average),
- F = percentage of private vehicles and taxis using the curb,
- D_1 = vehicle dwell time--private vehicles and taxis (combined average) in minutes,
- D_2 = vehicle dwell time (all other vehicles) in minutes,
- L_1 = average vehicle berth space (private vehicle and taxis) equals 25 ft,
- L_2 = average vehicle berth space (all other vehicles) equals 45 ft, and
- A = ratio of "other vehicles" to combined total of automobiles and taxis.

By using the values presented in Figure 3 for levels of service A through E, the amount of curb frontage can be estimated based on the desired service level. Conversely, based on a given curb length and volume of peak-hour air passengers, the level of service of the curb frontage can be determined.

Adjustment Factors

It should be noted that the values presented in Figure 3 are based on average values for vehicle occupancy, vehicle dwell times, proportion of vehicles using the curb, rate of flow of other traffic (non-private vehicles and taxis), and mode of arrival. Should it become necessary to deviate from these values, adjustment factors have been developed and are presented in Table 1. These factors should be applied to the linear footage of curb obtained in Figure 3. For example, at D/FW Airport a fee is charged for all vehicles entering the airport, even if they do not park. Thus, at D/FW, the percentage of vehicles using the curb is less than average. As a result, it would be necessary to adjust the value obtained from Figure 3 for this location. If, at a given airport, only 60 percent of vehicles use the curb, then by using Table 1 a factor of 0.80 should be multiplied by values presented in Figure 3.

Similar adjustment values are presented in Table 1 for other variables. Thus, at locations where private vehicle dwell times, vehicle occupancy, and percentage of vehicles using the curb vary from those typically experienced, adjustments can be made by using established values (Table 1).

With the characteristics mentioned considered constant, it is possible to estimate peak-hour enplaning or deplaning curb length requirements, knowing originating or terminating passenger volumes (i.e., excluding transfer passengers) and assuming a given level of service. In planning for future curb length requirements, it is important to consider possible changes in aircraft arrivals or departures that would alter the time or day of the peak period or the proportion of activity occurring during the peak period.

SOLUTION OPTIONS AND DESIGN CONSIDERATIONS

Several methods have been employed at terminal curb

Table 1. Adjustment factors for determining curb frontage.

Variable	Factor
Average vehicle occupancy (air passengers per vehicle)/(automobiles and taxi combined)	
1.0	1.35
1.1	1.25
1.2	1.18
1.3	1.10
1.4	1.05
1.5	1.00
1.6	0.95
1.7	0.90
1.8	0.88
1.9	0.85
2.0	0.80
Vehicles using curb (%)/(automobiles and taxi combined)	
60	0.80
65	0.85
70	0.90
75	0.95
80	1.00
85	1.05
90	1.10
95	1.15
100	1.18
Ratio of other vehicles versus automobiles and taxis (peak hour)	
Up to 3000 passengers	
0.10:1.00	0.85
0.15:1.00	0.90
0.20:1.00	1.00
0.25:1.00	1.05
0.30:1.00	1.10
4000 passengers or more	
0.05:1.00	0.85
0.10:1.00	0.90
0.15:1.00	1.00
0.20:1.00	1.05
0.25:1.00	1.10
Mode of arrival (%)/(automobiles and taxi combined)	
60	0.85
65	0.90
70	0.95
75	1.00
80	1.03
85	1.07
90	1.12
95	1.15
Vehicle dwell time (min) automobiles and taxi combined	
1.5	0.85
2.0	1.00
2.5	1.15
3.0	1.30
3.5	1.45
All other vehicles	
1.5	0.83
2.0	0.90
2.5	1.00
3.0	1.04
3.5	1.11
4.0	1.20

Notes: Factors of 1.00 indicate those values used in determining curb frontage requirements contained in Figure 3.
Automobiles reflect all private vehicles accommodating air passengers. Meeter/greeter vehicles without air passengers are included as part of all other vehicles.

frontage areas to increase capacity of the system. These methods, which include both physical and operational improvements, are described here.

Physical Improvements

Provision for additional curb frontage roadways, bypass lanes, and multiple entry and exit points would seem to be the simplest solution in terms of obtaining additional capacity at the curb frontage. Many airport terminal roadway facilities, however, are fixed in terms of (a) availability of space for expansion and (b) cost implications for the provision of additional lanes.

Other practices, such as the use of remote curbs, park-and-ride facilities (remote parking), and downtown satellite terminals, have also been suggested as methods to reduce terminal curb frontage roadway traffic. Although these methods appear to be attractive approaches, experience indicates that there are some inherent problems. For example, a remote curb is provided at LaGuardia Airport. The remote curb provides an attractive environment for loading and unloading passengers as it is protected from the weather and can be entered directly from the terminal approach road. Also, an enclosed pedestrian bridge with moving sidewalks connects the remote curb to the terminal building. Despite these amenities, less than 5 percent of all curbside traffic elects to use this facility, even during periods when the main upper-level terminal curb is operating at capacity. The airport operator has indicated that the major reason traffic does not use this remote curb is the absence of baggage check-ins at this location.

Downtown terminals are provided in several cities. For example, New York City's East Side Terminal provides scheduled bus transportation to the metropolitan airports; however, this terminal has not proved successful. The causes suggested for the low demand for this terminal have been, again, the lack of baggage check-in facilities (passengers must transport their luggage from the bus to their check-in positions), the scattered distribution of passenger origins throughout the region, and operation and maintenance costs. As many passenger trips neither originate nor terminate in the central city, but rather in the outlying suburbs, it is not convenient for these passengers to use a downtown terminal. Thus, the ability to check in baggage directly for a flight appears to be an important factor in planning a successful remote curb.

Operational Improvements

There are certain operational improvements that, if implemented, may increase the capacity of the curb frontage system. The most important of these is improved enforcement of parking restrictions at the curb. Enforcement at the curb has been shown to reduce vehicle dwell times and improve the efficiency of curb use as vehicles are directed to empty spaces by an authorized person. For example, a reduction in the average vehicle dwell time for private vehicles and taxis from 2.0 to 1.5 min can reduce total curb requirements by 15 percent. The problem of double and triple parking is also somewhat controlled. Curb use may also be improved by redistribution of airline industry signs on the curb frontage roadway.

Segregation of traffic is another mechanism that can increase curb frontage capacity. In order to accomplish this, dual curbs have to be established to separate public transit vehicles from private vehicles on the curb frontage.

To minimize pedestrian-vehicular conflicts that may be associated with center island curbs, several actions have proved helpful. First, the number of locations where passengers may cross active roadways should be kept to a minimum. Providing pedestrian bridges is one means of implementation, but properly identified at-grade pedestrian crossings are more commonly employed. To assure that passengers use these crossings, barriers are often placed parallel to the curb, with openings only at the crosswalks. Second, traffic signs and, sometimes, traffic control signals are used to show motorists the location of pedestrian crosswalks and to provide necessary gaps in the traffic stream. In a few instances speed bumps are used to control vehicular speeds on curbside roadways.

Another consideration is to charge vehicles for the use of curb frontage areas, similar to the use of regulated airport parking facilities. This would reduce the attractiveness of curbside areas when compared with short-term parking facilities. This solution would require toll facilities on all access roads. This method is used at D/FW where all vehicles entering the airport, regardless of whether or not they use the parking facilities, are charged a fee. There is no differentiation for short-term parking or use of the curb, only a reduced rate for long-term (remote) parkers.

Modification of airline schedules can reduce the peak-period demands by spreading the amount of activity more evenly over the entire day. Requirements of hotels and businesses, as well as airline competition, make this an unlikely alternative, however. Schedules have been modified at some airports to reduce noise levels during late night hours. Also, air carriers currently offer reduced fares for night coach flights, which means other users are paying a premium. Thus, through selective airport landing fees or other mechanisms, it is feasible to use existing capacity more effectively.

Design Considerations

In the actual design of curbside areas the following guidelines have proved helpful.

Travel lanes (11-12 ft wide) and parking and loading lanes 10 ft wide should be used. A typical curb frontage would require 44 ft (two 10-ft loading lanes and two 12-ft travel lanes).

In heavily trafficked areas minimum clear widths of 15 ft are desirable. Flow impediments such as signs, curbside check-in counters, and doors act as restrictions. Greater widths should be provided in these areas, especially adjacent to terminal doors.

Signs should be visible from both motorists' and pedestrians' eye levels, but should not interfere with circulation. Thus, messages such as airline names should be perpendicular to vehicular traffic flow. Sign placement can aid vehicular circulation and reduce congestion. For example, if the name of the dominant carrier(s) is repeated near several doors, passenger drop-offs will be distributed over a longer section, reducing the impact on a single point.

Especially at lower-level curbs, it is necessary to assure that structures such as walls do not interfere with the line of sight of motorists. Closely spaced columns present a forest atmosphere, distracting motorists and interfering with traffic operations. Walls, especially in merging and weaving areas, can also reduce sight distances and reduce operating efficiencies.

Areas for baggage drop off and check in should be distributed throughout the system to reduce congestion. Similar to doors, multiple facilities will diffuse the demand over a larger area.

SUMMARY

Airport curbside planning requires careful consideration of the airport passenger characteristics and how they may affect demand. Physical features and external constraints on demand must be addressed in order to balance supply and demand and provide an adequate service level. A suggested method for estimating demand has been presented to airport planners in considering the needs of their terminal and to assure this critical segment of the airport will operate efficiently, safely, and properly. With this method, curb space requirements can be adjusted to reflect alternative levels of service at the terminal curb. The suggested approach recognizes that at major airports there is a little variation in several factors influencing demand. Among these factors are the proportion of passengers arriving in private vehicles and taxis (75 percent), percentage of vehicles using the curb (80 percent), proportion of nonautomobile and taxi traffic stopping at the curb, and average dwell time (2.5 min). Holding these factors constant, curb space demand can be related directly to originating and terminating passenger activity. Adjustment procedures for atypical conditions are given.

ACKNOWLEDGMENT

We have performed research and studied airport curbside activities at several major airports. Studies at three airports (LaGuardia, Denver, and Miami) were sponsored by the U.S. Department of Transportation's Transportation Systems Center (TSC) and corresponding airport operating agencies. Studies at John F. Kennedy International Airport were sponsored by American and United Airlines. Other studies such as Lambert Field-St. Louis and D/FW were sponsored by the Airport Operating Authority. The views expressed in this paper do not necessarily represent the opinions of these organizations. We would like to thank Mark Gorstein, Technical Monitor of TSC, for the support and advice offered throughout the work for this paper.

REFERENCES

1. Highway Capacity Manual. HRB, Special Rept. 87, 1965.
2. R. DeNeufville. Airport Systems Planning. MIT Press, Cambridge, MA, 1967.
3. E.M. Whitlock and E.F. Cleary. Planning Ground Transportation. HRB, Highway Research Record 274, 1969, pp. 1-13.
4. R.M. Parsons. The Apron Terminal Complex. Air Transport Association of America, Washington, DC, Sept. 1973.
5. R. Tilles. Curb Space at Airport Terminals. Traffic Quarterly, Vol. 27, No. 4, Oct. 1973, pp. 563-582.
6. C.A. Hall and C.E. Dare. A Simulation Model for an Enplaning-Passenger-Vehicle Curbside at High-Volume Airports. Presented at 57th Annual Meeting, Transportation Research Board, Washington, DC, Jan. 1978.
7. W. Smith and Associates. Airport Curbside Planning Guide. Transportation Systems Center, Cambridge, MA, DOT-TSC-1446, March 1979.

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Analysis of New Orleans Airport Ground Transportation System

RAY A. MUNDY

The airport ground access problem is a familiar term to many large airport managers. A portion of an airport ground transportation analysis conducted as part of an overall travel and tourism study for the New Orleans, Louisiana, area is discussed in this report. The objectives of this analysis were to (a) analyze present ground transportation alternatives, (b) recommend curbside priority arrangements, (c) recommend a ground transportation financing plan, and (d) anticipate major future problems that could exist when serving large volumes of tourists and visitors to the area. Research methods used were primarily qualitative in nature, based on existing local consultant reports and available general literature on various aspects of the ground transportation problem. This report should be of general significance and interest to other airport managers and planners due to the methodological approach taken. That is, instead of viewing the airport access problem as one of facility design per se, it was viewed as one of facility management. Emphasis was placed on maximum use of high-occupancy vehicles and a fair and equitable financing plan for all vehicles that use the airport ground access system. The report recommends that all elements of the ground access system—buses, vans, taxis, private automobiles, rental cars, etc.—be included in such an analysis and financing plan to improve the airport ground transportation system. This generalized management and financial approach could be of assistance to other airports faced with an access problem.

Airport ground transportation has typically been overlooked in the physical design and construction of many U.S. airports, only to become a major source of community embarrassment as congestion and curbside confusion result. Visiting businesspeople and vacationers often label a city as a nice place to visit but impossible to get to from the airport, or they may remember their visit primarily for the expensive cab trip taken from the airport. It is in the community's best interest to clearly think through the type of image it wants to portray to visitors. Because the airport ground transportation trip will be the visitors' first impression of their city, major urban areas should seek to give the impression of a clean, well-managed, efficient, low-cost, high-value place to visit through their ground transportation system.

Airport authorities or boards also have a vested interest in the quality of their ground transport providers. The "image" of the airport is also very often the result of the travelers' experience at curbside. Moreover, passengers carried by authorized ground transportation providers represent substantial revenue to the authority. When friends or relatives meet or discharge passengers, they typically use airport roadway and curb space without paying for the privilege. Such traffic adds greatly to the curbside access problem and costs more through the need for increased capacity while paying none of the incremental costs. Coordinated airport ground transportation providers, on the other hand, significantly reduce the airport vehicular traffic volume and pay handsome revenue to the airport for the privilege.

Many major U.S. airports have experienced serious ground site congestion problems. Typically, this access problem is thought to be caused by inadequate parking or roadway capacity. Stated another way, the problem is perceived to be one of facility capacity. Unfortunately, the typical solution is to build additional parking capacity and add curb lanes to support additional traffic. The additional capacity is quickly filled by new traffic demands and even-more-monumental traffic jams, tie-ups, and delays result. One needs only to visit the Los Angeles International Airport or Miami Airport to see the results of such expansion. In reality, it is not the number of vehicles the airport curb facility can process, but the number of people it can handle with the given facility. Interpreted this way, the problem can be reformulated into one of facility management as opposed to facility capacity. Such thinking encourages more efficient and effective airport facilities.

STUDY OBJECTIVES

This report discusses a segment of a larger travel and tourism study performed for the New Orleans, Louisiana, area. It sought to address present and potential problems the area may have with respect to its airport ground transportation alternatives and the area's general ability to accommodate larger amounts of tourist traffic. Specific attention was given to the opportunity to provide self-supporting, low-cost, efficient, and effective high-occupancy-vehicle transportation from the New Orleans International Airport to points in and about New Orleans. The objectives of the study were to

1. Analyze the present airport ground transportation alternatives at the New Orleans International Airport and their appropriateness for businesspersons, tourists, and conventioneers;
2. Recommend curbside priority parking arrangements that emphasize continued preference for high-occupancy vehicles;
3. Recommend a ground transportation financing plan that offers a fair and equitable rate to be paid by airport ground transportation providers; and
4. Analyze the potential future problems connected with serving larger volumes of tourists and visitors to the New Orleans International Airport expected when new hotel and convention facilities are completed in the New Orleans area.

As will be shown, these objectives were combined into a general strategic plan for improved airport ground transportation at the New Orleans International Airport. The recommendations call for a reassessment of current plans to build a high-rise parking garage and a continued commitment to encourage low-cost, high-occupancy-vehicle curbside priority.

CURRENT CONGESTION PROBLEMS

Current traffic problems at the New Orleans International Airport stem from one of the poorest airport roadway access systems ever encountered. Two cardinal rules of airport roadway planning are to avoid at-grade traffic crossovers whenever possible and to decrease the curbside total traffic as much as possible. The present roadway pattern deliberately created an at-grade traffic crossover entering the airport access and routing all traffic in front of the terminal before going on to other destinations, i.e., car rentals, courtesy cars, employees, etc.

PARKING

Parking at the New Orleans International Airport was

Figure 1. Parking spaces provided in relation to enplaning passengers.

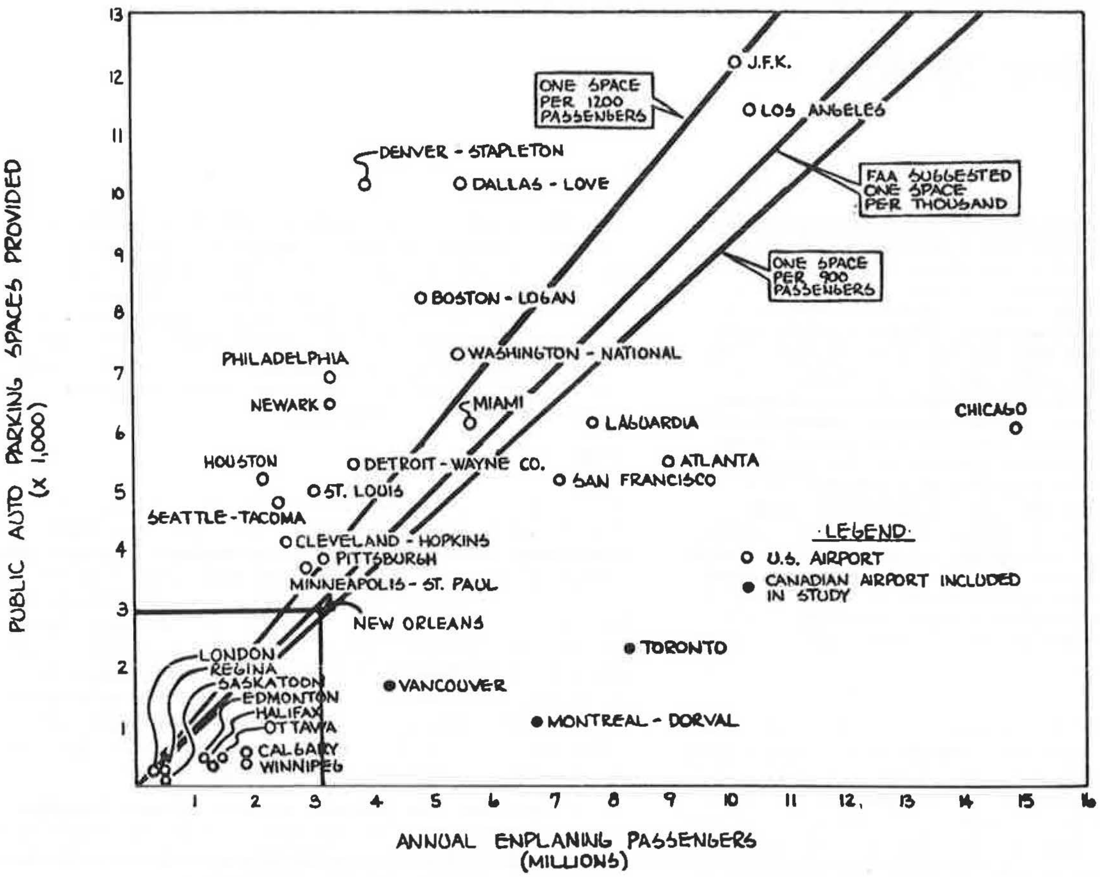


Table 1. New Orleans International Airport parking facility revenues.

Item	Revenues ($) Long Term[a]	Short Term[b]
Date		
January 1980	152 988.15	111 831.62
February 1980	135 408.60	112 707.58
March 1980	146 174.52	113 023.05
April 1980	143 148.50	111 205.20
May 1980	154 098.90	121 825.11
June 1980	164 321.93	127 961.61
July 1980	158 542.99	133 162.68
August 1980	159 173.50	142 732.05
September 1980	151 428.23	111 654.60
October 1980	168 227.18	120 752.10
November 1980	150 418.87	115 084.26
December 1980	153 022.05	121 428.85
Total	1 836 953.42	1 443 268.71
92.12 percent paid to New Orleans Aviation Board	1 692 201.49	1 329 631.26
Avg revenue per space	58.20	232.29
Avg revenue per vehicle	10.32	1.42

[a]No. of spaces = 2423; total no. of vehicles in lot (May 1979-May 1980) = 163 916.
[b]No. of spaces = 477; total no. of vehicles in lot (May 1979-May 1980) = 935 114.

perceived to be a major problem, and an additional 1539 parking spaces were recommended as necessary by the year 2000. An earlier study by Lambert and Associates (1) depicted parking demand to be saturated; however, in comparison with other major airports of similar size, New Orleans appeared to have adequate parking spaces available (Figure 1). As shown, New Orleans had 2900 parking spaces available for 3.2 million total enplaning passengers. This is well within the Federal Aviation Administration's recommended range (2).

