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The United States government supports a vast network of air traffic control and safety for aviation users throughout the country and across the Pacific and North Atlantic Oceans. This Airport and Airway System is operated not only through the Federal Aviation Administration, but also through a number of other federal agencies.

In the late 1960s the rapid growth in air traffic was straining the capacity of the Airport and Airway System and causing serious delays and airspace congestion. To help to remedy this, the U.S. Congress passed the Airport and Airway Development and Revenue Act of 1970[1], authorising a long-range programme for expanding and improving the nation's airports and airways. The Act directed the U.S. Department of Transportation (DOT) to undertake a cost allocation study with the following objectives:

1. To determine the costs of the federal Airport and Airways System.
2. To determine how these costs should be allocated among the various users, i.e., air carrier, general aviation, and military aviation.
3. To recommend equitable ways for recovering these costs.

In the fall of 1970 DOT launched the cost allocation study, which was undertaken by DOT personnel and supported by contract research personnel.

This paper[2], based partly on work carried out by the authors for the Department of Transportation, summarises the results of this inquiry and describes the separable costs/remaining benefits method for allocating costs to air carrier, general aviation, and military users.[3] The paper also provides a direct comparison of the allocated costs and user revenues from existing airport and airway charges. Large shortfalls in tax recovery are revealed, particularly in the general aviation sector, and the need for changes in the tax structure becomes apparent from the study results.

THE U.S. AIRPORT AND AIRWAY SYSTEM

Many federal programmes were examined as part of the cost allocation study. This paper focuses on five key programmes: those of the Federal Aviation Administration

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[1]For a description of this legislation, see Jeremy J. Warford [7].

[2]The authors thank Dr. David Nissen and Dr. Edgar Battison, senior economists of Resource Management Corporation, for their comments and suggestions.

[3]The study results were published by the U.S. Department of Transportation in [9] and in eighteen Cost Allocation Study Working Papers.

(FAA), the DOT-Office of the Secretary (OST), Department of Defence (DOD), Department of State (DOS), and the National Aeronautics and Space Administration (NASA).[4]

In services provided and in annual expenditures, the FAA is by far the dominant component of the Airport and Airway System; it is the core of the federal aviation system. The Office of the Secretary of DOT supports research programmes relating to long-range needs for air traffic control in the U.S.: these programmes are financed by the Airport and Airway System trust fund and were included in the cost allocation study. NASA also funds research programmes to improve the ultimate efficiency, safety and convenience of air travel in the national Airport and Airway System. The study covered only those programmes which directly increase the safety and efficiency of FAA facilities: all other NASA R & D programmes were excluded.

The Department of Defense owns and operates an extensive system of air bases and air traffic control. Most of these are used solely by miliatry aviation and were not included in the cost allocation study. But there are a number of DOD facilities which provide air traffic control services for civil aviation, and these were included.

The last programme included in the study was payments to the International Civil Aviation Organisation by the Department of State for joint financing of *en-route* communications and meteorological and air traffic control services in the North Atlantic.

Components of the system

For purposes of analysing the Airport and Airway System costs and making allocations to the air carrier, general aviation, and military users, five functional categories were defined:

1. *Airports*—including facilities and equipment not directly related to aircraft control, e.g., land, runways, taxiways, and aprons. Since airports are not generally operated by the federal government, federal participation is limited to grants for airport development and construction.
2. *Terminal Control*—facilities and equipment needed to assist and control aircraft terminal operations during takeoffs and landings.
3. *En Route Control*—including air traffic control to Instrument Flight Rule (IFR) users and navigation assistance to all categories of aircraft after takeoff operations are completed and prior to landing.
4. *Flight Services*—a wide variety of services for both Visual Flight Rule (VFR) and IFR users, including filing flight plans, weather information, flight advice, and rescue operations.
5. *Support*—all FAA facilities, equipment and programmes that are not directly part of the air traffic control mission, but essential to its continued operation and further development.

Each of these functional categories was in turn broken down into smaller components called "system elements". For example, the functional category for FAA

[4]These five programmes were included in the investigation of alternative cost allocation methods. In the final cost allocation analysis, the DOD and NASA programmes were excluded and costs for the National Oceanic and Atmospheric Administration Aviation Weather Services were added. The overall results were not significantly different from those reported in this paper.

terminal control was composed of 64 elements, including air traffic control towers, terminal control radars, communications equipment, instrument landing systems, etc. After this detailed breakdown of system elements, they were combined as needed into meaningful groupings for analysing and allocating system costs.

THE COST BASE

The annual costs of the Airport and Airway System comprise the "cost base" to be allocated to aviation users. The cost base was designed to cover an extended period (1966 to 1975), to smoothe out any erratic fluctuations in annual funding expenditures and to avoid atypical costs that can arise in any one year. The specific ten-year period was selected to achieve a balance between historical costs (1966 to 1972) and projected costs, including investment in new equipment (1973 to 1975). All costs were projected in constant 1971 dollars.

Cost categories

In preparing the cost base estimates, the costs for all functional categories and system elements were grouped into four cost categories, as follows:

1. *Research and Development (R & D) Costs*—including all expenditures needed to bring a new concept or system element to a point where prototype equipment or pilot facility is operating or can be tested in the Airport and Airway System inventory.
2. *Facilities and Equipment (F & E) Costs*—the one-time capital expenditures required for the procurement and installation of new facilities and all new equipment. F & E costs include all land costs, engineering, site preparation and construction, construction material, electronic equipment, installation and freight.
3. *Relocation and Modification (R & M) Costs*—annual investments to renovate and relocate elements of the system. Although most budgets included these costs as part of the F & E appropriation, R & M costs were treated as a separate cost category in this study.
4. *Operations and Maintenance (O & M) Costs*—annual expenses needed to operate and maintain items in the system. Operations costs include all personnel (e.g., controllers) who operate the equipment and perform the primary function of air traffic control. Maintenance costs include all maintenance personnel, stocks and stores, and overhead costs needed to keep the inventory of facilities and equipment in satisfactory operating condition.

Treatment of capital costs

In preparing the cost base for the Airport and Airway System, capital investment costs were treated as a series of annual charges (i.e., amortised costs) over a specified period of time. The capital costs incurred during the base period (1966 to 1975) were amortised over the economic life of the new facilities and equipment; thus these costs were extended into future years in which users would actually derive benefits from the investment. Similarly, the remaining values of facilities and equipment procured before the start of the base period were amortised over the 1966 to 1975 base period and added to the costs of current investment. In this way, users in the 1966 to 1975 base period are charged for prior investments.

The concept of remaining value of prior-year capital investments is related to the economic theory underlying capital investments. Assuming that the net capital stock at a given time is a composite of investments made over many years minus their depreciated values, charges for the capital services consumed during a given year should include charges for the investments of the previous years as well as the current year. The appropriate charge is the value of the depreciation plus the equivalent risk opportunity loss after consideration of the increased costs which would have been incurred if the investments had been delayed. Thus, it is proper to apply proportions of remaining value, depreciation and interest charges (as proxies for opportunity costs) to previous investments in calculating the stream of base period costs.

System element cost approach

Budget reports were a primary source of cost data for much of the Airport and Airway System cost base. These data were particularly useful for the research and development programmes and support activities, where costs are not directly related to air traffic operations. Similarly, FAA budget appropriations for grants-in-aid for airports were used directly in the cost base for the airport category.

