

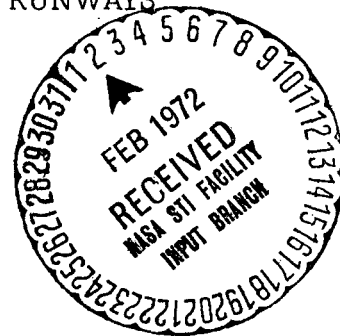
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ECONOMIC UTILIZATION OF
GENERAL AVIATION AIRPORT RUNWAYS

by
Robert R. Piper

April 1971



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CHAPTER I

Background and Introduction

Most urban general aviation airports have come under public ownership through political actions stemming from the intertwining of public and private sector activities that has been a characteristic of aviation almost since its inception. They are operated by or under the aegis of local government agencies, but very often with direct and indirect financial assistance from the Federal Government.

There has long been vigorous discussion of user charges at both federal and local levels. At the federal level, every administration since the mid-1940's sought user contributions to costs of operating and investments in the Federal Airways System (ground based aids to air traffic guidance). The Airport and Airway Revenue Act of 1970, which was signed into law on May 30, 1970, finally imposed some such charges, though the anticipated revenues will cover only part of the federal investment and operating expenditures that will be incurred. The new charges will also contribute to meeting the cost of the Federal-aid Airports Program (FAAP) from which well over \$30 million per year, matched by equivalent local funds, are authorized for investment in general aviation airports. The current federal revenue policy is to seek payments from users roughly in proportion to facilities use, and arguments about the allocation formula center on questions of equity rather than economic

logic. The federal outlays are made in response to whatever demand springs forth, with no concern about the prices charged for services at the airports.

At the local level, a fantastic hodge podge of pricing is found, mostly below cost in an economic sense and unrelated to cost. This is partly the result of a widespread philosophy among responsible officials that, since an airport is a public enterprise obligated to serve all comers, none should be turned away by price. Pricing strategies are set with little rhyme or reason beyond "what the traffic says it will bear" and vague hopes that the resulting revenue will bear a desired relationship to financial costs in the not too distant future. When use bumps up against capacity constraints, rationing by such regulation as "first come, first served" is adopted and additional general funds are sought to finance facility expansion. Rationing by use of price, to clear the market, is almost unknown.

The study reported herein treats a number of different aspects of urban general aviation airport economics, in the following order.

In Chapter II the demand for general aviation airport services is discussed. There are many different types of users, ranging from the Sunday pleasure flier to businesses transporting executives or clients. Results of surveys that have been made indicate that airport users come largely from middle to high income groups, as might be expected, given the high private cost of flying. Many are executives and professionals occupying positions of power and influence within the community.¹ Little

¹Appendix VII contains numerous substantiating tables from various sources.

can be said about the shape of their demand curve for airport services because their costs and valuations of alternatives to flying are unknown.

In Chapter III, the direct cost characteristics of the airport are summarized. The costs to the airport owner are largely fixed, given that outputs such as flight instruction where costs do vary with output are produced by airport tenants. Except at large airports serving executive jets or airline transport type aircraft, weight is not a significant factor in airport costs; pavement thicknesses and maintenance costs are, rather, determined by weather and soil conditions. Costs of producing additional (marginal¹) units of output, such as landings, are zero to the airport, although some operations impose congestion costs on other users during peak traffic periods.

In Chapter IV, questions of efficient use of an existing airport facility are explored. The focus is on the social cost of runway congestion as traffic density at the airport builds up and queues form. The theory of congestion cost pricing is reviewed with particular reference to the literature on air carrier airports, where congestion tends to be periodic when it occurs. Two peculiarities of general aviation airport operations tend to make implementation of conventional peak load pricing infeasible. These are the randomness of traffic peaks and the high collection costs of landing (take off) fees. Two pricing strategies that could be implemented

¹Marginal, here and throughout this report, is used in its economic sense of association with the last one in a series, the item at the margin where a series of items stops. For example, marginal cost is the cost of the last unit produced in a given run. This meaning of marginal is not to be confused with its common use in the sense, "of scarcely any value".

are proposed: peak load pricing against certain practice take offs and landings only, and surcharges for the privilege of jumping the airborne or take off queues.

In Chapter V, an analysis is developed of the trade off between aircraft operating costs and airport costs in terms of runway length. The airport and the aircraft fleet are considered to constitute a system producing flight hours; as airport land values climb, the runway length for minimum system cost diminishes. Sample calculations illustrating the import of the trade off are presented with a discussion of its significance for the future.¹

The difficult transition from theory to practice is treated in Chapter VI. Past policy of charging prices only on aircraft storage and on fuel (as a fee per gallon) are likely to continue because administrative costs usually preclude alternatives. The storage fee can be treated as a club dues type payment, revised upward or downward to achieve policy objectives such as the encouragement of V/STOL aircraft.

Some implications of the study from the standpoint of public policy are proposed in Chapter VII. As land values around airports in urban areas climb, pressure grows on management to put airport real estate to increasingly more intensive use. Pricing that spreads traffic peaks will

¹The sample calculations are based on activity at two general aviation airports measured by a survey described in Appendix I. Appendices II - IV document the assumptions used in computing aircraft insurance costs, variable operating costs, and depreciation, respectively. Appendix V outlines the computation of costs of hypothetical aircraft whose runway performance is improved but that are equivalent to the existing aircraft in all other respects. Airport landing area costs are defined in Appendix VI.

improve runway utilization. Prices that discriminate suitably against aircraft requiring long runways will cause owners to adopt V/STOL equipment and, in the long run, make short runway airports economically feasible. Failing imposition of such prices, no substantial V/STOL market will materialize and research devoted to V/STOL will not result in the hoped for benefits.

CHAPTER II

Who Are the Airport Users?

In order to analyze airports, it is helpful to know who patronizes the airport and for what purposes. No rational decisions regarding the size of the airport plant, the level of services to be supplied, can be made without some information about the demand for airport services. Demand information can be of some help in selecting pricing strategies. A description of users and uses can identify the direct beneficiaries of airport subsidy and aid in tracing any spillover benefits.

Airport users fall into three broad categories:

- 1) Owners of aircraft used for business or personal purposes, but not for hire. Included are individual owners and partnerships and corporate aircraft. These shall be referred to as individual owners.
- 2) Members of clubs that own and operate aircraft.
- 3) Customers of FBO's.¹ Included are students of flight schools, pilots who rent aircraft from FBO's, and people who charter aircraft from FBO's.

The spread among user categories reflects in part various strategies

¹The term FBO, meaning "fixed base operator," is explained in Chapter III. FBO's are tenant businesses at an airport. Many operate fleets of aircraft in flight schools or for rental and charter or both.

for coping with the costs of flying. A few examples are presented to show the magnitudes of these costs. Results of surveys confirming that flying is done largely by people of higher than average incomes are then reviewed.

The simplest way for a pilot to engage in flying is to rent an airplane from an FBO. The least expensive rental uncovered during interviews with FBO's in the southern San Francisco Bay area¹ was \$9.00 per hour for some relatively slow, two-place, World War II vintage aircraft (of the old J-3 Piper "Cub" generic type). The lowest rental on recent model, two-place aircraft was \$12.00 per hour, and the more usual rates were \$15.00 per hour, and higher. Four-place aircraft could be rented from one FBO for as little as \$14.50 for an 11-year old airplane, but more modern and faster aircraft cost much more: as much as \$35.00 per hour for a single engine aircraft and \$55.00 for a twin engine aircraft. Aircraft with six and more seats were rare in the fleet, and rented for \$30.00 per hour and up. For a licensed pilot flying only a few hours per year, rental is probably the least expensive solution, but he is still indulging in an expensive activity. If he flies but 50 hours during the year, he is spending a minimum of \$500 and more likely \$750 to \$1,000.²

If a pilot belongs to a club or owns an airplane, the amount he spends in a year will depend on how expensive the airplane is and how much he

¹These interviews took place in 1970 and are described in Appendix I.

²Charter, with crew, in contrast with rental, is usually limited to large aircraft such as four to six-place twins and is more expensive. A single pilot as crew is billed at \$7.00 per flight hour and up and more may be charged for ground time at the destination.

flies it. Typical annual costs are shown in Table II-1 for clubs and Table II-2 for individuals, based on results of an aircraft owner survey described in Appendix I. The column labeled "Total Cost" presents the ranges of total aircraft operating expenses for all respondents. These expenses include insurance, variable operating costs, and depreciation, computed by the procedures specified in Appendices II - IV, plus payments to the airport and a return of 10% on the aircraft market value.

Table II-1

Total Annual Costs of Flying - Clubs

<u>Total Cost</u>	<u>Number of Aircraft</u>	<u>Percentage of Aircraft</u>	<u>Cost per Member</u>
\$ 0 - \$ 1,000	1	4	\$ 0 - \$ 200
\$ 1,000 - \$ 3,000	2	7	\$ 200 - \$ 600
\$ 3,000 - \$ 5,000	8	30	\$ 600 - \$1,000
\$ 5,000 - \$ 7,500	12	44	\$1,000 - \$1,500
\$ 7,500 - \$10,000	3	11	\$1,500 - \$2,000
\$10,000 and over	1	4	\$2,000 and up

- Notes:
- a) Total costs exclude incidental flying expenses such as instruction, charts, travel to and from airports, annual medical examinations, etc.
 - b) Membership is assumed five per aircraft.
 - c) The lowest total cost computed was \$817.
 - d) Based on combined analysis of club respondents from Airports (2) and (3) of Appendix I.

Table II-2

Total Annual Costs of Flying - Individuals

<u>Total Cost</u>	<u>Number of Aircraft</u>	<u>Percentage of all Aircraft</u>	<u>Percentage of Aircraft Flown</u>
\$ 0 - \$ 1,000	21	16	12
\$ 1,000 - \$ 3,000	65	51	53
\$ 3,000 - \$ 5,000	23	18	19
\$ 5,000 - \$ 7,500	10	8	8
\$ 7,500 - \$10,000	4	3	3
\$10,000 and over	5	4	4

- Notes: a) Total costs exclude incidental flying expenses such as instruction, charts, travel to and from airports, annual medical examinations, etc.
- b) Six of the aircraft with costs under \$1,000 and one between \$1,000 and \$3,000 were not flown at all during the year.
- c) The lowest total cost computed for airplanes that were flown was \$636.
- d) Based on combined analysis of individual respondents from Airports (2) and (3) of Appendix I.

The costs of flying cited above are the annual costs of flying after a pilot has made his initial capital investment in obtaining a license. For those starting afresh in flying, the minimum investment to obtain a Private Pilot Certificate includes 20 hours of dual instruction with a certificated instructor on board and 20 hours of solo practice. The average total flight time will run 45 - 60 hours, depending on the school and on how compressed the curriculum. Instructor rates ranged from \$7.00 per hour to \$11.00 per hour among the schools interviewed. If \$9.00 per

hour is taken as typical, the 20 hours instruction cost \$180. The aircraft rental costs, assuming \$15.00 per hour and 45 hours, amount to \$675, or a total of \$855 without incidentals such as ground school and text materials. A student pilot can build up flight time in his own or in a club airplane at lower cost; he may also manage to hire a licensed, "moonlighting" instructor at less than flight school rates. These strategies are unlikely to lower the costs of his "Private Ticket" below \$500.

Surveys of pilots and airplane owners confirm the predominance of middle and upper income citizens among flyers that is expected on the basis of the high costs of flying. The Airplane Owners and Pilot Association (AOPA) surveyed members in 1968¹ and developed a convincing picture that pilots and aircraft owners are mostly in the successful, prosperous, and middle aged segments of society. Over 84% are over 30 years old. About 80% had 1968 incomes in excess of \$10,000. Over 80% claimed a net worth in excess of \$20,000. Over 81% were employed in executive positions and upper management or were in professional and technical classifications. Over 76% had been educated beyond the high school level. Almost 74% owned more than one automobile. The rest of the AOPA profile rounds out an image of movers, doers, and spenders.² It also suggests a group not lacking in political influence at all levels

¹AOPA 1969 Profile of Flying and Buying, p. 66. This report is based on tabulations of 46,249 responses, or 31.75%, of 145,689 questionnaires sent to AOPA members. In the report the profiles of the respondent sample were extrapolated to the entire population. No attempt to check for bias by querying non-respondents is mentioned.

²Tables A-VII-1 through A-VII-6 of Appendix VII present excerpts from the AOPA report detailing the results summarized above.

of government.

A market survey of pilots in 1969¹ showed many results parallel to those of the AOPA survey. The market survey was more illuminating than that of AOPA to the extent that it tabulated data according to the type of pilot certificate held and according to how the aircraft flown was owned, whether by: an individual owner, a private company, a partnership, a club, or an FBO (i.e., rented by the pilot).

Its results show that club and FBO aircraft pilots tend to have \$3,500 to \$6,000 less annual income than individual, private company, or partnership owners. Similarly, Student Pilots tend to be less well off and younger than Private and Commercial Pilots. The Student Pilots included inordinately large percentages of sales workers, craftsmen and foremen relative to Private and Commercial Pilots, suggesting that members of these lower income groups do not remain in aviation; presumably, many have a fling at learning to fly and decide that they cannot afford to continue. Nonetheless, 66% of Student Pilots fall in the professional, technical/managerial occupation class, as compared with 76% for Private Pilots and 75% for Commercial Pilots. Interestingly, 33% of Commercial Pilots lay in the 45 - 54 year age bracket, that of World War II veterans. Comparable percentages were 22 for Private and 12 for Student Pilots.

The survey showed that private owners, of both individually and company owned aircraft, fly more hours per year and over greater distances

¹An unpublished market study. Tables A-VII-8 and A-VII-9 of Appendix VII excerpt significant findings. A 1969 mail survey of 3,400 pilots netted about 760 usable responses that are the basis of the results presented.

than club owners or renters of FBO aircraft. This is particularly interesting since other surveys show that a significant number of pilots obtain their aircraft by rental from FBO's. The AOPA survey showed that 67% of respondents rent or charter aircraft at least occasionally.¹ A late 1967 survey² of Private Pilots without instrument ratings³ indicated that 50% of the pilots obtained aircraft by renting and 20% were in clubs.

The picture takes shape, then, of a large number of pilots, most of whom fly very little and are poor relative to the few who account for most of the flying done and who own most of the private aircraft. Very few even of the club owner and renter pilots, however, are poor relative to national mean incomes.

The full flavor of the variegated general aviation market is not revealed even by surveys and statistics. A glimmer can be gleaned from the organizations in the field. The AOPA has already been mentioned; it represents a wide cross-section of general aviation, though its own survey suggests that it represents airplane owners in greater proportion than it does pilots.

¹1969 Profile, op. cit., p. 10.

²J.J. Eggspuehler, G.S. Weislogel, et al, Study to Determine the Flight Profile and Mission of the Certificated Pilot, p. 34. In this mail survey, 1,192 usable responses were obtained from 2,693 questionnaires sent out to pilots randomly selected in each state in quantities proportional to the number of registered pilots in each state.

³Instrument ratings indicate a proficiency in piloting those aircraft suitably, and often expensively, equipped to permit safe flight under instrument flight conditions, meaning without visual reference to the ground. According to the 1968 FAA Statistical Handbook of Aviation, only 7,558 of the 253,312 Private Pilots certificated in 1967 held instrument ratings.

The next most prominent trade group is the National Business Aircraft Association (NBAA). Some 870 U.S. companies operating about 2,300 business aircraft make up the NBAA. About 900 of these aircraft are turbine powered.¹ The NBAA acts as spokesman for its members and, indirectly, for non-member business aircraft operators. During 1967, 275 of the Fortune 500² list of industrial firms operated transport category aircraft (9 and more seats). Still more firms operate light single or twin engine aircraft of 4 - 9 seats.³

Business aircraft are usually used for transportation of executives and skilled technicians. The larger firms employ professional personnel to man and sometimes to maintain the aircraft. Utilization is far higher than that of other general aviation (except flight school and commuter airline) aircraft. The larger aircraft are restricted to operations from airports with long runways, such as the air carrier airports and a small number of general aviation fields. The smaller aircraft, however, will use whatever airport is most convenient to the passengers.

¹Hearings before the House Committee on Interstate and Foreign Commerce on Aviation Facilities Maintenance and Development, 91st Cong., 1st Sess., Ser. No. 91-23 (1969), p. 459.

²Business and Commercial Aviation, August 1968, pp. 52-57. Among the 500 industrial firms highest in 1967 sales, 196 operated 445 transport-category turbine powered aircraft; 79 companies flew smaller aircraft, but still larger than the bulk of general aviation aircraft. See Table A-VII-13 of Appendix VII for further details.

³The National Industrial Conference Board, in its Studies in Business Policy, No. 132, Business Aviation Practices, (1970), reports that over 12,000 business organizations employ in excess of 24,000 aircraft in their operations, ranging in price from \$32,000 for a four-place, single-piston engine light plane to around \$4,500,000 for a 20-passenger jet.

To the extent that the NBAA is spokesman for these businesses, it represents an imposing amount of economic and political muscle. While its interests do not entirely coincide with those of other elements of general aviation, it can be expected to join them in promoting government policies of common benefit to all general aviation.

A second trade organization representing aircraft used primarily for transportation is the National Air Transportation Conferences, Inc. (NATC). The NATC represents 269 companies (1969 figure)¹ engaged in the transportation for hire of persons, property, and mail employing aircraft under 12,500 pounds design gross weight. These are the commuter air carriers that link small cities to one another and to large cities served by airlines. These commuter lines are part of general aviation. In urban areas, they tend to fly into the air carrier airports, both because part of their function is to provide an airline feeder service from outlying communities and because surface transportation is usually more readily obtained at the air carrier than the urban general aviation airport.

The FBO's are represented by the National Aviation Trades Association. FBO's are described in Chapter III. Basically, they are themselves operators of small airports or are airport tenants in the business of commercial sales and service, including flight instruction, in support of the general aviation fleet.

Besides the AOPA, the remaining users in the general aviation community do not generally have organized trade associations. There are

¹Hearings before the House Committee on Interstate and Foreign Commerce, op. cit., p. 494.

associations, primarily social in character, binding pilots of common professions or interests: The Flying Farmers, The Flying Doctors, The Flying Lawyers, The Antique Airplane Association, and The Experimental Aircraft Association, to name the more prominent. The last two include many owners in the lower income brackets of flyers. The Experimental Aircraft Association members, in particular, fabricate their own aircraft, on the basis of kits or their own designs, both for pleasure, as a hobby, and because it is a path to aircraft ownership with reduced out-of-pocket costs.

Note that, while Flying Farmers in many parts of the country fly primarily for transportation, most Flying Doctors and Flying Lawyers own aircraft for much the same reason as they do pleasure boats: recreation. In all three cases, members can be expected to fit in the high income bracket, community leader categories described earlier.

While NBAA and NATC members fly their aircraft for transportation and, with their high utilization per aircraft, account for a disproportionately large amount of the general aviation flying done, they represent only small fractions of the aircraft and pilots. The purposes served by flying for the majority are harder to define. Broadly, it falls in three broad categories:

- 1) Transportation
- 2) Recreation
- 3) Instruction (practice).

There is much overlap between these, however. When a businessman flies a client to an ordinary lunch at a restaurant on another airport,

taking the client for an airplane ride is the real objective, not the luncheon. Flight instruction and flying practice enjoy recreational characteristics in the same manner as golf or tennis lessons; if the "adventure of flying" emphasis of flight school advertising has any merit, then, clearly, many students take flying lessons for pleasure and excitement, not for future vocational advantage. Even business travel by air is often chosen more for the exhilaration and relaxation of flying than for convenience or cost vis-à-vis alternatives.¹

The tabulation of questionnaire responses to question 11 in Appendix I documents findings in the study about the purposes of the flying performed. Tables A-VII-14 through A-VII-17 reflect findings of other studies. In general, substantially less than one-half of the flying surveyed was for business, and a little over one-half was for local, pleasure flying.

The picture of flying that emerges, finally, is of a relatively small group of highly influential citizens using general aviation for business transportation purposes and a much larger group, a few of whom are similarly influential, for whom general aviation is primarily a leisure time activity. Aviators tend, in general, to come from middle and upper income brackets or to be wealthy or both. Occupationally, over 60% fall in the professional and managerial category. A substantial number are active in civic affairs and in politics. Most are middle aged. While there are low income participants in general aviation, there is firm

¹See the discussion of the replies to Question 13 of the survey of this study in Appendix I.

evidence that they fly fewer hours than their more prosperous fellows and there is an implication that many do not participate beyond the Student Pilot stage.

This picture is regrettably qualitative. In considering various airport pricing strategies, one would like to know in advance the impact on demand of price changes. That is, one would like to know the shape and location of the demand curves of all market segments. Such data do not exist and cannot readily be estimated.¹ There is no ready way to compute the difference in value between the business traveler's use of general aviation for transportation and his next best alternative. The similar computations for users whose flying is in large measure for pleasure is even more difficult. For the majority, substantial airport price increases could be expected to reduce patronage, but by how much is difficult to say.

The question of demand elasticity is important in forecasting industry trends. A number of prognostications of future general aviation activity have been made. FAA predictions, based largely on extrapolations of past trends, are for an increase in fleet size at about six per cent per year from 124,237 in 1969 to approximately 225,000 by 1980.² The

¹For commuter airlines, it might be possible to derive a demand curve per flight, based on costs, load factors, and fares, much as Joseph V. Yance has proposed for the regular airlines in his report to the Office of Systems Requirements, Plans and Information, Office of the Secretary of Transportation, The Theory of Air Carrier Demand for Slots (January, 1970). The commuter airlines, however, are rarely major users of urban general aviation airports.

²Aviation Week and Space Technology, March 2, 1970, p. 29.

Speas study, based on projections of GNP that may already be somewhat shifted, predicted a 1980 fleet size of 260,000 aircraft,¹ more optimistic than the FAA. Both predictions assume implicitly or explicitly "no significantly greater restrictions or limitations on the growth of General Aviation....than exist today."²

Prognosticators of general aviation growth view limitations on growth in terms of adequate facilities and services (e.g., airports, but airspace crowding poses additional problems in urban areas, problems partly resolvable with FAA furnished ground based traffic guidance facilities). "the degree to which a community provides the aircraft accommodations as required will determine the degree to which General Aviation can realize its full potential."³

The uninhibited growth predictions, in fact, provide the justification used for public spending to provide aviation facilities. The feedback from demand forecast to the general fund exists at both local and Federal levels as can be seen from Secretary of Transportation testimony regarding funding for airport development:

"In recent years there has been a gradual annual increase in the expenditure rate of FAAP funds for development projects. This upward trend is attributed to increasing community recognition of the need to keep pace with the continuing growth of all types of aviation activity....As part of the planning process in the Federal Aviation Administration, the dollar costs of new and additional airways and airport facilities and services required by

¹R. Dixon Speas Associates, Magnitude and Economic Impact of General Aviation, (1969), Section III.

²R. Dixon Speas Associates, op. cit., Section VIII, p. 20.

³Ibid.

the growth of civil aviation, were estimated over a period of ten years. This process of estimating systems requirements included consultation with representatives of the aviation community." (emphasis added)¹

Scarcely anywhere in the literature on general aviation is there discussion of the role that airport prices might exert on the demand for facilities. Yet the possibility is real that some "needs" and "requirements" arising from growing demand might disappear or be postponed by modifying demand through prices.

With this qualitative picture of the demand for general aviation flying as background, the next chapter describes the costs borne at the airports in supplying the services that make flying possible. The ways in which prices might be imposed to modify demand are then explored in Chapters IV - VI.

¹Hearings before the Subcommittee on Aviation, Senate Committee on Commerce, on Airport/Airways Development, 91st Cong., 1st Sess., Pt. 2 (1969), pp. 590 and 597. The FAAP is the Federal-aid Airports Program under which Federal funds are matched by local funds for airport development.

CHAPTER III

Cost Characteristics of a General Aviation Airport

An airport must offer a package of services, such as aircraft storage and service, fuel, surface access, etc., or else it is not an airport. Airports inevitably involve substantial commitments of real estate, plus the surrounding and overhead airspace.

On the airport property, a variety of more or less interrelated activities take place, much as at a shopping center. Modern airport management, indeed, has many parallels to shopping center management: space is rented out to entrepreneurs, in many instances competing FBO's, who store airplanes, run flight schools, sell maintenance and repair service, operate restaurants, and engage in a host of other commercial activity. Just as the shopping center owner is responsible for the common areas such as the mall and parking lots, so the airport owner is responsible for the common facilities: the landing area, taxiways, and some parking aprons.

Airport management boils down to that of a landlord and his staff: seeing to the maintenance of property, enforcing regulations on property use, collecting rent, balancing vacancy rates against the costs of assuring acceptable service levels, and deciding on new investments. The maintenance responsibility may include leased properties but always encompasses the common facilities.

From an economic standpoint most airport marginal costs are long run; in the short run, few costs vary with output. A full hangar costs its owner no more than an empty one. Weather, not use erodes paved surfaces. Clearing one snowfall can cause a significant cost peak to the airport owner, but his costs of a 2,000-operation¹ day are no greater than those of a two-operation day.² The variable (marginal) costs over the long run are new investments: to extend or otherwise modify the runway(s); to add a parallel runway; to install a new taxiway; to erect a new block of hangars; to build a new airport.³ The long run marginal costs are the indivisible or lumpy investments undertaken to expand the facility as capacity is reached. As with highways and bridges, airport capacity depends on the pattern of demand over time and the definition of capacity is necessarily arbitrary.

The difficult questions in defining airport capacity are those dealing with the runway/taxiway system. The capacity of the storage areas, given the aircraft configurations and an efficient layout, is well defined.

¹An operation is a take off or a landing.

²Allegedly some runway surfaces (blacktop) deteriorate faster without use than with use; in these cases an operation causes a negative marginal cost!

³A number of airport investments are more like new product offerings than long range marginal costs. An instrument landing system (ILS), for example, attracts an entirely new segment of clientele to an airport. An ILS is a complex of electronic and other gear that make it possible for properly equipped aircraft to land and take off in poor visibility. New traffic at the airport, like customers of a new specialty store at the shopping center, will influence the economics of the rest of the enterprise; price theory, unfortunately, is of little help in dealing with investments in new ventures.

A runway, however, is much like a ski-lift in that there is a maximum rate at which users can be accommodated; since demand fluctuates over time, queues build up when the "instantaneous" capacity is reached. Instantaneous capacity is the number of operations possible in a short period of time and is referred to as the runway acceptance rate.

Aircraft do not land and take off like a gaggle of geese; they do so sequentially, particularly at airports where traffic is controlled by a control tower. This sequencing is for safety reasons: it is impossible to see in all directions from a cockpit and there are pilot distractions during take offs and landings. (It is a commonplace that most aviation accidents occur on take off or landing.) These distractions are especially severe to student pilots, to whom no runway is long or wide enough. They are frequently exacerbated by phenomena such as cross winds. When aircraft of differing performance are in the traffic pattern, the spaces in the sequence must grow and the instantaneous capacity declines. This problem is far less severe at small general aviation airports than at the larger ones that receive business jets or at air carrier airports, but it does exist. Under FAA control tower procedures, instantaneous capacity at typical general aviation runways is about 3 - 4 operations per minute.

Instantaneous capacity acts as a choke only during periods of peak demand. At other times, no queuing takes place. In contrast to many hub airports serving scheduled airlines, peak hours seem to occur more randomly during the day and week at general aviation airports; although a trend toward heightened activity, hence peaks, on weekends and

holidays sometimes exists, it is not entirely reliable as a peak predictor.

When queuing takes place, no additional costs are borne by the airport. The users, of course, suffer inconvenience, aggravation, a loss of time, increased hazard, and minor incremental operating costs. These user costs are substantial when summed over all users in the queues and are discussed at length in Chapter IV. The natural result is that user pressure builds up and, at some frequency and extent of queuing, convinces management that facilities expansion is necessary.

The FAA has devoted extensive research to defining runway capacity (as "adequate" or "inadequate") and has published the results in a form suitable for application where the demand is accepted as a given. The criteria are in terms of total annual operations for airports of various configurations and for various airplane mixes (in terms of size, performance, etc.). A continuation of past traffic patterns is assumed and the criteria are based on various definitions of "reasonable average peak delays." An example, is: for "runways used by small aircraft only, this departure delay level is two minutes for the peak hour of the week."¹

The local government agency that owns the airport has the final say in making investment decisions, even under FAAP projects;² nonetheless, the lure of matching federal funds tempts many a city father to participate.

¹AC 150/5060-1A, Airport Capacity Criteria Used in Preparing the National Airport Plan, July 8, 1968, Department of Transportation, Federal Aviation Administration, p. 1.

²Under the FAAP, federal participation occurs only on the initiative and at the request of the local government which, after all, has to come up with the matching funds or their equivalent.

The FAA criteria apply in FAAP projects. Even if they did not, application of cost/benefit concepts would lead to somewhat similar criteria: the investment is a cost that yields benefits to the users by diminishing the social costs of congestion.

As explained in Chapter IV, at any airport faced with an increase in demand over time, pricing or other measures can be taken to ration capacity, limiting congestion and allocating the available storage space. Whether or not these measures are taken, user pressure will eventually trigger a management decision to invest in new capacity. The capacity expansions come in indivisible units such as a new runway and constitute the only variable (marginal) costs seen by the airport owner (the long-run marginal costs).

In summary, the costs of an airport, in the economic sense of resources allocated are:

- 1) Long run marginal costs of (indivisible) capital investment;
- 2) Operating overhead (labor and materials);
- 3) Land (and airspace)¹ opportunity cost.²

¹The minimum acreage for a 2,000 ft. runway landing area and clear zones is about 40 acres; most metropolitan airport runways are longer. Depending on local wind conditions, more than one runway may be necessary. Often, as traffic builds up, an additional runway parallel to the first is installed to increase airport capacity. Aircraft storage, for current single engine light planes, runs about 16 aircraft per acre tie-down and 14 in simple T-hangars. Land for buildings, automobile parking and access roads, fueling aprons, and land sometimes necessarily wasted is additional. Note an interesting contrast between general aviation airports and air carrier airports. General aviation in large measure is private transportation and the vehicles are parked at airports when not in use. Air carrier aircraft are few in number and spend a much higher fraction of their operating lives airborne; hence, their requirements for long term parking space are relatively less.

²Opportunity cost is the value of an alternative application of a resource that is sacrificed in a particular commitment. For example, if the prevailing interest rate, for a given risk, is 10%, the investor earning only 2% is bearing an 8% opportunity cost.

Analysis of airport economics without consideration of the user and his costs would be ill-fated. The user costs are separable into two categories:

- 1) Costs of airport congestion, when they arise;
- 2) Aircraft operating costs, including both fixed and variable components, but excluding payments to the airport.

The user payments to the airport are important in that they influence user behavior but they are not economic costs in the sense of productive resources consumed.

Congestion costs have attracted considerable attention in recent economics literature, leading, generally, to recommendations of prices aimed at dissuading use during periods of congestion. The nature of these recommendations and how they might be related to general aviation airport runways are treated in the following chapter.

CHAPTER IV

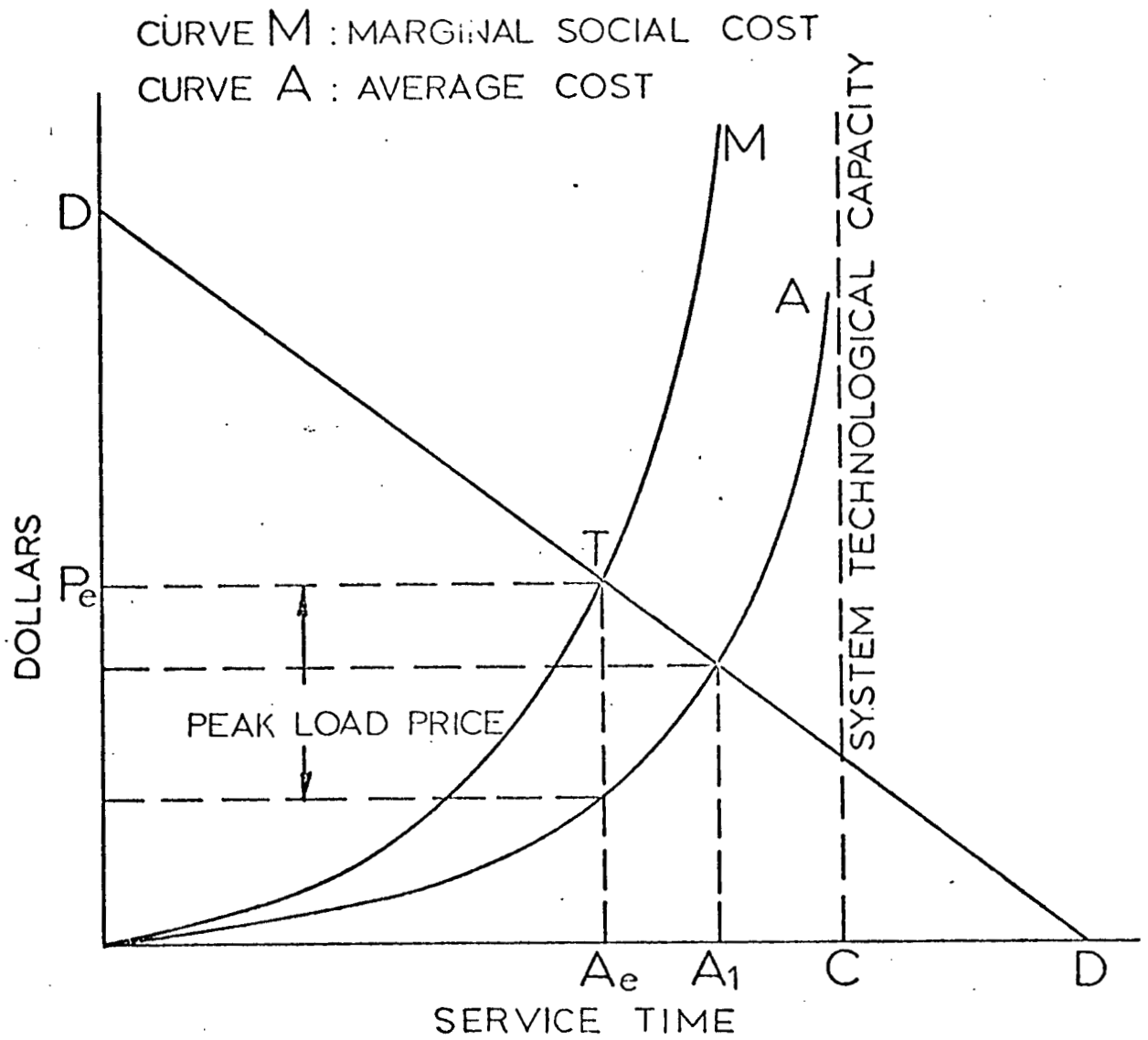
Efficient Use of the General Aviation Airport Runway During Congestion

Unless it is grossly over-built, any service facility, like an airport, will encounter periods when the rate at which users demand service exceeds the rate at which service can be supplied. The facility is then said to be congested. In this chapter the question of how best to ration the available capacity, how best to allocate access to the facility among would-be users, is explored.

Congestion can occur at a number of airport facilities such as hangar ingress or egress but is usually of major concern on the runway system. Runway congestion is usually a queuing problem somewhat similar to the crowding associated with mass transit and the choking of flow associated with vehicle movements over roads, both of which have received extensive treatment in the economics literature.

For simplicity of analysis, all congestion costs are lumped together in a substitute or proxy variable, time. People differ in their valuations of time. If given the opportunity, they would express this value by paying more to avoid waiting. The line D-D in Figure IV-1 is a "demand" schedule reflecting what users would pay for different levels of promptness of service.¹ Some users would be willing to pay increasingly more

¹The abscissa, Service Time, is not necessarily linear in units of time. Since service time increases as congestion increases, the abscissa measures increasing congestion, or an increasing number of users simultaneously demanding service.



A_1 : Average service time with no congestion based prices.

A_e : "Efficient" service time.

Figure IV-1. - Simplified representation of congestion costs.

for greater promptness of service. At the limit, one can imagine a user willing to pay a large sum to be served immediately. In the context of this study, an aviator with his own, private airport would be such a user. At the other limit are users whose value of time is so low that they are content to wait and would pay nothing for reduced service time.

The existence of some such demand curve can scarcely be doubted. It is observable in phenomena such as early departures by commuters to assure on-time arrival at work or, more impressively, in late departures by commuters from work to avoid congestion on the return journey. It is partly reflected in the high rents city dwellers pay to reduce both the out of pocket and the time costs of commuting.

The costs of congestion are shown by curves A and M of Figure IV-1. For purposes of setting prices that are uniform to all users contributing equally to congestion, certain approximations are necessary in deriving the cost curves. The simplest is to ascribe an average value of time to all users. The average cost curve, then, measures the product of the service delay (in units of time) and the average value of time (in dollars per unit of time). Curve A represents the private costs seen by the user as congestion increases and he is subjected to increasingly greater delay.¹

The congestion itself, of course, is the cumulative result of the presence of many individual users; each one contributes to the congestion,

¹For simplicity of exposition, the value of time is assumed herein to include vehicle operating costs, though these are separated out by some writers.

making it a little worse. Conversely, the removal of any user from the facility during a period of congestion would lessen congestion slightly for each of those remaining. The sum of the additional delay costs to all other users resulting from the presence of one user is the marginal congestion cost that he inflicts on them. The total, societal marginal cost of his using the facility, then, is the sum of his private costs (curve A of Figure IV-1) and the costs that his use of the facility imposes on others. It is represented by curve M in Figure IV-1, the marginal social cost curve.

According to welfare economics theory,¹ the price seen by the user should equal the marginal social cost incurred in serving him. This price is determined by the intersection of the demand curve, D-D, with the marginal social cost curve, M, and is shown as P_e . Since the user already pays a price for his use of the facility, shown by his average cost at that level of congestion, A_e , theory says he should be charged an additional amount, shown as "peak load price," to bring his total price equal to marginal cost,

$$P_e = MC_s.$$

If such prices are charged, some would-be users will be priced off the facility.² If, as is often the case, congestion is periodic, exhibiting

¹This prescription for the maximization of economic efficiency is derived in many articles and textbooks such as Richard A. Musgrave's, The Theory of Public Finance: A Study in Public Economy, Chapter 7.

²Assuming that patronage will fall off as prices are raised, that the demand is not price inelastic.

peaks at certain hours and valleys at others, then the congestion cost prices would be imposed only during the peaks; hence the designation, "peak load price" in Figure IV-1. In this case, some users are priced off completely and others will re-adjust their use patterns to patronize the facility at off-peak hours when prices are lower.

