DETERMINING GENERAL AVIATION AIRPORT SYSTEM BENEFITS

By Donald F. Wood

In attempts to justify – or plan for the wise use of – governmental expenditures, there has developed great interest in measuring their benefits. This paper describes an analytical approach for measuring the benefits from improving various general aviation airports within a system.[1] Emphasis is given to the interrelationships between airports. This is a departure from airport benefit analysis conducted to date, which has usually considered individual airports separately. To measure values of individual airport improvements within the framework of a general aviation airport *system*, benefits must be quantified in such a manner that *incremental* improvements at individual airports can be evaluated with respect to the contribution they make to the entire system.

The problem has one additional dimension: that of *projecting* future general aviation airport system benefits. One not only must develop a method of analysing benefits as they occur today, but also must be able to project future benefits – taking into account growth and changing patterns of activity.

In this paper, the system of general aviation airports for which benefits will be determined consists of approximately 100 airports within the state of Wisconsin.[2] About two-thirds of these airports now exist, and they vary in size; the other third are "planned." However, the system is not "closed." There is flight activity between Wisconsin general aviation airports and airports in neighbouring states; and there are flights between Wisconsin general aviation airports and Wisconsin airline airports.[3]

It is unfortunate – from an analytical standpoint – that the airport system could not be considered as "closed," i.e. having no relationships with airports outside the system. This presents a dilemma: while in theory all airports on the North American continent are potential trip ends for at least some general aviation aircraft, the continent is too large an area to be conveniently contained within a single analytical framework. Defining the size of the relevant area is difficult. If too large an area is chosen it may contain airports so far apart that they are beyond the range at which many general aviation aircraft can be efficiently employed. At the other extreme, if too small an area is chosen, it might involve distances less than those over which most general aviation aircraft are used. Compounding this

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[1]General aviation is defined as all aviation except scheduled airlines and military aviation. The approach in this paper is to consider airports serving only general aviation. The approach could be modified to include facilities (or portions of facilities) at airline airports which are used by general aviation.

[2]The state of Wisconsin covers approximately 60,000 square miles and contains 4·4 million people. About half its population and most of its rich farm lands are in its southeastern corner. Northern Wisconsin is heavily wooded and contains many resorts, but its population is not growing.

[3]Also there are flights between Wisconsin general aviation airports within the system and grass strips or small airfields operated by resorts.

TABLE I

Simplified Benefits Matrix

Airport Improvements					
A	B	C	D	E	
3	2	4	1	6	A
	5	0	2	4	B
		9	3	0	C
			2	1	D
				2	E

problem is that the general aviation fleet contains a heterogeneous collection of aircraft models, with a wide range of operating characteristics and advantages.

The benefits from an airport system can be shown on a triangular matrix, with each airport or airport improvement listed twice, once on each axis. It would appear, in simplified terms, as illustrated in Table I. The 6 in column E, row A, represents the benefit from improving airports A and E simultaneously. It is based on benefits from trips from A to E and return and trips from E to A and return. When it is necessary to improve simultaneously two airports, such as A and E, to obtain benefits, these benefits are referred to in this paper as "external."

A matrix such as this could depict the benefits from a closed system. If there were no anticipated benefits from certain combinations of projects, a zero could be entered in the matrix.[4]

Each project will also have an "internal" benefit, which will appear in the matrix where the row and column for the same improvement intersect, such as the 9 in column C, row C. These benefits are considered "internal" since they are, for purposes of analysis, unrelated to other airport improvements under consideration in the system. These "internal" benefits result from two completely different types of activities. The first type would be flight activity between an airport in the system and airports outside the system. The other type of activity would be what is known as a "local" flight. (A "local" flight occurs when the aircraft takes off and lands at the same airport, with no intermediate stops. Examples are flights for training, crop-dusting, aerial photography, etc.)

Returning to the example of projects A and E in Table I, the total benefits from improving them are their "external" benefits of 6 plus their two "internal" benefits of 3 and 2, or a total of 11. Using Weingartner's terminology, the projects form a "compound" project.[5] Although airports A and E may not be individually justified, the two airports – as a pair – might be justified because of interaction (projected benefits) between them. Thus, airport improvements need not be considered independently of each other. Instead, they should be evaluated in terms of the contribution they will make to the entire airport system.

[4]If there were negative interaction between airports, this could also be handled in the matrix as a reduction in "external" benefits. An example might be an area with acute airspace problems, where the addition of one airport would reduce the approach paths to another.

[5]H. Martin Weingartner, "Capital Budgeting of Interrelated Projects, Survey and Analysis," *Management Science*, 12, 7 (March 1966), pp. 485–516.

SELECTING THE MEASURE

Selection of the best measure of benefits is influenced, or constrained, by many factors. Some of the factors, based in economic theory, may appear to the practitioner to be esoteric. How does one, for example, evaluate the consumer's surplus enjoyed by most users of general aviation; and how does this compare with the consumer's surplus each individual might have enjoyed if he had spent his money on something else?[6]

Other factors influencing or constraining the selection are quite practical. The most pressing one is the lack of data concerning general aviation. Thus analytical efforts – such as this – employ a relatively large number of heroic assumptions.

Placing the proper focus on benefits is also difficult. If too broad a focus is selected, some benefits may be over-counted. If too narrow a focus is selected, some benefits may be missed. In a topic involving complex and interrelated private and public decision making, the focus should cover critical areas which include (or affect) the decision-making processes. For this paper this means, at least, that benefit measures should be of sufficient breadth to include an understanding of the private decisions as to when to use general aviation.

General aviation airport "benefit" studies to date have taken several forms. Most dealt with impact on the community served by the airport, and were based on surveys of expenditures made by general aviation passengers.[7] Such studies are of limited use for measuring benefits, since there is no indication of the alternatives for which the money might have been spent. Local communities are influenced by studies such as these because they assume that any spending in their community by visitors is a net addition to the community's income.[8] They overlook the fact that the same airport may be used by local residents to fly elsewhere to spend money that otherwise would have been spent at home.