Further analysis indicated the revenue received from long-term versus short-term spaces to be significantly different (Table 1). Short-term parking spaces generated $232 per month per space while long-term spaces generated only $58 per space per month. Given the normal costs associated with building parking structures (Table 2), it was not cost-effective to construct additional long-term parking spaces if parkers were drawn from the short-term lots.

On the other hand, additional short-term spaces, properly constructed, could represent handsome returns to the airport authority. Such additional spaces could be easily obtained by using existing spaces now dedicated to the taxi holding area and/or those currently being used by rental car companies.

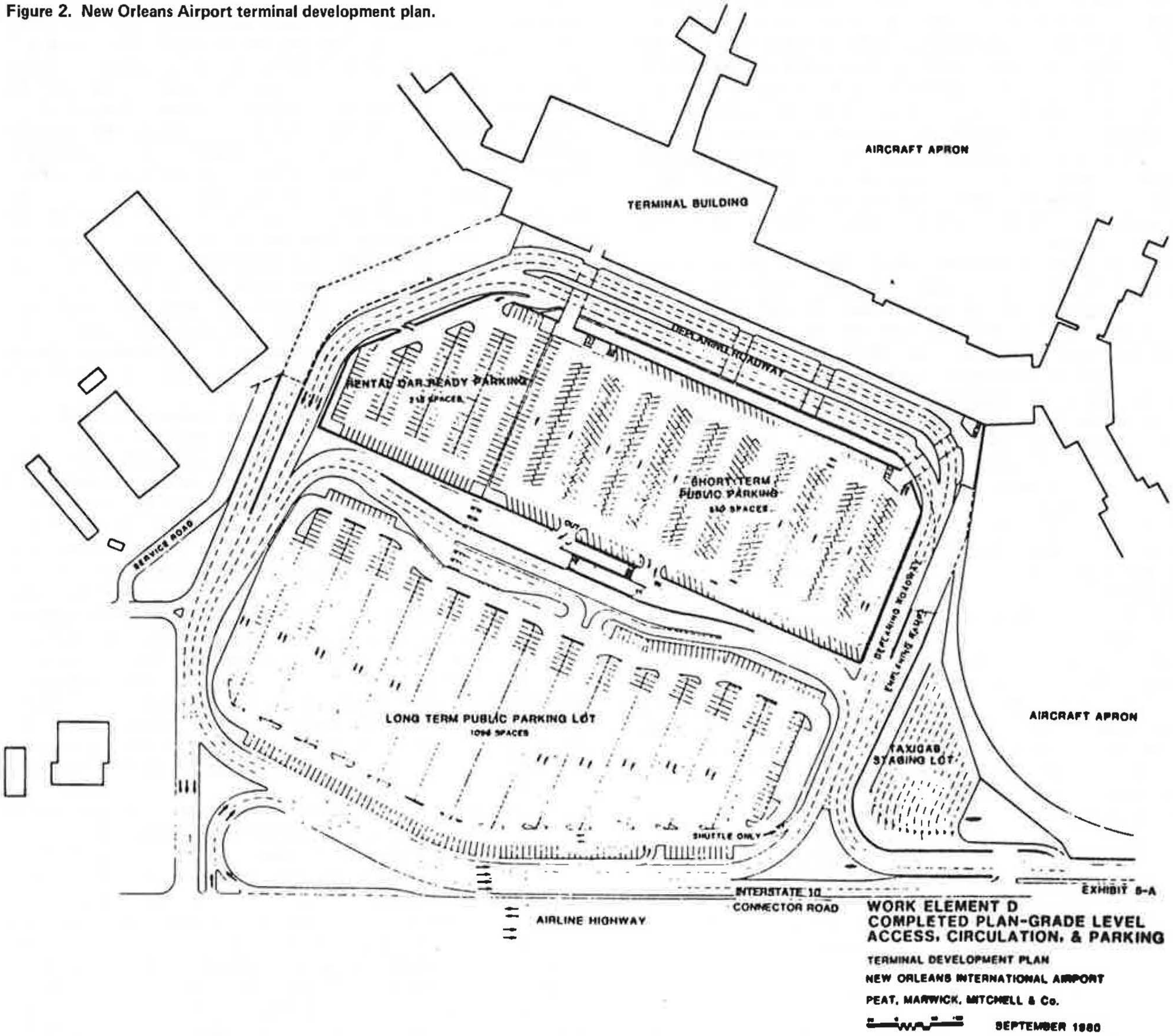
The taxicab holding area could easily be moved to the southeast side of the airport just off the main approach highway from New Orleans' Highway I-10 Connector (Figure 2). An equal or greater number of spaces for taxicab parking could be created with the same priority system granting two or three taxicabs at the designated airport curb. A simple green-light device would be used to signal cabs in the waiting area when additional cabs are needed. Most major airports have moved their cab holding area away from the terminal area in order to more effectively use these close-in spaces. While the taxicabs pay a fee to provide service at the airport, the fee ($200/year) should not entail them to occupy a close-in parking space that has the potential of generating $2784/year in revenue. Due to needed roadway space, not all 175 spaces used currently for the taxi holding area would be available for short-

Table 2. Surface parking costs.

Land ($/ft²)	Cost per Stall ($)	Construction[a] ($)	Annual Amortization[b] ($)	Annual Taxes[c] ($)	Annual Maintenance[d] ($)	Annual ($)	Monthly ($)
1	330	330	66	19.80	19.80	105.60	8.80
2	660	330	99	29.70	19.80	148.50	12.38
5	1650	330	198	59.40	19.80	148.50	12.38
10	3300	330	363	108.90	19.80	491.70	40.98
15	4950	330	528	158.40	19.80	706.20	58.85
20	6600	330	693	207.90	19.80	920.70	76.73
30	9900	330	1023	306.90	19.80	1349.70	111.48

[a] $1/ft². [b] 10 percent of land cost plus construction cost. [c] $12/$100 of assessed valuation at 25 percent of actual. [d] $0.06/ft².

Figure 2. New Orleans Airport terminal development plan.



term parking. However, if only 100 spaces were available, this would represent a potential revenue of $278 400/year in additional short-term parking fares.

Spaces currently occupied by rental car companies for close-in parking were also candidates for conversion to short-term parking. The new airport terminal traffic pattern (see Figure 2) recommended in a Peat, Marwick, and Mitchell report (1980) would encompass some of the area now used for rental car parking. Given the need to add parking availability without substantially adding to the cost, there is no reason why this valuable space should be used for rental car agencies at an airport the size of New Orleans International. As airports have grown and become more crowded, logical response is to move some nonessential functions out of the airport terminal if possible. In a large number of cases, this has meant, at first, the close-in parking for rental car agencies and, in cases of extreme congestion, such as at Los Angeles Airport and others, even the rental car agency booths were moved out of the main terminal. Such a move has a double positive effect on ground transportation traffic in that (a) it frees up valuable close-in parking spaces for more revenue producing activity (short-term parking) and

(b) it eliminates return rental car traffic inside the terminal area.

New Orleans International Airport travelers rented automobiles between 9 and 15 percent of the time. Thus, a significant amount of present amount of terminal area traffic would be eliminated if their return lots were removed from the immediate terminal area.

Rental car agencies paid the New Orleans Aviation Board 10 percent of their gross for the right to do business in the airport terminal building and park their vehicles on airport property. Removal of these automobiles to the remote lots currently used for storage of rental cars and shuttling passengers to and from the terminal building would not add significantly to the costs and is an acceptable mode of operation at major airports. The anticipated reduction in airport fees paid by the rental car firms should not be expected to be more than the increased cost of providing the shuttle service similar to that provided for employee parking in these remote lots. The 200 close-in short-term parking spaces currently occupied by the rental car companies represented a potential $556 800 in annual revenue with no additional costs once the new traffic plan had been implemented.

It was also suggested that the Aviation Board take a very pragmatic view toward long-term parking. Currently, it is generating $66.15 per space per month, with a current fee of $4/24 h. (It is suspected that rates may be held at this level to keep par with off-airport parking rates.) Given the average number of long-term parkers of 13 659/month, this represents an average of $10.32/parked vehicle in 1980 and 1981 or an average stay of 2.75 days. Pressure for more and more long-term parking will be brought to the Aviation Board. However, a proper balance between long- and short-term availability must be maintained. Because the Aviation Board derives more than $10/automobile in the long-term lot, as opposed to only $1.42/automobile in the short-term lot, there is no reason to rush into more long-term space availability. Providing this space may actually decrease the $232 average revenue currently derived from the short-term parking spaces. Clearly, the logical approach would be to expand short-term parking availability at present rates (i.e., maximizing revenue per space) and provide remote long-term parking with shuttle service that would draw present off-airport long-term parkers--not present short-term parkers.

A final note on airport parking suggested that the present long-term rate of $4/day for close-in, long-term parking is low in comparison with other airports of comparable size. Immediate consideration should be given to a three-tiered rate with (a) shuttle long term at $4/day, (b) adjacent long-term $6-8/day, and (c) existing short-term rates.

AIRPORT GROUND TRANSPORTATION SYSTEMS

Airport ground transportation at the New Orleans International Airport is provided by a number of private and public transportation providers, including taxicabs, private limousine and bus companies, private hotels and off-terminal parking courtesy cars, limited public transit service from the New Orleans Public Transit Operators, and, of course, the private automobile. A breakdown of entering passenger vehicle mode use is shown in Table 3. As shown, 23 percent of the airport travelers were carried in either buses or limousines that represented only 2 percent of the traffic. Taxicabs transported another 23 percent but represented only 10 percent of the vehicular traffic. Finally, it should be noted that private automobiles, while representing 87 percent of the vehicles on the roadway system, transported only 31 percent of the passengers for a ratio of 0.17 actual air passengers to every private automobile entering the terminal area. This is significantly below the national average for airports the size of New Orleans (Table 4). Ironically, the ratio of all air passengers to entering vehicles is exactly what it could be expected to be (0.48) or 2 vehicles entering for every one passenger. At the New Orleans International Airport, however, the average is being arrived at by a much higher than average number of arriving air passengers on bus, limousine, taxi, and shuttle vehicles, and a low number of actual air passengers arriving by private automobile. Clearly, there is an enormous amount of airport vehicular traffic that has no purpose in being routed through the terminal area. The recommended traffic plan should eliminate much of this unnecessary traffic and it should be understood that the New Orleans International Airport currently has an excellent ratio of public passenger vehicles use. Compared with airports larger than itself, New Orleans is much more effective in high-occupancy-vehicle use (Table 4). As shown, New Orleans International has 23 percent of arrivals in airport limousine or bus. This is matched only by Miami (25 percent), but nearly 42 percent of Miami arrivals come in private automobiles, while only 31 percent of New Orleans' arrivals come by private automobile--the difference being made by taxicab arrivals, 22 percent of Miami International versus 37 percent for New Orleans International.

Clearly, in any revamping and enlargement of the airport ground transportation access system, this historic good balance of airport passengers on public transportation vehicles should be maintained and encouraged. The present high use rate is the result of several factors--some planned such as frequent airport limousine and bus service and some not planned--buses cannot travel any other lane on the lower deplaning level other than the inside curb lane that dictates to them the premium curb space. In essence, the arriving passenger must consciously walk by the least expensive ground transportation modes (limousine and bus) before reaching taxicabs and private automobiles on lanes farther out. Thus, the curb prioritization currently provided for public high-occupancy vehicles is crucial in any recommendation for good future ground transportation systems.

At present, the authorized ground transportation provider--Orleans Transportation Service, Inc.--pays the highest percentage of any mode, 23.6 percent of revenue for the use of the highest priority curb lane, i.e., the one closest to the terminal. This represents the total amount of revenue of $300 000 annually to the airport (Table 5). Taxicabs are given second level and lane priority and represent a potential revenue of nearly $500 000/year at $200/cab with nearly 2500 permits authorized. (Only $110 000 has been collected, however.) It should be pointed out that total revenues (if collected) may be misleading. As a dollar amount per passenger, the authorized limousine and bus provider pays $1.18/passenger carried (23.6 percent of the $5 fare) to the airport, but taxicabs, handling 37 percent of the passengers or 1 184 000 passengers, pay only $500 000 (if collected) or 42 cents/passenger on a $14 fare to downtown, or 3 percent of the revenue.

Charter vans and limousines, not authorized for general pickup at the airport by agreement with airport authority, are assigned a level three lane priority and charged $400/year per charter van or limousine and $1/trip. Parking lot courtesy vehicles

Table 3. 1979 passenger distribution by mode of vehicle entrance per day.

Mode	No. of Vehicles	No. of Air Passengers	Percentage of Air Passengers	Air Passenger to Vehicle Ratio
Passenger car	11 550	1 972	31	0.17
Taxicab	1 340	2 385	37	1.78
Limousine and buses	200	1 500	23	7.50
Off-airport parking shuttles	215	590	9	2.74
Total	13 305	6 447		0.48

Table 4. Average observed modal choice patterns at Miami, Denver, LaGuardia, and New Orleans Airports.

	Airport (%)				
Mode of Arrival	Miami	Denver	LaGuardia	John F. Kennedy/ American Airlines	New Orleans
Private automobile	42	56	25	46	31
Car rental bus	11	14	9	3	
Taxi	22	13	46	35	37
Airport limousine	10	5	13	7	23
Bus	15	3	5	9	
Other		9	2		9

Note: Data exclude transfer passengers, based on 6-h surveys conducted by Wilbur Smith and Associates at Miami; March 17 and 18, 1978; Denver, April 20 and 21, 1978; LaGuardia, May 24 and 25, 1978; and John F. Kennedy/American Airlines, January 27, 1978; and data for New Orleans taken from Surface Transportation and Parking Study, Lambert and Associates, 1979.

Table 5. New Orleans Airport vehicle traffic fees.

Mode of Traffic	Revenue (%)	Rate per Vehicle	Lane Assignment Priority	Total per Year ($)
Charter limousine/bus	23.6		1	300 000
Other charter limousines and vans		1/trip	1	400[a]
Other charter buses		2/trip	1	600[a]
Taxis	3.0		2	500 000
Hotel courtesy cars/ limousines			3	400[a]
Off-airport parking shuttles			3	400[a]
Airport rental courtesy vehicles			3	400[a]

[a]Per vehicle.

are charged $400/year plus $10 for each parking space available at the parking lot operator's location. Thus, an off-airport parking facility with 100 spaces might pay the Aviation Board $1000/year for the 100 spaces and another $800 for two shuttle vehicles. Referring to the earlier discussion on long-term parking revenues, these 100 spaces for long-term parking have a yearly potential of $69 600 ($58/space per month times 12 months). If the off-airport parking facility operates at similar occupancy levels as does on-airport long-term parking, then the operator would be paying only 2.6 percent (1800 ÷ 69 600) of revenue for the right to provide the service.

Hotel and motel courtesy vehicles are also charged $400/vehicle used per year plus $2.50/year per room in each hotel or motel. Assuming a 100-room motel with a single courtesy vehicle, it would pay $400 plus $250 or $650 for using the outermost lane. If one-half of the motel's average room occupancy (typically, 70 percent) are airport passengers, this 35 percent of 100 rooms time 350 days would mean 12 600 motel guests generated by airport travelers. In other words, the motel would pay 5 cents/passenger to the airport for the right to pick up passengers on the outermost lane.

Private automobiles including rental cars pay no per-vehicle fee to use the outer lane priority unless they park their vehicles in short-term parking. In summary, the present airport ground transportation providers paid a wide range of fees to pick up arriving passengers from zero to $1.18/individual.

It should be pointed out that the majority of the analysis concentrated on deplaning or arriving passengers to the airport. This is so for several reasons. Initially, this is where the major airport congestion problems have occurred. Many vehicles vie for the limited curb space to await arriving passengers on the lower deck near the baggage claim areas. Enplaning passengers and traffic generally have no such problem. Even without lane prioritization there are seldom any traffic problems. All arriving vehicles are permitted to drop off at priority curb side lanes on a first-come, first-served basis. Because people are normally just being dropped off and no parking is permitted, there is seldom a congestion problem. As the curb length is expanded, as was currently being recommended in New Orleans and other major airports, there should be no future congestion in the enplaning level. It should further be mentioned, however, that this condition is highly dependent on policy enforcement of the no parking or standing rules at curbside. These must be maintained or a congestion problem will definitely ensue. Also, as with many two-level airport structures, policing arriving vehicles, taxis, limousines, vans, etc., that drop off passengers for the proper permit and use of a prioritized lane would be expensive and hardly worth the benefit.

Finally, there is the general public's feeling (right or wrong) that anyone should be permitted to drop off passengers without having to pay a fee. This popular view was apparently upheld in a local court action, Toye Brothers v. the City of New Orleans, where the plaintiff argued there should be no fee for discharging passengers at the public airport. The case is being challenged by the Aviation Board and its outcome is not yet known. Therefore, the analysis, with its emphasis on deplaning curb space prioritization, suggested to the Aviation Board that it retire from the concept that all for-hire vehicles entering the terminal area pay a fee to do so and, instead, charge for the right to stop and pick up passengers at one of their curb lanes, thereby eliminating the issue of the right to discharge passengers. In effect, the Aviation Board would be saying that anyone may drop off at the airport, but only those willing to pay a fair and equitable fee for the privilege will be able to stop and pick up passengers. Others may stop (including private automobiles) when they wish to pay the minimum short-term parking fee.

CURB PRIORITIZATION

It was recommended that curbside prioritization at the newly designed facility be developed to maintain or improve the present balance of passengers using public transportation modes. Special emphasis needed to be placed on the encouragement of high-occupancy-vehicle bus and limousine service at the airport. As previously shown, this mode represented the highest return per passenger for the Aviation Board ($1.18 versus 42 cents for the next highest return--taxis), while being the least-cost mode to the arriving passengers. The high-occupancy-vehicle capacity was definitely needed as New Orleans was adding significant hotel and convention capacity and planning to host the 1984 World's Fair. Also, it was noted that the high level of limousine and bus transportation being recommended in no way would deter from the parking revenue potential at the airport. In reality, there are two separate markets--parking primarily aimed at local residents going to the airport and bus and limousine transportation aimed at arriving visitors, businesspersons, and tourists. The objective is to maximize the potential revenue for the airport on a fair and equitable basis for the traveling airline public. Toward this end, a lane and fee prioritization recommendation was made for the New Orleans International Airport Aviation Board.

RECOMMENDED PLAN

The newly designed deplaning roadway system consisted of six lanes of traffic for both enplaning and deplaning passengers. (As previously noted, deplaning passengers, by far, need careful planning for their ground transportation. Therefore, a much more refined analysis of enplaning passengers needs was undertaken.) The six enplaning lanes were to be separated by a single divider creating an inner roadway of three lanes and an outer roadway of three lanes. At present, there are approximately 720 ft of curbside; however, expansion to more than 1000 ft was planned. For purposes of this study, it was assumed that usable curb space, i.e., that which one could effectively use without constructing new entrances to the terminal building, would be approximately 800 ft. It should be noted that, at present, only one-half of the existing inner curb space was effectively used. Due to the curvature of the terminal roadway, much of the ends of the valuable curb were used for official parking. Considering just the potential revenue from short-term parking and not the use value of this expensive curbside frontage, some individuals were receiving a very expensive parking fringe benefit. The new roadway design would eliminate most of this dead space and make it available for high-occupancy-vehicle curbside use.

It was recommended that lane prioritization not differ greatly from the present pattern. After all, present curbside prioritization had made the New Orleans International Airport one of the nation's most efficient in the use of high-occupancy-vehicle public transportation. Therefore, it was recommended that future lane prioritization continue to result in the authorized bus and limousine airport ground transportation providers possessing the premium inner lane closest to the terminal building. Widening of the curb width on this area would remove any present problems of pedestrian or baggage handling congestion.

Given the current revenue per rider of $1.18 or 23.6 percent of revenue, it was important also that the authorized carriers be permitted to allow these vehicles to remain at the priority curb until departure time.

There were two authorized carriers--Orleans Transportation, Inc., and Mississippi Gulf Coast. Orleans Transportation was by far the larger of the two carriers, offering high-frequency service to the French Quarter and all downtown hotels. Due to the need for smaller vehicles in the French Quarter, Orleans Transportation required curbside parking for both limousines and buses. Since limousines and buses carry an estimated 23 percent of the traffic with only 1.5 percent of the vehicles, it was recommended that their spaces be located as conveniently as possible for deplaning passengers. If possible, new curb assignments should not attempt to confuse existing users of these ground transportation services. Since most who use Mississippi Gulf expected to find their vans located immediately to the west side of the terminal building, it was recommended their new curb assignment be in the same general area. Specifically, it was recommended that Mississippi Gulf Lines be reserved 40 ft on the innermost lane. This provided space for two vehicles to enter and leave at the western edge of the newly designed terminal roadway between the crosswalk and the end of the inner lane and would leave the crosswalk free for passengers to leave and enter the terminal area. It was recommended that Orleans Transportation, Inc., be assigned the entire curb between the planned sidewalks, or approximately 350 ft. This permitted space for several vans and buses to load residents, as well as visitors and tourists who could be expected to have more baggage than businesspersons. It was further recommended that the 350-ft curb area be designated as the public transportation terminal area with greatly improved signing to instruct travelers as to their options and costs. Consideration needed to be given to creating a ground transportation booth within the terminal area to assist passengers. There was a wall between the major baggage claim areas that prevented a single ground transportation information center. Removal of this barrier would make it possible to move the present information and ticket booth from the outside curb area inside, thereby permitting arriving passengers to make their ground transportation arrangements before getting their luggage. At present, arriving passengers must obtain information at the curbside booth after they have gathered their luggage if they are traveling downtown to the French Quarter. Current fees paid by the authorized ground transportation carriers more than justified their inner-lane priority and waiting privileges.