Most discussions of congestion cost pricing have appeared in literature on surface transportation, particularly roads. Walters, Vickrey, and Mohring are among the writers who have advocated congestion tolls for roads. The congested road is a flow situation with a fairly well defined relationship, for a given roadway, between speed (the reciprocal of travel, or service, time) and flow (the rate of arrivals). This relationship makes it possible to compute the increase in travel time of all vehicles in the stream caused by the addition of a marginal vehicle to the stream (or, conversely, the diminution of travel times resulting from the removal of the marginal vehicle). By summing the delays to all the vehicles in the stream, save the marginal vehicle, and multiplying by an imputed value of time, the marginal cost imposed on others by the marginal vehicle is computed. By adding this marginal social cost of congestion to the direct (private) costs of the marginal vehicle, the total marginal social cost of the marginal user is computed and the recommended toll levels are calculated as explained above.

A facility like an airport runway is analytically different from the road in that consumers can only be served sequentially, one after the other. Where road congestion is analyzed as a flow problem, the runway problem is one of an enduring queue. For any combination of airplane mix

and weather conditions, a runway will have a maximum technological capacity, called an acceptance rate or a maximum processing rate.

The problem is easily visualized by analogy with a chair lift at a ski resort. The lift has a maximum capacity per hour determined by the cable speed and the seat spacing along the cable. When the arrival rate of skiers at the foot of the lift exceeds the acceptance rate of the lift, a queue forms. Each arrival in the queue imposes an additional delay on all subsequent arrivals so long as the queue persists.

The analytical difficulties to which this situation leads are discussed shortly. It is sufficient to point out here that higher prices during peak periods at either a ski lift or an airport runway would result in shorter average queue lengths. Some would-be users would be priced off the system, leaving shorter queues for those remaining and paying the higher price.

Before completing the discussion of congestion cost pricing, one aspect of economic efficiency that may be considered paradoxical by non-economists must be brought out. It is, namely, that the economically efficient processing rate need not be the same as the maximum possible processing rate. That is, where a road engineer might consider "efficient" road use to mean the maximum possible throughput, arrival rate (C) in Figure IV-1, the economist selects a somewhat lower processing rate (A_e). The reason he does so is to take account of the delay costs associated with operation at maximum capacity. On a road, operation at maximum throughput implies a lower cruise speed, hence, more

time in transit, than does operation at lower throughputs.¹ Similarly, because of unavoidable variations in skier arrival rate, the only way to achieve maximum throughput on a ski lift, all seats filled, is to maintain a queue constantly at the bottom. Economic efficiency conditions, by contrast, might require that chairs frequently go up empty, depending on the value of time to the remaining lift users, because of the time that would be dissipated in the queues of an "inefficient operation." When one reflects on his own sentiments when stuck in a queue or delayed by traffic, this picture of economic efficiency may strike a responsive chord.

Finally, it is noted that pricing is only one means of coping with congestion, though it is the solution that meets the theoretical conditions for optimal resource allocation. Another approach, less efficient economically, is to expand facility capacity. The reason that neither periodic nor continuous congestion has often been a problem at general aviation airports is that these facilities have usually been expanded to increase the runway acceptance rate when congestion has threatened. Given the availability of land, such facility expansions have been much less expensive at general aviation airports than at air carrier airports; runways are shorter and pavement much less thick and strong. At the outset, runway capacity has been increased by improving turnoffs and taxiways, largely to permit landing aircraft to depart the runway at higher speed and, ultimately, at any point along the runway. When a single

¹Neglecting situations of choked flow where both speed and throughput are down.

runway has been developed to its maximum technological capacity, a second, parallel runway has been installed if land has been available. The parallel runway bears an effectively independent traffic and can be gradually expanded in its turn to a maximum attainable capacity.

The historical tendency to react to prospective congestion by facilities expansion has been encouraged in many cases by Federal grants through the Federal-aid Airports Program (FAAP) and, more recently by various programs of state aid.¹ This essentially technical response to a problem in rationing facility use is open to criticism on economic grounds because of the probability of over-investment.² In urban areas, it is probable that constraints on the availability of land or reluctance of communities further to fund airport expansions or both will lead to more severe congestion problems in the future. Under these circumstances, technical solutions may no longer suffice.

In addition to FAAP monies to expand runway capacity, the FAA has stepped in to construct³ and man control towers at airports deemed to

¹California has funds available for airport grants from its 2¢/gallon aviation gas tax, which goes into the Airport Assistance Revolving Fund. See Thomas H. Hughes, "Aviation Fuel Tax Program," Course Notes, Tenth Short Course in Airport Management, Institute of Transportation and Traffic Engineering, University of California. See also the hearings before the Subcommittee on Aviation, Senate Committee on Commerce, on Airport/Airways Development, 91st Cong., 1st Sess., Pt. 2 (1969), 590, "About 35 of the 50 states have a grant-in-aid program for airports.... The bulk of such assistance has been given to the smaller communities of the state."

²William D. Grampp, "An Economic Remedy for Airport Congestion," Business Horizons, IX, No. 11 (1968), pp. 21-30.

³Until June 30, 1961, these were jointly funded by matching local sources and matching FAAP grants. Since then they have come entirely from the FAA Facilities and Equipment budget. PL 87-255, September, 1961.

have sufficient traffic to merit one. For purposes of perspective, it is noted that a control tower requires the same order of magnitude financial outlay, \$300,000 - \$400,000, as a 3,000 foot, paved runway on flat land purchased at \$10,000 per acre.

Runway Rationing Without Pricing

It is to the controller in these control towers that one looks to see how air traffic, and congestion, are handled in real life.¹ The controller is in radio contact with and controlling the aircraft in the traffic pattern, from the taxiway leading to the runway, through take off, and including aircraft approaching the airport to join the pattern overhead. His function is analogous to that of a policeman directing traffic at an intersection but is far more complicated. He must deal in three dimensions with vehicles travelling at different speeds. While pilots have a responsibility to look out constantly for other aircraft in busy traffic zones, the controller is responsible for maintaining safe separations among aircraft under his control.

The basic rule governing controlled runway use is that not more than one aircraft use the runway at a time. This means in the air or on the ground. A landing aircraft must not cross the runway threshold nor a departing aircraft start its take off run until a prior departing aircraft has cleared the opposite end of the runway. Similarly, an aircraft taking off may not initiate its run nor a landing aircraft cross the threshold until an aircraft that has just landed safely departs the runway proper.

¹Although the vast majority of general aviation airports have no control tower, it is primarily at the few that do that traffic becomes sufficiently dense to generate recurring congestion.

Equivalent rules apply for touch and go (practice) landings where the plane "touches" down to simulate the early stage of a landing and then carries through to become airborne ("goes") to rejoin the aerial traffic pattern.

When traffic becomes dense, the art of a good controller shows itself. His skill at judging the spacings among aircraft approaching at different speeds determines the acceptance rate of the runway. When queues form, the success of his judgment in keeping the runway continuously in use greatly influences the delays that individual aircraft impose on members of the queue behind them. Customarily, landing aircraft bear priority, largely for safety reasons; an aircraft sitting still waiting for take off clearance cannot run into anything.¹ In practice, when a queue of airplanes builds up awaiting an opportunity to take off, the controller will look for "holes" in the stream of landing aircraft into which one or two take offs can be sandwiched. If too many aircraft queue up on the ground, in the controller's judgment, he may create a hole in the landing stream by instructing approaching aircraft to delay their entry into the pattern for a period of, say, five minutes.

Another action a controller may take is to instruct pilots engaged in touch and go landings to depart the pattern for a period of time or to make a full stop landing -- and join the take off queue if they desire. This period may be five minutes to half an hour, during which the pilot is free

¹Conversely, in hot weather, the engines of many light aircraft will overheat after excessive ground idling time; hence, there is a safety incentive to preventing prolonged ground waits also.

to go wherever he wants.

Many such pilots, normally students with or without an instructor on board, will fly to a less busy airport and practice touch and goes there. Some flight schools "export" touch and go practice of beginning students to light traffic airports as a matter of policy so that the student is not overwhelmed by having to cope simultaneously with heavy traffic and piloting the aircraft. A result can be the build up of traffic and incipient congestion at a small community's airport, brought about by interlopers from inherently busier urban airports.¹ Because of a non-discrimination clause in the Federal Airport Act of 1946 and subsequent amendments,² local airports that have received FAAP grants do not discriminate by the base of an aircraft in charging for identical services. An egregious example of fiscal mercantilism takes place if the small community is obliged to expand its facilities to cope with overflow from neighboring urban communities.

¹William H. Parnesse in his paper, "Competition for General Tax Funds -- A Case Study," at the Tenth Short Course in Airport Management, published in the Course Notes, by the Institute of Transportation and Traffic Engineering, University of California, reported that a runway use survey at the Livermore airport showed that "of the total arrivals, only 25% were Livermore-based aircraft and 16% of the touch and go operations were our local planes." (page 14). Walter E. Gillfillan documents the same trend in his paper, "General Aviation Airport Capacity Problems in the Bay Area," Ibid., pp. 30-36.

²84 Stat. 229 Sec. 18(1)...."the airport will be available for public use on fair and reasonable terms and without unjust discrimination." The same clause is assumed to prevent locally owned airports from discriminating against residents of neighboring communities in the allocation of storage space. The author does not know if this interpretation of the clause has been judicially confirmed.

A final note on air traffic control is that aircraft are placed sequentially in the flight pattern, as in Figure IV-2. Although the dimensions of the pattern may expand somewhat to accommodate more aircraft in times of dense traffic, all aircraft must remain close enough to the tower to permit the controller visually to assess separations and closing speeds. Similarly, aircraft customarily queue up sequentially for take off, as at a ski race, not a horse race.

The mission of the controller is to assure safe operations. The challenge of his task is not merely to maximize runway throughput in times of congestion but to do so while "averaging out delays over all users" (within safety constraints). There is some delay bias, as mentioned, in favor of landing aircraft but the goal is to average delays among arriving aircraft and among departing aircraft. A skillful controller under the right conditions will slip an airplane into the pattern with a straight approach to the base leg or on final if there is a hole in the traffic and the pilot concurs. Conversely, if the pattern becomes too crowded, a controller may be obliged to make an aircraft turn away from the airport on the downwind leg, do what amounts to a long 360° turn in straight segments, and re-enter the pattern normally.

The objective of evening out average delays stems from a recognition that there are costs to queuing, from the requirements described above to process aircraft sequentially along a single path in space, and from a long tradition that the airport is a "first come, first served" market. The only common deviation from "first come, first served" is the discontinuance of touch and goes cited. This is justified on economic grounds: the

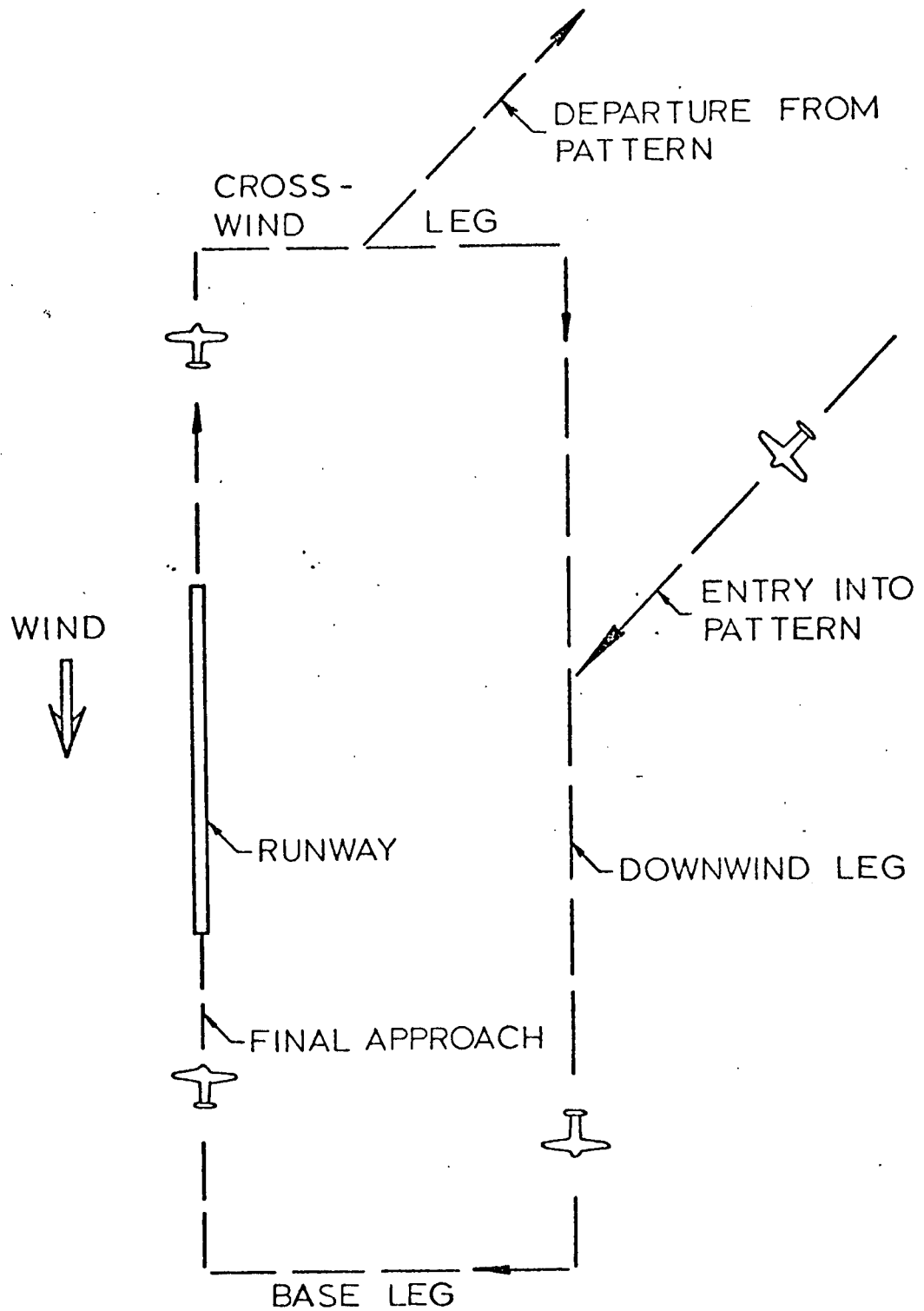


Figure IV-2. - Typical airport traffic pattern (not to scale).

students have alternatives almost as good, either to practice airwork away from the airport or to perform touch and goes at another airport. Continued touch and goes impose excessive delay costs on arrivals and departures.¹ The action clearly reflects an administrative decision aimed at increasing economic efficiency of runway use. The controller practice otherwise is to equalize delay times among users, regardless of the different values that individual users might attach to the delay. The delay periods being mentally averaged by the controller vary, of course, with the intensity and duration of the traffic peak.

Congestion Cost Pricing and the General Aviation Airport

The runway congestion problem has been addressed in recent papers from four sources: Grampp, Levine, Carlin and Park, and Yance.² All write primarily about air carrier airports. All likewise discuss economic efficiency of runway use and propose prices as a means of improving

¹About five (or more) aircraft flying touch and goes can so tie up the traffic pattern as to preclude entry into the pattern by arriving aircraft or take offs by departing aircraft.

²William D. Grampp, "An Economic Remedy for Airport Congestion" -- op. cit. Michael E. Levine, "Landing Fees and the Airport Congestion Problem," The Journal of Law and Economics, XII, No. 1 (1969), pp. 79-108. Alan Carlin and Rolla E. Park, The Efficient Use of Runway Capacity in a Time of Scarcity, RM-5817-PA, August, 1969, The Rand Corporation, Santa Monica, California. Modified portions of the Rand Report are found in "Marginal Cost Pricing of Airport Runway Capacity" in The American Economic Review, LX, No. 3 (1970), pp. 310-319, and in "A Model of Long Delays at Busy Airports," Journal of Transport Economics and Policy, IV, No. 1 (1970), pp. 37-52, both by the same authors. Joseph V. Yance, "Movement Time as a Cost in Airport Operations," Journal of Transport Economics and Policy, III, No. 1 (1969), pp. 28-36. Yance also submitted two reports to the Office of Systems Requirements, Plans and Information, Secretary of Transportation, in January, 1970: The Theory of Air Carrier Demand for Slots and The Demand for Use of Washington National Airport.

efficiency. All deal with air carrier airports where peaking is reasonably periodic; that is, arrival rates are irregularly distributed about long term peaks and valleys that occur regularly at certain times of the day and week. The major reason for the periodicity is the scheduling pattern of the air carriers plus the use patterns of business aircraft; of course, as with other commute-type peaking problems, airline schedules and transportation use patterns are in large measure a product of the rhythms of activity characteristic of the society. All four propose what amount to landing (and take off) fees that would be substantially higher during peak periods than during valleys. Only Carlin and Park venture to compute prices in specific situations or delve into the knotty problems of implementation.

Congestion of a general aviation airport runway is conceptually identical to that of an air carrier airport runway; however, operational differences complicate implementation of remedies. The remedy principally considered is imposition of fees on landings and take offs during peak periods (peak load pricing). Two problems arise. The first and most serious, discussed below, is the unscheduled nature of general aviation activity and the consequent randomness of peaking. The second is collection costs. These are likely to be higher than at an air carrier airport. The bulk of peak traffic at the latter is made up of air carrier operations that can be billed on the basis of published schedules. At the general aviation airport, operations would have to be monitored and payments collected on the basis of the recorded observations. A turnstile or tollbooth is hard to imagine at an airport. Monitoring and

collecting would be costly, labor intensive activities.

An important feature of congestion cost pricing as proposed both for roads and air carrier airports is the periodicity of peaks. By peak is meant a period during which the average arrival rate exceeds the acceptance or processing rate. Both the time of day during which the peak can be expected and its average duration are ascertained by observation; a corresponding schedule of prices is then imposed. One anticipated consequence is a flattening of the activity peaks and filling of the valleys as some of those tolled off shift their facility use to what would be off peak hours in the absence of peak load prices.

At most general aviation airports, the peaking is very irregular.¹ A peak at a certain time of one day would not necessarily recur the following day, nor on the same day of the following week. Given the varied nature of general aviation activity, this randomness is not terribly surprising. Basically, the activity is training, recreation, and transportation. While some airport patrons restrict their activity to daylight hours outside normal working hours, apparently many others do not.

There is no obvious reason why airport patrons would concentrate their recreational or practice flying at any particular time of the day. So far as transportation is concerned, the survey results of this study²

¹There may be general aviation airports with reliably periodic peaks but none was uncovered by the author in his small sample. If peaks at a general aviation airport were ever found to be reliably periodic, then conventional peak load prices could be levied if collection costs were held sufficiently low.

²See Appendix I, Table A-I-5, pg. 115.

showed flexibility of departure time to be the most important reason for using private aircraft. When used in private transportation, general aviation aircraft are analogous to automobiles, except that they have not historically been used for regular peak generating, commute-type trips.

If peaking is unpredictable in time and extent, it becomes impossible to lay on a schedule of peak load prices. One course of action would be a flexible pricing policy where fees would be imposed whenever traffic built up to such a level that queues formed. However, such a policy could formally lead to efficient runway use only if fantastic communications difficulties were overcome. One of the basic assumptions of the competitive economy is that consumers have perfect information regarding alternatives. For this to hold true with pricing schedules imposed as a function of random traffic density variations, it would be necessary that all users, prior to their decision to use the facility (whether departing their homes to drive to the airport or preparing to depart a location hundreds of miles away to fly to the airport), inquire what, if any price would prevail at the expected arrival time. Some sort of computer would be needed to estimate the probable delays and to set prices as appropriate, on the basis of these queries. But the decision of when to arrive would both determine and depend on the price. There is no assurance that a stable solution would emerge even if the communications problem were resolved, which it clearly could not be in practice.

The fundamental problem is that, if conventional, peak load prices

are imposed whenever traffic builds up, they cannot, in general, perform their function of modifying consumer behavior. If the consumer who would alter his decisions in order to avoid a fee has no way of knowing when it is to be imposed, he has no guidance in selecting among alternatives. The price system could not perform its usual function of influencing on resource allocation.

Although rigorous imposition of peak prices is unfeasible, there are two allied measures that could be taken to increase efficiency of runway use. One is imposition of fees on touch and go landings during peaks. The other is to initiate queue jumping, at a price.

Fees on touch and go landings during congested periods are not formally justified in this study.¹ Rather, the recommendation is based on value judgments that touch and goes constitute a runway use less valuable than most others. There is some evidence for this in that protests are not raised when controllers forbid touch and goes during periods of congestion.

Finally, there is a question of the drop out ratio among student pilots. It is they who perform most touch and go landings. One estimate² that has been quoted is that less than 50% of student starts carry through to obtain a license. Similar estimates were made by the author on the basis of statistics on airmen certificates published by the FAA.

¹A thoroughgoing cost/benefit analysis necessary to such a justification would have to resolve the controversial question of the value of touch and go landings to flight training.

²Reported in Aviation Week and Space Technology, November 2, 1970, p. 58.

While there may be no simple way to distinguish the washouts from the successful students, their very presence tends, on the average, to lower the long term social value of runway use for student flying.

The theoretical justification for imposing peak load prices on touch and goes and not on other operations when peaks occur is that the student has alternatives almost as good: he can go and practice air work or go and practice landings and take offs at another airport that is less crowded. Thus, pricing a student off the runway when it becomes congested only reduces the value of the runway use by the generally small difference between doing touch and goes on that runway and either of his almost as good alternatives. Conversely, the alternatives to most other users are relatively much less attractive.

As explained in Chapter VI, collection costs on touch and go fees would be low. The flight schools could keep the necessary records and make payments, if any, for continued touch and go operations after the runway had been declared congested. The labor intensive administrative procedures and costs for levying fees on all aircraft landings and take offs would be avoided.

The queue jumping proposal is a device permitting a small group who value prompt access to the facility to buy that access. If properly implemented, the costs of congestion would be lowered because those few who were willing to pay the most to avoid waiting would have an opportunity to do so. Implementation would be a joint effort by the controller, the pilot, and the airport management. Whatever the fee for queue jumping was, the pilot would announce his readiness to pay it. He would be

then vectored to the most expeditious landing approach, if airborne, or allowed to taxi to the head of the queue if awaiting take off. The airport management, monitoring the transmissions (as is customary), would take note and bill accordingly.

Price would have to be set by trial and error, low enough so that some would take advantage of the opportunity and high enough so that a secondary queue of queue jumpers did not form. Many a corporation would be happy to pay, say, \$100 to avoid having four or five executives or clients inconvenienced by waiting in a take off queue or circling in a pattern. While there is a strong tradition of first come, first served in aviation, users might well accept the concept that those willing to pay could buy a place at the head of the line. If it could be shown that revenues from this practice would be substantial enough contributions to meeting airport costs that other airport charges would be reduced, the non-paying queue members might even be enthusiastic about the concept.

Operationally, at airports with controlled traffic, there already exist two examples of allocating priorities. An aircraft with an in-flight emergency is granted priority over all other traffic. Everyone agrees that the value of avoiding a possible accident merits placing that airplane at the head of the queue. Similarly, when Air Force No. 1 (the President's aircraft) arrives on the scene, it will take precedence.

Ideally, one might like to see a scale of prices corresponding to different priorities of being served, rather than just the priority of going to the head of the queue. This would involve a formidable information

processing task because of users' inability to predict arrival times precisely and because of friction in the system. It is technologically difficult to juggle positions in the queue (without incurring a cost in jeopardized safety that most users would consider prohibitive).

In conclusion, the short run problem of efficient use for general aviation airport runways has not frequently arisen in the past. It may in future in urban areas as land use pressures force more intensive use of existing facilities. If congestion becomes periodic, schedules of peak load prices can be prescribed as has been proposed for air carrier airports. For the more general case where peaks do not occur regularly in time, efficiency can still be increased by special prices during peaks on touch and go practice and by high fees for queue jumping.

CHAPTER V

The Minimum Cost System to Produce Flight Activity

The bulk of the research performed in this study concerned the question: What is the optimum plant mix from the standpoint of minimizing production costs,¹ given that part of the plant, the airport, is furnished by the community and the rest, the aircraft, by the users. The genesis of the analysis was the observation that, wherever land becomes scarce, market pressures force it into increasingly intensive use. This being the case, what are the consequences for airports?

The conventional airport is separable roughly into two major components: the runway system, which consumes 15 - 60% of the space, depending on the number and length of runways, and the remainder. The remainder is used for purposes such as aircraft service and storage, offices, automobile access and parking, and other complementary (supporting) activities. Increasing intensity of use on this off runway airport land can and will be achieved in much the same manner as at other high land value centers such as central business districts and air carrier

¹Michael E. Levine suggested the logic of achieving some economic division of costs between airplane operators and airport operators in his article, "Landing Fees and the Airport Congestion Problem," The Journal of Law and Economics, Vol. XII (1), April, 1969, pp. 94-95. His example was landing gear footprint pressure, a variable that influences runway and taxiway thickness requirements and that is controllable by the aircraft designer.

airport terminals. Activities will be stacked one above the other in multi-level structures such as parking garages, and low value activities will be shifted to locations where property values are lower.

The runway system is fundamentally different in that its surface and airspace must be reserved for one sole use; they cannot be shared with other activities (except if these can be buried underneath). However, aircraft differ widely in the length of runway required. If a given amount of flying activity could be produced using a short rather than a long runway, then the intensity of space utilization on the shorter is clearly the higher. Furthermore, as airport land value increases, the space (real estate) market would push development in exactly this direction (short runways) if given free rein to do so.

There are consequences in the aircraft market of economic pressures toward short runways. Aircraft differ greatly in the length of runway required. To cite an extreme example, a 7-place helicopter requires only a landing pad, in contrast with a 4,000 - 5,000 ft. runway for a 7-place executive jet. It may be technologically feasible to manufacture a 7-place aircraft with the speed and range of the executive jet and runway requirements no greater than that of the helicopter. A substantial penalty is extracted in the form of higher fixed and variable costs borne by the aircraft operator. Designs for intermediate runway lengths would carry lesser penalties. The manner in which the space and aircraft market would jointly operate if free to do so is described and some sample results presented in the following discussion.

Conceptually, the simplest approach is to imagine that the airport

owner is also the owner of the aircraft fleet. There is no question that he could and, as a profit maximizer, would arrive at a least cost solution for a given mission, or combination of fleet consist and level of operations. That is, he could calculate the ideal runway length and the associated airplanes for his range-payload missions. To do so, he must construct curves (or functions) for both airport and aircraft costs as functions of runway length. The optimum runway length is that at which the sum of the curves (functions) shows a minimum cost. If the minimum cost is not sharply defined, but rather exhibits a wide, flat valley over a range of runway lengths, then the operator will be indifferent to what runway length he chooses within this range. As will be seen, this is the situation at low land values such as are found in flat, rural areas.

The airport costs are described in detail in Appendix VI, but their general nature is summarized below. The derivation of the aircraft cost function is then described; detailed discussions of aircraft costs are presented in Appendices II - V.

The annual airport costs include the land opportunity costs (imputed rent), the costs of labor and materials consumed in operations (including depreciation on improvements, where applicable, calculated on the basis of replacement costs), and interest on working capital and unamortized investment in depreciable assets.¹ Of these, the imputed rent usually predominates in urban areas. As stated, these costs can be separated into two components:

¹Taxes are neglected in this study for simplicity of analysis and exposition.

$$\text{Airport Costs} = A + B(L)$$

where L is runway length. $B(L)$ is conventionally of the form:

$$B(L) = C + DL$$

where C represents overruns and clear zones that exist at either end of the runway. The clear zone is not necessarily part of the airport property; it is the airspace above the land under the approaches to the runway that must be kept clear of obstacles to permit safe descents to and climb-outs from the runway. Use of airspace in the clear zones is thus severely restricted. Any activity on the land in the clear zones that might lead to extensive personal injury or property damage in the event of an accident such as an aircraft landing short or overshooting the runway is discouraged. Where the airport does not acquire title to the clear zones, restrictions are often sought through zoning or, as a compromise, through purchase of the air rights.

At short runway lengths, C need no longer be treated as a constant but will diminish with L . The reason is that aircraft capable of landing and taking off from short runways will also be capable of approaching and climbing away from the runway along much steeper paths than conventional aircraft, with the result that clear zones can be shortened. For the conventional case, C and D are both constants, proportional to the number of runways.

The aircraft cost curve poses greater difficulties. To derive it, the airport/aircraft fleet owner could take a leaf from the physical sciences and compute something akin to a frequency response curve. Instead of exciting a dynamic system over a frequency range and ascertaining

response curves, he would analyze hypothetical fleets of aircraft over a range of runway performances and ascertain the annual cost curve over that range. More specifically, he would accept as given the fleet consist in terms both of speed and payload¹ and of the utilization (number of hours flown during the year) of each aircraft. He would then compute costs at a series of discrete runway lengths by supposing that the entire fleet was made up of aircraft requiring just that length of runway but with the same distribution of speed, payload, and utilization as the given fleet (in which the actual aircraft have varying runway requirements).

With his functions of airport and aircraft costs defined, the owner would, mathematically, proceed in three steps:

- 1) Sum all relevant costs, expressed as functions of runway length.
- 2) Differentiate with respect to runway length.
- 3) Set the differentiated sum equal to zero and solve for runway length.

The summation and differentiation need not be performed analytically. They can and perhaps should be done graphically. A graphical presentation reveals at a glance how sharply defined is the minimum cost point, hence, what decisions will and will not appreciably influence the minimum cost.

Symbolically, the procedure would be as follows:

¹Structural criteria and range are other critical variables but most general aviation aircraft are designed to similar structural standards and to a common endurance based on pilot and passenger limitations; thus range is subsumed in speed and structural criteria are not variables.

$$C(L) = P(L) + R(L) + I(L) + O(L) + F(L) + D(L)$$

The symbol "L" is the independent variable, runway length. The functions are listed below and subsequently discussed. Optimum runway length is found by solving for "L" in

$$\frac{\partial C(L)}{\partial L} = 0$$

at the point where the function has a minimum.

All functions represent economic costs as previously defined and cover a time period such as one year.

- C(L): Total system
- P(L): Aircraft parking
- R(L): Landing area
- I(L): Capital improvements
- O(L): Overhead unrelated to runway length
- F(L): Aircraft fixed
- V(L): Aircraft operating (variable)
- D(L): Congestion or delay

P(L), representing the costs of parking, whether in a hangar, a shelter, or at a tie-down, including access aprons and taxiways, will not usually be a function of the aircraft landing and take off performance. At the limit of VTOL, however, the requirement for access taxiways could be reduced and the arrangement of parking and landing areas significantly altered; for example, a honeycomb airport layout with circular aircraft parking around several landing spots could be imagined. Parking costs are basically depreciation on improvements and imputed land rent. P(L)

(2)

must take into account the number of aircraft by the cost of each parking facility.

$R(L)$, representing landing area, is largely a land opportunity cost, including the runway proper, the buffer zones on either side of the runway, the taxiways serving the runway, and airspace over clear zones at the runway approaches. It also includes improvements such as runway and taxiway paving and lighting. $R(L)$ is independent of the number of aircraft but is a function of the number of runways. Multiple runways may occur either to facilitate operations where wind direction varies widely or to increase airport capacity in terms of operational frequency (i.e., parallel runways). $R(L)$ is an increasing function with L .

$I(L)$, representing capital improvement costs, encompasses non-depreciable capital improvements, such as clearing and leveling land, filling in swamps, installing drainage systems, etc. It is not a factor at existing airports where the resources in question were expended in the past and are sunk costs. It is a factor in optimizing for a new airport or an expansion, where the resources have yet to be committed. In optimizing such future facilities, a discounting procedure not reflected in the equation presented here would be necessary to take account of the one shot nature of the improvements, in contrast with the roughly continuous flow over time of the other costs.

$O(L)$ is airport overhead unrelated to runway length or, generally, to aircraft characteristics. General and administrative costs such as billing and security fall in this category. In the future, operating overhead costs could be imagined that influence aircraft landing and take off

performance while not being a function of runway length. For example, landing and take off aid devices like those on aircraft carriers (catapults, arresting gears, et al.) might be used as an alternative in optimizing the runway-aircraft system. In such a case the term would drop out during the differentiation but would be reflected in added aircraft costs appearing in functions that do not drop out; it would be an airport fixed cost relevant in establishing average costs.

$F(L)$, representing aircraft fixed costs, includes return on capital investment, most depreciation, and insurance. These are the costs encountered regardless of how much the aircraft flies. They are mostly related to first cost. First cost will climb because of increasing aircraft complexity and weight as runway requirements (take off or landing distance) are reduced. The function is the sum of these costs for all aircraft in the fleet; otherwise stated, it is the sum of the number of aircraft of each type times the cost per aircraft of that type.

$V(L)$, representing aircraft variable costs, includes the remaining, the out-of-pocket costs of flying the aircraft in a year: fuel, oil, maintenance, etc. These can most easily be calculated for each aircraft by multiplying the known (approximate) cost per hour by the number of hours flown. The function sums these costs over the entire fleet. The shorter the runways from which aircraft can fly, the higher will be the variable costs, for much the same reasons as aircraft fixed costs, namely, the greater installed power, weight, aerodynamic drag, and complexity.

$D(L)$, reflecting delay costs during periods of traffic congestion, is extremely difficult to calculate but may be an important factor. It is the

sum over all users in the traffic pattern of the opportunity cost of time lost because of delays encountered in the pattern and was discussed in Chapter IV. This function takes into account the fact that runway capacity at peak periods is measured in time as well as distance. The writer could find little data on the impact of aircraft technology on runway acceptance rate, or capacity. There is an aerodynamic question of how closely aircraft can follow one another in a pattern,¹ since the more nearly V/STOL the aircraft, the more agitated the aerodynamic wake behind and beneath it. There is also the ground handling or taxiing question: the time needed to touch down and vacate the landing area to make way for the next user. If operational experience indicates that this function is a significant and inherent function of the aircraft runway length requirement, it must be taken into account.

Several assumptions are necessary in the computation of aircraft and airport costs. These are described in the Appendices. In any application of this analysis, certain additional assumptions must be made. For purposes of this study, three simplifications were made.

- 1) Flight hours were assumed to be the appropriate measure of system output for each aircraft. At urban airports of the future, this may not be the most appropriate output on which to base cost minimization studies. If instructional and recreational flying were eliminated, for example, and only transportation

¹Conversely, V/STOL (vertical or short take off and landing) aircraft might be less obliged to follow identical flight patterns than conventional aircraft.

flying left, then passenger-miles or vehicle-miles might be used.

- 2) The system to be optimized was assumed to be a single airport. A rigorous analysis would take into account costs at all the airports in the airport network used by the aircraft fleet. If calculations were based on the existing airport system, one would guess intuitively that the complete analysis would result in a longer optimum runway since the resource (land) costs are lower outside the urbanized regions. If, on the other hand, calculations included airports yet to be constructed, the bias might be reversed. In any event, such a system-wide optimization implies some intercommunity transfer payments that would have to be resolved.
- 3) Finally, it was assumed that sufficient time had elapsed to permit adjustments by users of their aircraft investments. That is, the age distribution of the hypothetical fleet was assumed (in this study) to be the same as that in existing fleets. This assumption is necessary to obtain realistic fixed costs of aircraft operation. An aircraft's fixed costs of capital, depreciation, and hull insurance depend on its market value, which diminishes with age. Some assumptions regarding the ages of aircraft in the equilibrium fleet must be made; assuming that all are brand-new is clearly unrealistic.

Sample calculations of hypothetical fleet costs were performed for two airports for which 1969 operating data were developed on the basis

of a survey of owners of aircraft based at these airports.¹ The survey is described in Appendix I. Results of these calculations are presented in Table V-1. With these airplane operating costs, it was possible to postulate different airport land values and compare total system costs. Runway space requirements are shown in Figure V-1, based on Appendix VI. To recapitulate, the curves are derived as follows.

A curve of aircraft operating costs versus runway length is computed by calculating costs of hypothetical fleets at several discrete runway lengths. By hypothetical fleet is meant that, at each runway length, the costs of the aircraft actually based at the airport under study were modified to what they would have been had each airplane been designed to operate from exactly that length of runway. The point on the cost curve represents the sum of the costs of each aircraft in the hypothetical fleet assuming it flew the same number of hours during the period in question as did its real life counterpart.

The total cost of production is found as a function of runway length by summing together the curve of aircraft operating costs and the curve of runway costs, $B(L) = C + DL$. The lowest point on the cost of production curve defines what might be called the socially optimal runway length for that airport with the activity mix it exhibited and the land value postulated.

At low land values typical of flat rural and suburban areas, the results show, as one would expect, that the land rent plays a minor role

¹Scope limitations made it impossible to include a survey of transient aircraft in the study.

TABLE V-1: TOTAL OPERATING COSTS OF HYPOTHETICAL FLEETS

<u>Aircraft design Runway length, feet</u>	<u>Airport No. 2</u>	<u>Airport No. 3</u>
0	\$6478408.00	\$5741966.00
600	2848961.00	2575113.00
700	2658371.00	2398492.00
800	2471202.00	2230824.00
900	2285454.00	2063893.00
1000	2175271.00	1963924.00
1100	2117001.00	1913843.00
1200	2058192.00	1865625.00
1300	2002340.00	1817258.00
1400	1941712.00	1768107.00
1500	1899079.00	1731556.00
1600	1887737.00	1715873.00
1700	1880074.00	1702435.00
1800	1875970.00	1691242.00
1900	1872849.00	1682189.00
2000	1872297.00	1678773.00

Notes: a. Based on actual 1969 flight hours.
b. 418 aircraft based at No. 2.
c. 299 aircraft based at No. 3.
d. Payments to airport and property taxes excluded from costs.