Surveys have also been made of direct employment. With the exception of a few airports containing large service and sales facilities, general aviation airports and airport facilities generally do not employ large numbers.[9] Again, this is a difficult

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[6]Dealing with future consumer's surplus becomes difficult. If each individual decides to buy an airplane on the basis of the individual consumer's surplus he thinks he will enjoy, the result may be that so many planes are purchased that congestion results – reducing the amount of consumer's surplus enjoyed by each.

[7]For examples of passenger expenditure surveys, see: Michigan Department of Aeronautics, *Michigan Aviation Fact Finder Survey, Report No.* 1 (Lansing, Michigan: 1963); and Tucson Airport Authority, *Transient Aircraft Survey* (Tucson, Arizona: 1964).

[8]The Tucson study stated: "Exactly what these out-of-towners bought with their money, or where in Metropolitan Tucson they spent it, we do not know. However, we do know one important thing about their money . . . *they left it here!!*" (Emphasis in original text, p. 6).

[9]See, for example: Tri-State (Connecticut, New Jersey and New York) Transportation Committee, *General Aviation: Economics of Public-Use Airports in the Tri-State Region* (New York: 1965). The larger general aviation airports employed several hundred individuals, while the smallest airports averaged 1·1 employees apiece. This type of employment has no exceptional relationship to levels of business activity. Figures for Wisconsin show that the two categories of employment associated with general aviation – non-certificated air carriers, and fixed facilities and services related to air transport – have unemployment experience ratings (used to determine the unemployment compensation tax paid by employers) similar to those of most other industries.

method of measuring benefits, since the alternative employment for these individuals is unknown.

Advocates of general aviation airports claim that the airports result in many additional jobs within the local economy, apparently because of increased sales of manufacturing firms located within the community. Nearly any survey of airport users will show that a community's principal employers rely heavily on general aviation. While these benefits do exist, they tend to be difficult to measure; and, again, one must speculate on what would have occurred if no airport existed.

Sometimes benefit-cost analysis includes as a benefit, or objective, the redistribution of income. General aviation users, as an income class, cannot be thought of as needing to be the recipients of additional transfers of income. However, intuitively, it would appear that general aviation airports help to redistribute income geographically. Within economically-depressed areas, a community with an airport has certain advantages over communities without airports when it comes to attracting new employers or serving the needs of existing industries.[10]

Several studies have assumed that general aviation airports were necessary public facilities, and then attempted to justify or locate airports in terms of savings in ground transport costs incurred by users in reaching the airport.[11] In this situation the relevant alternative was ground transport costs to reach other (nearby) airports. Airports were related to each other in terms of ground travel times, and the vehicle in question was the automobile. The characteristics of the air trip were ignored. This was unfortunate, since the directions of general aviation trips are not spread evenly over 360 degrees of the compass. Airport locations in the same direction from a city's centre as most of its air traffic are more beneficial than those elsewhere. Also, increasing the distance between the airport and the city centre tends to reduce the benefits of general aviation; this can be seen by noting the decline in airport use as surface travel distances to reach it increase.[12] Both air and ground portions of the total trip should be taken into account.

Few of the measures of general aviation airport benefits developed to date are of much use in the planning process.

In order to be relevant to the planning or justification of a system of general aviation airports, the benefit measure should:

(a) take into account the relationships between airports – as both complements of and substitutes for each other;
(b) be capable of being related to other forms or modes of transport – again as complements of or substitutes for the airports;
(c) relate to incremental improvements in the airport system, i.e., permit

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[10]Income redistribution, or any type of "secondary" benefit, could – if measurable – be entered in the benefit matrix (Table I).

[11]*Public Investment in General Aviation Airports: An Application of Cost-Benefit Economics* (Princeton, New Jersey: Mathematica, 1967), and (Baltimore) Regional Planning Council, *The General Aviation Airport System: A Locational Analysis Process* (Baltimore, Maryland: 1968). The latter report developed a method for finding the low cost combination of general aviation airports that would be within given ground distances of potential users.

[12]See Wisconsin State Aeronautics Commission, *State Airport System Plan: Technical Supplement* (Madison, Wisconsin: 1966), pp. 57–62.

comparisons of conditions with or without the specific improvements;
(d) be measurable in money terms;
(e) make it possible to identify beneficiaries – as individuals or within groups – in case one might be interested in assessing user charges. (Also, this might indicate their ability to absorb such charges.)

The list could have been lengthened, although too many specifications cause difficulties for the practitioner. The following sections will develop and discuss one procedure which comes close to meeting the criteria just enumerated.

ADVANTAGES OF GENERAL AVIATION TO THOSE WHO USE IT

The bulk of general aviation benefit studies to date have ignored the direct benefits enjoyed by general aviation users. The motivation for this is sometimes political, since taxpayers frequently demand that – where possible – beneficiaries of government programmes be required to pay for them. To the extent that the public can be led to believe that general aviation benefits permeate the entire community, the public will be less likely to assess general aviation users for a portion of the rather ample public costs of airports and airways.

The benefits of general aviation airports can be achieved only through their use; and the users are the initial beneficiaries. While some benefits may be shifted, or even bring additional effects, this should not divert one from focusing on the user as the primary beneficiary.[13]

Unless an individual benefits from using general aviation, he will not use the airport. After he has decided to use the airport some additional benefits may accrue – to him or to others; but for this to occur other resources – in addition to the airport – usually must be brought into play. Thus it is probably sufficient to focus upon the airport user when attempting to establish airport benefits.

Most studies of the advantages of general aviation to its users have been conducted as market research efforts for the general aviation aircraft manufacturers. One survey of "particularly valuable uses" developed the following list (in descending order of mention): transport to and from out-of-the way locations, saving executive "out-of-office" time, immediate high speed travel, movement of supplies and services to other company locations, and movement of company's products. Another survey developed this list of advantages (again in descending order): time saving, scheduling flexibility, reliability, safety, ability to reach off-airline cities, "senior executives enjoy private aircraft," "serve market better," privacy, cost saving, "beat competition to sales prospects," and prestige.[14] Two advantages stand out in both these – and most other – lists of general aviation advantages: time savings and ability to reach cities without (or with inadequate) scheduled

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[13]See Richard M. Zettel, *Notes on the Incidence of Highway Benefits*, a paper prepared for the Workshop Conference on Economic Analysis in Highway Programming, Location and Design, National Academy of Sciences, Washington, D.C., September 18, 1959.