However, for the direct air traffic control activities—terminal control, en route control, flight services, and system support—budget data were not available at the level of detail necessary for making meaningful cost allocations. For these activities the cost base was estimated from unit cost data for F & E, O & M, and R & M costs for all system elements which could be defined in terms of operational inventories.[5] F & E unit costs were used to price out equipment procured, according to a prescribed time-phased programme for new authorised inventory. Total O & M costs were estimated for each system element by multiplying the inventory of operational facilities by its unit costs. Similarly, total R & M costs each year were computed by multiplying unit R & M cost factors and the operational inventory to give estimates of the average amount spent each year to upgrade and modernise each system element.

Summary of cost base results

Table 1 summarises the Airport and Airway System cost base used for allocating costs, described in the following sections of this paper. The capital costs were amortised at a 10 per cent discount rate.[6] The cost base includes the amortised costs of all capital items, including the remaining value (in 1965) of investments made in years

[5] The unit cost estimates are described in detail in the authors' work in DOT *Aviation Cost Allocation Study Working Paper No.* 2 [10].

[6] The 10 per cent discount rate is described as an estimate of the average rate of return on private investment, before taxes and after inflation. The 10 per cent figure was calculated by taking the average annual rate of return on productive or non-financial capital in the U.S. during the post-World War II period, up to 1966. This average rate turned out to be 12 per cent, and was readjusted to 10 per cent by subtracting the post-war inflation.

1950 to 1965. The costs presented in Table 1 summarise the cost base for each agency programme by cost category within the five major functional categories. A more detailed presentation of the cost base is given in the DOT cost allocation study working papers [11].

COST ALLOCATION METHODS

The design of user tax systems for the Airport and Airways System requires previous allocation of the costs of the joint use facilities to the main joint user classes: air carriers, general aviation and military. Allocation of the joint costs entails problems of cost base valuation, as explained in earlier sections, as well as the design of specific cost allocation rules, which are described here.

The cost allocation study considered several cost allocation methods, such as (1) *units of use* (allocating the costs of individual subsystems proportionally to units of use weighted by the manning requirements entailed by each unit of use), (2) *benefits* (allocating the total joint costs of the System in proportion to benefits), (3) *long-run marginal costs* (allocating the joint costs of each subsystem in proportion to the long-run marginal costs imposed by each user), (4) *long-run incremental costs* (a variation of the marginal costs, in which the intercepts of the cost functions are distributed proportionately to units of use), (5) *costs of separate facilities and systems* (allocating the total System costs in proportion to the costs of separate systems for each of the users), and (6) *separable costs/remaining benefits* (a cost allocation technique commonly used in Water Resources Project analysis and analysed by both O. Eckstein [2] and the Water Resources Green Book ([8], pp. 53–56). This article concentrates on the separable costs/remaining benefits method.[7]

Separable costs/Remaining benefits allocation method

The separable costs/remaining benefits methodology (described in detail in [14], p. 7-1) distinguishes the following concepts, which are incorporated into the specific allocation rules:

1. *Separable costs:* those costs that would be avoided if the user class did not exist. These costs are estimated through statistical cost regressions from which the avoidable costs due to each user are calculated.
2. *User benefits*: reductions to users in the costs of congestion and delays, cancellations and diversions; costs saved from reductions in accidents; as well as increases in consumer surpluses, all brought about by Airport and Airway System improvements. These benefit categories are similar to those developed several years earlier by Gary Fromm [3], [4], and the reader is referred there for more elaboration on these categories.
3. *Costs of separate systems and facilities*: costs associated with a hypothetical independent system designed solely to meet the needs of a specific user class.
4. *Justifiable costs:* these represent the lower of two values—user benefits and the costs of separate systems. Inherent in this concept is the efficiency rule,

[7] Those interested in reviewing in more detail the results of the other cost allocation methods investigated should refer to the authors' work in DOT *Aviation Cost Allocation Study Working Paper No.* 10 [14].

TABLE 1

Airport and Airway System Cost Base, Amortised Capital Costs Including Prior Year Investments (thousands of 1971 dollars)

Function Category	1966	1967	1969	1971	1973	1975	*Total*
Airport Systems							
FAA Trunk and Local F & E	65,374	75,269	86,532	110,962	157,694	212,157	1,198,399
All Other Airports F & E	17,865	20,094	24,113	26,986	39,053	53,104	308,086
R & D	2,787	2,986	3,086	3,382	4,341	5,866	37,347
Subtotal	86,026	96,349	113,731	141,330	201,088	271,127	1,543,832
Terminal Control							
FAA Trunk and Local F & E	33,411	35,621	46,586	54,810	67,314	80,715	546,920
Trunk and Local O & M	127,610	143,471	190,536	209,217	245,603	294,441	2,066,896
Trunk and Local R & M	13,069	13,358	14,113	14,410	16,293	18,513	149,929
All Other Airports F & E	2,414	2,822	3,269	3,669	4,031	4,318	35,029
All Other Airports O & M	6,906	9,395	14,703	18,165	22,542	29,354	176,118
All Other Airports R & M	738	815	952	1,163	1,272	1,988	10,798
R & D	19,169	20,878	23,810	27,360	34,446	46,976	289,612
DOD F & E	4,303	4,478	4,531	4,531	4,531	4,531	44,976
O & M	47,228	47,228	47,512	48,302	48,542	48,542	480,070
R & M	1,786	1,786	2,038	2,281	2,293	2,293	21,214
OST R & D	45	87	395	1,075	1,963	2,883	11,289
NASA R & D	0	0	0	2,036	3,745	5,454	19,710
Subtotal	256,679	279,939	348,445	387,019	452,575	539,408	3,852,501
En Route *Control*							
FAA Centre F & E and R & M	74,020	78,161	90,624	135,661	158,720	173,209	1,219,104
Centre O & M	163,531	179,833	231,828	239,027	262,005	291,337	2,341,104
Navaid F & E, O & M, R & M	32,084	31,906	32,319	34,124	35,242	37,118	338,959
R & D	33,578	35,892	40,402	50,907	64,777	75,597	513,378
DOD F & E	5,412	5,412	5,412	5,412	5,412	5,412	54,120
O & M	6,900	6,900	4,500	3,750	3,750	3,750	44,100
R & M	1,698	1,698	1,170	975	975	975	11,466
DOS O & M	1,641	2,190	1,610	1,773	2,069	2,069	19,032
OST R & D	45	87	395	1,095	1,963	2,883	11,289
NASA R & D	0	0	0	0	789	1,578	3,944
Subtotal	319,049	341,419	408,260	472,704	535,702	593,928	4,556,532
Flight Services							
FAA F & E	16,326	16,486	16,734	16,857	16,794	18,184	169,496
R & M	6,301	6,706	7,164	7,196	7,123	7,056	89,631
O & M	92,437	104,238	117,840	121,404	135,691	137,662	1,200,913
R & D	2,420	2,883	3,257	3,500	4,039	4,999	35,703
Subtotal	6,117,485	130,314	144,996	148,957	163,828	167,900	1,475,743
Support							
FAA F & E	15,311	15,831	16,187	16,475	19,160	27,108	184,221
R & M	1,707	1,708	1,693	1,501	1,485	1,347	15,722
O & M	267,313	260,466	272,241	302,145	390,400	440,754	3,241,343
R & D	7,481	7,639	8,165	8,322	10,597	17,815	97,632
Subtotal	291,812	285,644	298,286	328,442	421,642	487,023	3,538,918
TOTAL	1,071,050	1,133,664	1,313,717	1,478,452	1,774,834	2,059,387	14,967,524

which requires that benefits from the joint use of the Airport and Airway System exceed the costs of separate systems, since otherwise there would be no rationale for the joint use facilities.

