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AIRPORTS—AN ECONOMIC SURVEY

By A. A. Walters*

The enormous (about 12% a year) expansion in the number of aviation passengers over the 1950s and 1960s and the first half of the 1970s has created a large demand for airports. Technological developments in aircraft design—particularly the introduction of jets and wide-bodied aircraft—have changed the demand for airport capacity. Runways have been lengthened and strengthened and terminal facilities greatly expanded. The improvement of an airport (for example, to take jet airplanes) often involves investment in other airports. Consequently, rather than the gradual expansion of runways and buildings, there are many decisions to be made on "lumps" of investment, that is to say on all-or-nothing propositions. Similarly, the evidence suggests that there are large economies of scale in the operation of runways. Optimum size and location are important elements in the investment decision. The cost of access has a strong effect on both location and size. Modelling the access and air transport system, with a view to exploring optimum location and size, involves appropriately linking many sub-models of each activity.

Airports do not merely involve travel; there are implications for urban development, pollution, noise and industrial activity. Although the shape of cities influences the location of airports, airports in turn influence the structure of urban areas, and even regional development. The consequent costs and benefits, although not directly the responsibility of the airport authorities, are alleged to be significant or even dominating in the decision-making process. Constraints on building and land use are, for example, instruments of planners' policies. Planners may see the airport as a critical magnet to achieve what they regard as desired regional or urban form (Jodeau (1969), Goldstein (1973)).

Most air transport takes place between the great urban areas of the world, and large airports have become associated with the metropolitan areas that they serve. Yet air transport also plays a unique role in those areas where the population is so sparse, or the terrain so difficult, that the provision of surface transport is too expensive. Typically, the demand is for a very low-volume system with the basic minimum of runway facilities. Then there are the usual problems of upgrading the facilities to reduce unit cost and, incidentally, increase capacity.

Finally, airports are institutions with organisational objectives. The systems of charging should be rationalised in the general framework of airport finance. The general economic rule would be to charge marginal cost for the use of airports. Thus airports that were much in demand would have high landing fees, and there

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would be a differentiation according to whether the aircraft wished to use the services at peak or at off-peak periods. Although this general principle is most valuable, it must be modified in practice, primarily by the requirements of administrative ease and acceptability. Furthermore, because of the high fixed costs of low-volume airports, it is most unlikely that charges fixed on such a principle would enable the airport to cover its costs. It may be held that general subsidies for air operations are not desirable; then there is the problem of raising sufficient revenue to cover costs, while at the same time ensuring that the charges do not inefficiently deter traffic and lead to underutilisation of the airport. This suggests that some form of two-part tariff might be appropriate.

As technology improves and aircraft become larger, competition among airports becomes keener. The position has often been exacerbated by the tendency to overbuild airport capacity partly because an airport serves the purpose of a national monument (albeit an expensive one) and partly because airports usually are publicly owned and lack the necessary discipline on expenditure.

For short runways, there seems to be considerable scope for upgrading airports to accommodate jet or even turbo-prop operation where, at present, only light aircraft can operate. For long runways, the evidence suggests that the future demand could be absorbed substantially by more rational pricing policies and by utilising more efficiently the existing capacity through appropriate operating procedures and techniques, rather than by the provision of additional long runways. In fact, the increase in the number of passengers per aircraft may well take up all the expansion of demand for long hauls. Then no new long runways will be justified.[1]

THE AIRPORT MARKET

Air transport provides movement for both people and goods. The demand for personal travel arises from households (the ultimate consumers) and from businesses and government (a derived demand). Household demand is determined by the wealth of households and the price of a ticket, as well as by the prices of complementary and substitutable goods and services; probably most important influences are the quality characteristics of air travel and the progression of taste. Business demand is determined by the marginal productivity of a journey by air relative to its cost (in both money terms and time foregone) and, again, by the price of alternatives (such as telephone, surface transport, etc.).

The proximate demand is in the form of passengers to be moved from A to B. Airlines then plan aircraft movements which will meet this demand. Translating passenger demand into aircraft movements and schedules is one of the main problems of the airlines. On each movement, however, there are problems of servicing the aircraft, on the one hand, and the passengers on the other. Airports, like airlines, must serve aircraft movements as well as passenger movements. Aircraft require air space, runways, and other terminal capacity such as apron-stands, whereas passengers require terminal buildings with check-in facilities,

[1] This does not, of course, imply that there will be no more Dallas-Fort Worths and Mirabelles in the future.

restaurants, etc. These, in turn, are served by surface access such as roads and rail connections. Airport investment and location are influenced by the urban development required to provide people to man the airport.

This view of airports and air transport as an ever-widening circle of inter-acting consequences is compounded by the need for compatibility of airport and airplane schedules. The planning unit in airline economics is the route. Airports on the route must satisfy minimum requirements in terms of runway length, navigation aids, etc. Hence, there is a powerful motive to "keep up with the Joneses" so that a country or city is retained on the route. If a route is fixed, then upgrading one airport on the route will usually mean that all others should be considered for upgrading also. Piecemeal investment is likely to be inefficient; and this applies *a fortiori* to navigation systems.

DEMAND

Passengers and Freight

It would be convenient if one could always distinguish between the passengers who are travelling on their own account, sometimes called leisure traffic, and those who are paid for by some firm or governmental agency, often called business traffic. (We shall call them LT and BT, respectively.) The usual criterion for defining BT is whether the expenditure is allowed as a deduction for income tax purposes. The natural supposition is that LT is part of final consumption. In some models of consumer demand (such as those suggested by Lancaster) one would argue that even LT is an input among others for some more ultimate want, such as a week on a beach or a visit to one's mother. Verleger (1972)).

The determinants of the demand for LT may be considered from a list derived from Marshall's *Principles*: the level of income *per capita;* the relative price of air travel compared with close substitutes such as surface transit; the prices of complementary goods and services, such as the tariffs on hotel rooms or the fees for ski instruction. But air travel has the characteristic feature of generally being speedier than alternative forms of travel; consequently, the passenger's valuation of time will play a role in the choice.

The determinants of the demand for BT are clearly lhe marginal productivity of the travel to the firm (or government) compared with the price of the ticket and the time (presumably working time) taken up in travel. The travel will be bought if the marginal productivity exceeds the price — in both money and time.

As one might expect, BT and LT differ widely in their demand patterns and in the load imposed on facilities. BT tends to be concentrated in typical commuting hours — early morning and evening — whereas LT clusters around weekends and holidays, with baggage as a major problem. It is often conjectured that the demand elasticity for BT is very small compared with that for LT; but clearly much depends on the availability and price of close substitutes.

Time-series methods have been employed to measure the characteristics of the demand function (Brown and Watkins (1974)). The dependent variable is usually total revenue-passenger-miles (RPM), and the independent variables are fare per mile, disposal income *per capita*, and a time trend term. In aggregate time series, it is normally impossible to distinguish BT from LT; and thus such studies must be carefully interpreted. Probably in most countries BT dominates the air travel market, and one would expect that the lower the income level of the country the more important would BT become. (But clearly there are many low-income countries where tourism is a major industry and LT, for foreigners, tends to dominate.)

The results from the time series studies suggest that there is quite a high long-run elasticity of demand with respect to the fare—the point estimate in Brown and Watkins (1974) for the United States 1948-1966 is −1.71. No analysis was made of movements in the prices of substitutes, such as the price of a rail ticket or, more important, the cost of automobile travel. It is clear that the relative cost of inter-urban automobile travel fell quite dramatically over this period; this suggests that the true own-price elasticity of demand is rather higher (in absolute terms) than the estimate. The income elasticities have suffered from multicollinearity: over the time series, both incomes and passenger volumes have expanded together. Thus one must rely primarily on cross-section data.