[14]Both studies are cited in the National Business Aircraft Association special report 68–8, *Business Flying* (Washington, D.C.: 1968).

airline service. For example, one company described its decision to purchase a general aviation aircraft by saying:

> . . . We made a chart of every city that our executives visited where commercial air service was inconvenient or infrequent . . . we took the actual airline schedules and figured out the actual times down and back. Then we took the figures for the corporate jet and figured the same things. Take Joplin, Missouri, for example. The corporate jet, which can set its own arrival and departure times, showed a time saving of almost 29 hours and 30 minutes over the commercial lines because their schedules made an overnight layover a necessity. We also figured that there would be an average of 2·5 of our people on each trip. If you multiply the time by the number of people by the $25 per hour, you come up with a figure of $1,843 which is quite a saving on one trip. I mention Joplin, of course, because it was the most dramatic figure – some savings were as low as $120, figured on a similar basis.[15]

In a sense, the ability to reach areas without adequate airline service is another form of time saving. The alternative to general aviation is then either auto for the entire trip or a combination of airline and rented auto.[16] We conclude that the main purpose of the airport system is to reduce travel time. The key is to evaluate the time savings so that, for a given investment in airports, value in savings of time can be maximised.

Using the value of travel time saved reflects closely the actual practices of general aviation users with respect to buying equipment and assigning the equipment to perform certain flights. It represents a high level planning criterion and is measurable in dollar terms. Since time savings result only from trips between airports, it can be used to relate – and even measure – the interdependencies between airports. Lastly it can be used as a common denominator for measuring benefits of other, related, transport improvements. For example, one could determine congestion costs to general aviation and airline passengers at crowded airports, or determine "trade-offs" between a specific airport feature and improving ground travel routes from the airport to downtown.

Deciding to use value of time savings is one matter; determining the value of time savings is quite another. There are apparently no surveys covering the wage rates of general aviation passengers. Even if there were, there is no consensus that wage rates are the proper measure of time value. Should large blocks of time saving be valued at the same rate per hour as small blocks? Or, is the time saved productive, non-productive, or semi-productive? Rather than pursuing the "correct" answers to these types of questions, this paper will assume straightforwardly – and perhaps naively – that the value of time savings per passenger is $10 per hour.[17]

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[15] *Ibid.*, page 37. The quotation originally appeared in an unspecified issue of *Forbes*. See also: Edwin P. Harkins, *Business Aviation Practices* (New York: National Industrial Conference Board, Inc., 1970).

[16] In a 1964 survey of general aviation passenger trips in Wisconsin, 1041 individuals indicated that they had made the same trip by other modes: 891 by auto, 115 by airline, and 35 by "other."

[17] For some justification of this figure see: Gary Fromm, *Economic Criteria for Federal Aviation Expenditures* (Cambridge, Mass.: United Research, Inc., 1962), pp. III-17-19; and James R. Nelson, "The Value of Travel Time," *Problems in Public Expenditure Analysis*, Samuel Chase, editor (Washington, D.C.: The Brookings Institution, 1968), p. 108.

INCREMENTAL BENEFITS

We accept as given the institutional arrangements under which general aviation has developed in the United States; and we assume, more or less, that they will continue. Within this framework, it is desirable to define benefits in a way that can be related to incremental improvements (or combinations of improvements) within the airport system.

The best measure of incremental benefits is to compare the total travel costs to the passenger with and without the specific airport improvement. This assumes that the trip would have been made in any event.[18]

Using differences in costs to the passenger avoids some of the problems in identifying and measuring subsidies as they now exist. (If, for example, the relevant alternative is travel by scheduled airline, in the United States the "local service" airlines are subsidised directly by the government. In addition, the airline fare structure internally subsidises short hauls at the expense of long hauls.) Unravelling subsidies and cross-subsidies is difficult. (Another difficulty is determining the relationship between an airport system and the airways navigation system. The two systems are interdependent. The airways navigation system is used by some pilots when flying between airports. The airport system supplements the airways system by providing airports along a pilot's route which he could use for landings in case of emergencies or worsening weather.)

Focusing on increments forces one to define units of change, i.e., what change yields an increase (or decrease) in total benefits? When one is considering general aviation airports, the relevant change will be in the number of airports, the size of airports, or both. If one is concerned with the number of airports, the first increment will be a new additional airport. The alternative mode of travel with which comparisons probably should be made is the automobile. If size of airport were the object, then the incremental improvement would be an addition in physical dimensions (or other capabilities) so that the airport could accommodate larger, faster aircraft.[19] In this case, the alternative with which comparisons should be made would be travel on general aviation aircraft which required smaller airports.

We are not starting anew in an area with no airports and no airplanes. Instead, the majority of airports under consideration already exist, so the relevant decision is whether they should be expanded. Smaller Wisconsin communities have no general aviation airport facilities; in this case the relevant questions are whether they should be provided with a small airport initially, and whether later it should be expanded.

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[18]This benefit measure would not hold for induced passengers. Their expenditures on air travel are substitutes for other expenditures, and "the only additional benefits they realise are increases in consumer surplus from spending the funds for more or different aviation services instead of for something else." See Gary Fromm, "Civil Aviation Expenditures," in *Measuring Benefits of Government Investments*, Robert Dorfman, editor (Washington, D.C.: The Brookings Institution, 1965), p. 202.

[19]Using manufacturers' figures, regression analysis was applied to data for 98 models of new aircraft. Runway length requirements (in hundreds of feet) = 0·1857 + 0·2413 (number of seats) + 0·0738 (carrying capacity in hundreds of pounds) + 0·5265 (cruising range in hundreds of miles) + ·02985 (speed in miles per hour); R^2 = 0·69. T-value for number of seats was 0·8166; for other variables it was 1·9 or greater. Throughout this paper runway lengths are expressed at sea-level conditions. Higher elevations require greater runway length.