The remaining 350 ft of inner lane curb space was suggested for parking lot shuttles, charters, and other high-occupancy-vehicle users that wish to pay for the privilege of priority curbside parking. These vehicles would be picking up passengers by call or advance registration and, hence, should be able to comply with the 4-min suggested loading time. Charter buses would be the only exception, and these were to be made to comply with a 10-min maximum loading time recommendation.

In all likelihood, it was felt there would be a strong public attempt to open up the inner roadway curb lane to automobile traffic on the grounds that the new design provided for adequate traffic flow. Unfortunately, this rationale is severely deficient during peak loading times for deplaning passengers. That is, the theoretical capacity of the three-lane inner roadway would appear to be able to handle personal automobiles if the 4-min maximum wait were enforced. Seldom, however, will the airport operate at an average passenger load--especially with the introduction of newer wide-bodied aircraft and the increasing competitive desire of airlines to get travelers to their destinations at convenient times that are also peak travel times. Unless personal automobiles were kept from entering this inner roadway, even greater traffic tie-ups than those that existed would be the eventual result as business and tourism traffic grew, requiring additional policing efforts to keep traffic moving. Also, the center lane of the inner roadway was recommended to be kept open at all times--never permitting double parking or stopping to pick up passengers. Thus, it was recommended that a solid yellow center lane 8 ft wide be drawn on the pavement to connote its status as a fire lane. Strict enforcement of this no stopping or standing center lane needed to be undertaken at all times.

The outer lane of the inner roadway was recom-

Table 6. Recommended fee schedule for airport ground transportation vehicles.

Mode of Traffic	Revenue (%)	Rate per Vehicle	Lane Assignment Priority	Total per Year ($)	Recommended Fee Structure per Vehicle per Year ($)
Charter limousine/bus	23.6		1	300 000	No change
Other charter limousines and vans		1/trip	1	400[a]	1200
Other charter buses		2/trip	1	600[a]	1800
Taxis	3.0		2	500 000	600
Hotel courtesy cars/limousines			3	400[a]	1200 and 600[b]
Off-airport parking shuttles			3	400[a]	1200 and 600[b]
Airport rental courtesy vehicles			3	400[a]	1200[c]

[a] Per vehicle. [b] $1200 for inner roadway curb lane; $600 for outer roadway curb lane. [c] Plus $10/parking space per month.

mended for the exclusive use of taxicabs. Their current level of ridership, 37 percent, dictated a premium position and dedication of the entire third lane. Care was suggested to ensure that arriving passengers were properly informed of the existing taxi fares to common destinations for one, two, or three individuals. Finally, access from the remote taxi staging area recommended earlier was simplified by the recommendation of an electronic eye that determined whether or not vehicles were in the cab lane at the curb. As spaces were vacated by cabs, an electronic signal would transmit this information to the holding area and request additional cabs. In all probability, the present cab starter could not be eliminated, however; a human override control would be necessary to handle loads at peak times. The starter, it was felt, would also be necessary to prevent cabbies from leaving their vehicles to solicit passengers in the terminal area. Such soliciting is a common nuisance at many airports and should be eliminated if at all possible.

In this general plan, the major emphasis was on permitting only high-occupancy vehicles and public transportation (taxicabs) on the inner roadway. The outer roadway's three lanes were recommended for automobile traffic with pickup on the separating curb only and strict enforcement of the 4-min wait period. Obviously, it was in the best interest of the Aviation Board to have as many pick-up automobiles as possible park in the short-term parking lot at the $1 minimum. Therefore, parking in the outermost lane even for the 4-min minimum was not recommended. Double parking to pick up passengers waiting on the center curb would invariably take place. Only by keeping the outermost lane free from parking would continuous traffic flow be maintained. At peak times, therefore, it was recommended that this lane also be painted a solid yellow to connote its fire lane status.

GROUND TRANSPORTATION FINANCIAL PLAN

It was recommended to the New Orleans Aviation Board that a new ground transportation financial plan be developed and passed by the City Council as an ordinance aimed at equalizing the existing confused and highly discriminatory structure. As shown earlier, the least-cost mode, authorized bus and limousine, paid the highest percentage of revenue (23.6 percent of a $5 fare) and, by contracting obligation, agrees to provide service on a 24-h basis to common carrier airline passengers. Other fees ranged from 3 percent of revenue (taxis) to 2.3 percent for off-airport parking vans and less than 1 percent for hotel and motel courtesy vehicles. Finally, the current ruling in Toye Brothers, which prohibited the Aviation Board from assessing a fee for loading and unloading charter and courtesy vehicles, created a confusing situation that must be resolved. The right and responsibility of the Aviation Board to regulate airport ground transportation had to be affirmed. Such affirmation was necessary to both maintain the Aviation Board's ability to generate appropriate revenues from those who use the airport terminal and access facilities and avoid curbside congestion.

Recommendations for new ground transportation financial plans include the need to develop more short-term parking from existing spaces now dedicated to taxicabs and rental cars and a general increase in long-term parking rates. The plan also recognized that airport parking, for the most part, is an unrelated market to those out-of-town visitors, businesspersons, tourists, relatives, etc., that need airport ground transportation. The emphasis for out-of-town visitors was to be on maximizing a fair and equitable fee while encouraging low-cost high-occupancy vehicle public transportation. The current fees required by the different ground transportation providers and recommendations for new fees that would equalize the financial burden are given in Table 6.

As shown, the contract limousine and bus providers are maintained at their current 23.6 percent of revenue from deplaning passengers. This percentage was arrived at through a competitive bidding process and, although it is one of the highest in the United States, its rate could not be changed until the end of the current contract. This high percentage does, however, present a ceiling for all other fees to be paid.

Charter vans and limousines would be required to pay a one-time yearly fee of $1200, and no $1-per-trip costs to and from the airport. This recommendation was made for two reasons. Initially, the charter vans and limousines would be gaining a great improvement in their curb prioritization from what they now have, and the $1-per-trip charge elimination. The $1/trip is an administrative nightmare that is probably more expensive to collect than it is worth. Also, the $1200 fee would act to separate smaller "fly-by-night" operators that operate a sometime service from those who are attempting to build a larger volume of charter business. It was felt that the Aviation Board would have fewer charter companies to deal with but have as much or more service being offered by these strong charter carriers.

Charter bus fees would also be increased by $1200 to $1800/year with no $2-per-trip charge being assessed. As noted above, the per-trip charge is administratively difficult and expensive to administer. The increase in bus fees would also eliminate the casual provider and develop a few strong charter bus carriers that do business at the airport.

It should be noted that curb space is very valuable and, unless some mechanism such as a per-vehicle fee is used, curbside congestion and confusion can easily result. By charging significantly higher fees for charter limousine, van, and bus, it is felt that more-professional, high-quality service will result and, hence, better and more public transportation services. Also, the Aviation Board would begin to look on these carriers as significant revenue generators over those being picked up by a friend or relative and attempt to assist their development whenever possible.

Taxicabs currently pay an airport fee of $200 and were supposed to pay 25 cents/pick-up trip but there were some questions as to whether the 25 cents was ever collected. As previously noted, the taxi trip pays a substantially smaller amount per rider for the use of the inner roadway. Given the need to make their payment more equitable and eliminate the confusion over the 25-cent charge, a one-time annual permit fee of $600 was recommended. The average cab can easily generate between $150 and $200/day, so the $400 increase would be less than 0.005 of anticipated revenues and should not materially affect current cab fares. It would, however, act as a barrier to fly-by-night firms that provide less-than-adequate services.

Also, there appeared to be an oversight in the city ordinance that did not specify minimum insurance coverage required by taxicabs to serve the New Orleans International Airport. Just as charter vans or courtesy vehicles must have minimum insurance of 100/300/500, so should all taxicabs wishing to pick up at the airport. The public liability of the Aviation Board is greatly increased whenever they require a permit to provide services. If an airline passenger is unable to sue a fly-by-night taxi operator due to lack of financial assets for injuries incurred while traveling from the airport, the Aviation Board might be second in line because it had certified the taxi operator through its permit system. Clearly, whatever minimum public liability insurance is required of van, limousine, and bus operators on a per-person-accident basis should also be required of taxi operators. Such would greatly improve the overall quality of taxi service and guarantee a higher level of service to airline traveling passengers as well as provide the necessary protection for the Aviation Board.

Parking lot courtesy vehicles were currently paying only $400/year per courtesy vehicle and $10/year for each parking space available. Given the large amount of potential airport revenue that is being siphoned away by such operations, a $1200/year fee per courtesy vehicle was recommended and a $10/month fee for each parking space available at the operator's place of business. As new parking space is added by the Aviation Board, it would be necessary to protect the construction investment in these new facilities--especially if plans for the new high-rise parking structure were implemented. It might be necessary to raise such fees even higher if projected demand for these new parking spaces per number of airline passengers currently appeared to be adequate according to Federal Aviation Administration guidelines.

Hotel and motel courtesy vehicles, along with automobile rental courtesy vehicles, are typically a major source of congestion at airport deplaning curbs. Therefore, a two-tiered fee system was recommended for these vehicles. For those wishing to use the available inner roadway space for pick-ups, their permit fee would triple to $1200. However, if only the outer roadway lanes were used, their fee would be only $600/year per vehicle. In both fee structures, however, the $2.50 charge/year per room for assigned airport customer vehicles would remain. The $200 increase in present fees without improvement in prioritization would reflect the need of the Aviation Board to recover some portion of the new terminal roadway costs.

The recommended fee structure for airport ground transportation described above should greatly improve the flow of traffic from its present confused state and be a framework for continuing the high-occupancy-vehicle public transportation. It should also act as a catalyst for the present ground transportation providers to use larger equipment--buses versus vans in order to maintain the present low fare ($5) into the City of New Orleans. The need to provide an atmosphere where large vehicles are used cannot be understated. As more New Orleans convention and hotel capacity is added, more peak-time vehicles, i.e., buses, will be needed to transport passengers from the airport and around town. Through encouragement of frequent, high-occupancy vehicles at the airport, these vehicles will be in place when they are needed, thereby foregoing the expense of having to import buses to the New Orleans area during peak tourist times.

PEAK-TIME TOURIST PROBLEM AREAS

Most recommended plans are made for the normal operating capacity of a system, including airport ground transportation access systems. The recommended curb prioritization ensures that the bulk of premium curb space will be dedicated to high-occupancy vehicles that carry more than 60 percent of the airline passengers. However, New Orleans is a major tourist city with unusual visitor peaks for Mardi Gras and Superdome events, etc. Therefore, some attention had to be given to these travel peaks. When such peaks occur, the Aviation Board should have a ground transportation plan able to handle the load without confusion and needless congestion. It was suggested that the peak-travel plan call for an additional number of baggage handlers to be assigned and prioritized parking for high-occupancy vehicles. Although the appropriate number of baggage handlers needed was beyond the focus of this project, it was obvious that some attention be given to this since the increased number of baggage handlers vastly decreases the amount of wait time each vehicle will experience in loading passengers.

Two additional ground transportation recommendations were made specifically that will ease anticipated congestion problems. It was recommended that the eastern half of the third lane normally reserved for taxis would be temporarily dedicated to pick-up areas for parking lot, rental car, and hotel or motel courtesy vehicles and the entire inner lane (number 1) be reserved for authorized buses and limousines as well as charters. In addition, a staging area for high-occupancy vehicles waiting on arriving flights should be constructed away from the terminal area adjacent to the taxi staging area. These vehicles could then be called up by the groundside coordinator assigned to manage airport ground transportation during these peak times. Given the recommended plan and fee structure, it was felt that this would be the most efficient and equitable method of handling peak tourist times and yet maintain a reasonable traffic flow of the airport.

SUMMARY

This paper addresses the major airport ground transportation access problems and suggests recommendations for the New Orleans area. The major thrust has been to suggest ways in which more high-quality, high-occupancy-vehicle public transportation can be provided to handle the increase in tourist and business traffic expected in the future. Above all, the approach sought to make ground transportation options financially attractive to the Airport Aviation Board so that good operating relations will continue. The New Orleans International Airport has one of the best U.S. experiences in high-occupancy-vehicle transportation. Tourists and businesspersons from this country and others often remark how easy it is to get into the City with the alternatives of bus, limousine, cab, and rental cars readily available. It would be unfortunate if this reputation and high-occupancy-vehicle capacity were lost in the new airport roadway terminal system just when an influx of new business, tourist, and visitor traffic can be expected in the area. All should work together to see that an even better record in airport ground transportation is achieved here and elsewhere.

REFERENCES

1. F. Magna, P.B. Mandle, and E.M. Whitlock. Guidelines for Evaluation of Airport Landside Vehicular Traffic and Pedestrian Characteristics. Presented at 58th Annual Meeting, Transportation Research Board, Washington, DC, Jan. 1979, p. 15.
2. P.B. Mandle, E.M. Whitlock, and H.S. Levinson. Recent Developments in the Determination of Airport Parking Demands. Presented at 57th Annual Meeting, Transportation Research Board, Washington, DC, Jan. 1978, p. 9.

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Time-Series Analysis of Intercity Air Travel Volume

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This research develops a useful model from which to analyze intercity air travel demand and to produce short-term forecasts. Traditional techniques are presented and technical issues associated with these techniques are discussed. An alternative procedure developed by Box and Jenkins is then introduced. This procedure can be used to develop univariate models that account for monthly as well as seasonal patterns in a time series of historical data. Explanatory variables may also be added to form multivariate models. The technique involves four stages: identification, estimation, diagnostic checking, and forecasting. The Box and Jenkins methodology is applied to a monthly time series of visitor air travel from mainland North America to Hawaii. A univariate model is developed with monthly data from 1971 through 1978, and variations of the model are statistically compared. Forecasts based on the "best" univariate model are then computed for 1979 and 1980 and compared with actual data. Results show that the univariate model selected produced reasonably accurate short-term forecasts. Some 17 of 23 forecasts are not significantly different from the actual observations. When updated, these forecasts are even more accurate. Finally, a bivariate time-series model incorporating air fare as an explanatory variable is estimated. It does not produce a significantly better fit of the data in this case. However, these models are potentially useful from a management standpoint because elasticities can be derived and alternative strategies analyzed. In the Hawaii air travel market, additional research is needed to refine the underlying variable relations and their influence on demand.

The commercial air transportation industry has experienced tremendous growth since the middle of this century. However, current and potential carriers are faced with decisions in the 1980s that will determine their future prosperity if not survival. Recent developments in the industry, including deregulation and increasing fuel prices, are forcing carriers to make critical decisions with regard to fare pricing, fleet expansion, route structure, and flight scheduling. In the public sector, air terminal authorities are faced with serious problems resulting from the rapid growth of commercial and private air transportation in their communities. From these perspectives, decisionmakers need to understand the dynamics of the public demand for air transportation and, it is hoped, how their decisions interact with that demand.

This research is concerned with the analysis and forecasting of intercity air travel demand. The particular market chosen for study is that of visitor travel from mainland North America to the Hawaiian Islands. The importance of such a study goes beyond the frame of reference of air carrier or airport management. The notion of transportation as a derived demand is particularly clear in this market, where a vacation in Hawaii is the dominant trip purpose. From this perspective, travel demand patterns are also of major concern to those involved with the entire Hawaii visitor industry, including hotel, entertainment, and other service establishments.

AIR TRAVEL FORECASTING BACKGROUND

There are several ways to categorize air travel forecasting methods. One of the more general distinctions is between purely judgmental approaches and mathematical modeling.

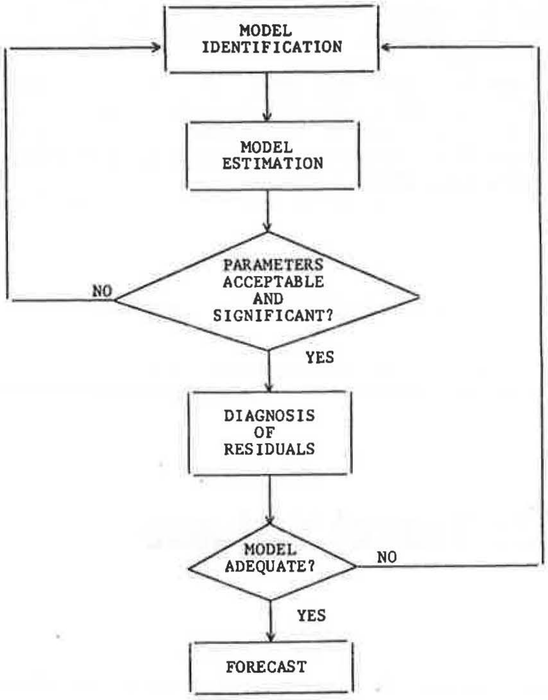
Judgmental methods elicit the personal opinions and predictions of experts in the various fields of air transportation. A popular technique used to obtain information in this way is the Delphi method, where several experts respond independently to several questions pertaining to future air travel demand (1). After seeing their fellow experts' predictions and reasoning, participants are given the opportunity to change their estimates. The intention is that some consensus will eventually be reached and that this consensus will be a good estimator of future demand. Problems with this method include the determination of consensus criteria and the possibility that responses will polarize rather than come together.

The other general procedure used to predict air travel is based on the use of mathematical models. The five-step procedure used to develop these models for prediction is well-established and it includes the following:

1. Variable specification,
2. Variable measurement,
3. Model formulation,
4. Model estimation, and
5. Policy analysis and forecasting.

One of the simplest types of air travel forecasting models relates the amount of travel observed to time. Models of this type are called trend extrapolation models and only one variable, namely the amount of travel, needs to be measured. An histor-

Figure 1. Box and Jenkins time-series analysis procedure.



ical time series of these data is collected and demand is expressed as a function of time, such that y = f(t), where y is observed travel and t is time in whatever interval the data have been collected.

This model is then used to predict future travel. However, it assumes that the trends contained in the historical data will continue, and there is no means of accounting for changes in those trends or the factors influencing them.

The other major form of mathematical model relates the travel observed to explanatory variables that influence demand. These are called structural or econometric models. In this case, either historical or cross-sectional data are collected and demand is expressed as a function of the explanatory variables that have been specified:

$$y = f(x_1, x_2, \ldots, x_n) \quad (1)$$

where y is observed travel and x_1, x_2,.... x_n is the specified set of explanatory variables.

These models rely on the estimated relation between travel and related variables rather than on historical trends. Thus, the demand levels predicted are conditional on the predicted future values of the explanatory variables. These models are much more useful from a policy analysis standpoint because they can include important decision variables such as fare, service frequency, in-flight service, and promotion. However, these forecasts are only as accurate as the assumptions about future values of the explanatory variables and the functional form of the demand relation.

An example of the use of econometric models for air travel forecasting in the United States is the methodology developed by the Federal Aviation Administration (FAA). A three-stage procedure is used to predict passenger enplanements nationwide and at 25 major hubs around the country (2-4). The models used include the following explanatory variables:

1. Yield, or airline revenue per passenger mile;
2. A price index of owning and operating a private vehicle (considered a substitute for flying);
3. A nationwide personal income index; and
4. The nationwide unemployment rate.

The FAA procedure incorporates projected geographic shifts in income, which is important, and it develops separate equations for originating, returning, and connecting passengers.

BOX AND JENKINS APPROACH TO TIME-SERIES ANALYSIS

This research develops both a trend model and a temporal-structural model of the demand for air travel from mainland North America to Hawaii. These models attempt to fit the patterns observed in a time series of historical data. The patterns are described by the autocorrelation of observations in a single series such as the observed number of air travelers in a market. Time-series analysis is used to study the autocorrelation patterns between successive observations in the time series and, in some cases, patterns between successive seasonal observations.

In 1976, Box and Jenkins developed a simple procedure for identifying and modeling the autocorrelation patterns within a time series (5-7). This procedure, diagrammed in Figure 1, includes three basic phases: (a) identification of a tentative model, (b) estimation of model parameters, and (c) diagnostic checking of residuals.