Cross-section analysis of the effect of fare per mile has again been mainly restricted to the U.S. domestic city pairs (Jung and Fujii (1976)). Clearly, there are difficult problems of standardising inter-city pairs so that they may be appropriately compared (Brown and Watkins (1974), p. 106). But also there is a question of identification. Interstate fares per mile are regulated by the Civil Aeronautics Board. The principle of regulation is that of "covering the cost". Although this may be subject to a very large number of interpretations in practice, it means that the more dense the traffic on the route, the lower the costs, and so the lower the regulated fare per mile. (Again, however, the gradual liberation of airlines from regulatory constraints has much blunted this effect in recent years.) In the cross section, therefore, one would observe fares per mile declining with the falling costs as passenger throughput increases. This effect is also compounded by the fact that the larger the number of passengers, the greater the service frequency and the more attractive the service. In the Brown and Watkins study, the extent of this proportional fall in fares was very close to the value for the price elasticity that they had derived from the time series analysis; but this correspondence cannot be taken as affirming that the fare elasticity is about −1.7. Computation of the fare elasticity from 1972-3 changes in fares for short (less than 500 miles) distances in the Southeast United States suggests that the elasticity may be much higher, in the range −1.8 to −3.1 (Jung and Fujii (1976)). The balance of evidence suggests that an elasticity of about −2.0 is appropriate.[2]

[2] If we treat the cross-section analysis as tracing out the regulated price (= average cost) for varying quantities of passenger miles, we should interpret it as:

$$\frac{\text{d. (log of average cost per passenger mile)}}{\text{d. (log of passenger miles)}} = -1/2$$

and so: Log of total costs = 0.5 (log of passenger miles) + constant. This suggests that, on this interpretation, there are considerable economies of scale in air operations. It is the square root rule — a doubling of traffic will increase costs by only 50%.

TABLE 1

Cross Section Estimate of Demand Elasticities

Miles	*Time Elasticity*	*Price Elasticity*
400	-0.51	1.02
650	-0.45	-1.07
2,500	-0.37	-1.17

Source: De Vaney (1974).

Another important variable in the cross section is the air journey time per mile—the Brown and Watkins results suggest that the elasticity with respect to journey time is about 0.5. As one would expect, it varies according to the length of the trip.[3] De Vaney has carried out the most detailed analysis of city pairs, and his main results are reported in Table 1.

It will be noted that these values allow for an assumed access time to airport of 50 minutes.[4] If only the flight time were incorporated in the elasticity formula, the values of the elasticities would fall considerably—to about -0.2, according to De Vaney (1972). In view of the increasing on-the-ground delays experienced in travel to and from airports and in security procedures, one suspects that the elasticities which incorporate the access and ground time have been rising considerably in recent years. The values may more nearly approximate to unity (as suggested by Brown and Watkins (1974), but for different reasons).[5] There are no separate results for business travel and leisure journeys, although one may readily conjecture

[3] If T is the total time of travel, a hours is spent in ground access and t hours spent in air travel, then $T = a + t$. Thus if ϵ_T is the absolute elasticity of demand with respect to T and ϵ_t is the absolute elasticity of demand with respect to t:

$$\epsilon_T = \frac{T}{X}\frac{dX}{dT}$$

$$= \frac{(a+t)}{X}\frac{dX}{dt} \quad \textit{if } a \textit{ is constant.}$$

$$\text{Thus} \quad \epsilon_T = \epsilon_t\left(1 + \frac{a}{t}\right) = \epsilon_t\frac{T}{t}$$

Or in words: Total Time Elasticity of Demand = (Air Time Elasticity) $\left(\frac{\text{Total Time}}{\text{Air Time}}\right)$

From the point of view of airport investment, the interesting variations are between access time and fare and demand. These are pursued below.

[4] De Vaney reports (letter to author) that he ended by only allowing for *one* access per trip. Thus the time elasticities reported above should be higher. Throughout all this analysis access time is valued the same as in-flight time.

[5] These results suggest interesting implications for the provision of fast access (by helicopter, for example) and for the types of configuration and design of airports. These are pursued in National Academy (1975).

the sort of figures one would obtain. On leisure trips, the price elasticity would be larger than average and the time elasticity smaller.[6]

It has been widely argued that the price elasticity of demand for business and official air travel is smaller than for leisure trips, certainly the airlines' attempt to segment the market is consistent with this hypotheses (Cooper and Maynard (1971)). Similarly, it has been suggested that the time elasticity is small; the business trip will be undertaken whatever the elapsed time required.[7] Variations in the time taken will not much affect the number of busines trips. This is another manifestation of the theme of fixed proportions in the production function of business firms. While it may be useful as a short-run approximation, it is unlikely to be a useful approximation for behaviour in the long run.[8] Indeed, the vast expansion of business travel in the 1960s, notwithstanding the improvement of telecommunications, was clearly associated with the reduction in travel time and in discomfort caused by the introduction of the jet airplane. It would probably be unwise to assume that the time elasticity of demand for business travel is substantially less than (absolute) unity.

Although rapidly growing, freight is still a relatively unimportant item in air carriage. Much is carried in the bellies of the large jets, and consequently the capacity available is closely associated with the primal passenger demand. Specialist freight services are all at present rather small, but are growing rapidly. All-freight carriers do cause special problems for airport management, but they will not be considered further in this survey.

To summarise, therefore, it appears that the measured elasticities considerably underestimate the true elasticities, which should reflect the generally increasing waiting and access time. One can make no accurate assessment of the effects of such confounding, but my conjecture is that the total (value of time *plus* fare) elasticity of demand is around 1.5 to 2.0, varying with the length of haul and the composition of traffic.

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[6] As in the case of ocean shipping, air transport has been divided into the scheduled (liner) sector usually operated under cartel conditions and a non-scheduled (tramp) sector consisting of charter, package deal, and other services. The international cartel IATA (International Air Transport Association) was sponsored by governments to maintain fares, revenues and orderly markets for scheduled services. Fares on scheduled services have been maintained at high levels, but the pressure of entry into the scheduled sector has resulted in low load factors (Wheatcroft (1969), Cooper and Maynard (1971)). The fact that non-scheduled operators have invaded that market, and particularly international flights, is largely explained by the inability of the cartelised scheduled operators (IATA) to prevent them from entering the business. (Laker is the most widely publicised break in IATA's defences.) And the scheduled/non scheduled distinction has faded. The traditional airlines offer a high probability of a seat and minimum waiting, whereas the low-fare airlines provide a lower chance of an available seat. Now the traditional airlines try to fill up their scheduled aircraft with "standby" and other low-fare customers.

[7] For example, see the evidence presented to the Roskill Commission summarised in its Report (1971).

[8] There is a problem of consistency. If it be admitted that the value of time for a business journey is high (perhaps almost double the wage paid to the person making the trip), then one might expect corresponding savings in time to be most valuable and to affect the frequency of trips where the marginal productivity exceeded the additional money cost. Furthermore, it would stimulate industries which used travel intensively compared with those that used it sparingly.

Size of Aircraft and Air Transport Movements

Given the estimate of the number of passenger trips which impinge on an airport, either as departures or as arrivals, the next step is to assess the implications in terms of number of aircraft movements. This translation turns very largely on finding the appropriate types of aircraft in terms of seating capacity, and on the estimated load factor on the route. These factors are to some extent simultaneously determined by the passenger demand - since that will itself be influenced by service frequency and by the fare, which will depend upon cost and so on aircraft size and load factor. There have been few attempts to model such a simultaneous system. The most common procedure, described in some detail in Volume VII (p. 79 *et seq*) of the Roskill (1971) papers, has been to regard the forecast number of passengers as relatively insensitive to small movements of fares and frequencies, or at least to assume that any such adjustments can be handled by *ad hoc* methods.