In Wisconsin, general aviation airports are classified by the length of their principal runway. Here is a list showing the airport size class, the principal runway length, and the type of aircraft that can be accommodated (while the plane is fully loaded): class 1, 2500 feet, light, single-engine piston; class 2, 3500 feet, light, twin-engine piston; class 3, 4500 feet, heavy twin-engine piston (frequently retired airline aircraft); and class 4, 5500 feet, small and medium sized business jets.[20]

The remainder of this section deals with how marginal benefits were determined for trips performed on various class sizes of general aviation aircraft. Under many circumstances, the costs to the traveller for travelling on larger aircraft are in fact less. This saving is the "benefit" from being able to use larger aircraft.

Table II shows how passenger costs per mile were calculated, but without a scaling effect based on trip distance. The heading divides aircraft into the four Wisconsin airport size classes, based on the aircraft's maximum runway requirement. The first row shows the cruising speeds of the different size classes of aircraft. They are based on manufacturers' data for new aircraft. Weighting (based on current sales) was applied to take into account relative distribution of planes within each size class. The speeds expressed are in statute miles.

The next rows attempt to incorporate "all-weather" flying capability. The larger classes of aircraft are believed to be nearly as well instrumented as air carrier aircraft, while most smaller planes are not.[21] This reduced effectiveness of the small planes is shown in several ways. Because of less power or inability to fly at high altitudes, the small plane may be unable to fly over bad weather. Or, because of fewer instruments, the smaller plane may be less able to fly under marginal

TABLE II

Passenger Mile Costs on General Aviation Aircraft (and Auto) – assuming constant cost per mile

	Airplane Class Size				*Auto*
	1	2	3	4	
Average cruising speed mph	137	235	310	540	55
Annual effectiveness as % of Class 4	70%	85%	100%	100%	—
Speed adjusted by effectiveness	96	200	310	540	55
Airplane cost per plane mile	$0·23	$0·65	$1·22	$1·55	$0·12
Average number of seats used	2·0	4·4	7·7	9·2	2·5
Aircraft cost per mile per seat used	$0·115	$0·147	$0·158	$0·168	$0·048
Value of passenger time per mile	$0·104	$0·050	$0·032	$0·018	$0·182
Total cost – aircraft + value of time – per mile	$0·219	$0·197	$0·190	$0·186	$0·230

[20]The runways at larger classes of airports are also wider and thicker.

[21]Each business jet sold in 1967 carried an average of $110,000 worth of navigation equipment. The comparable figure for small, single-engine planes was $2,300. See *Business Flying*, Special Report 68–8, p. 42.

visibility conditions. The actual delays are in cancelled or postponed trips, or delays en route. Bad weather at trip's origin or destination, or in between, may be reason for cancelling or delaying a trip. The assumption employed is that over a period of one year, and under weather conditions in the Upper Midwest, use of a class 1 plane would be possible for only 70 per cent of the time during which a class 3 or 4 aircraft could be used.

The airplane costs per mile are based on information submitted to the National Business Aircraft Association by its members. The information involved 116 firms operating a total of 163 aircraft.[22] This sample was used to compute an average cost by airplane size class. Since aircraft models were listed, the sample was weighted to be representative of the models within each size class as listed in the Federal Aviation Administration national registration records. In Table II, the cost per plane mile was obtained by dividing the total (fixed plus variable) cost per year by total miles flown per year.

The average number of seats used is based on FAA load factor studies conducted in 1965.[23] But, on the basis of recent sales of various models within class 1 and class 2 categories, the average passenger load of class 1 aircraft was adjusted downward (2·3 to 2·0) and of class 2 upward (3·5 to 4·4).

The last rows in Table II take into account the value of passenger's time. The first step in arriving at these figures was to divide the aircraft's cost per mile by average number of seats used, to obtain an aircraft cost per passenger mile. The second step was to calculate the value of passenger's time consumed per mile of travel. When combined, the figures show the advantages of the larger, faster aircraft.

The next step was to introduce a scaling effect, and Table III shows the effect of length of trip on passenger costs per mile. It is not until the aircraft is airborne and at a cruising altitude that it can take advantage of its speed. Table III was prepared by taking costs shown in the last row of Table II and allocating them on the basis of whether they were a function of trip length. From aircraft sales literature, averages were calculated for allocating (a) fuel consumption, (b) time consumption, and (c) horizontal miles covered during five distinct operations: (1) taxi and takeoff, (2) climbing to cruise altitude, (3) cruise, (4) descent, and (5) landing.

Any allocation of aircraft costs between those which are and those which are not associated with trip length is somewhat arbitrary. An aircraft owner would purchase equipment with characteristics suited to his overall needs: some models of planes are better adapted to making many short hops than are others. The assumption employed is that the owner routes his planes, and directs his pilots to operate them, in an efficient and safe manner.[24]

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[22]Copies of completed questionnaires were provided through the courtesy of the N.B.A.A. See also: FAA, *General Aviation Operating Costs* (1969).

[23]FAA, *General Aviation Occupant Load Factor* (1966).

[24]"Efficient" operation is not easily defined, because many interrelated variables must be considered by the pilot on any given trip. There are complex relationships between speed, altitude, fuel consumption, payload and range. For one discussion of trade-offs between performance characteristics, see Peter Garrison, "The Thinking Man's Cruise Control," *Flying*, 83, 4 (October, 1968), pp. 60–65 and 118.

TABLE III

Airplane Costs and Passenger Costs per passenger trip by General Aviation Aircraft Size (and Auto) – apportioned between those which are and those which are not functions of trip length

	Airplane Class Size				*Auto*
	1	2	3	4	
	$	$	$	$	$
Plane costs per takeoff and landing	1·16	7·28	25·60	25·67	—
Plane costs per mile (excluding takeoff and landing)	0·21	0·59	1·12	1·49	0·12
Costs per passenger takeoff and landing	6·19	8·19	9·43	9·41	5·02
Costs per passenger mile (excluding takeoff and landing)	0·209	0·184	0·177	0·163	0·229

On the basis of questionnaires submitted to the National Business Aircraft Association by its members, fuel and maintenance costs were subtracted from all other aircraft costs.[25] For each class of aircraft, calculations were then made of the portion of fuel and maintenance costs that could be allocated to the non-cruising portion of a typical trip.[26] The remainder of fuel and maintenance costs, along with all other aircraft costs, continued to be allocated on a straight per mile basis. Costs were then divided by the average number of seats used (see Table II) and assigned to each passenger.