Identification

Identification of the tentative model is accomplished through observing the patterns of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) of the series in question. The ACF at lag one is a combined measure of correlation between each value in the series and the value one period behind it; the ACF at lag two compares each value and the value two periods behind, etc. An exponentially decreasing pattern observed in the ACF is an indication of a particular type of autocorrelation and the resulting model is referred to as an autoregressive model. The number of autoregressive parameters to include in such a model is given by the number of significant values observed in the PACF. The ACF and PACF also indicate whether the data include a seasonal pattern. Once identified, the tentative model structure can be written. For example, by using monthly data, an autoregressive model with a single component of autocorrelation for successive values and a single seasonal component of autocorrelation for values 12 months apart can be represented as

$$(1 - \phi_1 B^1)(1 - \phi_{12} B^{12})\, y_t = a_t \quad (2)$$

where

- y_t = series observation at time t,
- ϕ_1 = autoregressive parameter indicating the relationship between successive values in the series,
- ϕ_{12} = autoregressive parameter indicating the seasonal relation between values in the series from year to year,
- B = backshift operator on Y such that $B^n Y_t = Y_{t-n}$, and
- A_t = residual error between observed and fitted values.

Expanding on Equation 2 we obtain

$$Y_t = \phi_1 B^1 Y_t + \phi_{12} B^{12} Y_t - \phi_1\, \phi_{12} B^{13} Y_t + a_t \quad (3)$$

Finally, eliminating the backshift operator notation, we have

$$Y_t = \phi_1 Y_{t-1} + \phi_{12} Y_{t-12} - \phi_1 \phi_{12} Y_{t-13} + a_t \quad (4)$$

Estimation

Once a tentative model has been identified, estimation of the autoregressive parameters is performed. There are several computer routines available to do this (8,9). Parameter values are checked for significance based on the level desired. Insignificant parameters are an indication of a misspecified or an overspecified model. All autoregressive parameters should fall between -1 and +1 for the model to be acceptable.

Diagnostic Checking

After the parameters have been estimated, the ACF and PACF patterns of the residuals are checked to see if there is any remaining autocorrelation unaccounted for by the model. Significant values at the early or seasonal lags are indicators that the model is underspecified and requires additional parameters. This phase will not detect an overspecification. A goodness-of-fit measure can be computed from the residual ACF and the null hypothesis that the model is adequate can be tested statistically. Once the model is deemed adequate, one may proceed with forecasting.

Model Verification

In an attempt to verify the Box-Jenkins methodology, this research includes an additional step, which compares the model obtained by the Box-Jenkins procedure with three alternative models and uses statistical tests to identify the best model.

The model represented by Equation 4 is basically a sophisticated trend model that contains no explanatory variables. It is referred to as a univariate model since only one time series, that representing the behavior itself, is analyzed. However, the Box-Jenkins philosophy allows for inclusion of explanatory variables in these time-series models. In this study, we first develop a univariate model of air travel from the mainland to Hawaii. This model is statistically compared with other models and its forecasts are validated by comparison to actual observations. Then we incorporate an explanatory variable that is hypothesized to influence demand. The resulting bivariate time-series model is compared statistically with the univariate model and analyzed from a management policy standpoint.

UNIVARIATE ANALYSIS OF TRAVEL VOLUME

We analyzed westbound visitor travel to Hawaii from mainland North America because this market includes mostly domestic traffic. Those arriving from the Far East and the South Pacific are excluded so as to minimize international factors and facilitate simpler data collection. The Hawaii Visitors Bureau (HVB) compiles monthly information on the number of westbound visitors destined for Hawaii. All passengers on flights bound for Hawaii are asked to fill out a questionnaire about themselves and their current trip. These forms are then tabulated and each year the HVB publishes its annual research report summarizing these statistics.

For our purposes, data were collected from the HVB annual reports for nine years from January 1971 through December 1979. Figures for the first 11 months of 1980 were subsequently obtained through personal correspondence.

Figure 2 is a plot of the time-series of westbound visitor travel to Hawaii. It exhibits an overall increasing trend and a seasonal pattern. The months of March and August are generally the heaviest in any given year, while May and September show the lowest amount of activity.

Several computer packages are available to perform univariate time-series analysis. One of the most convenient is SCRUNCH/SCRTIME, which was developed at Northwestern University and used in this research (8). The analysis is done on the data through December 1978 so that forecasts can be compared with actual observations in 1979 and 1980.

The ACF of the travel volume time series is shown in Figure 3. The exponentially decreasing pattern that is evident in the early lags is an indication of an autoregressive model. The number and types of autoregressive parameters to be included in the model are found by examining Figure 4, the PACF. Significant values at lag one and (marginally) at lag two mean that observations in the time series are related to previous values one and two periods before. The "spike" at lag 12 indicates a seasonal relation between observations 12 months apart.

The parameter estimates for this model are as follows:

Parameter	Estimate	95% Confidence Interval
ϕ_1	0.377	0.140 to 0.615
ϕ_2	0.333	0.088 to 0.578
ϕ_{12}	-0.383	-0.618 to -0.147
ϕ_0 (constant)	6660.0	828.0 to 124 91

Since all are significant at the 95 percent level, we proceed to the third step in the process, diagnosis.

The ACF of the residual series generated from the estimated model is shown in Figure 5. The model appears to be adequate since there are no significant residual autocorrelations through the first 30 lags. The Q-statistic reported by the estimation program is an overall measure of the adequacy of the model. This statistic can be used to test the null hypothesis that our model provides an adequate fit

Figure 2. Plot of monthly westbound visitors to Hawaii by air.

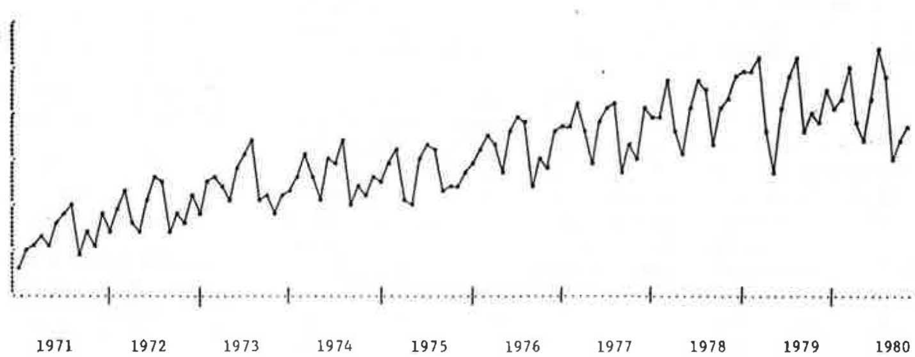


Figure 3. ACF for visitors series.

```
AUTOCORRELATIONS OF LAGS 1 - 30

Q(30, 84) = 83.474      SIG = .000

LAG  CORR   SE    -1  -.8  -.6  -.4  -.2   0   .2   .4   .6   .8   +1
                  +----+----+----+----+----+----+----+----+----+----+
 1   .481  .109                       [    IXXXX]XXXXXXX
 2   .391  .132                     [      IXXXXXX]XXX
 3   .246  .145                     [      IXXXXXX]
 4   .232  .150                    [       IXXXXXX ]
 5   .156  .154                    [       IXXXX   ]
 6   .108  .156                    [       IXXX    ]
 7   .157  .157                    [       IXXXX   ]
 8   .155  .159                    [       IXXXX   ]
 9   .184  .161                    [       IXXXXX  ]
10   .038  .163                    [       IX      ]
11   .087  .163                    [       IXX     ]
12  -.167  .164                    [   XXXXI       ]
13  -.087  .166                    [     XXI       ]
14  -.050  .166                    [      XI       ]
15  -.066  .167                    [     XXI       ]
16  -.054  .167                    [      XI       ]
17  -.022  .167                    [      XI       ]
18  -.000  .167                    [       I       ]
19  -.108  .167                    [    XXXI       ]
20  -.154  .168                    [   XXXXI       ]
21  -.263  .170                   [XXXXXXXXI       ]
22  -.171  .174                   [    XXXXI        ]
23  -.164  .176                   [    XXXXI        ]
24  -.217  .178                   [   XXXXXI        ]
25  -.076  .181                   [      XXI        ]
26  -.172  .182                   [    XXXXI        ]
27  -.100  .184                   [     XXXI        ]
28  -.175  .184                   [    XXXXI        ]
29  -.132  .186                   [     XXXI        ]
30  -.141  .187                   [    XXXXI        ]
                                 -2SE              +2SE
```

Figure 4. Partial PACF for visitors series.

```
PARTIAL AUTOCORRELATIONS OF LAGS 1 - 30

LAG  CORR   SE    -1  -.8  -.6  -.4  -.2   0   .2   .4   .6   .8   +1
                  +----+----+----+----+----+----+----+----+----+----+
 1   .481  .109                       [    IXXXX]XXXXXXX
 2   .208  .109                       [    IXXXX*
 3  -.004  .109                       [    I    ]
 4   .079  .109                       [    IXX  ]
 5  -.007  .109                       [    I    ]
 6  -.023  .109                       [   XI    ]
 7   .113  .109                       [    IXXX ]
 8   .049  .109                       [    IX   ]
 9   .066  .109                       [    IXX  ]
10  -.146  .109                       [XXXXI    ]
11   .047  .109                       [    IX   ]
12  -.306  .109                    XXX[XXXXI    ]
13   .048  .109                       [    IX   ]
14   .115  .109                       [    IXXX ]
15  -.075  .109                       [  XXI    ]
16   .007  .109                       [    I    ]
17   .050  .109                       [    IX   ]
18  -.038  .109                       [   XI    ]
19  -.107  .109                       [ XXXI    ]
20  -.074  .109                       [  XXI    ]
21  -.113  .109                       [ XXXI    ]
22  -.005  .109                       [    I    ]
23   .089  .109                       [    IXX  ]
24  -.220  .109                      X[XXXXI    ]
25   .146  .109                       [    IXXXX]
26  -.121  .109                       [ XXXI    ]
27   .006  .109                       [    I    ]
28  -.049  .109                       [   XI    ]
29   .055  .109                       [    IX   ]
30   .025  .109                       [    IX   ]
                                     -2SE     +2SE
```

Figure 5. ACF for residual series.

```
AUTOCORRELATIONS OF LAGS 1 - 30

Q(26, 70) = 16.664      SIG = .919

LAG  CORR   SE    -1  -.8  -.6  -.4  -.2   0   .2   .4   .6   .8   +1
                  +----+----+----+----+----+----+----+----+----+----+
 1  -.025  .120                      [    XI     ]
 2  -.043  .120                      [    XI     ]
 3   .090  .120                      [     IXX   ]
 4   .011  .121                      [     I     ]
 5  -.054  .121                      [    XI     ]
 6  -.149  .121                      [ XXXXI     ]
 7   .024  .124                      [     IX    ]
 8   .109  .124                      [     IXXX  ]
 9   .058  .125                      [     IX    ]
10  -.015  .126                      [     I     ]
11   .159  .126                      [     IXXXX ]
12  -.091  .128                      [   XXI     ]
13  -.115  .129                      [  XXXI     ]
14   .009  .131                     [      I      ]
15  -.011  .131                     [      I      ]
16  -.084  .131                     [    XXI      ]
17   .071  .132                     [      IXX    ]
18   .041  .132                     [      IX     ]
19  -.007  .132                     [      I      ]
20  -.046  .132                     [     XI      ]
21  -.179  .133                     [  XXXXI      ]
22   .098  .136                     [      IXX    ]
23   .064  .137                     [      IXX    ]
24  -.232  .137                     [XXXXXXI      ]
25   .125  .143                     [      IXXX   ]
26  -.021  .144                     [     XI      ]
27  -.004  .145                     [      I      ]
28  -.068  .145                     [    XXI      ]
29  -.030  .145                     [     XI      ]
30   .040  .145                     [      IX     ]
                                   -2SE          +2SE
```

Table 1. Alternative univariate models.

Seasonal Component	Monthly Component $(1 - \phi_1 B^1)$	 $(1 - \phi_1 B^1 - \phi_2 B^2)$
$(1 - B^{12})$	Model = 1 Trend = 8474.0 $\phi_1 = 0.477\ 48$ RSSQ = $0.114\ 67 \times 10^{11}$ NOBE = 70 DF = 68	Model = 2 Trend = 5816.6 $\phi_1 = 0.343\ 80$ $\phi_2 = 0.310\ 48$ RSSQ = $0.104\ 89 \times 10^{11}$ NOBE = 70 DF = 67
$[1 - (1 + \phi_{12})B^{12} + \phi_{12}B^{24}]$	Model = 3 Trend = 101 62.0 $\phi_1 = 0.543\ 62$ $\phi_{12} = -0.366\ 68$ RSSQ = $0.100\ 14 \times 10^{11}$ NOBE = 70 DF = 67	Model = 4 Trend = 6659.6 $\phi_1 = 0.377\ 51$ $\phi_2 = 0.333\ 04$ $\phi_{12} = -0.382\ 85$ RSSQ = $0.900\ 23 \times 10^{10}$ NOBE = 70 DF = 66

Note: RSSQ = residual sum of squares, NOBE = number of effective observations, NPAR = number of model parameters, and DF = degrees of freedom = NOBE - NPAR.

of the data by comparison with the chi-square distribution. In this case, the Q-statistic is 16.7, which is well within the 95 percent confidence limit of 38.9 for 26 degrees of freedom (DF). This means that we fail to reject the null hypothesis and, for now, conclude that the specified model is an adequate representation of westbound visitor travel to Hawaii from 1971 to 1978.

As an additional step, we attempted to verify the model obtained by using the Box-Jenkins methodology by statistically comparing it with three alternative autoregressive models. Summary estimation results and fit statistics of the four models are given in Table 1. Model 1 is the simplest model, models 2 and 3 are intermediate, and model 4 is the complete model identified above. F-ratios were computed to test whether the models with more parameters were significantly better than the simpler models. Figure 6 is a diagram showing the results of the statistical tests. Model 1 is rejected by all three larger models, and both model 2 and model 3 are rejected by model 4. This verification is encouraging, since it indicates that the model selected by using the Box-Jenkins procedure is the best statistical model as well.

By using Box-Jenkins notation, the model we have selected may be expressed as follows:

$$(1 - B^{12})(1 - \phi_1 B^1 - \phi_2 B^2)(1 - \phi_{12} B^{12})y_t = \phi_0 + a_t \qquad (5)$$

The first term on the left side of Equation 5 is a seasonal differencing factor, required prior to identification due to the upward seasonal trend of the data. Substituting the parameter estimates into Equation 6 and expanding, we obtain

$$\begin{aligned} Y_t = {} & 0.38Y_{t-1} + 0.33Y_{t-2} + 0.62Y_{t-12} - 0.23Y_{t-13} \\ & - 0.20Y_{t-14} + 0.38Y_{t-24} - 0.14Y_{t-25} \\ & - 0.13Y_{t-26} + 6660 + a_t \end{aligned} \qquad (6)$$

Because this equation is designed to fit the time series of data in Figure 2, it is necessarily somewhat complex. However, the important point is that it is relatively easy to identify this model by using the Box-Jenkins procedures.

Figure 6. F-test results for alternative models.

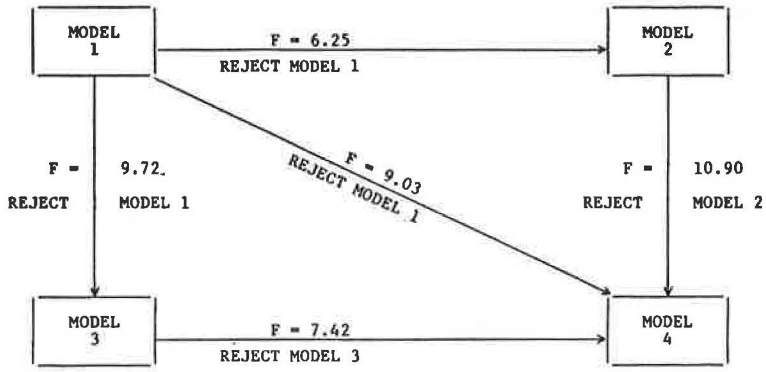
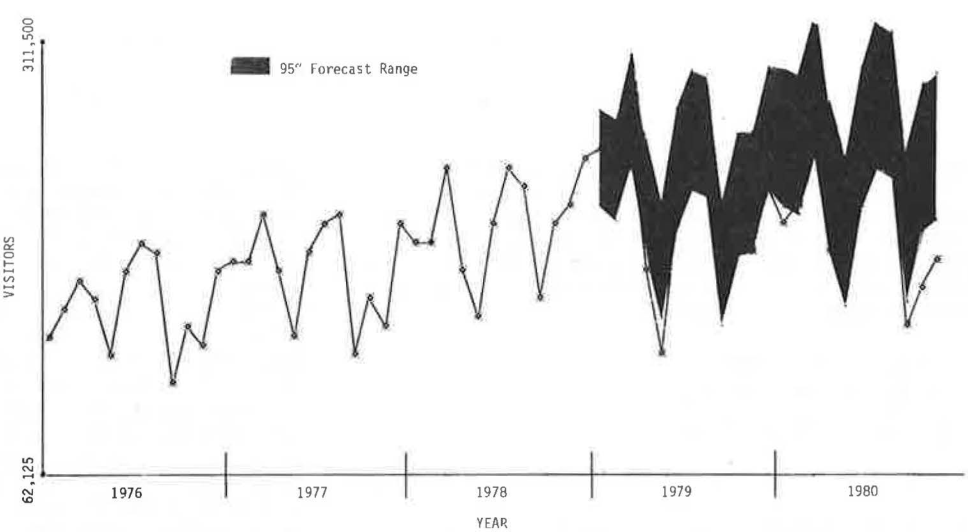


Figure 7. 1978-based forecast range compared with actual values for 1979 and 1980.



It can be seen from Equation 6 that the value of the series at time "t" is positively related to values 1, 2, 12, and 24 months before. (The negative coefficients for lags of 13, 14, 25, and 26 months are terms that eliminate double counting of successive period and seasonal effects.) Practically, this means that a monthly increase or decrease in travel tends to perpetuate itself successively for 2 months and seasonally for 2 years.

By using the univariate model selected above, forecast ranges were computed at a 95 percent level of confidence for each month from January 1979 through November 1980. These are plotted as the shaded areas in Figure 7.

Comparing these forecast intervals to actual experience, we see that 10 of the 12 months in 1979 were predicted within the 95 percent confidence range. The model significantly overpredicted the months of April and May. This is most probably explained by the fact that United Air Lines, with a large market share (more than 50 percent) of mainland-to-Hawaii air travel, suffered a work stoppage between March 31 and May 28, 1979. In 1980, the months of January, September, October, and November were significantly overpredicted by the model. In fact, most months in 1980 are only narrowly within the lower bound of the prediction range. This is most likely explained by the recent recession that caused the visitor industry in Hawaii to experience a pronounced slowdown in 1980. The univariate model developed through 1979 would not be able to predict this change in trend. This suggests the need to consider inclusion of descriptive variables to account for changing economic conditions.

In practice, of course, forecasts should be updated as additional data points become available. Two sets of updated forecasts for 1979 and 1980 by using the original model parameters were computed, one assuming immediate updating of information and one assuming updating with a 3-month delay. Because the United Air Lines strike represents a particularly sharp anomaly in the data for the months of April and May 1979, the data for this period were adjusted to the predicted volume in the absence of the work stoppage.

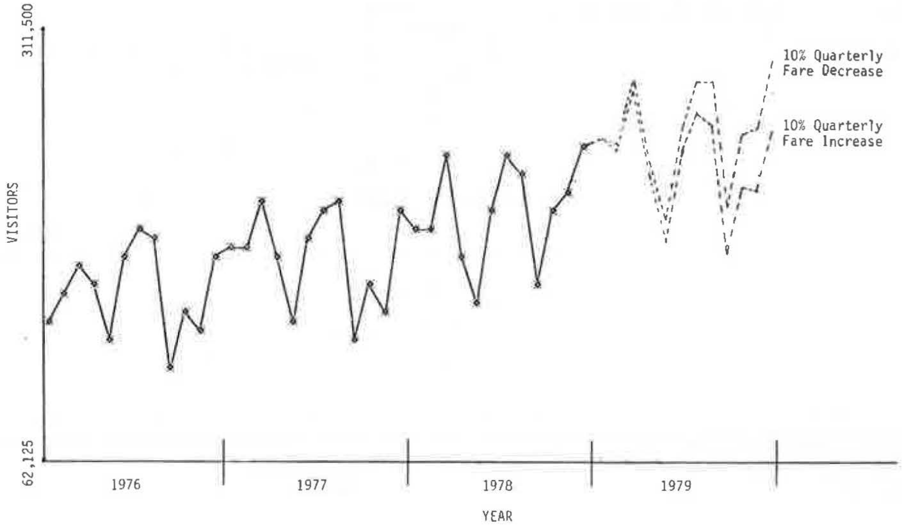
The effect of updating the travel demand information prior to forecasting a new month is to produce more accurate forecasts. The root-mean-square error (RMSE) is a measure of the overall deviation of a series of forecasts from actual experience. This measure decreased by 15 percent for updating with a 3-month delay and 32 percent when the series was updated with a 1-month delay prior to forecasting.