Load factors are largely determined by the amount of competition permitted on the route and by the regulation of fares (Edwards Report (1969)). In the United States, fares are regulated by the Civil Aeronautics Board. The form of the regulation tended to fix fares relatively high on dense routes and low on sparse routes.[9] The airlines then adjusted their frequencies and load factors to these regulated values. Each airline was induced to add a service to a route, provided the revenue covered the additional cost. Services expanded until the load factor was driven down to the breakeven level, and there was much wasteful excess capacity on dense routes. On the less dense routes, the opposite occurred and frequencies declined; this has led to subsidies being paid to induce airlines to provide an "adequate" service on such routes (Douglas and Mill (1974)).

For much international scheduled air travel, the number of flights is determined largely by negotiation, sometimes indeed at the diplomatic level. The ostensible purpose is to prevent "wasteful competition" and to ensure that the chauvinistic, if not the profitable, interests of governments are properly defended. Naturally, it is difficult to forecast the load factors that emerge from such horse trading. Forecasters have tended usually to assume that "normal" or "historical" average load factors are to persist in future years — although occasionally there is a rude awakening, such as that occasioned by the drastic cut in services and increases in load factor caused by the dramatic rise in the price of fuel in 1973-74. The airline industry is changing rapidly. Scheduled services now fill up with standby and other low-fare traffic and overall load factors of 70 per cent are now not uncommon.

The size of aircraft might be thought to be easy to forecast, since aircraft take a long lead time to plan and produce. Yet errors in allowing for aircraft size are most important for example, they accounted for the largest part of the gap between prediction and outcome in the Roskill (1971) forecasts of air transport movements. In fact it is not easy to forecast the "mix" of aircraft size likely to emerge larger aircraft were introduced far more quickly than the Roskill forecasts anticipated. The real problem is to judge the "success" of an aircraft. Sometimes it is relatively easy, as with Concorde's lack of it; but, on the other hand, few foresaw the failure of the Comet or the immense success enjoyed by the Boeing 747 and 727-200 series.

[9] In recent years the CAB has modified this principle, and fares are creeping closer to marginal cost

Yet the main trends are apparent. The increase in number of passengers per plane will arise largely from the larger aircraft and, at least for a time, from improvement in average load factors. Lord Boyd Carpenter, then Chairman of the Civil Aviation Authority, in a speech at Brighton in May 1976 thought it very unlikely that the "future increase in passengers per plane will fall below 5 per cent per annum." This is, of course, a pessimistic estimate — and my best guess would be about 7 per cent. This suggests that most of the expected increase in passenger demand may be absorbed by the increase in passengers per aircraft. And, allowing for improvements in ATC and general runway management, it is likely that we shall be near what Lord Boyd Carpenter called the "Boeing Equilibrium", where there is little or no demand for new runway space.

Airport Landing Fees and Substitution

Although traditionally economists consider price as the most important variable influencing demand, in airport discussions the landing fee is often treated in a paradoxical fashion. On the one hand, it is often alleged that variations in the landing fee will have little or no effect on the demand for runway capacity, since the landing fee is but a small fraction — perhaps about 2%, or at most 7% — of the total costs of the trip. On the other hand, one hears, often in the same speech and sometimes in the same sentence, that, if landing fees are increased too much at Heathrow, London will lose much valuable traffic to Paris.[10] This ambivalence illustrates Marshall's Law: the first point about the "importance of being small" shows that, *if there are no opportunities for substitution*, the elasticity of demand for an aircraft's use of the runway is simply the product of the elasticity of demand for the trip multiplied by the fraction that landing fee costs bear to the total costs of the trip.[11] But the second proposition illustrates the consequences of substitution; if Paris (Charles de Gaulle) is a very close substitute for London's transatlantic flights, a rise in the landing fee applied to all London's airports may see a substantial diversion of traffic.[12] Thus, while it is quite sensible to conclude that if *all* the competing airports in a region raised landing fees there would be little effect on air transport movements, it is misleading to suppose that there would be no effect on the demand for a particular airport's operations if it, and it alone put up its fees. Perhaps the main reactions would be expected from those operators to whom displacement to other airports is not expensive. These may include a very large fraction of general aviation movements,[13] as well as the package tour and charter firms.[14]

[10] The Chairman of the CAA, First Public Hearing, Roskill Commission, November 1968

[11] For an exposition of the theory, see Layard and Walters (1978).

[12] In Doganis and Thompson (1973) it is shown that landing fees are virtually always less than 7% of total costs. However, care must be exercised in interpreting these charges, airports usually extract a considerable monopoly rent from such facilities as duty free shops, rent a car agencies, parking, etc. In many American airports, the revenue from such facilities exceeds that from landing fees. And in many Third World countries there is an "airport tax" levied on passengers.

[13] General aviation consists primarily of light aircraft, air taxi, air commuter and light charter. Some idea of the elasticity of demand of general aviation can be gauged from the reaction to the large increase in landing fees in New York in 1969. See Carlin and Park (1970a) and Walters (1974).

[14] Evidence appears in the search of charter firms for cheap airports in the metropolitan areas of North America.

Since the general practices of airports were borrowed from those of seaports, one finds a similar form of discrimination in airport charges (Carlin and Park (1969), Little and McLeod (1972)). Virtually all airports increase charges according to the weight of the aircraft. Even in the use of runways there seems to be some increase of costs as the size of aircraft increases—for example, turbulence increases the distance between aircraft. With other terminal facilities, the cost increases with the number of passengers. The progression with weight, however, is greater than the increase in marginal costs of catering for the larger aircraft, and represents the application of the principle of "ability to pay" or what the traffic will bear. Large aircraft have fewer substitute airports than small, and so more is extracted from the airlines for the use of the scarce facilities. Most airports levy charges for passengers (and freight); sometimes these are paid by the airline, and in many countries an airport passenger tax is levied on departure. Long-distance (for example, intercontinental) flights are charged more than domestic or intracontinental services—again reflecting mainly ability to pay rather than costs.

Like any other service industry, many airports offer a wide variety of specialist services for the airlines, such as stand space, towing, fuel provision, aircraft repair and servicing, navigational aids for at least the vicinity of the airport, administrative offices, and so on. Some, such as the tower navigation services, are mandatory for all users; but many services are optional extras and are charged for. By regulating the supply of such services, the airport authority obviously has some power to extract a substantial surplus (which, of course, may be passed on to a trade union, as has happened so frequently in seaports). Direct services to passengers—such as car hire, duty-free shops, restaurants—provide other opportunities for the exploitation of its high rents of accessibility[15] as well as possibilities of excercising monopoly privileges. Little has been done to study these phenomena, but they are unquestionably important; many airports in the United States cover more than half their financial costs by revenue from such services.[16]

As with many other transport facilities, airports experience marked peaks in demand. The daily ebb and flow are a consequence of the hours of the business day, whereas the annual peaks are usually connected with holiday traffic. Yet changes in fees that vary with the time of day (and the diurnal variations are most important) are quite unusual. Generally, airport managements, particularly those in the United States, look upon them as discriminatory (which they are not) and much resented (which they are), and are reluctant to impose them until facilities become appallingly congested.[17] Indeed, the use of landing fees to influence

[15] As always, it is important to distinguish between rents of accessibility and monopoly profit. The former arise because of free competitive bidding for space, the latter because the quantity of space is restricted so that, for example, airport-located rent-a-cars are more expensive than under free entry conditions.