5. *Remaining benefits*: the residual for each user after its separable (or avoidable) costs are subtracted from the justifiable costs.

These cost and benefit concepts are then used in the following specific allocation rules:

1. Allocate the separable costs directly to each user class responsible for them.
2. Allocate the remainder of the Airport and Airway System costs (after the allocation of the separable costs) in proportion to the remaining benefits.

Before we immerse ourselves in the quantification of these concepts and allocation rules, some assessment of the method is in order. Essentially, separable costs/remaining benefits allocates the joint costs in accordance with cost savings that accrue from the joint use of facilities (the alternative would be complete separation of users). The more expensive a separate system would be for a user, the larger the portion of joint costs which will be assigned to him. If the benefits from joint use are smaller than the costs of a separate system, the user is not penalised by the system inefficiency, and benefits are then used to distribute the joint costs. Thus, if the benefits are so low that they barely exceed the separable costs, the method will not allocate more costs to this user, and the user's benefit/cost ratios, even based on allocated costs, will be favourable. In judging this allocation method we must consider both efficiency in output and efficiency in investment decisions. The consideration of justifiable costs, by focusing on the benefits from joint use and the costs of separate systems, highlights considerations of efficiency in investment decisions. Also, the costs of providing for separate systems for each user may be added and compared with the total Airport and Airway System costs to examine the logic behind the joint use System design.

Output decisions on the Airport and Airway System concern the user's response to the prices which result from the cost allocation. By allocating to each user class its separable (or avoidable) costs, the separable costs/remaining benefits method ensures that at least the users cover the incremental costs of providing the services—a rule which is said to be violated in the pricing of railroad services in the United States [5]. Focusing on separable (or avoidable) costs also aids in decisions regarding expansion of the system to accommodate other users with different equipment configurations and system requirements. Since the Airport and Airway System shows declining long-run average costs in several important services, such as *en route* control and radar terminal approach control [14, chapter 4], the federal government decision to press for full cost recovery has tended to minimise any disruptions in output decisions from the application of separable costs/remaining benefits.

The costs allocated according to separable costs/remaining benefits are usually greater than the marginal costs. In some cases the benefits are used as justifiable costs, and thus the allocation approximates Baumol-Bradford [1] pricing. Deviations from marginal cost pricing according to "willingness to pay" are indeed reflected in benefit concepts incorporating consumer surplus considerations. When justifible costs are defined in terms of separate systems and facilities, deviations from Baumol-Bradford efficient pricing will indeed occur, although, as Eckstein [2] argues, these distortions are small when contrasted with current pricing practices in United States transport.

ALLOCATION OF COSTS BY SEPARABLE COSTS/REMAINING BENEFITS

Earlier sections have described the methodology and theoretical underpinnings of the separable costs/remaining benefits method. This section describes how the cost allocation is carried out.

Estimation of separable costs

The separable costs are those so intimately associated with the needs and operation of an aviation user class that the costs would disappear if the user class did not exist. The separable costs include both directly assignable costs and avoidable costs. The directly assignable costs include the costs of non-joint facilities, such as the airport and terminal systems control costs of smaller general aviation airports (i.e., all airports other than Trunk and Local air carrier airports). The other directly assignable costs are Department of State *en route* control costs, which include some North Atlantic facilities maintained to service international air carriers.

The avoidable costs comprise those which would be avoided in joint use facilities if the user were not there. If the Airport and Airway System costs can be represented by linear cost functions of the activities of each user class, then the avoidable costs of each user class are calculated by multiplying each user class activity level by its linear regression coefficient. A difficulty encountered in estimating cost functions for the Airport and Airway System was the lack of cost data by subsystem type. However, using the unit cost factors by equipment type referred to earlier, we were able to develop costs for 252 individual trunk and local airports, 26 *en route* control centres and 80 flight services stations. After costing each of these facilities in constant 1971 dollars, the resulting cost dependent variables were estimated as a function of the activity variables in the manner shown in Table 2. These equations were then used to compute the 1971 avoidable costs which appear in Table 3. No *en route* control centres' F & E, R & M, and maintenance costs have been allocated to general aviation, which appears with a negative, albeit insignificant, regression coefficient in Equation 7 in Table 2.

Estimation of separate costs

Two main approaches were used to estimate the costs of separate facilities and systems for the three main classes of users. Statistical cost functions based on regression analysis were used extensively to estimate all separate systems costs, except for general aviation *en route* control systems, which relied on an engineering approach. The engineering approach to general aviation *en route* control is necessary because an entirely different system from the current one would have evolved if only general aviation needs had been considered in the system design.

The statistical cost function analysis was similar to the one conducted for the investigation of avoidable costs. Essentially 11 different regression functions were estimated for each category of air carrier airports (trunk and local) and general aviation airports (larger-than-general and utility) for a total of 44 terminals and airport cost functions. The 11 cost regressions estimated for each airport type included (1) land costs of airport systems, (2) paving costs of airport systems, (3) total F & E terminal control costs, (4) total O & M terminal control costs, (5) basic operations

TABLE 2

Airport and Airway System Cost Functions—1971
1971 *dollars*)

Equation No.	Dependent Variables	Activity Levels Used	Intercept or Constant	Regression Analysis Coefficients of the Independent Variables[a]: Air Carrier Activity	General Aviation Activity	Military Activity	Flight Services: Aircraft Contacts	Pilot Briefs	Flight Plans Filled	Air Miles Controlled by En Route Centres (in Logs)	Evaluation Statistics[b]: R^2	$\bar{R}^2$
1	Airport paving costs at trunks and local airports	Aircraft operations	5,096,641·68 (9·11)	51·98 (13·93)	11·11 (2·77)	85·65 (5·18)					0·84	0·45
2	Airport land costs at trunks and local airports	Aircraft operations	2,061,872·08 (4·10)	27·72 (8·27)	4·64 (1·29)	36·71 (2·47)					0·58	0·21
3	Terminal control F & E costs at trunk and local airports	Aircraft operations	913,057·77 (7·97)	15·56 (20·37)	1·56 (1·90)	14·07 (4·15)					0·86	0·62
4	Terminal control operations costs at trunk and local airports	Aircraft operations	126,101·06 (4·83)	4·26 (24·47)	0·94 (5·04)	2·72 (3·53)					0·87	0·71
5	Terminal control maintenance costs at trunk and local airports	Aircraft operations	75,476·41 (3·67)	2·55 (18·70)	0·33 (2·26)	1·66 (2·75)					0·78	0·58

6	Terminal control R & M costs at trunk and local airports	Aircraft operations	23,519·86 (5·45)	0·57 (19·90)	0·06 (1·95)	0·51 (4·03)					0·82	0·61
7	*En route* control centres F & E costs (in logs)	Millions of aircraft handled (in logs)	−0·80 (−0·59)	0·33 (2·33)	−0·14[c] (−1·22)	0·21 (3·27)				0·49 (3·53)	0·76	0·72
8	*En route* control centres operations costs (in logs)	Millions of aircraft handled (in logs)	3·21 (21·57)	0·62 (5·30)	0·15 (2·26)	0·24 (2·83)					0·94	0·93
9	*En route* control centres maintenance costs (in logs)	Millions of aircraft handled (in logs)	1·56 (5·41)	0·48 (2·02)	−0·04[c] (−0·22)	0·31 (2·92)					0·66	0·60
10	Flight services stations O & M costs	Types of flights services					1·71 (5·04)	1·51 (4·82)	1·12 (1·91)		0·86	0·67

[a] Figures in parentheses denote the *t*-values of the respective regression coefficients. All the variables are expressed in actual values, except for the *en route* control cost and aircraft handled variables, which are expressed in millions and appear in the cost functions in natural log forms. The air miles variable of *en route* control centres is expressed in actual terms, and its natural log is used in the *en route* control cost equation.