MULTIVARIATE ANALYSIS

We are interested in the way in which the travel volume series may be influenced by changes in exogenous variables. We chose to examine the effect of the price of air travel between mainland North America and Hawaii. Round-trip coach fares between Hawaii and four major metropolitan areas in North America were weighted according to the volume of Hawaii travel observed from those areas. A monthly time series of these average coach fares was computed and deflated by the consumer price index for each period from January 1971 to December 1978.

By using the multivariate time-series analysis

Figure 8. Forecasting results of alternative pricing strategies.



computer package called WMTS-1 (10), the average coach fare variable is incorporated and a transfer function model is estimated. The effect of price changes on demand one period later is observed. The same system of autoregressive components identified above is used here. The estimated equation for this bivariate model is as follows:

$$
\begin{aligned}
Y_t = {} & 0.36Y_{t-1} + 0.34Y_{t-2} + 0.62Y_{t-12} \\
& - 0.22Y_{t-13} - 0.21Y_{t-14} + 0.38Y_{t-24} \\
& - 0.14Y_{t-25} - 0.13Y_{t-26} \underline{\underline{- 90.7X_{t-1}}} \\
& + 279\ 92 + a_t \qquad (7)
\end{aligned}
$$

where Y is visitor travel from the mainland to Hawaii and X is the average round-trip coach fare from the mainland to Hawaii.

We notice that the autoregressive parameters for this model are virtually identical to those in Equation 6, as we would expect. The coefficient for average coach fare denotes the effect that a change in fare will have on demand. In this case, the magnitude and significance of the fare coefficient are rather low. Based on these results, the price elasticity of demand is approximately -0.1. In terms of overall fit, the bivariate model is not significantly better than the univariate model, suggesting either that the Hawaii market is rather inelastic with respect to price or that we have not captured the true price effect with this particular measure.

In fact, we believe that a preferred measure of cost should be an estimate of total cost for the Hawaii vacation including air fare, the cost of accommodations, and other local expenses. If air fare is approximately one-third of total vacation cost, the elasticity of demand to total cost implied by the results reported here would be in the range of -0.3.

POLICY ANALYSIS

One of the advantages of multivariate analysis is that policymakers and air carrier management can use the structural parameters to develop forecasts based on alternative future scenarios. This was done by using the bivariate model estimated above. Two alternative air fare pricing policies were analyzed in terms of their effect on forecasted travel for 1979. Air carriers have been faced with conflicting economic pressure to both raise fares due to rising costs of labor and fuel on the one hand, and to lower fares for competitive reasons on the other. Thus, the two alternative pricing strategies studied were (a) a 10 percent quarterly increase in the average coach fare for 1979 and (b) a 10 percent quarterly decrease in the average coach fare for 1979.

Figure 8 is a plot of the forecast results for 1979 by using the two alternative pricing scenarios. As we expect, a quarterly increase in fares results in a lower predicted demand than a quarterly decrease in fares, with the differences becoming more pronounced as the year goes on. However, due to the small magnitude of the fare coefficient, it is doubtful if this difference in forecasts is large enough to indicate significant impact of the alternative pricing strategies.

In summary, these results do not indicate a strong influence of fare alone on the demand for travel from mainland North America to Hawaii. Possible reasons for this include the fact that many holiday commitments are made many months in advance. In this case, fare may have a greater effect on demand after several periods. Furthermore, if fares to other vacation spots are increased concurrently, the incentive to shift to other destinations is reduced. Also, a large percentage of visitor travel to Hawaii is through organized tour agencies. The entire cost of the trip tends to be included in a single package, including air fare, hotel costs, and even entertainment expenses. Consequently, it is likely that demand for this type of travel is a function of several prices together rather than any single price component. Finally, it is possible that the demand for travel in this market is rather price inelastic. Many of these trips are once-in-a-lifetime experiences, and it is likely that other factors such as income or stage in the family life-cycle are operative. Consequently, these could outweigh the effect of air fare changes in determining the number of visitors who will travel to Hawaii.

SUMMARY AND CONCLUSIONS

To summarize our results, a univariate model of visitor travel from mainland North America to Hawaii is identified and estimated for the period from 1971 through 1978. The Box-Jenkins time-series analysis procedure is used. The resulting model is tested statistically against several alternative models and found to be preferable. It is further used to forecast travel from the mainland to Hawaii for 1979 and

1980. Although 17 of the 23 forecasts are not significantly different than the actual figures at the 95 percent level of confidence, the model tends to overpredict in general. This problem is alleviated substantially when the forecasts are updated each month with additional data points for 1979 and 1980.

In an attempt to add descriptive variables to the analysis, a bivariate time-series model is developed by using the average coach fare from mainland North America to Hawaii as the explanatory variable. The magnitude and significance of the fare parameter are low and the demand appears to be price inelastic. Alternative fare-pricing scenarios are studied, and their effect on forecasted demand is evident but not pronounced.

These results indicate that the Box-Jenkins methodology can be a useful tool in the analysis of an extensive time series of intercity travel demand. In cases where explanatory variables are poorly understood or where these data are unavailable, univariate analysis can result in a model that will produce useful short-term forecasts. Where a structural analysis is desired, explanatory variables can be added to the autoregressive components and transfer function models can be estimated. These are particularly useful to management and policy analysts who have some control over these variables. They can develop alternative future scenarios and study the effect these will have on future demand. Various elasticities of these variables with respect to demand can also be derived.

In terms of the Hawaii travel market, the bivariate model is a measure of the effect that fare alone has on demand. Research that uses a total visitor cost index would be useful in determining an overall cost elasticity of demand. Air carriers and other visitor industries could then determine their impact on this overall cost elasticity. Additional research might well be directed at the joint effect of price, economic activity, and changes in attractiveness of the destination market.

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This paper is a result of research performed at Northwestern University through its Transportation Center and Department of Civil Engineering. The paper is an abridged version of Oberhausen's master's thesis, completed in February 1981. Koppelman served as Oberhausen's advisor throughout the course of the research.

Several organizations in Hawaii were responsible for providing the data necessary for the analysis, including the HVB, the Tax Foundation of Hawaii, and the Airports Division of the Hawaii Department of Transportation.

REFERENCES

1. J.M. English and G.L. Kernan. The Prediction of Air Travel and Aircraft Technology to the Year 2000 Using the Delphi Method. Transportation Research, Vol. 10, 1976, pp. 1-8.
2. Aviation Forecasts, Hawaii. Federal Aviation Administration, March 1980.
3. I. Gershkoff and B. Hanna. Macro Air Carrier Forecasting Model, Appendix B. In Aviation Forecasts, FY 1979-1990, FAA, Sept. 1978.
4. Airline Domestic Hub Activity. Systems Analysis and Research Corporation, Washington, DC, Dec. 1976.
5. G. Box and G. Jenkins. Time Series Analysis: Forecasting and Control. Holden-Day, San Francisco, 1976.
6. L.J. McCain and R. McCleary. The Statistical Analysis of the Simple Interrupted Time-Series Quasi-Experiment. In T.D. Cook and D.T. Campbell, Quasi-Experimentation: Design and Analysis Issues for Field Settings, Rand-McNally, Chicago, Chapter 6, 1979.
7. R. McCleary and R.A. Hay, Jr. Applied Time-Series Analysis for the Social Sciences. Sage Publications, Beverly Hills, CA, 1980.
8. R.A. Hay, Jr. SCRUNCH/SCRTIME Reference Manual, An Interactive Statistical System for Interrupted Time Series Analysis. Department of Sociology and Vogelback Computing Center, Northwestern University, Evanston, IL, Oct. 1979.
9. D.J. Pack. A Computer Program for the Analysis of Time-Series Models Using the Box-Jenkins Philosophy. Ohio State University, Columbus, May 1977.
10. G.C. Tiao, G. Box, and others. The Wisconsin Multiple Time-Series Program (WMTS-1): A Preliminary Guide. Department of Statistics, Univ. of Wisconsin, Madison, Nov. 1979.

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Economic Justification of Air Service to Small Communities

JOHN HULET AND GORDON P. FISHER

This study is concerned with the allocation of air service to small communities (less than 50 000 population) at a time when the supply of that service is seriously diminishing and changing in character, especially since the Airline Deregulation Act of 1978. A quantitative methodology is developed as a tool for planning for short-haul service and establishes the minimum ridership required to justify the provision of air service. The model underlying the criterion takes into account two main factors: (a) the spatial separation of the community from a major hub and (b) the level of service offered at the nearest alternate airport and, if implemented, the local airport. The criterion equates the monetarized time savings of local air service and the incremental costs to implement the service. This paper emphasizes the description of the trade-off mechanism between time and money by using classical cost elements of economic theory. A graphic analysis illustrates the validity of the functional shape of the disutility concept. The ultimate product of the methodology is an optimal configuration of local air service in terms of (a) link to be served, (b) airport investment level, (c) type of flight equipment, and (d) frequency of service.

The provision of air service to small communities, those with less than 50 000 population, has seriously declined over the past several years as a result of changing carrier characteristics. Conversion by regional carriers to jet aircraft that are generally inappropriate to short-haul service and the escalating price of jet fuel have been principal causes of diminished service. The decline has been hastened by recent airline deregulation, which has made it easier for airlines to trim out unprofitable operations, typically the small communities with marginal air travel demand. The Airline Deregulation Act of 1978, in recognition of this problem, contains provisions aimed at guaranteeing at least "essential" air service to communities designated as "eligible points." Difficulty in implementing these provisions arises, of course, in the definition of "essential" and "eligible."

This paper, based on work by Hulet (1), proposes a rational quantitative criterion for determining the minimum air travel demand necessary in a community in order to justify a given type and level of air service. As a policy tool, the criterion is useful in selecting communities that ought to be on the air service network and, furthermore, provides a uniform basis for equitable treatment among those that should be included and excluded. The criterion determines the minimum ridership necessary to support local air service by equating the monetarized passengers' travel time savings--reflecting the demand--and the incremental costs to supply that service. Based on cost, the criterion essentially establishes the break-even point between supply and demand. It does not incorporate subjective sociopolitical factors associated with the notion of essentiality, but it does give a baseline solution against which to judge the proper level of service and any subsidy needed to maintain it.

A principal component of the criterion is the (generic) cost to a traveler of the delay caused by infrequent aircraft departures. A major part of this paper consists of the development of a proposed frequency delay function to define the disutility cost associated with the level of air service offered.

CRITERION FOR JUSTIFYING AIR SERVICE

Level of Service

A widely used measure of the level of service at an airport is the flight frequency F at the station (e.g., number of flights per day to all destinations) or, alternatively, the time between flights, the headway H = 1/F. Frequency is, of course, only one component of air service quality. Another component is the provision of adequate capacity by the carrier. In the following analysis, it is assumed that carriers usually respond to market demands with the type and the amount of equipment to provide proper capacity. Therefore, capacity is not explicitly dealt with, though it is recognized that capacity and frequency are intertwined service variables that work in opposite direction to satisfy a given travel demand: higher capacity versus lower frequency. This assumption is likely true for most major trunkline operations and reasonable as well for commuter airlines. In major markets that link important hubs, the airline industry in fact generally provides overcapacity. The assumption of adequate aircraft capacity is even more reasonable as airlines, in the deregulated environment of today, concentrate on their larger and longer market sectors to use their aircraft more efficiently. Curtailed flights due to frequency limitations, as an aftermath of the recent air traffic controllers' strike, have accentuated this trend, at least over the short run.

Various measures have been proposed to specify quantitatively the convenience of flight schedule in terms of the wait time associated with flight frequency. The one most commonly used is half the headway (H/2), i.e., the average time between departures. This measure implicitly assumes a random arrival of passengers at the airport, as if there were complete lack of knowledge about scheduled departures, and is not in accord with what is known about air traveler behavior, especially at small airports that typically offer infrequent service. Therefore, a better level-of-service indicator is sought.

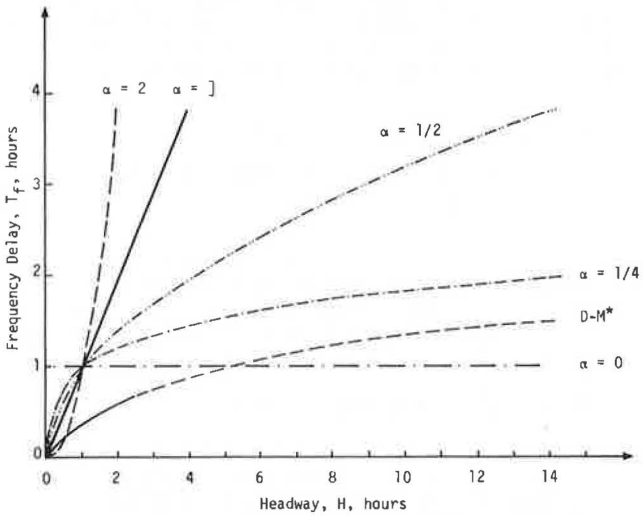
An alternative approach was taken by Douglas and Miller (2,3), which proposed a measure of service quality related to levels of delay incurred by passengers, thus introducing the concept of schedule delay as the total delay arising from two sources (3, pp. 110 and 120):

> Frequency delay, which is the mean absolute difference between the traveler's desired departure time and the scheduled departure time, in recognition that a departure might be scheduled at a time not convenient to or not desired by the traveler. As the daily frequency of flights increases, a decrease of frequency delay is to be expected.
>
> Stochastic delay, the time lost when the traveller cannot board his preferred flight and is caused to take another, less desirable flight. The preferred flight might be filled, for example, because of the not uncommon airline practice of "overbooking" flights to compensate for seasonal and stochastic demand fluctuations and "no-show" cases. This delay is a queuing phenomenon. When the level of service increases as additional flights are scheduled, the probability of being delayed and the expected magnitude of the delay will decrease.

Douglas and Miller simulated these delay processes. For the frequency delay, the daily time pattern of demand of a typical trunkline route--800 passengers/day served by at least 7 daily flights, corresponding with a maximum headway of about 2.5 h--was transformed into a discrete frequency distribution. Then a procedure was used to schedule 'F' flights during the day, such that each flight faced demand of equal size, optimizing the operator's schedule and cost. The difference between each traveler's desired departure time and the nearest scheduled flight was computed, and their absolute value summed for all travelers. The mean, or average delay, for each traveler was computed. The procedure was repeated for F+1, F+2, etc., thus generating the average or "expected" value of frequency delays as a function of the daily flight frequency. These observations were fitted to the function $T_f = 92\ F^{-0.456}$, where T_f is the expected frequency delay per passenger (measured in minutes) and F is the daily flight frequency. [See Douglas (3) for the detailed treatment of the stochastic component of delay, which, as explained later, is not an issue here.]

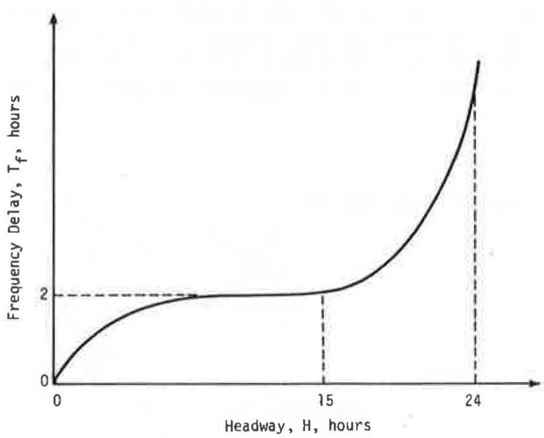
It should not be expected that the Douglas-Miller expression, having been calibrated for headways of less than 2.5 h in a major air corridor, can be extrapolated to high headways typical of the local, short-haul market that has radically different demand and flight frequency characteristics. Consequently, this paper attempts to develop a more general schedule delay function that can apply to both high- and low-frequency regimes.

Figure 1. Frequency delay versus headway for selected values of exponent α.



*D-M = Douglas and Miller: $T_f = 0.445\ H^{0.456}$, not calibrated for values of $H \geq 2.5$ hours.

Figure 2. Disutility of schedule: functional form.



The approach taken here departs from that of Douglas and Miller in two respects. First, for simplicity, the stochastic component of schedule delay is omitted, assuming that it will be minimized by adjustment of the load factor to provide a cushioning effect. Travel demand thus is taken as fixed. The use of a fixed load factor--actually an average load factor over the operating period--in lieu of unknown stochastic values imposes some lack of refinement on the analysis, but it is our opinion that the resulting imprecision is likely to be small, especially in low-density markets with infrequent flights. Moreover, the lack of data in these markets precludes reliable estimation of stochastic variation of demand. Second, frequency delay is not taken as an absolute time difference as used by Douglas and Miller, but is associated with the notion of disutility to the passenger--that is, with the level of inconvenience corresponding with a given flight frequency. Disutility is difficult to quantify, so the analysis adopts wait time as its surrogate and the operational measure of inconvenience. In this context, frequency delay is a virtual rather than actual wait time--more so for high headways--and is synonymous with disutility.

A relationship between frequency delay and flight frequency can be postulated in the general form: $T_f = (1/F)^{\alpha} = H^{\alpha}$, where T_f = frequency delay per passenger (h), F = daily flight frequency, H = headway (h), and α = a dimensionless exponent that is a measure of inconvenience associated with delay imposed by flight frequency. This relationship is depicted in Figure 1 for various exponent values:

$\alpha = 0$, implying total indifference of passengers to flight and disutility constant over all levels of service--an unrealistic case;
$0 < \alpha < 1$, marginally decreasing disutility;
$\alpha = 1$, linearly proportional disutility--also unrealistic; and
$\alpha > 1$, marginally increasing disutility (as headway increases, virtual wait time increases sharply, far exceeding actual wait time).

The Douglas-Miller expression, also shown in Figure 1, is of the second case. It is considered invalid for large headways, although its tendency to an upper bound is of some interest. The common assumption of $T_f = H/2$ is of the third case.

The other case of interest is $\alpha > 1$, which is proposed here as the form for describing the large headway region. Infrequent flights, say once every two days or even once a week, clearly are a source of great inconvenience and dissatisfaction to the passenger, who perceives his or her loss of value as far greater than the actual time delay incurred--and more so as headway increases. That is, the disutility the passenger experiences increases sharply as represented by the up-trending curve. In contrast, the Douglas-Miller curve, by tending to an upper bound, implies increasing indifference to schedule and decreasing marginal disutility and, therefore, is inappropriate at high headways. In short, it is deduced that the case of $\alpha < 1$, as proposed by Douglas and Miller, better describes the small headway range, that the case of $\alpha > 1$ better describes the large headway range, and that a general disutility relationship accounting for the underlying phenomenological differences of the two regimes is some combination of the two cases.

The proposed form of the disutility function is presented in Figure 2 as a relationship between frequency delay and headway. Conceptually, the function combines three main elements, namely (a) a concave portion at low headways, (b) a maximum wait time that travelers will tolerate under normal service conditions, and to which the concave part tends, and (c) a convex portion at high headways.

The nature of the trip (business or leisure) also has a bearing on the perception of the level of service. Timing of the departure is another crucial issue to the business person. Some of these considerations are discussed here.

For very low headways, corresponding with excellent service, any delay is viewed as a high level of inconvenience, especially to travelers who closely time their airport arrival in expectation of frequent and reliable air service. This would be the case of highly paid business executives planning their activities on an "air-shuttle" type of operation. A delay of an hour could have disastrous business consequences. The concave shape of the disutility function is the only form that picks up this high level of inconvenience as soon as the service deteriorates (steep rise in disutility at first).

As headway increases, the timing now becomes crucial if the air service is to provide a meaningful travel alternative to businesspersons. If the service deteriorates beyond a certain level, travelers will adjust their expectations to less-frequent service: they now are the business persons who unfortunately have no other alternative and the people who travel for personal reasons (leisure, family, etc.) and are less sensitive to either the timing or the frequency of service. If the timing of flights is poor, say departures 4-10 h apart, any delay will be viewed as equally bad and will entail an equal wait at the airport before the flight (personal contingency time plus airport processing time). For the captive customers facing a deteriorating quality of air service and with no other choice, the level of inconvenience runs high, but translates practically into the physical wait to be incurred in the process of traveling by air. However, it is reasonable to suppose that there is a maximum wait, say as long as 2 h, that travelers will tolerate under normal service conditions; this limit is determined by the difference between air travel time--including access, contingency, airport processing, and egress times--and the time required for the same trip by the next best travel alternative (e.g., automobile), if there is one for the short-haul market being considered ($\leq$300 miles). Thus the marginal disutility of wait time (slope of T_f) gradually tends to zero, explaining the flat portion of the disutility function. Beyond a certain level of service, say 15-h headway or 1 flight/day, disutility can be expected to increase sharply and convexly, reflecting severe loss of attractiveness and convenience as the traveler is forced to postpone his or her departure to another day. It is conceivable, of course, that local air service of one flight every other day, or even one a week, may be preferable to no service at all.