In addition to costs of operating the airplane, there were also costs in terms of passenger time consumed. These were also allocated to those that are and those that are not functions of trip length. In Table III, figures described as "cost per passenger takeoff and landing" were calculated by adding:

(1) The share per passenger of aircraft costs not associated with trip length.
(2) The amount (and value) of passenger time for reaching the airport. (This is based on mail surveys of Wisconsin registrants.)
(3) Vehicle cost of surface travel to airport calculated at $0·10 per mile. (The miles to airport were also based on mail surveys of Wisconsin registrants.)
(4) To include similar costs at destination, the figures calculated in (2) and (3) were doubled.
(5) The value of passenger time during climb to cruising speed and descent. (This was calculated from aircraft manufacturers' estimates of performance

[25]Maintenance costs were grouped with fuel costs in determining airplane costs assigned to non-cruising portions of a trip. Engine maintenance is performed on the basis of engine revolutions, and both taxiing and climbing accumulate more engine "time" per ground mile covered than does cruising. Also, takeoffs and landings may strain landing gear, jar electrical connections loose, etc.

[26]They represent the costs which could be avoided if no time, no fuel, and no aircraft power were required for the plane to taxi, takeoff, climb to a cruising altitude and reach cruising speed, and if these factors could also be completely avoided for a landing.

and was the excess of time over that which would have been used if the plane could move direct from origin to destination at cruising speed.)

The costs per passenger mile (excluding takeoff and landing costs) are (1) the value of passenger's time (per hour) divided by effective cruising speed (in miles per hour) plus (2) the passenger's share of the plane costs per mile (excluding take off and landing costs).

Costs per passenger trip, by class of plane, are calculated by adding (1) the costs per take off and landing and (2) the costs per mile times the trip length.

Comparable costs for automobile travel were calculated by assuming that the time and cost to reach airports by auto was equivalent to that required for the autos to reach highways at the edge of town where high-speed travel could begin. The auto is probably more advantageous than the table indicates. This is mainly because it provides more flexibility at either end of the trip. (A frequent complaint by individuals who fly into some small Wisconsin general aviation airports is that no car rental service is available.)

Lastly, one must take into account overnight lodging expenses in situations where a round trip could not be easily completed in one day. This item was included because Wisconsin traffic managers who were interviewed indicated that a major advantage to their firms of using general aviation was the saving in employees' overnight travel costs. Overnight costs of $16 per passenger were assumed. An additional assumption was that overnight expenses would not arise until more than six hours per day was devoted to travel. Table III deals with one-way trip costs, but the overnight costs had to be allocated over the round trip. Consequently, after the first three hours spent travelling in one direction, $8 was added to the cost of the one-way trip. For each additional three hours on the same one-way trip, another $8 was added.

Table IV shows the information graphically, in terms of costs per seat mile. As might be expected, larger planes cost more per takeoff and landing, but because of their speed become advantageous over longer hauls. It was somewhat surprising to find that class 4 planes became the most advantageous to the user for hops as short as seventy miles. But we must remember that aircraft were classified by their runway requirements, not by other operating or cost characteristics.

The figures in Tables III and IV represent costs. Smaller costs subtracted from larger costs represent savings; the savings (or incremental benefits) are the total passenger trip costs on a specific class of plane subtracted from the costs on the best existing alternative.[27] These savings are the general aviation benefits which occur within an institutional setting that provides airports and airways and relies upon users to supply and operate the aircraft.

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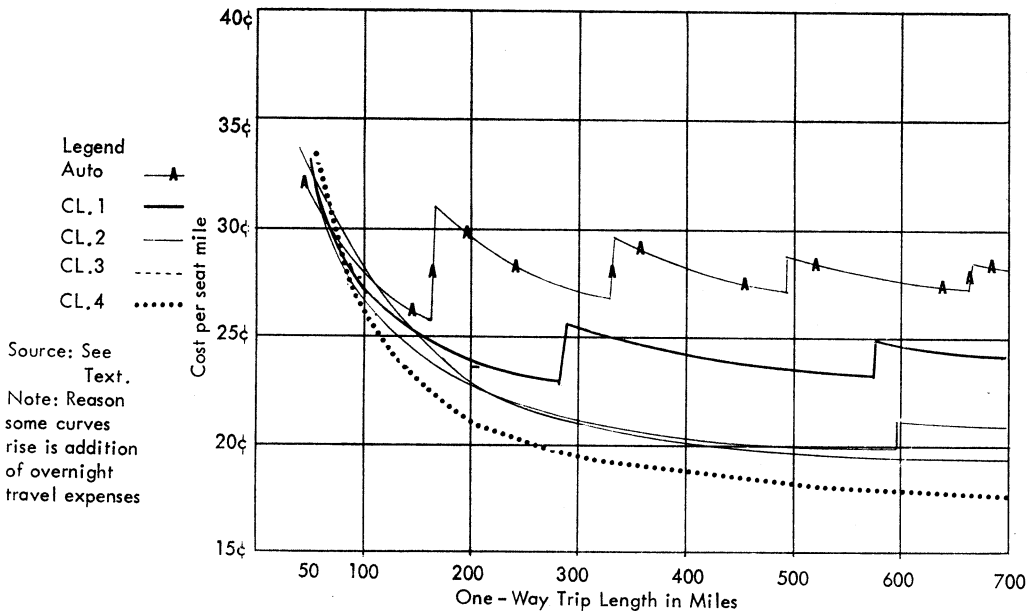
[27]When the approach described was applied to Wisconsin, travel on alternative modes was handled in the following manner. Straight-line distances were assumed for general aviation flights, but actual highway mileages were used to calculate travel by auto. Scheduled airline service was considered to be preferable to travel by general aviation if it were possible to make a round trip between two cities within one day (including an allowance for a stay of at least three hours in the city being visited).