[b] $\bar{R}^2$ denotes the multiple correlation coefficient around the mean, adjusted for degrees of freedom. The data base includes 252 trunk and local airports, 19 *en route* control centres, and 90 flight services stations.

[c] General aviation was assumed not to contribute to the costs of these Airport and Airways Systems.

TABLE 3

Avoidable Costs for Air Carrier, General Aviation and Military at Joint-Use Facilities—1971
(millions of 1971 dollars)

Functional Category and System Element Costs	Regression Number	Total Avoidable Costs			Annualised Avoidable Costs[a]		
		Air Carrier	General Aviation	Military	Air Carrier	General Aviation	Military
Airport Systems $(TR+LO)$[b]							
Paving costs	1	533·7	286·9	238·0	54·6	29·3	24·3
Land costs	2	284·6	119·8	102·0	28·5	12·3	10·2
Total F & E	1, 2	818·3	406·7	340·0	83·1	41·6	34·5
FAA Terminal Control $(TR+LO)$[b]							
Total F & E	3	159·8	40·3	39·1	21·7	5·5	5·3
Total O & M	4, 5	69·9	32·8	12·2	69·9	32·8	12·2
Total R & M	6	5·8	1·5	1·4	5·8	1·5	1·4
FAA En Route *Control*							
Total F & E	7	279·5	0·0	190·2	31·2	0·0	21·0
Total O & M	8, 9	148·3	29·5	67·3	148·3	29·5	67·3
Total R & M[c]	n	8·4	0·0	5·7	8·4	0·0	5·7
FAA Flight Service							
Total O & M	10	2·8	34·8	4·3	2·8	34·8	4·3
Total Avoidable Costs[d]		—	—	—	371·2	145·7	151·7

[a] Airport paving and land costs were amortised over 40 years, terminal control F & E costs were amortised over a 14-year life, and *en route* centres' costs were amortised over a 25-year life. Discount rates of 10 per cent annually were used in the amortisation.

[b] $(TR+LO)$ denotes facilities at trunk and local airports.

[c] Computed as 3 per cent of F & E cost.

[d] Note totals exclude FAA support costs and other agency costs.

(including the tower costs mainly), (8) instruments O & M costs, (9) radar approach control F & E costs, (10) radar approach control O & M costs, and (11) total R & M terminal control costs. The disaggregation of terminal costs into basic operations, instruments, and radar approach costs follows the attempt to disaggregate costs into categories which explain the variation of costs among terminal facilities as a function of activity levels.

Aircraft operation levels affect mostly the cost of basic operations, while instruments operations affect the instrument costs of terminal control systems, and radar approaches determine the radar approach costs of terminal facilities. The operations costs basically include the air traffic control tower and its associated subsystems. The instrument costs include the instrument landing system and its associated subsystems; the radar approach control costs cover the terminal radar control, the airport surveillance radar, and its kindred systems. Because of the impossibility of reproducing all this work in this paper, the reader is referred to our analysis in Working Paper No. 10 for more information.[8] The *en route* control and flight services cost functions are the same as shown in Table 2.

Air carrier separate systems

The air carriers' separate systems were estimated from the statistical cost regressions for each subsystem component at each trunk and local airport. Air carrier landings at general aviation airports were assumed to be shifted to the larger air carrier airports. The *en route* costs were estimated for all the *en route* facilities (except the separate TACAN sites which serve primarily military users), using the cost regressions Equations 7 and 8 from Table 2. Furthermore, the *en route* R & D programme assigned to air carriers under separate systems was diminished through the elimination of the R & D programme for *en route* centre automation, which was assumed not to be needed any more because of the reduced air traffic handled by centres. Both the 30 flight services stations (out of the 393 stations) and the eight international flight service stations, which account for over 80 per cent of the use of air carrier flight services, were included in the design of this separate air carrier system. All the DOD joint use facilities involving towers, terminal and surveillance radars, were assumed to be needed by the carriers.

Military separate systems

The costs of separate systems for the military were estimated by assuming that all military operations would be served by the runway and terminal control systems at local airports. Therefore, all the military operations at trunk, local, and other airports were costed by the cost functions for local airport configurations. All the flight services requirements of military uses were assumed to be provided by the 50 stations and eight international stations which provide the bulk of them; thus it was assumed that there was no military need for the other flight service stations in the current FAA inventory. All the DOD joint use was assumed to be needed by the military. Military *en route* system costs included the costs at 27 *en route* centres (including those in Guam and the Canal Zone), which were calculated from the Equations in Table 2.

[8] See [14] Table 4-2 and Tables 5-11 to 5-16, for an examination of these results.

General aviation separate systems

Obviously, a separate airport and airway system for general aviation would have no need of the 10,000-foot runways and other systems specifications available at trunk and local airports. For purposes of estimating the separate airport and terminal control costs of general aviation users, it was assumed that the service requirements of current general aviation landings at trunk and local airports would be met by general aviation airports at the same sites, while all other general aviation airport users continued to enjoy their present airport and terminal configurations. Also included in this separate system were all the flight service stations.

Separate *en route* systems for general aviation would entail a design completely different from the current system.[9] The basic elements and features of the proposed *en route* control system include the following ground facilities: (1) about 2,500 "basic" VOR stations sited on a grid plan suitable for general aviation airway fixing and terminal approaches, (2) expanded inventory of 75-MHZ vertical markers in relation to the increased VOR sites, (3) VHF ground communications, mostly along the line of facilities already developed, and (4) airway traffic control centres. Perhaps there would be some 500 of these, designed along the lines of expanded flight service stations.

Table 4 summarises the costs of the proposed general aviation *en route* system. The

TABLE 4

En route *Control Costs for Separate General Aviation System*—1971 (1971 *dollars*)

System Elements	*Postulated Inventory*	*Unit Costs (thousands)* F & E	O & M	R & M	*Total Cost (thousands)* F & E	O & M	R & M
Airway Control Centres							
New	189	500	400	10	94,500	75,600	1,890
Expanded FSS IV	311	100[a]	80[a]	2[a]	31,100	24,880	622
Communications							
RTRs	60[a]	40·0	8·0	0·8	2,400	480	48
RCOs	15[a]	158·0	14·0	3·2	2,370	210	48
LRCOs	294[a]	11·7	1·3	0·2	3,440	382	59
Navigation Aids							
"Basic" VOR	2,500	100	10·0	2·0	250,000	25,000	5,000
Vertical Marker	150	12	2·3	0·2	1,800	345	30
Total *En Route* Control	—	—	—	—	385,610	126,897	7,697

[a] Increase to current FSS system.

[9]The engineering underpinning of the system costed here was developed by George H. Litchford, and appears in *Aviation Cost Allocation Study Working Paper No. 8* [12]. The reader is referred there for a review not only of Litchford's work, but also of the more than ten aviation studies which during the period 1946–1971 have dealt with issues related to the design of a separate general aviation *en route* and terminal control system.

centre costs were based on an expanded flight service station facility cost with an average of 20 full-time persons to handle the air traffic control and flight advisory services. This is an increase of about six full-time operations personnel over the existing FSS facility. The inventory of communications facilities (RTRs, RCOs, and LRCOs) was estimated to increase in proportion to the number of centres being added (i.e., 311 to 500). The costs for these facilities were based on 1971 costs for FSS communication systems.