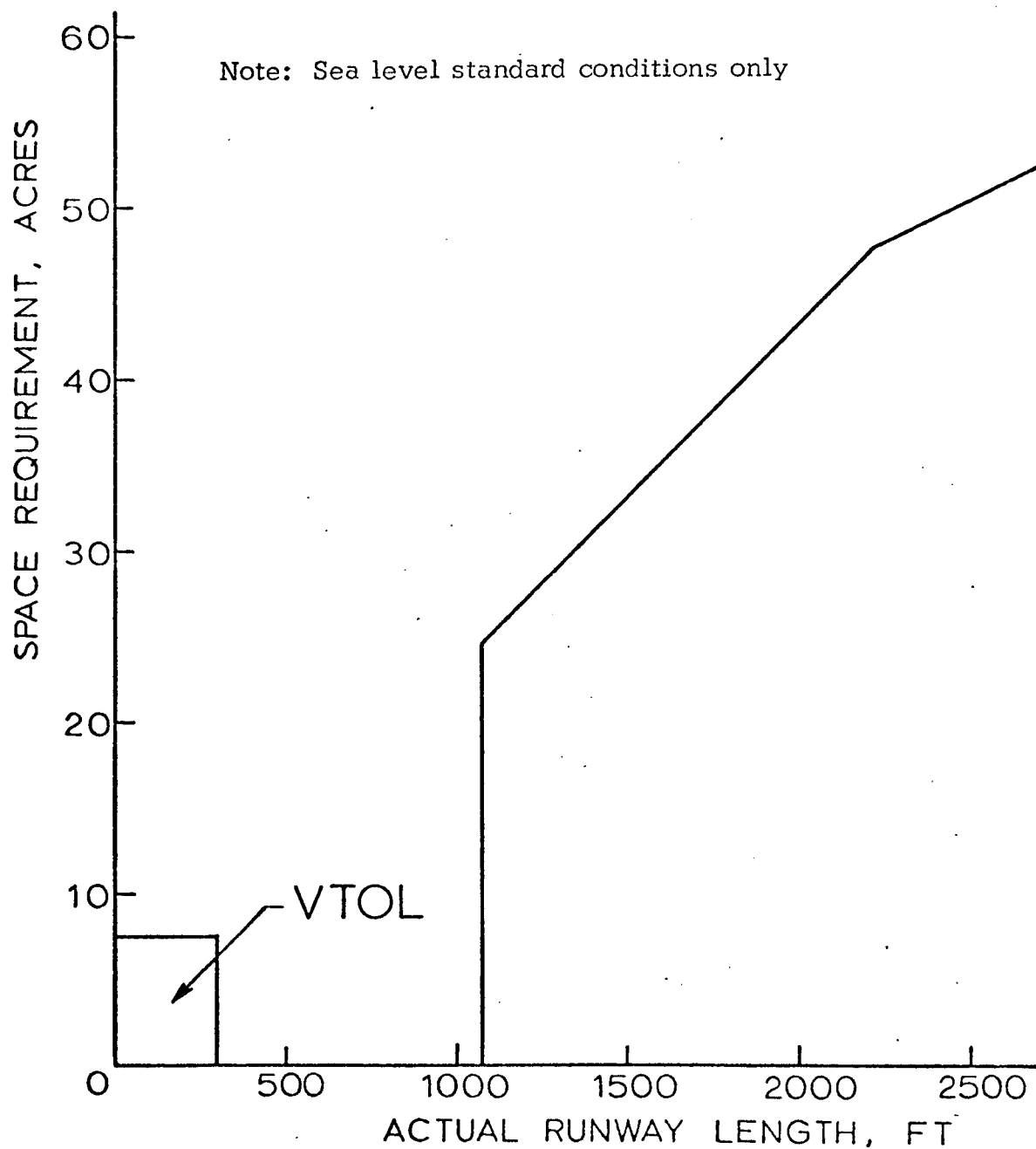


Figure V-1 - Surface pre-empted by landing area and clear zones as a function of runway length. Source: Appendix VI.

and there is no reason, on that account alone, to encourage aircraft of short runway performance. See Figures V-2(a) and V-2(b).¹ Historically, this was long the case with nearly all general aviation airports, with the result that what aircraft manufacturers chose to produce, aircraft of minimal operating costs, happily led, in general, to a minimum social cost of production.

The qualification "in general" merits comment. Land value or even runway construction costs on prepared land are not the only factors in airport development. Topography and improvement costs also play a role. Not all land where general aviation users might like to operate is flat nor readily leveled in strips several hundred feet long. The imposition of long runway airplanes on airport planners has effectively precluded general aviation activity from such areas. Were sufficient short take off and landing (STOL) aircraft to become available in service, some of these hitherto undevelopable airports might become economically feasible.

Similarly, when new airports are projected for urban areas (as they are presently in the FAA National Airport Plan) acquisition and improvement costs will often be such as to make short runways desirable. It is one thing to acquire bare land at a price representing the present, discounted value of the stream of income it would produce if put to its best and highest use. It is quite another to acquire land already developed to its present best and highest use, with structures already in place. In

¹The results for Airports No. 2 and No. 3, Figures V-2(a) and V-2(b), respectively, are so similar that subsequent examples are limited to Airport No. 2.

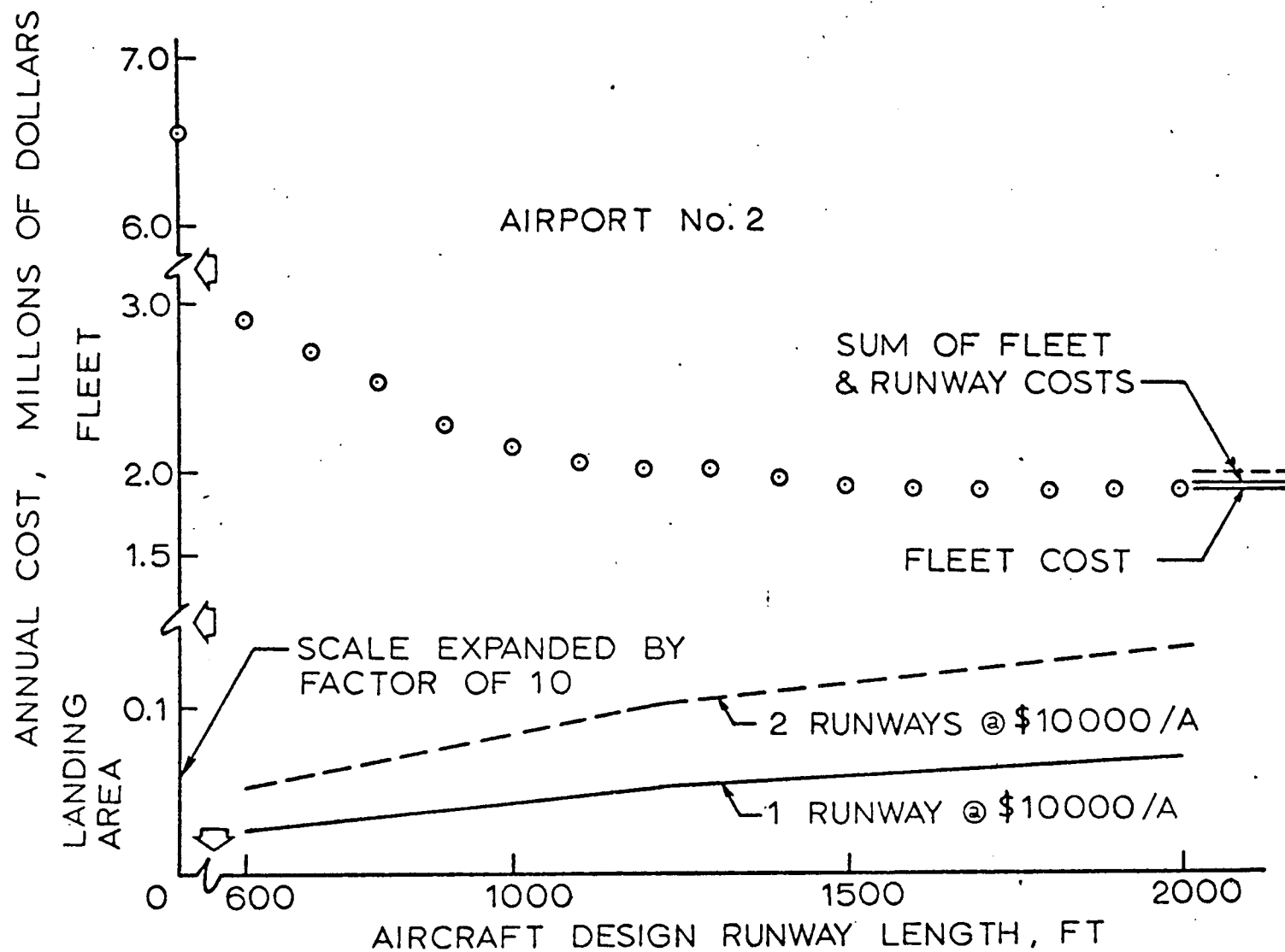


Figure V-2(a). - Aircraft operating costs and landing area costs at low land values. Airport No. 2.

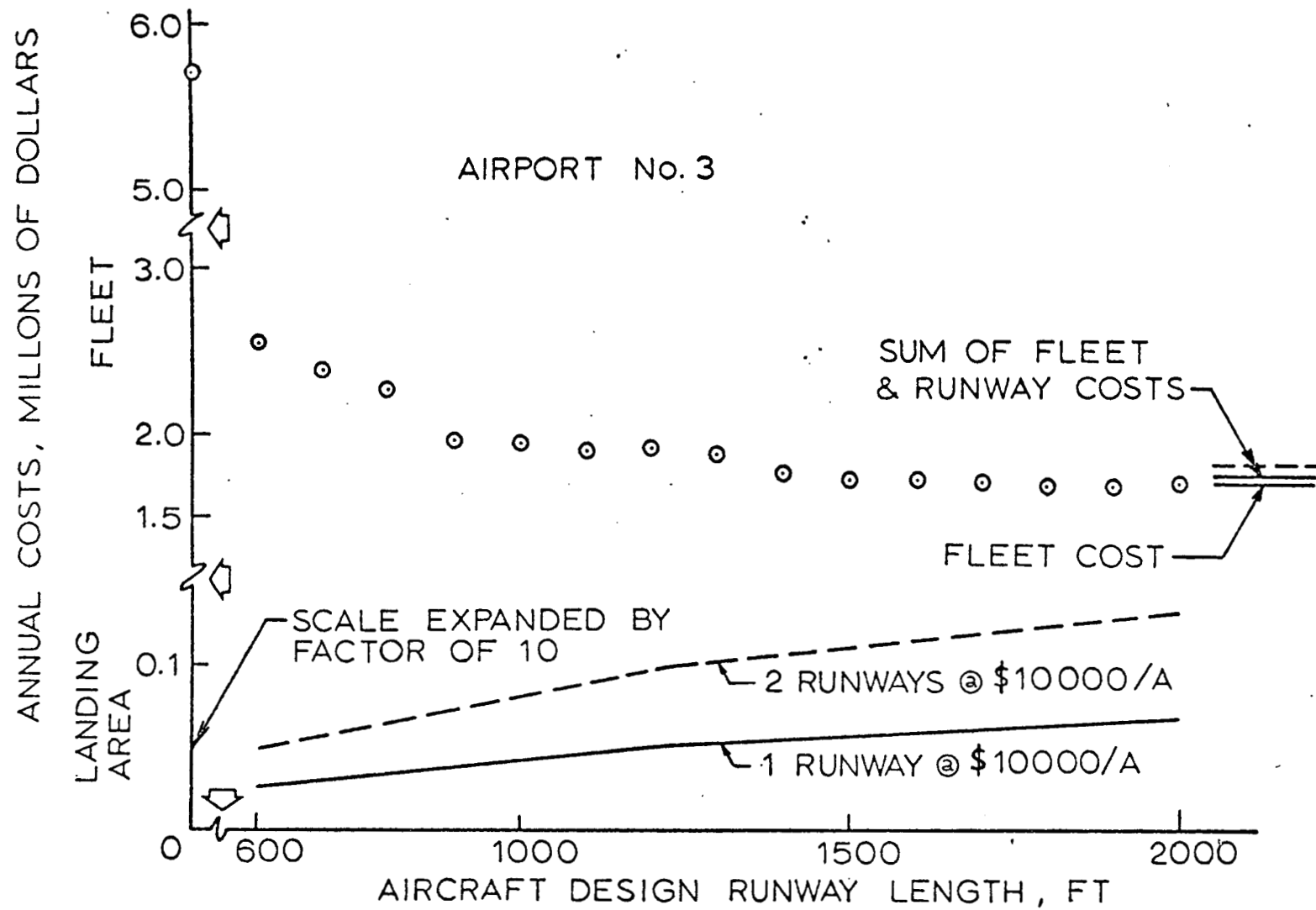


Figure V-2(b). - Aircraft operating costs and landing area costs at low land values. Airport No. 3.

these circumstances, a short runway airport may be the only one financially feasible.

Figure V-3 shows, as one would expect, that the number of runways at the airport has a significant influence on the total cost curve. A low activity airport, fortunately located where prevailing winds are so consistently from one direction (or opposite directions, as in a valley) that one runway suffices, is much less sensitive to land values than the more common case where two or more runways are needed. The contrast in runway land requirements can be substantial. An airport with three different oriented sets of parallel runways would require six times the runway space of the single runway airport. Imputed rent on this much land would cause the airport portion of system costs to become important at a far lower value per acre (one-sixth) than at the single runway airport.

A well defined minimum appears in Figure V-3 (upper curve) at an aircraft design runway length of about 900 feet¹ (far shorter than most general aviation aircraft in production). This minimum implies a system cost almost \$700,000 per year less than the costs at 2,000 feet. It would correspond to a one runway airport at a land value of \$400,000 per acre, an improbably high value of airport land, or to a single set of

¹As discussed in the Appendices, aircraft "design runway length" is the longer of landing or take off distance to or from a full stop with no wind at sea level standard conditions on a paved, dry runway, from or to a height of 50 feet, as established by flight test. An operational runway to serve an airplane of given design runway length would be longer by a safety factor to allow for errors in pilot judgment and other than perfect airplane and runway conditions. The factor used in this study, 80%, brings the actual runway length at the minimum cost point to 1,250 - 1,450 feet, without the added corrections needed to account for ambient temperature and altitude different from sea level standard conditions.

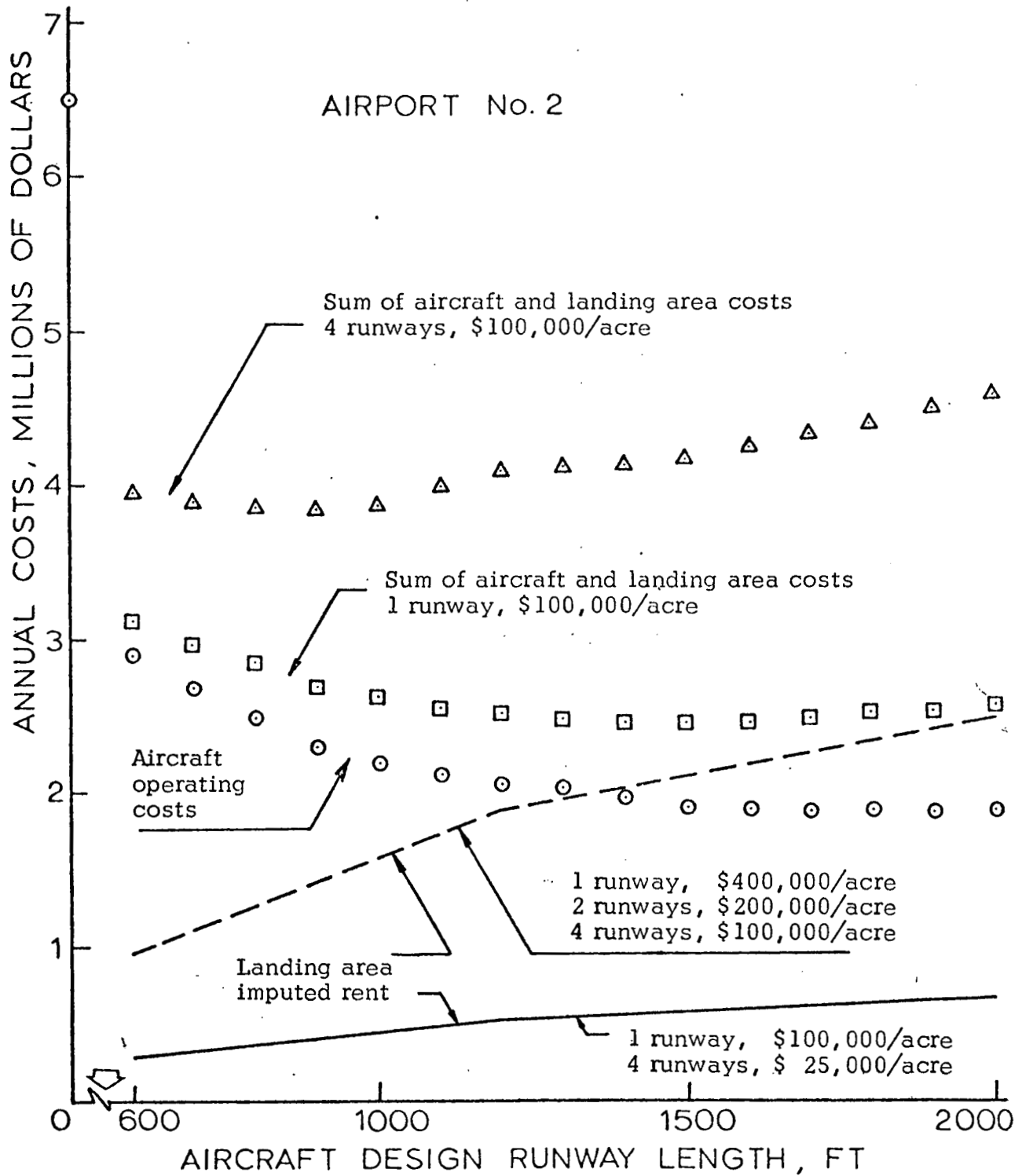


Figure V-3. - Sample combinations of aircraft operating costs and landing area costs. Airport No. 2 traffic and density altitude.

parallel runways at \$200,000 per acre, a value that will not be unusual at all by the early 1980's, if present trends continue. Alternatively, it would apply for two sets of parallel runways at \$100,000 per acre, a situation that probably exists in some cities already.

Conversely, increases in aircraft utilization or in the number of based aircraft or both will shift the optimum runway length to the right. Figure V-4 shows the influence of doubling the number of based aircraft, assuming typical 1969 utilization levels. The more aircraft based at the airport, the longer the optimum runway length, though the increase is not great. Figure V-5 shows the influence of doubling and halving utilization (flight hours per aircraft per year) of club and privately owned aircraft relative to actual 1969 utilizations. Except at unrealistically low utilizations, the influence on optimum runway length is similar but minor.

In Figure V-6, the influence of multiple runways can be seen at lower land values. Note that the ordinate scale is expanded relative to the earlier figures. Between 800 feet and 1,700 feet design runway length, total costs lie within a \$100,000 band around \$2,500,000, or 4%. Since few of the cost computations are accurate to 4%, the minimum shown, at about 1,500 ft., is of little significance. What is significant is the relative flatness of the total production cost curve, particularly for multi-runway airports at lower land values. That is, over a wide range of runway lengths, generally shorter than those currently in existence, it would not make much difference to the total costs of production what the length of the runway was if the users were operating suitable equipment. The question of what fraction of the production costs should be borne by the

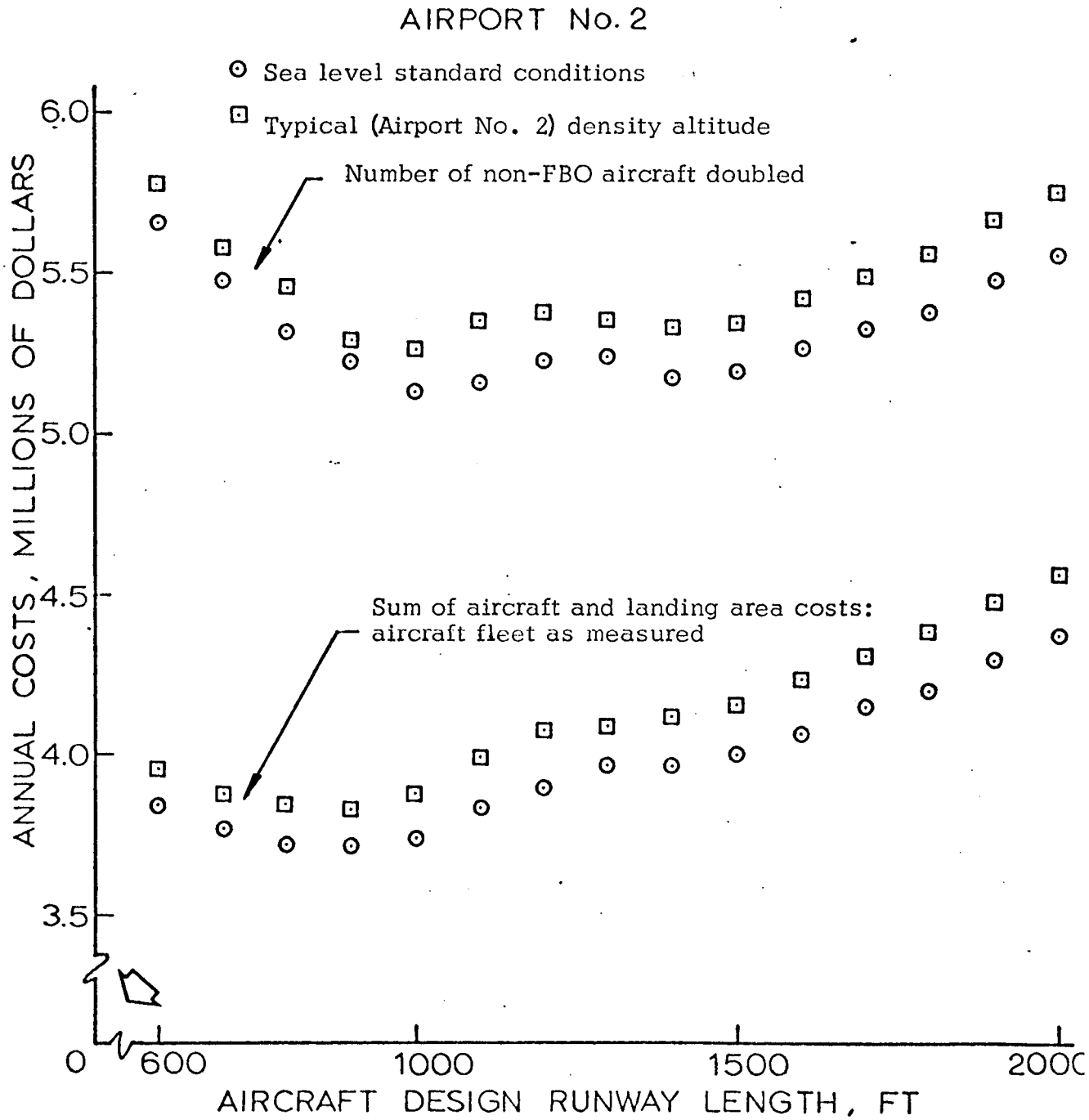


Figure V-4. - Influence on total system costs of the number of based aircraft and of density altitude. 4 runways, \$100,000/acre.

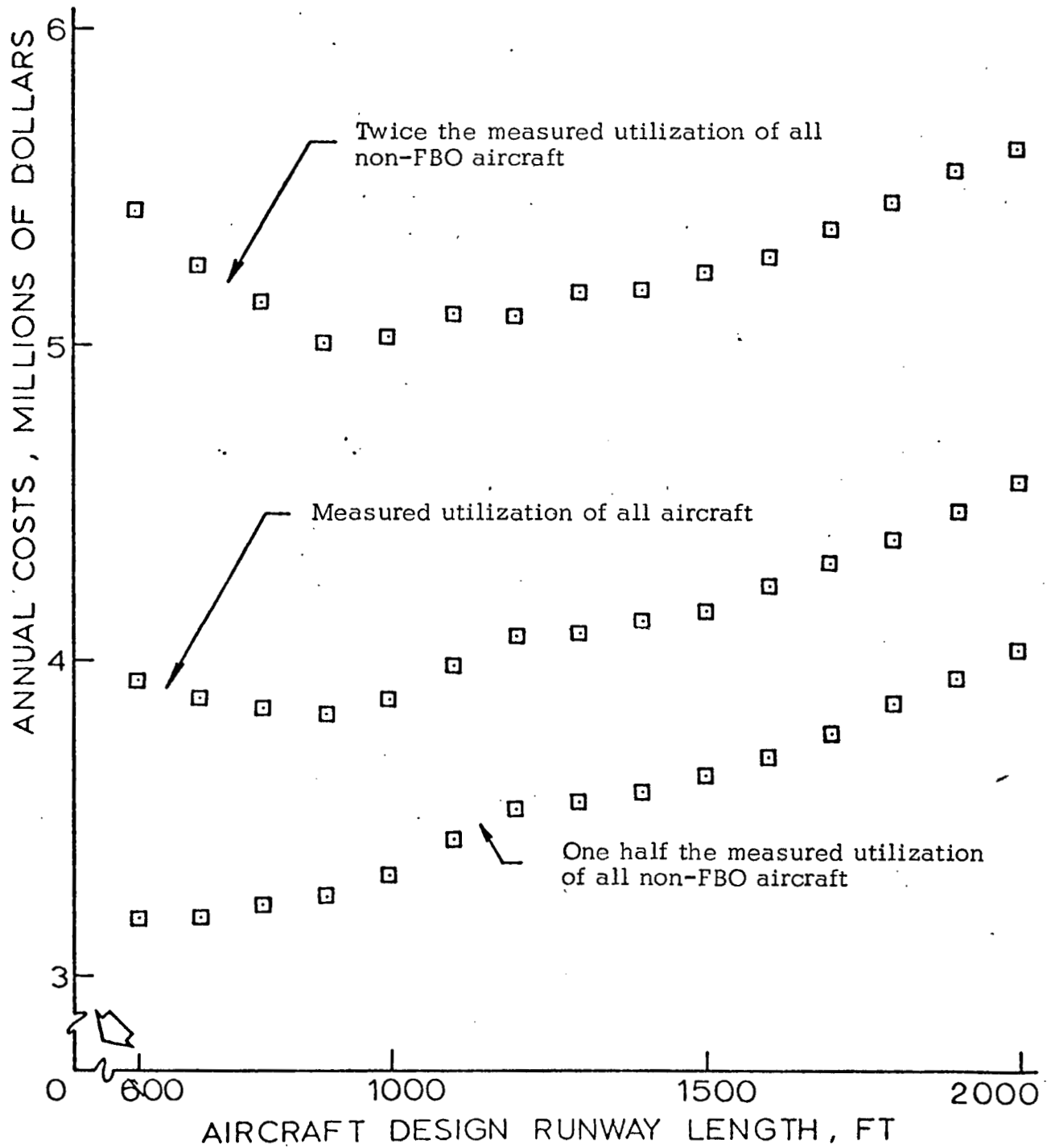


Figure V-5. - Influence of aircraft utilization on system costs.
4 runways, \$100,000/acre, Airport No. 2.

publicly furnished airport and what borne by the consumers through their operating costs is a matter of indifference between broadly separated limits in runway length.

The significance lies in the fact that policies could be adopted immediately, without raising production costs, that would give consumers an incentive to purchase, hence, manufacturers to produce, STOL aircraft. If such policies are effected gradually, fleet composition can change and be appropriate to predictable future conditions of high land values. If the aircraft inventory is not adjusted in the interim, total costs of producing flying will climb as a result of an inefficient plant. The inefficiency will result from an over-reliance on the publicly furnished portion of the plant, the runway system, rather than a shifting or production costs to the consumer-owned, aircraft portion of the system.

It is submitted in this study that prices constitute the most effective incentive to consumers to adopt less runway hungry aircraft and, further, that the minimum necessary incentive is a pricing schedule that makes the aircraft operator indifferent between operating his long runway aircraft and the desired, equivalent short runway aircraft. If such pricing schedules are put into effect at enough major airports, the inventory of aircraft will change in the direction of short runway varieties. It will then be possible, in some instances, to shorten landing areas and clear zones, thus making land and airspace available to other uses. In other instances, where runways are unusually long, it may be feasible to double the effective runway processing rates by having simultaneous STOL operations, landings on the downwind half of the runway and take

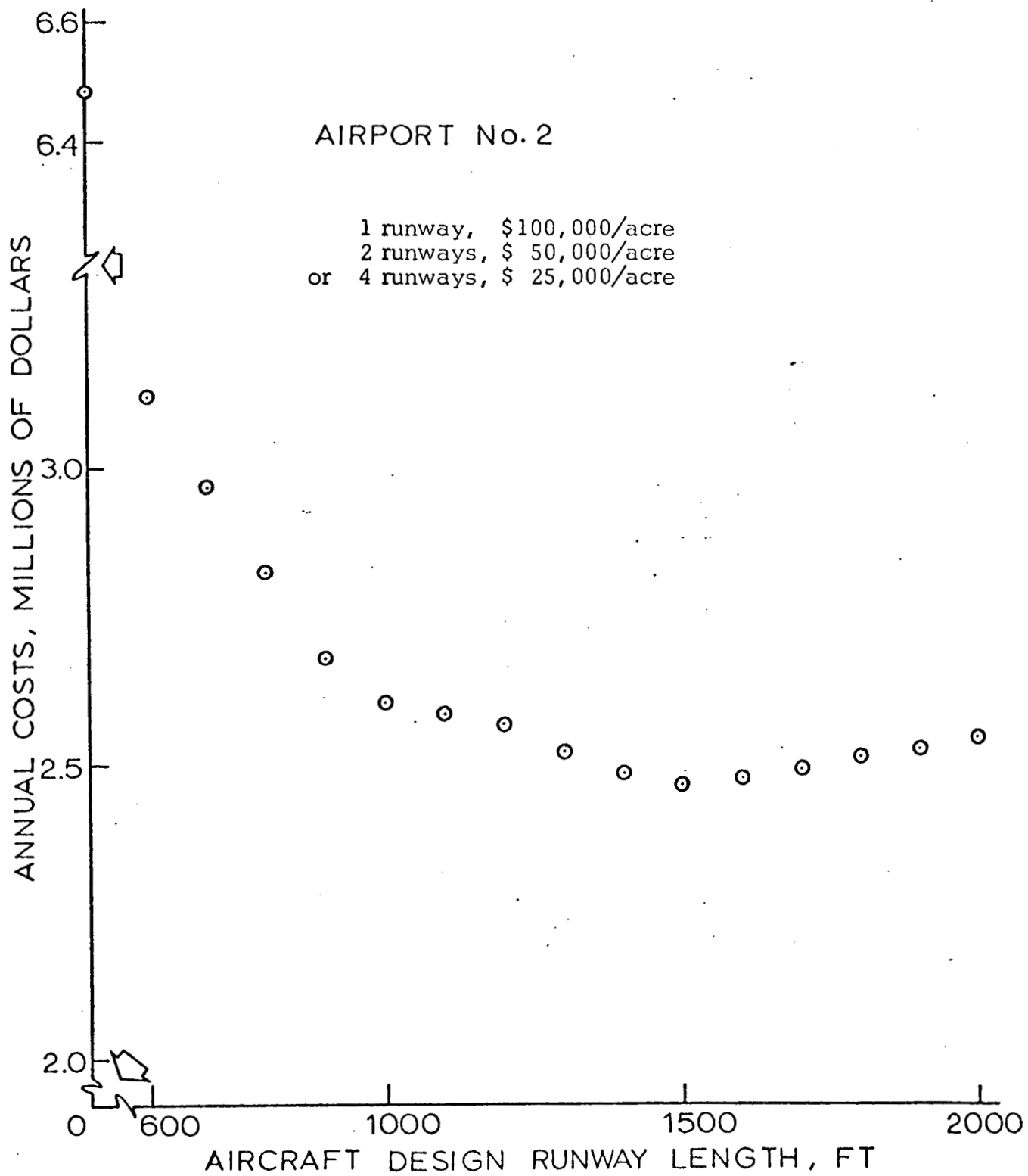


Figure V-6. - Sum of aircraft operating costs and landing area costs.
Airport No. 2 traffic and density altitude.

offs on the upwind half.

The analysis performed was limited to minimizing production costs in terms of runway length. That is, in the airport cost relation:

$$\text{Airport Costs} = A + B(L)$$

attention was given to $B(L)$ alone. As runway lengths diminish, $B(L)$ will decrease in significance relative to A . At the limit, one can imagine a helicopter landing pad that would be insignificant in extent in contrast with other space requirements, mainly aircraft storage and support and automobile access and parking.

If the concept of land opportunity costs is accepted and policy decisions made accordingly, existing techniques should suffice to facilitate efficient (intensive) use of off-runway airport land. The rules that say how high land values must climb before multi-story garages or rooftop parking of automobiles become viable apply equally at the airport. With minor modifications, the same principles should guide construction of multi-level aircraft storage facilities. The modifications concern the poor surface mobility of aircraft relative to automobiles. This obstacle can be overcome at a cost in time or equipment or both.

One technological feature that may be revived for aircraft storage in civil aviation is folding wings (or, for rotary wing aircraft, foldable rotors). Wing folding leads not only to the predictable aircraft costs in the added complexity and weight and to storage space savings but also to time and inconvenience costs of folding and unfolding. The latter constitute costs that cannot generally be evaluated; some users will find them more burdensome than others, and the same user will find them more

burdensome on some days than on others.

Because of the unknown elements in wing folding costs, a rigorous analysis comparable to that performed to find an optimal runway length cannot be carried out to determine an "optimal" set of storage dimensions. This matter would be of no concern except for pricing questions. Aircraft storage prices in real life must reflect not merely the space rent and allied costs of the storage space itself but also an allocated share of the costs of airport common areas (those used by all airport patrons). A change in price that reflected only the reduced storage space resulting from wing folding might appear to owners to be insufficient to justify the adoption of that equipment. In theory, their decision would mean simply that the storage cost savings resulting from wing folding were insufficient to justify the measureable plus the unmeasurable costs of wing folding. In fact, if direct storage costs are a small enough part of the price paid for storage, the reduction in price due to lower storage costs may be perceived as insignificant; the inclusion of allocated costs unrelated to storage in the basis of the storage price may distort the rationality of the owner's decision.

The conclusion is that, if a public policy is adopted that wing folding is to be encouraged, for economic or other reasons,¹ it may prove

¹One reason might be forward planning, taking account of lead times necessary to make suitable equipment available to the right segments of owner market by the time land values climb enough to justify the incentive. Another reason might be physical constraints limiting the expansion of available storage space. Theoretically, such limits should give rise to a market for land within the airport confines separate from, and at higher prevailing prices than, the market outside the airport. Were such a market to form, then storage cost savings could be gauged accordingly. The author knows of no airport where such a market exists. Wait lists rather than prices are customarily used to "clear" the market.

necessary to provide price incentives greater than the direct value of the space savings effected. The matter is not trivial, since manufacturers will not design and produce suitable aircraft unless a market exists, and the market will not materialize unless consumers find it in their interest to buy the aircraft.

The above examination of the major elements involved in a minimum cost system of flight activity rounds out the discussion of objectives that pricing strategies at general aviation airports might seek to achieve. Previous chapters have described the demand for airport services, the nature of airport operations, and the enhancement of the value of runway use possible by controlling congestion. In the next chapter, specific pricing strategies will be outlined with an emphasis on implementation.

CHAPTER VI

Elaboration of Pricing Strategies

The discussion thus far has been devoted largely to definition of economic costs at the airport. Costs comprise the dog that wags the price tail in a competitive, market economy if proper resource allocation is to result. Proper resource allocation in this context means that no shift of resources from one use to another could increase overall consumer welfare.

As has been discussed in the preceding chapters, practically all airport costs are fixed; they do not vary significantly with output in the short run. The only exception is the cost of congestion that was analyzed in Chapter IV and is briefly discussed below in connection with implementation of peak load prices for touch and go landings. The fixed costs are similar to those of a shopping center: the opportunity cost of the space being pre-empted, maintenance and depreciation, and administration. In urban areas, the imputed rent associated with the opportunity cost of space predominates.

Three separate aspects of implementing pricing strategies are discussed below:

- 1) Establishing the target revenue.
- 2) Delineating the goods and services on which it is administratively practical to levy charges.

3) Setting price levels on these goods and services.

Setting the revenue target is straightforward in principle. The cash operating expenses can be measured, as they are currently at most airports, and depreciation can be computed as well for airport facilities as for facilities in other fields. At urban airports, the largest component of cost to be recovered is the rent imputed to the land and airspace that is withheld from other uses by being committed to the airport. These total costs can be then modified upward or downward to the extent of external costs imposed on the community or external benefits provided to the community by the airport operation.

The accuracy with which imputed rent can be fixed does not match that of the cash expenses and depreciation. The problem is one of establishing market value in an imperfect market, real estate. An extensive literature exists dealing with real estate appraisal.¹ Pristine pure theory says a property is worth the present discounted value of the anticipated earnings stream. In practice, neither the discount rate nor the future earnings stream can be accurately established. Resort is therefore made to market values, in the reasonable belief that they properly reflect both the market rate of discount and the market anticipation of future earnings. But problems arise here also because market value is hard to establish in real estate; properties are not homogeneous and are

¹ See Richard U. Ratcliff, Modern Real Estate Valuation; Theory and Application, (Madison, Wis., : Democrat Press, 1965) and, by the same author, Current Practices in Income Property Appraisal, Research Report No. 30, Center for Real Estate and Urban Economics, University of California, Berkeley, 1967.

infrequently traded.

For general aviation airports, comparable (smaller) plots can be appraised in most cases, and either that value applied to airport land or a band be defined in which the value of the airport land is sure to lie. For policy purposes, such appraisals will usually have to be used, faute de mieux. If the airport expands by purchasing adjacent property, then the price paid for this property may constitute a basis for costing all airport land. To the extent that the seller is willing and the price paid is close to what other high bidders would have paid, then the new parcel determines the marginal cost of airport space, and should be then applied to the remainder. Thereafter, in general, it could be supposed that airport space values would climb at the same rate as those of surrounding properties, a rate that can be measured.

In conclusion, the airport land, and the surrounding air rights, whether pre-empted by zoning or purchased, can be appraised at an urban general aviation airport by competent appraisers. For policy purposes, namely, establishment of revenue goals, pinpoint accuracy is unnecessary. Sufficient information to establish the range within which target revenue must fall is all that is called for and it can usually be furnished.

Given the revenue target, the next problem is that of administrative practicality in levying charges. At general aviation airports, as has been discussed, there are three major user groups: FBO's, clubs, and

individuals.¹ The FBO's characteristically are tenants under relatively long term leases; 30-year leases are not uncommon for major FBO's. Sub-lessees of office or other space will have shorter term leases such as one year. FBO's and other business enterprises can be charged space rent in the same manner as are businesses at a shopping center. The pricing problem relates more to aircraft owned by clubs and individuals, whether tenants of the airport or sub-lessees of FBO's, to aircraft operated by FBO's, and to transient aircraft.