TABLE IV

Passenger Costs Per Seat Mile on General Aviation Aircraft (and Auto) – Expressed as Costs Per Seat Mile for One-Way Trips Between 50 *and* 700 *Miles*



PROJECTING FUTURE BENEFITS

Use of general aviation is increasing, and within this increase there is a change toward use of larger, more sophisticated aircraft. This section discusses briefly one process by which future general aviation airport system benefits can be projected. The procedure is first to project future trips, then to assign potential benefits, calculated on an incremental basis (increments being different classes of aircraft) as developed in Tables II, III and IV.

Future traffic flows consist of several components – existing traffic, increased traffic caused by secular changes, traffic diverted from other modes, and traffic "generated" by the availability of the new improvements. Measurement of all these components – especially of diverted and generated traffic – is difficult. Interviews with traffic managers of firms operating their own planes disclosed that they sometimes purchased aircraft with slightly greater capacity than they currently needed and then attempted to fill the excess capacity – and thus to justify their purchase. Also, once a decision is made that a company plane is to be flown on a specific trip, any empty seats can be filled at no increase (or virtually no increase) in aircraft operating costs.

Projecting past trends into the future for general aviation implies that present

practices of providing subsidised airports and airways will continue.[28] Also, since much of the general aviation activity will be conducted on aircraft based outside the system, it is assumed that decisions on providing or enlarging airports within the system will not influence the size of aircraft which most users desire to operate.[29] The procedure employed here will be to project national trends under the assumption that they are applicable to Wisconsin. Use will also be made of some cross-section analyses of general aviation activity observed in Wisconsin in 1964.

The first step was to determine the existing relationship between numbers of general aviation passengers and total population. With data from surveys conducted in Wisconsin in 1964 it was determined that the ratio of general aviation passengers embarking annually in Wisconsin to the population of the state was 0·083.[30] Through use of FAA projections of the nation's general aviation fleet, a change in total passengers to be carried was calculated.[31] It was assumed that load factors, by class of plane, would not change, i.e., seats on each aircraft of each class size would be as productive – in terms of passengers carried – in 1980 as in 1964. These calculations indicated that the *per capita* rate would increase from the 0·083 in 1964 to 0·207 in 1980.

Over the years, there has been a proportional shift within the total general aviation fleet toward larger, more sophisticated, aircraft. The assumption employed was that an increasing proportion of potential passengers would prefer larger classes of aircraft. National projections were used, and again were felt to be applicable to Wisconsin and neighbouring states. The projections show the distribution of general aviation passengers, by size class of plane, which will occur if present trends continue.[32] At the present time (1970) general aviation passengers are distributed – by size class of aircraft carrying them – in the following manner: class 1, 45 per cent; class 2, 26 per cent; class 3, 6 per cent; and class 4, 23 per cent. By 1980 the percentage carried on class 1 planes will decline to 30 per cent, and the percentage carried on class 4 planes will increase to 38 per cent. Classes 2 and 3 will carry the same percentages unless a business jet with class 3 airport requirements is developed, in which case the share of passengers carried by class 3 aircraft will increase.[33]

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[28]Patterns of subsidy may change under the Airport and Airway Development Act of 1970 (P.L. 91–258).

[29]If one were dealing with a "closed" system one could, through use of iterative processes, find the "ideal" solution for size and number of aircraft and their accompanying airport and airways needs. Possibly a system which encouraged use of aircraft with short takeoff and landing (STOL) characteristics would result.

[30]Estimates were for passengers boarding general aviation aircraft. The ratio was later confirmed by a national survey. See *General Aviation Occupant Load Factor, op. cit.*, pp. 6–7.

[31]See FAA, *Aviation Forecasts, Fiscal Years* 1970–1981 (1970). While load factors were assumed to remain the same, the numbers of available seats in class 1 and class 2 aircraft were expected to change. More recent (1971) data indicate that the seat figure for class 4 aircraft should be slightly lower than is shown in Table 2.

[32]When carried through 1980 these projections do not indicate that airspace congestion problems will occur over Wisconsin. However, unless air traffic control technology improves, congestion will occur over portions of Wisconsin in the early 1980's.

[33]See also: *The Magnitude and Economic Impact of General Aviation* (Washington, D.C. (?): R. Dixon Speas Associates, 1968, prepared for the Utility Airplane Council), chapter III.

It is necessary to relate these desires to use larger aircraft with Table IV, which shows that class 4 aircraft are advantageous for any trip longer than 70 miles. Tables II, III and IV neglected to show the amount of utilisation necessary for these various aircraft to be operated at such low costs. To achieve these costs, a typical class 1 aircraft must be flown about 150 hours per year (covering between 15,000 and 20,000 miles). A typical class 4 plane, however, must be flown between 400 and 500 hours per year (covering 200,000–300,000 miles). Thus firms operate smaller aircraft because they would not use a larger aircraft sufficiently to achieve such low costs per passenger mile. That explains the preponderance of smaller planes in the nation's general aviation fleet. (A second reason why some firms operate smaller planes is that many of the airports at which they wish to operate cannot accommodate larger planes.)

The estimates showing percentages of future passengers desiring to fly on different classes of aircraft were used as upper limits of potential benefits. The figures were used cumulatively. For example, in 1980, 100 per cent of the passengers would use class 1 airplanes if class 1 airports were the largest available; 70 per cent would use class 2 airplanes if this size airport were the largest available; 44 per cent, class 3; and 38 per cent, class 4. This approach is close to the practices of business firms which own – or charter, if necessary – planes of varying sizes. Later analysis sometimes showed that for short trips the large planes offered no advantage – their savings in passenger time being offset by the increased cost of aircraft operation. In such instances it was assumed that the trip was performed on smaller aircraft, which – to the user – offered the best advantage. This also follows business practices.

