TRANSPORTATION RESEARCH RECORD **1094**

Issues in Air Transport and Airport Management

TRB
TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1986

Transportation Research Record 1094
Price $8.20
Editor: Lisette Chou
Compositor: Lucinda Reeder
Layout: Theresa L. Johnson

mode
4 air transportation

subject areas
12 planning
14 finance
53 vehicle characteristics
54 operations and traffic control
55 traffic flow, capacity, and measurements

Transportation Research Board publications are available by ordering directly from TRB. They may also be obtained on a regular basis through organizational or individual affiliation with TRB; affiliates or library subscribers are eligible for substantial discounts. For further information, write to the Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

Printed in the United States of America

Library of Congress Cataloging-in-Publication Data
National Research Council. Transportation Research Board.

Issues in air transport and airport management.

(Transportation research record, ISSN 0361-1981 ; 1094)
Reports prepared for the 65th Annual Meeting of the Transportation Research Board.
1. Aeronautics, Commerical. I. National Research Council (U.S.). Transportation Research Board Meeting (65th : 1986 : Washington, D.C.) II. Series.
TE7.H5 no. 1094 380.5 s 87-7628
[TL552] [387.7]
ISBN 0-309-04114-7

Transportation Research Record 1094

The **Transportation Research Record** series consists of collections of papers on a given subject. Most of the papers in a Transportation Research Record were originally prepared for presentation at a TRB Annual Meeting. All papers (both Annual Meeting papers and those submitted solely for publication) have been reviewed and accepted for publication by TRB's peer review process according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The views expressed in these papers are those of the authors and do not necessarily reflect those of the sponsoring committee, the Transportation Research Board, the National Research Council, or the sponsors of TRB activities.

Transportation Research Records are issued irregularly; approximately 50 are released each year. Each is classified according to the modes and subject areas dealt with in the individual papers it contains. TRB publications are available on direct order from TRB, or they may be obtained on a regular basis through organizational or individual affiliation with TRB. Affiliates or library subscribers are eligible for substantial discounts. For further information, write to the Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

Contents

Alternatives to the Hub: A Survey of Nonstop Air Service Opportunities

JOSEPH P. SCHWIETERMAN AND FRANK A. SPENCER

A renewed interest in nonhub air services marks a significant change in the philosophy of the airline industry. Several major airlines are venturing boldly from traditional hub-and-spoke route systems into markets that can support nonstop service of their own. Others, encouraged by the success of these firms, have announced large-scale plans to dedicate much of their soon-to-be-acquired capacity to similar purposes. In an era dominated by hub-and-spoke route systems, a group of nonhub cities appears to have emerged as a lucrative target for the initiation of new nonstop air service. Civil Aeronautics Board traffic data and published schedule information are used to survey the opportunities for new nonstop air services. The current status of nonstop air service between 50 major metropolitan areas in the United States is assessed, and the large imbalances in the availability of nonstop service that have evolved are investigated. This provides a useful perspective on the relative attractiveness of these metropolitan areas to entrepreneurs. Secondly, America's most heavily traveled markets without highly-valued nonstop services are identified, drawing attention to an important set of market incentives that will play a critical role in the reshaping of America's air travel network. The results of the study indicate that the introduction of new nonstop services in markets traditionally served only with connecting flights constitutes a viable and an increasingly attractive means of product differentiation.

Intricate hub-and-spoke systems linking metropolitan areas have greatly changed the structure of air transportation in the United States. Firms have invested heavily in hub facilities to protect market share and serve as foundations for expansion in a highly competitive environment, and have utilized them in more than 75 percent of their expansion since 1980. Atlanta, Chicago, Dallas, Denver, Houston, and St. Louis have emerged as premier connecting hubs. A dozen other cities have become important regional or minihubs.

Recently, however, several major airlines have ventured boldly from traditional hub operations into markets that can support nonstop service of their own. Others, encouraged by the success of these firms, have announced large-scale plans to dedicate much of the soon-to-be-acquired capacity to similar purposes. In an era of hub-and-spoke expansion, a group of nonhub cities appears to have emerged as a lucrative target for the initiation of new nonstop air services.

The renewed interest in nonhub air service marks a significant reversal in philosophy of the airline industry. Such a redirection in strategic planning is likely to decentralize the U.S. intercity air network and greatly affect the quality of air service to many metropolitan areas. As airlines circumvent or supplement traditional hub operation with new point-to-point services, certain metropolitan areas are likely to experience disproportionate gains or losses in the scope of their nonstop air service.

The implications of these trends for both airlines and local economies indicate a need for ground-breaking research. Although previous studies provide useful econometric evidence of the effects of airline hubs *(1, 2)*, individual markets have not been studied in the detail required to develop insight into the likely unfolding of new nonstop service. The objective of this paper is to bring much-needed attention to this timely issue.

In surveying the status of nonstop service between the 50 largest U.S. metropolitan areas, an appreciation is fostered for the panorama of opportunities available to nonstop operators in an environment dominated by hub-and-spoke route systems. First, Civil Aeronautics Board (CAB) traffic data and published schedule information are used to explore the large imbalances in the availability of service that have evolved, and to illustrate the relative attractiveness of the metropolitan areas to entrepreneurs. Secondly, the most heavily traveled U.S. markets without highly valued nonstop services are identified. This draws attention to an important set of market incentives that will play a critical role in the reshaping of the U.S. air travel network.

Entrepreneurship in new nonstop services is ultimately affected by numerous variables ranging from airport facility constraints, geography, and manpower planning concerns to local economic conditions. By concentrating on only one factor in this complex equation—the current imbalances in the scope of nonstop services between metropolitan areas—the analysis surfaces key issues that have been overlooked by more broadly focused studies.

CHANGING MARKET CONDITIONS

Four marketing factors are chiefly responsible for the heightened interest in new nonstop services. These factors are encouraging greater flexibility and innovation in route development, and are dissuading firms from concentrating their investment into a few major hub operations. A brief summary of these four conditions will serve as a useful groundwork for the analysis in the following sections on nonstop market opportunities and on the largest unserved city pairs in the United States.

J. P. Schwieterman, United Airlines, EXOIM, Box 66100, Chicago, Ill. 60618. F. A. Spencer, Northwestern University, Evanston, Ill. 60201.

Product Differentiation Opportunities

The number of airline hubs has increased twofold since the Airline Deregulation Act of 1978, and the oligopolistic structure that once characterized most markets has been replaced by one of highly decentralized competition. The result has been a growing number of alternatives available to the consumer *(3)*.

The competition from the expanding number of hub operations, coupled with the successful expansion of low-cost operators, is exerting a powerful downward pressure on fares. In addition, competition is hampering the ability of firms to employ elaborate fare schemes designed to price discriminate *(4)*. The result has been a 20 percent real decline in industry yield since 1981 *(5)*.

Providing nonstop service in a traditionally one-stop market provides a firm with valuable product differentiation that, when used effectively, can shelter it from these highly competitive market conditions. A single nonstop flight in a market otherwise served only by connecting services generally provides a firm with a healthy base of full-fare business traffic, typically yielding over 20 cents per passenger mile, in the face of a rival's heavily discounted unrestricted fare that may yield less than 12 cents per passenger mile *(4)*. This product differentiation technique affords a simultaneous increase in both market share and passenger yield, and generally protects a firm from unfavorable pricing actions introduced by its competitors.

Technological Change

A key deterrent to innovation in nonhub route development has been the absence of a limited-capacity aircraft capable of cost-effective long-range flying. Nonhub routes often have been unable to support larger aircraft, and the high costs of operating smaller planes have made break-even load factors prohibitively high *(6)*.

However, a new generation of aircraft is markedly improving the economics of nonhub flying. The Fokker 100 aircraft, a German twin jet seating 85 passengers, and the British Aerospace 146 Jet with capacity ranging from 85 to 126 passengers, and others have sparked a flurry of entrepreneurship on routes previously unable to support nonstop service. Each has a maximum range exceeding 1,100 mi and provides service for less than 7 cents per seat-mile. This is well below the cost of their predecessors and only fractionally higher than that for larger aircraft *(6)*.

The recently introduced Boeing 737–300 aircraft, with total seating of up to 149 and a range of 1,500 mi, and the soon-to-be available McDonnell Douglas MD87 are encouraging similar innovation on long-haul routes. These aircraft are especially attractive to major airlines because of their compatibility with existing crew training and maintenance requirements, fuel efficiency, and two-man crews.

Declining Economies of Scale

Studies indicate that hub operations can reduce seat-mile costs by 10 percent or more *(2)*. However, as indicated next, recent escalations in hub operating expenses are rendering nonhub air services as an increasingly attractive economic alternative.

Airport congestion has become costly. Since 1980, the cost of air traffic delays has more than doubled, quickly offsetting many of the efficiency advantages of major hubs *(7)*. This problem has been particularly significant at the major hubs of Atlanta, Chicago, Dallas-Fort Worth, and St. Louis where ground, gate, and air traffic delays have risen 140 percent faster than at airports less densely served. In addition, many major hubs are raising gate rental and landing fees, and assessing fuel surcharges and departure taxes in an effort to alleviate congestion. These user fees have risen by nearly 125 percent at major hub complexes in the past 3 years, encouraging a transfer of resources to less congested facilities.

Reductions in Labor Expense

A 10 percent decline in labor costs since deregulation (as a percent of total costs) is also increasing the attractiveness of relatively manpower-intensive nonhub services *(7)*.

Hub-and-spoke operations permit manpower to be scheduled on efficient lines-of-flying from central locations, and allow more efficient planning for pilot and flight attendant reserve coverage. Nonhub operations tend to decentralize an airline's manpower needs. This not only complicates the effective allocation of manpower throughout the route system, but can inhibit the full utilization of labor as specified by labor contracts or federal law.

However, with the emergence of lower new-hire wage scales and a liberalization of work rules, the cost of layovers, waiting time, deadheading, and other operational problems associated with nonhub air service has steadily diminished. Only now, with these declining labor costs, are many firms able to justify departure from hub systems.

These four factors, coupled with spiraling demand for air passenger services, are largely responsible for the flurry of entrepreneurship in new nonstop air services. To provide a useful perspective on how these services are likely to unfold, the following section reviews the status of nonstop air services between the 50 largest population centers in the United States.

NONSTOP MARKET OPPORTUNITIES

The distribution of nonstop air services among metropolitan areas has been greatly affected by the popularity of hub-and-spoke route systems. Direct flights between nonhub cities has declined from 24.5 percent of total jet departures in 1978 to 13.3 percent today *(8)*, and important voids in nonstop service have emerged between nonhub cities. Some of this relative decline in nonhub flying is attributable to the formation of new hubs in cities such as Dayton, Detroit, Kansas City, and Phoenix. However, an even greater factor has been the disproportionate share of resources devoted to the expansion of existing hub complexes.

The opportunity for rapid market share expansion in many nonhub cities is attracting firms capable of filling these voids in service. Heavily populated metropolitan areas with limited nonstop service are emerging as lucrative targets for market entry. Others, already saturated with nonstop services or unable to support new nonstop services, appear to be benefitting little from the changing market conditions.

A useful measure of the scope of nonstop service available in a metropolitan area, and a revealing indication of its attractiveness to entrepreneurs, is the proportion of the traffic that is already served by nonstop flights. Termed "nonstop market penetration," this share of the market has already been captured by nonstop operators and thereby does not offer an opportunity for product differentiation through the introduction of new nonstop service.

A comparison of the nonstop market penetration rates in the 50 most heavily populated U.S. metropolitan areas provides a clear illustration of the widely divergent opportunities for the introduction of new nonstop services. The portion of the market that has not already been penetrated serves as an upper bound on the market share attainable through the introduction of new nonstop service in traditionally one-stop markets. With the industry's incessant battle for market share, it is a crucial variable in strategic planning.

For this comparison, 50 metropolitan areas are ranked according to official 1980 U.S. Census Bureau data (Table 1). Metropolitan areas outside the contiguous 48 states were excluded. Census data for the New York-Newark-Suffolk and San Francisco-Oakland-San Jose areas were consolidated into two listings due to their close proximity. Most airlines consider them as coterminals when planning operations and marketing. Although Los Angeles-Ontario, California and Detroit, Michigan-Toledo, Ohio are geographically close, they generally are not considered coterminals and are maintained as separate entries.

An audit of the availability of nonstop service from each of these metropolitan areas (or cities) was conducted using schedule information published by Official Airline Guides, Inc. The results are summarized in Figure 1. Figure 1 is organized alphabetically, similar to a highway mileage chart, and indicates the status of nonstop service between the 50 largest population centers in the United States.

The extent of nonstop service varies considerably between cities. For example, Chicago and Atlanta have nonstop service to all other cities listed, while San Antonio and Providence have nonstop service to fewer than a dozen cities. The total number of cities served on a nonstop basis (also summarized in Figure 1) is a descriptive measure of the scope of nonstop service available from a city.

Estimates of market penetration of nonstop services in each of the 50 metropolitan areas were made by analyzing traffic data reported by CAB *(10)*, which are the most recent and comprehensive data available. CAB organizes data on an origin-destination basis, and samples approximately 25 percent of domestic passenger traffic.

The analysis considers all city pairs reported in the CAB data and, thus, involves substantially more city pairs than are shown in Figure 1. In the case of Dayton, Ohio, for example, CAB reports traffic to roughly 200 destinations. Using schedule information for May 1985 reported in the Official Airlines Guide *(9)*, it was determined that 30 of these destinations had available nonstop service, and all others required connections at nearby hubs. The proportion of total traffic represented by

TABLE 1 POPULATION OF FIFTY LARGEST U.S. METROPOLITAN AREAS

Rank	Metropolitan Area	Population	Rank	Metropolitan Area	Population
1	New York-Newark-Suffolk, N.Y.-N.J.	13,692,128	26	Kansas City, Mo.-Kans.	1,327,106
2	Los Angeles-Long Beach-Anaheim, Calif.	9,910.212	27	Buffalo, N.Y.	1,242,826
3	Chicago-Gary-Hammond, Ill.-Ind.	7,746,405	28	Portland, Oreg.	1,242,594
4	Philadelphia, Pa.-N.J.	4,716,818	29	New Orleans, La.	1,187,073
5	Detroit, Mich.	4,353,413	30	Indianapolis, Ind.	1,166,575
6	San Francisco-Oakland-San Jose, Calif.	4,545,710	31	Columbus, Ohio	1,093,316
7	Washington, D.C.-Md.-Va.	3,060,922	32	San Antonio, Tex.	1,071,954
8	Dallas-Ft. Worth, Tex.	3,974,805	33	Fort Lauderdale-Hollywood, Calif.	1,108,200
9	Houston, Tex.	2,905,353	34	Sacramento, Calif.	1,014,002
10	Boston, Mass.	2,763,357	35	Rochester, N.Y.	971,230
11	St. Louis, Mo.	2,356,460	36	Salt Lake City-Odgen, Utah	936,255
12	Pittsburgh, Pa.	2,263,894	37	Providence-Warwick, R.I.-Mass.	919,216
13	Baltimore, Md.	2,174,023	38	Memphis, Tenn.	913,472
14	Minneapolis-St. Paul, Min-Wis.	2,113,533	39	Louisville, Ky.-Ind.	906,512
15	Atlanta, Ga.	2,029,710	40	Nashville-Davidson, Tenn.	850,505
16	Cleveland, Ohio	1,898,825	41	Birmingham, Ala.	837,487
17	San Diego, Calif.	1,861,846	42	Oklahoma City, Okla.	834,088
18	Miami, Fla.	1,625,781	43	Dayton, Ohio	830,070
19	Denver-Boulder, Colo.	1,620,902	44	Greensboro-Winston-Salem, N.C.	827,252
20	Seattle-Everett, Wash.	1,607,469	45	Norfolk-Virginia Beach, Va.	806,951
21	Tampa-St. Petersburg, Fla.	1,569,134	46	Albany-Schenectady-Troy, N.Y.	795,019
22	Ontario-Riverside, Calif.	1,558,182	47	Toledo, Ohio	791,599
23	Phoenix, Ariz.	1,509,052	48	Jacksonville, Fla.	737,541
24	Cincinnati, Ohio	1,401,491	49	Hartford Conn.	726,114
25	Milwaukee, Wis.	1,397,143	50	Orlando, Fla.	700,055

Source: U.S. Census Bureau Survey, 1980.

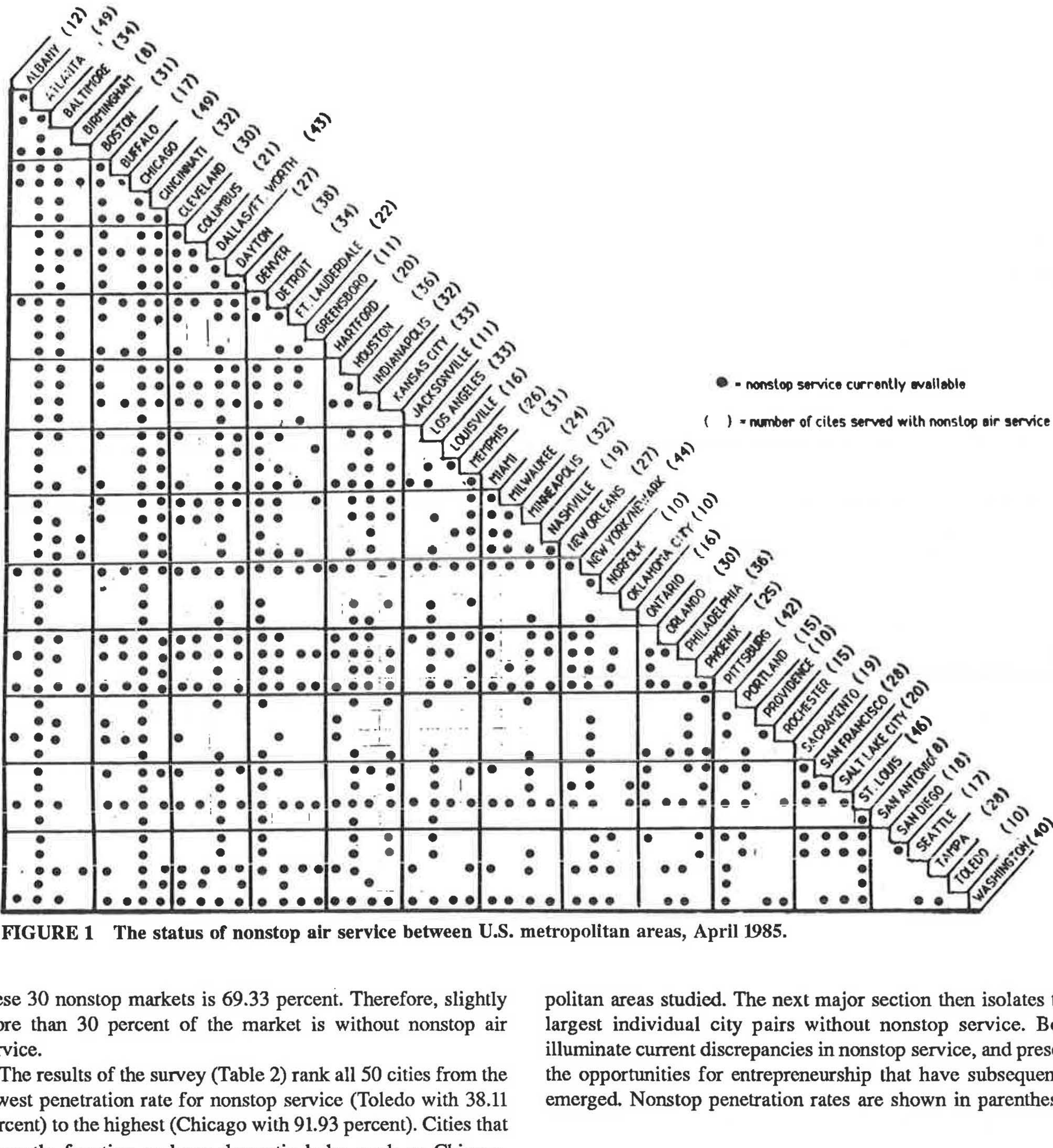

FIGURE 1 The status of nonstop air service between U.S. metropolitan areas, April 1985.

these 30 nonstop markets is 69.33 percent. Therefore, slightly more than 30 percent of the market is without nonstop air service.

The results of the survey (Table 2) rank all 50 cities from the lowest penetration rate for nonstop service (Toledo with 38.11 percent) to the highest (Chicago with 91.93 percent). Cities that currently function as large domestic hubs, such as Chicago, St. Louis, and Denver, are designated by symbols. An airline must be serving at least 20 destinations on direct flights from a metropolitan area for it to qualify as a hub.

It is no surprise that airline hubs have a higher penetration of nonstop service than nonstop cities. What is significant, however, is the magnitude of these differences. The share of the market having available nonhub service differs by more than 100 percent between the 50 largest metropolitan areas in the United States. Although the nonstop market exceeds 80 percent in 12 cities, it remains below 60 percent in 13 others. None of the 20 lowest-ranked cities are large hubs.

The following subsections briefly review the scope and market penetration of nonstop services in each of the 50 metropolitan areas studied. The next major section then isolates the largest individual city pairs without nonstop service. Both illuminate current discrepancies in nonstop service, and present the opportunities for entrepreneurship that have subsequently emerged. Nonstop penetration rates are shown in parenthesis.

Markets with Minimal Market Penetration

Consider first the 10 cities that currently have minimal levels of nonstop service (see Table 2). Service from these cities is principally limited to routes linking them with major hubs, and little entrepreneurship has taken place. The result has been a sizable void in nonstop service to major metropolitan areas.

Birmingham, Alabama (41.87 percent) and Toledo, Ohio (38.12 percent) offer the most vivid illustration of this effect, with nonstop services limited to 10 and 8 destinations, respectively. Travelers must make flight connections to reach over three-fourths of the metropolitan areas studied (Figure 1).

TABLE 2 NONSTOP MARKET PENETRATION RATES OF U.S. METROPOLITAN AREAS

Minimal Nonstop Penetration	Limited Nonstop Penetration	Moderate Nonstop Penetration	Heavy Nonstop Penetration	Extensive Nonstop Penetration
Toledo, Ohio, 38.12	Milwaukee, Wis., 55.12	Baltimore, Md.[a], 64.10	Fort Lauderdale, Fla., 73.01	Salt Lake City, Utah[a], 81.40
Birmingham, Ala., 41.18	Hartford, Conn., 56.19	Orlando, Fla., 64.82	Cleveland, Ohio[a], 73.18	Pittsburgh, Pa.[b], 81.41
San Antonio, Tex., 47.28	Ontario, N.Y., 58.39	New Orleans, La., 65.65	Detroit, Mich.[a], 74.89	Denver, Colo.[b], 83.13
Louisville, Ky., 48.61	Rochester, N.Y., 60.15	Buffalo, N.Y., 68.90	Cincinnati, Ohio[a], 76.12	New York-Newark, N.Y.-N.J.[b], 83.78
Oklahoma City, Okla., 49.55	Columbus, Ohio, 60.43	Philadelphia, Pa., 68.90	Sacramento, Calif., 77.80	Houston, Tex.[b], 84.59
Providence, R.I., 52.35	Indianapolis, Ind., 60.56	Dayton, Ohio[a], 69.33	Washington, D.C., 77.87	Minneapolis, Minn.[b], 84.64
Greensboro, N.C., 53.20	Jacksonville, Fla., 61.80	Phoenix, Ariz.[a], 70.06	Boston, Mass., 78.10	Dallas-Ft. Worth, Tex.[b], 86.14
Albany, N.Y., 53.40	Nashville, Tenn., 62.87	Miami, Fla., 71.88	Kansas City, Mo.[a], 78.83	St. Louis, Mo.[b], 87.11
San Diego, Calif., 53.49	Portland, Oreg., 63.05	Tampa, Fla., 72.57	San Francisco, Calif.[a], 80.15	Atlanta, Ga.[b], 89.74
Norfolk, Va., 55.09	Seattle, Wash., 63.82	Memphis, Tenn.[a], 72.93	Los Angeles, Calif., 80.47	Chicago, Ill.[b], 91.93

Note: Items categorized and listed in ascending order. All numbers are percentages.

[a]Secondary hub operations handling 1.0 to 2.5 million annual passengers on a single airline.

[b]Major hub operations handling more than 2.5 million annual passengers on an individual carrier.

Approximately 60 percent of the total traffic in these markets has no alternative to these connecting services.

The absence of nonstop service from these cities offers stark contrast to abundant service available from their similarly sized neighbors. Toledo has no nonstop service to the East Coast, Florida, or to points west of St. Louis. Its nonstop penetration rate is more than 30 percent lower than that of comparably sized Dayton, a thriving minihub with nonstop service to 27 of the cities. Birmingham, in contrast to nearby Memphis, has no nonstop service to major business centers such as New York, Philadelphia, Washington, or any West Coast destinations. These two cities also differ in nonstop penetration by more than 30 points. Because large portions of these markets remain untapped, Toledo and Birmingham are emerging as prime targets for new nonstop air services.

San Antonio, Texas (47.28 percent) and Oklahoma City, Oklahoma (49.55 percent) have also developed a heavy dependence on connecting hubs for long-haul air travel. They are among the largest U.S. metropolitan areas without nonstop service to the densely populated East Coast, and lack nonstop service to Florida, all cities in the Great Lakes region (except Chicago), and San Francisco. With nonstop service to only 8 and 10 of top population centers studied, respectively, they remain predominantly untapped markets.

Louisville, Kentucky (48.61 percent) and Greensboro, North Carolina (53.20 percent) are steadily building nonstop routes to certain East Coast and Midwestern destinations, but are without highly demanded service to the West Coast, most of Florida, and the Southwest. These cities have nonstop service to only 16 and 11 of the cities studied, respectively, and are attractive markets for expansion when compared to comparably sized neighbors such as Charlotte, North Carolina, and Memphis. Valuable market niches have been secured by nonstop operators to the east; similar developments can be anticipated to distant cities to the west such as Denver, Los Angeles, and San Francisco.

Furthermore, Albany, New York (53.40 percent), Norfolk, Virginia (55.09 percent), and Providence, Rhode Island (52.35 percent) have minimal levels of nonstop penetration. These cities have very little nonstop service to nonhub cities outside the eastern seaboard and have no nonstop service to points west of St. Louis. Regional operators recently have helped fill the void in nonstop service to upstate New York and New England cities, but little expansion has occurred to nonhub cities of the West or South. Providence and Norfolk are currently linked with only 10, and Albany with 12 of the metropolitan areas studied.

The largest city with only a minimal penetration of nonstop services is San Diego, California (53.49 percent), which ranks 18th in population and 42nd in nonstop penetration. Although it has nonstop service to most major hubs and to secondary hubs west of the Mississippi River, it is without nonstop service to almost all nonhub cities outside of the West Coast. Because of its peripheral location, San Diego is an attractive untapped market for airlines capable of long-range flying.

Markets with Limited Nonstop Penetration

The nonstop market penetration of cities in this category range between 55 and 64 percent, measurably higher than those in Category 1. A limited number of new nonstop routes already have been initiated from these cities, but these have been principally limited to regional destinations. Many heavily traveled distant destinations remain unserved.

This category includes Portland, Oregon (63.05 percent) and Seattle, Washington (63.83 percent)—the largest U.S. cities not linked to the important airline hubs of Cleveland, Detroit, Philadelphia, Pittsburgh, and Miami. They are without service to important nonhub cities such as Boston, Indianapolis, Philadelphia, or any Florida cities, and are linked with only 15 and 17 of the population centers studied, respectively. The peripheral location of the cities has undoubtedly been a factor in the sluggish development of nonstop services; however, with a new generation of limited-capacity narrowbody aircraft, they are emerging as attractive expansion targets.