There are basically only three goods or services for which charges can be imposed:

- 1) Landing or take off fees.
- 2) Space rental.
- 3) Fuel flowage fees (so much per gallon).

Landing fees are common at air carrier airports where a small number of customers (airlines) can be billed on the basis of published schedules. While feasible, they are definitely not convenient when dealing with large numbers of unscheduled general aviation operations and would lead to high collection costs. Ways to automate the collection process have yet to be proposed; metering, turnstiles, and tollgates do not appear feasible. A voluntary payment scheme might be feasible, but difficulties in policing and adjudicating disputes can be anticipated. More will be said about voluntary payments at the end of this chapter in connection with peak period touch and go landing fees.

¹Individuals here means all non-club aircraft owners who do not operate aircraft for hire. Subsumed are companies and partnerships.

One way to collect landing fees at a general aviation airport is to employ observers, whose sole function is to monitor operations, identifying each aircraft as it lands and takes off, and billers to trace the owners of the observed aircraft, bill them for fees owed, and assure collection. Much of the billing process can be automated, but at a cost. If done continuously, monitoring operations leads to substantial labor costs: most airports are open seven days per week and 16 or 24 hours per day. Traffic volume or fees or both must be high if a net revenue is to result.

The main problem with landing fees is that the resources expended in collection are dissipated to no avail if the objective in levying the fees can be achieved in some other, less costly manner. So long as the objective is only revenue generation, less costly alternatives are certainly available, namely, space rental and fuel flowage fees;¹ perhaps for this reason, these are the items on which prices have historically been imposed.

Except as noted subsequently, it is assumed that space rental and flowage fees are the only administratively practicable pricing subjects. The final problem is how best to generate the desired revenues by recourse to these sources; that is, what should be the levels of the flowage fee(s) and of space rental charges.

¹The flowage fee is a kind of sales tax. Many airports impose sales tax type fees on other goods sold at the airport, and charge a flowage fee on oil sold. The oil charge can be analyzed in roughly the same manner as the fuel flowage fee. Most of the others are strictly revenue generating devices akin to percentage leases and will not be treated in this study.

In considering the alternatives, two objectives are to be kept in mind. One is generation of the target revenue. The other is imposition of pricing incentives to effect the fleet adjustments toward STOL aircraft discussed in Chapter V. The first objective may imply higher prices than currently are charged. So long as an airport has excess capacity, meaning extra storage space and adequately uncongested facilities, price increases should logically be arranged so that no user whose payments at least equal costs directly traceable to him be priced off the system. There is nothing to be gained by driving him away. Conversely, if the airport is full such that there is a wait list of would-be owners (as is the case at many airports), then prices should logically be raised so as to "clear the market." Only by using prices to ration the available space can the airport management guarantee that the patrons who are on hand are those who value the facility the most.

Between these two extremes, economic theory does not help much in prescribing prices. Rather recourse is made to the club analogy. The members must agree on the amounts each will pay. In a club, discussions of equity would probably predominate in the bargaining. At the airport, the philosophy of the management will rule, but probably tempered by the pleas of users; in effect, bargaining will also take place. It is possible neither to predict how costs will be allocated among users nor rigorously to prescribe how they should be allocated.

It is possible, in a general way, to predict that successful efforts to expand greatly the total of payments made by users would have to be

by discriminatory¹ rather than uniform prices. In other words, pricing would be according to value of service. Greater payments would be extracted from those more willing and able to pay them; some users would pay more than others for like services. While discriminatory pricing smacks of unfairness, it is a scheme to which users must agree if increased revenue is necessary to justify keeping the facility open. Those paying more must realize that their allocated share of total costs would be even greater if those paying less were priced off the airport and made no contribution at all to meeting costs.

Airport prices are mildly discriminatory already. Storage fees are often scaled upward with the weight of the aircraft. The heavier aircraft (when new) are more expensive; hence, they are associated with owners willing to spend relatively more on flying. See Table VI-1 for a sample price schedule. Though some heavier aircraft are sufficiently bigger to require, say, larger hangars, the schedule applies even where facilities are identical in dimensions and structure. Thus, the price scheme seems not to be cost based but to have discrimination as its rationale.

Table VI-1

Sample Aircraft Storage Schedules

<u>Aircraft Certificated Gross Weight (lbs.)</u>	<u>Tie-Down Fee, Per Month</u>	<u>Hangar Fee, Per Month</u>
0 - 3,500	\$25	\$65
3,501 - 5,200	31	70
5,201 - 10,200	43	75
10,201 - 20,000	51	--

¹Discriminatory here bears its economic sense of discriminating among market segments.

The fuel flowage fee, though a uniform amount per gallon, is similarly discriminatory. The airport collects more from an owner the more he flies his airplane and the more powerful his airplane is. On both counts, approximately, his payments rise with the amount he spends on flying, which is a crude measure of how valuable flying is to him.

The fuel flowage fee is more closely discriminatory than are fees linked directly to aircraft weight. Since old heavy aircraft have depreciated in value to well below the values of many newer lightweight aircraft, aircraft weight is an unreliable indicator of an owner's inclination to spend for flying. However, neither is truly discriminatory, based on the results of this study. Basically, the range in aircraft values and that in total amount spent on flying are both proportionately far greater than the spread in weight-based storage fees and in fuel consumed.

Compare Tables VI-1 and VI-2.

Table VI-2

Comparison of Airport Fees and Aircraft Utilization
with Aircraft Value: Individual Owners

<u>Value Range</u>	<u>No. of Cases</u>	<u>M E A N S Total Annual Owner Costs</u>	<u>Storage Fee</u>	<u>Fuel Fee</u>	<u>Utilization (hours/year)</u>
\$ 0 - \$ 5,000	61	\$1,506	\$300	\$29	101
\$ 5,001 - \$10,000	45	3,169	331	43	166
\$10,001 - \$15,000	10	4,882	432	75	171
\$15,001 - \$20,000	5	6,797	564	88	243
\$20,001 - \$30,000	4	8,835	669	88	179
\$30,001 - \$40,000	2	13,563	276	77	240
\$40,001 - \$60,000	0	0	0	0	0
\$60,001 - \$80,000	1	21,565	276	105	250

Notes: a) Based on survey results at Airports (2) and (3). The survey is described in Appendix I.

b) Seven of the aircraft in the 0 - \$5,000 value category

were not flown at all in 1969; the total costs, fuel fee, and utilization means in this category are thus biased low.

- c) The three most expensive aircraft were all twin engine and were stored at tie-down facilities. It is believed that no hangars at the two airports big enough to hold them had space for rent. It is a matter for conjecture whether the owners would have paid more to hangar their aircraft had hangar space been available.
- d) Corresponding data for club and FBO aircraft (both running utilization and total cost means consistently and substantially higher than individual owners) are included in Tables A-VII-19 and A-VII-20 of Appendix VII.

It is probable that the owners of the more expensive aircraft could be charged substantially more than at present before being priced away from the airport. One way to approximate charges aimed at achieving value of service pricing would be to base fees on the market value of the aircraft rather than on its weight.¹

The choice between storage fees and fuel fees as a source of revenue is arbitrary, but the nod would probably go to the former, for two principal reasons:

- 1) A fuel fee tends to dissuade patrons from flying and there is no reason to do so, particularly if the runway system is underutilized. The result would be reduction in the value of the services provided by the airport. If runway system congestion builds up, then landing fees or other devices can be used to attack the problem as is discussed subsequently. Furthermore, a

¹In California, a 1-1/2% property tax is levied on aircraft, based on Bluebook values, already. This is not an airport user fee; however, it confirms the feasibility of Bluebook-based charges.

fuel fee penalizes the higher powered aircraft such as the STOL aircraft that a sensible management policy would encourage.

- 2) The storage fee can more readily be modified to reflect policies of the airport management, such as encouragement of STOL aircraft. It is highly visible, in contrast to the fuel fee which is buried in the pump price.

If storage fees were used to recover costs, and if airport services were so valuable as to make discriminatory pricing unnecessary, the elements of the storage fee might be as follows:

- 1) The physical costs of the storage facility, including interest on capital invested in improvements and depreciation, both at replacement cost, plus maintenance and utilities, both of the facility itself and a share of accessways.
- 2) An imputed rent on space consumed in the storage facility and the accessway share. This rent would be the average for the airport, modified upward or downward to reflect the locational advantage of one storage space relative to others on the airport if such advantages were significant. Locational advantage for aircraft storage might be relative proximity to fueling areas and to other functions of the airport. Locational advantage should also be reflected in FBO and other tenant business lease rates.
- 3) A share of the common areas and facilities such as landing areas, utilities, parking aprons, and administrative services not covered by other charges. In a non-discriminatory pricing scheme, these shares could be uniform, based on averaging

costs over all based aircraft. The share of common area costs would logically be applied to aircraft based on FBO leaseholds as well as to those at storage facilities managed directly by the airport owning agency.

- 4) Modifications upward and downward to reflect the runway requirements of the aircraft. As implied in Chapter V, the airport management would select (compute) the desired runway length and then modify rates charged all based aircraft so as to make owners indifferent between owning an aircraft of that design runway length and the one actually operated.¹

For transient aircraft aprons, charges could be similarly computed, only scaled upward to reflect the lower average occupancy of transient storage. That is, since these facilities are often only partly filled, those that do occupy them must pay guest fees sufficient to recoup the costs of making transient facilities available at all. At a given airport, it may be determined that guest aircraft are not to be charged for common areas, but it is logical that, over the course of a year, at least those costs directly incurred on behalf of transient aircraft be recouped from them. These costs are the space rental (based, say, on the average value of airport land), the costs of the transient storage facilities themselves, and administrative costs traceable to the transients.

¹To fix these charges in practice, a schedule of charges versus aircraft type will be required. To generate it, assumptions regarding utilization will have to be made to take account of aircraft variable cost. Selection of a higher than average utilization will make the incentive to adopt short runway aircraft effective to most operators of long runway aircraft.

While landing fees are generally rejected as a revenue source at general aviation airports because of high collection costs, there are instances where they might be used, namely during the congestion peaks that were discussed in Chapter IV. Basically, three situations arise:

- 1) Queue jumping fees that would be agreed to by the pilot in his conversation with the air traffic controller and for which he would subsequently be billed by administrative personnel monitoring the tower talk,
- 2) Landing fee imposition on all aircraft by monitoring and subsequent billing if congestion peaks ever become regular enough that a time schedule of fees can be laid on and,
- 3) Fees on touch and go landings imposed on flight schools during periods of congestion, with the flight schools themselves effecting collection voluntarily.

As discussed in Chapter IV, the setting of the charge levels for congestion cost fees must be done empirically. Lacking the input data needed rigorously to compute fare levels, the practitioner must use his judgment to determine when the price is right. He will experiment to see how high queue jumping fees must be so that the formation of a secondary queue made up of queue jumpers does not convert the process into an operational nightmare. If peaks are regular, he will find the price that, on the average, results in reasonably acceptable delay levels. He will set fees that discourage most but not quite all touch and go practice during congestion peaks. Implementation is straightforward for queue jumping fees and conventional peak load tolls but is elaborated

below for the touch and go fees.

As stated in Chapter IV, collection problems for touch and go fees during periods of congestion could probably be solved by a system of voluntary payments. The reason voluntary payments are proposed is that nearly all landing practice is done by a relatively few aircraft in the FBO flight schools. FBO's at most airports are regulated in some measure by the airport management, via lease contracts if nothing more. Agreements between FBO's and management providing for the provision of notification of when fees were to be imposed and for the monitoring by FBO's of their own operations can readily be imagined.

In conclusion, price setting at an airport must be done by those on the scene. A central agency can only provide policy guidelines. The local agency must measure the costs that user revenues are to meet, in accordance with policy guidelines. It may be that uniform prices to all users for identical services will fail to generate the target revenue; management would, in such a case, have to experiment to see which users would pay more than others for, basically, the same services. One approach suggested is to scale prices according to the value of the aircraft.

CHAPTER VII

Conclusion: Prices and Technology

The research reported has largely been focussed on pricing as a tool to influence the efficiency of airport operation. One branch of the effort was to apply the concepts of congestion cost pricing to the special case of general aviation airport runways. Adoption of such prices would make possible the basing of substantially more aircraft at a given airport than has typically been the case in the past. The increased patronage would lead to more business for FBO's at the airport, to a larger number of users over whom to spread airport fixed costs, and to diminished need for airport capacity expansion.

The other branch dealt with airport and aircraft technology and has wider implications. Economic analysis leads to the recommendation that airport management policy take into account the value of airport real estate; that is, responsible officials should expand the scope of their attention to include long run considerations of land use. In urban areas, external forces may compel them to do so in any event. The competition for urban space that pushes land values upward will insure, sooner or later, that all available land be used intensively. Long runways and low density aircraft parking do not fit the intensive use mold. Technology, in the form of V/STOL aircraft, can relieve the external pressures by shrinking the runway space requirements.

The pricing problem arises because no substantial market for V/STOL general aviation aircraft will materialize so long as communities provide long runway airports with no discrimination in charges according to the length of runway a user requires. Failing existence of such a market, quantity production of V/STOL aircraft will never be launched and they will never amount to more than a tiny fraction of the general aviation fleet. If most of the fleet requires long runways then the users will apply pressures on the communities to provide them. There are consequences for the network of general aviation airports and also for government policy regarding aeronautical research expenditures.

In regard to general aviation airports, it will remain economically unattractive to construct new, short runway airports in either urban or rugged rural locations so long as the number of aircraft in service capable of using these facilities remains small. Furthermore, as shown in Chapter V, increasingly greater resource waste will occur in urban areas where the long runways consume precious land that could be used for other purposes. In addition, since V/STOL aircraft can effect steeper climb outs and approaches and shorter radius in-flight turns than conventional aircraft, an opportunity to diminish the area around airports adversely affected by noise and hazard will be lost.

In regard to aeronautical research, it follows that resource expenditures on research and development of low-speed flight and other needs of V/STOL aircraft will never bear fruit so long as conditions in the marketplace are such that the findings will not be implemented. In evaluating research and development, it is insufficient to demonstrate potential

benefits of technological advances; it is necessary to demonstrate a high probability that these benefits will materialize.

There is no question that economic benefits could result from V/STOL research in general aviation type aircraft. Since current airport pricing policies effectively prevent the realization of these benefits, a strong argument for policy change exists. If pricing patterns are not changed, and with them the aircraft market conditions, then resources expended on associated V/STOL research, in both the private and public sectors, may be wasted. Strategies such as those proposed herein, penalizing long and rewarding short runway aircraft, would lead airport users to adjust their inventories. In the long run, airport layouts could be modified accordingly and the feasible economic benefits realized.

APPENDIX I

The Questionnaire: How It Was Coded and Lessons Learned

"Dear Sir,

I am not answering your questionnaire because
I am sick and tired of being dissected, referenced,
digitized, and cataloged -

Yours,

So much for the non-respondents. Their sentiments in large measure are accurately reflected in this note that one was kind enough to return. The questionnaire to which he made reference had been sent out in a survey to gather information about aviation activity. This information provided the basis for computing the costs developed in Chapter V. It also served to illuminate some aspects of general aviation flying. The survey, the questionnaire, and the processing of the results are described in this Appendix.

About 740 questionnaires were mailed to aircraft owners. Of these, 340 replied, for an overall response rate of about 45%. Some responses were not usable, reducing the effective response rate to about 42%, still quite satisfactory in comparison with many surveys.

¹The term "about" reflects the facts that certain questionnaires were given to others to be forwarded to potential respondents and others were sent to respondents with more than one airplane, in which case more than one response per respondent would be received.

The questionnaire is reproduced in Exhibit A-I-1. It was mailed to owners of aircraft based at:

- 1) One publicly owned airport serving scheduled air carrier, business jet aircraft, and 500 based general aviation aircraft from one long 9,000 x 150 ft. runway, a shorter 4,400 x 150 ft. one, and a 3,000 x 40 ft. strip for light aircraft.
- 2) One publicly owned Basic Utility Stage II¹ airport serving about 400 based aircraft from a single 3,100 x 75 ft. lighted runway.
- 3) One publicly owned Basic Utility Stage II¹ airport serving about 300 based aircraft from a single 2,500 x 75 ft. lighted runway.
- 4) One privately owned (on leased property) airport with a 3,500 x 30 ft. runway and 25 - 30 based aircraft.

These airports were selected because of their geographical convenience to the author. Since the primary objective of the survey was to develop input data for the analysis reported in Chapter V, it was not necessary that they be selected randomly from all airports. Since they were not randomly selected, caution should be exercised in citing activity statistics published in this report; nonetheless, there is little reason to suppose that these statistics exhibit any peculiar bias unless some exists as a result of the weather in the survey area which is far better for year round flying than is the case in most other parts of the country.

¹FAA classifications. Basic utility Stage II airports accommodate about 95% of all propeller aircraft with gross weights under 12,500 lbs. See Utility Airports - Air Access to National Transportation, FAA, AC 150/5300-4A, 1968, Chapter 2.

EXHIBIT A-I-1 (p. 1 of 2)

Stanford - NASA - E. R.
GENERAL AVIATION SURVEY

Spring, 1970

1. Airport where Aircraft is based: _____
2. Make and Model of Aircraft _____
3. Year of manufacture _____
4. Estimated current value of all avionics equipment installed \$ _____
5. Monthly Tiedown/shelter/hangar fee \$ _____
6. Please indicate (x) the business or industry in which the aircraft owner is primarily engaged.

____ Retail Trade
____ Wholesale Trade
____ Manufacturing
____ R & D
____ Finance

____ Education
____ Agriculture
____ Government
____ Other, please specify _____

IMPORTANT - ALL THE REMAINING QUESTIONS ON THIS FORM REFER TO ACTIVITIES WHICH OCCURRED DURING 1969. YOUR ANSWERS SHOULD APPLY ONLY TO THAT PORTION OF THE YEAR WHEN THE AIRCRAFT WAS REGISTERED BY YOU AND BASED AT THE ABOVE AIRPORT.

7. This aircraft was based at the above airport _____ months during 1969.
8. Please estimate the number of takeoffs from the base airport that were made for each of the following activities.
 _____ Local Flight (both takeoff and landing at base airport)
 _____ Touch and Go (practice takeoffs)
 _____ Flight to Another Airport
 _____ Total
9. Approximately how many hours were logged on this aircraft during 1969, while it was based at the above airport? _____ hrs.
10. Approximately what percent of these hours were logged during weekends and holidays? _____ %
11. Please indicate the percent of the total hours logged for each of the following purposes:
 _____ % Instructional
 _____ % Air Taxi or Charter Service
 _____ % Aviation Service (crop control, photography, etc.)
 _____ % Lease
 _____ % Company Business (not for hire)
 _____ % Individual Business (not for hire)
 _____ % Personal and Pleasure: under 100 mile radius
 _____ % Personal and Pleasure: over 100 mile radius
 _____ % Other
 _____ 100% (Should total 100%)
 =====

More questions overleaf - Please turn over!

EXHIBIT A-I-1 (p. 2 of 2)

12. If instruction flying was indicated, how many individual students were served by this aircraft? _____
13. If flying hours were indicated for business purposes (not for hire) or for long personal trips, why were General Aviation aircraft rather than Commercial Aircraft used? Please score each item on a scale from 0 to 5, where 5 means "extremely important" and zero means "not important at all."
- _____ Lack of commercial flights to desired destinations
 _____ Convenience to base airport
 _____ Cost considerations
 _____ Flexibility in scheduling trips
 _____ Other, please specify _____
14. In going to the base airport, what was the major user's most frequent departure point? The major user is the person who causes most of the flights -- e.g., the owner/pilot of the aircraft who flies for personal reasons, the business executive who uses an airplane for company business but hires a pilot to fly it, etc.
- _____ Residence _____ Place of Work
15. The location of the major user's most frequent departure is identified by what zip code? _____
16. Please estimate the number of trips to the base airport from the departure point made by the major user in 1969. _____
17. What is the primary occupation of the major user of the aircraft? (person described in Item 14).
- | | |
|------------------------------|-----------------------------------|
| _____ Professional Aviator | _____ Farmer |
| _____ Professional technical | _____ Salesman |
| _____ Manager, executive | _____ Education |
| _____ Secretarial, clerical | _____ Housewife, student, retired |
| _____ Mechanic, craftsman | _____ Other, please specify _____ |
| _____ factory worker | |
18. What was the primary reason that this airport was selected as a base rather than others? Please score each item on a scale from 0 to 5, where 5 means "extremely important" and zero means "not important at all."
- | | |
|---------------------------------------|------------------------------------|
| _____ Cost considerations | _____ Convenience to residence |
| _____ Safety consideration | _____ Convenience to place of work |
| _____ Services available at airport | _____ Other, please specify _____ |
| _____ Facilities available at airport | |

Thank you for your cooperation!

The questionnaires were enclosed with monthly billings to all owners who were tenants of the airport management at Airport No. 1, the air carrier airport. At Airports No. 2 and No. 3, address lists of airport tenants were obtained and the questionnaire sent out as a separate mailing. The response in these cases was appreciably lower than at Airport No. 1, where they enjoyed more of an aura of official approval, 40% as compared with 52%. The questionnaires were given to an officer of the club managing Airport No. 4 who agreed to mail them out with the billings. Response rate here was 30 - 35%, gratifyingly high from a group of owners who had by choice shunned the publicly owned airports and had little motivation to cooperate in a study so dimly related to their benefit. A cover letter (Exhibit A-I-2) and a stamped and addressed return envelope were enclosed with each questionnaire.

Though only about 740 questionnaires were mailed, there were some 1,200 aircraft based at the airports during 1969. About 15 - 20% of these, or 180 - 240 were in FBO fleets (flight schools, etc.) leaving something over 200 unaccounted for. A number of FBO's rent storage space, either hangars or tie-downs; such FBO tenants were not contacted. These aircraft included those in inventory awaiting sale (new and used); newly sold aircraft (new and used) whose buyers had not yet made other storage arrangements; and aircraft awaiting shop service or repairs. In other words, non-fleet aircraft based on FBO leaseholds were usually transient, unlikely to remain there longer than a few months.

Of the remaining unaccounted for aircraft, it is believed that the majority involve multiple-ownership by either individuals, firms, or clubs;

EXHIBIT A-I-2
Survey Cover Letter

EDUCATION / RESEARCH, INC.

A NON-PROFIT CORPORATION

2831 Seventh Street
Berkeley, California 94710
Telephone (415) 848-5527

April 30, 1970

Dear Aircraft Owner:

Education Research Inc. is undertaking a study of the economics of general aviation airports. The study is being performed with participation from the Stanford University Graduate School of Business under contract NAS2-5737 to the National Aeronautics and Space Administration. A major objective is to furnish guidance to NASA in future aeronautical research related to general aviation.

We are conducting a survey of all owners of aircraft based in Santa Clara County to learn more about the nature of their flying activity. Our data will be available to the responsible airport managements and may assist them in establishing policies regarding facilities and services. As there are only about 1000 aircraft owners in the region, each individual response is important. Your cooperation in completing the enclosed form, and returning it in the envelope provided, will be greatly appreciated. We should like to have the completed form returned within two weeks.

All of the information furnished will be treated as confidential; responses will be numerically coded so as to maintain respondents' anonymity.

We realize that it may be difficult to answer some of the questions on the survey form; none the less, it is important that information be supplied as completely and accurately as possible. Please furnish your "best estimate" figures for entries where records are not available.

If you have any questions concerning the survey, or our study, please send them in the enclosed envelope.

Sincerely yours,



Robert R. Piper
Principal Investigator

Enclosure

one questionnaire sent to each such owner would be inadequate for his fleet. Some instances of this nature were discovered and subsequently corrected (by furnishing additional questionnaires).

Non-fleet aircraft based with FBO's were generally omitted from the survey. Information on the FBO fleets was obtained by interview with 13 of the 16 FBO's operating flight schools at the airports. Fleet consists of the remaining three were obtained by other means. The utilization of the aircraft in these three fleets was estimated by observation of their operations in comparison with those of fleets on which data were obtained. Some of the FBO's who were aircraft dealers or who operated repair stations but who did not engage in rentals, charter flying, or flight schooling were also interviewed. In addition to three of the 16 flight school operators, one air taxi operator refused to be interviewed.

The questions on the questionnaire are discussed in turn below. The objective is stated, comments on its validity in hindsight are presented, and the associated coding is described. For purposes of this study, coding was laid out so as to fit all needed input data on one 80-column card.

Initial card coding was four digits for the questionnaire number. This proved invaluable in tracing coding errors or other corrections that became necessary. Two respondents were sophisticated enough to guarantee the anonymity promised in the cover letter, one by tearing the response number off and the other by altering it. The questionnaire number was coding variable V-1, columns 1-4.

Question Number 1,

the "base airport," was coding variable V-2, column 5. Digits 1-4 denoted the four airports.

Question Number 2,

"Make and model of aircraft," and

Question Number 3,

"year of manufacture," yielded several coding variables, as follows:

V-3, columns 6-7. Last two digits of year of manufacture, indicating the aircraft age.

V-4, column 8, number of seats on the aircraft, with 0 indicating 10 or more seats. The number of seats is a useful proxy for the aircraft payload. The pilot seat(s) is (are) included. For those rare aircraft that double as cargo carriers, an equivalent number of seats was assigned.

V-5, column 9, number and type of powerplant(s), was coded as follows:

<u>Number and type of powerplant</u>	<u>Code</u>
1 piston engine	1
2 piston engines	2
3 piston engines	3
4 piston engines	4
1 turboprop engine	5
2 turboprop engines	6
2 jet or fan engines	7
3 jet or fan engines	8
4 jet or fan engines	9

In the survey, the vast majority of the aircraft were single or twin engine piston varieties. There were a small number of twin turboprop aircraft; few single engine turboprop general aviation aircraft exist. There were two corporate jet aircraft based at the air carrier airport.

V-6, columns 10-12, was the rated horsepower per powerplant. Code 999 was used to indicate engines of 999 horsepower or more, a situation which arose only with a couple of World War II P-51 fighter planes maintained at the air carrier airport. In the case of turboprops, equivalent horsepower would be used, and for jets the rated thrust in hundreds of pounds. Were the study to be repeated, a two-digit engine make and model identification number would be coded instead of horsepower. Then both horsepower and hourly overhaul costs for each engine code could have been programmed separately, thus making possible considerable refinement of the cost computations of Appendix III.

V-7, columns 13-16, was the aircraft retail market value as of July 1969, expressed in hundreds of dollars. The source of these data was the ADSA Aircraft Bluebook that is discussed in Appendix IV. For some old aircraft not included in the Bluebook, values were estimated by evaluation with comparables. In a few cases appraisal values established by the County tax officials were used. As stated in Appendix IV, aircraft appraisal is a chancy business at best: the market is spread thin and nationwide; furthermore, each individual aircraft has its own maintenance history, time remaining before overhaul, and optional accessories. Prices fluctuate seasonally and with regional and national economic conditions. Despite these vagueries, the Bluebook values are the best guide to market value available and are probably within 20 per cent of market value for all but exceptionally good or poor condition aircraft.

V-8, columns 17-18, was the maximum rated airspeed in tens of miles per hour. Maximum rated airspeed is for level flight at design

gross weight at sea level, standard atmospheric conditions.

V-9, columns 19-21, was the required runway length, in tens of feet. Runway length as here defined is the longer of the distance to take off from a standing start and reach 50 feet of altitude or the distance to land and roll to a complete stop from an altitude of 50 feet at design gross weight and sea level, standard conditions. There is no legal (FAA) or industry standard by which these numbers are defined. The numbers are usually published in the owner's manual that accompanies each new airplane. They are generated during flights by company test pilots on dry, paved runways. Some airplanes are critical on take off, not landing; the margin of airspeed at the 50 foot height is considerably more important in determining landing (or take off) distance than how hard the pilot stands on his brakes or manipulates his flaps, etc.

One manufacturer stated that take off distances were established employing climb speeds that would enable a pilot to establish a safe glide in the event of sudden powerplant failure (for single engine aircraft); for twin engine aircraft an additional criterion is maintenance of directional control following single engine failure. This implies an airspeed of 1.15 - 1.25 times the power-off stall speed, depending on how abrupt the airplane stalling characteristics are. On landing, a power-off glide at 1.25 - 1.35 times power-off stalling speed is used, with the criterion being ability to execute a landing flare "without special skill." When installed (as they are on most modern aircraft), flaps are sometimes used during take off and climb out; they are always used during a "short field" approach glide but "dumped" to assist braking during the roll out.

Techniques used by other manufacturers are believed similar. It should be noted that the distances do not imply safe operations over a 50 foot obstacle, since some margin of clearance over the obstacle is normally desired. Both landing and take off performance deteriorate with unfavorable atmospheric conditions, primarily temperature and barometric pressure, the latter usually associated with altitude above sea level. Wet or icy runways clearly lengthen the landing run and an unpaved runway will lengthen the take off run and influence the landing run, probably lengthening it on the average. Since flight tests are scarcely ever performed at sea level, standard conditions, flight test results are corrected to these conditions using semi-empirical techniques developed and refined by each manufacturer.

A variety of sources were used to establish V-4 through V-9. The ADSA Aircraft Bluebook provides numbers in most cases. Toward the end of the coding process it was discovered that some ADSA performance figures were at variance with published manufacturers' numbers. This was particularly true with landing and take off distances which were often listed shorter than field lengths specified by manufacturers. In a number of cases cross checks were made with figures published in the annual "Forecast and Inventory" issue of the McGraw Hill weekly, Aviation Week and Space Technology, whose numbers were more often accurate though also not entirely reliable. For older aircraft, recourse was taken to back issues of Jane's All The World's Aircraft. In some instances, landing or take off roll only were given; at least, the distances were remarkably short, given the airplane wing loading and power loading, the primary

determinants of landing and take off performance. In these cases, runway requirements were estimated by reference to similar aircraft (general layout, wing loading, and power loading) whose performance was known.

A few aircraft had variable seating capacity, such as 6 - 7 or 2 - 4, depending on whether or not bench or jump seats for the additional passengers were installed. In such cases, where the airplane was a familiar one, judgment was used in assigning a high or low number of seats. In other cases, the middle of the range was used.

Question Number 4,

"estimated current value of all avionics equipment installed," proved to be a poor one. The objective had been to establish a realistic total value of the aircraft as equipped. It was initially assumed that Bluebook values were for the airframe without optional extras; hence, the value of major extras would have to be added. As it turned out, except for current year models (see Appendix IV), the Bluebook lists aircraft with "average" avionics installed. Thus the original objective of the question was vitiated by the nature of the reference source, except for current year (1969) aircraft. In addition, the concept of "estimated current value" is vague. List value, purchase price under list, value installed (generally considered 50 per cent of list) and some lower figures were all possible interpretations. There is no way of knowing which interpretation respondents used, except in the case of a few FBO's interviewed who specified list prices. Were the questionnaire repeated, the question would be best restricted to new aircraft and new value of avionics. It is noted that some owners have spent more on their avionics equipment than

the value of the airframe. The coding variable was V-10, columns 22-24, presenting value of avionics in hundreds of dollars.

Question Number 5,

"Monthly tie-down, shelter, or hangar fee," was intended to reflect the owner's payment to the airport management. It yielded straightforward responses from owners who were direct airport tenants for aircraft storage only. For FBO's who leased plots of land and erected buildings or hangars or tie-downs or some combination of these, the question was of no use. Similarly, it would have been of little help in fixing user payments to the airport of FBO sublessees had sublessees been included in the survey. At the air carrier airport, a "use fee" was imposed on FBO fleet aircraft, those used for flight school, rental, or charter. (None was imposed on aircraft held for sale.) For these aircraft, the use fee was inserted as the answer to question 5. Otherwise, for aircraft based with FBO's, the answer, zero, was inserted. The coding variable was V-11, columns 25-26, in dollars per month.

Question Number 6,

regarding the "business or industry in which the aircraft owner is primarily engaged," proved not to have been so suitable as hoped. Clubs were omitted from the list and constituted a major owner category. Fortunately, many clubs were identified as such under the "other" category. Also omitted were law, and medicine or dentistry, categories also picked up frequently under "other." The objective of the question was to develop something of an owner profile for comparison with regional and national profiles that have been compiled from other surveys. Since the

market area of the survey included residences of many airline personnel associated with two major air carrier airports and a nest of electronics and research and development firms, it is expected that these fields (the former reflected in "other" responses) are unusually prominent in the survey results. In some cases, responses to question 17, which was not coded at all, were used to clarify the answer to question 6; the assumption then was made that the "owner" and the "major user" were one and the same. The coding variable was V-13, columns 28-29. In these columns, 30 two digit codes were defined. Eleven were for clubs, defined to include partnerships of three or more. Two were for FBO's, one with and the other without a flight school, and 17 for different individual or corporate owners categories. "99" signified no response.

Question Number 7,

"the number of months during which the aircraft was based at the airport during 1969," was reasonably straightforward. Since the survey was made in May 1970, some addressees had not based aircraft in 1969 and some 1969 owners were not reached at all, having moved on or quit general aviation entirely. There is no convenient way to avoid this problem of peripatetic airplane owners in a survey. In computing airport activity and costs (questions 8, 9, and to a lesser extent 10 and 11) aircraft based less than the entire year were treated as though the monthly activity during their stay had been maintained all year. For example, an aircraft based two months and logging 20 hours was assumed to have logged 120 hours during the year. This device was resorted to in order to counter-balance aircraft that had departed during the year. Conceptually,

these were assumed replaced by those arriving late in the year (hence, still present in 1970). The assumption of constant year round activity is reasonable in the geographic area of the survey, where seasonal fluctuations in flying weather are not severe. Daylight hours are fewer toward the end of the calendar year and winter rain storms pose problems but otherwise conditions are uniformly good. The coding variable was V-12, column 27, and the coding was as follows:

Number of months based	1	2	3	4	5	6	7	8	9	10	11	12
Code	0	0	0	1	2	3	4	5	6	7	8	9

In computations of activity, code 0 was treated as two months.

Question Number 8,

"the number of take offs" of different types, was an effort to measure runway use by different owners. A small number of respondents went through their pilot logbooks and actually counted flights but such diligence is hardly to be expected during a survey! The simple fact is that remembering the number of take offs made in a year is very difficult. An individual who flies very little can estimate fairly closely but a club respondent has only a hazy notion of the activity of the other members. In brief, there seems no way of judging whether responses were distributed in some normal manner about the actual numbers of take offs, biased upward, or biased downward.

During the FBO interviews, rules of thumb were developed whereby it was possible to estimate the numbers of take offs by analyzing the use of the aircraft and the total hours flown. FBO's knew the total flight hours logged per airplane and the approximate portions of these devoted

to instruction, to rental, and to charter. Instructional hours¹ could be broken down, according to the level of instruction offered (to a Private Pilot or a Commercial Pilot Certificate) and accordingly subdivided into three categories: 1) airwork, 2) practice take offs and landings, and 3) cross country flying. Airwork flights averaged one hour in duration, or, one take off per hour. For take off and landing practice, estimates ranged from six per hour for full stop landings to 15 for one optimistic notion of four minutes per touch and go circuit. The average was about 8 - 10 take offs per hour. The average flight duration in cross country practice was 2-1/2 hours, leading to one take off (from the base airport) in that period. The proportions of training hours, both dual -- with an instructor on board -- and solo, devoted to these categories differed greatly among flight schools. A typical school qualifying a neophyte for a Private license in 50 hours would have him spend 23 hours on air work, 12 on cross country, and 15 on practice take offs and landings, all numbers plus or minus 2 or 3. Some schools devote one-third or less of this time to practice take offs and landings and twice as much to cross country. Corresponding distributions of training hours in programs preparing pilots for the Commercial certificate existed at each school.

For rental hours, the accounting for take offs was more difficult; however, rental hours were a minor part of the total and many FBO's could estimate the average rental flight duration, which would merit one take off. For charter work, most flights were cross country. Generally,

¹Instructional hours are those flown either with the instructor on board and teaching or "under his supervision" without his physical presence.

there was either little enough charter business or most of it was to a few destinations so that the FBO could estimate his average trip length and number of take offs with fair accuracy. For each FBO aircraft, take offs were computed according to flight practices the interviewed FBO described as characteristic of his operations. The coding variables were:

V-14, columns 30-31: tens of take offs on local flights

V-15, columns 32-34: tens of touch and go take offs

V-16, columns 35-36: tens of cross country take offs (from the base airport)

In cases of no response, 9's were entered.

Question Number 9,

"number of hours logged," was reasonably straightforward for most respondents. The number of hours flown serves as a flight activity measure, an indication of aircraft utilization, and a vital input to the aircraft operating cost computations of Appendix III. Some respondents did not remember the number of hours flown, did not wish to look them up, or did not keep thorough records. These owner's either guessed or did not reply. Among the 13 FBO's interviewed, most gave off-the-cuff answers based on their notions of average monthly utilization per aircraft. At two, competent secretaries had the numbers at hand in written records, and a third looked these up himself.

Although there was a spread in FBO aircraft utilization, there was less than each FBO gave the impression there would be; that is, some who considered their operations exceptionally efficient were deluding themselves. The more successful operators managed to average 100 hours per month on their basic training aircraft, while monthly utilization

of a few were as low as 60. The larger aircraft used predominantly for cross country flying flew about 50 - 60 hours per month. Unusual aircraft such as twin engine trainers or acrobatic aircraft rarely logged over 300 hours in a year. The coding variable was V-17, columns 37-39, in tens of hours; 999 signified no response.

Question Number 10,

"percent of flying on weekends," was seemingly straightforward except that, in interviews, it became apparent that people often tend not to realize that a weekend is nearly 30% of the week ($2/7 = 0.285$). It may be that the workweek so predominates in people's thinking, and the weekends pass so quickly, that their perception of how large a fraction of the week the weekend constitutes is somehow shrunken. Whether or not there is a downward bias to the estimates of the per cent flown on weekends, the response is accepted as a measure of weekend peaking of activity. The coding variable was V-18, column 40, in tenths (not hundredths), with 9 indicating 90% or more.

Question Number 11,

asking the "purposes of the flight hours," was aimed at defining the uses actually served by the airport. The choice of the word "lease" rather than "rental" was unfortunate but proved not to be a problem. Both lease and rental are associated with FBO's and the distinction was clarified during interviews. Lease is associated with the sale — lease-back arrangements described in Appendix IV, whereas rental is the use to which the aircraft is put by the FBO, who may be a lessee.

In retrospect, the results would have been more complete had the

purpose of the rentals also been established. That is, how much rental was business transportation, how much personal, etc. In practice, it was difficult enough to justify taking the time of FBO managers to obtain the information that was provided without probing other areas; in any event, it was not clear how well the FBO knew the purpose of rentals. He would be unlikely to ask. In a specific instance, the person handling the rental paperwork could make a good guess, but the manager probably could not aggregate these guesses.