[16] A recent controversy on the contribution of concessions to revenue is to be found on pages 52 *et seq* in National Academy (1975).

[17] For example, the New York Port Authority allowed small aircraft to land on duty runways during peak hours for a fee of $5 and this undoubtedly contributed much to the very long delays which were experienced at New York airports during 1968. When the fee was raised to $25, the heavy congestion disappeared. See Walters (1974). Peak pricing was introduced in London (Heathrow) in 1972 by imposing a surcharge of £20 per movement during the summer mornings. See Little and McLeod (1972)

demand, either by peak spreading or by redistributing marginal traffic, has only recently become a central concern of airport authorities, and then mainly in the United Kingdom. The process of "demand management", as it is usually called, is one of rationing of flight slots, "rationalising" services, using route or landing priorities to favour large scheduled aircraft, dispatching general aviation on circuitous routes, and so on. Agreements on flight slots are sometimes, as in the case of London (Heathrow) in the late 1960s and 1970s, evolved from a users' committee (Little and McLeod (1972)); at other times they may be negotiated with suitable reciprocity between the airline and the airport authority.[18] In effect, all such rationing procedures have the effect of dissipating the surplus which the airport could earn. Rationing is a substitute for revenue and involves substantial real costs.[19]

In reality, airport pricing policies are normally determined by accounting criteria – the need to keep a subsidy down to a certain level, the aim to break even or to earn a profit. A fundamental difficulty is that the accounts are presented in terms of historical costs and, if land is entered at all, it is shown usually at a low acquisition cost. This practice leads to economically perverse pricing – since the airports that were built earliest are "low cost" and so low priced; but these are often the airports that are close to the urban areas and so highest in order of preference of travellers, and so likely to be congested.[20] And, generally, it leads to too low a level of airport charges and probably to too much airport investment.

The application to airports of the principles of marginal cost pricing has not proceeded very far (Eckert, Dygert in Howard (1974), Carlin and Park (1970a), Little and McLeod (1972)). In principle, one should levy short-run marginal cost (including a so-called rent element necessary to ensure that demand is equal to supply at effective capacity) for existing facilities. Each airline takes account only of the costs it incurs in waiting in the stack or queuing for departure. It will not take into its accounts the costs of the delays that its additional flights impose on other airlines.[21] The well-known case for congestion pricing is that the marginal costs – including the additional congestion costs of all other airlines – should be reflected in the price for the use of the facilities.[22] These congestion charges are simply the quasi-rents for the scarce airport capacity; they are exactly analogous to the charges that would be levied by a competitive industry, if it were conceivable, in the rent-a-runway business.[23]

[18] On occasion, these negotiations develop such heat that they become diplomatic incidents – as in the case of the first refusal to allow Turkish airlines to operate from Heathrow. Threats of retaliation rapidly resulted in a reversal.

[19] In recent years airport pricing in Britain has been moving quite rapidly away from the rationing approach and toward a peak pricing system. Peak fees and passenger charges will be the major source of airport revenue.

[20] For example, the investment in Kennedy (Idlewild) was undertaken long before Newark, and landing fees in Newark were about twice those at Kennedy.

[21] An exception is where only one airline uses the airport (or nearly all the operations are by one airline).

[22] This is exactly analogous to congestion pricing on the highways.

[23] Note that these charges do *not* reflect the monopoly power of the airport authorities. Maximising the net revenue of the authority would call for even higher fees and a contraction of traffic, instead of setting the marginal cost (including congestion costs) equal to the fee, the authority would find the volume of traffic at which marginal revenue was equal to marginal cost (Eckert (1972) and (1973)).

Calculations of the congestion costs at *existing* levels of use have been made for various airports—probably the most sophisticated study was carried out for the New York airport system by Carlin and Park (1969). The marginal delay costs—which comprised almost all the costs during the busiest times at Kennedy during 1967 exceeded $2,000 per operation; they were over $500 at La Guardia, and were usually hundreds of dollars throughout business hours.[24] This gives a measure of the waste that is caused by congestion, but it does not, *per se*, give a guide to the appropriate fees to be levied. These must take into account the demand conditions that is to say the fees that users are willing to pay. Indeed, it was shown in New York that increases of general aviation fees to $25, only a small fraction of the marginal cost, were sufficient to reduce congestion considerably (Walters (1974)).

One serious difficulty in employing congestion levies is that aviation, probably more than any other form of transport, is much beset by uncertainties—of weather, technological failures, and conditions in other airports, including night curfews and administrative constraints. The capacity of an airport may be changed drastically in a matter of minutes by a wind reversal or by fog. Scheduled operations and fares and airport fees clearly can take into account "normal" conditions: one may hope that in so doing they balance the cost of delays during the bad weather with the modest underutilisation during the good.

Costs and investment

Fixing fees according to short-run marginal costs provides an appropriate pricing policy and also gives the groundwork for developing investment rules. If there were constant returns to scale in airports and if there were adequate divisibility of investment, the investment rule would be simple: expand airport capacity if the users, paying the fees discussed above, would cover the full costs of the extension. If the inputs, particularly land, were priced according to their opportunity costs, this rule would give rise to the best investment and would ensure that the airport authority just broke even. If, in the long run, airport services are supplied under conditions of decreasing returns (i.e. rising costs), airport capacity should be constrained so that substantial profits are earned. Finally, if there are increasing returns (declining costs), there is a *prima facie* case for subsidising airports.

It is difficult to make convincing generalisations about the pattern of costs in airports. Probably the main problem is their geographical specificity, and the difficulty of comparing like with like. In terms of aircraft and passenger throughput on runways, for example, it is likely that one four-runway airport is less expensive than two two-runway airports or four one-runway airports.[25]

Certain central services may be shared, and there are minimum viability levels for some activities. But, to the passengers, accessibility is of great importance. And concentrating all runways in one place, instead of spreading them about among the population, would substantially increase access costs. Economies of scale are

[24] The values are "per operation", which might be either an arrival or a departure.

[25] This issue was debated during the Roskill hearings, assuming away differences in terrain. Note, however, that the proposition applies only to *runways* and the aircraft throughput.