For simplicity and mathematical tractability, the subsequent analysis adopts a disutility function of the polynomial form:

$$T_f = H^3/600 - H^2/30 + H/4 \quad (1)$$

where T_f equals frequency delay and H equals headway (h). This curve approximates the one shown in Figure 2, with convexity beginning at a headway of about 15 h (1 flight/day) and a maximum acceptable wait time under less-frequent scheduling of about 2 h. Although other forms might be adopted, Equation 1 is quite satisfactory to illustrate this methodology.

Benefit-Cost Criterion

The foregoing discussion has been principally motivated by a desire to include the traveler disutility as an element of a cost function with the purpose of determining minimum ridership necessary to justify local air service. A basic formulation of a trade-off function between time savings and cost has been given by Dick (4). This analysis follows Dick but differs principally in the inclusion of the disutility concept, again to be able to model the large headway regime more realistically.

The spatial setting of the problem, shown in Figure 3, comprises a local airport at the trip origin L, destination D, and a nearby alternative airport A. Travelers may fly from L to D if offered direct air service. If not, they may drive to airport A and fly from there. In order to justify economically the provision of direct air service from L to D, the problem is framed as a balance between travel time savings and money costs, computed on an annual basis, for the two alternatives of (a) provision of an airport at L and operating flight $\overline{LD}$ and (b) driving to airport A and operating flight $\overline{AD}$. The notation for this analysis is summarized in Table 1.

The benefits are the net time savings of direct trip $\overline{LD}$ over indirect trip $\overline{LAD}$. The $\overline{LAD}$ trip time has three elements, namely $\overline{LA}$ driving time, $\overline{AD}$ flight time, and the frequency delay (disutility) at A as described by Equation 1. Taking the headway H_L at the local airport as a function of annual traffic X (i.e., $H_L = 15 \times 365\ L/X$), the annual net time savings are

$$TS = PX[(D_{LA} - D_{HL})/V_1 + (D_{AD} - D_{LD})/V_2 + H_A^3/600 - H_A^2/30 + H_A/4 - (2.73 \times 10^8)(L/X)^3 + (9.99 \times 10^5)(L/X)^2 - (1.37 \times 10^3)(L/X)] \quad (2)$$

The annual incremental costs of providing direct air service from L comprise the operating costs of flight $\overline{LD}$ less the avoided operating costs of trip $\overline{LAD}$, plus the annualized costs of the airport at L (construction and maintenance), namely:

$$IC = X[C_1(D_{HL} - D_{LA}) + (C_2/L)(D_{LD} - D_{AD})] + I_2 + M \quad (3)$$

Direct air service $\overline{LD}$, including its associated airport costs, is justified when benefits exceed costs. The break-even point then is defined by

$$TS - IC = 0 \quad (4)$$

The unknown X, which satisfies this break-even point is the minimum annual ridership required to justify direct $\overline{LD}$ air service and the cost of an airport of size I_2. Frequency of air service at the local airport can be computed as the annual ridership divided by the capacity of the selected flight equipment. It should be noted that the required ridership is smaller as the passenger disutility is higher.

Figure 3. Geographical setting of problem.

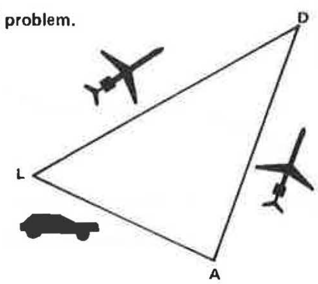


Table 1. Notation used in cost-benefit analysis.

Symbol	Definition
X	Total number of passengers to travel from L to D per year to justify building an airport at L
D_{LD}	Distance (air) $\overline{LD}$ (miles)
D_{AD}	Distance (air) $\overline{AD}$ (miles)
D_{LA}	Distance (surface) $\overline{LA}$ (miles)
D_{HL}	Distance from center of city L to local airport (miles)
L	Number of passengers per flight = seating capacity of plane x the planned load factor (say, 65 percent)
P	Passenger time value (e.g., \$10/h)
V_1	Car speed (mph)
V_2	Aircraft speed (mph)
C_1	Car costs, including amortization of original cost (\$/mile)
C_2	Aircraft costs, including amortization of original cost (\$/mile)
I_1	Initial airport capital investment (\$)
I_2	Annualized airport capital investment (\$): $I_2 = I_1 \cdot CRF$
CRF	Capital recovery factor = $i(1 + i)^n/(1 + i)^n - 1$
i	Annual rate of interest (%)
n	Economic life of airport (years)
M	Operating and maintenance costs of airport (\$/year)
F_A, F_L	Frequency at alternate airport A, at local airport L (number of flights per day)
T_{f_A}, T_{f_L}	Frequency delay at A, L = disutility associated with schedule at A, L (h)
H_A, H_L	Headway at airport A, L (h)

Equilibrium Analysis

To gain a better insight of the trade-off mechanism between time and money costs embedded in the formulation, the following graphical representation of the money is useful.

The time savings accruing from local airport operations at L were described by Equation 2. This equation is of the form

$$f(X) = P \cdot X \cdot (\alpha - \beta X^{-3} + \gamma X^{-2} - \delta X^{-1})$$

which, plotted on a graph displaying on the abscissa axis the yearly passenger volumes, X, and the time savings (in dollar units) on the ordinate axis, has the inverted S-shape shown in Figure 4. Time savings have negative values (from $-\infty$ to 0) over the range of patronage increases from 0 to X_E. This point illustrates the fact that, below the patronage level X_E, the flight frequency associated with lower passenger volumes at the local airport (e.g., one flight every two weeks) is too low to realize any time savings compared with the existing situation (drive to the nearest alternate hub). Only the positive values of time savings are of interest in the analysis.

The incremental costs were previously defined by Equation 3, which is of the general form $g(X) = aX + b$. The slope a represents the difference between variable operating costs of the direct and indirect trips. It is to be expected that, for an approximately equal flight distance from the alternate or local community to the desired destination, the biggest contribution in variable costs is attributable to driving to alternate airport A. So the coefficient a is always ≤ 0, that is, $D_{LA} \geq D_{HL}$. This relationship also is represented on Figure 4. The incremental cost function exhibits the correct slope in that the costs are distributed over a larger number of passengers as use increases.

The equilibrium values of X_i^* correspond with the minimum patronage level, which justifies a given level of investment for the local airport and direct air service operations. As the value of passengers' time increases, the minimum level of patronage decreases, which appears intuitively correct (shift from X_1^* to X_2^* on the graph). From passenger volume X_E onward, time savings are realized (positive values) but incremental costs are still greater than monetary time benefits derived from the local airport service. The increase in ridership from X_E to X_i^* is necessary to equalize benefits and costs. The shaded area on Figure 4 shows a region where the marginal benefit of providing the local service exceeds its marginal cost.

A more traditional representation in economics for the decision criterion between two alternatives (in the present case, the trip $\overline{LAD}$ and the trip $\overline{LD}$) is depicted in Figure 5. X^* is the threshold value, in terms of passenger volume, to justify the introduction of the second alternative, and AC_i is the average cost per passenger for alternative i. The same analysis can be used for this specific model and clearly illustrates the trade-off accomplished by the formulation between frequent and convenient local air service, as well as its associated cost.

Figure 6 displays the average cost per passenger for both alternatives (local airport and use of alternate airport). For the local airport, the costs consist of the direct monetary outlay m_L (construction of facility and flight operating expenses) and the time cost t_L associated with the frequency delay, converted into dollars by the use of the passengers' time value P. The curve m_L exhibits the classical hyperbolic shape of average fixed costs being distributed over more and more users. As the frequency of service at the local airport L increases, the wait related to the level of service is expected to decrease, which explains the decreasing time contribution being added to m_L. For the alternate airport A, already in existence and operational, the direct money outlay m_A is a fixed amount per passenger (marginal cost

Figure 4. General equilibrium: time savings/cost of local airport versus yearly traffic for selected time values.

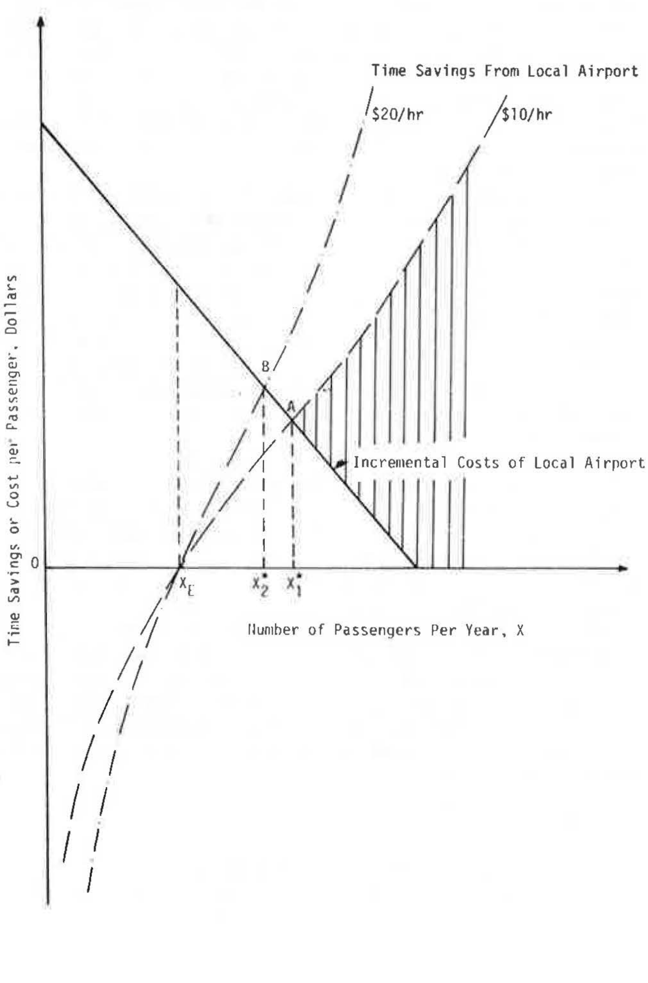


Figure 5. Economic comparison of two alternatives.

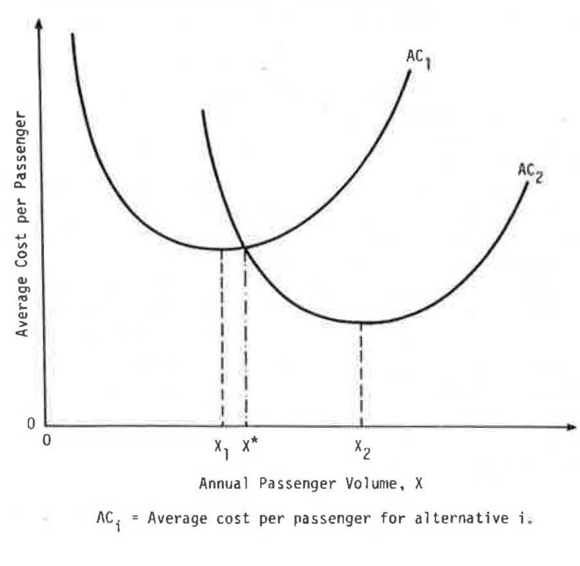
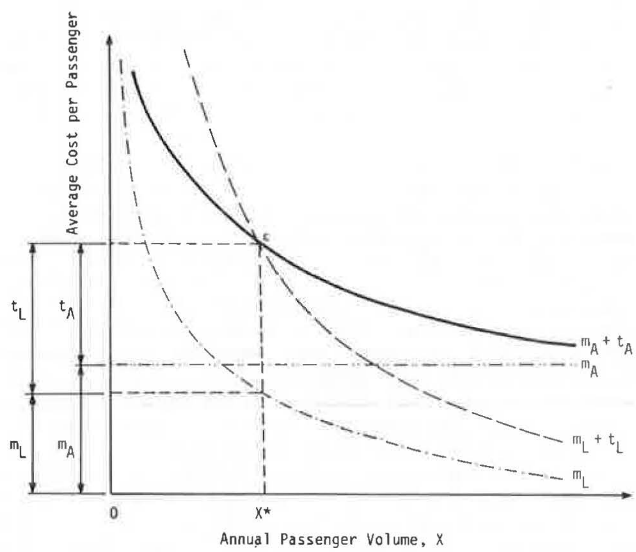


Figure 6. Economic comparison of local and alternate airports.



assumed to be zero) whereas the time cost t_A displays the same behavior as for location L, assuming the trunkline reacts to increased traffic level by increased flight frequency.

X^* is the equilibrium value below which the solution of local air service is more expensive ($M_L + t_L > m_A + t_A$) and above which the reverse is true ($m_L + t_L < m_A + t_A$).

The decomposition of the vertical segment ϵX^* into its money (m_A, m_L) and time (t_A, t_L) components for both alternatives reveals the compromise attained at the equilibrium solution: For the patronage X^*, the local airport L is cheaper in money terms ($m_L < m_A$) whereas the level of frequency at the local airport will never (except in special circumstances) rival the frequency offered at a medium or major trunkline air service center. This inconvenience of local operations is reflected in the inequality $t_L > t_A$ at equilibrium. In other words, the formulation provides the decisionmaker with a minimum value of patronage to justify local direct air operations, but that solution implies a sacrifice: In most cases, a small community can hardly expect the same level of service (flight frequency) as that offered at the nearest trunkline hub.

Time Savings per Passenger: A Measure of Merit

Comparison of the merit of various air service options can be further assisted by introducing the concept of time savings per passenger, $\overline{TS}$ (in monetary terms). The average time savings per passenger by definition are the total time savings divided by the total ridership, at equilibrium. In referring to Figure 4, which displays the general equilibrium between the time-savings and the incremental-cost curves regarding the local air service, the average time savings for a given passenger time value (say, \$10/h on the graph) are total time benefits (vertical segment AX_1^*) divided by the total patronage (horizontal segment OX_1^*). $\overline{TS}$, thus, may be viewed as a factor of merit of the air service and is mainly sensitive to flight frequency.

Isolation-Usage Index

From the foregoing concepts, a tool for planning and policy purposes, called the isolation-usage index, has been developed that can be used to characterize a community regarding its access to air service. The index, in its simplest form, is merely the ratio of the theoretical ridership X as predicted by the benefit-cost criterion of Equation 4 (degree of "isolation") to the actual or forecast air travel demand of the local community (usage). Its value will indicate whether the community is over- or under-supplied with air service, or if supply and demand are reasonably balanced. This matter, along with an illustrative application of the methodology to New York State communities, is covered in detail elsewhere by Hulet and Fisher (5).

SUMMARY AND CONCLUSIONS

A disutility function, relating air passenger inconvenience to delay imposed by flight scheduling, has been conceptualized and employed as an element of a benefit-cost criterion for the determination of the minimum theoretical travel demand necessary to justify air service from a local airport. The tradeoff mechanism between time and money is described by using classical elements of economic theory and a graphical equilibrium analysis shows the validity of the time savings curve as shaped by the disutility function.

The proposed methodology is particularly useful in planning and policymaking for short-haul, light-density air service markets--typified by small communities--and provides a uniform basis for selection of communities that should be part of an air service network.

If local air service from a community cannot be theoretically justified on the basis of an objective economic criterion as proposed herein and yet is provided as "essential" for subjective reasons, subsidy is usually called for. The proposed methodology is advantageous in making the need for and level of subsidy more visible, as well as the cost categories to which subsidy should be directed: capital investment (airport, aircraft) or operating costs (aircraft type, frequency, etc.). Thus, it may be helpful in the optimal allocation of federal funding for airport facilities, as in the National Airport System Plan.

The suitability of the model to parametric variation provides a means of studying the impact of various regulatory policies regarding minimum standards of service in terms, for example, of flight frequency, aircraft capacity, and load factor. Moreover, the range of variables in which the optimal configuration of local air service is specified allows the decisionmaker to study a variety of options for matching supply and demand, as well as to estimate the financial commitment required for each course of action.

Reliable and realistic application of the proposed methodology hinges on perfection of the concept of disutility associated with flight frequency, in particular the accurate estimate of maximum acceptable wait time and maximum acceptable headway. It would be highly desirable to develop an experimental methodology that would substantiate analytically the proposed concept suggested here. It is our opinion that it is better to include the disutility, even in its currently imperfect form, than to omit it entirely. All things considered the methodology provides a uniform and systematic framework for the rational allocation of air service to small communities.

REFERENCES

1. J.F. Hulet. Rational Allocation of Air Service to Small Communities. Cornell Univ., Ithaca, NY, Ph.D. dissertation, Aug. 1980.

2. G.W. Douglas and J.C. Miller, III. Economic Regulation of Domestic Air Transport: Theory and Policy. Brookings Institution, Washington, DC, 1974.
3. G.W. Douglas. Excess Capacity, Service Quality and the Structure of Airline Fares. Proc., Transportation Research Forum, XII-1, Washington, DC, 1971, pp. 109-122.
4. G.W. Dick. National Airport System Plan Entry Criteria for General Aviation Airports. Proc., Transportation Research Forum, XX-1, Washington, DC, 1979, pp. 481-487.
5. J.F. Hulet and G.P. Fisher. An Isolation-Usage Index for Rational Allocation of Air Service to Small Communities. Proc., Transportation Research Forum, XXII-1, Washington, DC, 1981, pp. 239-247.

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General Aviation and the Airport and Airway System: An Analysis of Cost Allocation and Recovery

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Since 1967 it has been the policy of the National Business Aircraft Association that all beneficiaries of the nation's airways system have an obligation to pay a share of its costs. As airport and airway user charges are taken up in the 97th Congress in 1981, the questions are, What is the fair share of system costs that should be recovered from general aviation, and how much of that share was recovered under the 1970 legislation, which has expired? This study addresses these questions and finds that between 58 and 73 percent of general aviation's fair share was recovered in FY 1978 (used herein as the study year) by the taxes enacted in 1970. This does not take into account any public (nonuser) benefit that Congress may assign to general aviation activities. Costs of federal expenditures on the airport and airway system allocable to general aviation amounted to $368.8 million, 13.2 percent of the total system cost, based on data in a Federal Aviation Administration cost-allocation and recovery report for FY 1978. Other allocated cost shares were $1400.5 million for air carriers, 50.3 percent of the total; $281.2 million for military and government aviation, 10.1 percent of the total; and $735.0 million for the public (nonusers), 26.4 percent of the total. Recovery of costs by taxes depends on federal policies that are based on the efficient allocation of national resources, maintaining fair competition among the several modes of transportation, and fair taxation. Absent a cohesive national transportation policy, applying a consistent policy for percentage of costs recovered for like transportation activities to the general aviation primary use categories results in general aviation's fair share of costs that should be recovered to lie within the range of $126.1-$157.5 million for the study year. A comparison, therefore, of the fair share of costs that should be recovered from general aviation, with recovery from the taxes imposed by the Airport and Airway Development and Revenue Acts of 1970, which amounted to $91.5 million in the FY 1978 study year, shows that between 58.1 and 72.6 percent of general aviation's share was recovered by that tax structure. The fourfold increase in petroleum prices since 1974 and the enactment of the Airline Deregulation Act of 1978 emphasize the increasing role of general aviation in the air taxi, executive, and business primary-use categories as a vital and unique transportation resource in the United States.

COST ALLOCATION IN EXPERIENCE AND THEORY

Earlier proposals to tax or charge users for federal expenditures on airports and airways finally resulted in passage of the Airport and Airway Development and Revenue Act of 1970 (1), which provided for the taxes set forth in Table 1 (5), many of which expired or were reduced on October 1, 1980. The legislation provided that receipts from collection of these taxes be paid into a trust fund to offset certain federal expenditures on airports and airways. There was an uncommitted balance in that fund of $3225 million at the beginning of FY 1981 (2).

Experience With Cost Allocation

Four cost-allocation studies are summarized in Table 2: Three were conducted by the Federal Aviation Administration (FAA) and predecessor organizations (in 1950, 1962, and 1978) and one in 1973 by the Office of the Secretary of the U.S. Department of Transportation (DOT). These works show that the annual federal costs of the airport and airway system have grown almost fiftyfold in the 30 years from FY 1949 to FY 1978 covered by these studies. The share of federal airport and airway costs allocable to general aviation varies from a low of 13 percent of all costs to a high of 32.1 percent of all costs, depending on the method of cost allocation used in the study. The existence of this wide range of costs, determined to have been attributable to general aviation, may be used to illustrate the difficulties of allocating costs (the cost-allocation process) and to illustrate what has been learned about that process over the years represented by studies.