One purpose of this question was to determine how much of the flying was for purposes of transportation. In this connection, the categories, "Company business, Personal business, and Personal and pleasure: over 100 mile radius," were defined to be transportation flying. In the 1969 time frame, instances where a traveler could effect portal to portal travel more advantageously by private aircraft than by automobile over a distance less than 100 miles were considered rare.

Although trips are frequently made to airports within the 100 mile radius, many, if not most, are made largely as an excuse to fly the airplane.¹ At least three airports within the radius boast popular restaurants that attract casual and business travelers. Trips made purely to patronize them cannot really be interpreted as transportation. The objective is to go for an airplane ride and the restaurant provides an excuse. The coding variables were as follows:

¹One notable exception was an airplane dealer who lived in the survey area and commuted by air to his place of work at another airport, 30 air miles away, rather than fight 40 miles of freeway at commute hours.

V-19, columns 41-42: per cent instructional

V-20, columns 43-44: per cent air taxi or charter

V-21, columns 45-46: per cent aviation service

V-22, columns 47-48: per cent lease (rental)

V-23, columns 49-50: per cent company business

V-24, columns 51-52: per cent individual business

V-25, columns 53-54: per cent personal, under 100 miles

V-26, columns 55-56: per cent personal, over 100 miles

V-27, columns 57-58: per cent other

The code, 99, indicated 99 or 100%; the code, 98, indicated no response.

The responses to questions are tabulated in Tables A-I-1, for all aircraft, A-I-2 for aircraft with annualized utilization under 100 hours, A-I-3 for utilization between 100 and 500 hours, and A-I-4 for utilization greater than 500 hours. By annualized is meant that V-17 (the number of hours flown while based at the airport) was modified upward whenever V-12, the reply to question 7, indicated that the aircraft had not been based an entire 12 months. V-17 was considered evenly distributed over the months based and the resulting monthly utilization multiplied by 12 to obtain annual utilization.

Replies for 520 aircraft are tabulated. From 220 - 230 of these are in FBO fleets; rarely do non-FBO aircraft qualify under V-19, V-20, or V-22, training, charter, and rental, respectively. The remaining approximately 300 aircraft in the tabulation are aircraft whose owners flew their aircraft in 1969 and who answered question 11 in their responses. Thus, while almost all FBO aircraft are included in the tabulation (save those

in sales inventory), only about one-third of the individually and club-owned aircraft are included. Since FBO aircraft tend to be utilized much more than non-FBO aircraft, care should be used in interpreting the tabulation. Probably a bare half dozen FBO aircraft are in the under 100 hours group, 75 - 80 are in the 100 - 500 hour group, and about 140 are in the over 500 hour group.

Question Number 12,

was intended to generate information on the number of students active at the airports. Only a few respondents indicated student activity. In hindsight, this was to be expected since few students purchase aircraft prior to obtaining a Private License. Some students are members of clubs owning aircraft but few club respondents answered the question. Nearly all instruction is by FBO's using their fleet aircraft. It proved impractical to extract meaningful data on numbers of students from FBO's. It would be interesting to measure the dropout rate among students but question 12 was not a suitable vehicle for this. Because of its limitations, the question was not coded.

Question Number 13,

was intended to elicit reasons why people used general aviation rather than commercial aviation for transportation purposes. It is believed that most respondents answered the question simply on the basis of why they used it for transportation at all. Although very few indicated "cost considerations" to be significant, some who did pointed out that cost per person became competitive as the seats on a 4- or 5-place airplane were filled (high load factor). Others commented that once the airplane

Table A-I-1

Tabulation of All Responses to Question 11

Variable	Percentage Ranges									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
V-19	304	33	35	15	11	2	7	20	24	69
V-20	487	4	5	1	9	1	1	3	1	8
V-21	517	0	0	0	1	0	0	1	0	1
V-22	420	22	5	7	14	14	11	16	9	2
V-23	439	14	8	7	11	4	2	7	7	21
V-24	459	22	15	5	3	2	.3	6	2	3
V-25	287	45	44	31	42	17	21	13	7	13
V-26	296	37	44	37	45	20	18	17	3	3
V-27	514	3	0	0	1	0	0	2	0	0

Table A-I-2

Tabulation of Responses to Question 11
for Those Aircraft Flown Up to 100 Hours During 1969

Variable	Percentage Range									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
V-19	111	2	1	0	3	0	0	0	0	0
V-20	118	0	0	0	0	0	0	0	0	7
V-21	117	0	0	0	1	0	0	1	0	6
V-22	119	0	0	0	1	0	0	0	0	5
V-23	100	3	0	2	2	0	1	5	2	10
V-24	109	3	4	0	1	0	0	1	1	6
V-25	28	16	12	5	21	7	10	8	4	14
V-26	42	11	12	12	22	3	8	9	1	5
V-27	118	1	0	0	0	0	0	1	0	5

Table A-I-3

Tabulation of Responses to Question 11 for Those Aircraft
Flown More Than 100 Hours and Up to 500 Hours During 1969

Variable	Percentage Ranges									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
V-19	169	22	10	3	5	0	2	3	13	18
V-20	223	4	4	1	5	1	1	3	1	2
V-21	245	0	0	0	0	0	0	0	0	0
V-22	214	5	4	4	9	2	2	1	2	2
V-23	188	10	8	5	9	4	1	2	5	13
V-24	198	17	10	5	2	2	3	5	1	2
V-25	127	22	31	18	17	8	10	5	3	4
V-26	113	24	26	21	22	17	9	8	2	3
V-27	241	2	0	0	1	0	0	1	0	0

Table A-I-4

Tabulation of Responses to Question 11
for Those Aircraft Flown More Than 500 Hours During 1969

Variables	Percentage Ranges									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
V-19	24	9	24	12	3	2	5	17	11	49
V-20	146	0	1	0	4	0	0	0	0	5
V-21	155	0	0	0	0	0	0	0	0	1
V-22	87	17	1	3	4	12	9	15	7	1
V-23	151	1	0	0	0	0	0	0	0	4
V-24	152	2	1	0	0	0	0	0	0	1
V-25	132	7	1	8	4	2	1	0	0	1
V-26	141	2	6	4	1	0	1	0	0	1
V-27	155	0	0	0	0	0	0	0	0	1

was owned and a commitment to meet its fixed costs made, for whatever purpose, additional out-of-pocket costs in using it for trips were quite low.

The most impressive feature of the replies to question 13 was the large number of respondents who volunteered under "Other, please specify" that the pleasure or fun of flying, or equivalent considerations, was a major reason for using general aviation. While it comes as no surprise to those close to general aviation that the psychic rewards of piloting loom high in people's minds, it was quite an eye opener that they loomed so high as to be a major reason for traveling by private airplane. This response was volunteered with absolutely no solicitation in the questionnaire.

Neither clubs nor FBO's answered the question, nor were they expected to do so. It would be of some interest to know why people charter aircraft for trips. One suspects that lack of commercial flights to desired destinations and flexibility in scheduling predominate as reasons.

Some respondents answered using the numerical scale as requested, although a tendency existed to use only the extremes (e.g., 5 or zero). Other respondents merely checkmarked the important items and left the others blank. In retrospect, better responses would have been obtained had the scale been printed out so that the respondent merely had to circle the desired response; that is, in lieu of "score each item," instructions would have better been to: "circle the appropriate score:

Not important at all

Very important

0

1

2

3

4

5"

The same critique applies to question 18, discussed later.

The coding variables for question 13 were:

V-28, column 59: lack of commercial flights

V-29, column 60: convenience of base airport

V-30, column 61: cost considerations

V-31, column 62: flexibility in scheduling

V-32, column 63: pleasure, fun of flying

V-33, column 64: other (besides pleasure)

If the sub-questions were fully answered, the coding was 0-5. If the sub-questions were answered with check marks only, then 6 indicated no check and 7 was for checked items. No response at all was shown by 9's. The responses from owners at all four airports are tabulated in Table A-I-5.

Table A-I-5

Reasons for Flying in Transportation

Response	0	1	2	3	4	5	no check	check
Lack of commercial flights to desired destinations								
V-28	66	13	32	36	32	65	17	10
Convenience of base airport								
V-29	65	15	26	43	40	52	16	13
Cost considerations								
V-30	81	25	36	49	16	36	21	6
Flexibility in scheduling trips								
V-31	32	4	15	22	41	127	11	19

(continued)

Table A-I-5 (Cont'd.)

Pleasure, fun of flying

V-32	184	0	1	3	7	53	15	8
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Other (excluding pleasure)

V-33	208	2	2	1	5	29	22	2
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NOTES:

- a) The tabulation is of individual owner responses to question 13.
Not all individuals responded and neither clubs nor FBO's were expected to reply. Responses are from Airports 1, 2, 3, and 4.
- b) Since "Pleasure, fun of flying" was a reply volunteered under "Other," the 184 "zero" and 15 "no check" (code 6) entries indicate "no response" rather than a low valuation of that reason.

Questions Number 14 and 15,

were intended to yield clues regarding the nature of the market areas served by the airports. Questions of this nature could provide useful information for planning airport access transportation and for locating future airports. The information could also help clarify the breakdown between personal and business flying and, with the data from question 15, could reflect the kind of neighborhoods where principal aircraft users are to be found. That is, recourse to census tract data and zip code will make possible an aggregated sociological description of the major users, to the extent that their departure points are well clustered. These data were not required in completion of the present study. They were gathered primarily for possible future studies.

In hindsight it is clear (as with question 16 also) that these responses will be of little help in access transportation planning. The drawback

centers on clubs and FBO's whose members and customers surely account for a majority of surface trips to and from the airport. There was no convenient way to establish origin points for this majority of the airport users. Since access planning was not a major objective of the study, a substantial time or money expenditure was not justified to process the responses to these questions.

The coding variable for question 14 was V-34, column 65, coded:

1 most frequent departure point is residence.

2 most frequent departure point is place of work.

3 most frequent departure point is both of these (both were checked).

9 no response.

For question 15, it was V-35, columns 66-69, the last four digits of the zip code. No response was coded 9999. The first digit was common to all respondents; hence, it did not have to be coded.

Question Number 16,

the number of trips made to the airport, was coding variable V-36, recorded in columns 70-71, tens of trips. Despite the conclusion that the data would be of limited utility for access planning, it was interesting to note that a few "major users" (owners) made many more trips to the airport than they logged flight hours or registered take offs (questions 8 and 9). Presumably these owners frequently came to the airport to work on the airplane rather than to fly it.

Question Number 17,

was included to develop further background on the user profile. It was pertinent only for individually or corporate owned aircraft, not for

clubs or FBO's. Clubs could have been requested to list information (on questions 14 - 17) on each member. The probability of a club going to the trouble to dig out such a large quantity of information is considered minute; in any event, they were not requested to do so. The response to question 17 would be significant only to the extent that the major user's occupation provided data substantively different from question 6, the business or industry in which the aircraft owner is primarily engaged. For example, it would be illuminating to know if "major users" of a corporate owned aircraft were executives or technicians. It was concluded from scanning the returned questionnaires that the additional information gained from question 17 was insignificant in the population surveyed; question 17 was, therefore, not coded.

Question Number 18,

was intended to determine the relative competitive advantages of the airports under study. It would suggest what airport characteristics were perceived as important to airport users (other than FBO's and their customers, from whom answers to the question were not solicited). This marketing information is relevant in a general way to airport planning. It was also hoped that the results would be of some interest to the managers of the airports studied.

Because of certain conscious parallelism in rate setting among the three publicly owned airports surveyed, cost considerations did not loom large. Patrons at the one private airport paid substantially less than their fellows at the other airports, but were few in number. Furthermore, the private field was remotely located relative to the major population

centers of the county and tended to serve the small local communities rather than the urban area served by the public airports.

So far as facilities and services at the airports were concerned, there was little to choose among the publicly owned airports in those facilities and services conveniently available and of benefit to the locally based light plane owner. The significant exception was the ILS (Instrument Landing System) at the air carrier airport. With this system, properly equipped aircraft could land and take off under conditions of reduced visibility; reliability of operations was thereby enhanced and this advantage was cited by a number of respondents. For the few large general aviation aircraft, the long runway at the air carrier airport was not merely preferable but necessary.

The nature of facilities and services available at an airport is likely to be of greater significance to transient airport users than to those locally based. The transient arrival will be interested in surface transportation such as car rental or public transport to his ultimate destination. He may need meal service and lounge facilities (for the flight crew), neither of which constitutes a pressing need to the locals. The survey did not include transients. The question was aimed primarily at the needs of the local, not the transient users.

Under "other," a number of respondents at the smaller airports indicated availability of storage space as the reason for their airport selection. All existing hangar, storage, and tie-down space at the air carrier airport, where these respondents would apparently have preferred to base their aircraft, was taken, with a long wait list for any vacancies that

might arise. The availability problem cropped up so often that it was accorded a separate coding variable, as was the ILS.

The responses were coded as in question 13. The coding variables were:

- V-37, column 72: cost considerations
- V-38, column 73: safety considerations
- V-39, column 74: services available
- V-40, column 75: facilities available
- V-41, column 76: convenience to residence
- V-42, column 77: convenience to place of work
- V-43, column 78: ILS facility
- V-44, column 79: only place with storage available
- V-45, column 80: other

APPENDIX II

Aircraft Insurance

Summary

General aviation insurance is most readily described to non-specialists by comparison with automobile insurance. There are parallels in the types of coverage and illuminating contrasts in the ways that premiums are written. One major coverage is hull, which can include "in-flight," corresponding to auto collision, and "ground," corresponding to auto comprehensive. The other is bodily injury and property damage liability (BI and PD), which corresponds to auto liability and may be expanded to cover suits entered by passengers. Aircraft accidents leading to liability claims are rare relative to single vehicle damage and accessory theft. Since aircraft are expensive to repair and accessories to replace, hull insurance commands most attention in the industry and accounts for the lion's share of the premium payments.

The primary difference between aircraft and auto insurance is the sparseness of statistical data on which to base premiums for aircraft insurance. The entire active general aviation fleet numbers only about 150,000 aircraft, of all ages. This barely surpasses the number of new automobiles that are delivered in just one average week. The tally of active pilots, 600,000 - 700,000, is likewise a tiny fraction of the number of licensed drivers. The time logged by both individual pilots and

vehicles is also lower than that of their highway counterparts. Finally, the number of general aviation accidents is far lower and the number of variables held to influence them somewhat greater. As a result, no sound actuarial basis exists to guide underwriters in evaluating risks and in rationally setting prices and terms of coverage. Perhaps in consequence, aviation insurance is the only one in the property and liability field (besides ocean marine) where prices are unregulated by governmental bodies.

The Coverages

The day to day business of aviation insurance centers on hull insurance which accounts for well over half of the premium expense. Annual rates range from as low as 1-1/2% of the aircraft value on big corporate aircraft to over 15% on small, old, low-valued aircraft. Hull coverage is responsible for the vast majority — perhaps 99% — of the claims¹ submitted. In contrast to automobile experience, few aviation accidents involve third parties. Most occur at the airport during take offs and landing or taxiing and result in limited damage. Hull claims tend to be for repair of partial, not total damage incidents or from theft or weather losses.

As owners invest increasingly in expensive avionics accessories to ease the piloting task, to increase safety of operations in congested airspace, and to permit flight under instrument conditions, theft has become an increasingly serious problem from a claims standpoint. The components are relatively easily removed from one aircraft in a condition suitable

¹Number of claims, not dollar amount of claims. Liability settlements following serious accidents can be high even though the number of liability claims is low.

for installation in another. Few airports go to the expense of providing adequate security, and the market for second hand avionics equipment is apparently large enough to absorb stolen systems and components.

There is also a jurisdictional problem in that no governmental agency exists to trace stolen gear (unless there is proof of interstate movement, in which case the FBI takes over). Thus, over one-half of the hull premium is normally made up by the "ground" or comprehensive portion. Claims under "ground" coverage also include weather damage such as can be incurred during wind or hailstorms.

Under some policies, the ground coverage includes taxiing; under others, the distinction is whether or not the aircraft is in motion under its own power. Taxiing accidents do happen. They can also give rise to third party property damage claims if, for example, the pilot taxis into another aircraft or vehicle. Since the deductible is generally lower for the ground portion of the policy than for the in-flight or in motion coverage, the distinction is generally spelled out carefully in the policy.

The majority of hull claims stem from bungled landings: ground looping, "gear up" landings with retractable landing gear aircraft, and, with certain aircraft, nose gear failure, etc. It is in this area that some underwriting finesse is called for. Aircraft differ both in how prone they are to landing accidents (how "forgiving" they are of pilot errors) and in how expensive the repair will be if a given type accident takes place. Since repairs are no less expensive on old, low-valued aircraft than on new ones, hull premiums climb as a fraction of the aircraft value as this value declines. Some insurers impose a minimum premium regardless of

aircraft value; conversely, a relatively new company has been formed that focuses on the low value aircraft segment shunned by most insurers.

As with automobile collision and comprehensive insurance, not everyone carries hull insurance. Many owners prefer to insure themselves. This is particularly true with owners of low valued aircraft (those worth under \$5,000) who would usually have to pay 10 - 20% of the market value to obtain coverage, an amount they prefer not to spend unless the aircraft is mortgaged and they are obliged by the lender to carry hull insurance. Some wealthy owners also carry no hull insurance at all, or just the "ground risk only" portion. Some owners purchase only ground coverage under a philosophy that is mildly macabre. They reason that any damage from a landing accident would fall within the deductible amount and that any in-flight accident would be so severe that they would not survive to collect under the policy. Others want ground only so as to protect against events over which they have no personal control, such as theft and the elements.

Limits of hull coverage vary. Although normally the limit (in the event of total loss) is the market value, the parties may agree to an agreed or stated value independent of the market. Particularly with old aircraft, policies may incorporate a component parts endorsement, specifying the maximum that will be paid for specific components such as a wing, an elevator, etc. The logic is to limit the liability of the insurer and enable him to sell the policy at a lower price because component repairs on an old aircraft are as expensive as on a new one; they can be even higher if the craft is out of production and the component must be hand fabricated.

Occasionally the policy is written only for the amount of a loan for which the aircraft is collateral. If the loan is for less than the market value, the insured must generally pay a surcharge or settle for a larger deductible than otherwise. As with automobiles, lenders accepting aircraft as security insist on hull coverage to protect themselves in case their collateral is destroyed. Oftentimes they will also request a "breach of warranty" coverage to assure repayment of the loan following aircraft loss under circumstances not covered by the hull policy. Such circumstances might be use by a pilot or in an application (e.g., flight instruction) not authorized in the insurance contract. This breach of warranty insurance is usually quoted at 0.5% of the unpaid balance.

Deductibles vary from one insurer to another and are sometimes subject for negotiation, with lower premiums associated with higher deductibles. The typical (single engine aircraft) policy specified \$50 or \$100 deductible on the ground and \$250 on the in motion coverages. For more expensive aircraft, the deductibles are often higher; for example, \$2,500 on a \$75,000 airplane.

Liability coverage corresponds to that for cars except that claims are infrequent and large since they usually stem from major accidents. The municipal airports studied in this project required minimum liability coverages on all based aircraft (even those under repair and not in flying condition!). The airport owner is thus protected against eventual suits entered by injured parties unsuccessful in suing the owner of an airplane based at the airport. The airport, by guaranteeing to all users a minimum financial responsibility for damages of all other users, effectively raises

the quality of service that it offers. In any event, both brokers and underwriters agreed that most owners carry limits higher than the required minima. The typical policy was 100/300/100, meaning \$100,000 limit per person, \$300,000 maximum bodily injury total, and \$100,000 property damage limit.

In contrast to hull coverage but in parallel with automotive insurance, liability limits are a function more of the insured's exposure to law suits than of the airplane type. With remuneration based on a per cent of the settlement, lawyers tend to work harder suing a wealthy individual or corporation than in suing less prosperous targets who could not afford a settlement were it imposed. Thus, wealthier owners tend to protect themselves with higher limits such as \$500,000 or \$1,000,000. The higher limit coverages tend to be "single limit" per accident; that is, sub limits per individual injured are not specified. In some measure, the more expensive aircraft tend to be owned by the more prosperous owners, who carry high limits; however some wealthy owners of inexpensive aircraft will also take out high limit coverages. With few exceptions, policy limits in excess of \$1,000,000 are no longer sold, as customers with exposure that great tend to carry "umbrella policies" extending over all manner of liability, not merely aviation.

A couple of sidelights emerged during discussions of liability coverage. One is that aircraft renters such as students or pilots renting an airplane for recreational flights can be held liable following an accident; their liability is not covered in the FBO's policy on the aircraft. Some companies offer special liability policies for and to renters. A further

wrinkle is that liability policies on FBO aircraft vary in whether or not the FBO is covered for suits entered by renters, or by renters' estates. Although one might think that a renter operates the aircraft at his own risk, such has not always been held to be the case. In the event of a serious accident, the FBO can be sued for renting an aircraft "beyond the pilot's abilities" or one that suffered mechanical deficiencies responsible for the accident.

People riding in aircraft are not covered by the typical third party liability contract. Although laws vary somewhat from one state to another, those in California make a distinction in riders between passengers and guests. A passenger is one whose presence on board can be construed to involve consideration, hence to impart responsibility to the aircraft owner. Examples include not only the clear cut case of paying passengers in charter or air taxi operations, but also employees flying in company work and prospects being flown to inspect real estate property. A guest is just a friend or relative up for a spin with no implied obligation or consideration. Following an accident, a passenger suit need only prove simple negligence, while a guest must prove gross negligence to win an award. Owners of aircraft carrying passengers tend to carry liability insurance to protect against passenger suits. The usual limit is \$100,000 per passenger seat when the policy is sold separately. Single limit liability policies, that do not limit the payments to any injured party but only a total limit per incident, will simply include an additional premium per seat.

Commercial operators flying passengers for hire (charter and air taxi)

must register with the Civil Aeronautics Board¹ and carry a minimum passenger liability limit coverage of \$75,000² per passenger seat. Since there is no question of liability in such situations, and since, nationwide, there have been a number of third level carrier accidents, the premiums are quite high. Although arrangements differ from one insurer to the next, a typical premium per charter seat is \$350 per year. The rate is higher than average if the flights are unusually hazardous, such as into small, mountain airports, and lower if the aircraft is used only infrequently for charter work.

Passenger liability insurance may incorporate a "medical payments" coverage similar to that sold in the automotive field. Limits vary but seldom exceed \$2,500. Payments made under this coverage imply no legal liability for the injury suffered; they are made whether or not such liability exists. Prompt payment under the medical payments portion of the passenger liability policy benefits the injured passenger and may also reduce his inclination to sue.

A final type of insurance is "admitted liability." Under it, payments are made in the event of death or dismemberment of passengers or guests, whether or not legal liability exists. Admitted liability coverages have never been widely sold to typical general aviation aircraft owners. They

¹Operators of aircraft under 12,500 lbs. design gross weight need only register, filing proof of insurance and other information. Those employing heavier aircraft must not merely provide proof of passenger liability insurance, but also be subject to other economic regulation.

²In California, the Public Utilities Commission requires a minimum limit of \$100,000 per passenger seat.

were formerly popular with large corporations operating fleets of business aircraft (such as executive jets) but are seldom written any more. The original intent was to reassure employees and their families that payments would be effected in the event of accidents during flights on company business. More recently, other company insurance policies have been extended to include the company aircraft and have made admitted liability coverage superfluous. If admitted liability coverage is provided on a company aircraft, then the premium for any passenger liability policy carried will logically be lower than otherwise, since the probability of a lawsuit would be diminished.

Liability insurance limits apply only to the amount of the award or settlement. The insurer also bears "reasonable" additional costs of the insured. In particular, the legal costs of negotiating a settlement or of defense in court are borne by the insurer. These costs can be of the same order of magnitude as the limit itself. As legal costs of defending against suits climb and the amounts awarded by the courts increase, so must the prices that insuring companies charge their insureds.

The Underwriting: Types of Ownership

In contrast to most other property and liability insurance fields where premiums are proposed by rating bureaus for commissioner approval, aviation insurance premiums are set by the individual companies. About ten companies sell the bulk of the policies. Each provides rate schedules and guidelines to its regional underwriters who enjoy substantial autonomy in selecting within the guidelines the premium cost appropriate to a particular customer. Most companies represent pools (or "markets") of

insurance companies whose primary business is not aviation. Each pool member, typically, is limited in the extent of participation in premium revenues — and losses. The companies operate on what amounts to a commission basis and do not participate in losses. Under this arrangement the pool organizer can conceivably prosper in the short run (a few years) at the expense of the pool members. This will happen if the premium level is so low in relation to the risks that net losses are suffered by the pool.

Most insurers that write aviation insurance, as in other fields of insurance, operate through independent agents or brokers but two are "direct writers." In the former cases, the broker or agent contacted by the customer (the "risk" in trade parlance) acts as go-between; he either selects an insurer he knows is appropriate and obtains a quote from that company's underwriter or he obtains quotes from a number of underwriters and chooses the best. The broker, or agent, of course, receives a commission for his service. When the "risk" contacts a "direct writing" company, he deals directly with a salesman, who is a salaried employee of the firm, with some underwriting authority. The industry is competitive. A risk will often shop around to see where he can secure the most favorable rate and coverage package.

The insurance companies work to minimize their "loss ratio," or annual ratio of loss payments to premium intake. The loss ratio must be under about 65% if the operation is to be profitable to the pool members, who receive only about 70 cents of the premium dollar. Agent or broker commissions run 10 - 15% and occasionally less on a large line, and the

insurers themselves (the underwriting firms) have costs and target profits. One insurer claimed a loss ratio under 50%, but most seemed to lie in the 55 - 65% range.

It is through analysis of loss ratios and competition that rates are set. That is, results are reviewed after the fact in search of significant patterns that would justify rate and coverage adjustments in the future. The justifications are often tenuous, with the result that underwriting is a highly subjective, personal business. For example, one insurer will suffer a rash of accidents (meaning perhaps as few as two or three) with one model of airplane and react by increasing premiums or even by refusing to cover further risks with that model. These are often inconsistent from one insurer to the next and lead to the differences in rates and coverages that brokers and agents must learn. With rate setting so dependent on experience and judgment rather than sound statistics, it is not hard to understand why shopping by aircraft owners can be a sensible exercise.

Within a geographic region, the underwriter evaluates his risk in terms of aircraft type, the pilot or pilots who fly it, and the kind of flying to be performed. Among regions, exposure to risk varies because the hazards and the types of operation differ. Weather and topography exert obvious influences on the probability of accidents. Local flying out of a small town airport in the plains states is less likely to result in an accident than hunting trips to Alaska. The temptation to and likelihood of thieves may be less in the plains town than in an urban area, but the probability of hail damage may be higher. Because of these factors,

underwriters tend to become specialists in the territory where they practice.

Neglecting small, special use groups like crop dusters and firefighters, airplane ownership falls into three broad categories:

- 1) Business and personal (B. and P.)
- 2) Clubs
- 3) Commercial (FBO's)

Insurers tend to prefer insuring the B. and P. risks. These are aircraft owned by individuals (or partnerships of up to three members, depending on the company) or businesses using the aircraft for purposes that are not directly revenue producing. The loss experience is best and processing costs the lowest in this category. One company does not handle FBO's at all and another tries to avoid both commercial and club risks. The rate structures tend to be about twice as high for clubs and commercial risks as for B. and P. policies. The club is the hardest to define, as discussed below. The commercial category involves, basically, use of the aircraft for hire and, as a practical matter, includes primarily flight school, rental, and charter or air taxi aircraft.

Flying clubs exist in several guises and each may be treated differently by the same insurer or by different insurers. The most commonly accepted definition of a club is a group of individuals who have banded together to own and fly aircraft. Some firms insist that the club be formally incorporated and that each member share equally in the ownership of the aircraft. Numerical limits such as a minimum of three members and a maximum of eight members per aircraft are typical. Average clubs will

have six to seven members per aircraft, and fleet size varies from one to eight or nine. Some clubs that are properly incorporated and own aircraft are captives to an FBO active in aircraft sales. The salesman organizes the club and manipulates it so as to maximize the frequency of aircraft purchases or trades on which he can collect his commission. Other types of flying clubs are organized by FBO's to fly FBO owned aircraft at reduced rates. Still others center around one legal owner who organizes the club to defray his fixed costs of ownership. Sometimes such an owner will have a flight instructor rating and is, in fact, operating a flight school in competition with the local FBO's. At airports where such quasi-commercial enterprises are forbidden, they must be carried on surreptitiously. The fortunate club will include as a member a licensed and competent mechanic to perform inspections and maintenance as required.

From an insurance standpoint, the principal feature — and disadvantage — of clubs is the high risk exposure relative to B. and P. aircraft. The whole *raison d'être* of a club is to increase utilization of the aircraft so as to spread fixed costs over more flight hours and thereby to reduce the per hour costs to the members; consequently, there is more flight time in a year, and flight time is accident exposure time. Additionally, several pilots have access to the airplane and the experience and expertise of each may be lower than those of a single or of two pilots per aircraft; pilot competence has a bearing on risk exposure when the

aircraft is in flight.¹

Many of the same considerations that work against insuring club aircraft are common to FBO operations: high aircraft utilization and many pilots per aircraft. While a well managed FBO will exercise close control over who rents his aircraft, the same cannot be said for all FBO's. A pilot may be less inclined to exercise care with a rented airplane than with one he owns. For aircraft used primarily in charter work, many underwriters will assume a professional, fully qualified pilot and provide rate breaks in liability and hull coverage accordingly. However, charter aircraft must carry passenger liability coverage which pushes the total premium upward.

Juggling the Airplane - Pilot Mix

The finesse in underwriting lies in matching the aircraft and pilot(s) to a premium and a coverage. There is an element of revenue maximization here, trying to sell as much coverage as possible without driving the would-be client into the arms of a competitor. But the main goal is to avoid entirely those risks believed to be excessively bad and to match premiums to the estimated risk of those applications on which a quote is made.

The first item for attention is the aircraft itself. Aircraft differ widely in complexity and in how difficult they are to keep under control. A twin engine aircraft that cruises at 205 mph and has flaps and retractable

¹There are flying clubs made up of airline pilots; underwriters will clearly rate these clubs more kindly than those including student or relative novice pilots, providing that the airline pilots are "current" in light aircraft.

landing gear is clearly more demanding in pilot skill than an old, surplus World War II spotter plane with only a control stick, rudder pedals, throttle, and a carburetor ice flap and whose cruise speed is about 80 mph. The "hotter" the airplane, the more experience one would like to see under the pilot's belt. The more experience he has in that model of aircraft ("time in type"), the better acquainted he should be with its mechanisms — and foibles. In addition to differences in how "hot" the airplane is, and how complex, aircraft of a given general capability differ in flying qualities. This is partly a question of traditional stability and control as studied in the classroom; it is more a matter of how forgiving the airplane is as the pilot allows it to depart from the desired flight condition: in an emergency, is control loss gentle so that the pilot can recover or is it abrupt such that only violent maneuvers and an altitude drop can serve to regain control? How great are the margins before loss of control becomes a problem? These are questions to which aeronautical science has yet to provide convincing answers. What happens is that aircraft develop reputations among pilots; in some cases they develop consistent accident histories that identify flight conditions to be avoided. To the insurer, such flight conditions are a red flag; sooner or later the pilot will forget, and then there will be trouble.

Examples abound. Probably all companies, and many individual underwriters, have blacklists of aircraft they will not cover at all, or only at certain minimum premiums, regardless of pilot qualifications. The blacklists sometimes, but not always, overlap between insurers, a fact that emphasizes the subjective element in aviation underwriting. Many

insurers shun amphibians and seaplanes. This is not necessarily a castigation of the aircraft design. It is rather based on experience that debris in the water frequently damages such aircraft; at 70 mph during a take off or landing run a partially submerged log can barely be seen, much less avoided if in the aircraft path. Other aircraft are placed on black-lists with far less imposing rationales.

The design, vintage, and spare parts situation of the aircraft play a role by influencing the cost of repairs which may have to be effected. If parts are scarce or expensive or both, repair costs climb. If the design is such that a given accident causes extensive damage (in relation to other aircraft) allowance must be made in the premium. In the event of total loss, market value of the aircraft rather than replacement value of components comes in question for the usual B. and P. policy (unless a stated value is specified) as this is what the risk will be paid (less the deductible). In some cases of total losses of FBO aircraft, the insurer may simply replace the aircraft with an equivalent one; either the company or the FBO may be able to acquire aircraft at wholesale. Such replacement can be quite satisfactory both to the FBO and to his mortgagor.

Where and how the aircraft is based can influence rates, particularly for hull coverage. What is the theft experience? Is the aircraft hangared, to protect it from the elements, and in a securely locked and lit hangar to dissuade thieves? In addition to the base airport, the other destinations are also important. If the owner is active in real estate or construction, will the aircraft be flown into crude, inadequate strips in the boondocks? Similarly, if the owner takes the aircraft on vacations, will these be in

rough terrain that the pilot is not accustomed to handling, or along established airways to well developed airports that pose no unusual hazards? How the airplane is based may give clues as to how well the owner maintains it: an owner who keeps an airplane in a high rent hangar is considered less likely to skimp on maintenance than one whose "bird" is tied down on an unpaved area of the airport, or at an airport where storage charges are low.

The most important factor, of course, is the pilot, or pilots. When more than one pilot is involved, the premium must be based on the least qualified, the most risky. Natural questions are age (at both ends of the scale), physical condition, and recent prior flight history. Consideration is given to prior record such as FAA citations (that are rare) and drunk driving convictions, under the assumption that a pilot who mixes drinking and driving might also try mixing drinking and flying. Last, but not least, is the pilot occupation, with some occupations being considered more favorably than others.

In addition to total flight time and time in type, a pilot with a current instrument rating will receive lower rates from some, if not all, insurers. The reason is that many bad accidents result from pilots flying into weather conditions where they lose visual contact with the ground. Without visual ground reference it is difficult to judge the aircraft attitude in space (little things, like whether or not it is right side up). A properly trained, instrument rated pilot with reasonably recent practice can fairly readily remain "on top" of the situation by referring to the aircraft instruments. He is thus less likely to become a victim after flying

into instrument flight rules (IFR) conditions.

In summary, companies generally provide their underwriters with guidelines in the nature of a two-dimensional grid. On one axis is the aircraft degree of difficulty and spread along the other axis are pilot qualifications for each degree of difficulty, divided into rate categories. For example, for a simple airplane based in a hangar, a single pilot with over 500 hours total and 150 hours "in type" might receive the lowest rate; the same airplane, unhangared, with pilots including a 16 year-old student pilot would bear the highest rate. For a twin engine business aircraft, a single, instrument rated pilot with over 5,000 hours total and 1,000 in type might be the lowest category and no insurance would be sold at all by some firms if a pilot had under 1,000 hours total and less than 50 hours "in type." Within these guidelines, the underwriter has considerable flexibility in selecting among the pilot categories to fix the rate to be quoted. The broker or agent will negotiate with the risk prospect to settle on policy limits.

Helicopters and V/STOL

If there is a dearth of statistical data on conventional general aviation aircraft, the situation is far worse with helicopters and STOL aircraft and impossible for VTOL's since none (other than helicopters) are in service. The fleet sizes for helicopters and STOL are both minute and, in large measure, these aircraft are employed in hazardous, special tasks not characteristic of the recreational and transportation missions of most general aviation. The STOL situation is the simpler and is dealt with first.

A few STOL's are in use and some insurers admit insuring them. STOL aircraft in this context are those that land and take off over a fifty foot obstacle in less than 1,000 feet under "standard" atmospheric conditions.¹ Most of these aircraft are operated by professional (high time) pilots. Markets that insure them do so at roughly the same rates as conventional aircraft of comparable speed and payload. Since the STOL aircraft initial cost is greater, the hull premium is higher, but it is not set extraordinarily high as a per cent of aircraft market value.

Those underwriters and brokers experienced in STOL who were interviewed expressed reservations about pilot technique and the kind of landing spots used. Most believed that special piloting techniques were necessary to push these aircraft to their maximum performance and that accident rates might be higher if many were operated by other than professional pilots.

STOL policies that charge no more than on comparable conventional aircraft generally incorporate an endorsement restricting operations to regular, paved runways, somehow defined. Of course, the major reason for investing the extra funds necessary to buy STOL capability is usually to fly in and out of short fields; if operations are restricted to conventional airports, the STOL loses much of its *raison d'être*. Many owners need the STOL ability to fly in and out of short and sometimes crude strips in the woods or mountains. They presumably pay extra premiums. In short, STOL's operated from airports usable by conventional aircraft pay no more

¹Sea level and 59° F.

for insurance than conventional aircraft of the same value. Whether accident rates would increase, and with them insurance costs, were STOL's operated from paved and sophisticated, but short, urban runways is a matter for speculation.

The situation with helicopters is decidedly less attractive. Hull insurance experience with helicopters has been so disastrous that no American markets currently will handle them. They must be re-insured through London markets (e.g., Lloyd's) and only a few of these will handle them. Liability rates are not extraordinarily high relative to conventional aircraft except insofar as London rates generally are somewhat higher than domestic.

The fundamental problem with helicopters is the difficulty in having any accident that is not serious in terms of destruction to the machine. A landing mishap that might result in only a scraped wing tip with a conventional airplane would result in rotor contact with a helicopter. A rotor in motion simply must not strike a solid object. With extreme good fortune, only one blade need be replaced....a matter of \$1,000 - \$2,000 for most small helicopters. More often than not, all blades are involved and pilot corrective action is often unsuccessful in preventing a roll over accident (on a small machine). A helicopter that rolls over at operating RPM will be a total loss. Indeed, one of every three helicopter accidents does result in a total loss, according to one underwriter.

As a result, hull coverage rates and deductibles are imposingly high. The lowest rate cited was 13% and it was matched to a "rotor in motion" deductible of 10%. "Rotor not in motion" deductible is less of a blow:

\$250 - \$1,000 for small helicopters. The premium climbs as a per cent of market value as market value declines, for the same reason as on conventional aircraft: it costs as much to replace or repair the rotor system and, as necessary, controls, transmission, and cockpit shell on a well depreciated machine as on a new one. The per cent deductible tends to diminish as market value climbs, but there are so few helicopters of greater than five seats in service that trends are not necessarily meaningful.