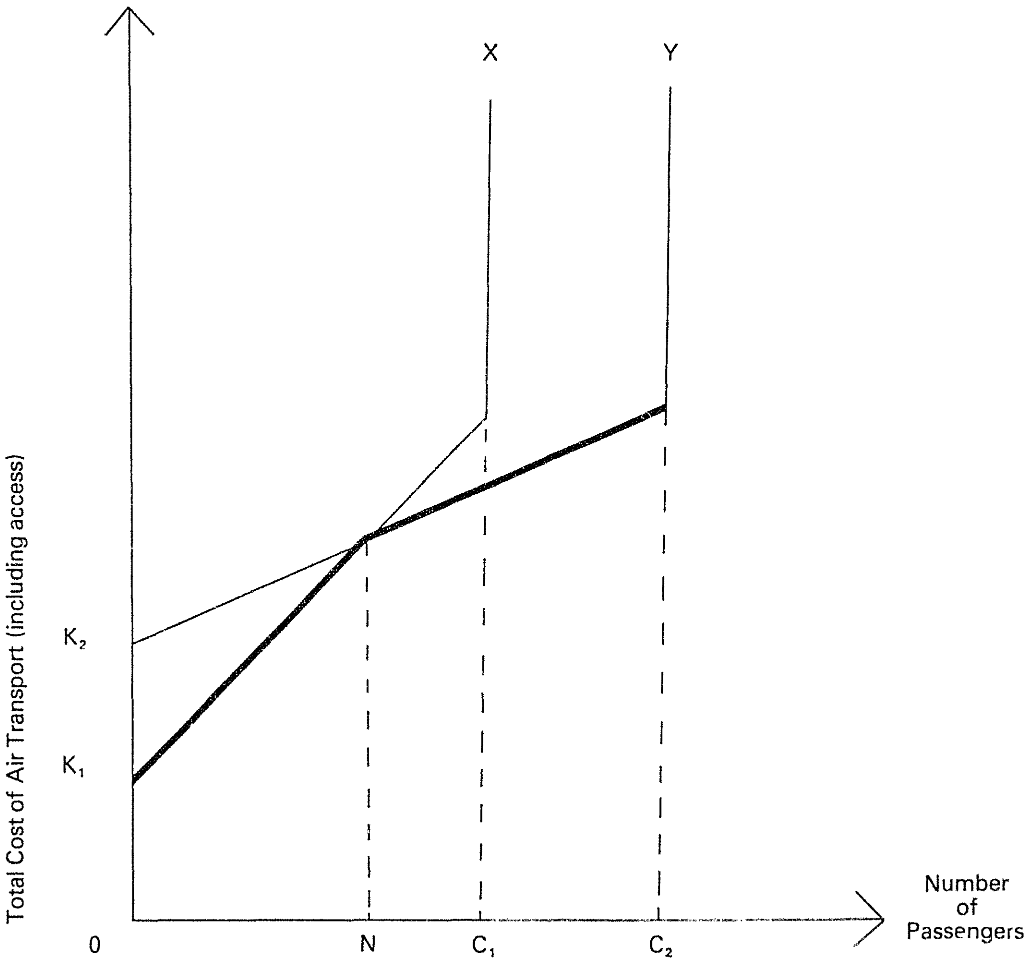
limited by the size of the market. It is likely also that, as additional airport capacity is built, less and less desirable sites must be chosen; the best get built up first, and, because of the requirements of airspace, the next sites will be inferior. There are thus "natural" diseconomies which reinforce the diseconomies of access. Furthermore, it seems certain that, with the forecast increase in the number of passengers per aircraft, severe diseconomies will be apparent in the terminal passenger services for more than two or three long runways. Small airports can "process" passengers more quickly than large ones (see National Academy (1975)).

At the minimum level of service and for the small airports there is an important "lumpiness" in the fact that a runway is needed as a minimum requirement. The spectrum begins with a short runway, with no taxi-way, suitable for only light propeller aircraft. As demand increases, so the use of the runway expands, until the question arrives whether to strengthen and lengthen to enable jets (two- or three-engined) to operate. It is unlikely that the short runway will be fully used (indeed it is likely still to be used very far below capacity) before it becomes desirable, because of cost reductions due to larger aircraft, to build the longer jet runway. Thus the form of the total cost functions, somewhat stylised to show a constant variable cost up to capacity, is shown in Figure 1: the heavy line shows the minimum cost expansion path. It will be noted that marginal costs are always below average costs for the range of throughputs on the expansion path. This constitutes an element of the case for subsidising small airports.

Over a certain size, however, capacity becomes the dominant consideration. This is certainly true for the 3,000-metre runways, and probably for many of the 2,000-metre runways. Then the large airport will find it efficient to operate at effective capacity (i.e. on the vertical section of the total cost curve); and additional capacity will be added (in lumps) by new runways. But the upgrading of airports in many developing countries to accommodate intercontinental jets is usually carried out long before there is any capacity constraint on an existing 2,000-metre runway. Thus, except for the main airports in European and North American cities, the pattern of relevant costs is represented by the concave expansion path shown in Figure 1. In practice, there is not the extreme discontinuity shown in the figure. Capacity can be increased by providing taxi-ways, fast turn-offs, different patterns of runway usage, provision of a short runway for light aircraft, etc. These round the corners of the cost function and modify the slopes; but the essential pattern remains.

So far, the discussion has been concerned with runways — but another important element of airport investment is terminal capacity, to deal primarily with passengers. There is little lumpiness of units of investment in passenger handling. But there is a choice between capital-intensive methods (finger piers, ramps, moving walkways) and labour-intensive ones (mobile lounges). This suggests that low volume airports and seasonal peak traffic at high-volume airports should use the mobile lounges, while the hard-core traffic is accommodated through the finger piers, etc. (see FitzGerald and Abdelmoneim (1977)).

Although it is clear that there are marked economies of scale in the provision of runways, it seems equally likely that size eventually brings diseconomies in the provision of terminal facilities, such as car parks, access to airplane, etc. It is not only in the old airports but also in new ones, such as Dallas Fort Worth, that the



K_1 = capital cost of short-runway airport
K_2 = capital cost of long-runway airport
C_1 = capacity of short-runway airport
C_2 = capacity of long-runway airport
K_1 to X = total cost curve for short runway
K_2 to Y = total cost curve for long runway

FIGURE 1

Costs and Scale (Runways only)

length of time required for a passenger to pass through the terminals increases with the size of the airport. Thus it is the diseconomies of terminal operation that may well limit the size of airports in the future. On present estimates, by 1990 the number of passengers per aircraft will mean that at capacity over 20 million passengers per annum will pass through a one-runway airport. The balancing of the diseconomies of terminals with the economies of runways suggests that future airports should be limited to two independent runways. But this is only a provisional conjecture; the evidence for each paricular case must be assessed.

Pricing policies for small airports

With small airports which experience no congestion, landing fees and other user charges should reflect the low costs of using underutilised runways. But this marginal-cost pricing will give rise to financial deficits which must be financed from one source or another. In developed Western countries, many small airports are subsidised partly by the municipality (the residents of which are thought to be the main beneficiaries of the airport) and partly by central government (Gellman (1975)). In LDCs the responsibility is usually borne entirely by central government, and in some cases the expenditure is considered part of the defence appropriations.

The strong objections to subsidy no doubt may be held to apply particularly to airports. The discipline of "covering the costs" may mean desirable air movements foregone, but it is likely to forestall overbuilding, overgilding and featherbedding. Suggestions for pricing policies give a balanced budget range from some sort of average cost pricing (often under the guise of long-run marginal cost pricing and discriminatory pricing according to the elasticity of demand) to various forms of multi-part tariff.[26] In practice, some form of two-part tariff is often used for airport finance; thus an airline that uses a particular airport on a regular basis will find it profitable to enter into a long-term contract for airport services, and may simply pay an annual rent for the right to use the runway. Casual users, of course, are charged a normal landing fee. But it is not so easy to apply multi-part tariffs in the same way as in electricity and gas supply, largely because there is no essential and exclusive "hook-up" equipment.

Protagonists of a full-cost pricing policy for airports rely on the proposition that the elasticity of demand for an airport's services is likely to be small—and so the distortion of resources is probably trivial.[27] This is likely to be valid only if *all* alternative airports follow suit; otherwise there is the chance of a large-scale switch to the subsidised airports.

This discussion raises an old issue: would it not be best to permit the unsubsidised competitive provision of airports by the private sector? There has been little research on the likely consequences of freedom to enter the airport business. One may conjecture that there is sufficient competition from other modes, the threat of new entrants, and the performance of competing airports to provide both

[26] An ingenious development of a programming approach to give simultaneously a "fair" contribution to fixed costs and an investment test is to be found in Littlechild and Thompson (1977).

[27] See evidence by Sir Peter Masefield, Chairman of British Airports Authority, to the Roskill Commission: Papers and Proceedings, Public Hearings, Part I.

constraints and incentive for the private owner. Apart from the extensive system of general aviation airports in many states in the USA, however, such competitive provision has never been explored. Government subsidies are a potent drug which airport authorities are most unwilling to forgo.