Origin-destination data collected for general aviation passenger travel in Wisconsin in 1964 were examined to determine whether, through use of multiple regression analysis, "gravity" relationships could be developed for use in predictive equations. For intrastate traffic, county-to-county movements were analysed. Numerous exogenous variables were included, and data were also converted to logarithms to determine whether a "better-fitting" equation could be obtained. Observations were also divided into smaller groups. In no instance, when all the observations were included, was an R^2 greater than 0·30 obtained. In instances where different groupings of observations were run the highest R^2 was just under 0·50.

Table V shows the equation selected to predict intrastate general aviation passenger trips. Note that at the destination seasonal resort rooms complement population as an attraction for trips.

Table VI shows similar equations for interstate traffic. Fewer independent variables were included for testing, since they do not exist on a comparable basis for all five neighbouring states.[34] Both air and road miles were included because several large bodies of water lie between Wisconsin and the other states.

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[34]The five neighbouring states were included in the projection procedures because they include most of the "trip-ends" of interstate general aviation trips originating or terminating in Wisconsin. This was learned from surveys conducted at Wisconsin airports. For an idea of origin-destination patterns of traffic at a few general aviation airports throughout the United States, see FAA, *The Airport – Its Influence on the Community Economy* (1967).

TABLE V

Equation for Predicting Wisconsin's Annual Intrastate (County-to-County) General Aviation Passenger Trips

	Constant	*Population Originating County (in 00's)*	*Distance (Air Miles)*	*Population Destination County (in 00's)*	*Seasonal Resort Rooms Destination County*	*R2*
Regression coefficient	105·2544	0·0814	−1·0903	0·0535	0·0250	0·2945
(Standard error)	(12·7841)	(0·0035)	(0·0947)	(0·0038)	(0·0049)	

Source: The mail survey sample consisted of 950 Wisconsin-based aircraft making approximately 50,000 airplane trips between 1,834 county-to-county combinations. The passenger loads were based on interviews at 30 Wisconsin airports. Both surveys were in 1964.

TABLE VI

Equations for Predicting Wisconsin's Annual Interstate General Aviation Passenger Trips

	Constant	*Population Originating Region (000)*	*Distance (Road Miles)*	*Population Destination Region (000)*	*Seasonal Resort Rooms Destination Region*	*R2*
Regression coefficient	3356·5551	1·7815	−24·7569	2·7012	0·2177	0·5141
(Standard error)	(1901·7930)	(0·2682)	(4·7452)	(0·6034)	(·1233)	
Regression coefficient	4217·5126	1·7635	−22·9349	2·6244	—	0·4964
(Standard error)	(1860·4094)	(0·2712)	(4·6876)	(0·6091)		

Source: Mail survey of a 10 per cent sample of aircraft registrants in neighbouring states. Over 57 per cent replied, although some indicated that they did not fly to Wisconsin. The usable sample consisted of 387 planes based in Minnesota, Iowa, Illinois, Indiana and Michigan which flew to Wisconsin in 1964. They made a total of 7,863 aircraft trips to Wisconsin that year. Because of sample size, movements were calculated between 13 multi-county regions in 5 neighbouring states and 7 multi-county regions in Wisconsin.

Tallies and projections of resort rooms are unavailable for neighbouring states; the lower equation was used for projecting trips originating in Wisconsin and terminating in the neighbouring states.

Trips (and benefits) were projected in the following manner. Projections of population and resort rooms were employed in the gravity equations. These figures were adjusted to take into account the increased *per capita* rates for general aviation passengers. The potential passengers were then tentatively assigned to travel on various size classes of aircraft.

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Benefits were then calculated for each trip. These benefits applied to trips projected to occur between counties or regions. They were then assigned to specific airports, in accordance with each airport's "ground service" area, as had been determined by surveys. (We must remember that sometimes it would be necessary to improve airports at both ends of the trip before the benefits would result; in other instances only one airport would require improvement.)

Cumbersome as it may appear, the method meets fairly well the criteria for benefit measures outlined earlier. Some attempts were made at simplification, but were dropped because they either ignored or were contrary to real world conditions.

IDENTIFYING THE BENEFICIARIES

There are several practical reasons for identifying potential beneficiaries. The first is to know the specific groups that do or will benefit from governmental programmes. Fritz Machlup asserts: "In democratic decision making it is perfectly proper to ask why society should accept a system . . . if it helps chiefly one group."[35] If one were contemplating a system of user charges, it would also help to have the beneficiaries of the improvement identified. The amount and distribution of benefits is one consideration when determining schemes of assessment of charges.

We will continue to assume that the general aviation airport users are the prime beneficiaries.[36] Reliance on the approach developed so far requires acceptance of the various assumptions upon which projections and benefit measures were developed. If a different approach were employed, the distribution of benefits might vary.

It is easiest to assign benefits by class of airplane. It is estimated that in 1970, 68 per cent of the total benefits will accrue to users of class 1 aircraft; 24 per cent, class 2; 1 per cent, class 3; and 7 per cent, class 4. By 1980, this pattern will change; 61 per cent will go to users of class 1 aircraft; 28 per cent, class 2; 1 per cent, class 3; and 10 per cent, class 4. These benefits would result only if adequate airports – adequate especially to handle larger sizes of aircraft – were provided. Note the preponderance of benefits for the smaller classes of aircraft. This is because many of Wisconsin's projected general aviation trips are of relatively short length.[37]

Benefits may also be examined in relation to their distribution, geographically or over time. In both instances the characteristics of the projection techniques are reflected. Trips projected between areas with little population change will increase

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[35]In *Measuring Benefits of Government Investments*, pp. 151–152.

[36]Another identifiable group of general aviation airport beneficiaries might be adjoining landowners – in case the airport attracts additional development. However, airport noise and height controls on structures limit the use of many lands in the vicinity of airports, and thus offset many potential benefits.

[37]It may be that a larger geographic area should have been used to project interstate trips to and from Wisconsin. The region used encompassed an area extending about 500 miles from the centre of Wisconsin. Surveys of general aviation in Wisconsin do not find many trips longer than that. One reason is that there is relatively little population in the ring 500 to 800 miles from the centre, and consequently few actual (or potential) trips start or end there.

by only about 50 per cent between 1970 and 1980, while trips between growing areas are projected to increase by over 80 per cent. Areas with projected traffic giving unusually high benefits had one of two characteristics. The first was that the road network serving the area was so poor that aircraft travel appeared much more advantageous. The second was that the area was just over 3 hours' driving time (one-way) from large population centres; and, under assumptions employed here, use of general aviation would avoid costs to the traveller of staying overnight.