Total costs of separate systems

The summary of total costs of separate facilities and systems calculated by the procedures presented above appears in Table 5. The costs of the subsystems (basic operations, instruments and radar approach control costs) are combined into a single total-cost estimate for each user by converting the F & E costs into equivalent annual costs and spreading these costs over their economic life. The average economic life values for each functional category are described in Table 5. A 10 per cent discount rate is used throughout the analysis; this is consistent with other parts of the allocation study. These separate systems costs, which amount to $2,245·1 million in 1971, are more than 50 per cent above the annualised joint use costs of $1,478·8 million during the same period; this provides evidence of the cost savings from the joint use design.

Estimation of justifiable costs and remaining benefits

Justifiable costs

In the development of justifiable costs, the costs of separate systems are compared with the level of benefits, and the smaller of the two values is defined as justifiable costs. Estimates by Jack Faucett Associates and the authors [13] of benefits of the Airport and Airway System distinguished two types of benefits from the System: (1) incremental benefits, defined as improvements in safety and reductions in accidents, congestion, delays, cancellations and diversions, brought about by Airport and Airway System expenditures since 1960, and (2) consumer surplus benefits (or value of service benefits) brought about by these expenditures; the latter, in the absence of knowledge on demand elasticities of the user classes, were assumed to be proportional to total aviation expenditures incurred by the users. Both estimates showed larger benefits than the costs of separate systems.

Taking air carriers as an example, the incremental benefits of the carriers as shown in Table 6 were already greater than their separate costs by 1973; this suggests that if the value of service estimates were incorporated into the analysis the total benefits would outweigh their separate costs. For general aviation, too, the incremental benefits will be higher than separate costs by 1974. Since the incremental benefits exceed the cost of separate systems, we conclude that *total* benefits would far outweigh these costs. Thus, justifiable costs may be defined as the costs of the separate systems.

Remaining benefits

The estimate of remaining benefits for each system category is the difference between justifiable costs (i.e., separate systems costs) and the avoidable cost for each category

TABLE 5

Separate System Costs for Air Carrier, General Aviation and Military Users—1971
(*millions of* 1971 *dollars*)

Functional Category	*Cost Category*	*Annualised Cost*		
		Air Carrier	*General Aviation*	*Military*
Airports Systems—operations at trunk and local airports[a]	F & E	453·5	129·5	142·3
Airport Systems—operations at larger than general and utility airports[b]	F & E	0·0	54·0	0·0
FAA Terminal Control at trunk and local airports[a]	F & E	60·5	21·1	25·5
	R & M	13·6	3·6	3·6
	O & M	143·1	51·4	36·1
FAA Terminal Control—operations at larger-than-general and utility airports[b]	F & E	0·0	3·7	0·0
	R & M	0·0	1·2	0·0
	O & M	0·0	18·2	0·0
FAA En Route *Control*[a]	F & E	121·3	54·3	94·6
	R & M	26·3	7·7	19·8
	O & M	208·4	126·9	133·4
FAA Flight Service[a]	F & E	3·7	27·6	5·5
	R & M	1·0	7·2	1·5
	O & M	7·0	104·0	12·6
DOD Terminal Control[a]	F & E	7·5	0·0	9·8
	R & M	1·6	0·0	2·1
	O & M	47·7	0·0	48·2
DOD En Route *Control*[a]	F & E	0·7	0·4	0·7
	R & M	0·1	0·1	0·1
	O & M	0·4	0·3	0·4
DOS En Route *Control*[b]	O & M	1·8	0·0	0·0
Total Separate System Costs		1,090·1	610·9	536·1

[a] All F & E costs amortised at 10 per cent discount rate. Airport F & E costs include paving and land costs amortised over a 40-year life, FAA and DOD terminal control F & E costs amortised over a 14-year life, FAA and DOD *en route* control F & E costs amortised over a 13-year life, and flight service systems F & E costs amortised over a 25-year life.

[b] Annualised costs for these directly assignable facilities are estimated using cost base figures for year 1971. Airport F & E costs for general aviation larger-than-general and utility airports are estimated at two times cost base figures, assuming 50 per cent federal government funding as part of Grants-in-Aid-to-Airports.

of users. Both sets of values have been computed. Table 7 presents the results by functional category and system element costs. For each calculation, costs have been converted to an annual basis. The costs for separate systems are taken directly from Table 5; the avoidable costs are from Table 3. The directly assignable costs, which are added to the avoidable costs to compute the separable costs, are the DOS *en route*

TABLE 6

Comparison of Separate Systems Costs and Incremental Benefits (millions of 1971 dollars)

User	1971 *Separate System Cost (on annual basis)*	*Incremental Benefits*[a] 1973	1974
Air carrier	1,098·1	1,280·0	1,800·0
General aviation	610·9	560·0	680·0

[a] From *Aviation Cost Allocation Study, Working Paper No.* 9 [13], Table 1.

TABLE 7

Synopsis of Remaining Benefit Computations for Air Carriers, General Aviation, and Military Users—Separate Systems Cost Less Separable Cost—for Selected Cost Categories—1971 *(millions of* 1971 *dollars)*

	Value of Remaining Benefits			*Proportional Remaining Benefits*		
Selected Functional Category and System Element Costs Categories	*Air Carrier*	*General Aviation*	*Military*	*Air Carrier*	*General Aviation*	*Military*
Airports (TR+LO)						
1. F & E	370·4	87·9	107·8	0·654	0·155	0·191
FAA Terminal Control (TR+LO)						
2. F & E	38·8	15·6	20·2	0·520	0·209	0·271
3. R & M	7·8	2·1	2·2	0·645	0·174	0·181
4. O & M	73·2	18·6	23·9	0·632	0·161	0·207
5. Total	119·8	36·3	46·3	0·592	0·179	0·229
FAA En Route *Control*						
6. F & E	90·1	54·3	73·6	0·413	0·249	0·338
7. R & M	17·9	7·7	14·1	0·451	0·194	0·355
8. O & M	60·1	97·4	66·1	0·269	0·436	0·296
9. Total	168·1	159·4	153·8	0·349	0·331	0·320
Flight Service Systems						
10. O & M	4·2	69·2	8·3	0·052	0·047	0·101
11. FAA Cost Totals	662·5	352·8	316·2	0·498	0·265	0·237
12. DOD Terminal Control Systems	56·8	0·0	60·1	0·486	0·000	0·514
13. DOD *En Route* Control Systems	1·2	0·8	1·2	0·375	0·250	0·375

control and the FAA airport and terminal control costs at larger-than-general and utility airports, which appear in Table 5.

The proportional values of remaining benefits are derived from the dollar estimates and are also shown in Table 7, excluding the DOD costs. These values are the basis for the remaining benefits portion of the cost allocation of FAA costs.