Externalities

Externalities are usually defined as effects (bad or good or some mixture) of a production process for which there is no market transaction. Thus polluters do not have to pay for the inferior air quality that they impose on the affected population. In airports, the most important cost that does not appear in the accounts of airlines or airports is that of noise. The householder or landlord who resides under the flight path near an airport has no right to regulate the flights over his territory.[28] Nor has he the automatic right to redress for the intrusion of considerable noise. In the United Kingdom, there has been no disposition on the part of the courts to provide any compensation. On the other hand, in the United States, and particularly in California, courts have made awards of substantial damages in suits against the airport. Predominantly, however, aircraft noise remains an externality which affects large numbers of people. In principle, it would be possible for all the households affected by noise to agree with the airport authority on the quantity of noise and the compensation they require for suffering the din. But agreement between large numbers of people is difficult to reach, and each has an incentive to hide his true preferences — a typical example of the "free rider" problem.

The quantification and, *a fortiori*, the valuation of this externality have been the subject of hot dispute. On one side (e.g. Crowley (1973)), it has been argued that virtually all the disamenity of noise will be reflected in the lower values of noisy sites compared with the quiet plots. On the other hand, it has been suggested that there can be no adequate measure of the disamenity of noise, and certainly no sufficiently comprehensive valuation of it can be adduced from property values (National Academy (1977)). Nevertheless, there appears to be a minimum consensus that the differential property value provides *some* sort of measure - although views differ on whether that tells the whole story (Paul (1971); Mishan (1970)).

Fortunately, for the analyst, aircraft noise is a local phenomenon and is confined to a narrow tongue extending for some kilometres from the end of the runway (Flowerdew (1972), Walters (1975)). The proximity of noisy houses to quiet ones provides the opportunity for *ceteris paribus* comparisons of the selling prices (or, where not controlled, the free market rents) of houses or, more rarely, plots of land. For most well-established airports with more than a decade of jet operations, these noise differentials in the prices of houses approximate to the long-term market value of quiet.[29] And the quantity of quiet will be very different just beyond the threshold of the runway from the quantity five or six miles away.

Although there is no natural quantitative measure of noise, accousticians have devised ordinal scales, such as the Noise Number Index in the United Kingdom

[28] The old principle that a landowner disposes of the resources under the land and the airspace above it was abolished by Section 9(1) of the Air Navigation Act in Britain in 1920. His air rights were expropriated and vested in the aviation industry.

[29] Over a decade or so, it is likely that there is so much natural movement that the costs of movement may be ignored in the evaluation; see below.

(NNI), the Composite Noise Rating (CNR) and the Noise Exposure Forecast (NEF) in the United States, and the Isosophique (I) in France. All are weighted averages of the high frequency peak noise and number of occasions on which the noise of an aircraft is heard, and all broadly give the same results.[30]

In most studies of aircraft noise, the area surrounding the airport has been divided into contours according to NNI, CNR, etc., and the depreciation of houses ostensibly due to aircraft noise has been noted. The results of these studies, summarised in Walters (1974) and Nelson (1976), suggest a degree of consistency which is surprising in view of the diverse methodologies and measures. They suggest that the number of percentage points increase in the depreciation of the price of a house due to a one-unit increase in NNI or CNR is between 0.3 and 1.0 or between 0.45 and 1.5, respectively. Furthermore, with suitable assumptions they can be interpreted to show that the demand for quiet is elastic with respect to permanent income (somewhere around 1.5 to 2.0).

There are various levels at which one may make use of these noise differentials in planning the location of new airports, or the demise of old ones. A crude approach is simply to debit or credit the differentials multiplied by the number of households affected.[31] This will give differences between alternative locations for the airport, which are often quite good enough for a first comparison of sites. There is, however, a large variance in individuals' tolerance to noise; some are much upset but others may happily put up with it. Consequently, the simple differential does not take into account the fact that people may move to more preferred locations. At a cost, the sensitive may avoid noise by moving away—allowing the imperturbables to move in; and, if there is a sufficient lead time for a new airport, there is always the normal movement of households which can take into account the effects of noise. The process of natural movement, noise-induced moves, and so on is one that has been modelled in the Roskill papers.[32] The principles are simple, but the calculations are complex.

Many of the uses of such noise differentials are for the purpose of deciding on the costs and locations of *new* airports, or at least of new or lengthened runways on existing airports. But what about *closing* existing airports or runways—is it possible simply to write the costs of noise as benefits? Unfortunately, no. The population around existing airports has long ago adjusted to the environment; and the lower prices for houses in noisy zones, and any movement costs that arise as imperturbables sell to the sensitive because of the new peace, must be *debited* to the closure. This gives considerable strength to the case for leaving existing airports open even when, as in the case of London's Heathrow and New York's Kennedy, they have very considerable effects on large numbers of families.

Nevertheless the noise studies do indicate how to arrive at sensible decisions on the widely touted solutions to the problem of airport noise. These include, *inter*

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[30] See Walters (1975). They are approximately linear transforms of each other.

[31] This encompasses only the noise effects on households and is thought not to cover the noise on schools, hospitals, parks, etc. It is likely, however, that much of these effects will be reflected in the house price differentials. See Walters (1975).

[32] Roskill, Papers and Proceedings, Vol. VII, 1970. Walters (1975), however, shows that the final figures fit a simple linear pattern.

alia, spreading the operations around so that each part of the community gets its share of the noise (bad because it does less harm to concentrate the noise experience), restricting night operations (probably good, since night movements cause about ten times the annoyance of any day movements), hushing the noisy jet engines by retrofit (doubtful, since much of the benefit can be obtained by less costly methods), and levying landing charges according to the amount of noise emission (see Walters (1975), Nelson (1976), and De Vaney (1976)). A number of airport authorities, e.g. Japan, France and the Netherlands, have introduced airport landing fees that vary with the noisiness of the aircraft—but there is a long way to go before the fee reflects the calculated cost of noise.[33]

Notwithstanding the fact that the price of a noisy house near an airport may be 30% less than the more expensive houses (Walters (1975)), the calculations of total noise costs, and the differentials between new airport sites, are relatively small when compared with the prior expectations of many informed observers and with the other costs, such as those of surface access. And this is in spite of the biases toward magnifying noise costs.[34] Nevertheless, partly because of the substantial returns that accrue from quite a small expenditure on lobbying and political pressure, it seems that noise is likely to bulk large in airport decisions.

The problems of truly compensating those who suffer are complicated by the process of capitalisation of expected compensation in the price of assets. In the United States (and particularly in California) the courts have made a series of decisions requiring airport authorities to pay compensation.[35] In the United Kingdom, the Land Compensation Act of 1973 provides for a money payment to be made to those property owners who are affected by a *new* runway or *changed use* of an existing runway. This measure is likely to reduce the immediate depreciation of price of houses under the flight path, so that the existing owners do not suffer so much loss; however, after a time, the differential will revert to its long-run pattern.[36]

Although noise is the dominant (bad) externality of airports it is by no means the only one. Others, such as air pollution and traffic congestion, are associated with all such projects, and the location problem is one of "here rather than there." Airport authorities are inclined to emphasise the good externalities of their facilities—such as higher wages and plentiful jobs—which themselves increase rents and house prices in the vicinity of the airport. Although again this is a question of

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[33] See Suurland (1976) and US Council on Wages and Price Stability (1977). Certain guidelines on charging for aircraft noise were being studied by an OECD panel and were scheduled for release in early 1978. Meanwhile, in Britain, the Civil Aviation Bill (published 15 December 1977) allows airports to "discriminate" in favour of quieter aircraft.