Extensive short-haul nonstop services are available from Columbus, Ohio (60.43 percent); Hartford, New York (56.19 percent); Indianapolis, Indiana (60.56 percent); and Rochester, New York (60.15 percent); often with high frequencies and numerous airlines. However, many highly demanded long-haul markets from these cities remain uptapped. With the exception of Indianapolis, these cities are among the largest metropolitan areas not linked with the important mid-United States hubs of Denver, Houston, and Memphis and the western cities of Los Angeles and San Francisco. Although Indianapolis has developed a slightly more extensive nonstop network, the pervasiveness of its nonstop services dims in comparison with its comparably sized neighbors of Cincinnati and Dayton.

Jacksonville, Florida (61.80 percent) and Nashville, Tennessee (62.87 percent) are also highly dependent on connecting air services. Nashville is linked with only 19 of the population centers in the study, Jacksonville with only 11. Neither has nonstop service to Boston, Detroit, Houston, Los Angeles, or San Francisco. These voids in service have recently attracted new nonstop operators.

The final two metropolitan areas with limited nonstop penetration are Milwaukee, Wisconsin (55.12 percent) and Ontario, California (58.39 percent). These cities are located within close proximity to much larger metropolitan areas, and exhibit market penetration rates considerably below their rank in population. Ontario is the largest metropolitan area in the United States without nonstop transcontinental service and has nonstop links to 16 of the cities studied. Milwaukee, the largest U.S. city without nonstop service to the West Coast, has nonstop service to 24 cities. Nonstop networks from these cities are primarily limited to destinations within 500 mi.

Markets with Moderate Nonstop Penetration

Metropolitan areas in this category have developed moderate nonstop networks consisting of both long- and short-haul routes. Baltimore, Maryland; Dayton, Ohio; Memphis, Tennessee; and Phoenix, Arizona, are fledgling minihubs. The six others are nonhub cities that enjoy above-average levels of nonstop service.

Dayton (69.33 percent) and Memphis (72.93 percent) are more densely saturated with nonstop service than any cities of their size in the United States, and are the smallest mid-U.S. cities to offer nonstop service to Denver, Los Angeles, and San Francisco. As rapidly expanding airline hubs, these cities are linked with more than 25 of the cities studied, and offer comparatively few opportunities for new nonstop services.

Baltimore (64.10 percent) and Phoenix (70.06 percent), on the other hand, offer several of the United States' most densely traveled one-stop markets. They are fledgling regionally oriented domestic hubs, although they lack significant long-haul nonstop service. Transcontinental service is limited to a single route from both of these cities. Phoenix is linked nonstop to 25 of the metropolitan areas in the study; Baltimore is linked to 34.

Miami, Florida (71.88 percent); Orlando, Florida (64.82 percent); and Tampa-St. Petersburg, Florida (72.57 percent)—important leisure destinations—are steadily developing services to many larger nonhub cities and enjoy frequent, nonstop service to most major hubs. Among the larger unserved markets are upstate New York, most California destinations, and smaller nonhub midwestern cities. Miami, Orlando, and Tampa-St. Petersburg enjoy nonstop service to 31, 30, and 28 of the cities studied, respectively. These levels of service are well above other comparably sized nonhub cities.

The final three cities with moderate levels of nonstop service are Buffalo, New York (68.90 percent); New Orleans, Louisiana (65.65 percent); and Philadelphia, Pennsylvania (68.90 percent) all with nonstop penetration considerably higher than other nonhub cities of their size. The opportunities for new nonstop service are primarily in long-haul markets. New Orleans and Philadelphia serve only two cities west of Denver, and are linked with 27 and 36 of the cities studied, respectively. Buffalo and Rochester have no nonstop service to destinations west of St. Louis, and are linked with 17 and 15 of the cities studied, respectively. The size of these metropolitan areas makes them prime candidates for the introduction of new transcontinental air services.

Markets with Heavy Nonstop Penetration

Fifteen of the 20 metropolitan areas most densely penetrated with nonstop service are airline hubs. Boston, Ft. Lauderdale, Los Angeles, Sacramento, and Washington—all with metropolitan area populations exceeding one million—are the only nonhub U.S. cities offering nonstop services to more than three-fourths of their consumers.

Boston (78.10 percent) and Washington (77.87 percent) have both developed extensive nonstop air service networks. Washington is linked to 40 of the United States' top 50 metropolitan areas—more than any nonhub city; Boston is linked with 31. These developments have helped these cities overcome many of the disadvantages of their nonhub status.

Nevertheless, opportunities remain. The Washington area ranks seventh in population, but 16th in nonstop service penetration, and 10th in the number of top population centers served. Boston ranks 10th in population, but 15th in nonstop service penetration, and 19th in the number of top population centers served. The absence of service to destinations such as Phoenix, San Antonio, San Diego, and Seattle represent lucrative opportunities for entrepreneurs.

Cincinnati, Ohio (76.12 percent); Cleveland, Ohio (76.12 percent); Detroit, Michigan (74.89 percent); Kansas City, Missouri (78.83 percent); and San Francisco, California (80.15 percent) are most characteristic of cities in this category. As expanding airline hubs, their nonstop market penetration rates exceed 70 percent. All have nonstop service to each of the nation's 15 largest cities. With nonstop service to an average of 31 cities, these cities offer comparatively few opportunities for market share expansion through the introduction of new nonstop service.

The United States' largest city not considered a hub for domestic purposes is Los Angeles, California (80.47 percent). Although it is an important international hub, the scope of its domestic nonstop services is considerably poorer than domestic hubs such as Chicago and New York. Los Angeles ranks 11th in market penetration and is linked with 33 of the cities studied. The 12 nonhub cities east of the Mississippi that lack nonstop service to Los Angeles, which include Columbus, Milwaukee, Orlando, and Tampa-St. Petersburg, are especially attractive expansion targets.

Ft. Lauderdale, Florida (73.01 percent) and Sacramento, California (77.80 percent) also exhibit exceptionally high market penetration rates among nonhub cities. They have become important regional transportation centers and are linked with nearly every major hub in the United States. Ft. Lauderdale's network of nonstop service links it with 22 of the cities studied.

Sacramento is linked with only 19. Both are without transcontinental air service.

Markets with Extensive Nonstop Service

The 10 most comprehensive airline hubs in the United States have nonstop market penetration rates exceeding 81 percent. Nine of these cities have nonstop service penetration that ranks considerably higher than their population rank—Salt Lake City is the most extreme example, ranking 36th in population and 10th in nonstop penetration.

This select group, in ascending order of nonstop penetration, consists of Salt Lake City, Utah (81.40 percent); Pittsburgh, Pennsylvania (81.41); Denver, Colorado (83.14 percent); Houston, Texas (84.59 percent); Dallas-Ft. Worth, Texas (86.54 percent); Minneapolis-St. Paul, Minnesota (84.64 percent); St. Louis, Missouri (87.11 percent); Atlanta, Georgia (89.74 percent); and Chicago, Illinois (91.93 percent).

On average, the nine major hubs in this category are linked with nonstop flights to all but six of the metropolitan areas studied. The cities not served principally rank below 25th in population and are over 1,500 mi distant. Atlanta and Chicago are linked with all population centers studied, with market penetration approaching or exceeding 90 percent, which is almost double the average for cities in the first category.

With at least two airlines establishing major hubs in each of these nine locations (with the exception of Pittsburgh), these cities offer little opportunity for rapid expansion of market share through the initiation of new nonstop routes. On the contrary, there is evidence to suggest that the concentration of services at hubs is having detrimental effects on many airlines' efforts to achieve break-even load factors. *(3)*.

New York-Newark (83.78 percent) is the only metropolitan area in this category performing below its rank in population in terms of both nonstop market penetration and the number of cities served. Though easily ranking first in population, it ranks seventh in market penetration and fourth in the number of population centers served (44). Its Newark hub, despite a 200 percent expansion in flights in only three years, still lacks the scope of more centrally located facilities.

A brief summary has been presented of the diverse opportunities available to entrepreneurs in each of the 50 metropolitan areas. To supplement this city-by-city summary, it is useful to review the most heavily traveled markets (city pairs) without nonstop service in the United States.

THE LARGEST UNSERVED CITY PAIRS IN THE UNITED STATES

Using data from Figure 1 and CAB, the most heavily traveled city pairs without nonstop service in the United States are identified, and insight into likely patterns in the development of new nonstop services is provided. A review of these markets illustrates some of the effects of the existing imbalance in nonstop air service between cities, and suggests that the benefits of new nonstop services are likely to accrue unevenly.

The findings are given in Table 3. The 60 largest unserved city pairs are ranked, and an index is shown indicating the nondirectional volume of local traffic in the CAB sample. The development of new nonstop routes would be expected to be closely correlated with the amount of local traffic traveling over the route.

The CAB data indicate that San Diego-Washington, D.C. is the nation's most heavily traveled market without nonstop service—CAB recorded 16,278 passengers in their sample. Closely following is the New York-San Antonio market (13,431). Other high-volume one-stop markets include New Orleans-San Francisco (11,815), and Orlando-Los Angeles (11,810), closely followed by Phoenix-Washington (11,028), Boston-Seattle (9,848), Boston-Phoenix (9,846), and Ft. Lauderdale-Los Angeles (9,432).

Possible sampling errors dictate a need to use caution in interpreting the data for individual city pairs. In addition, the differing characteristics of ridership might render the findings a misleading indicator of the potential profitability of nonstop air service. However, the general trend clearly supports the observation that nonhub cities appear to offer considerably greater opportunities than most hub cities. Nonhub cities account for 110 of the 140 entries in Table 3, or 78 percent. Major hubs are represented only seven times. Secondary air hubs such as Cincinnati, Kansas City, Memphis, Salt Lake City, and San Francisco are slightly more pervasive, appearing 23 times.

The likelihood of a city appearing in Table 3 is closely associated with the classification of its nonstop service (discussed in the previous section). Nine of the 10 cities with minimal nonstop service are represented (Albany does not appear). All 10 cities with limited nonstop service, and nine cities with moderate nonstop service, are represented. Dayton does not appear. Seven cities (80 percent with heavy levels of nonstop service, and only four (40 percent) of the cities with extensive nonstop service, are represented.

An even more illustrative measure of the differing attractiveness of metropolitan areas is the frequency with which they are represented. Eighteen cities appear three or more times on the list, and 14 of these are nonhub cities.

Boston appears most frequently with nonstop service to fewer destinations than any other city of comparable size. It appears nine times in three of the first 12 entires. The pervasiveness of Boston and other nonhub eastern cities such as Washington, D.C. and Philadelphia (which appear 6 and 7 times, respectively), reflects important voids in nonstop air service to distant destinations such as Birmingha, Phoenix, San Antonio, San Diego, and Seattle.

San Diego, already shown to be the largest U.S. city with a minimal level of nonstop service, appears eight times, second only to Boston. With an absence of nonstop service to top 10 population centers such as Boston, Detroit, Washington, San Diego appears three times among the first 15 entries.

Los Angeles, the largest U.S. city not serving as a hub according to the definition from the Section on nonstop market opportunities, also appears eight times. There is a strong latent demand for nonstop air service between Los Angeles and nonhub destinations throughout the South and Midwest.

Other nonhub cities that appear most frequently are New Orleans (seven times) Miami (six), Seattle (six), Orlando (five), Nashville (five), Tampa (five), San Antonio (four), Indianapolis (three), Norfolk (three), and Columbus (three). The lack of nonstop services to other nonhub destinations such as Boston,

TABLE 3 RANKING OF U.S. CITY PAIRS WITHOUT NONSTOP AIR SERVICE

Rank	City Pair	Index	Rank	City Pair	Index
1	San Diego, Calif.-Washington, D.C.	16278	36	New Orleans, La.-Oklahoma City, Okla.	4633
2	New York, N.Y.-San Antonio, Tex.	13431	37	Indianapolis, Ind.-Houston, Tex.	4554
3	New Orleans, La.-San Francisco, Calif.	11815	38	Cleveland, Ohio-San Diego, Calif.	4243
4	Orlando, Fla.-Los Angeles, Calif.	11810	39	Columbus, Ohio-Miami, Fla.	4169
5	Phoenix, Ariz.-Washington, D.C.	10028	40	Nashville, Tenn.-Los Angeles, Calif.	4143
6	Boston, Mass.-Phoenix, Ariz.	9846	41	Ontario, Calif.-New York, N.Y.	3984
7	Ft. Lauderdale, Fla.-Los Angeles, Calif.	9432	42	Boston, Mass.-Portland, Oreg.	3854
8	Boston, Mass.-Seattle, Wash.	9421	43	Boston, Tex.-Jacksonville, Tenn.	3792
9	Detroit, Mich.-San Diego, Calif.	9176	44	Norfolk, Va.-Orlando, Fla.	3783
10	New York, N.Y.-Oklahoma City, Okla.	8962	45	Miami, Fla.-Louisville, Ky.	3742
11	Boston, Mass.-New Orleans, La.	8298	46	Memphis, Tenn.-Philadelphia, Tenn.	3771
12	San Antonio, Tex.-Washington, D.C.	8217	47	Rochester, N.Y.-Orlando, Fla.	3762
13	Philadelphia, Pa.-San Diego, Calif.	7750	48	New Orleans, La.-Minneapolis, Minn.	3743
14	Hartford, Conn.-Los Angeles, Calif.	7698	49	Philadelphia, Pa.-San Antonio, Tex.	3682
15	Philadelphia, Pa.-Pheonix, Ariz.	7318	50	Nashville, Tenn.-Boston, Mass.	3619
16	Cleveland, Ohio-Phoenix, Ariz.	7028	51	Buffalo, N.Y.-Los Angeles, Calif.	3616
17	San Francisco, Calif-Tampa, Fla.	6753	52	Columbus, Ohio-San Francisco, Calif.	3583
18	Orlando, Fla.-San Francisco, Calif.	6536	53	Boston, Mass.-San Antonio, Tex.	3576
19	Ft. Lauderdale, Fla.-San Francisco, Calif.	6269	54	Phoenix, Ariz.-Miami, Fla.	3549
20	Philadelphia, Pa.-Seattle, Wash.	6164	55	Jacksonville, Fla.-Philadelphia, Pa.	3492
21	Hartford, Conn.-San Francisco, Calif.	6162	56	Baltimore, Md.-San Diego, Calif.	3546
22	Columbus, Ohio-Los Angeles, Calif.	6006	57	New Orleans, La. Seattle, Wash.	3434
23	Detroit, Mich.-Seattle, Wash.	5919	58	Birmingham, Ala.-Washington, D.C.	3406
24	Baltimore, Md.-San Francisco, Calif.	5533	59	Indianapolis, Ind.-San Diego, Calif.	3406
25	Portland, Oreg.-Washington, D.C.	5467	60	Oklahoma City, Okla.-San Francisco, Calif.	3376
26	Orlando, Fla.-Kansas City, Mo.	5387	61	New Orleans, La.-Phoenix, Ariz.	3439
27	Miami, Fla.-Norfolk, Va.	5300	62	Rochester, N.Y.-Tampa, Fla.	3328
28	Houston, Tex.-Nashville, Tenn.	5196	63	Providence, R.I.-Tampa, Fla.	3315
29	Los Angeles, Calif.-Milwaukee, Wis.	4994	64	Boston, Mass.-Salt Lake City, Utah	3256
30	Nashville, Tenn.-Detroit, Mich.	4967	65	Louisville, Ky.-Philadelphia, Pa.	3242
31	Boston, Mass.-Indianapolis, Ind.	4869	66	New York, N.Y.-Toledo, Ohio	3212
32	Nashville, Tenn.-Miami, Fla.	4830	67	New Orleans, La.-San Diego, Calif.	3209
33	Miami, Fla.-Seattle, Wash.	4813	68	Greensboro, N.C.-Los Angeles, Calif.	3278
34	Milwaukee, Wis.-San Diego, Calif.	4792	69	Seattle, Wash.-Tampa, Fla.	3197
35	Oklahoma City, Okla.-Washington, D.C.	4694	70	Norfolk, Va.-Tampa, Fla.	3190

Los Angeles, and Philadelphia explains the frequency of these cities and offers excellent opportunities for entrepreneurship. Nashville and New Orleans are by far the smallest cities to be represented five or more times.

Four cities functioning as airline hubs appear three times or more on the list: Detroit (three times), New York (four), San Francisco (eight), and Phoenix (six). The frequency with which these cities appear reflects the opportunities that exist to many transcontinental destinations and illustrates the limited scope of these air hubs when compared with more centrally located hub complexes. There appears to be strong demand for nonstop air service from these cities to mid-U.S. nonhub cities such as Birmingham, Oklahoma City, and San Antonio. Of these three cities, the most lucrative opportunities appear to be from Phoenix. Four of the city's unserved destinations—Boston, Cleveland, Philadelphia, and Washington, D.C.—appear among the first 20 entries. This reflects the concentration of nonstop service from Phoenix to points west of the Mississippi River.

Of 10 cities not represented, eight currently function as hubs: Atlanta, Chicago, Cincinnati, Dallas-Ft. Worth, Dayton, Denver, Pittsburgh, and St. Louis. Two nonhub cities, Albany and Sacramento, do not appear. Of course, these hub facilities will continue to expand as important connecting complexes. However, from the perspective of the local population, they offer considerably less opportunity for market share expansion, and this factor will play a critical role in future route development *(3)*.

IMPLICATIONS FOR THE INDUSTRY

Changing market conditions suggest that successful airlines will begin to shift their focus from conventional hub-and-spoke flights to new nonstop services. Many variables will ultimately affect the development of new nonstop air service in the United States. However, as has been shown, the current imbalances in nonstop service fostered by the development of hub-and-spoke route structures are likely to play a significant role in future route growth. Entrepreneurs are attracted by markets offering opportunities for product differentiation and rapid expansion of market share. These opportunities exist in markets where nonstop air service is currently unavailable especially as nonhub service is becoming more cost effective.

There are numerous other methodologies in which this issue can be viewed; no individual assessment can be considered complete. The objective of this study is simply to bring much needed attention to this timely issue. In surveying the status of nonstop service between 50 metropolitan areas, an attempt has been made to foster an appreciation for the numerous opportunities available to nonstop operators in an environment dominated by hub-and spoke route structures.

The results of this study are not intended as forecasts for the future development or profitability of nonstop service but rather as the identification of an important set of market incentives that will affect growth. The evidence suggests, for example, that the most lucrative opportunities for new nonstop services radiate from major nonhub metropolitan areas such as Boston, Philadelphia, Los Angeles, San Antonio, and San Diego, in addition to several regionally oriented hubs such as Detroit and San Francisco. The development of nonstop services in these markets has only partially offset the imbalances engendered by hub-and spoke systems, leaving many major city pairs unserved. The bulk of these are of distances unsuitable for the regional airlines that have been most aggressive in filling these service niches.

The greatest imbalances in nonstop service exists in cities with populations of less than one million. In these markets, nonstop penetration ranges from 38 to 70 percent, and hub cities in this category exhibit penetration rates almost 40 percent higher than nonhub cities. Although a broad scope of service is available to major hub cities, there is comparatively little service from these cities to major nonhub destinations. With traffic data indicating that these city pairs are among the largest without nonstop service, new service between these cities is likely to bring about important structural changes in the U.S. air network

In metropolitan areas with populations of one to two million—where hub cities exhibit nonstop penetration rates 30 percent higher than nonhub cities—the evidence suggests that the industry is responding more briskly to the imbalances in service. Many carriers are enjoying a rapid escalation in market share from these cities by supplementing their existing hub operations with new point-to-point services. Nevertheless, opportunities remain, and many of the largest markets in the United States without nonstop service radiate from these cities.

A costly consequence of the cautious response of most major carriers has been the rapid expansion of new low-cost airlines, generally with significant cost advances. Thus far, only a handful of major firms have invested significantly in nonhub air services, leaving lucrative opportunities for newly formed airlines.

These rapidly growing airlines have flourished in an environment dominated by hub-and-spoke systems. Virtually no corner of the country remains untouched by these new entrepreneurs, and they are providing new nonstop services from nonhub cities such as Buffalo, Milwaukee, New Orleans, and Orlando. Others are rapidly seeking financing for services from cities overly dependent on connecting services such as Columbus, Rochester, and San Jose.

In the incessant battle for market share, it is becoming increasingly important for airlines to differentiate their products. As shown in this paper, the introduction of new nonstop services in markets traditionally served only with connecting services constitutes a viable and an increasingly attractive means of gaining a competitive advantage. The potential market share gain from the implementation of this technique appears greatest in a select group of nonhub cities.

REFERENCES

1. R. J. Jones. Deregulation and Non-Hub Airports: Discriminant Analysis. Proc., Transportation Research Forum, Boston, Mass., 1985.
2. N. K. Taneja. *Airlines in Transition*, Lexington Press, Lesington, Mass., 1981.
3. J. Muldutis. *The Airlines 1984—A Brave New World.* Salomon Brothers, Inc., New York, N.Y., April 26, 1984.
4. J. Schwieterman. No Strings Attached: The Benefits of Deregulation to Business Fliers. *Regulation*, American Enterprise Institute, Washington, D.C., Aug. 1985.
5. Airline Traffic Association. Yield and CPI. *Aviation Daily*, March 1984.
6. J. R. Meyer and C. V. Oster, Jr. *Deregulation and the New Airline Entrepreneurs*, The MIT Press, Cambridge, Mass., 1984.
7. Air Transport World 1984 Market Development Report. *Air Transport World*, May 1985.
8. Non Jet Service Growing Rapidly. *Airline Executive*, Jan. 1985.
9. *Official Airline Guide: North American Edition, January-August, 1985*. Official Airline Guides, Inc., Oak Brook, Ill., 1985.
10. *Civil Aeronautics Board Origin-Destination Summary of Air Passenger Traffic, 2nd Quarter 1984.* Airline Traffic Association, Washington, D.C., 1984.

Publication of this paper sponsored by Committee on Aviation Economics.

Accessibility in the Deregulated Domestic Airline Network

MAHMOUD GHAFOURI AND TENNY N. LAM

Airline service to a sample of 27 airport hubs in the contiguous 48 states randomly selected from 145 hubs classified as large, medium, and small in 1977 was compared between 1977 and 1984. The purpose is to determine changes in accessibility by air travel since deregulation. The empirical analysis indicates that accessibility had become significantly better in 1984 when compared to 1977, the year before deregulation.

Since the deregulation of U.S. airlines in 1978, the industry has become more efficient and competitive *(1)*. Total revenue passenger-miles increased by nearly 50 percent between 1976 and 1983 *(1)*. Between 1978 and 1983, scheduled carriers supplied 36 percent more seat-miles *(2)*. As service becomes better over some parts of the air transportation system, some communities have lost a significant amount of their air service or have to adjust to smaller aircrafts, smaller carriers, and less direct routing *(3, 4)*. However, it is generally agreed that changes in schedule convenience, price and service options, and total supply have been positive *(1–4)*.

Given the goals of deregulation, changes in the level of air service are expected to be nonuniform. This study is an attempt to look at the changes that have occurred at a sample of individual airport hubs. A hub is either a single airport or a group of airports serving the same community. Emphasis is placed on the larger hubs: hubs that are classified as large, medium, and small. Each of these hubs generates at least 0.05 percent of the annual national total number of enplaned passengers. Nonhubs, those generating less than 0.05 percent of the national traffic, are not considered here because they have been extensively studied *(1, 3–9)*.

The question to be asked is what changes, if any, have taken place in the accessibility of air travel at the sampled hubs. Accessibility is an indication of the ability to travel between points in a network by using the service available in the system. It is a measure of systemwide travel convenience. It may be indicated by the number of places connected by airline service and the number of different types of flights per week between places. In this study, both connectivity and the weekly frequencies at 27 randomly selected airport hubs are examined for March 1977 (before deregulation) and March 1984 (after deregulation). These comparisons can show only the changes that have taken place, bearing in mind that the changes might not necessarily be caused by deregulation alone. In addition, some statistics of airline supply for March 1985 are also presented to show a continuation of the trends at the medium and small hubs in the study sample.

One major change after deregulation has been the restructuring of the route system. Many airlines reorganized their route structure to improve operational efficiency, market penetration, and service quality. The present supply pattern of scheduled airline service reflects the desire of the airlines to optimize equipment and labor utilization. Other factors, such as entries and exits of operators, the air traffic restrictions imposed after the controllers' strike, and the fluctuations in fuel prices, have given added impetus to the design of route structures that are flexible and responsive to dynamic changes in the operational environment. Of particular interest from a traveler's viewpoint are the collective effects resulting from all the route changes made by each individual airline.

The structure of a transport net incorporates both the existence of links and the frequency of service on the links. In addition, connectivity in space and time is also important. A dominant feature of the rationalized domestic route network is the hub-and-spoke pattern *(10)*. Gone was much of the so-called direct service that meandered through small hubs and intermediate stops. The separation of feeder and line haul functions within a hub-and-spoke network also intensifies the specialization by carriers. These measures improve not only the accessibility in the network but also the economies of operation. With well-coordinated timed transfers at the hubs, added flight frequencies can be offered between more origins and destinations without additional equipment or crew. Ideally, few trips need more than two transfers, except between very remote places.

To the travelers, route structuring affects their convenience and accessibility. Other aspects of service quality, such as travel time, scheduling, and fare, are also important, but they will not be addressed here. By using a simulation technique, Bailey, Graham, and Kaplan integrated many of the route and schedule factors in their study *(11, 12)*. However, it is not unreasonable to assume that in general, more frequent service means more convenient scheduling and the type of flights (nonstop, direct, or connection) is indicative of the travel time. Only convenient connection flights are generally listed in the Official Airline Guide *(13)*, which is the data source here. Moreover, a criterion of a maximum of two transfers is also imposed here in the tabulation of the connected flights. Capacity and equipment are also important issues, but they are not dealt with in this study. It is assumed that under deregulation, airlines will meet passenger demand and preferences with adequate capacity and appropriate equipment whenever it is profitable to do so.

SAMPLE AND DATA

Twenty-seven hubs were selected from the 145 hubs in the 48 contiguous states and classified as large, medium, and small in 1977. The sampling was carried out by a stratified random

Department of Civil Engineering, University of California, Davis, Davis, Calif. 95616.

TABLE 1 HUBS SELECTED FOR THE STUDY

Region	Hub Size		
	Large	Medium	Small
East	BOS, Boston[a]	MEM, Memphis[a]	CAE, Columbia, S.C.[a]
	WAS, Washington, D.C.[b]	BDL, Hartford, Conn.[b]	BTV, Burlington, Vt.[b]
	ATL, Atlanta[b]	RDU, Raleigh, N.C.[b]	ALB, Albany, N.Y.[b]
Central	DTT, Detroit[a]	ABQ, Albuquerque[a]	FWA, Fort Wayne[a]
	STL, St. Louis[b]	CVG, Cincinnati[b]	SGF, Springfield, Mo.[b]
	HOU, Houston[b]	DSM, Des Moines[b]	LIT, Little Rock[b]
West	DEN, Denver[a]	SAN, San Diego[a]	BOI, Boise[a]
	SFO, San Francisco[a]	SLC, Salt Lake City[b]	GTF, Great Falls, Mont.[b]
	SEA, Seattle[b]	PDX, Portland, Oreg.[b]	SMF, Sacramento[b]

[a]Full sample of 145 origins.
[b]Random sample of 40 origins.

procedure. Three large, three medium, and three small hubs were randomly sampled from the hubs located in each of three geographical regions. The three regions cover the east, central, and west of the 48 states. The distribution of the hubs in the sample are given in Table 1, and their locations are shown in Figure 1 in which the solid circles represent hubs studied with all origins and the open circles represent hubs studied with a random sample of 40 origins. The size of the symbol indicates the size of the base hub. In 1983, there were only 110 large, medium, and small hubs in the 48 contiguous states. The hub size distributions are given in Table 2. Of the 27 hubs in the sample, there were six hub classification changes between 1977 and 1983. The changes are given as follows. The 1983 classification is cited here because it is the latest available.