The practical consequences are that insurance rates prevent many a helicopter business from ever starting and contribute, together with expenses such as maintenance, to keeping operating costs well above the prices that many services could bear. It should be recalled that not only are the rates extraordinarily high relative to conventional aircraft but so also are the base values on which they are computed. A helicopter will cost three to four times as much to purchase as a conventional aircraft of comparable speed, range, and payload. The premiums become substantial. For example, a would-be entrepreneur may be able to buy a used, three- to four-place helicopter for \$18,000. He may find it impossible to obtain a hull insurance quote based at less than \$20,000. At this value, the rate might be 17%, leading to a hull insurance expense of \$3,400; if he has an accident and the deductible is 10%, he will pay the first \$2,000 of repair, or if the machine is totally destroyed, get his \$18,000 back. Insurance on a comparable fixed wing aircraft might run \$600 with a \$250 deductible.

Of course, present helicopter accident experience and insurance

rates are based on the machines and applications typical of the past. The applications are largely special purpose missions characterized by low altitude and proximity to obstacles, sometimes with the added fillip of sling load operations. Apparently not enough helicopters are in service performing strictly transportation duties between safe, prepared landing spots to establish the different accident rates one would expect.

In short, helicopter rates may be unduly high to reflect rates appropriate to uses typical of general aviation, but insurance costs must remain high relative to fixed wing aircraft because of the inherent vulnerability of helicopters to serious damage in the event of accident, coupled to an inherently greater cost. The prospect for other VTOL concepts is clouded but similar. All involve large power sources activating devices to accelerate air downward in low speed flight. In many cases, the probability of an accident following a loss of control over all this power may be higher than on a helicopter, but the critical unknown for insurance purposes will be the relative probabilities of minor and major accidents.

Implementation: Costs Used in the Calculations

For purposes of this study, the objective was to sift available data on insurance and to develop numbers that would be representative of the insurance costs borne by airport users. By representative is meant an average among a series of means taken in identifiable categories. The procedure followed was to gather estimates made by practitioners in the field and to suppose that each practitioner accurately identified the means among rates and coverages that were assumed normally distributed

among his risks. Finally, the means of different practitioners were given approximately equal weights in arriving at composite insurance costs to be applied to the fleet.

A drawback of the procedure was that no provision is made for casualty costs borne by the users but not covered by insurance. These include the deductibles under policies that have deductibles, losses that were not insured, and losses on which claims were not submitted for one reason or another. They are believed insignificant in the aggregate. To the extent that they are significant, the insurance costs used in the study understate the casualty costs actually borne by general aviation.

The calculation started with plots (where applicable) against convenient parameters of values considered by practitioners to be typical of the policies sold. Straight lines suitable for simple mathematical presentation on the computer were drawn through the resulting points (Figure A-II-1) and the corresponding equations defined. These equations were then modified (downward) to reflect the consensus of practitioners regarding the percentages of users who purchased the coverages at all. For example, hull insurance on a \$4,000 airplane might be charged at 10% or \$400 but if only 25% of the owners carry hull coverage then 2.5% is the composite rate.

The resulting insurance cost components used in the aircraft cost computations are as follows:

1. Business and Personal

- A. Bodily Injury and Property Damage (BI and PD)

- 1) Single engine aircraft valued at \$20,000 or less: \$65.00

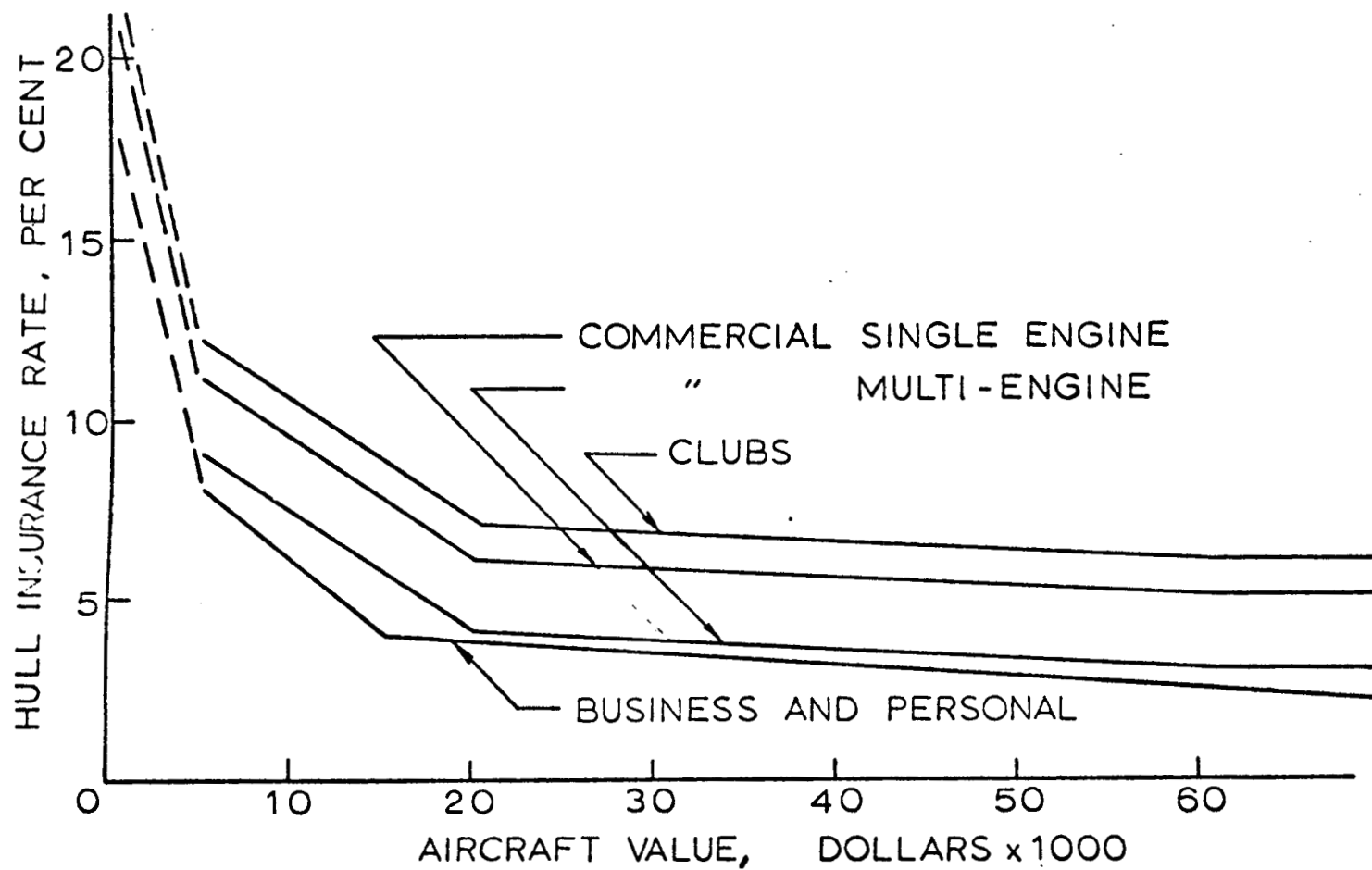


Figure A-II-1. - Typical hull insurance rates

- 2) Multi-engine aircraft and all aircraft valued over \$20,000: \$100.00
- 3) Assumptions are that \$65.00 is typical premium for the 100/300/100 BI & PD coverage commonly carried and that \$100.00 is a fair representation of higher limit policies carried by businesses and financially vulnerable (rich) owners. The approximation is made that these higher limits (\$500,000 or \$1,000,000) can be associated with the higher valued aircraft. Note that not many multi-engine aircraft valued at under \$20,000 are in service. All aircraft based at the airports studied had to carry minimum liability coverages to comply with local laws.

B. Passenger Liability

A rate of \$35 per passenger seat (total number of seats less one) is charged to all multi-engine aircraft, to all aircraft valued at over \$20,000 and to all other aircraft used over 20% of the time for company or private business. It is assumed that all aircraft in these categories, but no others, will carry passenger liability coverage and that \$35 is a representative rate. Note that single limit policies would, in practice, combine the passenger and other liability coverages by formulae more complicated than simple addition. Neglect of this complexity is believed not to influence the resulting average rates significantly.

C. Hull

- 1) Aircraft value ($V_{a/c}$) less than \$5,000: $\$0.05 V_{a/c}$
- 2) $\$5,000 \leq V_{a/c} < \$15,000$: $\$0.006 \frac{25,000 - V_{a/c}}{2,500} V_{a/c}$

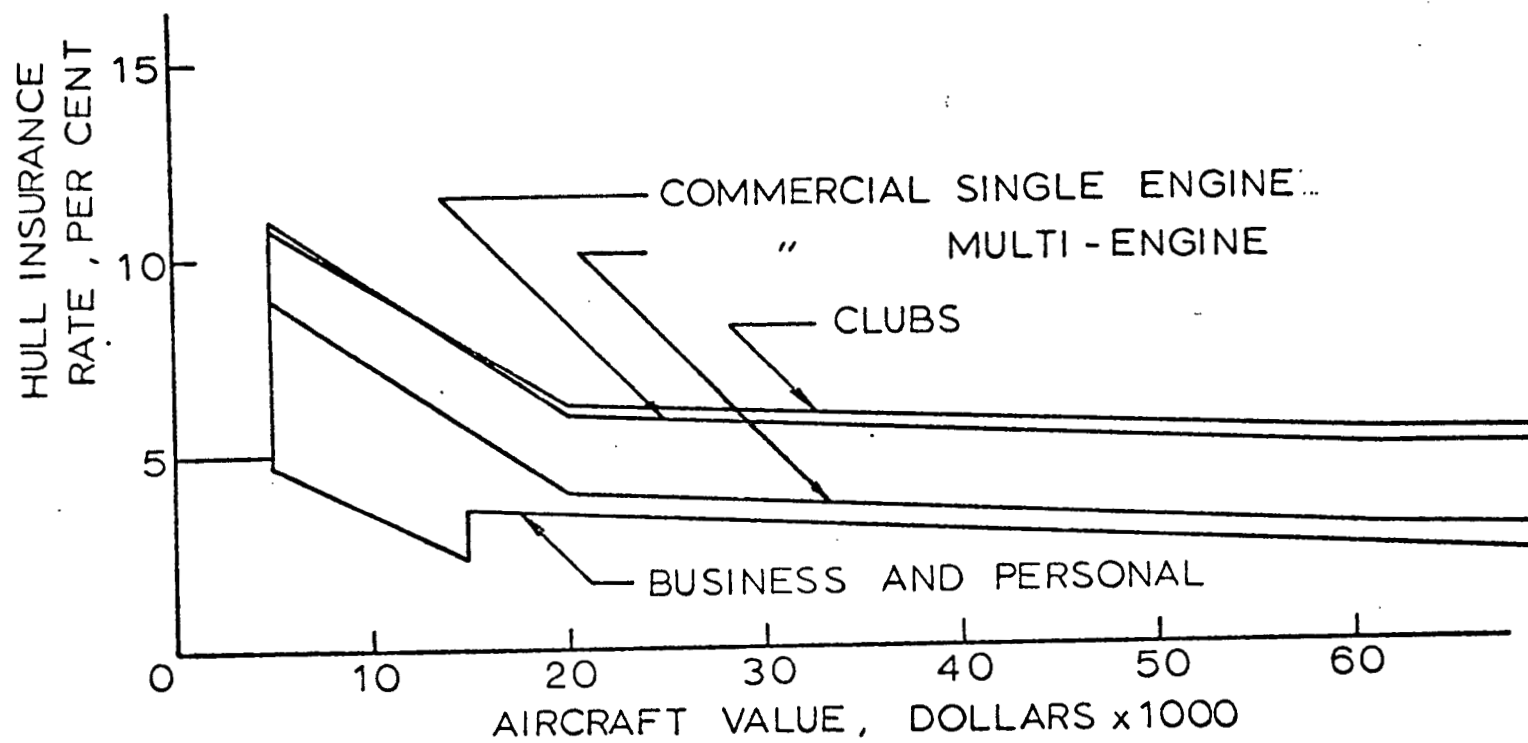


Figure A-II-2. - Hull insurance rates used in calculations

$$3) \quad \$15,000 \leq V_{a/c} < \$85,000: \quad \$0.009 \frac{155,000 - V_{a/c}}{35,000} V_{a/c}$$

$$4) \quad \$85,000 \leq V_{a/c} \quad : \quad \$0.018 V_{a/c}$$

- 5) Assumptions: (a) few aircraft valued at under \$5,000 will carry hull insurance, perhaps 25%; however, rates charged for these few, as a per cent of aircraft value, are so high that 5% is the best estimate of the average rate.

(b) That the combination of owners in the \$5,000 - \$15,000 who take no hull coverage at all, or who take only ground coverage (about 50% - 65% of full coverage, depending on whether or not the aircraft is hangared) leads to an effective fraction of 60% of the typical premium in this range, which is

$$\left(8 - \frac{V_{a/c} - 5,000}{2,500} \right) \%$$

(c) That the corresponding fraction for higher priced aircraft is 90%; most risks carry hull but a few are self insured and others settle either for higher deductibles than normal or for a stated value limit less than the aircraft value. The assumed premium in the \$15,000 - \$85,000 range is

$$\left(4 - \frac{V_{a/c} - 15,000}{35,000} \right) \%$$

and, over \$85,000, 2%.

2. Clubs

A. Bodily Injury and Property Damage

The basic coverage is assumed to be 100/300/100 at a premium

of \$150.00 for all aircraft. Quotes alleged to be typical of clubs ranged from about \$85 to \$200. The \$150.00 figure may be a little higher than the actual club average.

B. Passenger Liability

The typical premium on a \$100,000 limit per passenger seat is taken to be \$100/seat, but it is assumed that only 10% of all clubs carry the coverage at all so that the average annual payment is \$10/passenger seat. Few clubs, and none in the survey sample, operate aircraft with more than six seats. One insurer would offer only a maximum limit of \$50,000/seat because of its poor experience with clubs.

C. Hull

The rate formula used were:

- 1) $V_{a/c} < \$5,000$: $\$0.05 V_{a/c}$
- 2) $\$5,000 \leq V_{a/c} < \$20,000$: $\$0.009 \frac{(41,000 - V_{a/c})}{3,000} V_{a/c}$
- 3) $\$20,000 \leq V_{a/c} < \$60,000$: $\$0.009 \frac{(300,000 - V_{a/c})}{40,000} V_{a/c}$
- 4) $\$60,000 \leq V_{a/c}$: $\$0.054 V_{a/c}$
- 5) The assumptions are similar to those set forth under Business and Pleasure hull coverage. For low valued aircraft 5% is taken as an approximation reflecting the fact that many such club aircraft will not be insured; many clubs owning unmortgaged aircraft find it more advantageous for members to make periodic payments into a contingency or new airplane kitty rather than to take out relatively expensive insurance. For aircraft valued \$5,000 or more, it is

assumed that 90% are insured for full risk hull coverage.

3. Commercial

A. Bodily Injury and Property Damage

The base rate is assumed to be \$150.00 for 100/300/100 coverage. Few FBO's will purchase higher limits. Aircraft used solely for charter may be charged lower premiums than others because it is assumed that the pilots are professional and fully qualified, even though utilization (hence, exposure) may be high.

B. Passenger Liability

- 1) Less than 10% charter flying. It is assumed that all such FBO aircraft are insured for passenger liability according to the formula $\$150 + \$100 \times (\text{number of passenger seats})$, or, \$250 for a two-place airplane, \$350 for a three-place, etc.
- 2) More than 10% charter flying. The base rate per passenger seat is assumed to be \$350.00. All aircraft used over 10% charter are assumed to be insured for the full year at the California legally required \$100,000 limit. FBO's who use aircraft for charter only occasionally may make arrangement for temporary coverage, as needed, or otherwise economize on premiums; therefore, in the computations, the lower, standard commercial rate was applied to FBO aircraft flown less than 10% of the time in charter service.

C. Hull

- 1) Single Engine

$$\begin{aligned}
 V_{a/c} &< \$5,000 && : \$0.05 V_{a/c} \\
 \$5,000 &\leq V_{a/c} < \$20,000: \$0.01 \frac{(38,000 - V_{a/c})}{3,000} V_{a/c} \\
 \$20,000 &\leq V_{a/c} < \$60,000: \$0.01 \frac{(260,000 - V_{a/c})}{40,000} V_{a/c} \\
 \$60,000 &\leq V_{a/c} && : \$0.05 V_{a/c}
 \end{aligned}$$

2) Multi-Engine

$$\begin{aligned}
 \$5,000 &\leq V_{a/c} < \$20,000: \$0.01 \frac{(32,000 - V_{a/c})}{3,000} V_{a/c} \\
 \$20,000 &\leq V_{a/c} < \$60,000: \$0.01 \frac{(180,000 - V_{a/c})}{40,000} V_{a/c} \\
 \$60,000 &\leq V_{a/c} && : \$0.03 V_{a/c}
 \end{aligned}$$

3) Assumptions

- (a) That many FBO's will self insure their low valued aircraft rather than pay high hull premiums.
- (b) That all FBO aircraft over \$5,000 in value will carry all risk hull insurance.
- (c) That twin engine aircraft (the only multi-engine type pertinent to this study) will qualify for somewhat lower rates than single engine aircraft because of multi-engine reliability (safety) and the assumption that they are generally flown by competent, professional pilots, as in charter work.

In conclusion, it is emphasized that these numbers result from aggregating and simplifying inputs from several sources. The inputs were, in all cases, estimates only and did not always refer to comparable policies and risks. They should lie within the range of premiums charged by all

insurers and, hopefully, close to the average premiums of most, based, as indicated, on the average of owners' preferences in how much insurance to carry.

APPENDIX III

Variable Operating Costs

Summary

As analyzed in this and other studies,¹ aircraft variable costs are of three major types:

- 1) Fuel and oil consumption.
- 2) Powerplant and propeller wear, reflected in overhaul costs that can be pro-rated over the time between overhauls (TBO).
- 3) Airframe wear and deterioration, part of which is unrelated to flight hours but all of which is customarily assigned to periodic maintenance and inspection costs, pro-rated over the hours flown.

The hourly fuel costs of piston engine aircraft are the easiest to approximate since average fuel consumption can be estimated within 10 - 20% from engine horsepower. Engine and propeller costs can be fixed with corresponding accuracy if the engine make and model is known; in the study, make and model were not included in the data and an approximate per hour cost curve in terms of engine horsepower was defined and used. Maintenance and inspection costs vary with labor rate, the prior

¹For example, General Aviation Aircraft Operating Costs, Department of Transportation, Federal Aviation Administration, Office of Policy Development, February, 1969. This FAA report includes certain additional costs that are treated differently herein.

maintenance history of the aircraft, and the operator's maintenance philosophy; consequently, these costs are very difficult to estimate accurately. A multiple regression analysis of a small sample of estimated maintenance costs was performed. It yielded a cost function in terms of horsepower and maximum speed.

Fuel

Fuel cost is computed on an hourly basis. It is the hourly fuel consumption, in gallons, times the cost per gallon. The fuel consumed by an aircraft will vary, as does that of an automobile, with pilot technique, aircraft loading, and, to a minor extent, engine condition. Many of these variations are indicated in the owner's manuals that are supplied with each new aircraft. For purposes of this study, the following assumptions were made:

Specific fuel consumption : 0.51 lbs/hp. hr.

Throttle setting : 70% rated hp.

Fuel density : 6 lbs/gal.

Resulting fuel consumption: $(0.51) (0.7) / 6 = 0.06 \text{ gal/rhp-hr.}$

(where rhp means rated horsepower).

This formula was found to underestimate some manufacturers' claims for "normal" fuel consumption and to overestimate others, but the discrepancy was rarely over 20%. For turbine powered aircraft, other formulae would hold, but none was analyzed in the study. With a turbine, both the specific fuel consumption and the throttle setting would be higher, and the fuel perhaps a little more dense, but the combinations are more complicated by airspeed and altitude than they are with piston engines.

In 1969, the pump price per gallon of aviation fuel included in the following components:

- 1) The wholesale price (less taxes collected) paid to the supplier (the oil company). For 80 octane gas in Santa Clara County, California, in 1969 this price was approximately 26¢.
- 2) The federal gas tax of 4¢. Of this, the buyer could apply for a 2¢ refund, while the remaining 2¢ went into the Highway Trust Fund.¹
- 3) The state gas tax. In California, this amounts to 7¢;² the buyer can request a refund of 5¢, the remaining 2¢ going into an Aeronautics Fund and an Airport Assistance Revolving Fund (AARF). If the owner requests the refund, then he must pay the state sales tax of 5% on the price paid less the 7¢ state tax. For prices in the 45 - 50¢ range, the sales tax reduces the effective refund to about 3¢.
- 4) The pumping costs. These include direct labor and allocated equipment depreciation and operating costs, plus allocated rental on land. The direct, per gallon costs of fueling a large aircraft are less than those of fueling a small aircraft. One

¹Under Sec. 202 of the Airport and Airway Revenue Act of 1970, 84 Stat. 237, the federal tax was increased by 3¢ to 7¢ as of 1 July, 1970 on all fuel used in general aviation save that used for agricultural purposes and other minor exceptions. None of the 7% tax is refundable; all monies are now transferred to the Airport and Airway Trust Fund.

²A brief outline of the state tax situation nationwide is presented by Thomas H. Hughes in "Aviation Fuel Tax Program," pages 15-18 of the Course Notes, Tenth Short Course in Airport Management, Institute of Transportation and Traffic Engineering, University of California.

estimate of the cost range was 1 - 3¢/gal.

- 5) Fuel flowage fees to the airport owner (when FBO's other than the airport owner pump the fuel). These fees represent a significant source of user payment to the airport. Various schedules of fees are found: in some a fixed fee is levied on every gallon pumped; in most, the fee varies with the number of gallons that are sold by that outlet in the year. The fee increases in some cases but decreases in most so as to give the FBO an incentive to increase business (by increasing his marginal return per gallon). A typical fee structure would be:¹

4 cents per gallon for the first 150,000 gallons of fuel.

3 cents per gallon for the next 150,000 gallons of fuel.

2 cents per gallon for each and every gallon thereafter.

- 6) Profit to the pumping organization, hopefully reflecting a desired rate of return on investment in pumping facilities and equipment. If the airport owner (the government at publicly owned airports) sells the fuel, this profit can be considered the user payment in lieu of a fuel flowage fee. Its amount is obviously a function of markup over costs.

When the fuel is purchased by an FBO (or certain other privileged users) a price reduction such as 2¢/gal under the pump price is sometimes made. If an FBO sells fuel, then the price he sees in fueling his

¹From Airport Ordinance, Rules, and Regulations, County of Santa Clara, January, 1968. An 8¢ per gallon fee was also levied on oil and lubricants. In February, 1970, the fuel fees were increased by 2¢ each, with the same quantity break points.

own aircraft is his total costs, items 1 - 5, plus his target rate of return.

Of these price components, the refundable taxes are clearly not valid costs to the buyer. It is his prerogative not to collect refunds to which he is entitled. His failure to do so means only that he is indulging in unsolicited philanthropy to his government, not that his costs of flying are raised. The aviation fuel taxes that were paid into the highway trust fund, in particular, but to other regional funds also, bear no direct relation to resources consumed. They can be considered reimbursement by the users for economic costs imposed on the public only in an indirect and irregular sense. (Some highway trust fund monies go to improve access to some airports; the State Division of Aeronautics and its AARF provide resources of direct benefit to some aviators). The unfunded taxes are not direct payments to the airport but are unavoidable elements in the price that the user must pay; hence, in this study, they have been considered as part of his fuel cost per gallon.

For each airport, then, the cost borne by the user per gallon has been computed as illustrated in the following example:

	Cents/gallon
Pump Price (1969; 80 octane)	46
State tax	7
Price subject to sales tax	39
Refund requestable	5
Sales tax at 5%	1.95
Effective amount of state refund	3.05

Federal tax refund	2
Total tax refunds	<u>5.05</u>
Price corrected for tax refunds	40.95
Fuel flowage fee to airport	<u>3.5</u>
Price to buyer less payment to airport	<u>37.45</u>

Note that pump prices were not identical at all airports, that the pump price to an FBO was less, by two cents, and that the price of 100 octane gas was higher by four or five cents per gallon. In the calculations, it was assumed that all engines under 250 horsepower burned 80 octane gas and that the rest burned 100 octane gas. The fees paid to the airport are costs to the buyer but were subtracted from the price to the buyer because they are subjects of the study.

Powerplant and Propeller Overhaul

Most powerplants in general aviation are still piston engines and attention was given exclusively to their costs. Several engines, spanning a horsepower range from about 65 to 450, are in service. Two manufacturers account for most of the market but two others have appreciable shares. Comparable competing engines of a given horsepower, whether of one manufacturer's line or of different manufacturers, differ not only in time between overhaul (TBO) and cost of overhaul but also in operating characteristics. Pertinent differences include fuel consumption, relation between output power and R.P.M., reliability, ease of starting, serviceability, etc. Engines of a given horsepower also differ in sophistication over a range from the simple, aspirated (carburetor), direct drive models upward through fuel injection, geared, partly supercharged, and

fully turbocharged versions, each offering cost and performance advantages and penalties.

Overhaul costs are largely direct labor and, therefore, vary with labor rate. San Francisco Bay area labor rates were held by most shop managers interviewed to push total overhaul costs some 20 - 25% higher than those prevailing in other parts of the country. When an engine is sufficiently worn that acceptable tolerances can no longer be maintained through overhaul, it can be subjected to remanufacturing, at a cost about 25 - 30% greater than an overhaul. Overhaul costs climb with sophistication, taking a big jump in most cases of full supercharging and a lesser, but still significant jump with gearing. Overhaul costs tend, in the aggregate, to climb with rated horsepower; however, both design variations and the experience of shop personnel with a particular model (related to the number in service) cause minor irregularities in this trend, even for engines of the same complexity.

Overhaul costs logically include not only the price charged by the specialized shops that perform them, but also other work which may come to light upon engine removal for overhaul. Engine mounts may have deteriorated and require service. Accessories such as starter or magnetos may not be included in the overhaul cost and need attention. The latter costs are hard to estimate, because they depend so much on the maintenance and use history of the aircraft and on things like variations in manufacturing quality and how the aircraft is stored.

TBO is determined by design and how widely the engine type has been in service. Long and widespread time in service leads to thorough debugging

and to an experience base that permit increasing the TBO. TBO tends irregularly to decline as rated power increases. The decline may be more a result of the fact that the larger engines in service are fewer in number and have, in general, been on the market a shorter time rather than of an inherent tendency toward more rapid wear.

Propellers are usually overhauled at the same time as the powerplant. For simple, fixed pitch propellers, overhaul consists mainly in filing down knicks and resurfacing. For variable pitch propellers, the pitch change mechanism and, as appropriate, governor will require attention. Generally, propeller size, complexity, and overhaul cost will climb with engine horsepower.

For purposes of the study, overhaul cost estimates and TBO data on a variety of engines were obtained from three separate sources and converted into overhaul costs per hour. These cost points were then plotted versus horsepower. A curve consisting of two linear segments was drawn that seemed best to summarize the scatter exhibited by all the three groups of points. High points corresponding to turbocharged engines (known to be rare in the fleet under study) were subjectively accorded less weight than other points. Otherwise, no weighting was performed. It was considered beyond the scope of the study and unnecessary to its objectives to ascertain how many engines of each model, were in service and to weight the points accordingly.

The final curve, Figure A-III-1, was of the form:

$$\begin{array}{ll} \text{rhp} \leq 106 & : \$0.75/\text{hr} \\ \text{rhp} > 106 & : \$0.01 (1.2 \text{ rhp}-50)/\text{hr}. \end{array}$$

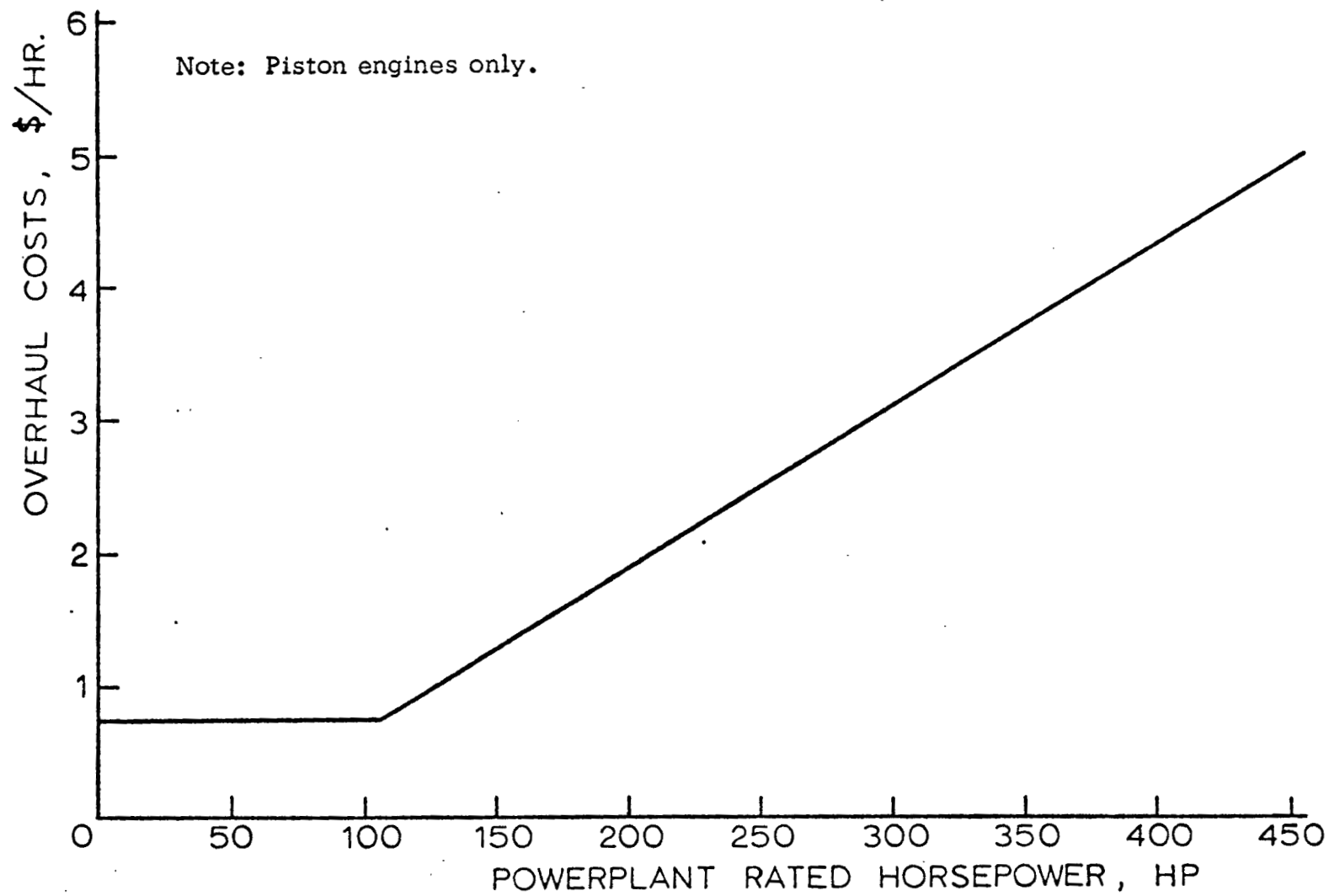


Figure A-III-1. - Engine and propeller overhaul costs

Maintenance and Inspection

Maintenance and inspection costs are, if anything, harder to pinpoint than insurance costs (Appendix II). Not only do aircraft differ in design, both in how fast they wear out and in how easy it is to inspect and service parts that do wear out, but wear and deterioration will vary with how the aircraft are used and stored. Most important, maintenance can be traded off against accelerated deterioration, which is reflected both in a loss in value that an expert buyer can detect and in degraded safety that is hard to quantify in monetary terms.

Owners differ greatly in their approach to maintenance. Prosperous owners and many business owners will have their aircraft serviced at regular intervals by the manufacturers' authorized dealers. The dealers usually are FBO's in their own right and do the maintenance on their own fleets. Dealer service leads to high visible out-of-pocket costs that are shunned by the majority of individual owners who own old rather than new aircraft. These less prosperous owners resort to various stratagems to effect the maintenance they consider necessary and the annual inspection that is legally required.

First, there are established shops unaffiliated with dealers (as in the automotive field). These shops may have lower overhead costs and billed labor rates than dealers; they sometimes use parts manufactured by other than original equipment manufacturers (OEMs) and sold at lower prices than offered by OEMs.

Second, and a more common stratagem, is the "rolling repair station" which consists of a tool kit in the trunk of a licensed mechanic's automobile.

This mechanic works on other people's aircraft in his spare time (moon-lights). His labor rate is probably about half that charged by the regular shops. The quality of work offered by rolling repair stations probably varies over a wide range. Nonetheless, these men can legally perform the required annual inspection and, within the limits of their toolbox and imagination, remedy deficiencies uncovered during the inspection.

Lastly, the owner may do much of the maintenance and inspection work himself. Much of the work requires more in terms of time than special skills and can be handled by reasonably capable do-it-yourselfers. Not unknown is the owner who has an aircraft for the joy of working on it rather than for the pleasure or utility of flying it; almost one per cent of the airplanes surveyed were grounded during all of 1969. Antique and home-built airplane clubs are remarkably active. These owners then contact a licensed mechanic, who may not even have a rolling repair shop, to come and inspect their handiwork. He will sign the required forms for a small fee such as \$25.00.

The spread in monetary costs implied above for these different approaches to maintenance is not merely in labor and, occasionally, in non-OEM parts. It is often in mark downs from retail. The safety conscious owner will change oil every 50 hours.¹ The dealer will charge the full retail rate of around 60 - 70 cents per quart. The owner can purchase oil in bulk elsewhere for as little as 36¢. Discounts on other items may be significant. For example, there are two spark plugs per

¹Every 25 hours if his engine lacks an oil filter. Typical engine capacities run between 6 and 14 quarts.

cylinder, four or six cylinders per engine; spark plugs retail for about \$5.50 each, or about \$14.00 for "platinum" plugs that are believed more reliable but both can be purchased at 20 - 40% under retail. Since spark plugs should last about 300 hours, the resultant savings per hour are not gigantic, but several such economies can mount up to appreciable sums.

The chief difference between dealer and non-dealer service probably centers on intensity of maintenance. Prosperous individual and business aircraft owners usually have aircraft inspected every 100 hours even though an annual inspection is all that the law requires. Commercial operators such as FBO's are legally required to inspect at every 100 hours and usually submit to 50 hour inspections as well. These inspections are in search of deficiencies: safety of flight items that must be tended to. During the operational history of any aircraft model, safety related engineering changes, such as a component re-design, occur. Most are confirmed by FAA Airworthiness Directives (AD's) sent to all registered owners of that model directing that the changes be incorporated either immediately or at the time of the next inspection. The manufacturer also furnishes his dealers with service bulletins concerning remedies for troublesome components. The dealer, during inspections, will automatically note unincorporated AD's with other deficiencies and will also list "squawks," which are items such as service bulletins or work recommended to forestall costlier subsequent repairs.

The approach taken for the study was to seek an expression for hourly maintenance costs at dealer shops in terms of variables that were available on the data cards (Appendix I). Dealer shop managers were asked to

estimate maintenance costs on specific aircraft. The aircraft were of known characteristics: installed power, number of seats (a proxy for payload), and maximum speed. Under the assumption that maintenance costs could be defined as a linear relationship among these variables,¹ a multiple regression analysis was performed using cost estimates on 45 different airplane types.

The results of the preliminary analysis are shown in Exhibit A-III-1. The number of seats is seen, in the correlation matrix, to correlate positively with both horsepower and speed. That is, the more seats on board, the greater the installed power, as is to be expected, but also the greater the cruising speed. The probable explanation is that multi-passenger aircraft are used more for transportation, where speed is important. More to the point, the number of seats was insignificant as a predictor of maintenance and inspection costs, as can be seen from the small value of Beta squared.

In the second analysis, Exhibit A-III-2, the number of seats was omitted as a predictor. Scarcely any accuracy was lost, as measured by the coefficient of multiple correlation, plus 0.937 without number of

¹Some shop managers stated that maintenance and inspection costs per period would climb as the aircraft aged because some components simply deteriorate with age. This deterioration would occur more rapidly for aircraft not hangared than for hangared aircraft but would inevitably show itself. A sophisticated analysis would correct for age as a variable and, perhaps, include the storage history. In the present study, it was assumed that these cost differences were so small (and the storage history not available) as to be overshadowed by the differences in labor cost cited; they have, therefore, been ignored. They may also be partially reflected in deterioration and, thence, in depreciation cost.

seats and plus 0.938 with. Since 1.0 would mean perfect correlation, the prediction is considered satisfactory. The distribution in variable values is discernable from the means and standard deviations shown. The final equation for maintenance and inspection (including oil changes) cost, in dollars per hour, was:

$$C_m = -1.52 + 0.013 \text{ HP} + 0.019 V_m$$

where HP is the rated horsepower and V_m is the design maximum speed in miles per hour.

The resulting linear equation should accurately reflect average dealer charges on well maintained aircraft. For aircraft serviced under contract, for other FBO's or for the lessors of leaseback aircraft, typically, a 10 per cent reduction (to $0.9 C_m$) would be given by the dealer shops. It was assumed in the study that business aircraft would be maintained by dealer shops and non-business aircraft would be otherwise maintained. The breakpoint was arbitrarily chosen to be 35% or more of flight hours for business purposes; such aircraft were charged the full C_m . The cost for non-business aircraft was correspondingly set at 60% of the dealer shop cost, $0.6 C_m$, to reflect the lower costs incurred, on the average, by owners not patronizing dealer shops. It is assumed to include any depreciation in value in excess of normal that results if the cheaper maintenance is, indeed, substandard.

Although the regression analysis is straightforward, some comments on the input cost data are in order. These were based on off-the-cuff estimates by five shop managers.¹ The managers were asked to quote

¹Three from one manufacturer and one each from two other manufacturers.