[34] In the Roskill research, for example, it was assumed that, through a time trend, people at a given income level would increase their valuation of quiet life; tastes were thought to grow continuously more quiet and contemplative. If one discounts the *ex cathedra* statements by eminent town planners, there seems to be little evidence of such a sea change.

[35] In the Westchester (1976) decision the Supreme Court of California ruled that, notwithstanding the fact that a property owner bought his interest at a noise discount, he was nevertheless entitled to *additional* compensation from the airport authorities! Legal opinion, however, suggests that this is unlikely to stand.

[36] The Act sets strict limits on the amount of compensation; in practice, it is likely to fall considerably below the actual depreciation due to noise.

"here rather than there", such increased values are a windfall to the owners and are part of the benefits of an airport that are only partially, through real estate and income taxes, appropriated by government.

Externalities planning

With understandable professional chauvinism, planners have often proclaimed that decisions about airport investment are first and foremost issues that should be determined by planning criteria.[37] In principle, the planner claims not merely to take into consideration, but also to weigh and judge, those aspects of human experience which are not, or are only inadequately, comprehended by the market. As an objective this Olympian ideal is unexceptionable, but the reality is what matters. In practice, planning has no methodological discipline and no way of organising evidence in a coherent form beyond the form that appears in cost-benefit studies. The use of "consultation" to discover what people really want is largely a matter for public relations rather than a tool of research, although these planning inquiries can be useful in illuminating issues which may otherwise be obscured. In fact, the planner will normally make a judgment about the appropriate location of an airport on a mixture of personal, aesthetic and material grounds[38].

Nevertheless, the urban consequences of an airport location may be of considerable importance. Some locations may make it cheap to accommodate airport workers and ancilliary industry and population, whereas other locations may be much more expensive. The present state of the art of urban economics, however, is far from the stage where it can model and evaluate all the multitude of facets of the residence-work location process.[39] The accurate prediction of the levels of rent is far beyond the power of empirical economics. Nevertheless, some startling differences may be worth noting. For example, in the Roskill study, it was observed that the Maplin (then called Foulness) site would involve building most of the airport town on piles; thus the Commission took into account this additional cost in the cost-benefit study. It is probably possible to take into account the differentials in supplying other services, such as water and sewerage, for different locations, and, if these services are provided at cost, the differences will be reflected in house prices and rents. That is about as far as the present state of the art will take us.

Access by surface

The main cost-benefit studies have shown that, among the various factors considered, surface access costs are very important and indeed dominate the discrimination between sites. And this gives rise to the much-publicised dilemma – put the airport near the people and put up with the noise for the convenient access, or locate far away and buy peace at the expense of poor access

[37] Professor (now Sir) Colin Buchanan frequently and eloquently put this case during the course of the Roskill Commission. See Roskill Report (1971) and Hall (1970).

[38] Perhaps the best account of the planning mind is to be found in the eloquent minority report by Buchanan in Roskill Report (1971).

[39] The New Urban Economics which deals with these issues is in the stage where it is producing parables, not policies.

(de Neufville in Howard (1974)). Many populists allege that poor access can be banished by high-speed, usually unconventional, forms of transport to the airport. Investigations have shown, however, that there is no magic solution to the access problem—and, as experience has confirmed, conventional methods, such as car, bus and ordinary steel-on-steel rail, are the only options worth considering.[40] And the need to link airport traffic into the metropolitan distribution system suggests that the closer the access system is to the conventional network the better.[41]

The methodology of assessing surface access, therefore, tends to follow the conventional forms of transport models but with one big difference. The destinations for outbound passengers, and similarly the origins for inbound travellers, are few: namely, the airports considered in the system. The choice of airport and access to it is a joint choice, depending upon the price (in a general sense, reflecting all the costs) of the air trip and the journey to or from the airport. This interaction is complicated further by the fact that the larger the number of services the greater the attractiveness of an airport. (A large airport will generally have more inter-line and feeder services as well as more frequent departures and arrivals.)

It is, however, extraordinarily difficult to model this scale effect of attractiveness formally into the transport model. It is best dealt with as a separable effect in allocating traffic between airports. In the Roskill analysis, for example, the attractiveness of an airport was calibrated along conventional gravity model lines. In other airport modelling such as that which has been used in centrally planned economies—the allocation of traffic is finally solved by simple *dirigisme*. In situations where there is considerable freedom of choice, the authorities appear to have much underestimated the deterrent effect of access distance and few services.[42]

A preliminary decision of some importance is to define what airports and what catchment area of traffic are to be included in the system. The more airports and the wider the area included in the assignment procedure, the greater the complexity of the analysis and the likelihood that errors will compound the forecasts. A judgment must be made on the point at which detailed articulation of the access analysis gives way to a more summary aggregate treatment. For example, a detailed treatment of the jet airports in the south-east was clearly worth pursuing in the Roskill enquiry; and it was probably worth while modelling in the Midland, and even the Manchester, airports. But the airports and traffic in Scotland and the far north of England were treated on a summary residual basis only.

With known flights and passengers at each airport in the system, the problem remains to forecast passengers' domestic origins and destinations and allocate them

[40] Note that even fast "conventional" rail methods, such as the Advanced Passenger Train and the fast trains of Japan National Railways, are not suitable for transit distances of less than 100 kilometres. See, however, Miller (1971)

[41] This was one of the main reasons for extending the London Underground to Heathrow as an alternative to a faster British Rail connection.

[42] Probably the best known case is the Dulles National competition in Washington, D.C. Dulles, although a splendid airport, is about 50km from the central business district, whereas National is a mere 8 km. Dulles has remained underutilised for many years, while National has been much overcrowded. Rationing of flights into National has diverted traffic both to Dulles and to Baltimore Washington International Airport.

to airports. The forecast of catchment areas is determined primarily by calibration with respect to income *per capita,* population and the location of business. The really difficult part is to allocate passengers to airports. Minimum access cost is a criterion which is clearly inconsistent with the evidence; people will often undertake longer and more costly journeys in pursuit of the appropriate departure time or type of service. Some sort of "assignment curve" technique or probit analysis may be used to model (but to cover our ignorance of) the complex set of factors that determine passenger choice.[43]

It is difficult to judge the success of these methods of allocation and assignment. No doubt they are easier in the case of the extension of an existing airport than in the assignment of a new airport. One would expect that an analysis of the outcome in the case of those new airports that have been built, such as Dulles and Charles de Gaulle, would be of some interest in testing the veracity of such models but so far as one can discover no work has been published along these lines. One particularly important issue, on which there is little information and analysis, is that of modal choice. Airport access is somewhat different from the traditional concerns of modal choice analysis (usually commuter or relatively long-distance traffic), since it is often highly seasonal with much baggage. Fortunately it appears that, for deciding the location of airports, modal choice is probably not a dominant determinant, although it gives rise to some doubts about the shaping of transport systems and terminals.

The evaluation of alternatives has been carried out by the conventional methodology. But in location studies it has been normal for the passenger benefits to be taken as given for all options, so that the differential is one of costs only. Benefits will differ according to the extent to which different airport locations will generate or repress traffic. The reluctance of analysts to place much, if any, weight on generated traffic arises partly from ignorance and partly from the argument that the differences in costs between different airport configurations are only such a small part of the total costs of the trip that they can have only a miniscule effect on the propensity to travel. (But, as pointed out above, there may be a switch outside the system.)