TABLE 2 HUB SIZE DISTRIBUTIONS

Hub Size	1977	1983
Large	24	25
Medium	34	33
Small	87	52
Total	145	110

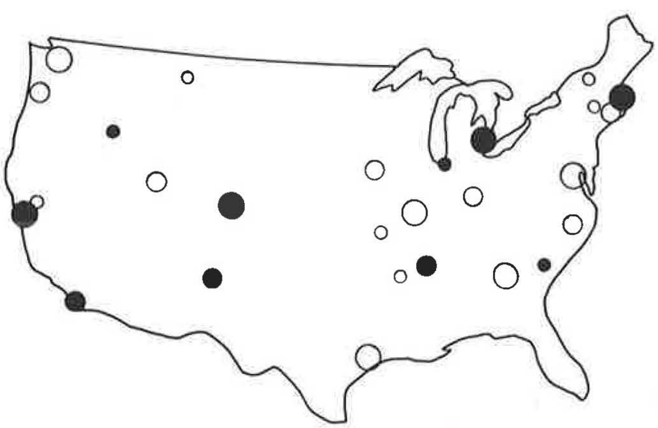

FIGURE 1 Geographical distribution of the base hubs in the study.

SAN, San Diego	M –> L
SLC, Salt Lake City	M –> L
SMF, Sacramento	S –> M
DSM, Des Moines	M –> S
SGF, Springfield, Mo.	S –> NH
GTF, Great Falls, Mont.	S –> NH

The sample represents approximately 37 percent of the large hubs, 26 percent of the medium hubs, and 10 percent of the small hubs. Of the 27 hubs in the sample, 10 were selected for a complete study, in which all the flights from the other 144 origin hubs to each of these base hubs were included in the analyses. A total of 1,440 city (hub) pairs are involved for these 10 base hubs. The remaining 17 base hubs in the sample were studied with respect to the service from a sample of 40 origin hubs randomly selected from the 144 in the population. Seventeen different samples of 40 were used for these 17 bases. This adds another 680 hub pairs to the study, for a total of 2,120 hub pairs. In the study by Bailey, Graham, and Kaplan *(11, 12)*, a sample of 200 markets (hub pairs) was used. For each hub pair, the weekly frequencies of nonstop, direct (same plane through service), and connection flights were tabulated from the Official Airline Guide *(13)* for March 1977 and March 1984, as well as March 1985 for three medium and three small base hubs in the sample. The data were then analyzed with respect to base hub size and region and with respect to origin hub size. Only the flights to the 27 selected bases (destinations) are analyzed.

SPATIAL ACCESSIBILITY

A well-connected transportation system offers travel opportunity to many places. Obviously, those places that generate and attract more travel will be better served. The average percentage of potential origin hubs in each hub size group that were connected to the base hubs in the sample by nonstop flights is given in Table 3. These are the basic links radiating from each base hub into the total network. Building on the nonstop links, the network is formed and the direct and connection flights are constituted. Across all groupings of base-origin hub sizes, the base hubs were connected by nonstop flights, on

TABLE 3 AVERAGE PERCENTAGE OF ORIGINS SERVING THE BASE WITHIN EACH ORIGIN/BASE HUB SIZE GROUPING

BASE HUB SIZE	ORIGIN HUB SIZE: LARGE(24) 1984	LARGE(24) 1977	MEDIUM(34) 1984	MEDIUM(34) 1977	SMALL(87) 1984	SMALL(87) 1977
NONSTOP SERVICE						
LARGE	89	84	50	37	16	12
MEDIUM	53	41	14	12	7	6
SMALL	18	16	7	7	3	3
DIRECT SERVICE						
LARGE	98	98	80	79	40	39
MEDIUM	80	77	44	39	17	12
SMALL	39	39	19	13	9	5

Note: Parentheses show number of flights involved.

average, to more origins in 1984 than in 1977. The largest increase was between large and medium hubs. Nonstop accessibility between hubs classified as medium and small was not significantly changed between 1984 and 1977. This was a continuation of the trend reported for 1981 in comparison with 1978 *(14)*.

The number of nonstop origin hubs deleted and added between 1977 and 1984 is tabulated in Table 4 for each of the 10 base hubs analyzed with a full sample of origin hubs. The data are separated for each origin hub size group. Also shown are the changes in weekly nonstop flight frequencies involved. Overall, there were more additions than deletions, both in terms

TABLE 4 ORIGIN HUBS DELETED AND ADDED TO NONSTOP SERVICE BETWEEN 1977 AND 1984

BASE HUB	ORIGIN: LARGE HUBS (24) DELETION	LARGE HUBS (24) ADDITION	MEDIUM HUBS(34) DELETION	MEDIUM HUBS(34) ADDITION	SMALL HUBS (87) DELETION	SMALL HUBS (87) ADDITION
LARGE BASE HUBS						
SFO	2 (19)	1 (14)	6 (62)	1 (7)	1 (3)	0 (0)
DEN	0 (0)	3 (109)	0 (0)	10 (136)	4 (35)	10 (136)
DTT	1 (20)	3 (82)	2 (14)	2 (47)	3 (21)	4 (57)
BOS	1 (7)	1 (20)	3 (27)	4 (65)	1 (13)	2 (25)
MEDIUM BASE HUBS						
SAN	1 (7)	4 (69)	1 (21)	2 (21)	1 (14)	0 (0)
ABQ	0 (0)	2 (34)	1 (7)	1 (14)	1 (7)	0 (0)
MEM	0 (0)	4 (68)	1 (14)	3 (46)	2 (14)	4 (42)
SMALL BASE HUBS						
BOI	1 (7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
FWA	0 (0)	1 (7)	1 (35)	2 (21)	0 (0)	1 (8)
CAE	2 (14)	0 (0)	0 (0)	2 (19)	0 (0)	1 (6)

Note: Parentheses show number of flights involved.

TABLE 5 DISTRIBUTION OF THE NUMBER OF BASE HUBS IN THE SAMPLE WITH SERVICE FROM VARYING ORIGINS BETWEEN 1977 AND 1984

BASE HUB SIZE	ORIGIN HUB SIZE: LARGE +	LARGE 0	LARGE -	MEDIUM +	MEDIUM 0	MEDIUM -	SMALL +	SMALL 0	SMALL -
NONSTOP SERVICE									
LARGE	5	2	2	5	3	1	6	1	2
MEDIUM	7	2	0	4	4	1	4	3	2
SMALL	3	3	3	2	7	0	4	4	1
DIRECT SERVICE									
LARGE	0	9	0	3	2	4	4	1	4
MEDIUM	5	0	4	3	3	3	6	3	0
SMALL	2	3	4	4	4	1	7	1	1

Note: + = more, o = same, and - = fewer.

of the number of hubs and the number of flights. Most changes occurred at Denver, Memphis, and San Francisco.

Realizing that an efficient network must also involve a large degree of passenger consolidation over lesser traffic routes, one may look at the extent of hubs connected by direct or through service that includes nonstop flights and flights involving one or more intermediate stops but without a change of plane. Such data for 1984 and 1977 are also given in Table 3. The average percentage of origin hubs serving the base was either about the same or slightly increased. With direct flights the accessibility of large and medium base hubs was greatly improved. However, small base hubs were not connected to too many other hubs even with direct flights.

A great deal of the service improvement since deregulation has been concentrated on a few of the markets. To a traveler, the specific individual airports are important. The distribution of the number of base hubs in the sample with service from more, the same, and fewer origins is given in Table 5. For nonstop service, the ratio is about two to one between base hubs with more origins and base hubs with fewer origins. The changes were minor for direct service, with the noticeable exceptions in the accessibility between medium and small hubs and between small hubs and small hubs.

The number of origin hubs not listed with any service with two or fewer transfers to the 10 base hubs analyzed with 144 origins is tabulated in Table 6. Again, the improvements of 1984 over 1977 are evident. The most dramatic improvements were for connections between small hubs and medium hubs. However, the accessibility between two small hubs remained poor in 1984, in spite of the significant systemwide improvements over 1977. Because nonstop or direct flights are available between all large hubs, it is theoretically possible to travel from one small hub to another small hub by involving only two transfers and three flight segments. The lack of listing in the Official Airline Guide for many small hubs and small hub connections may be a result of either the lack of travel demand or poor schedules.

FREQUENCIES

Flight frequencies are as important as the number of hubs served. Many qualities of service important to air travelers are

TABLE 6 NUMBER OF ORIGIN HUBS NOT LISTED WITH ANY SERVICE IN THE OFFICIAL AIRLINE GUIDE IN MARCH 1977 AND 1984

BASE HUB	ORIGIN: LARGE HUBS (24) 1984	LARGE HUBS (24) 1977	MEDIUM HUBS(34) 1984	MEDIUM HUBS(34) 1977	SMALL HUBS (87) 1984	SMALL HUBS (87) 1977
LARGE BASE HUBS						
SFO					3	4
DEN					4	7
DTT					2	4
BOS					2	0
MEDIUM BASE HUBS						
SAN					8	14
ABQ				1	9	40
MEM					9	20
SMALL BASE HUBS						
BOI		2	12	21	58	71
FWA	1	1	9	13	57	73
CAE		2	1	9	44	68

Note: Parentheses show number of flights involved.

related to or affected by flight frequencies. When there are more flights, the departure times are more convenient, there are more seats available, and there is stronger competition among the carriers. In this section, the frequencies are compared between 1984 and 1977 for the hubs in the study. The distribution of changes in nonstop and direct frequencies is given in Table 7. Direct flights involve same plane through service and include nonstop flights. Only one large hub and one small hub among the 27 hubs studied had fewer total nonstop flights in 1984 than in 1977. On the other hand, six of the 27 hubs had

TABLE 7 DISTRIBUTION OF THE NUMBER OF BASE HUBS IN THE SAMPLE WITH VARYING FREQUENCIES BETWEEN 1977 AND 1984

	ORIGIN HUB SIZE								
BASE HUB SIZE	LARGE			MEDIUM			SMALL		
	+	0	-	+	0	-	+	0	-
NONSTOP SERVICE									
LARGE	8	0	1	9	0	0	7	1	1
MEDIUM	9	0	0	5	4	0	6	1	2
SMALL	6	2	1	3	5	1	3	5	1
DIRECT SERVICE									
LARGE	7	0	2	8	0	1	7	0	2
MEDIUM	8	0	1	7	0	2	8	0	1
SMALL	6	0	3	6	2	1	6	0	3

Note: + = more, 0 = same, and - = fewer.

fewer direct flights. A comparison of the average total frequency between a base hub of certain size classification and other hubs in each of the three hub size groups is shown in Figures 2–4. On the average, frequency increased across all base-origin hub size groupings for both nonstop and direct flights. There were considerably more direct flights in 1984 than in 1977. Because all airline flights are formed of nonstop stages, the frequencies of nonstop flights are the most important to network accessibility.

A graphical depiction shows that the distribution of the improvements is almost across the board for the four large hubs, the three medium hubs, and the three small hubs that were studied with a full sample of 144 origins. Figure 2 is a comparison of the nonstop and direct frequencies between each of the four large base hubs and the origins in each of the three hub size groups. Similar comparisons for the medium and small base hubs are shown, respectively, in Figures 3 and 4. Another look at frequencies is on the distribution of the increases. Were the increases across the board or between only a few selected origin hubs? The number of origin hubs with increased and decreased frequencies to each of the 10 bases studied with a full sample of origins is listed in Table 8 according to origin hub size grouping. As can be seen, there were generally far more origin hubs with increased nonstop frequencies than there were origin hubs with declines.

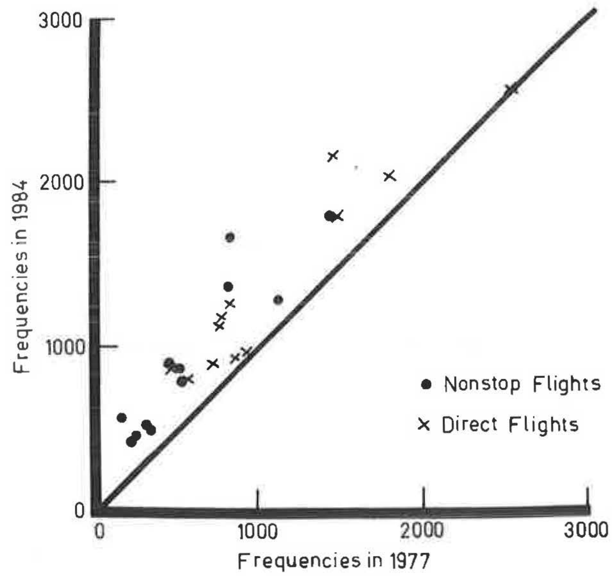

FIGURE 2 Comparison of the weekly frequencies in 1977 with those in 1984 for four large base hubs and each of three origin hub size groups.

DISTRIBUTIONAL PATTERNS

It is evident from the statistics presented up to this point that accessibility in 1984 was better than in 1977. For each of the hubs in the study, there were generally more flights to connect to more places. However, the improvements were not uniform across the whole system. There were gains and there were losses. However, the gains seem to outweigh the losses. A general observation was that extensive long-distance nonstop services of low demand were substituted with direct or connection flights. Also, the nonstop frequencies that were reduced

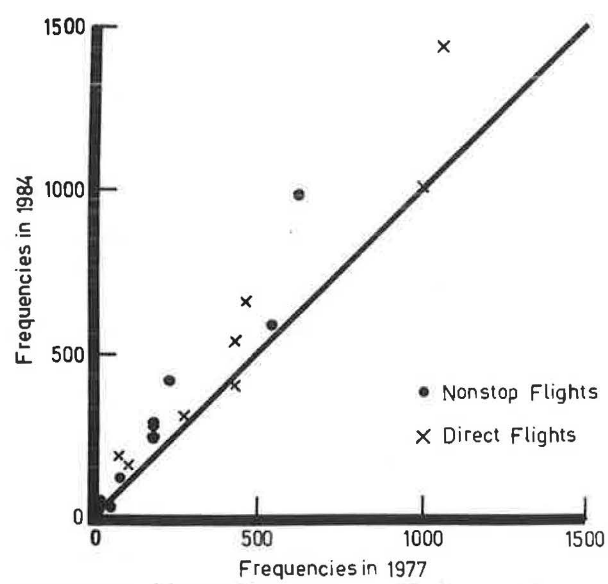

FIGURE 3 Comparison of the weekly frequencies in 1977 with those in 1984 for three medium base hubs and each of three origin hub size groups.

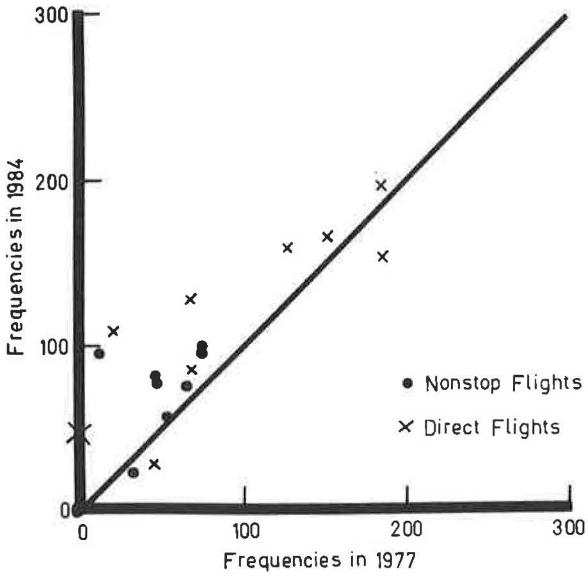

FIGURE 4 Comparison of the weekly frequencies in 1977 with those in 1984 for three small base hubs and each of three origin hub size groups.

were usually those that were either very high or very low in 1977.

There are two aspects of accessibility that may be subjected to biases in the reorganization of the airline network. One is the possibility of a reduction in supplies. The usual measure of supply is the plane-miles of nonstop flights, the backbone of the network. Another possible bias is that the accessibility gained may come at the expense of some segments of the market. This section examines the total plane-miles of nonstop flights; the average distances of nonstop, direct, and connection flights; and the average population of the origins weighted by nonstop, direct, and connection frequencies for the 10 base hubs studied with a full sample of 144 origins. The last item is an attempt to look at the direction of change in the frequency of flights with respect to the size of the markets served by the different levels of service.

The data for the nine base hubs show that supplies between small origin hubs and large base hubs enjoyed sizable increases. This is an indication that each large hub has become a major feeder point of small hubs within its market area. Looking at the small base hubs, the increase in nonstop plane-miles from large hubs was not as great. The asymmetric relationship implies that there were more small hubs feeding into each large hub, while the service to each small hub was not significantly changed from the level in 1977.

If the accessibility has improved, there would be more flights to more places, including places that are near and far. In transportation, demand generally decreases with distance when everything else is being equal. A trend towards better accessibility may imply more and better service to farther places. Comparisons in the average distance between each base hub and the hubs served within each origin hub size group are shown in Figures 5–7. Three average distances are shown. The average distances were obtained by using the frequencies of nonstop, direct, and all flights as weights. The direct flights include nonstop flights and all flights include nonstop, direct, and connection flights. From the figures, it can be seen that the average distances increase with a lower level of flight service.

TABLE 8 NUMBER OF HUBS WITH INCREASED AND DECLINED NONSTOP FREQUENCIES BETWEEN 1977 AND 1984

BASE HUB	ORIGIN: LARGE HUBS (24) INCREASED	LARGE HUBS (24) DECLINED	MEDIUM HUBS(34) INCREASED	MEDIUM HUBS(34) DECLINED	SMALL HUBS (87) INCREASED	SMALL HUBS (87) DECLINED
LARGE BASE HUBS						
SFO	12	6	5	8	9	3
DEN	22	1	24	0	24	6
DTT	18	2	12	6	9	5
BOS	7	9	11	3	7	1
MEDIUM BASE HUBS						
SAN	11	2	2	1	2	2
ABQ	6	4	2	1	2	1
MEM	12	5	6	4	8	4
SMALL BASE HUBS						
BOI	3	1	1	2	N/A	N/A
FWA	3	1	2	1	2	0
CAE	1	3	3	1	3	1

Note: Parentheses show number of flights involved.

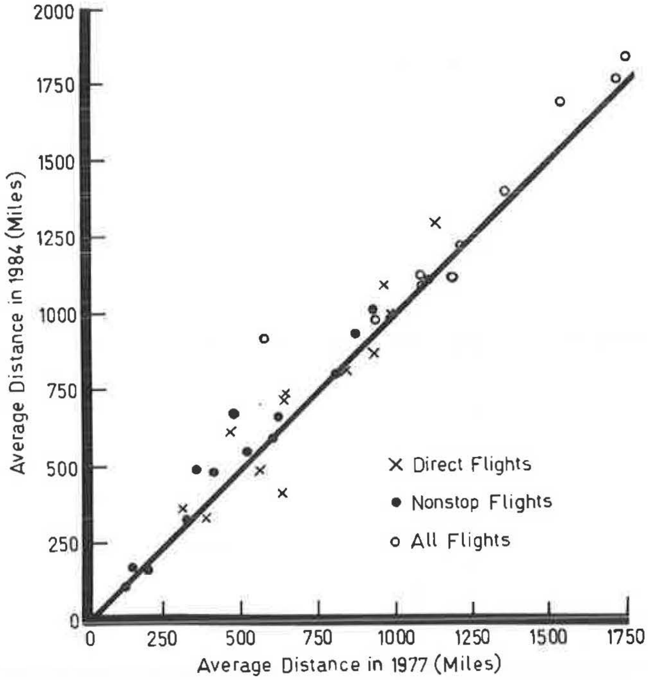

FIGURE 5 Comparison of the average distance between origin and destination for three types of flight service between 1977 and 1984 for four large base hubs and each of three origin hub size groups.

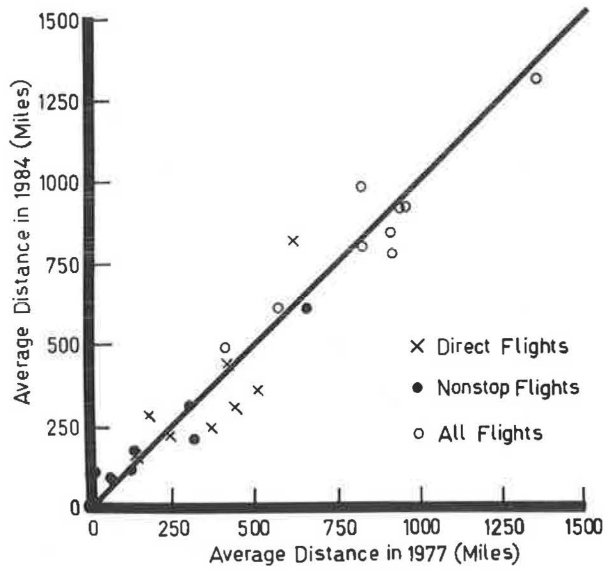

FIGURE 7 Comparison of the average distance between origin and destination for three types of flight service between 1977 and 1984 for three small base hubs and each of three origin hub size groups.

For example, farther places become more accessible with direct flights versus nonstop flights. The figures also show that there were more increases (above the 45 degree line) in the average distance in 1984 than there were decreases (below the 45 degree line) for large and medium base hubs (Figures 5 and 6).

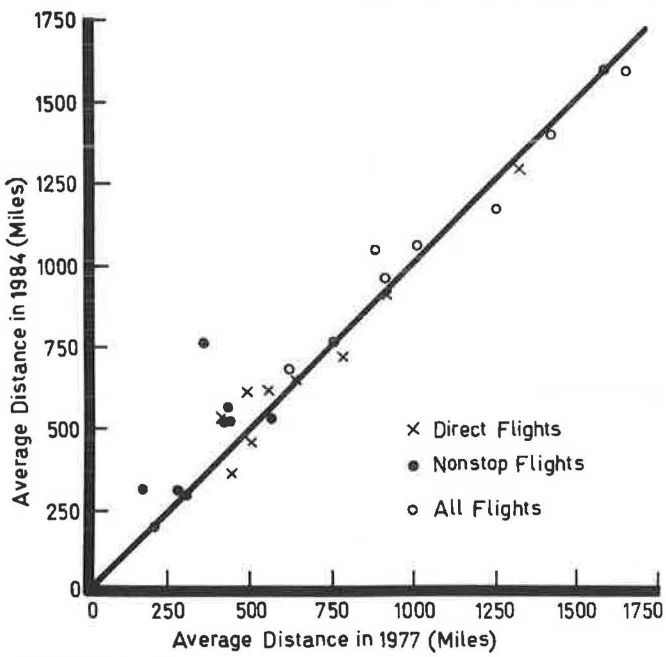

FIGURE 6 Comparison of the average distance between origin and destination for three types of flight service between 1977 and 1984 for three medium base hubs and each of three origin hub size groups.

However, it is the opposite for the small base hubs, as shown in Figure 7.

Similar to average distance, the average population of the origin hubs serving each of the base hubs was also calculated. The changes in the averages of population weighted by nonstop, direct and all frequencies were analyzed with data. If accessibility becomes more uniformly distributed, the averages should approach the unweighted average, which is the ratio of one. The results do not indicate any general trend and the differences between 1984 and 1977 are small. Since the averages were computed for different origin hub size groups, there does not seem to be any bias toward larger markets within each hub size category.

SOME 1985 DATA

Although the results of this study support the conclusions of many studies that the level of air transportation service had improved up to 1984, there is still a continuing concern over air service at smaller communities. For this reason, data from March 1985 were compiled for the three medium hubs and three small hubs that were studied with 144 origin hubs. In Table 9, the nonstop and direct weekly frequencies for 1977, 1984, and 1985 are compared for these six hubs. There were generally more flights in 1985, but the changes were uneven. The accessibility between these six hubs and the nonhubs for 1985 and 1977 is compared with the data in Table 10. Again, the changes varied from hub to hub. A general sense is that the improvements outweighed the declines.

CONCLUSIONS

This study compares airline service between 1984 and 1977. In 1978, the airline industry in the U.S. was deregulated from

TABLE 9 WEEKLY FREQUENCIES OF NONSTOP AND DIRECT FLIGHTS

DESTINATION HUB	ORIGIN: LARGE HUBS 1985	LARGE HUBS 1984	LARGE HUBS 1977	MEDIUM HUBS 1985	MEDIUM HUBS 1984	MEDIUM HUBS 1977	SMALL HUBS 1985	SMALL HUBS 1984	SMALL HUBS 1977
SAN	1093	993	619	27	21	21	108	38	53
	1662	1441	1068	226	260	193	299	310	280
ABQ	457	409	254	100	109	90	74	46	36
	817	665	460	223	166	119	255	197	90
MEM	687	586	547	253	224	194	281	292	178
	1162	1012	1000	411	400	426	474	548	436
BOI	126	80	49	92	99	77	13	0	0
	208	161	187	180	159	129	50	46	0
FWA	91	77	68	63	21	35	59	94	15
	185	167	152	108	28	48	78	108	22
CAE	95	95	77	58	78	49	40	58	56
	167	197	182	91	129	70	66	84	70

Note: Top entries show nonstop flights, and bottom entries show direct flights.

government control. Of particular interest to this study is the pattern of accessibility after the airlines had reorganized their route structure in order to become more competitive. The method used is one of selecting 27 hubs by stratified random sampling to represent large, medium, and small hubs in the eastern, central, and western regions. The nonstop, direct, and connection flight frequencies, either from all 145 hubs classified as large, medium, and small in 1977 in the contiguous 48 states or from 40 hubs randomly sampled from the 145, were analyzed with respect to measures related to accessibility. Because only the large, medium, and small hubs were studied, the emphasis of the study is placed on the major hubs. The nonhubs were not included in the study.

The statistics show that accessibility improved between 1977 and 1984 for hubs of all three sizes. In terms of the number of places serving the base hubs, there were more places accessible in 1984 by nonstop and direct flights. Large hubs served a much larger role in the reorganized network, especially as gateways for transferring to flights serving small hubs in the local market region. Medium hubs received improved nonstop services to and from large hubs. However, accessibility from small hubs to other small hubs improved only slightly. It appears that accessibility improved with the hub-and-spoke network. There is no identifiable geographical difference in the changes.

TABLE 10 NUMBER OF NONHUB ORIGINS CONNECTED TO THE BASE AND THE TOTAL WEEKLY FREQUENCY

DESTINATION HUB	NONSTOP FLIGHTS 1985	NONSTOP FLIGHTS 1977	DIRECT FLIGHTS 1985	DIRECT FLIGHTS 1977
SAN	1	3	5	8
	13	43	33	87
ABQ	11	12	15	20
	330	167	435	283
MEM	20	11	27	28
	353	169	551	394
BOI	8	6	11	9
	185	82	248	119
FWA	1	0	1	1
	7	0	7	7
CAE	3	1	5	1
	15	7	39	7

Note: Top entries show nonhub origins connected to the base, and bottom entries show total weekly frequency.