Exhibit A-III-1

Results of Regression Analysis Using Three Variables to Predict
Maintenance and Inspection Costs

Correlation Matrix

	HP	No. of Seats	V _m	C _m
HP	1.000	0.754	0.903	0.930
No. of Seats	0.754	1.000	0.715	0.684
V _m	0.903	0.715	1.000	0.889
C _m	0.930	0.684	0.889	1.000

Coefficient of Multiple Correlation, R: + 0.938

F for analysis of variance on R: 97.337 (Number of degrees of freedom: 3,40)

Contributors to R:

Predictor	Beta Squared
HP	0.527
No. of Seats	0.004
V _m	0.078

Nature of Data:

Test	Mean	Standard Deviation
HP	348.07	161.98
No. of Seats	5.55	1.66
V _m	200.52	41.05
C _m	6.7361	2.9678

Exhibit A-III-2

Results of Regression Analysis Using Two Variables to Predict
Maintenance and Inspection Costs

Correlation Matrix

	HP	V _m	C _m
HP	1.000	0.903	0.930
V _m	0.903	1.000	0.889
C _m	0.930	0.889	1.000

Coefficient of Multiple Correlation, R: + 0.937

F for analysis of variance on R: 147.309 (Number of degrees of freedom: 2,41)

Contributors to R:

Predictor	Beta Squared
HP	0.475
V _m	0.071

Nature of Data:

Test	Mean	Standard Deviation
HP	348.07	161.98
V _m	200.52	41.05
C _m	6.7361	2.9678

Final Computed Equation:

$$C_m = -1.52416 + 0.01262 \text{ HP} + 0.01928 \text{ V}_m$$

from memory the billings for service costs over a 100 hour period, including inspections, oil changes, and maintenance according to manufacturer guidelines; that is, a 100-hour, a 50-hour and sometimes two 25-hour inspections, oil changes, repairs and adjustments. Inspection and standard servicing charges do not vary much over different aircraft of a particular model, given the dealer's inspection labor rate (which was usually \$1.00 - \$2.00 lower than the standard labor rate). Some variation occurs because mechanics work at different speeds and because any mechanic can inspect and service an airplane with whose maintenance history he is familiar faster than he can one of the same type that he is inspecting for the first time. But the major uncertainty leading to variations in estimates (over and above variations due to billing rate differences) lies in the costs of rectifying deficiencies and squawks uncovered during inspections. In none of the shops had billings ever been statistically analyzed to ascertain standard costs.

All rejected as unrealistically low the average hourly maintenance costs published in their own manufacturer's sales literature. The kindest estimate was that the actual costs are greater by 33%, but some discrepancies of 150% were admitted. Most managers agreed that the differences were only partly accounted for by the high local labor billing rates (which include overhead rates running 100 - 150 per cent).

The preceding discussion relates to inspections and maintenance on the airframe and includes the normal engine and propeller service besides overhaul. It does not include servicing of electronic equipment. Nearly all aircraft operating in metropolitan areas have at least radio communications

gear on board for contact with control towers. Most have navigation aid equipment in addition. Increasingly, aircraft have stabilization devices to aid in the piloting task. Some have instrument landing aids on board. Those flying in high density traffic areas carry radar transponders (to assist ground based air traffic controllers in aircraft identification). Laws in some areas require the installation of emergency radio beacons to assist searchers after a crash in uninhabited areas. All of this avionics gear is subject to failure, hence to servicing, repair, and replacement costs. Avionics maintenance requirements are best described as stochastic. Equipment in one installation will function flawlessly for years while supposedly identical equipment in another installation will be continuously in and out of the repair shop. No data were found on which to base average avionics maintenance costs. They have been ignored in the study, a clear understatement of costs but one whose extent is unknown.

In conclusion, the typical dealer shop maintenance charges computed would overstate monetary costs if applied over the entire fleet: shoestring many operators simply do not purchase services of dealer quality and price. The 60% factor used to reduce dealer costs on aircraft predominantly used for other than business purposes may, itself, be high. On the other hand, neglect of avionics related costs leads toward understatement of total maintenance costs. It is assumed, for want of better information, that the effects are self-cancelling on the average.

APPENDIX IV

Depreciation Costs

Depreciation is the decrease in economic value of a fixed asset over time, whether the result of deterioration, technological obsolescence, style change, or whatever. As the Civil Aeronautics Board has written for airline aircraft,

"Aircraft do not deteriorate in a physical sense. Under normal maintenance, they can be kept in an operational state for indefinite periods of time. Thus, depreciation is essentially caused by the loss in market value of the aircraft attributable to technological obsolescence factors."¹

The same holds true for general aviation aircraft.

The annual decrease in value is a cost to the asset owner. It will usually diminish in magnitude as the asset ages. The following section describes research performed to derive a schedule showing depreciation costs as a function of aircraft age. A statistical analysis of used aircraft values was performed to develop the schedule for aircraft over one year old. A means for estimating depreciation during the first year was developed on the basis of interviews. A complicating factor in regard to new aircraft is the large number that are in the hands of FBO's under sale-leaseback agreements that are, accordingly, also discussed. Note that economic depreciation in this context is the loss in market value over a

¹Aviation Week and Space Technology, August 17, 1970, p. 37.

12-month period, measured in constant dollars, and is quite different from depreciation used for financial accounting or tax purposes.

Since a basic input to the computations, as explained in Appendix I, was the 1969 market value of each aircraft, a function expressing the depreciation during the year, 1969, in terms of this variable was sought. To do so, a statistical analysis of market value decreases for over 40 aircraft types was performed. The change in market value over a 12-month period was expressed as a fraction of the final value. Factors of the form:

$$\frac{\text{Value in year (y-1)} - \text{Value in year y}}{\text{Value in year y}}$$

were generated for several airplanes of different ages for $y = 1969$ and $y = 1968$.

The analysis was premised on the simplifying assumption that, on the average, all aircraft decrease the same per cent in value during the n th year of life. In fact, some models depreciate less because of a reputation for quality and others depreciate more. An individual airplane will be evaluated in the marketplace on the basis of its actual condition (overall, and flight time since last powerplant overhaul) and the accessories installed. Average aircraft condition and average equipment were assumed in the analysis.

The source of market data was the Aircraft Dealers Service Association (ADSA) Aircraft Bluebook. The ADSA Bluebook is published quarterly. The origins of the retail and wholesale prices contained in it are not specified but are understood to be aircraft auctions that take place periodically, tempered by information contributed by dealers and by much judgment. The Bluebook data are not the ultimate in reliability as measures

of market value because the market for used aircraft is very thin. Sample sizes in many models are not large enough to justify great confidence in the Bluebook prices. In many cases, there are simply not enough aircraft in existence to provide a proper market, even if all were traded in the period of observation, as they clearly are not. Of the aircraft sales and trades that do take place, a large fraction are between individuals and not reported. Of the others, many involve trades, so that it is difficult to sort out what price is associated with which aircraft.

That the sample size must be small becomes obvious when it is recalled that only about 150,000 aircraft are in the whole general aviation fleet, spread through all 50 states. Of this fleet, only six models were even manufactured in quantities as great as 1,000 in one year. Of those in service, only a small fraction can be expected to be on the market at all during a given period and only a few of these become part of the sample.

Swings in the economy influence demand (hence, prices). The market was relatively strong in 1967-68, but the bottom had fallen out by 1970. To avoid the problem of cyclical swings, a thoroughgoing study would include several years. In the current study, three successive years, or two year pairs were taken: 1967-68, and 1968-69 (third quarter data).

To correct for the fact that some models were produced in far larger quantities than others, hence could be expected to constitute a larger part of the market, the depreciation factor for each model was weighted by the number of aircraft manufactured in that model and year. The production figures were taken from industry output summaries published annually in the magazine, Aviation Week and Space Technology, formerly

Aviation Week. In cases of some older aircraft where Aviation Week data were not available, production run lengths were inferred from beginning and ending serial numbers; it was assumed that aircraft were numbered consecutively (i.e., that no serial numbers were skipped).

Finally, a correction was applied to correct for inflation. The consumer durables price index was used to express all prices and price changes in 1969 dollars. 1967 prices were accordingly multiplied by 1.07 and 1968 prices by 1.037.

A sample calculation is shown in Exhibit A-IV-1. The results for the year pair 1967-68 are shown in Exhibit A-IV-2 and for 1968-69 in Exhibit A-IV-3. Comparison of the two shows some significant differences that are assumed to be the result of the small sample sizes behind the Blue-book values. The two year pairs are combined in Exhibit A-IV-4, which is the basis for the points shown in Figure A-IV-1. The straight line curves of Figure A-IV-1 were drawn somewhat arbitrarily. There was no reason to suppose that the sawtooth pattern of the data points would persist if further comparisons were made. The 1967-68 results alone do not exhibit it (Exhibit A-IV-2). Since it is a commonplace in the industry that the bulk of depreciation takes place in the early years of the aircraft life, the early portion of the curve was made correspondingly steep. Note, in interpreting both the tables and the curve, that an aircraft y years old is in its $(y+1)$ th year; that is, a one year old airplane is in its second year. The ordinate scale of Figure A-IV-1, then, presents the depreciation during the n th year as a per cent of the aircraft value at the end of the n th year; the abscissa scale presents the aircraft age at the

start of the nth year.

The Bluebook prices were for aircraft with "average" equipment. Although there are substantial variations possible in trim, powerplant, and other aircraft accessories, the equipment question usually revolves around avionics. The Bluebook does not distinguish between an airplane from a rural airport containing only a simple radio and one based at a city and containing full instrument landing aids, auto-pilot, weather radar, radar transponder, etc., even though participants in an individual transaction would. One reason for this is the rapid write off of avionics, partly itself a result of high retail markup (100% or more). The other reason is the spread in owner preferences that reduces the marketability of installed avionics: the second owner may just not be interested in first owner's avionics package.

For new aircraft, the Bluebook lists a "Fly away Factory" price, without options. Two problems arise. First, some cost is associated with the loss in value of options and it must be computed. Second, the "Fly away Factory" list price does not accurately reflect market, what buyers actually pay. Because of these uncertainties, the statistical analysis could not be used to compute the first year depreciation costs. Instead, the approach taken was to assume that avionics were the only options in question and to treat avionics depreciation separately from airframe depreciation. The input data from the survey included the owner's estimate of the value of his avionics equipment. While the accuracy and meaning of his estimate are open to question (as discussed in Appendix I) the number he provided is better than none at all. It was assumed to be the

Exhibit A-IV-1

Sample Calculation of Depreciation Factor

Aircraft Model	01
Year of Manufacture	1966
1967 Market Value	\$6600
1968 Market Value	\$6000
1969 Market Value	\$5750
Number of Aircraft Manufactured	138

1967 value in 1969 dollars: $(1.07) (6600) = 7070$

1968 value in 1969 dollars: $(1.037) (6000) = 6230$

Year of aircraft life during 1967 2nd

Year of aircraft life during 1968 3rd

2nd year Depreciation Factor:

$$\frac{7070 - 6230}{6230} = \frac{840}{6230} = 13.5\%$$

3rd year Depreciation Factor:

$$\frac{6230 - 5750}{5750} = \frac{480}{5750} = 8.3\%$$

Weighting factor used in combining these with 2nd year factors and 3rd

year factors of other aircraft models: 138

Exhibit A-IV-2

Depreciation Means and Standard Deviations Using Bluebook Values
for Years 1967 and 1968

<u>Years Old</u>	<u>No. of Cases</u>	<u>Weighted Mean</u>	<u>Weighted Standard Deviation</u>
1	46	0.121	0.054
2	40	0.111	0.050
3	38	0.101	0.047
4	30	0.087	0.047
5	27	0.085	0.054
6	26	0.068	0.057
7	27	0.071	0.062
8	24	0.078	0.059
9	23	0.077	0.066
10	16	0.062	0.067
11	16	0.051	0.072
12	13	0.057	0.068
13	10	0.035	0.035
14	7	0.045	0.051
15	--	0.000	0.000

Exhibit A-IV-3

Depreciation Means and Standard Deviations Using Bluebook Values
for Years 1968 and 1969

<u>Years Old</u>	<u>No. of Cases</u>	<u>Weighted Mean</u>	<u>Weighted Standard Deviation</u>
1	50	0.104	0.085
2	46	0.074	0.071
3	40	0.062	0.046
4	38	0.067	0.041
5	30	0.090	0.043
6	27	0.093	0.044
7	26	0.085	0.045
8	27	0.064	0.067
9	24	0.055	0.064
10	23	0.052	0.075
11	16	0.096	0.055
12	16	0.127	0.072
13	13	0.060	0.086
14	10	0.045	0.069
15	7	0.028	0.040

Exhibit A-IV-4

Depreciation Means and Standard Deviations Using Bluebook Values
for Years 1967, 1968 and 1969

<u>Years Old</u>	<u>No. of Cases</u>	<u>Weighted Mean</u>	<u>Weighted Standard Deviation</u>	<u>Weighted No. of Cases</u>
1	96	0.113	0.070	154541.000
2	86	0.092	0.065	165331.000
3	78	0.080	0.050	148791.000
4	68	0.076	0.045	121790.000
5	57	0.087	0.049	103448.000
6	53	0.081	0.052	95843.000
7	53	0.077	0.055	102824.000
8	51	0.071	0.063	123582.000
9	47	0.064	0.066	117977.000
10	39	0.056	0.072	94560.000
11	32	0.075	0.067	81255.000
12	29	0.094	0.078	71251.000
13	23	0.050	0.071	55803.000
14	17	0.045	0.060	48287.000
15	7	0.027	0.041	25508.000

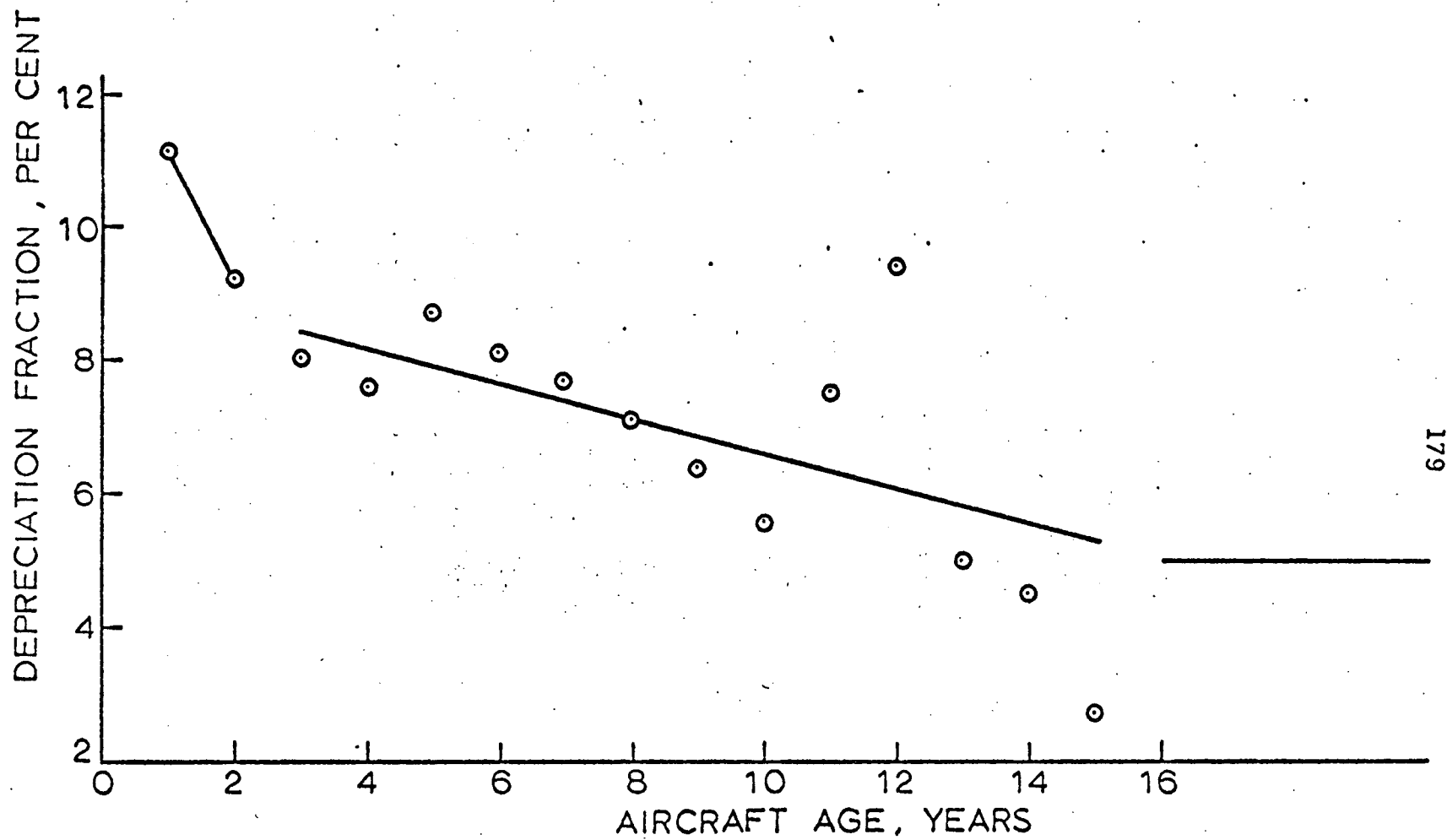


Figure A-IV-1. - Depreciation schedule used in computations for aircraft one year old and older

list value, new, for new aircraft (1969 aircraft in this study). The trade rule of thumb is that avionics equipment drops to 50% of its retail value as soon as it is installed in the airplane and retains this value during its first year in the aircraft. Based on interviews with dealers it is assumed that new avionics equipment on the average is sold at 10% off list. The depreciation cost to the owner during the first year is then 40% of list. In the computations, then, owners of 1969 aircraft were charged an avionics depreciation cost of 40% of the value they had listed for avionics equipment installed.

Similarly, the trade consensus was that aircraft depreciate to 75% of factory list during the first year and that they sell, on the average, at 5% off list. Under these assumptions, the owner suffers a depreciation loss equal to 20% of the "Fly away Factory" price listed in the Blue-book. An example of the calculation of depreciation costs on a new aircraft and electronics is presented in Exhibit A-IV-5.

The calculation of first year depreciation cost was complicated by two facts. In the first place, the majority of new aircraft sold become parts of the FBO fleets. One estimate is that 70% of new sales are for FBO's. In the second place, most modern FBO fleets are operated partly under sale-leaseback arrangements. Some FBO's operate only leased aircraft. These arrangements are discussed below.

In a fleet composed of mixed owned and leased aircraft, it can usually be assumed that the FBO pays only the wholesale price for his aircraft, generally about 80% of list. He suffers only a 5% depreciation cost if he sells the aircraft after a year at retail, 75% of list. The lessor

Exhibit A-IV-5

Sample Depreciation Calculation for New Aircraft

<u>Bluebook</u> , "Fly away Factory" value	\$20,000	
Airframe Depreciation (20%)		\$4,000
Owner's estimate of avionics value	\$10,000	
Avionics Depreciation (40%)		<u>\$4,000</u>
Total Depreciation Cost		\$8,000
What owner paid:		
Airframe (95% of list)	\$19,000	
Avionics (90% of list)	<u>\$ 9,000</u>	
Total	\$28,000	
Resulting assumed Market Value at end of year		\$20,000
Which equals 75% Airframe list		\$15,000
plus 50% Avionics list		<u>\$ 5,000</u>
		\$20,000

usually, but not always, pays the full list price for the aircraft, and suffers depreciation costs accordingly. These vagueries have been taken into account in the assumptions cited for computing first year depreciation costs.

The leaseback arrangements are a product of tax laws; details of the contracts are shaped by Internal Revenue Service regulations and guidelines. In general, an individual buys the aircraft new (under a bank or finance company loan) and enters a lease contract with the FBO. Usually the lessor receives little or no guaranteed rent, but is paid a certain amount for every hour the airplane is flown. The hourly lease payments vary with the airplane, of course, and with whether the lease is wet or dry. Under a dry lease the FBO is responsible for all aircraft operating costs, including maintenance and insurance. Under a wet lease, the form predominating in the survey, the lessor is responsible for insurance, maintenance, taxes, and fuel. There are also in between arrangements, the most common being where the FBO fuels the aircraft but the lessor is responsible for other operating expenses. The lessor normally enjoys a reduction such as 10% on maintenance performed by the lessee; he may also profit from any fleet rate insurance premium reductions negotiated by the FBO.

The lessor is usually a pilot who can use his aircraft — with informal priority over other FBO customers. He pays the standard rental fee to the FBO. Since part of this rental fee comes back to him as a lease payment, his per hour, out of pocket cost of flying is less than straight rental. The lessor enters into the lease agreement in the belief that his total, after

tax flying costs will be lower than they would be if he either owned the aircraft and did not lease it out or rented FBO aircraft. That is, if the lease payments contribute to his fixed costs and if he flies enough, the costs of his flying are lower than they would be otherwise.

From the FBO's standpoint, the leaseback serves its usual purpose of freeing capital for other purposes. Also, with lease payments largely or wholly on a per flight hour basis, the risk of a business downturn is passed on to the lessor. If the FBO is an aircraft dealer, then he earns a profit on the aircraft sale; indeed, most sale-leaseback deals are engineered by salesmen.

Two final comments regarding the depreciation computations used in the report are offered. First, it is emphasized that the depreciation factors are based on market value, not book value as in conventional depreciation calculations. As a result, although the factors total well over 100%, each factor is applied to a depreciated, market value such that depreciation to zero value does not occur. Indeed, since the depreciation schedule is assumed to start from a value equal to 75% of list at the end of the first year, the aircraft are assumed to decrease to about 25% of their value new (in constant dollars) at the end of 15 years.

Second, the analysis and its schedules and conclusions apply only to light planes of the type that comprised nearly all the aircraft in the survey. The situation may be different for larger, more sophisticated aircraft such as executive jets used in business transportation. No analysis of the prices paid nor of the depreciation suffered on these aircraft was performed.

APPENDIX V

Costs of the Hypothetical Fleets

The hypothetical fleets were those assumed in computing the curves of fleet operating costs versus runway length used in Chapter V. The hypothetical fleet is one in which all aircraft are designed to one and the same runway length.¹ The aircraft in the fleet are otherwise the same as those in the actual 1969 fleet in terms of age, mission capability,² and general quality. The assumption of no change in the age distribution of the fleet implies that sufficient time has passed for the fleet to reach equilibrium at a new technology level; if new aircraft only were used, the aircraft values and associated fixed costs would be unrealistically high. Costs of the hypothetical fleet for the year 1969 are computed under the assumption that each hypothetical aircraft flew the exact number of hours as did its real life counterpart.

The curves of airplane operating cost versus runway length, L , in Chapter V, were found by computing costs at 15 discreet values of L . A separate, 16th point was computed for VTOL and is considered to apply

¹Throughout this discussion, required runway length is understood to be the longer of take off or landing to or from 50 feet height at sea level, 59° F, on a dry, paved runway.

²Speed, range and payload.

over the entire range $0 < L \leq 600$ feet.¹ In order to perform the computations, means had to be devised to express yearly costs of any aircraft in terms of runway length. As is evident from Appendices II - IV, fixed costs, with the exception of some liability insurance premiums, are functions of aircraft value. The variable aircraft operating costs, correspondingly, are functions of aircraft horsepower, except for design speed corrections which are of no concern since the hypothetical aircraft are assumed to fly at the same speeds as their real life counterparts. The problem, then, was to develop relationships between runway length and both aircraft price and installed horsepower.

The relationships found are presented in Figures A-V-1 and A-V-2 whose interpretation and development are discussed below. The following nomenclature is defined:

- Bhp Base horsepower (defined below)
- BV Base aircraft value (defined below)
- hp Rated horsepower (from survey analysis, Appendix I)
- Hhp Horsepower required in hypothetical aircraft
- HV Value ascribed to hypothetical aircraft
- L Aircraft design runway length
- V Aircraft value (from survey analysis, Appendix I)
- V_m Aircraft maximum design airspeed.

All variables apply either to the actual aircraft (based on the survey) or

¹For purposes of this study, 600 feet was assumed to be the shortest distance from which reasonably conventional fixed wing aircraft could be designed to operate.

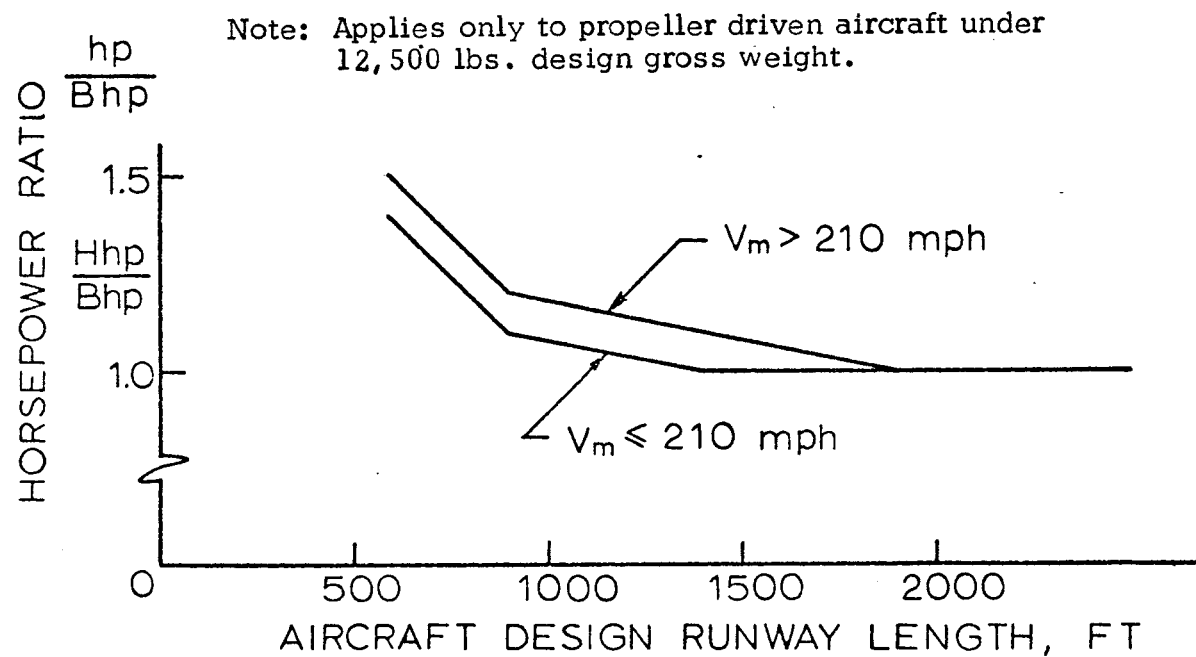


Figure A-V-1. - Assumed horsepower variation used in cost calculations of hypothetical aircraft.

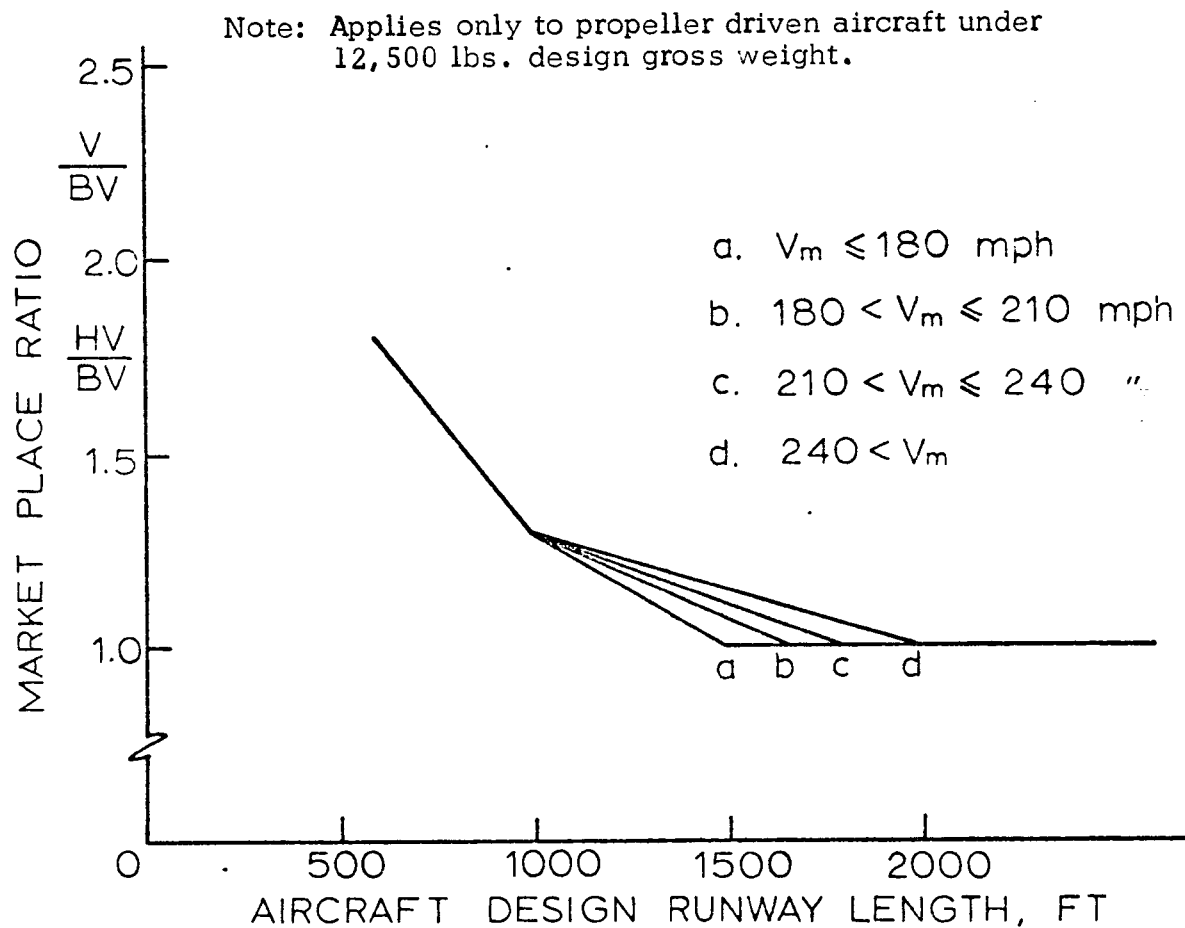


Figure A-V-2. - Assumed value variation used in cost calculations of hypothetical aircraft.

to their hypothetical counterparts or, in the case of V_m , to both.

The total cost of the hypothetical fleet at each runway length, L , is computed by summing the costs of all hypothetical aircraft. Each hypothetical aircraft is assumed to have been designed for just that runway length. A hypothetical aircraft is associated with every aircraft that was based at the airport under study during the period in question (1969, in this report). Each hypothetical aircraft has a power of H_{hp} that is used to compute variable costs following the procedures laid out in Appendix III and a value, HV , used to compute fixed costs, such as return on investment and depreciation. Insurance costs are computed as explained in Appendix II, using both H_{hp} and HV wherever horsepower and aircraft value enter the calculations. The purpose of the following discussion is to describe how H_{hp} and HV are computed.

At the start it should be made clear that aircraft designers try to optimize designs for certain missions, and that they are reasonably successful at doing so. Among general aviation aircraft, the characteristic of greatest importance in determining design configurations¹ is cruise speed (which is usually around 90% of maximum design speed). Aircraft designed for high speed cruise have higher wing loadings than those cruising at lower speeds. Because of the higher wing loading, the minimum safe speed of the faster aircraft is generally higher than that of the slower; consequently, the landing and take off speeds are also higher, and the required runway length greater. Correspondingly, for any aircraft, the

¹For a given payload and range or flight endurance.

requirement to accelerate to take off speed means added thrust as the distance in which this acceleration must be achieved diminishes. The added thrust means increased horsepower, which accounts for the increase in slope at the left ends of the Figure A-V-1 curves.

Since many existing aircraft have not been optimized for runway length, it turns out that relatively minor modifications could be made to improve their runway performance. The horizontal portions of the curves in Figures A-V-1 and A-V-2 correspond to the base horsepower and value that aircraft would exhibit if no sacrifice were made that improved runway performance. As examples, it is assumed that any aircraft with a maximum speed of 210 miles per hour (mph) could be designed to a runway length of 1,400 feet without additional power. The added sophistication, however, could add to initial costs at somewhat greater runway lengths. Curve (b) in Figure A-V-2 shows that cost penalties would be incurred at runway performances better than 1,650 feet, where curve (b) starts to climb.

Some existing aircraft do incorporate the additional power or the other modifications necessary to improve runway performance. These aircraft are assumed to be oversized relative to the base aircraft for their mission. The sloped portions of the curves make it possible to compute what the base horsepower, Bhp, and base value, BV, of these aircraft would be. The computation is illustrated by an example.

Characteristics of the based airplane:

Rated horsepower, hp	260
Take off distance	1,240 feet

Landing distance	1,000 feet
Design runway length (the longer of landing or take off), L	1,240 feet
Aircraft Value, V	\$14,000
Aircraft maximum design speed, V_m	166 mph

The base horsepower, Bhp, and base price, BV, are calculated by reference to the curves.

For $V_m = 166$, use the lower curve in Figure A-V-1, that for $V_m \leq 210$, to find hp/Bhp. At $L = 1,240$ feet, this value is 1.03. The base horsepower is then: $Bhp = 260/1.03 = \underline{252}$. Similarly, use curve (a) in Figure A-V-2, that for $V_m \leq 180$, to find BV/V. At $L = 1,240$, this value is about 1.16. The base price is then: $BV = 14,000/1.16 = \underline{\$12,100}$.

With the base horsepower and the base price in hand, exactly the same curves serve to derive the hypothetical horsepower and hypothetical price. Continuing the same example:

Given: $V_m = 166$ mph

Bhp = 252

BV = \$12,100,

- 1) Find Hhp and HV corresponding to $L = 1,000$ feet. Use the same curves as previously in Figures A-V-1 and A-V-2.

At $L = 1,000$, $Hhp/Bhp = 1.08$

and $HV/BV = 1.3$

Thus: $Hhp = (1.08)(252) = 273$

and $HV = (1.3)(12,100) = \$15,740$

2) Find Hhp and HP corresponding to $L = 800$ feet.

At $L = 800$, $Hhp/Bhp = 1.20$

and $HV/BV = 1.55$

Thus: $Hhp = (1.2)(252) = 303$

and $HV = (1.55)(12,100) = \$18,800$

It should be emphasized that Figures A-V-1 and A-V-2 are assumed to reflect all the design changes needed to effect short runway performance. Some of the design implications are discussed below.

For light wing loading aircraft, runway performance can be easily improved by increasing low speed propeller thrust and some relatively minor aerodynamic form and control modification to make low speed flight safely pilotable. The increased thrust usually means more horsepower, perhaps with the added complexity of gearing and a more complex than otherwise propeller. The modifications add to the aircraft empty weight; consequently, the entire airplane is somewhat bigger and heavier to accomplish a given mission. In some respects (such as propeller and gearing) maintenance and overhaul costs will be increased. The horsepower ratio curve represents an estimate of what these design changes would do to variable costs. The added power and other design features increase the initial cost of the airplane, hence its depreciated value and all cost items associated with aircraft value.¹

The higher wing loading aircraft associated with higher maximum

¹It is assumed, for want of better information, that depreciation on STOL aircraft operated from paved airports would follow the same pattern as was calculated for conventional general aviation aircraft in Appendix IV.

cruise speeds have greater difficulty in achieving the low speed flight necessary for short runway performance, particularly landings. Either the wing area must be increased, e.g., flaps, or extraordinarily high lift coefficients safely and controllably achieved. The latter probably implies powered lift, such as a blown wing, during the approach, to land successfully at runway lengths near and below 1,000 feet. Additional power will usually be needed to accelerate to take off speed. With current technology, the propeller that will quietly produce the needed low speed thrust will function inefficiently in high speed cruise.¹ As a result, power requirements will climb in order to maintain cruise capability even on those few high cruise speed aircraft that currently have enough power installed to permit relatively short take offs. The combination of design features making possible short field performance on high speed aircraft causes initial costs (hence, fixed costs) and installed power (hence, variable costs) to start climbing at higher values of L than they do for lower speed aircraft.

Since no short field aircraft are in widespread use, nor in large scale production, nor firm data source exists on which to base the curves. Of all STOL aircraft in civil service, probably less than a dozen aircraft in total cruise in excess of 210 mph. Those operating at lower speeds are not available in sufficient quantities to provide experience indicating what selling prices would be if they were no longer to reflect

¹Research and development on propellers that would perform well in both flight regimes has been carried on for some years, but has yet to result in operational hardware.

development costs and if efficient, larger scale production were launched.

The half dozen or fewer firms worldwide that produce STOLS have designed their aircraft for the rough terrain, special use missions where the present market lies. There is no production experience, in the United States or elsewhere, in STOL aircraft designed for the general aviation market, characterized for the most part by paved or well manicured sod runways. It is difficult to estimate the premium paid in the existing designs for the extra ruggedness they incorporate.

Other firms are successfully marketing modifications to existing light aircraft that improve runway performance 20 - 80%, depending on the model, at new cost premiums ranging from 11 per cent on aircraft in the \$50,000 class to 40 per cent in the \$10,000 class.

Some STOL designs could fly faster if fitted with retractable landing gear; however, STOL implies steep approaches and relatively hard landings, which historically have led to heavy, long stroke landing gear. Design of sturdy, long stroke, retractable gear poses nasty, though tractable design problems and can involve substantial weight and cost penalties that have been avoided in the designs heretofore. Innovation in flare control might negate the need for special landing gears by reducing the harshness of the landings that the gear must be designed to withstand.

The fact remains that STOL aircraft capable of cruising much faster than 200 mph have not been produced in quantity for general aviation buyers. The market has never been large enough to tempt serious attention from designers. Since these aircraft, in order to cruise efficiently, have smaller wings (higher wing loadings) than their lower cruise brethren,

designs for low speed flight will require some ingenious gadgetry in the wing-powerplant combination and in control systems. For example, multi-propeller aircraft may need propeller interconnects to protect against loss of control following powerplant failure at low speeds. There is no reason to doubt that designers are up to the task. The question is what the resulting costs would be.

In the absence of adequate data, the curves were based on extrapolation of trends in existing data and a knowledge of the general technological consequences imposed by designing for short field performance. The validity of the extrapolation and judgments made about technological consequences are open to some question because there are so many unknowns in STOL. One reason is that there has been an almost total hiatus in pertinent propeller and low speed aerodynamics research for some 25 years; problems of transonic, then supersonic flight, missiles, and space exploration have pre-empted the imaginations and exhausted the budgets of competent researchers. Another and equally fundamental reason is the absence of production experience in low cost, light weight implementation of what aerodynamicists and specialists in aircraft control already know. Further research and production experience will reduce the uncertainties underlying the curves.

The only operational VTOL aircraft¹ are helicopters, and a number of these are performing yeoman service in special general aviation applications. A problem with helicopters is achievement of significant forward

¹Military aircraft excepted; a few jet-lift VTOL warcraft do exist.

speeds, even as great as those of the slowest of the fixed wing general aviation aircraft. Large helicopters are capable of speeds somewhat in excess of 200 mph, particularly if aided by a fixed wing or auxiliary forward propulsion, or both. But small helicopters of 2 - 6 seats have yet to operate at speeds as high as 150 mph and may always remain incapable of the higher speeds and the range, payload combinations of much of the general aviation fleet.