ALLOCATION OF COST BASE

Costs in the Airport and Airway System cost base are apportioned to air carrier, general aviation, and military users according to the following rules:

Functional Category	*Allocation Rule*
Airport System	
Trunk and local costs	Separable costs/remaining benefits
All other airports	Directly assignable to general aviation
Airport R & D	Proportional to total remaining benefits of airports (Table 7, line 1)
FAA Terminal Control	
Trunk and local (F & E, R & M, O & M)	Separable costs/remaining benefits
All other airports (F & E, R & M, O & M)	Directly assignable to general aviation
Terminal R & D costs	Proportional to total remaining benefits of terminal control (Table 7, line 5)
FAA En Route *Control*	
Centres (F & E, R & M, O & M)	Separable costs/remaining benefits
Navaids (F & E, R & M, O & M)	Equally assigned to all users
En route R & D	Proportional to total remaining benefits of *en route* control (Table 7, line 9)
Flight Service System	
F & E, R & M, R & D	Proportional to O & M cost allocation
O & M	Separable costs/remaining benefits
FAA Support Costs	
Support to terminal	Proportional to total remaining benefits of terminal control (Table 7, line 5)
Support to *en route*	Proportional to total remaining benefits of *en route* control (Table 7, line 9)
Strictly support	Proportional to total remaining benefits (Table 7, line 11)
DOD terminal control costs	Proportional to total remaining benefits of DOD terminals (Table 7, line 18)
DOD en route *control costs*	Proportional to total remaining benefits of DOD *en route* system (Table 7, line 13)

NASA terminal R & D costs	Proportional to total remaining benefits of FAA terminal control (Table 7, line 5)
NASA en route *R & D costs*	Proportional to total remaining benefits of FAA *en route* control (Table 7, line 9)
OST terminal R & D costs	Proportional to total remaining benefits of FAA terminal control (Table 7, line 5)
OST en route *R & D costs*	Proportional to total remaining benefits of FAA *en route* control (Table 7, line 9)
DOS en route *costs*	Directly assignable to international air carriers

Where the allocation involves separable costs/remaining benefits, the calculations are made as follows:

1. Allocate separable costs directly to users.
2. Compute remaining system costs.
3. Allocate remainder in proportion to remaining benefits.

Tables 8 through 10 exhibit the total allocations to the three user groups (air carrier, general aviation, and military) for all functional category/system element costs of the Airport and Airway System cost base. The allocations follow the procedures outlined above.

Development of a cost structure for user tax analysis

The comparison of cost allocation with user tax analysis requires that costs and user taxes be contrasted with a common reference or analysis structure.

An analysis [15] of the structure of user taxes, which is discussed next, reveals that these taxes are incurred by the users as the result of:

1. Operations involving arrivals and departures from terminal facilities.
2. Hours and distances of flight through the *en route* portion of the Airport and Airway System.
3. Owning aircraft subjected to registration taxes; that is, a charge not related to their use of the system.

The user taxes paid as the result of arrivals and departures include the per-passenger international tax, and the taxes on tyres and tubes. The user taxes paid as the result of flying through the *en route* system include a large proportion of the fuel tax, the ticket tax, and the waybill tax. The correspondence of the costs of the major Airport and Airway System functions to the user tax analysis structure is obvious. The costs of the Airport and Airway System directly related to arrivals and departures include:

Landings-Oriented Costs

FAA airport costs
FAA terminal control costs
FAA flight services costs associated with pilot briefs and flight plans filed
FAA support costs to terminal control systems
OST terminal control R & D costs
DOD terminal control costs
NASA terminal control R & D costs

TABLE 8

Separable Costs/Remaining Benefits Allocation
Air Carrier Cost
(millions of 1971 dollars)

	Year 1966	1967	1969	1971	1973	1975	*Total*
Landing-Oriented Costs	259·4	279·5	322·9	367·5	449·6	565·3	3,786·5
FAA Airports							
Trunk and local airports	34·1	38·2	45·2	57·9	82·3	117·7	635·6
All other airports	0·0	0·0	0·0	0·0	0·0	0·0	0·0
R & D	1·8	2·0	2·0	2·2	2·8	3·8	24·4
FAA Terminal Control							
Trunk and local F & E	22·2	23·3	29·0	33·3	39·8	46·8	332·4
Trunk and local O & M	77·9	88·0	117·7	129·5	152·5	183·4	1,279·2
Trunk and local R & M	8·6	8·8	9·3	9·0	10·7	12·1	98·4
All other airports F & E	0·0	0·0	0·0	0·0	0·0	0·0	0·0
All other airports O & M	0·0	0·0	0·0	0·0	0·0	0·0	0·0
All other airports R & M	0·0	0·0	0·0	0·0	0·0	0·0	0·0
R & D	11·3	12·4	14·1	16·2	20·4	27·8	171·4
FAA flight services	3·4	3·9	4·8	5·1	5·7	6·1	49·2
FAA support	74·2	76·8	74·3	85·2	105·1	135·8	912·2
DOD terminal control	25·9	26·0	26·3	26·8	26·9	26·9	265·5
NASA terminal R & D	0·0	0·0	0·0	1·2	2·2	3·2	11·6
OST terminal R & D	0·0	0·1	0·2	0·6	1·2	1·7	6·6
Distance-Oriented Costs	195·4	205·3	248·9	281·3	307·0	321·3	2,663·6
FAA *En route* control							
Centre F & E and R & M	40·9	42·3	47·6	66·4	76·0	82·1	606·3
Centre O & M	98·9	108·8	140·3	144·6	152·8	160·7	1,383·9
NAVAID F & E, O & M, and R & M	10·7	10·6	10·8	11·4	11·7	12·4	113·0
R & D	11·7	12·5	14·1	17·8	22·6	26·4	179·2
FAA flight services systems	3·5	3·7	3·5	3·4	3·6	3·4	35·2
FAA support costs	23·1	20·2	26·7	31·7	33·4	28·8	280·4
DOD *en route* control	5·0	5·0	4·2	3·8	3·8	3·8	41·2
NASA *en route* R & D	0·0	0·0	0·0	0·0	0·3	0·6	1·4
OST *en route* R & D	0·0	0·0	0·1	0·4	0·7	1·0	3·9
DOS *en route* costs	1·6	2·2	1·6	1·8	2·1	2·1	19·0
Nonuse-Oriented Costs							
FAA strictly support	50·0	48·8	48·0	46·7	73·9	87·2	595·1
TOTAL	504·8	533·6	619·8	695·5	830·5	973·8	7,045·2
PERCENTAGE OF GRAND TOTAL	47·2	47·1	47·2	47·0	46·8	47·3	47·1

TABLE 9

Separable Costs/Remaining Benefits Allocation
General Aviation Cost
(millions of 1971 dollars)