In addition to improvements in spatial connectivity, the frequencies and total supply in terms of plane-miles also increased significantly between 1977 and 1984. With the added frequencies, the quality of service undoubtedly has also become better. The only deterioration in service is the need to make transfers for some passengers. Some attitudinal survey may be needed to find out the trade-offs from the passengers' point of view. However, from a network's stand point, the changes do not appear to result in biases unfavorable to accessibility.

The conclusions of this study agree with other studies on the same aspects of air transportation. The results indicate that accessibility did not deteriorate after deregulation. However, even for the larger hubs that were studied here, there were winners and losers. Overall, the losses were minor and for only a few of the hubs. There were large improvements for some of the hubs. For most of the hubs studied, the changes were generally positive. It is not possible within the scope of this study to relate the changes to deregulation. It is quite possible that the changes came naturally with growth and the maturity of the industry, independent of deregulation.

REFERENCES

1. *Report to Congress: Implementation of the Provisions of the Airline Deregulation Act of 1978.* Civil Aeronautics Board, Washington, D.C., Jan. 31, 1984.
2. M. A. Brenner, J. O. Leet, and E. Schott. *Airline Deregulation.* Eno Foundation for Transportation, Inc., Westport, Conn., 1985.
3. U.S. Congress. *Hearings before the Subcommittee on Aviation,*

Committee on Commerce, Science, and Transportation, Serial No. 98–15. Government Printing Office, Washington, D.C., 1983.
4. U.S. Congress. *Hearings before the Subcommittee on Aviation, Committee on Commerce, Science, and Transportation, Serial No. 98–38*. Government Printing Office, Washington, D.C., 1983.
5. Y. Chan. Airline Deregulation and Service to Small Communities. In *Transportation Research Record 851*, TRB, National Research Council, Washington, D.C., 1984, pp. 29–37.
6. T. R. Jones and S. I. Cocke. Deregulation and Non-hub Airports: Discriminant Analysis of Economic, Demographic and Geographic Factors. In *Proceedings, Transportation Research Forum*, Vol. XXVI, pp. 251–257, 1984.
7. D. Ming, D. Tolliver, and D. Zink. Effects of Airline Deregulation on North Dakota Fares and Service. In *Proceedings, Transportation Research Forum*, Vol. XXVI, 1984, pp. 265–274.
8. F. J. Stephenson and F. J. Beier. The Effects of Airline Deregulation on Air Service to Small Communities. *Transportation Journal*, 1981, pp. 54–61.
9. J. F. Molloy, Jr., *The U.S. Commuter Airline Industry*. Lexington Books, Lexington, Mass., 1985.
10. A. Kanafani and A. Ghobrial. Airline Hubbing, Some Implications for Airport Economics. *Transportation Research*, Vol. 9, No. 2, 1985, pp. 109–114.
11. D. R. Graham and D. P. Kaplan. *Competition and the Airlines: An Evaluation of Deregulation*. Staff Report, Office of Economic Analysis, Civil Aeronautics Board, Dec. 1982.
12. E. E. Bailey, D. R. Graham, and D. P. Kaplan. *Deregulating the Airlines*. M.I.T. Press, Cambridge, Mass., 1985.
13. *Official Airline Guide*. North American ed., 2 vols., Reuben H. Donnelley Corp., New York, N.Y., March 1977 and March 1984.
14. *A Staff Report on Airline Service, Fares, Traffic, Load Factors and Market Shares*. Civil Aeronautics Board, Aug. 1981.

Publication of this paper sponsored by Committee on Aviation Economics.

Air Transport Deregulation and Airport Congestion: The Search for Efficient Solutions

J. R. G. Brander and B. A. Cook

Two broad approaches to the congestion problem exist. It is possible to expand slot availability. This analysis suggests the futility of such action. The other solution is to use price to ration capacity. Peak load pricing reduces social cost, shifts traffic to less congested periods, and improves the overall utilization of the airports. An auction mechanism would be the most efficient alternative. Under this approach, each slot would be awarded to the highest bidder. In addition to controlling congestion, the approach maximizes the return that could be generated by each slot and, hence, airport revenues.

A deregulated air transportation system is an open access commons. This is a system characterized by unrestricted (or open) access to everyone. This results in some form of adverse interaction among system users, which generates external costs such as congestion or, in the case of natural resource systems, depletion. The common property nature of the air passengers, the absence of entry barriers, and the ease with which productive capacity can be reallocated among the various air travel markets all establish the parallel. Economic rents will be totally exhausted if there are no constraints on landing slots. The available passenger stock will be over exploited and excess capacity will emerge. Congestion will develop exacerbated by the inherent tendency toward service scheduling. The congestion generates social costs due to overcrowding. Note that, strictly speaking, economic rent is the return to a resource with a supply that is absolutely fixed and nonaugmentable. However, when some inputs are fixed only in a short-run sense, this return may be called a quasi-rent.

A brief review of the applicability of the common property framework to the industry is given at the beginning of the paper. Industry equilibrium is then discussed. Next, the tendency toward service scheduling and the resultant traffic peaks are reviewed. A variety of proposed solutions, both supply side and demand side, are reviewed in light of the analysis. In conclusion, demand management policies are required to increase the social surplus and control congestion.

Department of Economics, University of New Brunswick, P.O. Box 4400, Fredericton, New Brunswick, Canada E3B 5A3.

THE AIRLINES AND COMMON PROPERTY EQUILIBRIUM

The theoretical structure, which was developed in the original paper *(1)* and on which this policy analysis is based, utilized a framework developed by Copes *(2)*. Copes followed Carroll, Ciscil, and Chisholm *(3)* by focusing on the imperfect specification of property rights and the negative externalities that this creates for existing firms. Copes used that framework to demonstrate the common property outcome. Such an outcome aptly describes a deregulated airline industry. For a particular passenger volume, increases in the number of flights on a particular link will occur, constrained only by the number of landing slots available. Economic rents will be dissipated as the industry expands capacity above socially desirable levels. Restricting entry will increase the social surplus, but may have adverse effects on the consumer.

In an existing market, the industry will establish a level of output that equates price and average costs. Should output be below this level, economic rents will exist. This results in the entry of new firms, the expansion of existing carriers, or both. The process continues until all rents are dissipated. This situation is shown in Figure 1, which shows the marginal social cost (MSC) curve, as well as the marginal private cost (MPC) curve that, according to Walters *(4)*, is also the average social cost (ASC) curve. MPC is the cost incurred by an additional unit of output from producers. MSC consists of the MPC of the private sector producer plus the external cost incurred in producing an additional unit of output.

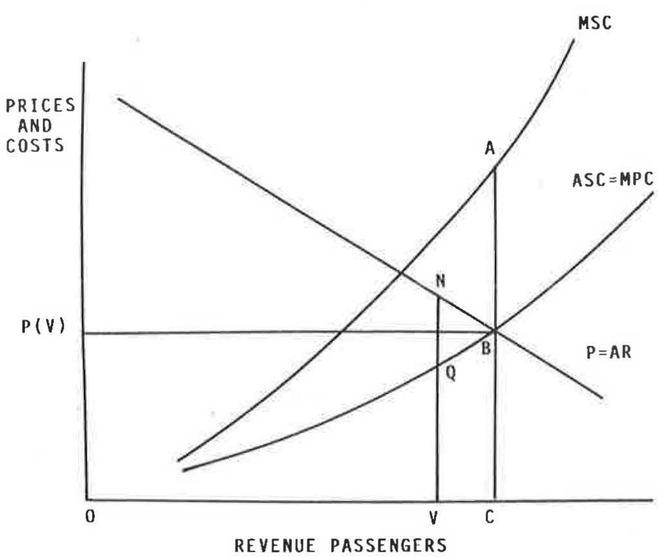

FIGURE 1 The dissipation of economic rents.

The demand curve is P = AR. Suppose initially the traffic volume is OV. Price is VN and exceeds MPC by NQ, generating a rent per unit of that amount. The existence of this economic rent will lead to capacity expansion, and output will expand to OC. At that output level, P = AR = MPC. All economic rents have been dissipated. This result follows from the open access common property nature of the deregulated airline industry. Firms make their decisions on what they perceive to be their marginal private cost curve (that is, on the average social cost curve). It is to be noted that at that level of traffic, there are social costs, represented in the diagram as AB, that the firms are able to externalize.

Across markets, the process will continue until profit ratios are equalized, which is the same result as before. Average revenue and average cost are equal for the typical firm; therefore, economic profits (or rents) are zero. Specific firms may be more or less efficient than the average. Therefore, some firms will earn a positive intramarginal rent, or suffer an economic loss. All markets will move toward the rent-exhausting level of output, a level that will be reached in the absence of constraints on the availability of airport capacity. This is the same outcome that occurs any time a commons is involved.

The supply of runway landing slots is finite, and may limit the number of flights (that is, the amount of effort) that is possible (Figure 2). A constraint is imposed on the number of landing slots, and hence, on the potential passenger volume. Given the constraint, passenger volume is limited to OM. Where the constraint is at an output level below the common property outcome (here, OM), all economic rents are not dissipated. Excess demand for slots exists because the airlines want to exploit the unexhausted profit opportunities, and establish a passenger volume of OC as in Figure 1. Conflict over slot availability and allocation between the airlines and the airport operators is inevitable in this situation. This excess demand for slots is exacerbated by the clustering of flights, especially at the hub airports. As shown later in this paper, such clustering is an inherent characteristic of the industry.

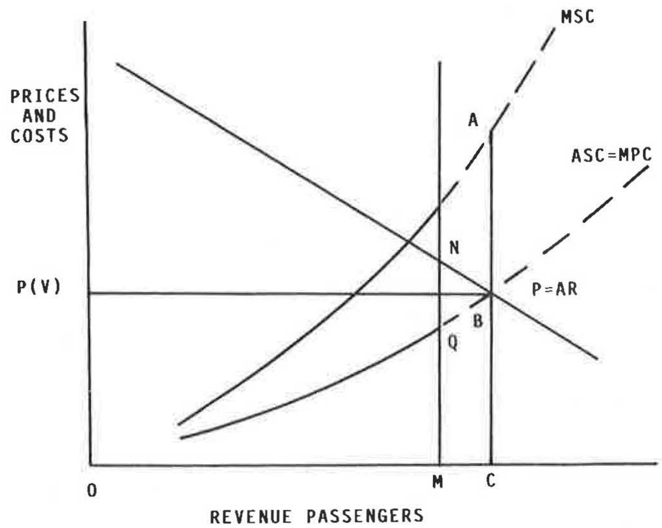

FIGURE 2 Slot constrained congestion externality.

Two observations must be made about this constrained equilibrium. First, it does not generate maximum rents for the industry as a whole. Closely related is the fact that the social surplus is not maximized in terms of output due to excess capacity. The social surplus includes both rent and consumer surplus, and is defined as the difference between total costs of output and total utility derived from the consumption of this output. Maximizing the social surplus is equivalent to the marginal-cost pricing decision. Second, from the perspective of the individual airlines, the existence of unexploited rents will lead to demands for capacity expansion. Should this occur, total exhaustion of the rents will follow. This outcome emerges because individuals make their decisions based on the average social cost and benefit curves that they perceive to be their marginal private cost and marginal private benefit curves.

Social costs are not included in the decision-making process. Individuals operating in isolation can make myopic decisions without recognizing the full societal impacts.

SERVICE SCHEDULING

The low profit ratios of the airline industry have been observed for many years. Economists frequently commented that the industry had a tendency to compete away almost all of the potential economic rents. Such erosion was seen as the result of head-to-head scheduling that, in turn, was seen as the outcome of a regulatory regime in which price competition was precluded. Industry consensus was that the best way to increase the passenger-load factor was to schedule departures to meet those of competitors. Such a practice is not related to a particular regulatory system. It is a natural outcome of the desire to maximize profits.

Decades ago, Hotelling sought to determine the best location for a new entrant to a market *(5)*. His example involved a ribbon community currently served by one general store located exactly at the midpoint. Hotelling concluded that the optimal strategy for the new entrant was to locate next door to the existing firm. Doing so maximizes the number of customers, and, given the assumed constancy of costs, also its profits. This is the clustering phenomenon, and is readily observable in a variety of economic activities.

From the perspective of the airlines, the argument can be either temporal (a schedule change) or spatial (an attempt to enter a new market); however, the concept remains the same. In the case of the former, relocation can only occur at the time of a schedule change. It then involves a minimum of transactions costs. If start-up costs are ignored, this also applies to an airline's relocation in space. If start-up costs are incorporated into the analysis, relocation costs arise but will affect only the timing of relocation and not the decision to relocate.

The airline market can be divided into two more or less equal parts. First, the business market has a travel demand pattern with a bimodal distribution involving early morning and late afternoon flights. This component is highly sensitive to time of departure. The other, termed the recreational market, is much more sensitive to price and much more evenly spread over the day.

A hypothetical demand pattern for the New York to Los Angeles link is given in the first column of Table 1. It is based on the notion that one-half of the business market (that is, 25 percent of the total traffic) desires early morning departures; however, the balance of that market desires late afternoon and early evening departures. On the other hand, the recreational market is assumed to be evenly spread throughout the day. When the two are combined, the travel demand pattern of the first column in Table 1 emerges. This pattern can be compared with actual available seats on the link for four different time frames. The pattern of seat departures may be expected to mirror the demand pattern, but this is not the case. Instead, the clustering of flights is observed, with the tendency apparently becoming stronger as a consequence of deregulation and the increase of competition it has engendered. During April 1985, for example, 47 percent of the seat departures occurred between 5 p.m. and 11 p.m. The two peak periods combined accounted for 82.6 percent of the seat departures, but for only 74.9 percent of the hypothetical demand for seats. Clustering of flights is therefore observed in the market and provides prima facie evidence that the Hotelling clustering theory applies in the airline case.

Therefore it can be concluded that head-to-head scheduling is an inherent characteristic of the industry. It contributes to excess capacity and to the dissipation of the economic rents that could otherwise be earned. More important, from the perspective of the present discussion, head-to-head scheduling exacerbates the congestion problem.

Hartwick *(6)* suggests, in a common property model, that firms make their decisions exclusively on the basis of the present. They have no concern for the future because any gains realized from present abstinence will have to be shared with their competitors later on. In the current context, this point can be considered from the perspective of scheduled departure time. Any action by a carrier to voluntarily reduce peak flights in favor of off-peak departures would result in a loss of traffic and, hence, lower profits. Rival firms, of course, gain.

Congestion arises because of the confluence of airport capacity that is fixed in the short run, and a traffic volume that varies intertemporally. At the limit, congestion occurs whenever two or more carriers simultaneously need to use the landing slot. Congestion problems are both time related and specific. Their effect increases both the operating costs of the carriers and the

TABLE 1 PERCENTAGE TIME DISTRIBUTION OF HYPOTHETICAL DEMAND AND ACTUAL SEAT DEPARTURES FOR NEW YORK TO LOS ANGELES DAILY NONSTOP FLIGHTS

Time of Day	Hypothetical Demand	Actual Seat Departures			
		Nov. 1977	Nov. 1980	Dec. 1984	April 1985
8 a.m.–10:59 a.m.	33.3	18.1	23.2	27.0	36.5
11 a.m.–12:59 p.m.	8.3	22.1	15.0	7.3	7.4
1 p.m.–2:59 p.m.	8.3	0.0	0.0	0.0	0.0
3 p.m.–4:59 p.m.	8.3	10.1	6.4	20.9	9.9
5 p.m.–6:59 p.m.	20.8	26.2	34.1	21.2	31.9
7 p.m.–10 p.m.	20.8	23.5	23.2	23.6	15.1

Sources: M. Brennan and Associates, November 1977 and November 1980. Official Airline Guide, December 1984 and April 1985.

time delay costs experienced by the industry and its passengers. Congestion stems from the common property nature of the deregulated industry, and is complicated by the inherent tendency on the part of the carriers toward head-to-head scheduling which creates traffic peaks.

TOWARD AN EFFICIENT SOLUTION FOR AIRPORT CONGESTION

The foregoing analysis has profound policy implications. It has been shown that service scheduling is an inherent characteristics of the industry. With open access there will be overexpansion of capacity, and rent dissipation at the industry level. Potential solutions to the slot shortage problem need to be assessed in light of the model. Solutions exist on both the supply side and the demand side of the market. Several of these, together with their probable impacts, are given in Table 2. In each case, the policy and its impact on congestion, the social surplus, and industry rents are shown. The "do nothing" option is shown only for the purpose of baseline comparisons.

One possibility is to pursue demand management. It has been applied rarely, though has been widely discussed in the literature. It is to this side of the market that attention is first to be turned. The U.S. Department of Transportation has reviewed the slot shortage problem by focusing on three alternatives to alleviate the difficulties. As reported by Ott *(7)*, these were (*a*) allowing airlines to buy and sell slots, (*b*) refusing new entry at airports that are overly congested, and (*c*) an administrative allocation of the available capacity. Each of these, together with the semiannual slot auction proposed by the Port Authority of New York and New Jersey, must be assessed against the aforementioned theoretical background.

The policy option first discussed by Ott and given in Table 2 is the slot aftermarket. It neither deals with the congestion problem, nor does it presume to do so. The policy option simply allows the private sector to reallocate slots after some other mechanism has been used to make the initial allocation. It provides the individual airline with the choice of utilizing the slot or of selling to a competitor. The profit-maximizing airline would choose the alternative that provides the greatest return. The existence of such markets strongly suggests that the initial allocation, however made, was suboptimal. Unless the buying airline could make more profitable use of the slot than could the selling airline, the sale would not occur. On that basis, it might be concluded that allowing the sale of slots increases the social surplus even though the number of flights is not reduced. However, because the slot resale market does not address the question of the number of flights and passengers, it will not maximize the social surplus. In spite of this, the slot resale market is a useful correcting mechanism, and should be retained in the airport's system.

One potential negative side effect of the purchase and sale of landing slots should be noted. There is considerable danger that by allowing such transactions the runway slot will be converted into a new property right, if only in the short run. From this perspective, the landing slot, being transferable, would replace the operating authority that existed during the days of regulation. Therefore, each time slots were somehow allocated, there would be potential transitional gains for those obtaining the initial allocation. Furthermore, because potential gains would exist, individual airlines would have a vested interest in requesting more slots than are actually required. The potential for increasing the excess demand for landing slots must be recognized, as well as the related pressures on the selected allocative mechanism caused by allowing the resale market to function.

The second policy option discussed by Ott and the second option given in Table 2 is the refusal of a new entry policy. It gives the illusion of freezing the excess demands for runway slots at their existing levels by refusing new entry at congested airports. However, it is not clear whether carriers already holding at least one landing slot at such a facility could increase the number of slots requested. If so, the new entry policy simply reintroduces entry control, albeit in a new form, and reestablishes protection of the existing firms in a market. In effect, carriers currently using a congested airport are given grandfather rights to their landing slots just as existing carriers were granted grandfather rights when economic regulation was first initiated. The parallel is too striking to ignore. Even if this is not the case, the policy gives quasi-permanent property rights to slots to carriers currently using a highly congested airport and provides them with potential transitional gains when this option is combined with the slot market. As Tullock *(8)* observed, there is a trap in providing transitional gains. In his view, actions resulting in such gains are largely irreversible. In effect, the system would have come full cycle, except for the hidden nature of the reregulation of air transport. Such action is to be avoided, for all of the old problems would recur, albeit in different forms.

Furthermore, the approach makes the implicit assumption that the slots are better used by existing carriers than by new

TABLE 2 IMPACTS OF VARIOUS POLICY ALTERNATIVES

Policy Option	Impacts		
	Congestion	Social Surplus	Economic Rents
Slot aftermarket	None	Increases	Increases
Refusing new entry	None	Reduces	Reduces
Administrative allocation	None	Reduces	Reduces
Increase slots	Reduces	Reduces	Reduces
Congestion pricing	Reduces	Increases	Increases
Do nothing	Worsens	Reduces	Reduces

entrants.This suggests that the current allocation of slots is optimal from the societal viewpoint, and that the slots are currently being used this way by the incumbents. No documentation has been found regarding this. From the perspective of the social surplus, the exclusion of new carriers is a solution that is inferior to the administrative allocation of slots. As Koran and Ogur *(9)* observed, administrative allocation is inferior, in turn, to some kind of market allocation.

The third policy option discussed by Ott is the administrative allocation policy given in Table 2. It simply involves an administrative allocation of the available capacity. Comment on this option is difficult because all such mechanisms tend to be highly specific, and because the large number of alternative approaches differ primarily in the parameters incorporated into their formulas and in the weights given to each factor. What can be said is that, with current practices, any such allocative mechanism would be administered by the FAA, and that the solution amounts to the reregulation of air transportation in the United States.

One possible approach to the administrative allocation of airport runway landing slots has been suggested by Geisinger *(10)*. It is profitable to review his methodology, for it is illustrative of the difficulties encountered in dealing with scarcity through any mechanism involving administrative fiat.

Geisinger's proposal involves a two-stage allocative procedure. First, slots are allocated among airlines on the basis of enplanements and deplanements per operation and an undefined "re-allocation factor." This factor determines the fraction of current slots that an airline may keep. A number of slots is set aside for new entrants to the market, although the mechanics of determining the number is not explained. Responding to a critic of his paper, Geisinger suggests that "the current thinking is that four slots would be a reasonable number" *(10*, p.7). From the total slots available, those reserved for new entrants and the base allocations of existing carriers are subtracted. The raw allocation is achieved by taking the remainder and dividing it among existing carriers on the basis of their relative shares of enplanements and deplanements per day and their base allocations.

As Brander *(10)* suggested, this approach to the allocation of scarce runway slots is overly protective of the existing carriers. In defence of that criticism, Geisinger argues that "turbulence caused by sudden and drastic changes in allocations would be harmful to everyone" *(10)*. He also notes the investment made by the existing carriers in developing their markets and suggests that gross changes would be bad. The nature of these defences suggests that the protection of incumbents against the inroads of new competition is likely to be a factor of some importance in any administrative allocation mechanism. However, this is equivalent to substituting one form of regulation for another.

The new regulatory system would differ from the old in being hidden rather than open. There would also be less concern with economic factors in making decisions and concomitantly more concern with political ones. If the desire is to maximize the social surplus, any arbitrary approach to the allocation of runway slots is to be avoided.

The fourth option given in Table 2 involves supply side adjustments. On the supply side, for example, it is possible to expand a given airport, or to increase its capacity by changing the rules regarding landing separations and, hence, runway acceptance rates. This expands the volume of flights and, hence, revenue passengers. The option has had an unknown impact on congestion in the absence of information regarding the level of excess demand for existing landing slots. However, supply side adjustments are likely to reduce rather than increase the social surplus in terms of output because the slot constraint shifts to the right. With this supply side adjustment, either the conflict between the airlines and the airport authorities will continue or all economic rents will be dissipated. However, the approach is politically attractive, because of the potential to match the desired number of flights at a hub with its capacity to handle those flights. Conflict between the airlines and airports would disappear, if only in the short run. Supply side adjustments must therefore be rejected because they deal with the consequences of the problem rather than its causes.

TOWARD A PREFERRED ALTERNATIVE

The fifth policy option given in Table 2 allows some agency to estimate the marginal social costs of congestion and to use these estimates as the basis for a set of congestion tolls. Price would thus be used to restrict the demand for landing slots, reducing congestion and increasing both the social surplus and economic rents. However, the number of slots for which such estimates would have to be made is large, being the cross product of the number of airports and the number of slots at each. It is possible to estimate the optimal price for each slot and to perform the necessary reestimations as often as required. Although feasible, this exercise is both time consuming and costly. The auction approach does provide one mechanism by which this can be done: sealed tender bids for each slot being awarded to the highest bidder. Although not all carriers would be completely satisfied with the outcome, and although excess demand for slots might well remain, the approach does provide an efficient solution for the present difficulties. As Koran and Ogur *(9)* have stated with reference to the slot aftermarket, the larger carriers need not dominate such an auction. The ability to pay for a slot reflects the profitability of particular flights rather than carrier size.

In addition to shifting the cost calculations to the airlines, the approach has a second major advantage. It would move the system to the optimal price more quickly than would any successive approximation approach that would have to be employed by government. There is, of course, one risk to be noted that involves the potential for collusion among the carriers in making bids for the slots. However, with open access the market is contestable, as termed by Baumol *(11)*, and this seems to preclude significant amounts of collusion.

At least one auction approach has been proposed. This proposal comes from the Port Authority of New York and New Jersey *(12)*. Under this scheme, slots would be auctioned to the highest bidder. So far there is no problem. The difficulty arises with the notion of refunding the proceeds of the auction at the end of the relevant period on the basis of some performance indicator or other. The rationale for the approach is not entirely clear, but relates to some extent to the desire to re-allocate airline scheduling voluntarily to less congested periods of the day. Because a slot auction process would have this effect by itself, it is uncertain as to why the refundability concept was added.

A final point must be made. Available literature suggests that one problem with congestion pricing is that there is a low cross elasticity of demand between peak and off-peak periods. This is seen as reducing the effectiveness of congestion pricing. To the extent that this is true, it may be necessary to supplement the peak period toll with an off-peak subsidy in order to encourage the necessary traffic diversion. Then, peak period congestion tolls could be used to subsidize the users of the airports at off-peak periods. This would provide additional incentive to move to off-peak periods. The balance of the congestion toll revenue could be used to finance necessary airport improvements.

CONCLUSIONS

Two broad approaches to the congestion problems exist. On the one hand, it is possible to expand capacity and increase slot availability. The foregoing analysis suggests the futility of such an approach. The pressures of excess demand would continue as long as profit opportunities exist. The other solution uses price to ration capacity, and to divert traffic to off-peak periods. Would the airport system be more optimally used with congestion demand management techniques in place? From the foregoing analysis, the answer is clearly yes. Peak load pricing would reduce social cost during peak loading periods, shifting traffic to less congested time slots and, on average, result in improved utilization of the infrastructure. In addition, it would maximize the social surplus in terms of output though some consumer surplus would be transferred to the airlines.

The adoption of the auction approach to the allocation of runway slots would easily deal with the runway slot shortage problem. It would do so in the same fashion as the price mechanism always operates: shortages lead to increases in price and this increase in price decreases the volume demand. The alternatives appear to be a government attempt to establish a market clearing price through some kind of trial and error process, or to take refuge in the arbitrary formula-type allocation process. The former has the potential to work, provided the agency is prepared to hold firm for long enough. The auction approach would get the system to that point much faster. The most significant danger here is the potential for political interference that leads to a reduction in the price in response to the demands of the airline operators. However, the auction scheme is still preferable if it is recalled that another objective is to have the airport operators maximize their revenues. Under the auction approach, each slot would go to the highest bidder. This would maximize the return that could be generated by a given slot. Given the small number of firms involved, collusion is possible. However, it appears that open access would preclude long-run collusion.