Where the costs of providing a facility or service are uniquely and exclusively traceable to a single user, they are said to be clearly allocable or clearly assignable costs and may be charged entirely to that user. Unfortunately, most of the facilities and services provided by federal expenditures on the airport and airway system cannot be so uniquely traced. The system serves all users pretty much on a first-come, first-served basis--considered to be one of its great strengths by many in the aviation community. But in such cases, the so-called "joint" costs or "common" costs must be allocated to the different users and user groups. This--the first flaw in the cost-allocation process--is a flaw because any known way of allocating joint costs [and there are many (3)] is necessarily arbitrary and imperfect, although some methods are generally considered to be more fair and more reasonable than others (4).

Thus, user costs in the two earlier studies were allocated between general aviation [the 1961 FAA study allocated costs only between commercial aviation and military aviation (6)], air carrier, and military aviation simply on the basis of use: so many landings at FAA-manned tower airports, so many enroute fix-postings, and the like. There are at least two objections to the application of this method. First, the resulting allocation of joint or common costs to a user does not necessarily reflect

Table 1. Summary description of aviation user tax structure, 1978-1980.

Type of Tax	Tax Base	Rate: Through September 1980	Rate: Starting October 1980
Domestic passenger ticket tax[a]	Passenger transportation charges	8 percent	5 percent
International air passenger enplanement tax	Passenger enplanements	$3/person	0
Domestic air cargo waybill tax[b]	Cargo transportation charges	5 percent	0
Aviation gasoline	Fuel purchases	7 cents/gal	1.5 cents/gal
Jet fuel	Fuel purchases	7 cents/gal	0
Aircraft registration	Aircraft	$25/aircraft	0
Aircraft weight tax			
Nonturbine-powered	Aircraft weight	2 cents/lb over 2500 lb	0
Turbine-powered	Aircraft weight	3.5 cents/lb	0
Aircraft sales tax			
Tires	Tire weight	5 cents/lb	5 cents/lb
Tubes	Tube weight	10 cents/lb	9 cents/lb

[a]Tax on the transportation of persons by air. [b]Tax on the transportation of property by air.

Table 2. Summary of principal airport and airway cost allocation studies, 1950-1978.

Item	1978 FAA Study FY 1978 Forecast Data	1973 DOT Study FY 1975 Forecast Data	1961 FAA Study FY 1962 Data	1950 CAA Study FY 1949 Data
Airport and airway system costs (millions)	$2785	$1820	$431.4	$58.7
Basis:	FAA annual appropriation. Included in allocation below under "public and other" are public interest costs (regulation and other government expenses $236.2 million, nonaviation weather expenses $28.1 million, clearly allocable defense costs $90.1 million and expenses associated with subsidized air transportation service to small communities $44.4 million) and service benefits limited to local users (National and Dulles Airport expenses $33.5 million) amounting to $432.3 million total. Investment costs treated as current costs.	Included are DOT research and development and FAA airport and airway materiel and services; DOD enroute services overseas and NOAA net aviation weather costs. Excluded are FAA safety regulation, National Capital Airports and Aviation War Risk Revolving Fund; Coast Guard search and rescue and operation of navigation aids; National Transportation Safety Board; joint use DOD facilities; NASA; and CAB subsidy and regulatory activities. Investment costs treated: (a) as current costs, (b) amortized after start of base period, (c) amortized prior to start of base period.	FAA annual maintenance and operations costs including administrative costs, depreciation on capital investment, amortization of long range research and development costs and interest on unamortized investment in capital facilities and in long range research and development projects. No credit for military standby value.	Annual cost of maintenance and operation, amortization of depreciation charges, and interest on unamortized investment of the domestic part of the Federal Airways System. No credit for military standby value.
Allocation of costs (millions) and share of total (%)				
General aviation	$368.8-$671.6 (13-24%)	$373-$536 (19.6-32.1%)	$302.4 (70.0%)	$15.7 (26.7%)
Air carrier	$1400.5 (50%)	$861-$928 (47.3-51.0%)		$27.0 (46.1%)
Military and government aviation	$281.2 (10%)	$356-$584 (19.6-32.1%)	$129.0 (29.9%)	$16.0 (27.2%)
Public and other	$432.3-$735.0 (16-27%)	None shown	None shown	None shown
Basis:	Allocations are based on two methods; new investment-marginal cost method and the requirement for minimum service method. In the latter method, the "cost of common system" ($302.7 million) is subtracted from general aviation and added to public and other.	Ten-year system costs are allocated by 10 different methodologies for the three different treatments of investment costs. Study singles out long-run marginal cost method as preferred; that and one other method, benefits/value of service, are shown above to provide range.	Costs of 5 groups of domestic airway facilities are allocated on 5 different bases of use; e.g., the sum of costs for terminal area radars, instrument landing systems and approach lighting are allocated on basis of instrument approaches. No breakdown of commercial aviation between general aviation and air carrier is shown.	Costs of terminal aids and enroute aids allocated on basis of use (variously tower operations, approaches, fix postings and mileage).
User tax revenues (millions) and share of allocable costs covered (%)				
General aviation	$91.5 (14-25%)	$94 (17.5-25.2%)	$20.3 (6.7%)	$0.4
Air carrier	$1229.2 (88%)	$882 (95.0-102.4%)		$8.1
Basis:	Air passenger ticket tax 8 percent, international enplanement tax $3, cargo waybill tax 5 percent, gasoline and jet fuel sales tax 7¢/gal, aircraft registration fee $25, weight tax 2¢/lb nonturbine over 2500 lb and 3.5¢/lb turbine, tire and tube sales tax 5¢/lb tire weight and 10¢/lb tube weight.	Same as 1978 FAA study.	2¢/gal tax on aviation gasoline. Proposed adding 0.5¢/gal per year until properly allocable costs to civil aviation are substantially recovered.	For the year 1953 based on recommended new federal 1.5¢/gal tax on all jet aviation fuel and all aviation gasoline of 91 or greater octane rating; the latter to exempt the smaller type of aircraft, which are essentially nonusers of the airways.

the costs incurred to serve that user. For example, the different aircraft of the separate user groups vary in performance (flight speed) and equipment carried and, hence, impose different controller workloads and system costs for the use of the system. The 1973 DOT study attempted to take some of these differences into account by devising and applying weights to the amount of system use made by different users (3).

But there is a second and more fundamental objection to the measure-of-use method of allocating joint costs, and it is that relatively little attention is paid to what each user wants and is willing to pay for. Usually a single facility or service is offered the user as a result of federal expenditures on airports and airways--the user accepts the single service or none at all (when that choice exists). Yet a particular facility or service may have been designed for a higher level of performance than a particular user needs or wants.

Special Question of Public or Nonuser Cost Share

The 1973 DOT study made an extensive study of the allocation of joint costs among users, in addition to improvements in the units-of-use method noted above: In all, 10 different methods were applied. The study has been characterized as basically flawed, however, because "it decided there was no merit in general tax support of the system as a matter of public interest" (8,9); that is, no share of system costs was allocated to nonusers. At that time, a reasonable literature had begun to develop around concepts of measuring the economic benefits from air transportation activities such as share of gross national product (air carrier, $10-11 billion, about 1 percent of the U.S. total in 1971, and general aviation, $2-3 billion) and the number of workers employed in industry jobs [920 000 in 1971 (3,10)], the number employed in supplying the industry, and the number employed in serving the people who earn their living in the industry.

These data are useful for a number of purposes, including estimation of the value of benefits to users for the purpose of allocating joint or common costs (as distinguished from methods based on measures of use and costs). But to the professional economist, these data do not provide the basis in our mixed public and private enterprise market system for determining what the general public (as distinguished from system users) should be willing to pay for the airport and airway system supported by expenditures of the federal government. This is also true of similar values of gross national product (GNP) and employment that pertain to the baking of bread or the manufacture of steel; they do not indicate the share of those activities that should be borne by the public out of general tax revenues. There must be a showing of foregone activities--i.e., these people would not be working at all, or as well, if they were not working in air transportation (11), or significant reductions in GNP and the national standard of living would be precipitated by the lack of expenditures on the airport and airway system (12). No estimates of public benefit based on these principles of economic theory have been found.

However, other nonuser benefits of air transportation have been identified (11):

> The increase in capitalized value of real property due to improved access is one benefit that transportation users clearly do not reap. Improved air transportation has allowed a number of Americans to take winter vacations of relatively short duration in the Caribbean, in Florida, and at Western ski resorts--a certain benefit. However, a major gain accrues to the owners of property in these areas who have seen their property values rise substantially--that is, to nonusers of air transportation. The same comment can be made when a new airport increases the value of industrial and commercial property located near it.

The gain in tax revenues to communities so situated might also be added.

The 1973 DOT study concluded no share of FAA expenditures should be allocated to nonusers. The 1978 FAA study moved in two ways to identify nonuser federal expenditures on the airport and airway system and to separate these from the costs allocable to the user groups. The military ultra-high frequency communication requirement was noted. It was similarly found that certain regulation and other government expenses, nonaviation weather expenses, expenses associated with subsidized air transportation services to small communities and the expenses of National and Dulles Airports, where service benefits are limited to local uses, could be identified as public expenses, not to be included in FAA expenses to be allocated among the users of the system.

The 1978 FAA study took one additional step in the identification of public interest costs. In reaction to the 1973 DOT study, the general aviation community had also observed that it was being overwhelmed with facilities and services provided by the FAA that it did not want or require (9).

In the 1978 study a separate minimum-requirements airport and airway system was designed for each user group--general aviation, air carrier, and military and government aviation--and used as the basis for allocating costs among the users. The residual or left-over costs (FAA expenditures less the costs of the three separate systems added together) in the amount of $302.7 million annually (FY 1978) were allocated as the public share.

ALLOCATION METHODOLOGY SELECTED

Multiple and sometimes conflicting evaluation criteria exist to select the method for allocating joint and common costs. The 1978 FAA study applied the following criteria: "economic efficiency, equity, ability to pay, and minimizing or reducing funding deficits. The selection is also constrained by desirability to minimize administrative burdens, i.e., consideration of the practical problems of implementation" (4).

The method selected here to allocate joint and common costs is the minimum separate requirements method reported in the 1978 FAA study. This is consistent with the cost-allocation methodology developed by the U.S. Army Corps of Engineers over the years to allocate cost among multipurpose water projects, the basis of which is that no single-purpose project should be allocated a greater share of multipurpose costs than the costs that project would incur "going it alone" (13). Although economists admit to the arbitrary nature of the various methods for allocating joint costs, they are in agreement that "no group of users should have to pay more overall than they would pay for a separate system of their own" (14).

Conclusion

Therefore, by using the most recent data and analysis available, that from the FAA 1978 study and shown in Table 3, experience and theory suggest that federal expenditures on the airport and airway system should be allocated as follows: 26.4 percent to

Table 3. Allocation of federal expenditures on airports and airways based on FY 1978 data.

Item	Cost ($ millions)	Percentage of Total
Total airport and airway system cost	2785.5	100.0
Public (nonuser) costs	735.0	26.4
General aviation (5)	368.8	13.2
Air carrier[a]	1400.5	50.3
Military and government aviation	281.2	10.1

[a]Includes allocation to both direct and indirect users.

the public (nonusers), 13.2 percent to general aviation, 50.3 percent to air carriers, and 10.1 percent to military and government aviation. The general aviation and air carrier share includes both the direct users' share (the aircraft operators) and the indirect users' share (the passengers and shippers that use and, hence, directly benefit from the service provided by the aircraft operators).

COST RECOVERY IN EXPERIENCE AND THEORY

The level of recovery of federal expenditures on a particular element of our transportation system has been determined from time to time through the political process, responding largely to the goals of a particular transitory bureaucracy then in power, to the local interests that the legislators individually represent, and to pressure of the several usually well-organized interest groups representing the various industry elements affected. The overall pattern of recovery resulting from this process has not been uniform: The level of recovery is not the same for all modes, the kinds of changes and taxes levied are not the same for all users who are told they must pay, and the kinds of federal expenditures (maintenance, operators, and investment) on which taxes for recovery are based varies. When full recovery of federal expenditures is not made, the gap is made up by a transfer payment from general revenues (15).

Basis for Recovery

The user tax concept supporting the specific tax levies on users of the airport and airway system enacted in 1970 (shown in Table 1), is grounded in basic principles of efficient allocation of resources, fair competition, and fair taxation (16,17). Each merits careful consideration.

Efficient Allocation of Resources

It is an accepted principle of economic theory that when prices or average revenues are set equal to the marginal costs of production, the private market system, operating in free and open competition in the private sector, will efficiently allocate the nation's scarce resources (18,19). This concept has been extended to encompass the idea that "if users of special services or facilities are not required to pay their share of the costs, the market system for matching demand and supply at a price reflecting value to the purchaser and cost to the supplier will be inoperative. The users will demand more of the services or facilities than they would if the price fully reflected the cost, and resources will be shifted from more productive activities to the special services or facilities" (16).

These concepts are not relevant to, and do not support, taxes equivalent to full cost recovery from general aviation users of the airport and airway system on the grounds that economic efficiency is thereby enhanced through a better allocation of scarce resources. In the first place, for the theoretically efficient allocation to occur, price must be equated to marginal not average cost and "it is no simple matter to measure marginal costs" (16). "This test of value is rather crude, since total revenues are compared with total cost, and no tests are performed at the margin" (20).

But a much more fundamental flaw in applying the efficiency logic from economic thinking to justify a user tax on general aviation equivalent to full cost recovery is that the desired result of efficient allocation of the nation's scarce resources is achieved only in competitive markets. "Competitive behavior assures the equation of price and marginal cost that is required if free consumer choices are to result in the optimal allocation of resources" (18). The FAA provides goods and services to general aviation as a monopolist; there is no competition and in reality no market at all in any conventional sense. Under the conditions of monopoly, average revenues or price exceeds marginal costs. "Inefficient allocation results, and consideration must be given to public policies that force firms to produce at an optimal output where AR equals MC" (21).

The other parts of the argument, not necessarily related to full cost recovery, are based on the benefit principle, and the free-goods concept. Both have limited applicability to cost recovery of federal expenditures on airports and airways from general aviation users.

The benefit principle calls for the distribution of taxes in accordance with the benefits received from the expenditures on which the taxes are spent. It is a sort of substitute for the market test in the private economy; people pay for the goods and services received in the private economy, so why not in the public sector? "After all, if the people who will benefit from expenditures are not willing to pay for them through their taxes, presumably they are not worth the cost and should not be undertaken" (20). The difficulty is that the general aviation user has no choice; the airport and airway system are there to provide safety to all users. A user cannot decide the system or part of it is not worth the cost and should not be undertaken unless the user stops flying altogether. If he or she flies at all, the user must pay all the taxes. Most of the time you can pay the toll and use the turnpike, or not pay the toll and take an alternate route. Here, there is no such choice.

The other part of the argument, namely that one will use less of a resource if one has to pay for it, also provides only limited support for the collection of user taxes from general aviation on the grounds of enhancing the efficient use of resources. The kind of taxes to which this relates--a terminal charge at airports with FAA towers or an enroute service fee--have been considered time and time again, and rejected on the grounds of safety and administrative complexity (5). It cannot be played both ways; on the one hand, justifying taxes on the grounds payment will discourage use of a free good or service, and then turning around and imposing taxes that do not relate to use or nonuse of any particular good or service that is offered.

Fair Competition

The scheduled airlines and in general aviation--the air taxi operators, executive transportation, and business transportation--compete with water, rail, and highway carriers for the movement of both passengers and freight (16). For each mode of transportation to bear its share of the cost of federally

Table 4. Elements of transportation bill, by market, 1978.

Market	Revenues and Private Expenditures ($ millions)	Subsidy by Governments ($millions)	Total Transportation Bill ($ millions)	Percentage of Total Bill Paid by Subsidy	Private Share
U.S. International	9 419	892	10 311	8.65	0.913
Freight	5 693	829	6 522	12.7	0.873
Water	4 928	761	5 689	13.4	0.866
Air	765	68	833	8.16	0.918
Passenger	3 726	63	3 789	1.66	0.983
Air	3 445	62	3 507	1.77	0.982
Water	281	1	282	0.35	0.996
Intercity	159 137	8 756	167 893	5.21	0.948
Freight	69 517	2 962	72 479	4.09	0.959
Truck	47 272	1 667	48 939	3.41	0.966
Regulated	22 000	NA	NA	NA	
Other	25 272	NA	NA	NA	
Rail	16 509	282	16 791	1.68	0.983
Water	2 434	768	3 202	24.0	0.760
Domestic ocean	1 136	NA	NA	NA	
Inland waterway	950	NA	NA	NA	
Great Lakes	348	NA	NA	NA	
Pipeline	2 229	26	2 255	1.15	0.988
Oil	1 317	NA	NA	NA	
Gas	912	NA	NA	NA	
Aviation	1 073	219	1 292	16.9	0.831
Passenger	89 620	5 794	95 414	6.07	0.939
Automobile	71 933	4 361	76 294	5.72	0.943
Aviation	16 315	1 115	17 430	6.40	0.936
Carriers	11 581	NA	NA	NA	
General	4 734	NA	NA	NA	
Rail	340	308	648	47.5	0.525
Bus	1 016	0	1 016	0.00	1.000
Water	16	10	26	38.5	0.615
Local	133 008	7 532	140 540	5.36	0.946
Freight, truck	47 790	209	47 999	0.43	0.996
Passenger	85 218	7 323	92 541	7.91	0.921
Automobile	82 732	3 397	86 129	3.94	0.961
Owner operated	81 150	NA	NA	NA	
Taxi	1 582	NA	NA	NA	
Transit	2 200	2 038	4 238	48.1	0.519
Bus	600	NA	NA	NA	
Rail	1 401	NA	NA	NA	
Commuter	199	NA	NA	NA	
School bus	286	1 888	2 174	86.8	0.131
Miscellaneous	3 973	263	4 236	6.21	0.938
Boats	1 754	263	2 017	13.0	0.870
Recreation	NA	NA	NA	NA	
Commercial fishing	NA	NA	NA	NA	
Other	2 219	0	2 219	0.00	1.000
Total	305 537	17 443	322 980	5.40	0.946

provided transport facilities is necessary to ensure fair competition. Of the 39 million h flown in general aviation in 1978, more than 17 million h, 44 percent of the total of all hours flown, were in those categories where uneven federal expenditures might give one mode a competitive advantage over another mode. However, applying this basic principle of federal tax parity across modes to provide competitive equity ignores the fact that more than 9 million general aviation h (more than 24 percent of all hours) were for personal flying, not associated with a business or profession, and not for hire (22). There is no basis to recover federal expenditures on airports and airways from this segment of the general aviation community on the grounds that competitive equity among modes must be maintained fairly.

Fair Taxation

Another rationale to support taxes on general aviation to recover federal expenditures on the airport and airway system is that the costs of special services and facilities should be borne by those who use them and reap the benefit, rather than by the general taxpayer. Thus, where the persons benefited are fully able to pay, they should do so, unless there is some overriding justification provided by national policy for redistributing income from the general taxpayer to the users.

A recent tabulation was made for 1975 by the National Transportation Policy Study Commission, showing separately the revenues and private expenditures on transportation and government subsidy to transportation (23). As shown in Table 4 (23), the government subsidy varies widely as the share of the total transportation bill: in the extreme, from 86.6 percent in the case of school buses to 0 percent for intercity passenger transportation by bus. Virtually no one else in the transportation community operates without some subsidy from government. The costs of intercity freight movements by air were borne 16.9 percent by government subsidy, the cost of intercity passenger movements by air 6.4 percent by government subsidy, and the cost of intercity passenger movements by rail 47.5 percent by government subsidy.

A recent study of taxes imposed by states and local communities on general aviation shows a similar deviation among taxing sources (24). Some 90 percent of the states were found to impose three or more taxes (sales tax, fuel tax, and aircraft registration fee). Some 24 states have a special "aviation fund" into which some or all of the taxes collected flow, and 10 states allocate all aviation tax receipts to general state funds. The study estimated that on the order of $147 million was collected by state and local governments from general aviation users.

Conclusion

Fair competition, fair taxation, and, to a limited extent, economic efficiency provide the rationale to recover some of the federal expenditures on the airport and airway system by taxing general aviation users of that system. To correctly determine how much should be recovered by taxes under the principle of fair competition requires further development of the competitive situation between general aviation and other modes of transport. To correctly determine how much should be recovered under the principle of fair taxation requires a more complete explication of national transportation policy. This is undertaken in the next two sections. Presented first is a profile of general aviation and, second, a review of national transportation policy as it pertains to the issues at hand. Certainly, general aviation should not pay less than its fair share; nor should it be required to pay more, comparatively, than the other beneficiaries of federal expenditures on transportation.

Table 5. General aviation number of aircraft and hours flown, by type and primary use, 1978.