	Year						Total
	1966	1967	1969	1971	1973	1975	
Landing-Oriented Costs	161·9	181·5	218·8	246·5	302·3	360·8	2,500·9
FAA Airports							
Trunk and local airports	17·1	19·1	22·6	29·0	41·2	49·8	304·9
All other airports	17·9	20·1	24·1	27·0	39·1	53·1	308·2
R & D	0·4	0·5	0·5	0·5	0·7	0·9	5·8
FAA Terminal Control							
Trunk and local F & E	5·7	6·2	8·4	10·2	12·8	15·6	101·4
Trunk and local O & M	34·8	37·4	45·0	48·0	53·8	61·7	475·7
Trunk and local R & M	2·3	2·3	2·4	2·5	2·8	3·2	25·9
All other airports F & E	2·4	2·8	3·3	3·7	4·0	4·3	35·0
All other airports O & M	6·9	9·4	14·7	18·2	22·5	29·3	176·0
All other airports R & M	0·7	0·8	1·0	1·2	1·3	1·4	10·9
R & D	3·4	3·7	4·3	4·9	6·2	8·4	51·8
FAA flight services	47·9	56·0	69·9	74·9	85·0	90·5	723·8
FAA support	22·4	23·2	22·5	25·8	31·8	41·1	275·9
DOD terminal control	0·0	0·0	0·0	0·0	0·0	0·0	0·0
NASA terminal R & D	0·0	0·0	0·0	0·4	0·7	1·0	3·6
OST terminal R & D	0·0	0·0	0·1	0·2	0·4	0·5	2·0
Distance-Oriented Costs	122·5	126·0	141·3	160·3	183·5	198·2	1,576·0
FAA *en route* control							
Centre F & E and R & M	5·1	5·9	8·9	19·8	25·4	28·9	164·7
Centre O & M	19·7	21·6	27·9	28·8	36·9	49·7	312·4
NAVAID F & E, O & M, and R & M	10·7	10·6	10·8	11·4	11·7	12·4	113·0
R & D	11·1	11·9	13·4	16·9	21·4	25·0	170·0
FAA flight services	50·7	53·6	52·1	50·4	53·0	50·9	517·8
FAA support	21·9	19·1	25·3	30·1	31·6	27·3	265·8
DOD *en route* control	3·3	3·3	2·8	2·5	2·5	2·5	27·2
NASA *en route* R & D	0·0	0·0	0·0	0·0	0·3	0·5	1·3
OST *en route* R & D	0·0	0·0	0·1	0·4	0·7	1·0	3·8
DOS *en route* costs	0·0	0·0	0·0	0·0	0·0	0·0	0·0
Nonuse-Oriented Costs							
FAA strictly support	26·6	26·0	25·5	24·8	39·3	46·4	316·5
TOTAL	311·0	333·5	385·6	431·6	525·1	605·4	4,393·4
PERCENTAGE OF GRAND TOTAL	29·0	29·4	29·3	29·2	29·6	29·4	29·3

TABLE 10

Separable Costs/Remaining Benefits Allocation
Military Cost
(millions of 1971 dollars)

	Year						Total
	1966	1967	1969	1971	1973	1975	
Landing-Oriented Costs	103·5	111·7	129·3	147·3	180·5	221·4	1,510·1
FAA Airports							
Trunk and local airports	14·2	15·9	18·8	24·0	34·2	44·6	257·8
All other airports	0·0	0·0	0·0	0·0	0·0	0·0	0·0
R & D	0·5	0·6	0·6	0·6	0·8	1·1	7·0
FAA Terminal Control							
Trunk and local F & E	5·5	6·1	9·1	11·3	14·7	18·4	112·9
Trunk and local O & M	14·8	18·1	27·9	31·7	39·3	49·4	312·0
Trunk and local R & M	2·2	2·2	2·4	2·4	2·8	3·2	25·4
All other airports F & E	0·0	0·0	0·0	0·0	0·0	0·0	0·0
All other airports O & M	0·0	0·0	0·0	0·0	0·0	0·0	0·0
All other airports R & M	0·0	0·0	0·0	0·0	0·0	0·0	0·0
R & D	4·4	4·8	5·5	6·3	7·9	10·8	66·5
FAA flight services	5·8	6·8	8·4	9·0	10·2	10·9	87·4
FAA support	28·7	29·7	28·7	33·0	40·7	52·5	353·0
DOD terminal control	27·4	27·5	27·8	28·3	28·5	28·5	280·9
NASA terminal R & D	0·0	0·0	0·0	0·5	0·9	1·2	4·6
OST terminal R & D	0·0	0·0	0·1	0·2	0·5	0·7	2·6
Distance-Oriented Costs	127·4	131·4	156·7	182·1	203·7	217·4	1,735·6
FAA *en route* control							
Centre F & E and R & M	28·8	29·9	34·2	49·5	57·3	62·2	448·0
Centre O & M	44·9	49·4	63·7	65·6	72·3	80·9	644·8
NAVAID F & E, O & M, and R & M	10·7	10·6	10·8	11·4	11·7	12·4	113·0
R & D	10·7	11·5	12·9	16·3	20·7	24·2	164·2
FAA flight services	6·1	6·5	6·3	6·1	6·4	6·1	62·5
FAA support	21·2	18·5	24·5	29·1	30·6	26·4	257·1
DOD *en route* control	5·0	5·0	4·2	3·8	3·8	3·8	41·2
NASA *en route* R & D	0·0	0·0	0·0	0·0	0·3	0·5	1·3
OST *en route* R & D	0·0	0·0	0·1	0·3	0·6	0·9	3·5
DOS *en route* costs	0·0	0·0	0·0	0·0	0·0	0·0	0·0
Nonuse-Oriented Costs							
FAA Stictly Support	23·8	23·2	22·8	22·2	35·2	41·5	283·0
TOTAL	254·7	266·3	308·8	351·6	419·4	480·2	3,528·7
PERCENTAGE OF GRAND TOTAL	23·8	23·5	23·5	23·8	23·6	23·3	23·6

The Airport and Airway System costs incurred as the result of hours or miles flown in the system have been grouped into the following category:

Distance-Oriented Costs

FAA *en route* control centres and Navaids
FAA flight service costs associated with aircraft contacts
FAA support costs to *en route* centres and Navaids
OST *en route* control R. & D costs
DOD *en route* control costs
NASA *en route* control R. & D costs
DOS *en route* costs

Finally, those strictly FAA support costs which cannot be identified as directly supporting either terminal control or *en route* control systems comprise the last category, labelled "nonuse-oriented". These costs are largely independent of use and include items such as flight standards, medical programmes, and FAA aircraft.

The correspondence of the cost analysis and user tax payments structures was designed specifically to contrast not only the absolute amounts of costs and user tax payments by user groups, but also the structure of these payments. The fact that most user taxes are in the distance-oriented category accounts for a distance- (or *en route*-) oriented user tax system, which finances an Airport and Airway System whose costs are mainly landing-oriented. The costs reported in this fashion appear in Tables 8 to 10.

REVENUE-COST COMPARISONS BY USER CLASS

The Airport and Airway Revenue Act of 1970[10] specified a system of user taxes comprising (1) an 8 per cent domestic air passenger ticket tax, (2) a \$3·00 per person international air passenger enplanement tax, (3) a 5 per cent domestic air cargo waybill tax, (4) a 7¢ per gallon fuel tax on general aviation users, (5) an aircraft registration and weight tax of \$25 per aircraft plus 2¢ per pound for non-turbine powered aircraft and 3·5¢ per pound for turbine-powered craft, and (6) an aircraft tyre and tube sales tax of 5¢ per pound of tube weight.

The airport and airway user taxes have been classified as landings-oriented, distance-oriented, and non-use-oriented, following the same classification of costs. Taxes on tyres and tubes and international passenger enplanement taxes are essentially landings-oriented taxes, since they are independent of the use of *en route* control systems. The general aviation fuel tax is essentially an *en route* or distance-oriented user tax, since only 10 per cent of the fuel consumption of general aviation aircraft is consumed in takeoffs and landings. Passenger ticket taxes are also essentially distance- (or *en route*-) oriented taxes, since the terminal charge of the CAB ticket formulas accounts for roughly 25 per cent of the value of the passenger ticket. The reason for the classification of user tax systems into landings and distance-oriented systems is that, as will be shown later, the Airport and Airway System consists of a landings-oriented system financed mainly through *en route* or distance-oriented user taxes.

To specify the proportion of landings and distance (*en route*) charges implicit in

[10]Sections 4041, 4071, 4081, 4261, 5271, and 4491.