REFERENCES

1. J. R. G. Brander and B. A. Cook. Air Transport Deregulation and Airport Congestion Problems. In *Papers and Proceedings of the Transportation Research Forum*, Vol. 26, No. 1, 1985.
2. P. Copes. The Market as an Open Access Commons: A Neglected Aspect of Excess Capacity. *De Economist*, Vol. 132, No. 1, 1984.
3. T. M. Carroll, D. H. Ciscil, and R. K. Chisholm. The Market as a Commons: An Unconventional View of Property Rights. *Journal of Economic Issues*, Vol. XII, 1979.
4. A. A. Walters. The Theory and Measurement of Private and Social Cost of Highway Congestion. *Econometrica*, Vol. 36, No. 3–4, 1968.
5. H. Hotelling. Stability in Competition. *Economic Journal*, Vol. 39, March 1929.
6. J. Hartwick. Free Entry and the Dynamics of the Fishery. In *Essays in the Economics of Renewable Resources* (L. J. Mirman and D. F. Spulber, eds.), North-Holland, Amsterdam, The Netherlands, 1982, p. 160.
7. J. Ott. U.S. Reviews Airport Slot Policy. *Aviation Week and Space Technology*, April 16, 1984.
8. G. Tullock. The Transitional Gains Trap. *Bell Journal*, Vol. 6, No. 2, 1975.
9. D. Koran and J. D. Ogur. *Airport Access Problems: Lesson Learned from Slot Allocation by the FAA*. Federal Trade Commission, Washington, D.C., 1983.
10. J. R. G. Brander. Method of Allocating Airport Runway Slots: Discussion.In *Transportation Research Record 768*, TRB, National Research Council, Washington, D.C., 1980, pp. 1–7.
11. W. J. Baumol et al. *The Theory of Contestable Markets*. Harcourt Brace, San Diego, Calif., 1982.
12. J. Ott. Regionals Raise Questions on Sale of Airport Slots. *Aviation Week and Space Technology*, Vol. 120, No. 22, May 28, 1984.

Publication of this paper sponsored by Committee on Aviation Economics.

Methodology for Planning and Operations Management of Airport Terminal Facilities

S. MUMAYIZ AND N. ASHFORD

An approach to the systematic evaluation of the performance of airport terminal facilities is presented in this paper. The proposed methodology adopts new concepts to establish service standards through special surveys that can achieve better interpretation of capacity of individual facilities by relating demand levels imposed to relevant service measures. It can enhance existing practices in planning and management of airport terminals, and may prove to be a practical and convenient tool to airport terminal planners, consultants, and airport managers. The methodology is intended to be simple in structure, and moderately easy to implement. It is structured to minimize data requirements and uses simple measures and practical techniques that require minimal interference with terminal operations. Theoretical and practical aspects that feature the methodology and were considered in establishing its procedures are described and discussed.

The main objective of the methodology is to establish practical, easily implemented, reasonably realistic, and systematically efficient procedures capable of providing (through quantitative measures) a proper assessment of operational conditions of the processing centers at airport terminals. The approach necessitates defining some fundamental principles that could facilitate the setting up of appropriate service standards for terminal facilities, preferably based on simple, effective, and realistic measures.

The derived standards can then be used to evaluate the performance of the terminals' processing facilities by establishing a properly graded level of service framework that would be utilized to distinguish between different levels of operational performance. In this context the methodology could be a useful instrument to airport operators and planners and provide a mechanism capable of linking components' capacities with some generally accepted and calibrated service standards.

It is hoped that the method will subsequently lead to more adequate standards of space allocation in new airports and better assessment of the operation of existing ones.

CRITIQUE OF CURRENT PRACTICES

There is a degree of subjectivity in current practices of planning and designing airport terminals. Essentially, there are no generally accepted design procedures for airport terminal facilities; instead there is a loosely knit, mostly empirical, collection of approaches derived from the accumulated knowledge of airport-related organizations and consultants. The basic design variable most commonly used is some form of the peak hourly flow, and the criterion for design is based on this. In spite of the great influence of seasonal and daily variations in patterns of traffic on operational performance of the system, it is only the peak hourly demand that is usually considered either in capacity analysis or for planning purposes. The different forms of the design criterion vary, but they include the typical peak hour passenger (TPHP) used by the Federal Aviation Administration *(1)*, standard busy rate (SBR) used by the British Airports Authority *(2)*, or planning peak hour passenger (PPHP) used by Transport Canada *(3)*. These expressions are empirically derived and reflect the need to compromise between efficiency in accommodating annual flows and economy by choosing a design hour that is not the highest. The approach is to be equivalent to the 30th highest-hour-volume widely used in highway design practice *(4)*. Most current approaches to airport design and analysis implement this criterion. However, shortcomings associated with the approach—mainly the likelihood of future deviations from the design hour volume chosen—imply that current methodologies lack structural flexibility. This approach has averaging effects or is "oversimplistic, accommodating the whole on average..." *(5)*, thereby demonstrating insensitivity towards different demand levels. The criteria used are void of any consideration of the stochastic nature of operations and the time-variant influence of demand on the performance of facilities. When used to assess operational performance, they neglect the important dynamic features associated with the stochastic nature of demand because one of the major measures of performance, congestion, is the direct result of randomness in the operation of service facilities *(6)*. These shortcomings have already been recognized by others *(5)*:

> First, it is erroneous to focus on averages; it is the local extremes that will limit the performance of a facility. Second, the loads on any particular facility need to be taken over its critical period, the time over which the transient surges in traffic build up congestion. If we fail to do this, we will underestimate the degree of congestion that will occur.

Therefore, a more realistic approach would appear to be necessary to fill this gap, with due consideration of the influence of the stochastic nature and time variation of demand on operation, and incorporating the dynamics of congestion and queueing phenomena. The stochastic nature and the variation of demand are included in the design criterion suggested by the approach in this paper, and as mentioned in the capacity procedure.

With respect to service standards, the technical literature lacks any comprehensive values that have been implemented

S. Mumayiz, University of Texas at Austin, College of Engineering, Center for Transportation Research, Suite 200, 3208 Red River, Austin, Tex. 78705-2650. N. Ashford, Department of Transport Technology, Loughborough University, Loughborough, England.

other than those recommended by the International Air Transport Association (IATA) based on the British Airport Authority's acquired experience in passenger handling. These values were empirically derived and do not involve passenger perception of service levels. The proposed methodology has the merit of considering passenger perception and response to operational conditions in setting of levels of service to facilitate the grading of performance. The various levels are contained in a structured framework based on realistic measures of service that describe operational performance, and are systematically derived by a predefined procedure. Note that structurally, this methodology is arranged to deal with two procedures: level of service and capacity.

LEVEL OF SERVICE PROCEDURE

Service standards should ideally reflect the views of the public and promote its interests and desires. Keeney *(7)* specifies that standards should be set in terms of both the alternatives available and public values. In the case of airports, standards should be set according to how the travelling public perceives the operational and environmental conditions met inside airports, in terms of the prevailing or potentially available operational service.

The three main parties involved with operations of airports are users (air travelling public), air carriers, and airport operators. It is the interaction of these groups, as well as other minor parties, that drives airport activities and keeps the airport running on its designated course to provide efficient, convenient, and safe transfer of air passengers and their baggage between surface and air transport modes. Although the active presence of these three parties is essential to the airport system, their interests and objectives are not necessarily identical. In fact, they could conflict. Air passengers want to spend a brief yet comfortable and enjoyable time in the terminal, air carriers look mainly for the economics of the operation in terms of net profit, and the operator is concerned with regulating this transfer safely, lawfully, and efficiently, usually in terms of best possible exploitation of capital investment of the airport.

Certain decisions made with respect to airport and air transport planning inevitably characterize the system. These decisions are related to the nature, objectives, and priorities of the planning process; the definition of problems; and the criteria of evaluation. These decisions are strongly influenced by sociopolitical issues, which explains the significant features that differentiate national practices. These issues include concept of the role of government, concepts of public interest, what constitutes public benefits, purpose of commercial enterprise, and so on. Often those responsible for making decisions that affect the public do not use the public values, but have their own set of values that are significantly different *(7)*. This seems to apply to airport terminals because their service standards have been set according to the values of carriers or operators and not of users.

Another aspect of the problem in consideration is determining adequate methods to set standards that would really reflect the air travelling public's interests and desires. The objectives of air carriers and airport operators could be explored according to the approach to the investigation adopted (e.g., economic analysis, market research, administrative regulations, management techniques, labor relations, etc.); but the definition of service standards is more problematic. There is an essential and urgent need to develop some mechanism that can reasonably interpret and quantitatively determine service standards of passengers in airport terminals.

A level of service procedure is devised here for the purpose of delineating distinct levels of operational service that can be used to set service standards for terminals. In implementing this procedure, service conditions at a facility are evaluated and assessed in terms of some measure of service, based on desires of passengers themselves and their perception of service at a facility subject to a certain demand level.

Delay in service seemed the most relevant service measure that might contribute to or influence standards of airport terminals. From different spatial, temporal, econometric, statistical, and other measures that may be used to evaluate service, delay (as the major component of total time spent) was chosen for its suitability, both theoretically and practically, for implementation in some procedure to interpret passengers' perceptions and reactions to operational service. Delay is theoretically suitable because it is the major contributor to congestion (with crowding) that affects operational conditions. It is practically suitable because it appears to be the foremost factor in the minds of passengers that influences attitudes. Perception and reaction towards service provision can be obtained conveniently through surveys.

There are two basic approaches to surveying of this type. The most obvious way of obtaining passengers' perception and reaction to service conditions is to ask them directly. Inevitably, this particular approach requires a proper airport survey of the passengers themselves. In such an inquiry, passengers would state their perception (preferably expressed in three or more levels of satisfaction with service) of different times spent in a particular facility or process at an airport. The implicit assumption in using the results is that current circumstances of operation are permanent. However, a second approach can also be pursued, particularly when a proper passenger survey cannot be conducted for one reason or another. This alternative approach uses a panel of experts representing the different parties and organizations associated with handling and processing airport passengers. Participants are asked to state their perception of service to passengers, and they inevitably represent the views and opinions of their own airports. Both methods were tried and used in this work.

As shown in Figure 1, the level of service procedure is conducted according to the following steps: (*a*) collection of information, (*b*) construction of the passenger perception-response models, and (*c*) definition of service regions (levels).

Collection of Information

Required information is collected by means of passenger surveys conducted separately for departure and arrival channels. Major information includes delay information, passenger eval-

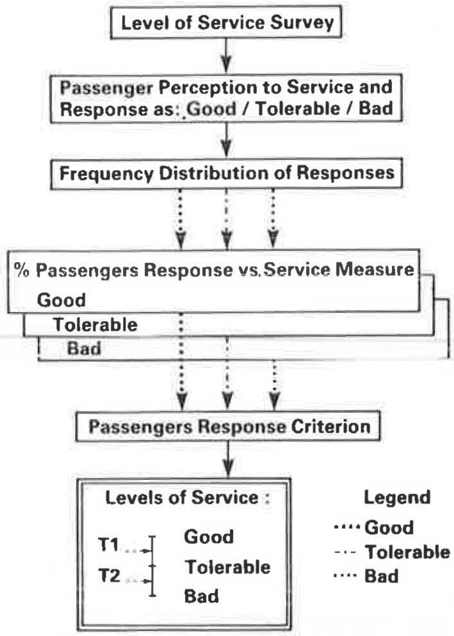

FIGURE 1 Level of service procedure.

uation of service conditions resulting from different delay times, and certain passenger-specific information.

Delay Information

The amount of time passengers are delayed or spend in the processing facilities of the terminal at the time of the survey is required in order to check the replies of the passengers against the overall operating conditions that prevailed during the survey period.

Passenger Perception and Response

A prime objective of the survey, passenger perception and response facilitate the construction of the perception-response (P-R) models. In the case of passenger surveys, this is the most sensitive part of information sought mainly because of

1. The way that passengers could be conveniently directed to conscientiously and accurately state their perception and reaction to service,
2. The ability of the individual passenger to clearly distinguish between three or more different states of satisfaction levels and to tie each level with some boundary,
3. Influence of past experience with other airports on the passenger when expressing the satisfaction level, and
4. Probabilities of inconsistent or shifted answers resulting from a variety of causes and reasons.

Each reply constitutes a set reflecting the passenger's perception and response to delay or time spent at a facility and is expressed (in this work) in terms of three distinct levels of satisfaction towards different service conditions, which range from very short to very long times at that particular facility.

Passenger-Specific Information

Passenger-specific information includes factors related to demand that identify the individual passenger and differentiate between various flight and passenger categories, such as flight type, purpose of trip, range of flight (medium or long haul), nationality, and other details that the surveyor might find important.

Building Perception-Response Models

The P-R model is defined as the graphical presentation of the collective attitudes of a category of passengers towards the range of operational service at a facility, expressed in terms of the perception of the passenger population of different amounts of the service measure, and response to the respective service conditions. The latter is classified into distinct levels of satisfaction with service. The percentage of passengers replying to whether a certain amount of time (delay or time spent) at a particular facility was perceived as good, tolerable, or bad is related to amount of time (delayed or spent). The conceptual diagram for this model is shown in Figure 2.

The significance of the P-R model is that it can be practically implemented to derive and set service standards for airport processing facilities based on passengers'opinions and reactions towards operational service at those facilities. Although the model involves a degree of role-playing, it serves functionally as a scaling device to grade operational service in terms of the service measure, time. Implementing P-R models could achieve certain goals such as the assessment of service

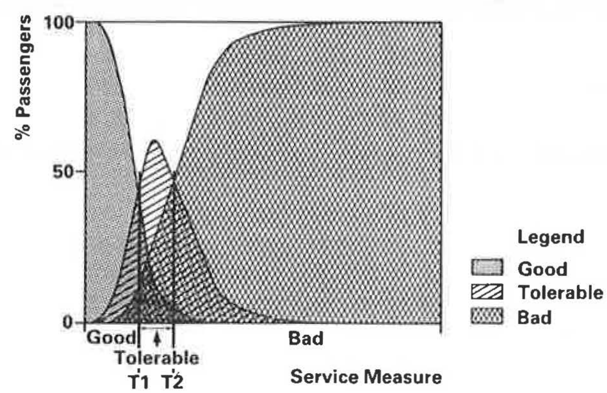

FIGURE 2 Conceptual drawing of P-R model.

for all possible conditions of service attainable at a particular facility. Also, the convenient superposition and disaggregation of P-R models as related to the categories of passengers and flight and types of facilities could be facilitated. Several categories of passengers and flights can be merged to form one P-R model, or a single P-R model of a facility can be split into several P-R models for these categories using that facility. This approach will result in obtaining the accuracy desired by controlling the graduation (increment) of the service measure, as well as easy determination of the response to service of any percentile of the passenger population.

Nevertheless, in implementing this technique, the following should be considered.

1. Perception of passengers to service is dynamic. This is particularly important when setting service standards for a group of airports, or for the same airport at different times when certain aspects of operation, demand, or both can change.

2. Because replies are based on passengers' responses to the observer, they can be easily biased by bad communication and poor or nonstandard survey techniques.

3. Although P-R models are based on passengers' personal perception and response to service, the influence of carriers and operators is implicitly recognized and included in the P-R model. Operational service that passengers actually experience is assumed to be the kind that carriers and operators intend or can provide to the travelling public. Operators' decisions and policies derive from their perception of resources available; from regulations imposed, operational procedures adopted, or technologies utilized; and from various considerations induced by the specific and unique nature of the air travel market.

Establishing Level of Service Framework

Service standards in terms of a framework for processing facilities in question can now be established. Time values (T1 and T2) delineating the boundaries of service levels were deduced. This was achieved by examining the three curves representing passenger response to the service as good, tolerable, or bad. It was found that using more than three levels of service would be impractical because it is difficult for passengers to differentiate clearly between more than three and to assign a boundary to each level. The opinion of passengers towards different time durations (delay or time spent) in particular facilities is plotted in terms of response curves. From these curves, the point at which there is a shift in perception of the majority of passengers from one state to another can be defined as the point of change of level of service. This occurs when there is a change in the opinion of the majority of the passenger population where one level of satisfaction is dominant over the other two. This description is best demonstrated in Figure 2 by the unshaded area between the three curves. To the left of T1 the level is predominantly perceived as good. To the right of T2 the service is predominantly perceived as bad. Between T1 and T2 the service is tolerable.

Normally, when the passenger population surveyed is homogeneous and there is a high degree of consensus among them in formulating their opinion about the state of service, changes in levels of service usually occur around the 50th percentile, reflecting the views of the average passenger in the population. However, when the passenger population is not homogeneous, when there is a lack of consensus on service, or lack of knowledge or confusion regarding the nature of the service at a particular facility, changes in the levels of service are not close to the median. Lack of homogeneity here implies that the P-R model is actually composed of more than one model, depending on the number of homogeneous groups (e.g., flights) in the passenger population surveyed. In special circumstances, there could be some drastic shifts in opinions between extreme states of service, resulting in the absence of a middle tolerable state of service, and ending with a framework that has only two levels of service (good and bad).

In the methodology developed in this research, only processing facilities were considered. Such facilities are most important to the operating conditions of the airport system to the extent that they actually characterize the system's environment and largely define the function and size of the airport. However, other facilities serve mainly as staging and auxiliary components in the overall passenger and baggage transfer process between the surface and air transport modes. Existing standards adopted from available literature are sufficient and adequate for nonprocessing areas. Work by Fruin *(8)* on pedestrians in terminals and Perrett *(9)* on planning aspects of airport terminals exemplify such standards for linking and storing facilities.

The level of service framework for Birmingham International Airport (BHX), expressed in terms of T1 and T2, is given in Table 1. Values of T1 and T2 were obtained, as mentioned, from the P-R models of the respective facilities. For example, the P-R model for the charter flight check-in facility is shown in Figure 3 with the values of T1 and T2 for this facility marked. Values of T1 and T2 for the other processing facilities in Table 1 were similarly derived from P-R models of the respective facility (Figures 4–10). Although the level of service framework given in Table 1 is for total passengers, a framework for the various processing facilities can be broken down into the different passenger and flight categories *(10)*.

TABLE 1 LEVEL OF SERVICE FRAMEWORK FOR BIRMINGHAM INTERNATIONAL AIRPORT

	Total Time Spent in Facility (min)[a]	
Facility	T1 (Good/Tolerable)	T2 (Tolerable/Bad)
Airline check-in		
Charter inclusive tour	11.0	21.0
Scheduled long haul	15.0	25.0
Scheduled European	7.5	14.0
Security check	6.5	10.5
Passport control	6.5	10.5
Immigration	6.5	14.5
Baggage claim	12.5	22.5
Customs control	6.5	11.5

[a]Minutes rounded to nearest half minute.

CAPACITY PROCEDURE

The capacity procedure establishes the relationship between the service volume of a facility and some expression that would reasonably describe the level of service provided at that service volume (demand). The expression for the service standards (the service measure) could be interpreted in terms of average time per user, maximum number of users waiting for service at any time, the density of users per unit area, or any other suitable expression.

The appropriate means to establish capacity relations (or performance models) is simulation. It is usually very costly and often infeasible to gather the required information to construct such relationships from real-world operational conditions. Therefore, simulation techniques have been devised and developed to simulate the operation of various kinds of processes following two broad approaches:

1. The macroscopic approach whereby total system simulation models are used to describe the complete system in consideration, including interactions between its components.

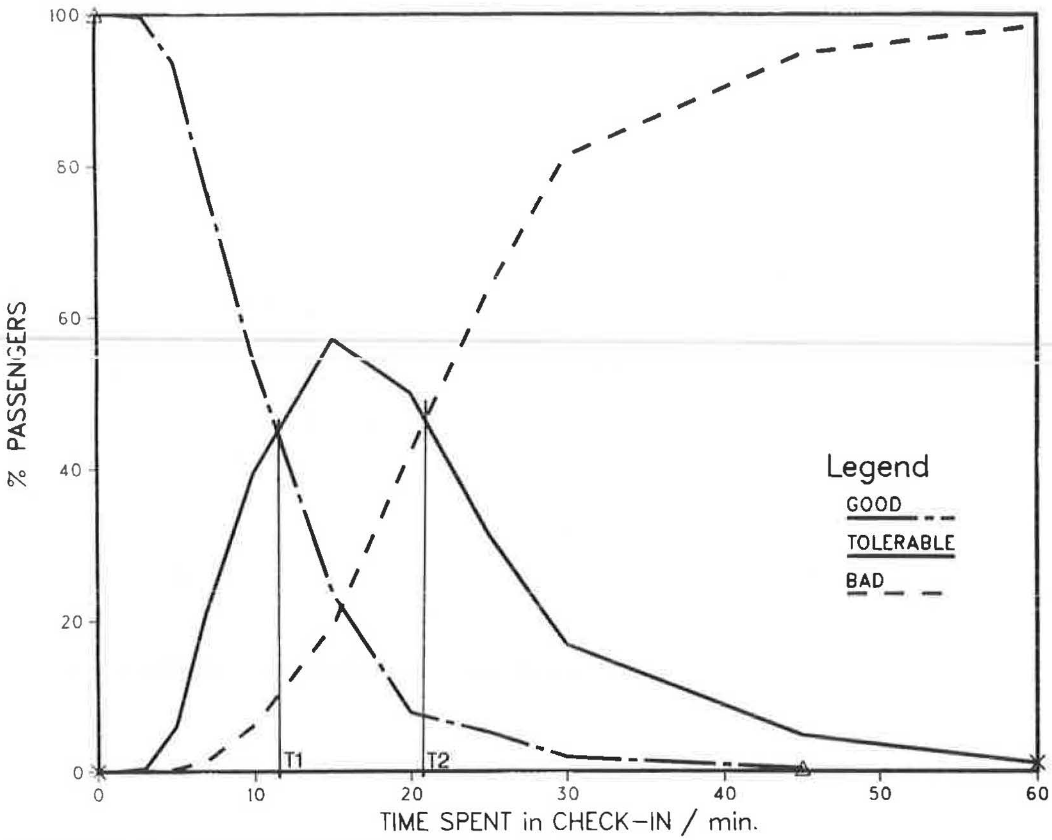

FIGURE 3 Birmingham International Airport survey: P-R model for charter inclusive tour passengers at check-in.

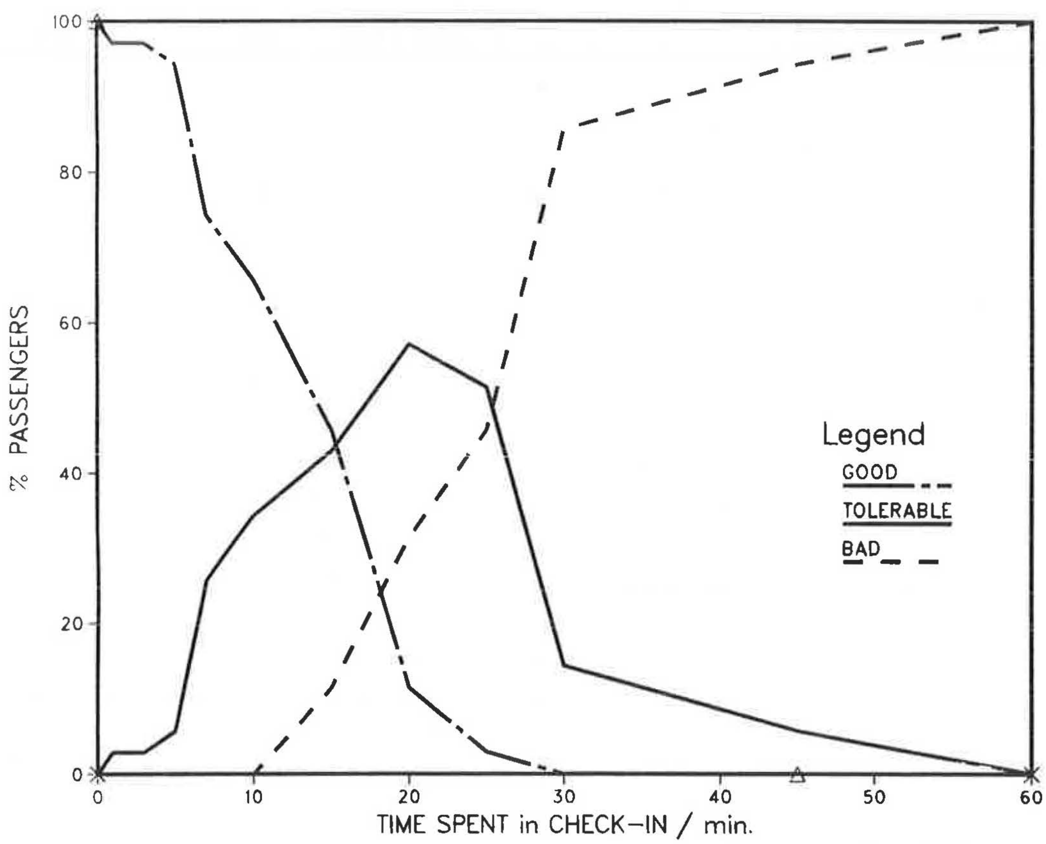

FIGURE 4 Birmingham International Airport survey: P-R model for scheduled long-haul passengers at check-in.

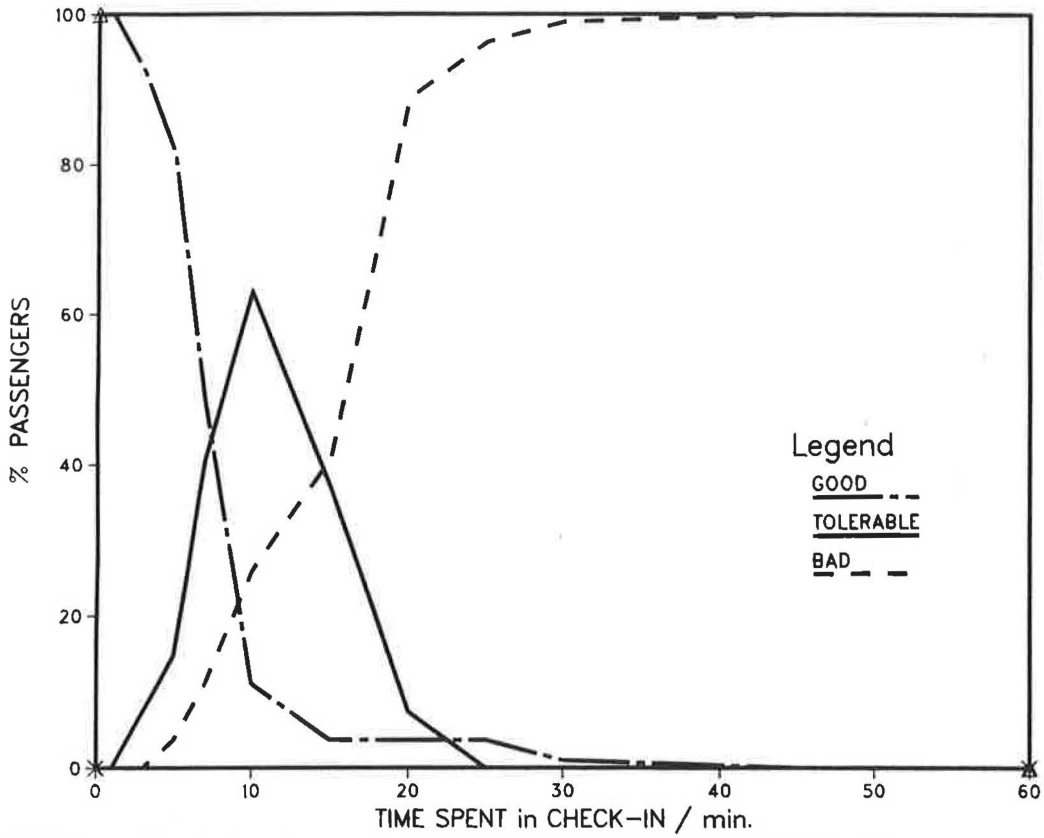

FIGURE 5 Birmingham International Airport survey: P-R model for scheduled European passengers at check-in.