On the other hand, substantial research over the past 15 years on other forms of VTOL aircraft has shown that at least two configurations have promise in small sizes. These are the tilt rotor and tilt wing. Both have been flown experimentally and are theoretically capable of matching the speeds and ranges of propeller driven general aviation aircraft. Unfortunately, there is absolutely no operational or production experience on which to hazard estimates of fixed and variable operating costs.

A reasonable conclusion, for want of data, is that costs would be similar to those of helicopters. Roughly equivalent control mechanisms, gear boxes, shafting, and bearings will be installed, implying similar mechanical complexity to influence production and maintenance costs. Unless the diameter of the lifting rotor(s) or propeller(s) relative to the vehicle weight diminishes (higher effective disc loading), which should not be necessary with small machines, the power requirements would be about the same. Advocates of these configurations claim that maintenance costs would be lower than on helicopters because the cruise flight aerodynamic force inputs would be far less oscillatory; they are probably correct but it will be years before one can say so with certainty. In the

computations these hoped for advantages have been ignored.

While VTOL general aviation aircraft are technologically feasible, they pose unusual piloting problems. None shows evidence of being appreciably easier to fly in lowspeed flight than helicopters. Both helicopter and VTOL flying characteristics can be vastly improved by addition of electro-mechanical systems between the pilot and the controls. These relieve the pilot of much of his workload in stabilizing the machine in flight. They could also help him avoid the borders of his safe flight envelope. Indeed, by resort to on-board computers, push button control is feasible. The problem is that this electro-mechanical equipment is exceedingly expensive in its current versions and compounds maintenance problems.

In order to complete the cost curve, a series of arbitrary assumptions were made, based on discussions with engineers experienced in the field.

- 1) The value of the hypothetical VTOL is four times that of the base aircraft. $HV = 4BV$.
- 2) The hypothetical horsepower is twice that of the base aircraft. $Hhp = 2Bhp$.
- 3) Procedures for computing costs of powerplant overhaul, depreciation, liability insurance, and capital remain unchanged.
- 4) The fixed wing maintenance and inspection cost formula of Appendix III are used, but multiplied by a factor of two.¹

¹Since horsepower is the major determinant of fixed wing maintenance costs and the VTOL horsepower is twice as great, this means a total factor of roughly 4.

- 5) The hull insurance premium formulae are used but with rates multiplied by three.¹

Although not treated in the present study, there are over 2,000 jet or fan propelled aircraft in the general aviation fleet. These "executive jets" often fly out of relatively short fields such as the 2,500 - 3,000 ft. runways studied herein. They do so by operating "off-loaded," at well under design gross weight. To design such aircraft to operate at full gross weight from fields as short as 1,000 ft. will require substantially more radical design innovations than with propeller driven aircraft. The problem will be compounded by the noise of the powerplants; some lifting thrust will be called for, in addition to forward thrust greater than that typically installed. Current executive jets sometimes stir up violent community objections around those urban general aviation airports where they operate. The prospects for future aircraft with relatively greater thrust and noise in relatively more densely settled urban communities is unpromising. On the other hand, steeper descents and climbouts than current aircraft may localize the problem and adequate progress may be made in suppressing powerplant noise.

What is clear regarding executive jets is that they could be designed to operate from fields far shorter than currently typical. While current runway lengths at full gross weight run 3,000 - 6,000 ft., modifications

¹Note that, if deductibles are included, the factor, three, implies lower rates than typical of current helicopter policies as described in Appendix II; however, with hull insurance computed as a per cent of aircraft value and with aircraft value four times as great, the premium amount is 12 times greater than on fixed wing aircraft.

using existing technology could reduce the distance to near 2,000 ft. if proper incentives were applied. There would be penalties: a heavier empty weight, greater fuel consumption, and design complexity; as a result, both capital and operating costs would be raised substantially. An analysis similar to that performed in Chapter V could be performed to establish the optimum division of costs between such airplanes and the general aviation airports serving them. No such analysis has been undertaken herein.

APPENDIX VI

The Landing Area Costs

At any airport, economic costs will include:

- 1) Labor, for the staff and other personnel required for maintenance, repairs, accounting, billing, legal services, etc.
- 2) Materials.
- 3) Utilities.
- 4) Depreciation on depreciable facilities and equipment, valued at replacement prices.
- 5) Insurance, to the extent carried.
- 6) Interest on capital invested in improvements.
- 7) Imputed rent (based on land and airspace opportunity cost, and assumed to subsume interest on capital invested in land acquisition and site preparation).

These costs will differ from one airport to the next depending on location, weather, extent and method of development, and other factors.

The purpose of this appendix is to focus on the runway costs; specifically it is to define those costs that are functions of runway length. In an urban area, the imputed rent is usually so great relative to other costs related to runway length that the latter can be ignored in computations.¹

¹ Maintenance costs for the landing area and runway lighting would presumably increase with runway length; so would the initial construction costs, hence, the interest on capital invested in improvements.

The nature, purposes, and dimensions of the components of land and space in question are summarized below on the basis of descriptions in the FAA publication AC 150/5300-4A, Utility Airports - Air Access to National Transportation, November, 1968. AC 150/5300-4A is an advisory circular presenting information and criteria for the planning and development of general aviation airports intended for use by small airplanes rather than by transport-type aircraft.

The basic elements of the landing area are shown in Figure A-VI-1. The "runway," defined as a visibly definable and specially prepared all-weather surface designed specifically for the landing and take off of aircraft, consumes only a small part of the required space. At an urban, as opposed to a rural, airport there will be sufficient traffic that a taxiway will also be necessary. Land between the runway and the taxiway and on either side is kept clear as a safety or buffer zone to allow for the occasional instances when pilots lose control of aircraft on the ground and depart the runway or taxiway. Additionally, there are overrun areas extending 200 feet at both ends of the runway. Finally, there are the clear zones at the runway approaches. The clear zones are a consumption of airspace over land that is not (necessarily) a part of the airport proper. The clear zones protect the arrival and departure flight paths of aircraft using the runway. From a safety standpoint, it is obviously undesirable to have trees or man-made structures penetrating the clear zones; the FAA recommends further that no structures at all be permitted under clear zones and that congregations of people or bird habitats also be avoided.

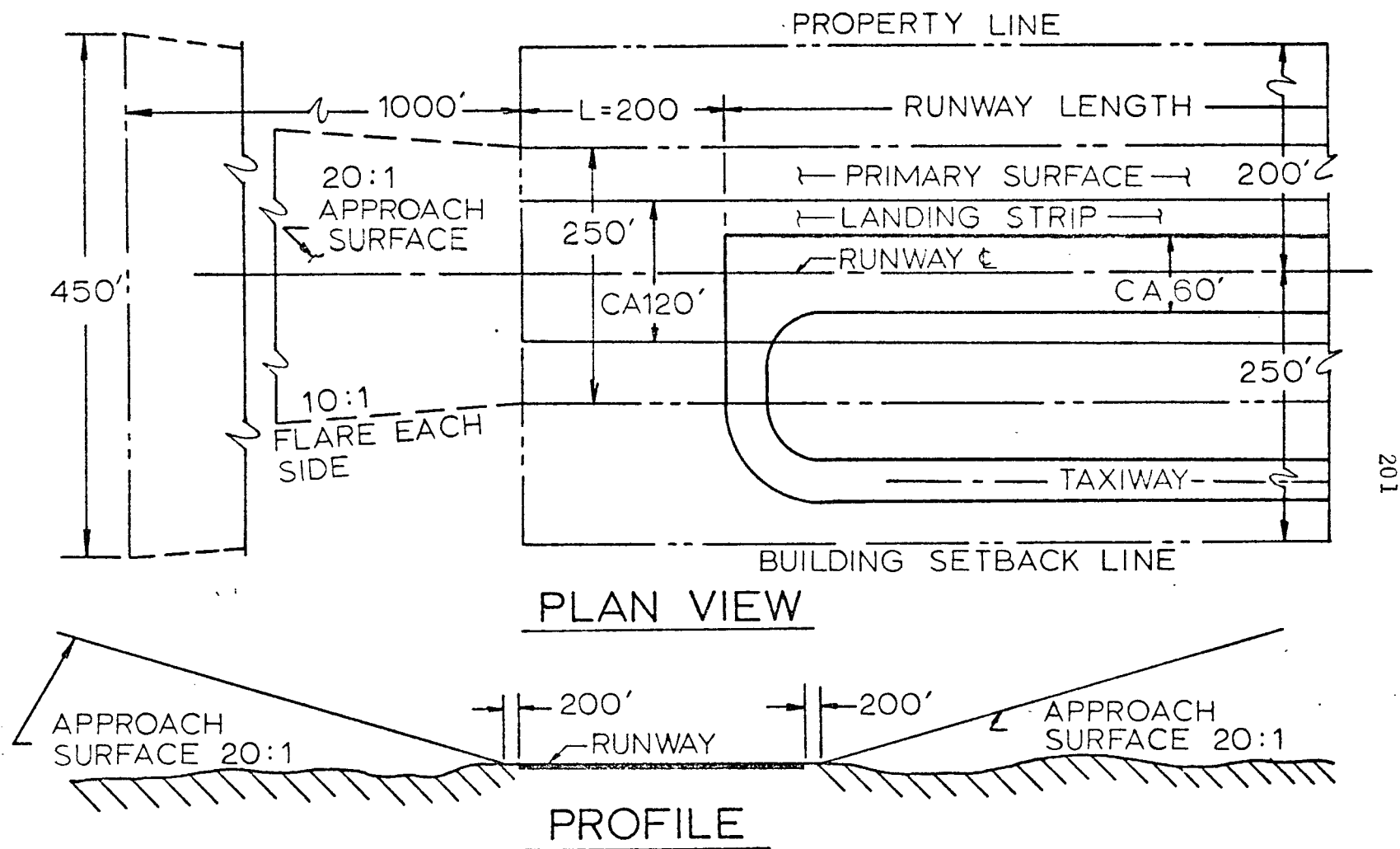


Figure A-VI-1. - Landing area space requirements. Source: FAA, AC 150/5300-4A, pp. 30, 31, 80, and 81.

Although the airports surveyed in this study were fortunately situated with respect to prevailing winds such that one runway sufficed (or two parallel runways), this is not normally the case. Where winds from different directions occur frequently and are strong enough, two and perhaps three runways must be provided. If crosswinds are infrequent and weak, it may be possible to avoid extra runways but probably at a cost in widening the surviving runway and its buffer zones; a wider runway will make crosswind landings easier.

While there is overlap of runway and buffer zone areas at intersections of multi-runway (not parallel) airports, there is also open space, fillet shaped, between the runways that can usually not be used for anything (excepting, perhaps, agricultural purposes of relatively low value); consequently, as a first approximation, multi-runway airports can be considered to occupy the space requirement of one runway multiplied by the number of runways. For example, an airport with two intersecting runways of equal length is assumed to devote twice the land and airspace to runways as the single runway airport. The same is assumed true for two parallel runways since these are usually separated by sufficient distance that they can be considered two separate systems.

The dimensions shown in Figure A-VI-1 are the minima recommended by the FAA. As can be seen, a strip of land 450 feet wide, extending 200 feet beyond the runway length proper, must be withheld from other uses for the landing area, not counting the restrictions on use of land in the clear zones and on adjacent airspace. This means, with 43,560 square feet in an acre, a minimum of 0.01033 acres is associated with every

foot of runway length. In dollar terms, if VL is the market price per acre, then the market value per foot of runway is \$0.01033 VL per foot. In this study, a return of 10 per cent is assumed; the imputed rent is then \$0.001033 VL per foot per year.

It should be noted that the concept of seeking a market rent on land is not entirely unknown at publicly owned airports. It comes to light in some FBO ground leases. These leases are usually written for long terms such as 30 years so that the lessee has reasonable confidence of his tenure and will thus be encouraged to erect substantial rather than shoddy improvements; at some airports, however, the lease terms include provision for periodic appraisal of the land and renegotiation of the lease terms on the basis of a target rate on the appraised value. One example of the target rate is 8-1/2% but the negotiations do not always result in rates as high as the target. At most airports, the rent on FBO occupied land is lower than what market rates would be.¹

The common areas of the airport, the runways, taxiways, parking aprons, automobile parking lots, etc., are also necessarily used by FBO's and their customers. FBO leases, in general, make no contribution to meeting the imputed rent or the other costs associated with this, the major part of the airport.

While the runway layout described reflects the minima recommended by the FAA, many airports in operation have smaller buffer zones, or

¹Since property taxes are not paid on government owned land, there would be some logic to charging higher than the "free market" rate of return to compensate for the fact that the latter is computed after property taxes.

safety areas. Safety is a paramount consideration in aviation and, from a safety standpoint, the FAA specifications are presumably well justified by accumulated experience. In many cases the dimensions recommended would be even greater.¹ Where twin engine aircraft operate frequently, this is reflected in 100 foot wider minimum landing areas as at the FAA "General Utility" category airports. In conclusion, the dimensions shown in Figure A-VI-1 yield low side estimates of the space requirements of runway systems serving general aviation in urban communities.

In the present study, runway length is analyzed in terms of the performance of aircraft using the runway. While the costs of the aircraft as functions of their design runway performance are discussed in Appendix V, "Costs of the Hypothetical Fleet," the relationship between design runway performance and actual runway requirements is not. The aircraft design runway length used there meant take off to or landing from a 50 foot height, as established by a professional pilot operating from a paved, dry runway at sea level. It does not mean that that length would be adequate, say, for a "Sunday" pilot landing at a strange airport under unfavorable weather conditions.

The 50 foot height does imply a little margin of safety where approaches are clear of obstacles such that a pilot could cross the runway threshold at less than 50 feet height; however, even under good conditions, a 50 foot

¹Certain types of instrument landing systems (ILS) require use of land well beyond the clear zone extremities for approach lighting. Such ILS systems are rare at general aviation airports and the associated land opportunity costs are ignored in the current study. Similarly ignored are certain airspace reservations for aviation use above land to either side of the runway.

clearance at the runway threshold is not a comfortable safety margin. Even the non-pilot can see that, at typical landing speeds (60 - 100 mph), this does not give much room for error in judging the approach; nor does it imply much time to react in the event of powerplant difficulties on take off.

The FAA, in Flight Standards Service Safety Education Series 4A, recommends that pilots use a safety margin of 80% in computing landing and take off; that is, 80% over the distances that are specified in the aircraft operating manual for the ambient altitude and temperature. The recommendation stems from an analysis of aircraft accidents performed by National Aviation Underwriters, one of the major insurers in general aviation. In this study, the 80% safety factor has been adopted in defining runway requirements associated with any given aircraft design runway length. This margin is conservative for professional pilots and for airports with completely clear approaches; however, general aviation airports must be designed to permit safe flying not only by the best pilots but also by the worst,¹ and clear approaches are the exception, not the rule.

With the 80% margin, the aircraft design runway length assumed to be the minimum possible with fixed wing aircraft, 600 feet, converts to a required runway length of 1,080 feet (at sea level standard conditions). The minimum FAA general aviation airport category, "Basic Utility - Stage I," offers a minimum runway length of 2,200 feet, which converts to an

¹Worst not merely in terms of inherent ability and competence but also under the worst combination of physical and emotional conditions and under unfavorable weather conditions.

aircraft design runway length of 1,220 feet, (i.e., 2,200/1.8). In this study, aircraft of design runway length between 600 and 1,220 feet are considered to be STOL and of greater than 1,220 feet to be conventional aircraft. This distinction is reasonable for propeller driven aircraft that are not excessively refined for high speed cruise flight.

As the airport elevation above sea level and the "normal maximum temperature"¹ increase, the recommended runway length must also grow to allow for the deterioration of aircraft performance in the lower density air that results. The corrections² applied are:

7% / 1,000 feet elevation
0.5% / degree Fahrenheit

In this study, the correction factors used to raise runway lengths from sea level standard conditions to those prevailing at Airports (2) and (3) were:

Airport (2): 1.14
Airport (3): 1.10

These are typical of the corrections at urban airports.

As can be seen from Figure A-VI-1, for the conventional, general aviation airport landing area, there is a space requirement fixed by the overruns and clear zones at both ends in addition to a space requirement

¹The normal maximum temperature is the arithmetical average of the daily highest temperature during the hottest month.

²These corrections are presumably based on piston engine aircraft. As turbine engines come increasingly into use, both corrections, but particularly the temperature one, will probably be revised upward because turbine performance is more sensitive to temperature and to air density than piston engines and some aircraft will be runway limited by power available for take off.

proportional to runway length. Clear zone requirements diminish as aircraft depart from the conventional in the direction of shorter runway capability. STOL aircraft can fly at lower speeds. Better control of the touch down spot along the runway can thus be achieved and both steeper approaches and climbouts effected. Consequently, the overruns and clear zones can be shorter. Lateral (side to side) control is not greatly improved as airspeed decreases; it is unlikely, therefore, that landing area lateral dimensions for STOL aircraft will be reduced, in comparison with conventional general aviation aircraft.

In low speed regimes, the STOL aircraft tend to be as readily disturbed by wind gusts as conventional aircraft and more sluggish in response to pilot recovery control actions. For successful VTOL aircraft, on the other hand, lateral control will be adequate to permit much reduced lateral clearances, one half or less of those for fixed wing conventional and STOL aircraft.

The overruns and clear zones assumed for different aircraft are compared in Table A-VI-1.

Table A-VI-1

Overrun and Approach Slope Requirements for Different Airport Types

	<u>Overrun</u>	<u>Clear Zone</u>	<u>Approach Zone</u>
Conventional Aircraft	200 ft.	1,000 ft.	20:1
STOL Aircraft	150 ft.	500 ft.	10:1
VTOL Aircraft	0 ft.	400 ft.	8:1

Note: 1) All distances apply at each runway end.

2) STOL requirements are taken from proposed Design

Criteria for STOL Ports and C/STOL Ports, promulgated in 1969 by the California Department of Aeronautics, except for the overrun where California recommends 200 feet but other industry sources plan on 150 feet.

- 3) Clear Zone length is calculated on the basis of approach slope to an elevation 50 feet above the runway or landing platform.
- 4) The VTOL requirements are taken from the FAA Heliport Design Guide, AC 150/5390-1A, November, 1969, p. 33.

Table A-VI-1 implies that the function expressing space requirements (or their costs) in terms of runway length has some slope changes at the short runway end of the curve. This is particularly true for VTOL aircraft for which the function exhibits a discontinuity. Military experience with helicopters suggests that a landing pad measuring 300 ft. x 300 ft. would be more than adequate for a general aviation VTOL landing area.

The resulting land requirements are shown in Figure A-VI-2. The assumption made in the range of runway lengths associated with STOL aircraft is that the overrun and clear zones are increased continuously to the FAA recommendations for conventional aircraft, which take effect at 2,200 feet runway length (at sea level standard conditions). As shown in the figure, this adjustment was assumed to be linear. The dimensions assumed slightly overstate fixed wing clear zone areas in that the FAA recommended clear zone width is only 250 feet wide at its start on the end of the landing area, not 450 feet as calculated herein.

One caution in interpreting the curve is that, while crosswind runways for the fixed wing aircraft (STOL and conventional) duplicate the entire space requirements of one runway, those for a VTOL port duplicate only the clear zone areas. The same pad should be usable for approaches from

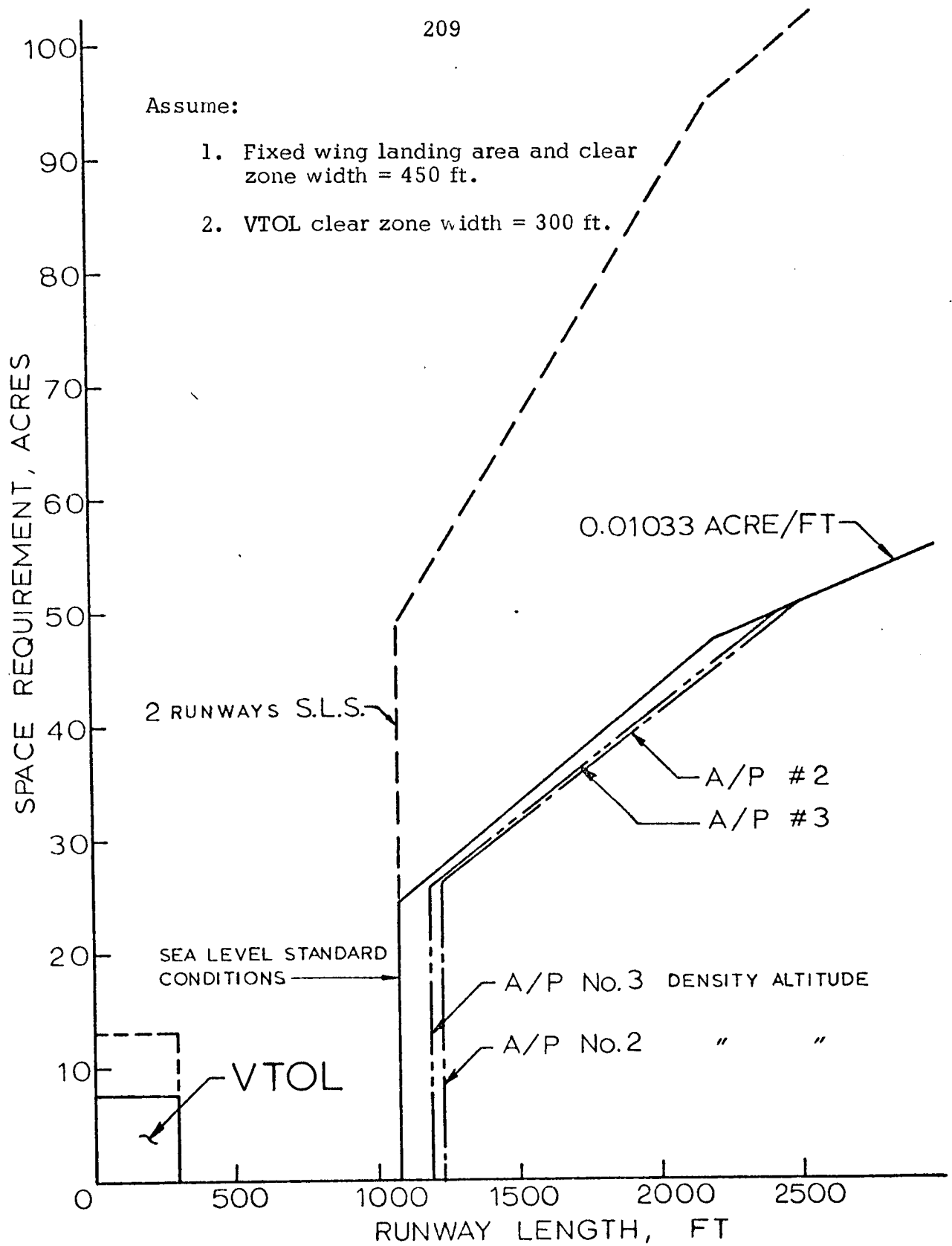


Figure A-VI-2. - Surface pre-empted by landing area and clear zones as a function of runway length.

several directions.

From a land use standpoint, the logic in focusing on the runway system to the exclusion of the remainder of the airport loses its appeal at the shorter runway lengths and for VTOL, particularly when land values climb sufficiently. At some land value, it will become economical to make the runway (landing pad) the roof of a structure within which other airport functions such as aircraft storage, automobile parking, and offices are located. Either the depreciation (amortization) and interest costs of the building will be less than the rent on the land thereby saved or other constraints will make impossible the spreading out of all these functions. The logic is that, while the airspace above a runway is unusable for other purposes, that beneath it can be put to use.

The VTOL port offers the most obvious example of dimensions convenient for the top of a structure. There is ample military experience with aircraft carriers to demonstrate the feasibility of both aircraft elevators and multi-layer storage. Since the VTOL pad would probably constitute 10% of the surface requirements of a busy general aviation port, 90% of the entire surface requirements could theoretically be saved by a 10 - 15 story structure. Such an arrangement lowers the airspace constraints on surrounding property, hence, other opportunity costs chargeable to the airport.¹ Multi-story aircraft hangars do not exist but there

¹There would probably be spillover costs as a result of noise and hazard to surrounding developments. How these costs would compare with the benefit that the VTOL or STOL port would provide in improved access is a matter for speculation.

is extensive experience with rooftop heliports. No detailed analysis of costs of multi-story structures has been performed in this study.

APPENDIX VII

Selected Pilot Profile and Other Data

Table A-VII-1¹

What is your age?	Per cent
Under 21	1.03
21-24	3.41
25-30	11.39
31-34	9.66
35-40	18.40
41-44	15.67
45-49	17.92
50-54	12.32
55-60	6.33
Over 60	3.48
No response	0.39
	<u>100.00</u>

Table A-VII-2²

What was your total income for 1968?	Per cent
Under \$5,000	3.06
\$ 5,000 - \$ 7,000	3.45
\$ 7,001 - \$ 8,000	3.09
\$ 8,001 - \$ 9,000	3.67
\$ 9,001 - \$10,000	5.20
\$10,001 - \$15,000	22.91
\$15,001 - \$20,000	17.61
\$20,001 - \$25,000	11.05
\$25,001 - \$30,000	7.37
\$30,001 - \$40,000	7.68
\$40,001 - \$50,000	5.03
\$50,000 - \$100,000	6.46
More than \$100,000	1.98
No response	1.89
	<u>100.00</u>

¹AOPA 1969 Profile of Flying and Buying, p. 27.

²Ibid., p. 27.

Table A-VIII-3¹

What is your approximate total net worth?	Per cent
\$10,000 - \$20,000	14.37
\$20,001 - \$20,000	10.18
\$30,001 - \$40,000	7.52
\$40,001 - \$50,000	8.85
\$50,001 - \$75,000	12.25
\$75,001 - \$100,000	10.48
Over \$100,000	30.85
No response	5.50
	<u>100.00</u>

Table A-VII-4²

In what capacity are you employed?	Per cent
Top management	35.30
Middle management	13.78
Professional and technical	28.78
Other executive	3.58
Non-executive	6.84
Airline pilot	1.63
Air taxi pilot	1.03
No response	9.06
	<u>100.00</u>

Note: 16.5 per cent of the respondents were employed within the aviation industry.

Table A-VII-5³

What was your maximum level of educational attainment?	Per cent
Grade school	1.76
Attended, but did not complete high school	3.91
High school graduate	18.33
Attended, but did not complete college	26.60
College graduate	30.67
Post-graduate degree	18.17
No response	0.56
	<u>100.00</u>

¹Ibid., p. 28.

²Ibid., p. 29.

³Ibid., p. 29.

Table A-VII-6¹

How many cars do you own?	Per cent
One	24.96
Two	52.94
Three	14.39
More than three	6.33
No response	<u>1.38</u>
	100.00

Table A-VII-7²

Are you a public official in any of the following capacities?	Per cent
Mayor of a borough, town, or city	0.30
Councilman of a borough, town, or city	0.94
County commissioner	0.31
Representative in state legislature	0.07
State Senator	0.02
Member of city, regional, or area planning commission	2.54
Member of the municipal or county hospital board of trustees	0.71
Member of city, county, or state board of education	1.11
Other public offices in this frame of reference	4.75

Note: Fifteen U.S. Congressmen and four U.S. Senators of the 91st Congress were known to be AOPA members as were four state governors.

The AOPA report cited includes a variety of other data, all of which hammer home the message that their membership comprise a prosperous and spending oriented group of consumers. Included are: family status, business in which engaged, value of primary residence, maintenance of vacation home (18 per cent did), ownership of pleasure boat (24 per cent did) and its value, amount spent on leisure time activity and in what major categories, amounts spent for vacations and for airline travel, credit cards held, and amount of life insurance carried.

¹Ibid., p. 31.

²Ibid., p. 32.

Table A-VII-8¹Selected Pilot Characteristics by Owner Group

In the following, pilots are divided into five groups:

- Individuals - flying their own aircraft
- Companies - flying aircraft of private companies (but not FBO's)
- Partnership - flying aircraft owned in partnership
- Club - flying club-owned aircraft
- FBO - flying aircraft rented from FBO's

<u>Individuals</u>	<u>Companies</u>	<u>Partnership</u>	<u>Club</u>	<u>FBO</u>
Median hours flown per year				
88	100	70	66	30
Per cent of flights making stop over 100 miles from home airport				
70	68	57	49	32
Median age, years				
43	40	42	35	32
Median 1968 family income, dollars				
17,600	19,200	18,000	14,000	13,200

Table A-VII-9²Selected Pilot Characteristics by Certificate Group

<u>Student Pilot</u>	<u>Private Pilot</u>	<u>Commercial Pilot</u>
Median hours flown per year		
25	51	100
Per cent of flights making stop over 100 miles from home airport		
30	51	55

¹An unpublished market survey.

²Ibid.

Table A-VII-9² (Cont'd.)

<u>Student Pilot</u>	<u>Private Pilot</u>	<u>Commercial Pilot</u>
Median age (years)		
32	37	39
Median 1968 family income, dollars		
13,000	15,300	14,700

Table A-VII-10¹

How the Private Pilot Obtains an Aircraft for
Piloting Purposes

<u>Method</u>	<u>Per cent of Sample</u>
Rent	50
Sole Owner	23
Club	20
Part Owner	14
Friend or Relative	9
Employer	6

Table A-VII-11²

Money Income - Per cent Distribution of Recipients, by
Income Level, by Sex, 1968

	M A L E		F E M A L E	
	<u>All</u>	<u>Minority Races</u>	<u>All</u>	<u>Minority Races</u>
Under \$1,000	11.5	17.3	30.8	33
\$1,000 - \$1,999	8.9	13.2	18.9	22.6
\$2,000 - \$2,999	7.3	10.1	12.1	14.0
\$3,000 - \$3,999	7.2	11.4	12.1	12.1

¹J.J. Eggspuehler, G.S. Weislogel et al, Study to Determine the Flight Profile and Mission of the Certificated Private Pilot, p. 34.

²U.S. Bureau of the Census, Statistical Abstract of the United States: 1970 (91st Edition), Washington, D.C., 1970, p. 326.

Table A-VII-11 (Cont'd.)

	<u>All</u>	<u>Minority Races</u>	<u>All</u>	<u>Minority Races</u>
\$4,000 - \$4,999	7.1	10.8	8.7	7.8
\$5,000 - \$5,999	8.2	9.8	6.4	4.3
\$6,000 - \$6,999	8.6	8.0	4.4	2.8
\$7,000 - \$9,999	21.6	14.0	5.0	2.9
\$10,000 and over	19.7	5.5	1.8	0.6
Median Income	\$5,980	\$3,829	\$2,019	\$1,688
Per cent with income	92.4	88.3	64.8	72.6

Table A-VII-12¹

Money Income - Per cent Distribution of Families and Unrelated
Individuals, by Income Level and by Race: 1968

	<u>F A M I L I E S</u>			<u>Unrelated Individuals</u>		
	<u>All</u>	<u>White</u>	<u>Negro</u>	<u>All</u>	<u>White</u>	<u>Negro</u>
Under \$1,000	1.8	1.5	3.9	14.8	13.8	21.1
\$1,000 - \$1,999	3.4	2.9	9.1	24.5	23.9	29.7
\$2,000 - \$2,999	5.1	4.5	11.0	12.8	12.8	12.4
\$3,000 - \$3,999	6.1	5.4	12.3	10.0	11.0	10.0
\$4,000 - \$4,999	6.0	5.6	10.6	8.0	8.1	7.2
\$5,000 - \$5,999	6.9	6.7	8.8	6.7	6.7	6.7
\$6,000 - \$6,999	7.6	7.6	7.6	5.3	5.5	4.4
\$7,000 - \$9,999	23.4	24.0	17.6	10.2	10.6	7.3
\$10,000 and over	39.7	41.9	19.1	6.7	7.5	1.1
Median Income	\$8,632	\$8,937	\$5,360	\$2,786	\$2,952	\$1,964
Per cent with income less than \$3,000	10.3	8.9	24.0	52.1	50.5	63.2

¹U.S. Bureau of the Census, Statistical Abstract of the United States: 1970 (91st Edition), Washington, D.C., 1970, p. 324.

Table A-VII-13¹

Turbine Transport Operators by Sales Rank in Fortune's 1968 Top 500
Industrials

<u>Banking Group</u>	<u>No. of Operators</u>
1 - 50	42
51 - 100	36
101 - 150	30
151 - 200	22
201 - 250	22
251 - 300	11
301 - 350	12
351 - 400	13
401 - 450	3
451 - 500	5

- Note: 1) Non-industrials such as utilities, banks, insurance, transportation, and merchandising companies and privately held companies are also frequently operators of large and small business aircraft.
- 2) An additional 79 of the top 500 operated smaller transport category aircraft.
- 3) Probably still more operate light twin aircraft excluded from the Business and Commercial Aviation survey.

Table A-VII-14²

Will you give us some idea as to the percentage of your plane's total time each year devoted to business and pleasure flying?

Per cent of airplane owner respondents

100% Business		6.67
90% "	10% Pleasure	12.83
80% "	20% "	6.69
70% "	30% "	4.90
60% "	40% "	3.10
50% "	50% "	8.64

¹Business and Commercial Aviation, August, 1968, p. 52.

²AOPA 1969 Profile of Flying and Buying, p. 10.

Table A-VII-14 (Cont'd.)

<u>Per cent of airplane owner respondents</u>		
40% Business	60% Pleasure	3.32
30% "	70% "	5.46
20% "	80% "	7.66
10% "	90% "	16.88
	100% "	<u>23.85</u>
		100.00

42.73% of respondents use aircraft 50% or more of the time for business.

65.81% of the respondents use aircraft 50% or more of the time for pleasure.

Table A-VII-15¹

(Among respondents who rent or charter aircraft) what percentage of the rental period is it used for business purposes?

	<u>Per cent of respondents</u>
More than 50%	28.01
Less than 50%	71.06
No response	<u>0.93</u>
	100.00

Table A-VII-16²

Private Pilots' Primary Purpose for Piloting

<u>Primary purpose for piloting</u>	<u>Per cent of respondents</u>
Pleasure	50
Business transportation	34
Personal transportation	12
Use of aircraft in business	2
No response	<u>2</u>
	100

¹Ibid., p. 11.

²J.J. Eggspuehler, et al, Study of Private Pilot, op. cit., p. 56.

Table A-VII-17¹

Private Pilots' Reasons for Piloting
Percentage of Respondents Primarily

	<u>Local Pleasure</u>	<u>Business Transportation</u>	<u>Pleasure Transportation</u>	<u>Other</u>
Much	62	25	38	5
Little	25	28	44	11
Never	5	33	7	54
No response	8	14	11	30

Note: "Other" includes pastimes such as racing, photography, sky-diving, experimental.

Table A-VII-18

Transportation Use of Aircraft

Aircraft Value

	0 - \$4,999	\$5,000 - \$9,999	\$10,000 - \$14,999	\$15,000 - \$19,999	\$20,000 - \$29,999	\$30,000 - \$99,999	over \$100,000
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Number of FBO aircraft

11	75	44	14	30	15	3
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Percentage of FBO aircraft with transportation the major use

0	1.3	6.8	7.1	13.3	53.3	100.0
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Percentage of FBO flight hours devoted to transportation

0	0.8	5.3	9.1	15.6	35.8	93.6
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Number of non-FBO aircraft

104	117	59	21	15	11	4
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¹J.J. Eggspuehler, et al, Study of Private Pilot, op. cit., p. 58. In regard to both Tables A-VII-16 and A-VII-17, it is emphasized that the survey excluded instrument flight rated Private Pilots. This group, though relatively small in number, probably flies far more per year, on the average, than these respondents, and engages in relatively more transportation flying.

Table A-VII-18 (Cont'd.)

	0 - \$4,999	\$5,000 - \$9,999	\$10,000 - \$14,999	\$15,000 - \$19,999	\$20,000 - \$29,999	\$30,000 - \$99,999	over \$100,000
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Percentage of non-FBO aircraft with transportation the major use

24.0	60.7	69.5	85.7	73.3	45.5	0
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Percentage of non-FBO flight hours devoted to transportation

23.7	45.8	55.4	57.3	52.3	59.6	49.1
------	------	------	------	------	------	------

- Notes: a) Based on responses to questions 9 and 11 of survey (Appendix I).
- b) Transportation use has been defined to include:
1. Air taxi or charter service,
 2. One-half of aircraft rental (lease),
 3. Company business (not for hire),
 4. Individual business (not for hire), and
 5. Personal and pleasure: over 100 mile radius.
- c) If the total percentages in the above categories totalled 50% or more, the aircraft was defined to have transportation as its major use.
- d) Four turbine powered corporate aircraft, each valued in excess of \$100,000 and used exclusively for business transportation, were inadvertently omitted from the count.

Table A-VII-19

Comparison of Airport Fees and Aircraft Utilization With Aircraft Value: Club Owners

M E A N S

<u>Value Range</u>	<u>No. of Cases</u>	<u>Total Annual Owner Costs</u>	<u>Storage Fee</u>	<u>Fuel Fee</u>	<u>Utilization (hours/year)</u>
\$ 0 - \$ 5,000	11	\$ 4,030	\$231	\$215	697
\$ 5,001 - \$10,000	10	5,495	362	141	423
\$10,001 - \$15,000	4	7,367	600	211	500
\$15,001 - \$20,000	2	10,219	510	335	500

(none higher in value than \$15,500)

Based on survey results at Airports (2) and (3). Survey described in Appendix I.

Table A-VII-20

Comparison of Airport Fees and Aircraft Utilization With Aircraft
Value: FBO Owners

M E A N S				
<u>Value Range</u>	<u>No. of Cases</u>	<u>Total Annual Owner Costs</u>	<u>Fuel Fee</u>	<u>Utilization (hours/year)</u>
\$ 0 - \$ 5,000	10	\$ 2,766	\$121	435
\$ 5,001 - \$10,000	36	6,756	201	689
\$10,001 - \$15,000	28	10,594	293	741
\$15,001 - \$20,000	8	12,798	374	588
\$20,001 - \$30,000	19	14,236	237	578
\$30,001 - \$40,000	3	17,150	282	423
\$40,001 - \$60,000	2	18,170	82	255
\$60,001 - \$80,000	0	0	0	0
\$80,001 - \$150,000	5	44,045	303	844

Based on survey results at Airports (2) and (3). Survey described in Appendix I. FBO's at these airports paid no per aircraft fee but leased land from the airport. A storage fee per aircraft based on the lease was not computed.

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