TABLE 12

Projected Allocations of User Tax Liabilities Among Sub-System Facilities of the Airport and Airway System Reflecting Services Obtained in Each Phase (in millions of 1971 dollars)[a]

User: Type of User Tax	1971			1972			1973			1974			1975		
	Distance-Oriented	*Landing-Oriented*	*Nonuse-Oriented*	*Distance-Oriented*	*Landing-Oriented*	*Nonuse-Oriented*	*Distance-Oriented*	*Landing-Oriented*	*Nonuse-Oriented*	*Distance-Oriented*	*Landing-Oriented*	*Nonuse-Oriented*	*Distance-Oriented*	*Landing-Oriented*	*Nonuse-Oriented*
Air Carrier:															
Domestic Passenger Ticket Tax	382·66	120·86		414·25	131·25		463·08	146·72		518·97	164·42		578·21	183·19	
International Enplanement Tax		38·40			41·40			45·90			51·00			56·70	
Registration Fee and Weight Tax			11·00			11·60			12·10			12·90			13·80
Waybill Tax: Freight and Express	23·15	9·74		24·15	10·22		27·20	11·70		30·57	13·32		34·45	15·16	
Tyres and Tubes Tax[b]		1·60			1·70			1·75			1·85			1·95	
TOTAL AIR CARRIERS	405·81	170·60	11·00	438·40	184·60	11·60	490·28	206·07	12·10	549·54	230·59	12·90	612·66	257·00	13·80
General Aviation:															
Commuter Waybill Tax	0·40	0·20		0·46	0·24		0·53	0·27		0·67	0·33		0·79	0·41	
Wholesale and Retail Aviation Fuel Tax	41·05	4·25		43·40	4·50		45·67	4·73		47·39	4·91		50·20	5·20	
Registration Fee and Weight Tax			9·30			7·40			7·80			8·20			8·90
Tyres and Tubes Tax[b]		1·60			1·70			1·75			1·85			1·95	
Commuter Passenger Ticket Tax	2·68	3·42		3·07	3·92		3·56	4·54		4·08	5·22		4·70	6·00	
TOTAL GENERAL AVIATION	44·13	9·47	9·30	46·93	10·36	7·40	49·76	11·29	7·80	52·14	12·31	8·20	55·69	13·56	8·90
TOTAL AIR CARRIERS AND GENERAL AVIATION	449·94	180·07	20·30	485·33	194·96	19·00	540·04	217·46	19·90	601·68	242·90	21·10	668·35	270·56	22·70

[a] Projections from 1972 to 1975.

[b] Divided equally between General Aviation and Air Carriers.

Source: [15], p. 62.

TABLE 11

Characterisation of Airport and Airway User Tax Systems

User Tax Systems	*System Orientation Estimates*		
	Landings-Oriented Percentage	*Distance-Oriented Percentage*	*Non-Use-Oriented Percentage*
Type of User Tax			
Air Carrier			
Domestic Passenger Ticket Tax	24·06	75·94	—
International Enplanement Tax	100·00	Deemed Negligible	
Registration Fee and Weight Tax	—	—	100·0
Waybill Tax for Freight and Express	33·4	66·6	—
Tyres and Tubes Tax	100·0	—	—
General Aviation			
Wholesale and Retail Aviation Fuel Tax	9·39	90·61	—
Registration Fee and Weight Tax	—	—	100·0
Tyres and Tubes Tax	100·0	—	—
Air Taxi Passenger Ticket Tax	56·09	43·91	—

Source: [15], p. 60.

the airport and airway user tax system, regressions were run of (1) air passenger fares and (2) air taxi commuter fares as a function of distances between the city pairs. The intercepts or constant terms of the regressions denote the landings-oriented charges implicit in both air carrier and air taxi fares. Evaluated at the average distances flown by air carriers and air taxis, the terminal charges represented by the intercepts became 24 and 56 per cent of the air carrier and air taxi passenger fares charged.[11] Air freight rates per hundredweight were also estimated as a function of intercity mileage for north–south and east–west shipments.[12] With the exception of westbound shipments, the intercept of the air freight rates regressions was 10 per cent of the fares for mean distances flown, and this factor was used to impute 90 per cent of waybill freight tax receipts to distance-oriented taxes. Identical procedures were used for estimating general aviation fuel consumption as a function of miles flown [15], and as a result 10 per cent of fuel consumption was imputed as the landings-oriented portion of this tax. The structure of airport and airway user taxes appears in Table 11, exhibiting the apportionment of user taxes into the landings-, distance-, and non-use-oriented components.

User tax liabilities for the period 1971–1975, given in Table 12, show the air carriers contributing as much as 90 per cent of the airport and airway user tax revenues in fiscal year 1971. From Table 12 we note that, until fiscal year 1971,

[11]For a review of the work of Dr. Edgar Battison on these regressions, see [15], pp. 50–54.
[12]The air freight rates regressions were taken from [6], p. 16.

69 per cent of the air carrier taxes were distance-related and 29 per cent of their user taxes were landings-oriented; these figures contrast with proportions of 52·8 and 40·5 per cent respectively for the air carriers' landings- and distance-oriented costs. Thus air carrier distance- (or *en route*-) oriented charges are financing landings-oriented (terminal) costs. The same is true of general aviation user tax revenues, 70 per cent of which are distance-oriented, though distance-oriented costs are less than 38 per cent of general aviation costs. A summary of the structure of costs and user tax revenues for 1971 appears in Table 13.

Finally, 1971 comparisons of costs and tax revenues by user class are summarised in Table 13. In 1971, the air carriers were basically paying 84·5 per cent of their allocated costs, even though there was an imbalance in the structure of landings and distance components of user taxes and costs. In the general aviation class, user taxes were covering only 14·5 per cent of their allocated costs, a deficit accompanied by a substantial imbalance in the relative proportion of landings to distance-oriented user charges. In view of this large general aviation deficit, the Department of Transportation has recommended to Congress [9] that charges on general aviation be gradually increased, so that eventually the general aviation costs and user tax revenues would be balanced.

Alternative user charges and prices

Faced with this imbalance in the structure of the airport and airway user tax system, namely, that an *en route*-oriented tax system (dominated by the passenger ticket tax and the general aviation fuel tax) is financing a system whose costs accrue mainly in terminal control, a drastic change in the structure of the tax system is in order.

TABLE 13

Sub-System Allocations of User Tax Liabilities and Costs as Percentages of Total Liabilities and Costs in 1971

	Proportions of Costs and User Taxes			*Total*
	Landings-Oriented	*Distance-Oriented*	*Non-Use-Oriented*	*(millions of 1971 dollars)*
	%	%	%	
Tax Liabilities				
Air carriers	29·0	69·1	1·9	587·41
General aviation	15·0	70·2	14·8	62·90
Combined users	27·7	69·2	3·1	650·31
Costs				
Air carriers	52·83	40·45	6·72	695·5
General aviation	57·11	37·14	5·74	431·6
Combined users	54·48	39·18	6·34	1,127·1

Source: Tables 11 and 12.

Landing fees (with congestion surcharges depending on local airport conditions) appear appropriate for financing the terminal control costs, although flight plan fees may also be used to finance the terminal control systems. *En route* control charges—similar to Eurocontrol—appear appropriate to finance the *en route* control systems, although gasoline taxes may also be used in view of their ease in administration. Final decisions on these user tax systems await continuing studies on these subjects; but the serious distortions in the structure and the level of the current airport and airway user tax system should spur immediate action to reshape the system.

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