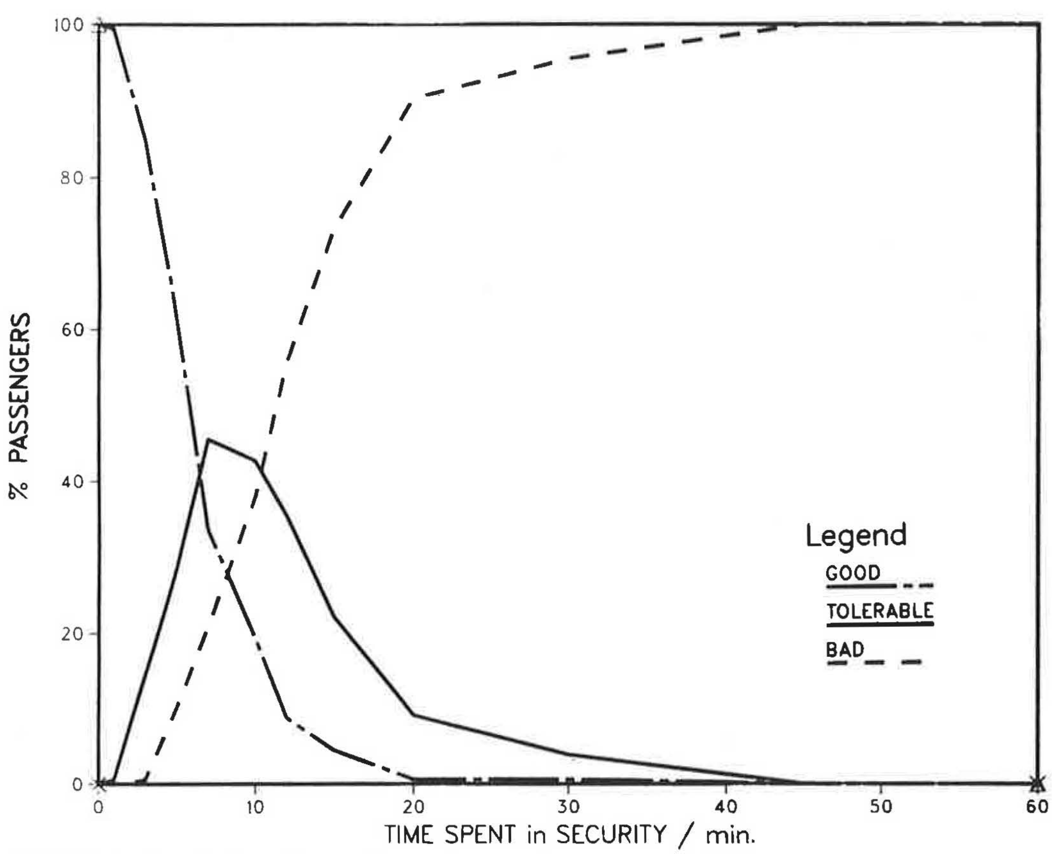

FIGURE 6 Birmingham International Airport survey: P-R model for total departing passengers in security.

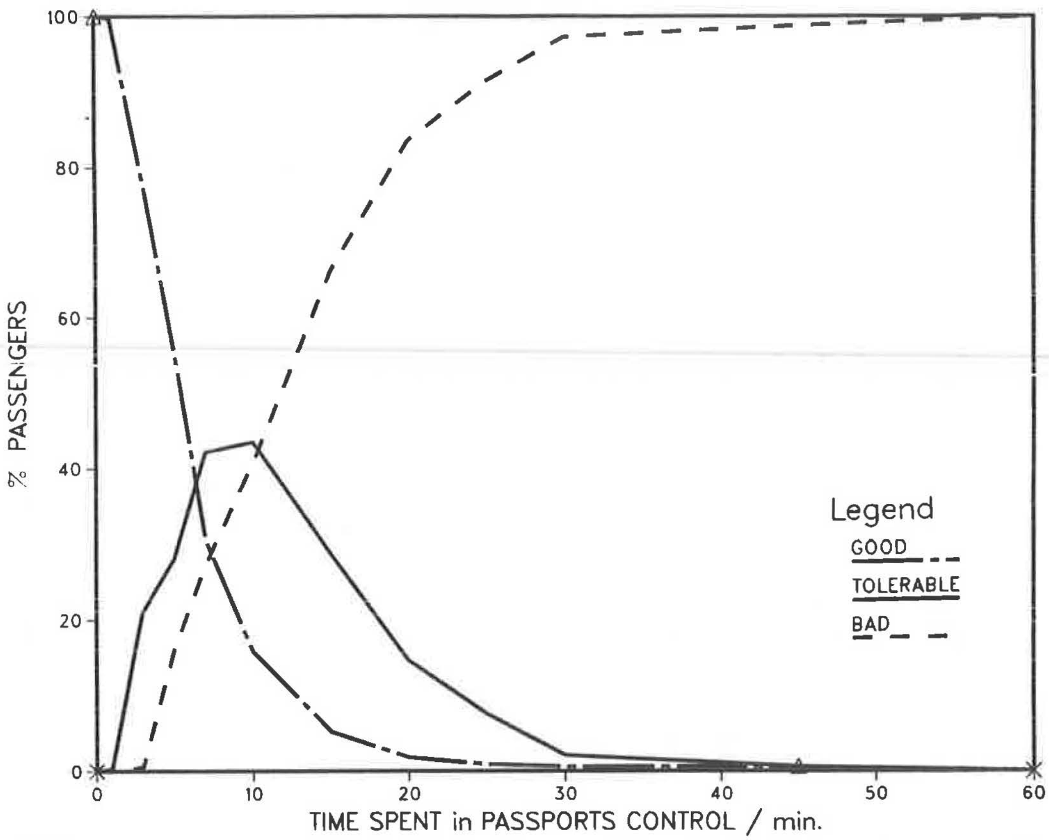

FIGURE 7 Birmingham International Airport survey: P-R model for total departing passengers in passport control.

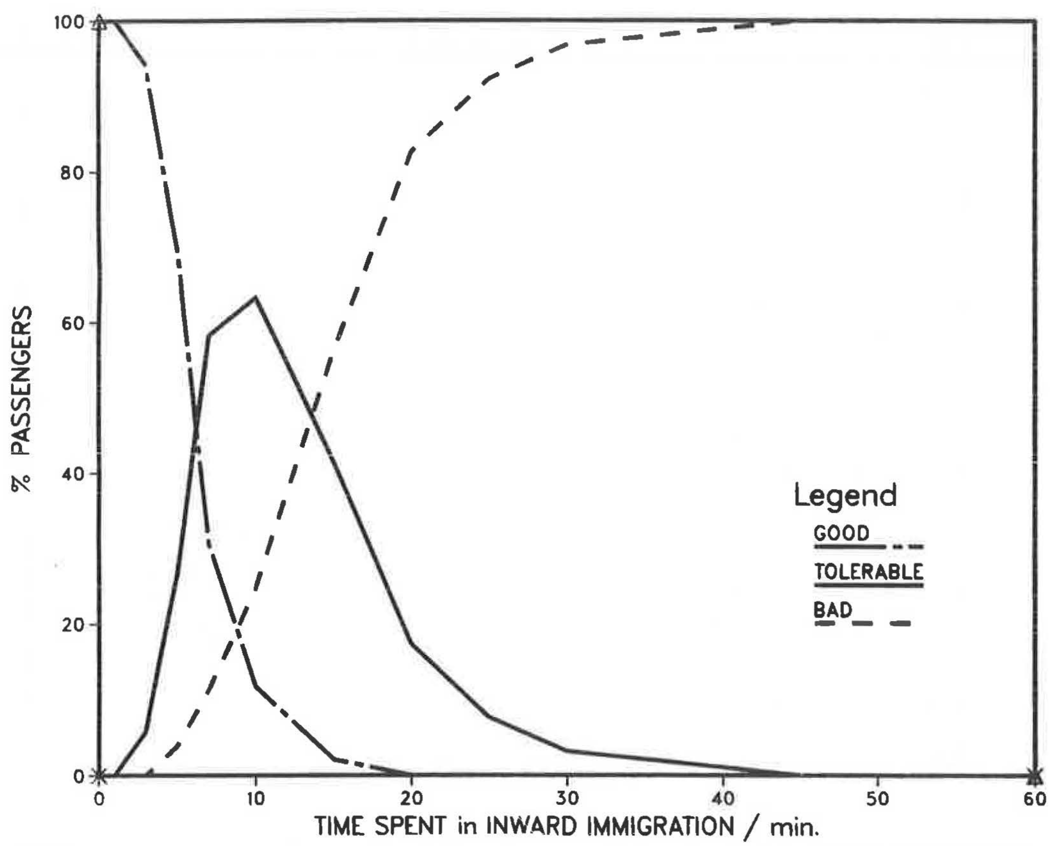

FIGURE 8 Birmingham International Airport survey: P-R model for total arriving passengers in inward immigration.

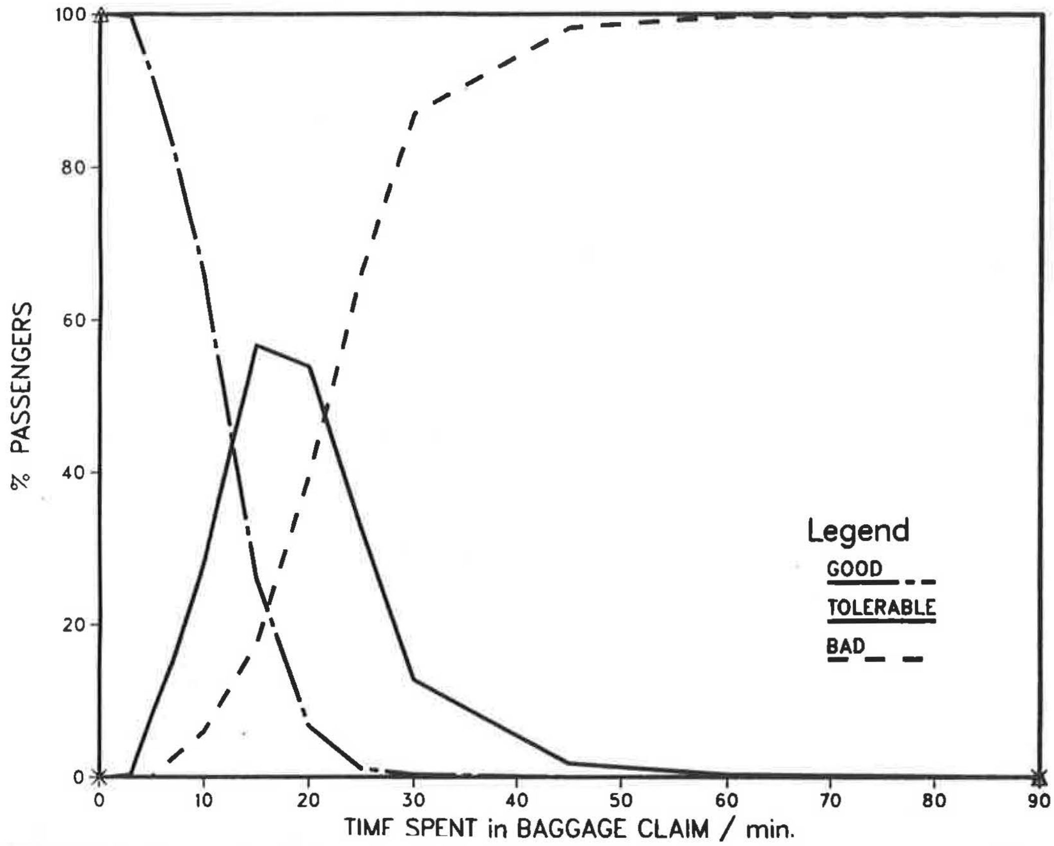

FIGURE 9 Birmingham International Airport survey: P-R model for total arriving passengers in baggage claim.

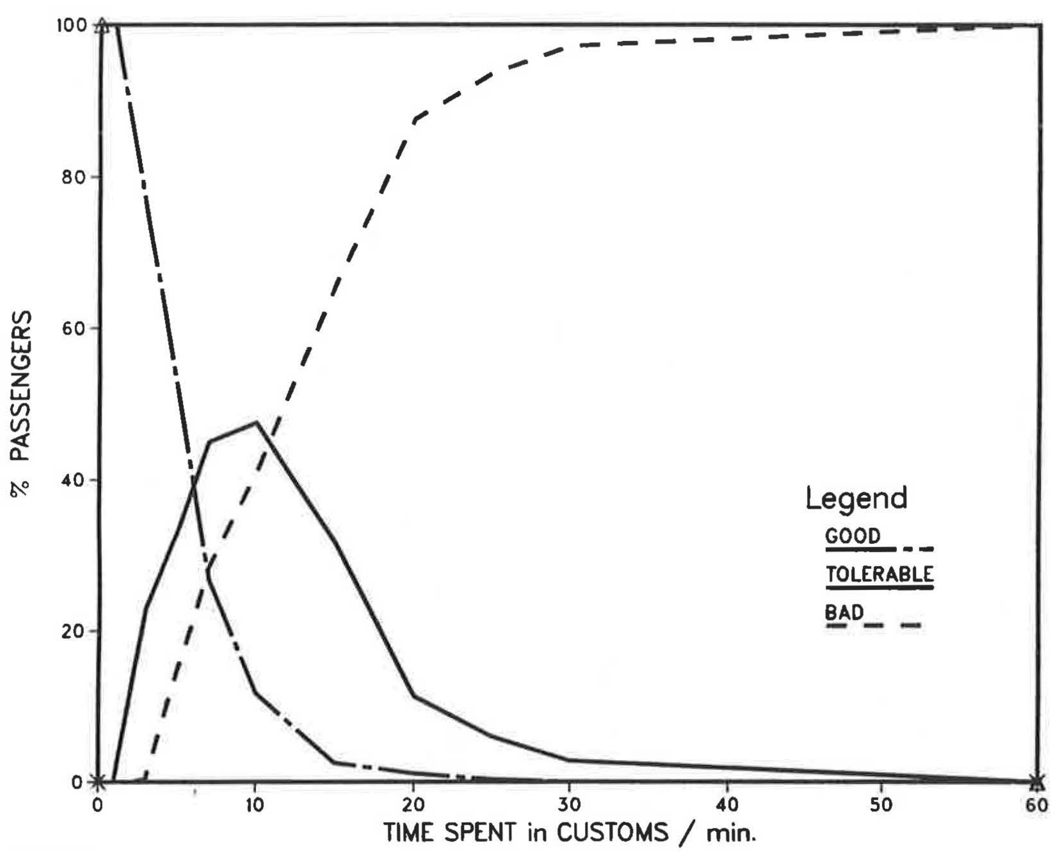

FIGURE 10 Birmingham International Airport Survey: P-R model for total arriving passengers in customs.

2. The microscopic approach whereby the system's components are considered individually, and activity simulation is utilized to model operation at the respective component.

For reasons of practicality, the second approach was used in this research. It was realized that additional information normally needed as input for total-system simulation models could be spared only if individual facilities were considered. In certain ways, this approach is analogous to analyzing a structure in mechanics by considering the free-body diagram of its respective components.

In broad terms, the capacity procedure follows these steps, shown in Figure 11: (*a*) definition of input parameters, (*b*) executing simulation runs, and (*c*) establishing relationships.

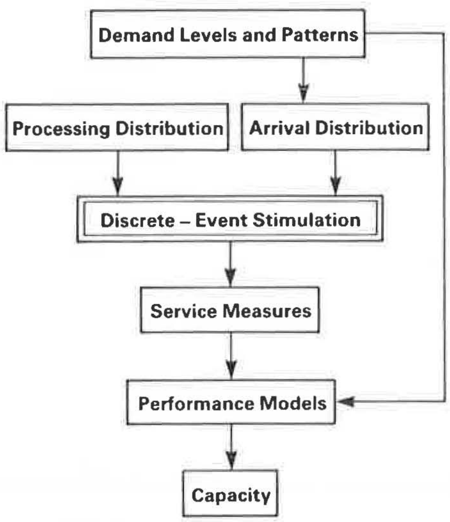

FIGURE 11 Capacity procedure.

Definition of Input Parameters

Operational parameters associated with a certain process define and characterize the behavior of the performance function of that particular process. These input parameters include the arrival distribution, processing (servicing) time distribution, the number of channels, plus other less significant parameters as described in the following sections.

Arrival Distribution

Arrival (rate and distribution) of passengers at a facility is the major input to any servicing process and should resemble the imposed demand for service at that particular facility. Probabilistic arrival at and departure from a servicing system is a special case of the Markovian birth-and-death process *(11)*, in which the state of the system changes by at most one (up or down) in any infinitesimal interval. The distribution of interarrival times (times between successive arrivals of entities) is equally important in the mathematical designation of the process. For the airport environs particularly, the implementation of the Poisson distribution for modeling arrivals at the airport processing facilities has been verified and recommended by previous research *(12)*.

Processing (Servicing) Time Distribution

Service time distribution is another important element of a queueing model, which can define the actual departure of passengers from the servicing facility—hence its capacity in handling passengers, which reflects the supply side of operation. The expression consists of the rate of processing or servicing (and departure from the system), and the pattern of occurrence of individual service times or frequency distribution of service times. By determining the frequency of occurrence of various values of service times throughout operation, this major input to the servicing process could characterize capacity of the servicing unit of a processing facility.

In simulation, service times are randomly selected from a particular frequency distribution with a given statistical parameter (usually the mean). Apart from this statistical parameter, the shape of frequency distributions is of special importance in simulation because it is derived from the population of service time values from which the frequency distribution was initially constructed. It is the means of reestablishing the particular distribution and making it known to the simulation technique. The most commonly adopted distribution in similar systems is the gamma family, especially exponential and Erlangian. These are used to describe random variables bounded at one end, specifically in queueing theory. Previous research *(13)* showed that service times observed at airport terminals fitted both exponential and Erlangian distributions. Shifted negative exponential distribution may be used for conditions where servicing is somewhat varying, and the Erlangian distribution for more uniform service conditions.

Number of Channels

Although service time reflects the supply of an individual processing unit, the number of operational channels arranged in parallel indicates the overall supply of the facility. This defines the capacity and characterizes the overall size of a facility.

Simulation Runs

A recognized simulation technique, SLAM *(14)*, was used in this study to execute several runs to establish the performance model. Those runs covered all service volumes that could possibly be processed by that particular facility. Depending on the specific features of the technique and the information required, the output of these runs typically included statistics on the following:

1. Time (delay or total time spent) per passenger at the particular facility expressed as mean, maximum, minimum, standard deviation, and frequency distribution of occurrence;

2. Queue length expressed in the same statistical parameters as those mentioned in the FAA report *(1)*;

3. Percentage utilization of servers expressed as mean, maximum, minimum, and standard deviation;

4. Number of observations (sample size) from which statistics were calculated; and

5. Other more specific information of interest to the modeler, depending largely on available facilities and capabilities of the simulation package.

Performance Models

From the synthesized data generated by means of simulation, it would now be possible to construct the performance models that describe the following relationships:

1. Average time (in terms of delay or total time spent) per passenger in the particular facility at different demand levels;

2. Maximum queue length or maximum number of pas-

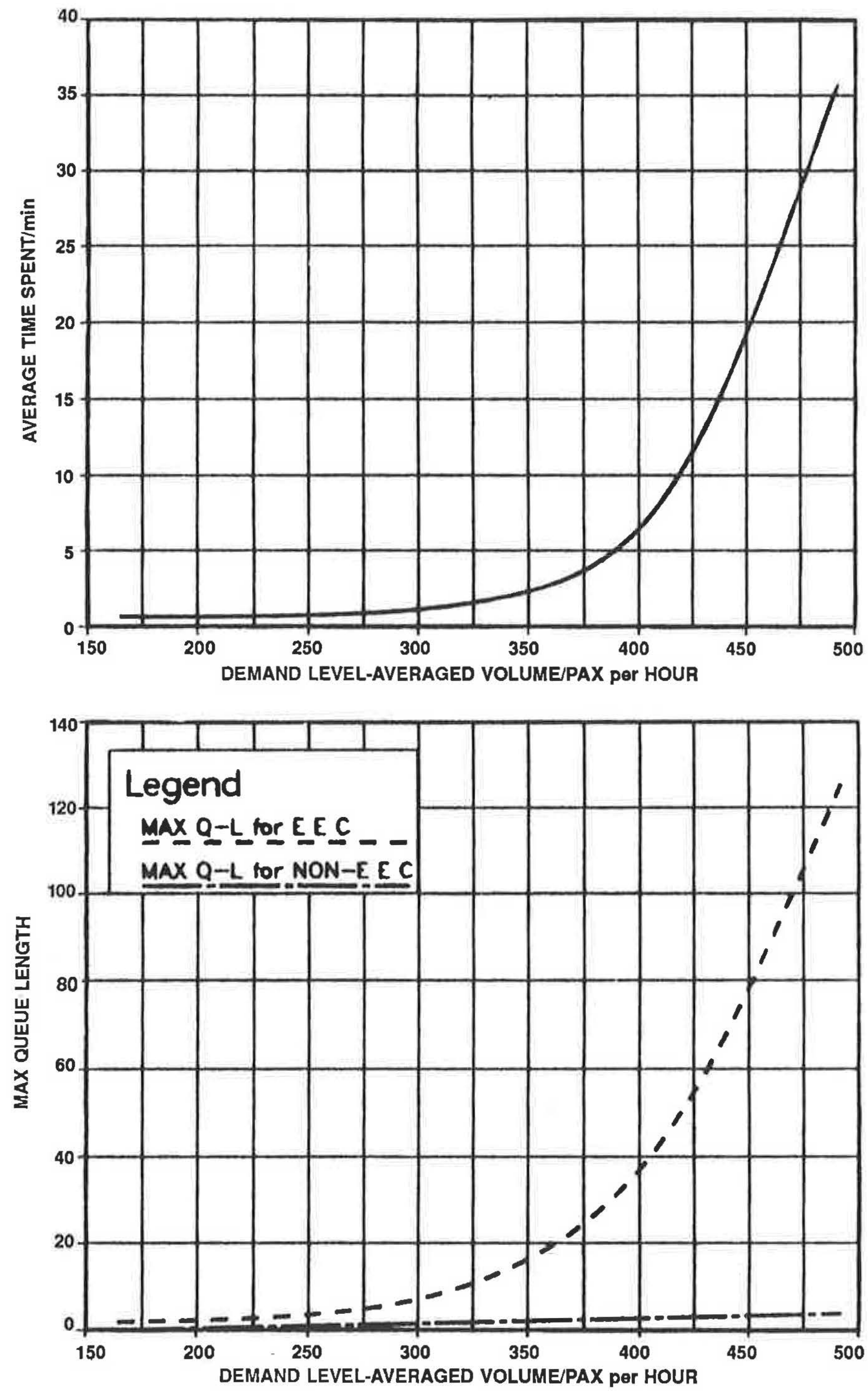

FIGURE 12 A typical P-R model for inward immigration control at Birmingham International Airport.

sengers waiting for service at that facility at different demand levels; and

3. If required, the average percentage of server utilization at the facility as related to different demand levels.

Figure 12 is a sample of the performance model of the processing facility for immigration control based on information collected at British regional airports *(10)*. Note that for European Economic Community (EEC) passport holders, there are four servers where service times are divided by exponential 0.50. For non-EEC passport holders, there are two servers where service times are divided by exponential 2.00.

OPERATIONS ASSESSMENT: CAPACITY AND LEVEL OF SERVICE RELATIONS

Following the two procedures presented earlier, it was possible to establish a relation between capacity and service standards of facilities in consideration. This was achieved by marking the boundary values of the level of service framework previously obtained from the P-R models on the performance model.

Effectively, operating conditions at different demand levels in a facility are assessed and evaluated in terms of the prevailing operational service as perceived by the passengers. The performance model can be divided into segments or regions, where resulting operational service is considered as good, tolerable, or bad, by boundary values (in terms of demand levels) at the corresponding levels of service. This was done for various categories of passengers and flight types. The approach therefore can provide a systematic method for assessing operational conditions where capacities of processing facilities are directly linked and related to service standards. Assessment of operational service for processing facilities at British regional airports considered in the research *(10)* is summarized in Tables 2 and 3.

APPLICATIONS

Applications of this methodology included the following studies *(10)*:

TABLE 2 LEVELS OF OPERATIONAL SERVICE FOR AIRLINE FLIGHT CHECK-IN AT BIRMINGHAM INTERNATIONAL AIRPORT

Measure	Charter Inclusive Tour	Scheduled Long Haul	Scheduled European
Good			
Demand level[a]	205	265	120
Average time spent (T1)[b]	11.0	15.0	7.5
Maximum passengers waiting	32	48	20
Tolerable (no data)			
Bad			
Demand level[a]	260	310	160
Average time spent (T2)[b]	21.0	25.5	14.0
Maximum passengers waiting	60	72	40

[a]Passengers on flights.
[b]Minutes (from Table 1).

TABLE 3 LEVELS OF OPERATIONAL SERVICE FOR PROCESSING FACILITIES AT BIRMINGHAM INTERNATIONAL AIRPORT

Measure	Security Check	Immigration Control	Customs Control
Good			
Demand level			
Average volume[a]	238	400	455
Peak hour	450	604	678
Average time spent (T1)[b]	6.5	6.5	6.5
Maximum passengers waiting	90	38/3[c]	160/1[d]
Tolerable (no data)			
Bad			
Demand level			
Average volume[a]	254	435	485
Peak hour	485	657	723
Average time spent (T2)[b]	10.5	14.5	11.5
Maximum passengers waiting	150	60/4[c]	240/1[d]

[a]Passengers per hour for peak period.
[b]Minutes (from Table 1).
[c]European Economic Community (EEC)/non-EEC immigration.
[d]Green/red customs channel.

1. East Midlands Airport (EMA), where a pilot passenger survey was launched to test different aspects of P-R model building. Sample size was small and only chartered flight passengers were included.

2. Manchester International Airport (MAN), where both P-R and performance models were built, and operations conditions for the departure channel were assessed. Analysis divided passengers into flight categories: charter, scheduled long haul, and scheduled European (medium haul).

3. Birmingham International Airport (BHX), where a complete application of this methodology was performed. P-R models for the different flight categories, as well as performance models, were built, and assessment of operational conditions for both arrival and departure channels was carried out. This included all processing facilities of both channels (except baggage claim) that handled passengers on international flights.

4. A panel-of-experts survey was conducted at Loughborough University, England, to test the suitability of an alternative approach to passenger surveys. The panel consisted of 25 experts from 14 major European airports representing both airport authorities and airlines. Because participants represented different airports that have different operational conditions with varying practices, it was not possible to construct P-R models for such a case. Instead, the survey questionnaire consisted of two parts: (*a*) participants were asked to consider service conditions at their own airports and reply accordingly; and (*b*) a hypothetical airport of given size and annual throughput was to be considered by all participants. The first part of the questionnaire was actually redundant and its only function was to provide an "adaptation level" for the participants to enable them to answer the second part.

CONCLUSION

A method of determining realistic level of service standards for processing facilities at airport terminals is defined by the research in this paper. Because of resource constraints, the work must be regarded as prototypical, defining as it does only three levels: good, tolerable, and bad. Unlike existing suggested level of service standards, those developed in this research have been calibrated on user responses and have been found to be nonlinear. Further work of a more detailed nature is required to subcategorize the three levels into a more finely divided structure, and to determine the influence of other variables such as airport throughput and geographical location. The findings presented here suggest, however, that the concept of level of service already used in the design and analysis of highways and pedestrian facilities can be usefully applied to airport terminals. The methodology is useful both for the design and operational phases of terminal life.