Type	Number of Aircraft	Percent of Total	Hours Flown (000s)	Percent of Total	Average Hours per Aircraft
Aerial application (total)	7 418	3.75	2 066	5.25	278
Piston one-engine	6 335		1 800		284
All other piston	281		46		163
Turbine	12		1		69
Rotorcraft	785		219		279
Other	1		-[a]		-
Air taxi (total)	7 936	4.01	4 423	11.3	557
Piston one-engine	2 770		1 210		437
All other piston	3 314		1 684		508
Turbine	614		683		1111
Rotorcraft	1 215		828		682
Other	19		2		94
Business transport (total)	42 809	21.6	8 014	20.4	187
Piston one-engine	31 548		5 613		178
All other piston	10 074		2 089		207
Turbine	362		155		428
Rotorcraft	641		138		215
Other	181		13		75
Executive transport (total)	12 666	6.40	4 882	12.4	385
Piston one-engine	3 214		1 253		390
All other piston	4 764		1 575		331
Turbine	4 166		1 784		428
Rotorcraft	487		267		549
Other	32		2		54
Industrial-specialist (total)	2 059	1.04	702	1.79	341
Piston one-engine	1 388		411		296
All other piston	242		74		307
Turbine	17		5		303
Rotorcraft	402		211		525
Other	7		-[a]		-
Instructional flying (total)	14 742	7.45	5 009	12.75	340
Piston one-engine	13 438		4 693		349
All other piston	533		123		230
Turbine	22		11		486
Rotorcraft	269		100		373
Other	476		86		180
Personal flying (total)	96 209	48.6	9 601	24.4	100
Piston one-engine	89 847		9 040		101
All other piston	2 908		352		121
Turbine	56		14		249
Rotorcraft	512		27		53
Other	2 881		171		59
Rental aircraft (total)	8 189	4.14	3 284	8.36	401
Piston one-engine	7 419		3 024		408
All other piston	348		120		345
Turbine	35		23		663
Rotorcraft	130		73		566
Other	255		45		177
Other (total)	6 749	3.41	1 308	3.32	194
Piston one-engine	4 687		717		153
All other piston	700		97		139
Turbine	318		102		322
Rotorcraft	869		365		420
Other	173		18		103
Active (total)	198 778	100.0	39 290	100.0	198
Piston one-engine	160 651		27 857		173
All other piston	23 171		6 186		267
Turbine	5 610		2 801		499
Rotorcraft	5 315		2 228		419
Other	4 028		338		84
Inactive (total)	35 169				
Piston one-engine	28 289				
All other piston	2 866				
Turbine	498				
Rotorcraft	2 365				
Other	1 148				

[a]Less than 1000 h.

PROFILE OF GENERAL AVIATION: PAST AND TRENDS

Definition of General Aviation

General aviation is what economists would call a "residual"--that which is left over after specific items have been subtracted from a larger group of items. It is all aircraft in the U.S. civil fleet except those operated under Federal Aviation Regulations Parts 121 and 127. These two parts cover the operations of fixed-wing aircraft and rotorcraft, respectively, that (a) have been issued a certificate of public convenience and necessity by the Civil Aeronautics Board authorizing the performance of scheduled air transportation over specified routes and a limited amount of non-scheduled operations and (b) are used by large aircraft commercial operators. The FAA has classified this diverse collection of aircraft into eight categories of primary use plus "other" (25). (Enactment, in 1980 of Part 125, Certification and Operation Rules for Certain Large Airplanes, further codified a segment of general aviation activity.)

General Aviation in 1978 and Trends

The number of aircraft by type and hours flown by primary use in general aviation are shown for 1978 in Table 5 (22). In 1978 about one-half the aircraft (48.6 percent) in the general aviation fleet provided about one-quarter (24.4 percent) of the hours flown in personal flying. On the other hand, 4 percent of the aircraft produced 11 percent of the hours flown in air taxi, 6 percent of the aircraft 12 percent of the hours flown in executive transport, and 22 percent of the aircraft 20 percent of the hours flown in business transportation. The highest utilization (average hours flown per aircraft) was achieved by turbine-powered airplanes (499 h/aircraft) and rotorcraft (419 h/aircraft) in air taxi, business, executive, and industrial use.

An analysis of the general aviation fleet and its use for the years 1973 through 1978 shows that the total active aircraft count and total hours flown grew at about the same annual rate 5.33 percent/year and 5.63 percent/year, respectively, but that significant deviations from these mean fleet values occurred among the individual aircraft types (25). The fastest growth of any type in terms of total hours flown occurred with the turbine-powered rotorcraft with an average annual growth rate of 55.51 percent/year (starting, however, from a small base). Most of these rotorcraft are used commercially and in business--for aerial application, air taxi, business and executive transport, and industrial-specialist use. They are highly utilized. The 1075 turbine rotorcraft in air taxi were used 733 h in 1978 on the average (22), four times the total fleet.

Twin-engine turbojets and twin-engine turboprops (1-12 seats) also experienced almost double the average of total hours flown from 1973 through 1978, with average annual growth rates of 11.36 percent/year, and 10.91 percent/year, respectively. In contrast, single-engine piston airplanes experienced very little growth over the period, whether measured by total hours flown (0.79 percent average annual growth) or aircraft count (2.93 percent average annual growth).

In general, therefore, from 1973 through 1978, the larger, more sophisticated aircraft in the general aviation fleet were increasing both in numbers and total hours flown than other components of the fleet.

Impact of Higher Fuel Prices

The steadily increasing price of petroleum fuels since the 1973 embargo has had serious impacts on the greatest user of these products, the transportation industry, and general aviation is no exception.

Increases in fuel prices have had the effect of decreasing travel, as their impact has been to raise travel costs. This impacts most heavily on discretionary travel, which can be either postponed or canceled.

The effect of increasing fuel costs of general aviation, therefore, will be to reduce the established growth rate in hours flown for primary uses, but to disproportionately reduce the hours flown in non-business and discretionary use such as personal flying. This effect has already been felt in aircraft sales. In January 1981, a representative of the General Aviation Manufacturers Association reported that "today, at least 90 percent of the industries' sales are for business purposes" (26).

Impact of Airline Deregulation: Airline Deregulation Act of 1978

A basic objective of the Airline Deregulation Act of 1978 was to increase competition between the trunk, local service, and regional certificated air carriers. It was thought that load factors were too high and that there was too much service competition and not enough price competition. Greatly simplifying the Civil Aeronautics Board's restrictions on rates and routes for these carriers should raise load factors and lower the price of airline tickets because the competitive forces of the private market system would then be free to operate. To a considerable extent this has happened (28,29), but there has been a side effect favorable to some general aviation primary uses.

Higher load factors mean lower seat prices, but it also means it is harder to get seats. This has had its greatest impact on the on-demand business traveler who often cannot plan a trip very much in advance. The effect has been to stimulate general aviation in the air taxi, business, and executive use categories.

The legislation has had an additional favorable impact on general aviation. The Airline Deregulation Act of 1978 introduced a new policy regarding service to small communities: "The maintenance of a comprehensive and convenient system of continuous scheduled airline service for small communities and for isolated areas, with direct Federal assistance where appropriate..." was declared to be in the public interest (27). The legislation backed up the policy statement by guaranteeing essential air service to 555 eligible points, by providing a new federal subsidy program directed toward helping the communities not the carriers, and by making federally guaranteed loans available to commuter air carriers to purchase equipment.

Service to small communities is what general aviation is all about. In 1978 there were 14 746 airports of record in the United States--4651 with runway lights, 5618 with paved runways, and 499 with airport traffic control towers (22). The FAA has identified 147 air traffic hubs (which enplaned 96.1 percent of all air carrier traffic) and, together, the air carriers and commuters provide service to but 880 airports (30).

Air service at the great majority of airports, mostly in small communities, is provided by general aviation. As of February 1, 1981, commuter air carriers were being relied on exclusively to provide essential air service to 201 small communities outside Alaska (31) and to provide replacement service for trunkline and local service carriers at an additional 78 airports (29). Where plants have been located at small towns to diversify in the national interest or to develop particular local resources efficiently, general aviation is most often the only form of air transportation available.

Conclusion

General aviation is in a period of transition. The rise in popularity of private aircraft among business-oriented users, whether the aircraft ownership rests in the hands of the company or an individual within the business firm, is strong and continuing. The great increase in fuel prices over the past few years will contribute to this trend and against personal flying. The Airline Deregulation Act of 1978 will stimulate further growth in air taxi, business, and executive transportation.

CONTRIBUTION OF NATIONAL TRANSPORTATION POLICY

Statements of national transportation policy abound (23). The most comprehensive, mandated by the Congress, is the final report, National Transportation Policies Through the Year 2000, of the National Transportation Policy Study Commission (NTPSC), issued in June 1979 (23).

NTPSC

The NTPSC study addressed regulation; ownership and operations; finance, pricing, and taxation; planning and information; and government organization, calling these functional categories representations of instruments of policy. As did the earlier Doyle study (32), it, too, found that the United States had no unified national transportation policy. "Instead, there is an assortment of policies and programs which have been developed in an ad hoc fashion to achieve sundry goals or resolve various issues. The sheer bulk of federal transport policies and programs (64 federal agencies that implement approximately 100 policies and programs) is enough evidence to convince many observers of the ad hoc nature of Federal transportation policymaking" (23).

A number of specific policies were addressed and recommendations were made by the NTPSC. On the need for uniformity in national transportation policy, NTPSC reported "that there is no uniform set of policies to guide federal actions, or to improve the performance of the private sector. Most policies or programs are individually directed at particular problems. Although most are well-meaning, both individually and collectively they have at times tended to frustrate the effective functioning of competitive markets (23).

The NTPSC was heavily oriented toward using economic techniques to make government more efficient. Thus, on the requirement that users and those who benefit from federal actions should pay, it re-

Table 6. Cost-allocation and recovery proposal for general aviation based on 1978 data.

Primary Use and Recovery Basis	Private Share	Percent of Hours Flown	Weighted Private Share
Aerial application	0.957	5.25	0.0502
Local freight truck[a]			
Air taxi	0.525	11.3	0.0593
Intercity passenger rail[a]			
Business transportation	0.525	20.4	0.107
Intercity passenger rail[a]			
Executive transportation	0.936	12.2	0.114
Intercity passenger aviation[a]			
Industrial-specialist	0.957	1.79	0.0171
Local freight truck[a]			
Instructional flying	0.132	12.7	0.0168
Local passenger school bus[a]			
Personal flying	0.00	24.4	0.0000
Recreational boating			
Rental aircraft	0.525	8.36	0.0439
Intercity passenger rail[a]			
Other	0.570	3.32	0.0189
Unweighted average of the above			
Total		100.0	0.4272

Notes: Method 1: No credit for payment

Allocated costs (1978 FAA study, see Table 3)	$368.8 million
Recoverable costs ($368.8 x 0.4272)	157.5
Present recovery (1978 FAA study)	$ 91.5 million
Recoverable costs (%)	58.1

Method 2: Credit for payment to states

Allocated costs (1978 FAA study, see Table 3)	$368.8 million
Less one-half of tax payment to states	(73.5)
Adjusted allocated costs	295.3
Recoverable costs ($295.3 x 0.4272)	126.1
Present recovery (1978 FAA study)	$ 91.5 million
Recoverable costs (%)	72.6

[a]See Table 4.

ported: "Free markets operate on the principle that those who benefit must pay for the costs. When government provides costly facilities, benefits, or services, it too should assess charges that recover costs against users and others who benefit. In some cases, such as urban and rural transit and air traffic control, where benefits are widespread, it may be appropriate to assess a general tax to recover federally incurred costs" (23).

Similarly, in the discussion on finance, pricing, and taxation, NTPSC policies were focused on creating private "market like" efficiencies in the operation of the government. For example, it was suggested that congestion tolls might be employed during peak periods of facility use (23).

Conclusion

This review of national transportation policy makes three suggestions that are applicable to an analysis of general aviation cost allocation and recovery of federal expenditures on the airport and airway system. First, absent some well-defined benefits that are widespread, the users and those who benefit from federal actions should pay for the benefits they receive. Second, there is no uniform set of policies to guide federal action in transportation. Third, uniformity and consistency in the application of policy are a desirable end. A recent study offers a suggestion to find transportation policy: "There is a loose programmatic policy which must be inferred from currently existing Congressional legislation and agency regulations" (33).

COST ALLOCATION AND RECOVERY: AN ANALYSIS FOR GENERAL AVIATION

The eight categories of primary use that make up general aviation cover a wide spectrum of diverse aviation activity. Because of this, no single tax, or the combination of taxes imposed by the Airport and Airway Revenue Act of 1970 to recover part of the federal expenditures on airports and airways (see Table 1), can be equally fair and equitable to each general aviation primary user. The National Business Aircraft Association, Inc., has adopted the following policy position (34):

> Consideration of aviation user tax levels must first establish the value to be imputed to the air transportation system in terms of national public benefit, and of national military-defense benefit. Only after such determination is made should attention be given to the remainder of system costs to be recovered by user taxes. Whatever specific forms user taxes may take, they should be predicted on certain equity principles....

Systems of taxes other than the one imposed by the Congress in 1970 have been considered on several occasions and rejected, usually on the basis that they are too costly to administer, or that they would compromise the safety of the airport and airways system (5).

No attempt is made here to reopen the question of how to collect the tax. The issue addressed is how much should be collected--what is a fair and equitable overall tax burden for general aviation to bear. The procedure is to weight by total hours flown estimates of the private share paid for other activities in transportation, comparable to the eight categories of primary use comprising general aviation. This is in line with a national transportation policy that seeks uniformity and consistency in charging taxpayers who receive the benefits of goods and services provided by the government. The weighted private share, so determined, is applied to costs allocated to general aviation (from Table 3), and the recoverable costs are then compared with the estimated recovery under the tax structure enacted in 1970. The data base used is the 1978 FAA study, which, along with the calculations, is shown in Table 6.

Thus, the private share for local truck from the NTPSC report is applied to aerial application and industrial-specialist primary general aviation users. The comparability is the short-haul transportation of goods that all of this transportation involves. For air taxi, business transportation, and rental aircraft, the NTPSC private share for intercity rail passenger service is used. The comparability is short-haul passenger service. However, for executive transportation, the private share for intercity passenger aviation was selected because this general aviation primary-use category makes up the largest share of multiengine piston and turbine aircraft. These provide longer-haul air passenger service comparable to that offered by the air carriers.

Instructional flying serves two purposes--education, learning to fly--and maintaining flight proficiency as required by FAA regulation. The latter purpose is principally to enhance safety that the FAA study determined to be a public (nonuser) cost, so assigning the NTPSC local passenger school bus private share to all instructional flying is probably conservative. Personal flying was treated the same as recreational boating, which at the present time makes no payments for use of the navigation aids and other services provided by the U.S. Coast Guard, nor for the use of the inland waterway system.

Finally, there is the question of credit for the payment of like taxes to the states. Income tax laws typically allow the deduction, in computing net income subject to tax, of certain types of state and local taxes paid or incurred by the taxpayer (35).

Accordingly, the position may be advanced that some, if not all, of the $147 million paid by general aviation users to the states should be credited to the share of allocated costs based on federal airport and airway expenditures. The data readily available do not permit the detailed analysis that will be required to determine which, if any, state taxes paid should be so credited. However, crediting one-half of taxes paid to the states serves to provide an upper bound in estimating the percentage of full recovery now paid by general aviation users. This example is based on crediting state taxes against taxable income for a taxpayer in the 50 percent tax bracket.

Under the assumptions made and the methods applied, the costs to be recovered by federal taxes from general aviation users range from a low of $126.1 million to a high of $157.5 million. Comparing these values with estimated revenues of $91.5 million (under the 1970 tax system) suggests that general aviation was paying between 58 and 72.6 percent of its fair share of federal expenditures on airports and airways in the 1978 study year; the range was determined by whether or not credit against general aviation's fair share of federal expenditures is given for taxes paid to states. The foregoing does not take into account any public (nonuser) benefit that Congress may assign to general aviation activities and is based on cost data supplied by FAA.

REFERENCES

1. Airport and Airway Development and Revenue Acts of 1970. P.L. 91-258, May 21, 1970.
2. Airport and Airways System Development Act of 1979. Hearings Before the Subcommittee on Aviation of the Committee on Commerce, Science, and Transportation, U.S. Senate, Serial No. 96-58, 1980.
3. Airport and Airway Cost Allocation Study: Part 1, Report--Determination, Allocation and Recovery of System Costs. U.S. Department of Transportation, Sept. 1973.
4. R.L. Fain and D.S. Garvett. Airport and Airway System Cost Allocation. Mitre Corp., McLean, VA; FAA, U.S. Department of Transportation, Sept. 1977.
5. Financing the Airport and Airway System: Cost Allocation and Recovery. FAA, Rept. No. FAA-AVP-78-14, Nov. 1978.
6. A Study of User Charges for the Domestic Federal Airway System. FAA, U.S. Department of Transportation, April 1961.
7. A Program of User Charges for the Federal Airways System. Civil Aeronautics Administration, U.S. Department of Commerce, Feb. 3, 1950.
8. Airport and Airway Trust Fund. Statement of General Aviation Manufacturers Association and Statement of National Business Aircraft Association Before the Subcommittee on Taxation and Debt Management Generally of the Committee on Finance, U.S. Senate, Sept. 8, 1980.
9. Review of the Aviation User Charge Situation. Aircraft Owners and Pilots Assoc., Washington, DC, Feb. 7, 1975.
10. G. Fromm. Value of Aviation Activity. Data Resources, Inc., Jan. 1973.
11. H.A. Hovey. Some Conceptual Issues in Cost Allocation for Air Transportation. Battelle Memorial Institute, Seattle, March 6, 1970.
12. Benefits: Aviation Cost Allocation Study. Office of Policy Review, U.S. Department of Transportation, Working Paper No. 9, Oct. 1972.
13. Navigation Cost Allocation Study: A Feasibility Case Study--Main Report. U.S. Army Corps of Engineers, Washington, DC, Oct. 5, 1980.
14. D.B. Lee. Recent Advances in Highway Cost Allocation Analysis. Transportation Systems Center, U.S. Department of Transportation, Cambridge, MA, Jan. 1981.
15. J.H. Winant. Additional Remarks Before the Subcommittee on Aviation, Committee on Commerce, Science, and Transportation, U.S. Senate, Jan. 26, 1981.
16. D.S. Collinson. Statement Before U.S. House of Representatives Committee on Ways and Means, April 12, 1976.
17. Airway User Charges. National Business Aircraft Assoc., Inc., Washington, DC, March 1, 1968.
18. A.E. Kahn. The Economics of Regulation: Principles and Institutions. Wiley, New York, Vol. 1, 1970.
19. W.J. Baumol and D.F. Bradford. Optimal Departures from Marginal Cost Pricing. American Economic Review, Vol. 60, No. 3, June 1970.
20. O. Eckstein. Public Finance. Prentice-Hall, Englewood Cliffs, NJ, 1964.
21. R.A. Musgrave. Theory of Public Finance: A Study in Public Economy. McGraw-Hill, New York, 1959.
22. FAA Statistical Handbook of Aviation, Calendar Year 1979. FAA, U.S. Department of Transportation, Dec. 31, 1979.
23. National Transportation Policies Through the Year 2000. National Transportation Policy Study Commission, Washington, DC, Final Rept., June 1979.
24. The Incidence of State Imposed Taxes on General Aviation. Gellman Research Assoc., Inc.; Office of General Aviation, FAA, U.S. Department of Transportation, Final Rept., Nov. 1978.
25. 1978 General Aviation Activity and Avionics Survey (Annual Summary Report). FAA, U.S. Department of Transportation, March 1980.
26. Industry Report. General Aviation Manufacturers Assoc., Washington, DC, Jan. 16, 1981.
27. Airline Deregulation Act of 1978. P.L. 95-504, Oct. 24, 1978.
28. S.E. Eastman. Economic Regulation of Air Service to Small Communities: Origins to the Airline Deregulation Act of 1978. Presented at TRB 60th Annual Meeting, Washington, DC, Jan. 1981.
29. C.S. Murphy. Air Service to Small Communities After Two Years of Deregulation: Overview. Presented at TRB 60th Annual Meeting, Washington, DC, Jan. 1981.
30. 1980 Annual Report. Commuter Airline Assoc. of America, Washington, DC, Nov. 1980.
31. Commuter Air Carriers Being Relied Upon for Essential Service as of February 1, 1981, for Points Outside Alaska. Commuter Airline Assoc. of America, Washington, DC, 1981.
32. National Transportation Policy. Report of the Committee on Commerce, 87th Congress, 1st Sess., U.S. Senate, Rept. No. 445, June 1961.
33. Transport Tomorrow: A National Priority--A Prescription for Effective Transportation Policies. National Chamber Foundation, Washington, DC, 1981.
34. New Administration Proposals to Drastically Increase Aviation Fuel Taxes Up to 65¢ per Gallon by 1986. National Business Aircraft Assn., Inc., Washington, DC, Action Bull., AB 81-6, March 25, 1981.
35. Deductions. 71 Amer. Juris., 2nd 811.

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