Another way of distributing benefits would be according to level of government. Potential benefits from improving a "typical" small new airport in Wisconsin would be distributed in the following manner:

	%
(1) Benefits from local flights by planes that will be based at airport	3
(2) Benefits from intrastate transient flights to and from existing airports by planes that will be based at airport	15
(3) Benefits from intrastate transient flights by planes based at other existing Wisconsin airports	16
(4) Benefits from interstate transient flights by planes that will be based at airport	11
(5) Benefits from interstate transient flights by planes based out-of-state	49
(6) Subtotal: "Internal" benefits	94
(7) "External" benefits, *i.e.* from additional intrastate traffic which would develop between this airport and improvements at all other airports under consideration, if they all were made	6
(8) Total	100

The particular focus from which this table was constructed was at the state level. Benefits from interstate travel (items 4 and 5) are 60 per cent of the actual amount; it was assumed that only one half of them would accrue to Wisconsin. Item 7 shows the interrelationships between airports.[38] Airport advocates frequently use the "telephone" analogy: the more there are, the more valuable – or useful – each becomes.

Recent federal legislation (P.L. 91–258) requires the U.S. Secretary of Transportation to study "the appropriate method for allocating the cost of the airport and airway system to the various users," and to identify "the value to be assigned to any general public benefit, including military, which may be determined to exist." Even though several different distributions of benefits were described, they were all based on rearranging the initial total benefits enjoyed by the users. The only additional benefit – of a public nature – resulting from a system of general aviation airports is that they are available for emergency use by airline or military aircraft. Or specific airports may serve additional public safety functions, such as medical evacuation or fighting forest fires.

[38]"External" and "internal" are defined near Table I, *supra*. These figures are from *State Airport System Plan: Technical Supplement*, pp. 133–134. Benefits were projected in a slightly different manner from that described in this paper. Local flights were assumed to be for training purposes, and the benefits assigned were equal to the amounts paid by students for training flights.

USER CHARGES

Users of publicly provided general aviation airports in the United States are subsidised. The degree of subsidy differs from state to state, although it is unlikely that many examples could be found where it is non-existent. To the extent that the general aviation operator uses the federal airways system, he benefits from another expensive governmental programme.

Data developed in earlier sections could be used to identify beneficiaries. Costs could also be identified and formulas devised for allocating them among users.

The type of user fee employed would depend on the purpose it was intended to serve. Landing fees would be the most effective for handling problems of congestion. The aviation fuel tax is the most closely correlated with aircraft use. Registration fees could vary with a plane's dimensions or age. In theory one could, through combinations of schedules, collect fees from users in the same approximate manner as costs (or benefits) might be apportioned. In some instances only actual application of the charges would demonstrate their feasibility. Perhaps the most useful thing to do here is to test the hypothesis that general aviation users can, in fact, bear additional charges.

"Gravity" models offer some insight, since the number of trips between points is, among other things, an inverse function of the "friction" between them. This friction can be expressed in terms of miles, time, or cost of travel. Multiple regression techniques were applied to the results of the mail survey of Wisconsin registrants to determine a gravity model for intrastate county-to-county general aviation traffic. (This was based on approximately 50,000 airplane movements between 1,834 different origination-destination pairs.) The friction factor was miles between origination and destination.

Assuming constant cost per mile, a 5 per cent increase in cost would reduce single-engine trips by 5·5 per cent. However, it would reduce twin-engine (propeller aircraft) trips by only 3·6 per cent. The data were divided between trip lengths which were greater and those less than the mean (111 miles). For single-engine trips of less than 111 miles (new mean 64 miles), a 5 per cent increase in friction would result in a 7·3 per cent decrease in trips. For single-engine trips greater than 111 miles (new mean 174 miles), a 5 per cent increase in friction would reduce trips by only 3·7 per cent. From this it can be concluded that an increase in costs (friction) would have less effect on twin-engine trips than on single-engine trips, and less effect on longer single-engine trips than on shorter single-engine trips. These differing sensitivities to increases in cost are also indicative of the relative value of the airport system for trips of varying characteristics.[39]

Assume that the user fees were earmarked for accelerating an airport construction programme. Two variables in some of the "gravity" equations with positive coefficients were the number of airports in the origin county and the number of airports in the destination county. If it is assumed that these are indicative of

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[39]Most types of user fees, including a fuel tax, would tend to increase short trip costs more – in percentage terms. They would, therefore, have a greater impact on short trips than indicated in the text. Also, it appears from these calculations that many users of general aviation enjoy some element of consumer's surplus.

general aviation airport improvements, the impact on trips of accelerating an airport programme can be calculated. A 5 per cent increase in airports would increase single-engine trips by 6·2 per cent and twin-engine trips by 2·6 per cent. Calculations were then made of the impact that a 6 cents per gallon tax on aviation gasoline in Wisconsin would have on both (1) aircraft operating costs and (2) ability to expand the state's general aviation airport system. The net effect was that the total volume of general aviation activity would increase. Trips were encouraged much more by additional facilities than they were discouraged by additional costs.[40] If carried to its conclusion, this line of reasoning indicates that general aviation interests would be further ahead by insisting on paying user fees if the revenues were earmarked to expanding the airport programme. Concurrently, it would appear that the amounts of public subsidies could be somewhat reduced.

CONCLUSIONS

This paper has developed a methodology for measuring general aviation benefits. It was based on the straightforward assumptions that only through use can the benefits be realised and that users are, in fact, the beneficiaries. Projecting future benefits is more difficult and may be subjected to more vicissitudes because of the rapid – and not necessarily even – growth in general aviation activity. Lastly, if a system of user charges were contemplated, the users are readily identifiable and there is no evidence that they are unable to bear a larger proportion of the costs of the airport programme.

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[40]The calculations did not take into account any taxes on jet fuel.