REFERENCES

1. Federal Aviation Administration. *Aviation Demand and Airport Facility Requirements Forecasts for Medium Air Transportation Hubs Through 1980s*. U.S. Department of Transportation, Washington, D.C., Jan. 1969.
2. *Glossary of Terms*, 3rd ed., British Airports Authority, London, England, Nov. 1981.
3. S. G. Hamzawi. Technical Report TE3935E: *Airport Traffic Analysis Model*, 2nd ed. Transport Canada, Ottawa, July 1983.
4. *Highway Capacity Manual*. HRB Special Report 87. HRB, National Research Council, Washington, D.C., 1965.
5. R. De Neufville and M. Grillot. Design of Pedestrian Space in Airport Terminals. *Transportation Engineering Journal, ASCE*, Vol. 108, No. 1, Jan. 1982, pp. 87–102.
6. H. Taha. *Operations Research—An Introduction*, 3rd ed., Macmillan, New York, New York, 1981.
7. R. Keeney. Issues In Evaluating Standards. *Interfaces*, Vol. 13, No. 2, April 1983, pp. 12–22.
8. J. J. Fruin. *Pedestrian Planning and Design*. Metropolitan Association of Urban Designers and Environmental Planners, New York, New York, 1971.
9. J. D. Perrett. "The Capacity of Airports: Planning Considerations." Paper 7372, *Proc., Institution of Civil Engineers*, London, England, Vol. 50, Dec. 1971, pp. 435–450.
10. S. A. Mumayiz. *A Methodology for Planning and Operations Management of Airport Passenger Terminals: A Capacity/Level of Service Approach*. Ph.D. thesis. Department of Transport Technology, Loughborough University of Technology, Loughborough, England, 1985.
11. R. Larson and A. Odoni. *Urban Operations Research*. Prentice-Hall, New Jersey, 1981.
12. D. Bennetts et al. *Stochastic Modelling of Airport Processing*. Report TT 7509. Department of Transport Technology, Loughborough University of Technology, Loughborough, England, July 1975.
13. D. Bennetts et al. *Survey Analysis of Airport Terminal Passenger Processing*. Report TT 7502. Department of Transport Technology, Loughborough University of Technology, Loughborough, England, April 1975.
14. A. Pritsker and C. Pegden. *Introduction to Simulation and SLAM*. John Wiley-Halstead Press, New York, New York, 1979.

Publication of this paper sponsored by Committee on Airport Landside Operations.

A Prescription for Efficiency: Managing the Canadian Government's Civilian Aircraft Fleet

HAROLD M. KOHN

In Canada, one federal department, Transport Canada, operates and maintains the majority of civilian aircraft used by the federal government. The 90 fixed and rotary wing fleet consists of 29 different aircraft types located at 17 bases across Canada. The fleet is used for flight calibration and inspection; regulatory enforcement, inspection, and monitoring; pilot proficiency training; Canadian Coast Guard operations; and accident investigation by the independent Canadian Aviation Safety Board. The branch within Transport Canada charged with the responsibility of ensuring that the aircraft are safely and efficiently operated is the Flight Services Directorate. The Directorate has been awarded an operating certificate and operates under the same laws and regulations affecting all air carriers in Canada. Although the responsibility for training pilots and aircraft technicians rests with Flight Services, the Directorate provides the aircraft according to the demands of others. Flight Services essentially provides a centralized charter service under management contract with several clients, most of whom are other branches within Transport Canada. Faced with an urgent desire to simultaneously minimize expenditures and maximize the level of service to its clients at an acceptable level of safety, the Flight Services Directorate faces a massive challenge. The multitasked nature of the operation, many different aircraft types, geographic displacement, and a service driven by clients' need have led Flight Services to embark on a series of major initiatives to examine how to maximize efficiency and cost effectiveness. These initiatives include a thorough examination of annual aircraft flying rates, usability, serviceability, labor productivity, and operating costs, including comparisons with the Canadian private sector. In addition, Flight Services has been taking action to rationalize the fleet and has been comparing operations from one base to another. The results of these analyses to date are outlined in this paper.

In Canada, one federal government department, Transport Canada, operates and maintains the majority of civilian aircraft used by the federal government. The 90 fixed and rotary wing aircraft in the fleet are used for flight calibration and inspection; regulatory enforcement, inspection and monitoring; pilot proficiency training; Canadian Coast Guard operations; and accident investigation by the independent Canadian Aviation Safety Board. In addition, Transport Canada provides maintenance assistance to the fleet of the Royal Canadian Mounted Police, as well as maintaining aircraft owned by the Department of the Environment and the Department of Fisheries and Oceans. Approximately 44,000 hr are flown on an annual basis by the Transport Canada fleet (Table 1).

TABLE 1 THE FLIGHT SERVICES FLEET FOR TRANSPORT CANADA

Aircraft Type	No. in Fleet	Flying Hours in 1984–1985
Bell 206B Jet Ranger	24	10,738
Alouette III SE3160	3	1,790
Sikorsky S–61N	1	623
Bell 212	5	2,626
MBB–BO–105–CBS	2	867
Gulfstream G–1159 (G–II)	1	860
Cessna 182/U206	2	582
DHC–6 Twin Otter	6	3,539
DHC–2 Beaver	4	1,019
Beech 95–B55 Baron	10	3,677
Beech 65–B80 Queen Air	3	1,608
Beech A90 King Air	8	4,102
Beech A100 King Air	6	3,422
Beech 200 Super King Air	1	723
Douglas DC–3	6	3,005
Lockheed 1329 Jetstar	4	1,452
Challenger CL600/601	2	747
Total	88	41,380

Within Transport Canada, the branch responsible for the safe and efficient operation of the fleet is the Flight Services Directorate. The Directorate's main base is located in Ottawa. Regional and local bases exist at 16 other locations in Canada from St. John's, Newfoundland, to Victoria, British Columbia. Approximately 500 employees work for Flight Services at the 17 bases. Staff members include Coast Guard pilots; quality assurance inspectors; maintenance engineers; avionics technicians; training pilots; maintenance trainers; and planning, administration, and managerial staff. Although Flight Services directly employs only Coast Guard pilots who fly the rotary wing equipment, the other pilots who fly the regulatory and calibration aircraft are directly employed by other branches in Transport Canada engaged in these activities. The training of these pilots, as well as all ground personnel, is, however, carried out by Flight Services. The Flight Services Directorate operates under a government-approved operating certificate that requires Flight Services to operate under the same regulations and laws as any other operator in Canada.

Although Flight Services essentially trains all pilots and ground personnel and maintains the aircraft, all flying operations of the aircraft are controlled by the clients of Flight Services, such as the Canadian Coast Guard, the regulatory branches of Transport Canada, the air navigation branches of Transport Canada, and the Canadian Aviation Safety Board. Tasking of the aircraft is determined by the client, who operates

Flight Services Directorate, Transport Canada, 2829C Baycrest Drive, Ottawa, Ontario, Canada K1V 7P6.

under a management contract with Flight Services. Budgetary funds are delegated directly to Flight Services and are used by Flight Services to fund the operations of its clients. The management contracts outline the nature and scope of the operations. Flight Services is obligated to meet the needs of its clients by providing the aircraft as well as the training. In essence, because none of the clients operate a scheduled service, Flight Services operates a demand service, not unlike a charter operator. This complicates setting schedules for preventive maintenance and leaves Flight Services little control over the annual flying rates of the aircraft.

Faced with an urgent desire to simultaneously minimize expenditures and maximize the level of service to its clients at an acceptable level of safety, the Flight Services Directorate faces a great challenge. The multitasked nature of the operation, many different aircraft types, geographic displacement, and a service driven by clients' needs have led Flight Services to embark on a series of major initiatives to examine how to maximize efficiency and cost effectiveness. The initiatives include a thorough examination of annual aircraft flying rates, usability, serviceability, labor productivity, and operating costs, including comparisons with the Canadian private sector as well as comparisons between its own bases. In addition, Flight Services has taken action to rationalize and change its fleet to meet clients' needs in a more effective and efficient manner.

The results and uses of this work are outlined in this paper. The concepts described in this paper may be of benefit to other carriers interested in obtaining an accurate measurement of their costs and labor productivity.

THE FLIGHT SERVICES COST ACCOUNTING SYSTEM

In the early 1960s, a cost accounting system known as the Aircraft Cost Accounting System was designed and put in operation in Flight Services. Because the original system had very few checks and balances and contained significant errors in accuracy, the system was revamped in 1983, complete with internal cross checks plus an educational process designed to ensure the accuracy of the information.

The system is composed of two parts, financial and labor. All financial transactions that occur in Flight Services across the country are coded in such a way that costs accruing to specific aircraft are identified to that aircraft and no other. In some cases, specific aircraft cannot be identified for a cost item, such as administrative overhead or cleaning fluid. To solve this problem, a hierarchical system has been developed to classify the cost in the most specific manner. In cases where the aircraft for a specific cost cannot be identified, the aircraft type would be used. For example, if a box of nuts and bolts were bought suitable for King Air 100 aircraft only, the costs associated with the box could not be identified against a specific aircraft. The costs would be shown against the fleet of King Air 100s. The principle used to distribute the costs between the various aircraft in the King Air 100 fleet is that of distributing the indirect costs based on direct cost. In the same way, costs such as management and administrative overhead are distributed against all aircraft in the fleet.

The principle is to identify the specific aircraft, but if this is not possible, the next highest level is used. The current system contains six levels. The elements of cost contained in the system are very disaggregated, but it is possible to aggregate them. The elements used by Flight Services for costing purposes are fuel, materials and supplies, labor, pilot salaries, hangar rentals, and other salaries and costs.

In a similar fashion, approximately 260 maintenance staff across the country fill out daily labor distribution time sheets. Each hour of the day is accounted for and broken down into the same hierarchical structure used for the costs. These labor hours are used to distribute the labor salaries by aircraft. In addition, the system permits an analysis of labor by site and is broken down into 10 shops operated by Flight Services. Hours are further broken down by eight categories of work such as daily inspections, routine maintenance, and snags.

The Aircraft Cost Reporting System has allowed Flight Services to develop accurate costs per hour in two ways: direct and indirect costs, as well as fixed and variable costs. The information can be used for planning and budgeting purposes, as well as to compare the same aircraft type located at different sites. These costs can be used to examine each aircraft within the same type over time to determine whether any particular aircraft is more costly to operate. The cost information can also be used by management to measure costs over time and to study the effects of cost-cutting measures.

The cost information has also been used to compare the cost of operation with that of the private sector (Table 2). This study has shown that based on fares published by over 100 carriers in Canada who fly the same equipment as that of Flight Services, the taxpayer would have to pay twice the current expenditure of $40 million (Canadian) per year if the fleet were leased from the private sector. This study was thoroughly and critically reviewed by the Canadian Auditor General with no issues raised.

TABLE 2 FLIGHT SERVICES COST COMPARISON WITH THE CANADIAN PRIVATE SECTOR

Aircraft Type	Flight Services Cost Per Hour (Canadian $)[a]	Private Sector Long-Term Cost Per Hour (Canadian $)
Alouette III SE3160	777	775
Sikorsky S–61N	3,065	4,223
Bell 212	1,233	1,658
MBB–BO–105–CBS	1,064	N.A.[b]
Gulfstream G–1159 (G–II)	3,522	6,177
Cessna 182/U206	382	432
DHC–6 Twin Otter	626	1,499
DHC–2 Beaver	522	1,635
Beech 95–B55 Baron	419	940
Beech 65–B80 Queen Air	463	697
Beech A90 King Air	673	1,250
Beech A100 King Air	734	1,055
Beech 200 Super King Air	646	1,429
Douglas DC–3	1,068	1,518

[a]Includes 15 percent profit.
[b]Not applicable.

The labor hour analysis (Table 3) has been extended to a point where, for each aircraft in the fleet, it is possible to measure the amount of labor hours required per hour of flying. This ratio can be used for a variety of purposes, such as

1. Measuring labor productivity over time;
2. Measuring labor productivity for the same aircraft type located at different sites, thereby allowing for cross-site comparisons;
3. Measuring labor expenditures on a month-to-month basis;
4. Identifying specific aircraft requiring higher-than-average labor expenditures (making the aircraft a prime candidate for removal from the fleet); and
5. Developing staffing requirements and formulas.

TABLE 3 FLIGHT SERVICES LABOR HOUR ANALYSIS

Aircraft Type	Hands-on Labor Hours Required Per Hour of Flight
Bell 206B Jet Ranger	5.0
Alouette III SE3160	2.6
Sikorsky S–61N	10.1
Bell 212	6.8
MBB–BO–105–CBS	5.4
Gulfstream G–1159 (G–II)	9.2
Cessna 182/U206	2.2
DHC–6 Twin Otter	3.4
DHC–2 Beaver	4.5
Beech 95–B55 Baron	3.5
Beech 65–B80 Queen Air	5.3
Beech A90 King Air	3.6
Beech A100 King Air	4.8
Beech 200 Super King Air	3.1
Douglas DC–3	6.8
Lockheed 1329 Jetstar	17.2
Challenger CL600/601	16.2

OTHER MEASURES OF THE OPERATION

Flight Services has developed measures of performance other than costs and labor productivity, as described earlier.

Serviceability

One of the key maintenance indicators is the serviceability rate, which is defined as the percentage of time aircraft are serviceable and ready for flying during working hours. For the entire fleet, the 1984 rate was 80 percent. During the other 20 percent of the time, the aircraft were unserviceable. Data on the reasons for the unserviceable aircraft are also recorded. For the fleet in general, scheduled maintenance accounts for 59.3 percent of downtime, 24.8 percent of snags, 3.8 percent of waiting for parts, 7.2 percent of aircraft modifications, 3 percent of calibration, and 4.6 percent of other reasons.

These data are kept for each aircraft in the fleet. The information permits management to gauge its level of service provided to the client as well as to pinpoint reasons for unserviceable aircraft. Any extreme or anomalous situations that arise can be dealt with in an informed and effective way. Cross-site comparisons are also being made.

Usability

Although Flight Services is responsible for maintaining the aircraft, it does not itself determine the tasking of the aircraft. This is determined by the clients. However, Flight Services is committed to maximizing the use of the aircraft and in the past has informed clients that certain aircraft are not being used to a maximum and that retention of the aircraft may not be warranted. Rentals can be used when demand is limited.

To this end, Flight Services collects information as to the percentage of time the aircraft are used during the time they are serviceable. For the fleet in total, the usability rate is approximately 60 percent. These data are also available on an individual aircraft basis.

These data are imperative if the fleet is to be used to the maximum extent possible. Current planning studies have target usability rates that in some cases almost double current annual utilization. Only in this fashion can Flight Services ensure that the fleet is fully utilized and that the fleet itself is pared down to the least number of aircraft. To this end, Flight Services is working closely with the clients of the service to improve booking and reservation practices by pilots to ensure maximum utilization of the aircraft.

FLEET RATIONALIZATION

Faced with a fleet comprised of 29 different aircraft types, Flight Services cannot hope to reap any benefits of economies of scale. The fleet mix produces a complex training requirement, large storage areas, large inventories, and so on. To this end, Flight Services has begun to rationalize the fleet with a view to reducing the number of aircraft types, increasing annual utilization, and streamlining the operation. To date, action has already been taken to reduce the flight calibration fleet from eight to four aircraft comprised of two types. This rationalized fleet has produced savings in terms of operating costs as well as staff.

In addition, Flight Services has just completed a proposal to reduce the fleet used by the regulatory inspectors from the current fleet of 38 aircraft comprised of 12 different types to 34 aircraft comprised of five different types by 1995. The proposal is more significant than it first appears because the proposed fleet is intended to cover a projected increase in flying activity of 30 percent over current levels. Despite the increase, no additional maintenance staff will be required, which is a benefit reaped by streamlining the operation. In addition, a life-cycle costing analysis indicates that over 15 years the proposed fleet would save Canadian taxpayers $136 million current dollars. An analysis shows that during the same time period taxpayers would save $170 million by continuing to operate the service within the government rather than leasing the fleet from the private sector on a long-term basis.

CONCLUSION

In the last 2 years, Flight Services has begun to deal with a massive challenge to provide an adequate level of service at an acceptable level of safety despite budget cutbacks. A number of initiatives have taken place that have produced and will produce a more streamlined operation and that provide management with the tools and information vital to the operation of an efficient and cost-effective operation. It has been shown that government can compete with the private sector, despite the burdensome and restrictive costs of government. Future work and initiatives ensure that Flight Services will maintain a competitive position in the aviation industry.

Publication of this paper sponsored by Committee on Airport Landside Operations.

Analyzing the Financial Impact on Airports of Remote Airport Ground Transportation Terminals

RAY A. MUNDY, C. JOHN LANGLEY, AND TIMOTHY D. WARD

Airline deregulation in the United States has had a significant impact not only on the airlines but also on the airports that facilitate air travel. Airline "wars" and competition have received considerable attention, but little has been written on competition among airports for airline travellers. Recent steep discounting of fares between major airport hubs and the withdrawal of major carrier service from many smaller airports has led major airport hubs to expand their geographic base, drawing patrons away from smaller airports nearby (50 to 100 mi). This trend has had obvious negative effects on the smaller airports and positive benefits on the more fortunate, larger hubs, which now enjoy greater revenue from additional patrons. In addition, an upward spiral effect is evident when airlines view the hub as a larger market and add additional or more direct flight service. This only accelerates the move away from smaller airports. Seeking to provide service and profit from this national trend, airport ground transportation operators, airlines, and airports are looking at remote ground transportation terminals in distant cities as a means of facilitating this long-distance traffic and increasing its potential. Some airports are motivated by the obvious financial gain, but others are especially hard pressed to provide roadway and parking space for the private vehicles emanating from this new passenger influx. Remote terminals, however, may have negative financial impacts in the form of lost parking and car rental income. Therefore, a methodology for analyzing the potential market for remote airport ground transportation terminals and their financial impacts is presented in this paper. The methodology is explained through the actual data used in an analysis for the Detroit Metropolitan Airport.

In 1983 Republic Airlines developed a proposal to offer complimentary ground transportation to their Detroit Metropolitan Airport (DMA) hub from selected cities 50 to 100 mi away. The purpose of this paper is to outline the methodology utilized in analyzing the feasibility and financial impacts this proposal would have on DMA.

BACKGROUND

Republic Airlines Proposal

In general, the Republic Airlines proposal was designed to feed passengers into DMA through the use of high-quality ground transportation service. The proposed service would apply principally to passengers who currently originate their trips at airports other than Detroit. This would have the effect of diverting additional passenger traffic to Detroit. The service was to be oriented toward, but not restricted to, passengers who find it preferable to fly Republic Airlines in and out of Detroit.

R. A. Mundy and C. J. Langley, University of Tennessee, 320 Stokely Management Center, College of Business, Knoxville, Tenn. 37996. T. D. Ward, Detroit Metropolitan Airport, Building 515, Detroit, Mich. 48242-9998.

The service was to generate a larger passenger base at DMA for all carriers.

Discussions with officials of Republic Airlines and DMA resulted in a recommendation that four cities be considered as possible origin points for the Republic ground service. With the approximate distances between the cities and DMA shown in parentheses, the cities were Toledo (45 mi), Flint (72 mi), Jackson (57 mi), and Lansing (80 mi). The opportunity to divert traffic from Ann Arbor, Michigan, was considered at the time, but this idea was not pursued at length due to the proximity of Ann Arbor and the obvious high percentage of Ann Arbor residents who currently drive to the DMA for outbound flights.

Republic Airlines planned to offer the proposed ground service at no additional cost to passengers who subsequently boarded Republic flights in Detroit. The cost of service in such cases was to be absorbed by Republic Airlines. In the case of a passenger who used the Republic ground service to access a flight at Detroit on an airline other than Republic, a charge was to be made to cover the cost of service. In either case, DMA was to receive concession revenue in the form of a percentage of the payments by Republic to ground operators under contract to provide the service.

It was felt that there were three factors having a significant influence on the extent to which passengers would be interested in such coordinated ground-air service: (*a*) price, (*b*) total origin-destination travel time, and (*c*) frequency of service. The extent to which coordinated ground-air service could be competitive in these areas is discussed in the demand analysis section of this paper.

Detailed Operating Plan

In addition to the passenger's attitude toward price, total travel time, and frequency of service, willingness to accept the intermodal service as an alternative to current travel patterns must be considered. Attitude obviously depends on the quality, reliability, and general atmosphere of the combined intermodal service, facilities, and personnel.

The proposed plan, as related by officials of Republic Airlines, was to establish a ground transportation terminal in each target city that would provide, at a minimum, typical counter services such as baggage check-in, ticket processing, seat assignment, and a comfortable waiting area. Free parking was or was not provided depending on ultimate site selection.

When passengers had checked their baggage and received their seat assignments, they were to board the bus for a nonstop expressway trip to DMA. Initial plans called for minimal services on-board the bus, but future amenities (e.g., hostess, beverage service, etc.) were being considered. Each vehicle was to be equipped with an on-board restroom and full climate control. On arrival at DMA, Republic passengers were to be dropped at the Republic curb where they would proceed to their connecting gates. Passengers of other airlines would then be dropped off at their respective airlines' curb areas. All baggage would be taken to the Republic baggage area for sorting to appropriate flights.

Returning intermodal passengers would be assembled at the Republic intermodal gate (or waiting area) just as they would for any connecting flight. Passengers would then use an airline exit door and walk down steps to board the bus. Operational problems that could have precluded the use of a regular departure gate were to be worked out through future negotiations. Bus drivers would have to have clearance to drive in the area of aircraft. Arriving passengers would have their baggage transferred to the bus as if to any other connecting flight. Tentative plans called for nine round trips daily to meet Republic's flight banks. Buses were to arrive 30 min before departure time and would leave as soon as the arriving passengers' baggage had cleared.

Rationale for Proposal

As a result of many factors, including general economic conditions and the regulatory reform that has taken place in the commercial airline industry, passenger enplanements had declined recently at all airports (1982–1983) in the area; however, percentage losses at DMA have not been as severe as at other airports.

The Republic proposal was intended to route through Detroit certain traffic that was currently bypassing the airport. The airlines and airports themselves were more competitive than ever, and it was clear that many innovative ideas were being considered. The coordinated ground-air concept, for example, had been implemented by Frontier Airlines between Ft. Collins, Colorado, and Denver's Stapleton Airport (70 mi away), as well as between Boulder, Colorado, and Stapleton (40 mi away). Also, Republic Airlines had begun such service over the 90 mi between Ft. Benning/Columbus, Georgia, and Atlanta's Hartsfield International Airport.

DEMAND ANALYSIS

Civil Aeronautics Board data indicate that in the 12-month period from October 1, 1981, to September 30, 1982, passenger enplanements at Toledo, Flint, Jackson, and Lansing totaled 588,330. This figure is broken down as follows:

Airport	*Passenger Enplanements*
Toledo	351,680
Flint	51,650
Jackson	1,210
Lansing	183,790
Total	588,330

Therefore, the grand total of passengers who conceivably could be diverted to Detroit from other airports was 588,330. This number represented about 13 percent of Detroit's total enplanements for fiscal year 1982 of 4,498,839 (data supplied by DMA officials). However, before the upper limit of 588,330 could take on a realistic meaning, it was necessary first to determine the extent to which coordinated ground-air service would be preferable, and second, to estimate the proportion of air travelers who would use such a service if it were available and attractive.

There were three other categories of passengers who might patronize the ground-air service, and each represented a class of passenger that drives to or from outlying areas in relation to the DMA. The first category consisted of people who currently drive from Toledo, Flint, Jackson, or Lansing, and who park in one of the airport parking lots at Detroit. The second category consisted of those who came from these other cities but were driven by a friend, relative, or business associate and dropped off at Detroit. The third category consisted of people who rented cars at DMA and who would use the ground service if it were available.

In summary, there were four types of airport patrons who would be likely to patronize the coordinated ground-air service to be offered by Republic Airlines:

1. Those diverted from other airports,
2. Those who drive and park,
3. Those who are driven and dropped off, and
4. Those who rent cars (inbound).

Each is discussed in the following sections.

Patrons Diverted From Other Airports

Implicit in this portion of the analysis was the assumption that patrons of other airports could be diverted most easily to Detroit in cases where final destinations were among the major markets served from Detroit by Republic and other airlines. Actually, the top 25 or so major markets served by any origin city typically account for 75 to 80 percent of the city's total passenger enplanements. In the case of Detroit, for example, enplanements of the top 25 destinations account for about 79 percent of total enplanements. The major destination points served from each of the airports studied are listed in Table 1 in order of importance. The last column shows the top 25 markets served by Republic from Detroit. Also, it should be noted that the top 15 destination points served from Jackson captured nearly all of Jackson's traffic, and there were no additional significant destination points.

Next, a variety of information was acquired in relation to each of the origin-destination (O-D) pairs identified in Table 1. Specific types of information included

1. Enplanement statistics on each O-D pair over the past 6 years (for the Civil Aeronautics Board 10 percent samples of passenger enplanements);
2. Profile of existing flights between each O-D pair for all airlines together and for Republic Airlines separately—flight data were broken down into the categories of nonstop, direct, connecting on-line, and connecting off-line;
3. Y-class fare data for each O-D pair acquired both for Republic Airlines and for other airlines;

TABLE 1 PRINCIPAL DESTINATION CITIES SERVED BY VARIOUS AIRPORTS UNDER STUDY

RANK	TOLEDO	FLINT	JACKSON	LANSING	DETROIT	DETROIT (RC)
1	Chicago	New York	Minneapolis	Chicago	New York	Boston
2	Tampa	Chicago	St. Louis	New York	Chicago	Toronto
3	Denver	Tampa	New York	Washington	Los Angeles	Milwaukee
4	Atlanta	Washington	Houston	Tampa	Washington	Baltimore
5	Miami	Orlando	Oklahoma City	Los Angeles	Atlanta	Los Angeles
6	New York	Dallas/Ft. Worth	Los Angeles	Boston	Tampa	Minneapolis
7	Los Angeles	Philadelphia	Orlando	Denver	Boston	Philadelphia
8	Washington	Boston	San Francisco	Miami	Miami	New York
9	Pittsburgh	Los Angeles	Atlanta	Houston	Philadelphia	Tampa
10	Phoenix	Houston	Chicago	Minneapolis	Houston	Grand Rapids
11	Ft. Lauderdale	Miami	Dallas/Ft. Worth	Dallas/Ft. Worth	San Francisco	Nashville
12	Dallas/Ft. Worth	Atlanta	Duluth	Detroit	Ft. Lauderdale	Phoenix
13	Philadelphia	St. Louis	Greensboro	San Francisco	Cleveland	Kansas City
14	Ft. Myers	Minneapolis	Boston	Orlando	Orlando	Atlanta
15	San Francisco	Pittsburgh	Kansas City	Phoenix	Denver	Montreal
16	Las Vegas	Norfolk		Sarasota	Dallas/Ft. Worth	Houston
17	Houston	Phoenix		Milwaukee	Phoenix	Orlando
18	San Diego	Milwaukee		Atlanta	Minneapolis	Memphis
19	Seattle	Detroit		Baltimore	St. Louis	Sarasota
20	Cincinnati	Oklahoma City		Philadelphia	Milwaukee	Ft. Myers
21	Boston	Denver		St. Louis	Las Vegas	Cincinnati
22	West Palm Beach	Indianapolis		Kansas City	West Palm Beach	West Palm Beach
23	St. Louis	San Francisco		Greensboro	Indianapolis	Saginaw
24	Salt Lake City	Baltimore		Madison	Pittsburgh	Lansing
25	Sarasota	Memphis		Ft. Lauderdale	Sarasota	Traverse City

4. Discount fare data for each O-D pair, for Republic and other airline flights; and
5. Minimum and maximum travel times between origins and destination via Republic and other airlines.

As stated previously, there were three factors that would be given top consideration by patrons of other airports who would be considering the use of coordinated ground-air service. The first was price. Potential patrons of Republic's service obviously would prefer a lower fare for the trip. As a general statement, air fares from Detroit to major markets were approximately equal to or lower than fares from Toledo, Flint, Jackson, or Lansing. With few exceptions, Detroit would be the preferable origin airport. Also, this relationship would be maintained in the case of coordinated ground service connecting to Republic flights because the cost of ground service would be absorbed by Republic. In cases where the connection was to another airline, the passenger would have to pay for the cost of the ground service, or have it absorbed by the connecting carrier, but in most cases this would not absolutely affect the price advantage enjoyed by Detroit.

The second factor was that of total O-D travel time, and this would include the time associated with the ground portion of Republic's coordinated service. Third, the frequency of service factor was important to many air travellers, and Detroit generally offered a far greater choice of departure times to most destinations than was available through Toledo, Flint, Jackson, or Lansing.

For each of the major market areas served by Republic and other airlines from Detroit, an analysis was conducted to assess the extent to which traffic would be diverted from other airports if the coordinated ground-air service were available. Because there were three factors (e.g., price, total O-D travel time, and frequency of service) considered as influential by air travellers, it was desirable to consider them simultaneously to evaluate the relative attractiveness of the ground-air service. The procedure followed would make an overall evaluation as to whether the ground-air service would be preferable for travel from Toledo, Flint, Jackson, or Lansing to major markets served by Republic and other airlines from Detroit. Therefore, the ground-air alternative for each O-D pair was characterized by one of the following designations:

1. Preferable, connecting to Republic flight in Detroit (RC);
2. Preferable, connecting to non-Republic flight in Detroit (other);
3. Approximately equal, connecting to Republic flight in Detroit (RC*);
4. Approximately equal, connecting to non-Republic flight in Detroit (other*); and
5. Not preferable.

The O-D pairs for which Republic Airlines' ground-air proposal was thought to be either preferable or approximately equal to originating air service from one of the other airports are listed in Table 2. Shown for each O-D pair is the ground-air evaluation (RC, RC*, Other, or Other*) as given in the foregoing list, and the market potential measured in terms of 1982 enplanements (from the Civil Aeronautics Board study referenced earlier). Also included in Table 2 are the market penetra-

TABLE 2 ORIGIN-DESTINATION PAIRS FOR WHICH COORDINATED GROUND-AIR SERVICE WOULD BE MOST ATTRACTIVE

ORIGIN	DESTINATION	GROUND-AIR EVALUATION	MARKET POTENTIAL (1982 ENPLANEMENT)	MARKET PENETRATION FACTOR	PROJECTED DEMAND
TOLEDO	ATLANTA	RC*	16340	.12	1961
TOLEDO	BOSTON	RC	3700	.25	925
TOLEDO	DALLAS/FT. WORTH	OTHER	6770	.10	677
TOLEDO	DENVER	RC*	19520	.12	2342
TOLEDO	FT. LAUDERDALE	OTHER	7460	.10	746
TOLEDO	FT. MYERS	RC	6370	.25	1593
TOLEDO	HOUSTON	RC	6090	.25	1523
TOLEDO	LAS VEGAS	OTHER	4890	.10	489
TOLEDO	LAS ANGELES	RC	9540	.25	2380
TOLEDO	MIAMI	OTHER	11220	.10	1122
TOLEDO	NEW YORK	RC	11360	.25	2840
TOLEDO	PHILADELPHIA	RC	7420	.25	1855
TOLEDO	PHEONIX	RC	6710	.25	1678
TOLEDO	ST. LOUIS	OTHER	3160	.05	158
TOLEDO	SAN FRANCISCO	OTHER*	6130	.10	613

TABLE 2 *continued*

ORIGIN	DESTINATION	GROUND-AIR EVALUATION	MARKET POTENTIAL (1982 ENPLANEMENT)	MARKET PENETRATION FACTOR	PROJECTED DEMAND
TOLEDO	SARASOTA	RC	2950	.25	738
TOLEDO	TAMPA	RC	25220	.25	6350
TOLEDO	WASHINGTON	RC	7400	.25	1850
TOLEDO	WEST PALM BEACH	OTHER	4630	.10	463
FLINT	ATLANTA	RC	1150	.25	288
FLINT	BALTIMORE	RC	550	.25	138
FLINT	BOSTON	RC	1110	.25	278
FLINT	DALLAS/FT. WORTH	OTHER	1640	.10	164
FLINT	DENVER	OTHER	770	.10	77
FLINT	HOUSTON	RC	1400	.25	350
FLINT	INDIANAPOLIS	OTHER	570	.10	57
FLINT	LOS ANGELES	RC	1580	.25	395
FLINT	MEMPHIS	RC	640	.25	160
FLINT	MIAMI	OTHER	360	.10	36
FLINT	MILWAUKEE	RC	950	.25	238
FLINT	MINNEAPOLIS	RC	1340	.25	335
FLINT	NEW YORK	RC	3810	.25	953
FLINT	PHILADELPHIA	OTHER*	1910	.05	96
FLINT	PHOENIX	RC*	990	.12	119
FLINT	ST. LOUIS	OTHER	1330	.05	67
FLINT	SAN FRANCISCO	OTHER	620	.10	62
FLINT	TAMPA	RC	970	.25	243
FLINT	TORONTO	RC	N/A	.25	N/A
FLINT	WASHINGTON	RC	2020	.25	505
JACKSON	ATLANTA	RC	10	.25	3
JACKSON	BOSTON	RC	NEG	.25	NEG
JACKSON	DALLAS/FT. WORTH	OTHER	60	.10	6
JACKSON	HOUSTON	RC	30	.25	8
JACKSON	LANSING	RC	NEG	.25	NEG
JACKSON	LOS ANGELES	RC	40	.25	10
JACKSON	MINNEAPOLIS	RC	120	.25	30
JACKSON	NEW YORK	RC	60	.25	15
JACKSON	ORLANDO	RC	40	.25	10
JACKSON	ST. LOUIS	OTHER	80	.10	8
JACKSON	SAN FRANCISCO	OTHER	20	.10	2
LANSING	ATLANTA	RC	3190	.25	798

TABLE 2 *continued*

ORIGIN	DESTINATION	GROUND-AIR EVALUATION	MARKET POTENTIAL (1982 ENPLANEMENT)	MARKET PENETRATION FACTOR	PROJECTED DEMAND
LANSING	BALTIMORE	RC	3430	.25	858
LANSING	BOSTON	RC	5920	.25	1480
LANSING	DALLAS/FT. WORTH	OTHER	3720	.10	372
LANSING	DENVER	OTHER	6000	.10	600
LANSING	FT. LAUDERDALE	OTHER	2210	.10	221
LANSING	HOUSTON	RC	5040	.25	1260
LANSING	KANSAS CITY	RC	2550	.25	638
LANSING	LAS VEGAS	OTHER	830	.10	83
LANSING	LOS ANGELES	RC	6060	.25	1515
LANSING	MIAMI	OTHER	3370	.10	337
LANSING	MILWAUKEE	RC*	3420	.12	410
LANSING	MINNEAPOLIS	RC	5990	.25	1498
LANSING	NEW YORK	RC	11040	.25	2760
LANSING	ORLANDO	RC	2030	.25	508
LANSING	PHILADELPHIA	RC	2720	.25	680
LANSING	PHOENIX	RC	2780	.25	695
LANSING	ST. LOUIS	OTHER	2220	.10	222
LANSING	SAN FRANCISCO	OTHER	4150	.10	415
LANSING	SARASOTA	RC	3190	.25	798
LANSING	TAMPA	RC	5520	.25	1380
LANSING	WASHINGTON	RC	7910	.25	1978
	TOTAL		284,320		54,417

tion factors that estimate the extent to which the ground-air service, if promoted satisfactorily by Republic Airlines, would be able to capture the passengers currently travelling between each O-D pair. The percentages shown on Table 2 were assumed to represent realistic estimates of market penetration. The last column of Table 2 shows the projected demand for each O-D pair. This figure was obtained by multiplying the market potential for each pair by the market penetration factor.

Summarized in Table 3 are the projected demand totals for each O-D pair. Using the assumptions stated, the total projected demand for such a service is 54,417 passengers. Of this total, 47,392 would connect in Detroit to Republic flights, and 12,093 would connect to flights of other airlines. Most of the patronage would be diverted from Toledo (56 percent), with smaller portions from Flint (8 percent), Jackson (less than 1 percent), and Lansing (36 percent).

As indicated earlier in this section, the 12-month period ending September 30, 1982, showed total enplanements at Toledo, Flint, Jackson, and Lansing of 588,330. The projected demand of 54,417, derived through the use of somewhat conservative estimates of market potential, represents approximately 9.2 percent of this total. Although it is quite possible that actual patronage of Republic Airlines' coordinated ground-air service could exceed the projected demand, the conserva-

TABLE 3 SUMMARY OF PROJECTED DEMAND

Current Origin City	Projected Demand at Detroit Total	Republic	Other
Toledo	30,258	25,990	4,268
Flint	4,561	4,002	559
Jackson	92	76	16
Lansing	19,506	17,324	7,250
Total	54,417	47,392	12,093

TABLE 4 RESULTS OF LICENSE PLATE SURVEY FOR WEDNESDAY EVENING, JULY 27, 1983

LOT	NUMBER OF CARS	PERCENT OUT-OF-STATE	PERCENT OHIO	PERCENT ONTARIO	PERCENT OTHERS
DECK (Level 1-4)	1932	6.73 (130)	4.30 (83)	.78 (15)	1.66 (32)
LONG TERM	941	17.22 (162)	10.00 (94)	2.34 (22)	4.98 (46)
MAIN LOT	414	10.87 (45)	5.31 (22)	1.21 (5)	4.35 (18)
ANNEX	392	5.61 (22)	3.57 (14)	.77 (3)	1.28 (5)
INTL.	216	7.41 (16)	3.70 (8)	1.39 (3)	2.31 (5)
TOTAL	3895	9.63 (375)	5.67 (221)	1.23 (48)	2.72 (106)

Note: Parentheses show number of parking lot patrons.

tive figure of 54,417 was used throughout the remainder of the analysis.

Patrons Who Drive and Park

DMA patrons who currently drive from Toledo, Flint, Jackson, or Lansing and who park their personal automobiles in one of the airport's parking lots make up the next group. The goal here was to estimate the number of people who would patronize the Republic-coordinated ground-air service instead of using the airport parking lot. This is not to suggest that Republic was interested in promoting such a diversion of traffic. What is meant, however, is that it is inevitable that certain airport patrons may wish to switch from the drive-and-park mode to the use of Republic's ground-air service.

In order to obtain data regarding the number of Detroit airport patrons who drive from Toledo, Flint, Jackson, or Lansing and who park their personal automobiles in one of the airport's parking lots, a license plate survey was incorporated into the analysis. The number of cars parked in the various parking areas on Wednesday evening, August 27, 1983, is given in Table 4, and each total is divided into the following categories: out-of-state, Ohio, Ontario, and other. If all of the cars bearing Ohio license plates found Republic's coordinated ground-air service from Toledo more attractive than the currently used drive-and-park mode, then 221 or 5.67 percent of the parking lot patrons are indicated in this category in Table 4. The parking revenues and total cars parked in each lot from July 1982 through June 1983 are given in Table 5. It is indicated in Table 5 that a ground total of 2,951,106 cars entered the parking lots during that time interval. Therefore, it was estimated that 167,328 cars (5.67 percent of 2,951,106) is the yearly total number of cars from Ohio. Because these vehicles are parked in varying quantities in all of the airport parking areas,

TABLE 5 PARKING REVENUES AND VEHICLES BY PARKING LOTS, JULY 1, 1982 THROUGH JUNE 30, 1983

	TOTAL DOLLARS	TOTAL VEHICLES	AVERAGE DOLLARS PER VEHICLE
HOTEL	562,970.00	275,029	2.05
INTERNATIONAL	395,766.25	187,583	2.11
EXPRESS II	370,513.00	197,288	1.88
EXPRESS III	292,225.50	153,673	1.90
LONG TERM	1,013,840.50	142,632	7.11
MAIN-DECK	7,761,430.10	1,994,901	3.89
TOTAL	10,396,745.00	2,951,106	3.52

TABLE 6 ESTIMATED DRIVE-AND-PARK DIVERSIONS BY CITY

CITY	PERCENTAGE OF PROJECTED DEMAND	ESTIMATED NUMBER OF DIVERSIONS
TOLEDO	56	33,466
FLINT	8	4,781
JACKSON	1	598
LANSING	36	21,514
	100	60,359

this fact was considered later in the analysis of parking revenue for each such patron. Finally, it was assumed that only 20 percent of these 167,328 cars can realistically be expected to switch from the drive-and-park mode; therefore, the total number of cars so diverted would be 33,466.

Although it was expected that the license plate survey would indicate the number of cars from the Flint, Jackson, and Lansing areas, no such breakdown was possible. This is because license plate numbers are assigned randomly in the state of Michigan, and it is not possible to decode a license number to determine the residence area of a vehicle or its operator. Therefore, in order to estimate the number of drive-and-park patrons who originated from Flint, Jackson, and Lansing and who would divert to Republic's service, the same relative percentages of projected demand by origin city given in Table 3 were used here. Using those percentages and the estimated number of Toledo drive-and-park diversions, 33,466, the expected number of drive-and-park diversions by city is given in Table 6. Therefore, it was estimated that approximately 60,359 people could switch from the drive-and-park mode and use Republic's coordinated ground-air service instead.

Patrons Who Are Driven and Dropped Off

A study conducted for DMA in 1968 indicated that approximately 43 percent of enplaning passengers arrived in private automobiles and were dropped off at the airport. Although this percentage is not inconsistent with what would be expected in 1983, it did not offer any information regarding the proportions of such passengers who were driven from the areas of Toledo, Flint, Jackson, or Lansing. In order to resolve this problem, an assumption was made that the number of passengers in this category from the various origin areas could be computed as 25 percent of the people in the respective drive-and-park categories who would begin to use the coordinated ground-air service. The expected number of patrons to come from each of the other origin cities is summarized in Table 7.

Inbound Rental Cars

Data provided by officials of the DMA indicated that during fiscal year 1982 the rental car agencies (Avis, Budget, Dollar, Hertz, and National) reported gross revenues of $28,556,001. Using an average rental charge of $100 per vehicle, it was estimated that the number of cars actually rented during fiscal year 1982 was equal to $28,556,001 divided by 100, or 285,560 rentals. Assuming that approximately 5.63 percent (16,077) of these rental-car trips are to the Toledo area, and that the rental-car trips to the other cities can be estimated similar to the drive-and-park analysis, the expected diversions by city to use of coordinated ground-air service are given in Table 8. Therefore, it was estimated that a total of 10,300 rental-car patrons would be diverted to the use of the Republic service.

TABLE 7 ESTIMATED DRIVE-AND-DROP-OFF DIVERSIONS BY CITY

CITY	DRIVE AND PARK[a]	DROPPED OFF
TOLEDO	33,466	8,367
FLINT	4,781	1,195
JACKSON	598	150
LANSING	21,514	5,379
		15,091

[a]Data from Table 6.

Summary

Results of the demand analysis by category of passenger (market segment) and by current origin area are given in Table 9. It is important to reiterate that although the principal market targeted by Republic Airlines was composed of those people who currently fly out of other airports, a certain portion of Detroit's existing customer base undoubtedly would find the coordinated ground-air service attractive.

POTENTIAL IMPACTS

There are a number of effects on DMA that might result from the implementation by Republic Airlines of coordinated ground-air service. Those that would be viewed as positive from the airport perspective are related to concession revenue, ground operator revenue, and overall increases in enplanements from DMA. Negative effects could possibly result in areas related to parking revenue, rental car revenue, revenues from commuter airlines to Detroit, and relations with other

TABLE 8 ESTIMATED RENTAL CAR DIVERSIONS BY CITY

CITY	PERCENTAGE OF PROJECTED DEMAND	ESTIMATED NUMBER OF DIVERSIONS
TOLEDO	56	3,215*
FLINT	8	459
JACKSON	1	57
LANSING	36	2,067
	100	5,798

*Computed as 20 percent of the 16,077 cars rented to Toledo.

airports and other airlines. These are discussed in the following sections.

Concession Revenue

In fiscal year 1982 the concession revenues that could reasonably be expected to vary with marginal increases or decreases in enplanements totaled $4,280,256. This figure was broken down in Table 10 into specific revenue sources. Based on fiscal year 1982 enplanements in DMA of 4,498,839, the average concession revenue that varies per passenger is $4,280,256 divided by 4,498,839, or $0.95 per passenger . Therefore, each additional passenger enplaning at Detroit could be viewed as generating an expected concession revenue of $0.95.

Ground Operator Revenue

As stated previously, Republic Airlines planned to absorb the cost of the ground service for passengers connecting in Detroit to an on-line flight and to assess off-line patrons a reasonable charge for the service. In either case Republic would pay the ground operator for the contract services, and DMA would recover 10 percent of the payments received by the ground operator for transporting deplaning passengers. This was consistent with the existing arrangement with limousine services, bus operators, and so on. For example, if the ground operators receive an average of $15 per deplaning person transported, the airport would recover $1.50 per patron. This figure was used to estimate the monetary effect on the airport from the use of contract ground services by Republic.

Overall Increases in Enplanements

To the extent that overall air traffic into and out of Detroit increases as a result of this program, it was conceivable that Republic and other airlines would add more flights over time to accommodate the additional demand for service. As a result, the landing fee revenue received by the airport could be seen to increase. Although this impact was not estimated in dollar terms for purposes of this analysis, it did represent a longer-term factor that could be significant.

Parking Revenue

To the extent that current patrons of airport parking lots are diverted to the use of the ground-air service, a decline in parking revenues would result. The average revenue per parked car by lot for the period July 1982 through June 1983 is given in

TABLE 9 SUMMARY OF DEMAND ANALYSIS

	ORIGIN AREAS				
MARKET SEGMENTS	TOLEDO	FLINT	JACKSON	LANSING	TOTAL
DIVERT FROM OTHER AREAS	30,258	4,561	92	19,506	54,417
DRIVE AND PARK	33,466	4,781	598	21,514	60,359
DRIVE AND BE DROPPED OFF	8,367	1,195	150	5,379	15,091
RENTAL CARS INBOUND	3,215	459	57	2,067	5,798
TOTALS	75,306	10,996	897	48,466	135,665

TABLE 10 SOURCES OF CONCESSION REVENUES THAT VARY DIRECTLY WITH PASSENGER ENPLANEMENTS

SOURCE		AMOUNT RECEIVED BY AIRPORT ($)
Aero Enterprise		
General Merchandise		$ 194,055.44
Lottery		3,964.07
Aeroplex Stands-Newsstand		695,166.84
American Foods		1,850.87
Detroit Airport Advertising		
TV Chairs		12,600.00
Dobbs House, Inc.		1,247,387.05
Don's Vending Service		29,632.49
GODOGA		
L.C. Smith Game Room		82,929.96
Host International		
Food		771,130.79
In-flight food		275,140.26
Liquor		575,758.50
Cigarette Vending		6,907.79
Amusement Vending		2,239.19
Mobile Food Carts		53,870.12
Howell J&E Enterprises		
Ice Cream Shack		17,076.94
Keys Enterprises		23,874.35
Northwest Airlines		
Pierre's Vending		1,232.65
Paradise Airport Shop		171,381.08
Smarte Carte, Inc.		666.40
Tele-Trip Insurance		
Insurance		41,221.49
Vita-Stat		7,129.69
Walou		65,040.13
	TOTAL	4,280,256.10

Table 11. The last figure in Table 11, $3.52, is the weighted average dollar amount that a vehicle parked at the airport would pay for that privilege. The figure of $3.52 is based on the average revenues per car for each of the individual lots weighted by the number of vehicles parked in each (see Table 5). Therefore, each parked car lost to the coordinated ground-air service would result in an average loss to DMA of $3.52.

Rental Car Revenues

Assuming an average gross revenue from the rental of a car as $100, the airport would receive 10 percent, or $10 for each car rented. This figure was used to assist in calculating the income foregone by the airport in the case of patrons who would be diverted from the rental cars to the coordinated ground-air service.

Revenue from Commuter Airlines to Detroit

It is possible that patrons of the coordinated ground-air service might include certain passengers who would ordinarily take a commuter airline to Detroit to connect with a major carrier. If any commuter flights were cancelled in response to decreasing load factors, landing fee receipts would be affected. On the positive side, however, these diverted passengers would generate ground operator revenue as discussed earlier, and the airport would receive 10 percent of the incremental revenue. In any event, these patrons would still be "through" passengers connecting in DMA. In an overall sense, this impact was somewhat remote and difficult to estimate. It was not regarded as being of great significance, particularly in the short run, and did not receive further consideration in the analysis.

TABLE 11 AVERAGE REVENUE PER PARKED CAR BY LOT

	MAIN DECK (SHORT-TERM)	HOTEL	INTL	EXPRESS II	EXPRESS III	LONG TERM	TOTAL
JULY '82	$2.85	$1.82	$1.55	$1.69	$1.73	$4.44	$ 2.59
AUG. '82	2.89	1.79	1.58	1.63	1.75	4.75	2.58
SEPT. '82	3.27	1.83	1.72	1.65	1.63	4.24	2.40
OCT. '82	3.61	1.81	1.81	1.62	1.61	4.58	3.15
NOV. '82	3.53	1.86	1.87	1.65	1.66	4.46	3.15
DEC. '82	3.32	1.87	1.88	1.79	1.84	7.72	3.04
JAN. '83	4.07	1.90	2.25	1.68	1.70	9.73	3.65
FEB. '83	5.18	2.46	2.93	2.21	2.17	10.09	4.67
MAR. '83	5.12	2.43	2.63	2.26	2.28	10.83	4.66
APR. '83	4.81	2.33	2.84	2.16	2.15	11.22	4.44
MAY '83	4.64	2.33	2.53	2.07	2.20	10.11	4.24
JUNE '83	4.05	2.38	2.32	2.20	2.32	9.60	3.82
JULY '82- JUNE '83	3.89	2.05	2.11	1.88	1.90	7.11	3.52

Relations with Other Airports and Other Airlines

A major effect of the proposal would be to draw traffic from other airports (particularly Toledo) to Detroit, and this would not be received enthusiastically by the operators of those airports. Because the airline and airport industries are becoming more competitive, it was necessary for all parties involved to attempt to be as responsive as possible to the needs of the marketplace. To the extent that patronage of the ground-air service increases, this is an indication that such a service is meeting a previously unfilled need. It was recommended, therefore, that officials of DMA be aware of and sensitive to the impacts of the service on the other airports, but at the same time proceed with the project if it is otherwise acceptable.

Finally, other airlines may express an opinion about the coordinated ground-air service offered by Republic, but the fact is that the arrangement between the airport and Republic would be the same as that between the airport and any other ground operator. Because the airport would not be discriminating in favor of Republic Airlines (or against the other airlines), there was really no basis for legitimate complaint by any of the competing airlines.

Summary of Potential Impacts

The estimated impact in dollars that each market segment under consideration would have on concession revenue, parking revenue, rental car revenue, and ground operator revenue is given in Table 12. The figures shown represent the dollar amount that would be received by the airport itself in terms of direct income (or loss). The dollar values shown in each cell of Table 12 were obtained by multiplying the marginal dollar impact of each person in each market segment. The coordinated ground-air service by Republic Airlines was estimated to result in a slight gain of $7,386 to DMA as indicated in Table 12. This amount was small enough to conclude that Republic's proposal was break-even in nature based on the short-run revenue-cost analysis.

RECOMMENDATIONS AND SUMMARY

It has been shown that the proposed air-ground intermodal service by Republic Airlines was basically a break-even proposition for DMA. Therefore, it was recommended that Republic be encouraged to begin their service as soon as a detailed plan could be submitted. DMA could expect some concerns by other airlines that might be adversely affected, but Republic's request should be regarded as a means of improving overall growth of DMA.

Care was required, however, to evaluate the true impact of Republic's proposed new service on airport revenue loss. As shown by the analysis, parking and automobile rental losses of current DMA patrons are largely offset by gains from passengers diverted from other airports. These new passengers represent new income from ground operator franchise fees (10 percent of deplaning passengers) and through-airport concessions.

However, if the assumptions used to estimate losses in the analysis were not valid, greater losses could occur. For example, if ridership on the proposed systems were mainly current DMA users, there would be a negative cash flow to DMA as a

TABLE 12 ANALYSIS OF ECONOMIC IMPACTS OF PROPOSAL

MARKET SEGMENT	PROJECTED DEMAND	CONCESSION REVENUE + $.95	PARKING REVENUE - $3.52	RENTAL CAR REVENUE -$10.00	GROUND OPERATOR REVENUE + $1.50	TOTALS
DIVERT FROM OTHER AIRPORTS	54,417 people	+ $51,696	NONE	NONE	+ $81,626	+ $133,322
DRIVE AND PARK	60,359 cars 72,431 people*	NONE	- $212,464	NONE	+ $108,647	- $103,817
DRIVE AND BE DROPPED OFF	15,091 cars 18,109 people*	NONE	NONE	NONE	+ $27,164	+ $ 27,164
RENTAL CARS	5,798	NONE	NONE	- $103,000	+ $ 8,697	- $ 49,283
TOTALS		+ $51,696	-212,464	- $ 57,980	+ $ 7,386	+ $ 7,386

*For the "drive and park" and "drive and be dropped off" market segments, projected demand (cars) has been multiplied by a factor of 1.2 to obtain an estimate of projected demand in terms of passengers.

TABLE 13 EXPECTED GROUND TRANSPORTATION RIDERSHIP LEVELS

CITY	PRESENT ANNUAL RIDERSHIP	DRIVE AND DROPPED OFF DIVERSIONS	DIVERSIONS	DRIVE AND PARK	AUTO RENTALS	TOTAL ANNUAL DEMANDS	AVERAGE DAILY DEMAND	AVERAGE PASSENGER PER SERVICE LEVEL "A" 18 Trips	"B" 9 Trips
TOLEDO	7,800	8,367	30,258	33,466	3,215	83,106	227.7	12.65	
FLINT	N/A	1,195	4,561	4,781	459	10,996	30.1		3.38
JACKSON	N/A	150	92	598	57	897 (12,401)*	2.46 (39.17)*		0.58 (4.35)*
LANSING	3,000	5,379	19,506	5,379	2,067	35,331	99.24	5.51	

*Potential air/ground ridership without essential air service 409 subsidy to Simmons Airline.

result of the service. In this case, the DMA would find it necessary to raise foregone revenue from alternative sources.

In order to safeguard itself from potential revenue losses, it was recommended that DMA reserve the right to establish a final franchise fee for ground transportation carriers until further operational data were gathered. The current 10 percent fee on deplaning passengers appears sufficient to cover expected losses based on the assumptions of the foregoing analysis. However, a statistical sample of diverted new versus existing old customers who formerly parked would be the only way of knowing if these previous assumptions were correct. Therefore the recommendation was made that Republic sample the passengers using the service after 3, 6, and 9 months to determine the mode split (Table 13).

If a significant revenue loss was evident, there were several options open to DMA to balance the system financially:

1. Charge a fee on enplaning passengers, such as a bus landing fee;
2. Assess a 10 percent fee on automobile rentals derived from remote terminals; and
3. Receive commission on parking revenue received, if any, by remote terminal operators.

Publication of this paper sponsored by Committee on Airport Landside Operations.