The costs are conveniently divided into operating costs (and the implied value of time) and capital costs. The treatment of capital costs must vary according to the pattern of transport planning used. In Britain, there is a well-formulated planned sequence of upgrading and new building of roads. The main effect of an airport will be to bring forward in time some of the improvements, while delaying others. Since motorways and freeways are large lumpy pieces of investment, it is sometimes possible for the airport traffic to be accommodated easily in the lee of one of the investment waves.[44] The "bringing forward" technique avoids many of the problems said to be involved in allocating the costs of a new highway between airport and non-airport users. In the case of Dulles, the FAA "solved" this problem by ensuring that the access road was restricted almost entirely to airport users. Such

[43] One recent study of this kind is Metra (1975).

[44] It will be noted that, if the site is sensibly chosen, it will be where there are existing good communications; sites where there are poor communications and few planned (e.g. Foulness called Maplin) are unlikely to be good sites.

conspicuous waste is hardly to be commended. In investment planning, there is no reason why airport users should be singled out for either fair treatment or foul.[45] For rail investment—including the desirability of a new rail line, either trunk or spur—the issues are more complicated. The critical flow of passengers is high in order to achieve frequencies which make the rail service widely preferred to the bus alternative. In a few cases (e.g. Gatwick), the airport traffic can simply be grafted on to existing suburban services. But many large metropolitan areas do not have such a convenient network of rail services, and so the building of a special line is mooted. However, it is very unlikely that any airport will have a sufficient load of traffic *per se* to justify a new rail line—other than a short and inexpensive spur to an existing line. And new general passenger lines are unlikely to be built in most metropolitan areas of the world.

The operating costs are calculated from the relationship between capacity and the expected volume of traffic, and for evaluation purposes they are entered net of taxes. Perhaps the fiercest disagreements have been generated over the treatment of time savings. The differences in time for alternative sites tend to be rather small on the average—although this average difference applies to a large number of passengers. There is an abiding feeling that small differences in time, incurred on only a small number of occasions per annum per person, are imperceptible, and so not valuable—or at least that their value is considerably less than the proportionate amount of a large chunk of time.[46] For the business traveller, the transformation of a time saving into a money cost involves finding the labour cost to firms of those who travel on business; this implies taking the hourly wage or salary and adding the additional costs of employing a person.[47] Under competitive conditions, this is merely another way of measuring the loss in real output—the marginal productivity per hour—of the additional time spent in travelling. Criticisms of such measures have usually hinged on allegations of the invalidity of the marginal productivity theory of distribution and the existence of spare labour capacity. In my view, such criticisms have not carried the day, and, subject always to the uncertainty of the statistical base, the labour cost approach is the best we have. For leisure travel, however, one can marshal in evidence no such marginal productivity theory. One must depend on observing people's behaviour. Most studies that have been made are concerned with commuting, and only fragmentary evidence is available for airport access trade-offs. The general result is to suggest that leisure time should be valued at 25% to 50% of the hourly wage *receipt* before tax is deducted.[48]

[45] In much informal discussion, it is sometimes argued that the authorities should discriminate against airport users, since on the average their income is higher than that of the rest of the population, and public investment should have a "distribution bias" towards the poor and needy.

[46] At first sight, it might seem that, to be consistent, governments that use a value of time to evaluate road projects should not demur from using that same value in justifying or rejecting airport projects. However, where there is a will .... And the argument for such asymmetrical treatment is deduced from the proposition that airport access journeys are "different" from the normal trip. See Hearings, Roskill (1969).

[47] Surveys show, however, that businessmen claim to do a considerable amount of work while seated in aircraft or lounge.

[48] For a comprehensive survey of the values of time see Yucel (1975).

The appropriate valuation of time is the subject of a long-standing dispute in transport economics, which can be resolved or at least hushed only by the further study of decision-making involving the time-money trade-off. This remains meanwhile a large uncertainty in the evaluation. It is usually dealt with by sensitivity tests with different values of time (see for example CTLA Report (1970)). But this is hardly satisfactory.[49]

Access by air

The criteria for air access are quite different from those for surface access. Air space is the prime requirement; and, for the ideal Air Traffic Control conditions, large airports must be a minimum of 32 miles apart.[50] However, such ideals are very misleading. For example, the New York system contains three airports within this radius; but it will be noted that they are not four-runway airports, and the ATC for New York is operated as one integrated system. The real point is that some sacrifice in terms of the reduced use of runways may be a good thing if there are countervailing benefits from the location. But this is not the only cost, for the location of the airport can have a considerable differential effect on the number of kilometres that aircraft must travel to gain access to the airport and air routes.

The modelling of air traffic is made analytically difficult by the very large number of variables involved—type of aircraft, weather conditions, time of day, mix of traffic, etc. Analytical methods such as the theory of queues have a very limited application. Most useful models have proceeded to simulate the traffic and ATC procedures and runway utilisation.[51] The inputs of traffic, a weather mix, ATC procedures, etc., are fed into the model and there emerges the utilisation of runways, the throughput of aircraft on each runway, and the distribution of waiting times in the "stack."

These outputs then provide the basic data for the evaluation of: first, the location of the airport relative to some alternative; second, the benefits from having an additional runway; and third, the costs of different alignments of runway at a particular location. In practice, however, it is usually possible to settle this last (alignment) problem without recourse to the model. Runway operation which is unimpeded by conflicts of air space can vary from about 35 to 40 movements to as many as 60 or even 70 movements an hour—much depending on whether visual flight rules are in operation, whether it is operating as a joint landing and departure runway or exclusively one or the other, and so on. The appropriate design of runways has been changing remarkably. The "complete independence" requirement was that runways should be 5,000 feet apart; but now it appears that new ATC procedures enable close-spaced parallel runways to be operated with

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[49] A further complication is that it is often alleged that those who suffer the noise are poor, while it is the rich air traveller who saves time. Much has been made of the asymmetry of this trade-off (Nwaneri (1970)).

[50] This requirement, for full independent operation under instrument flying conditions, does not take into account the possibility of a micro-wave landing system (MLS).

[51] One much-used model is that developed by Airborne Instruments Laboratory (1969). This was used in the simulations for CTLA (1970). More recent simulations are available from the FAA--see FAA (1977).

something near to the capacity of the independents. This emphasises the difficulties of making the long-range forecasts that are required in airport planning.[52]

The cost-benefit criterion for new runway capacity is simple: a new runway should be built when the present value of the benefits in terms of the amount which airlines (and ultimately their passengers) are willing to pay for the additional facilities exceeds the present value of costs when a charge equal to the short-run marginal cost is levied for the use of the runway. This is the normal area-under-the-demand-curve criterion. But airports do not use marginal cost pricing, and consequently, with too little runway capacity, there is the familiar process of queueing in the stack. Whether one should count the reduction in queueing costs of existing traffic as part of the benefits of a new runway depends on whether one takes the pricing policy (below marginal cost on the existing runway) of an airport as given. If it is so fixed, the reduction in queueing costs of existing traffic is indeed part of the benefits of a new runway; and traffic on the enlarged airport will not be as large as it "ought to be" because the price is above the much lower short-run marginal cost.[53] This is no more than an application of the theory of the second best.

In airport planning, however, a rule-of-thumb is normally proposed. This is that the runways should have sufficient capacity to handle, with small delays, the fortieth busiest hour during the year. Although as a rough guide to future investment this is not ridiculous, the criterion cannot be used for detailed study of investment plans. It ignores items such as the costs of providing the capacity and the ability to spread or repel demand by peak hour pricing.

The evaluation of the air traffic implications of a particular site relative to its alternatives can be conveniently assessed in the form of: first, the loss of runway utilisation, and second, costs of additional travel. The loss of runway capacity because of conflicting flight paths can be evaluated by the costs of bringing forward in time the additional runways that will be required, given the assumptions on pricing policy, etc. The loss due to additional air kilometres involves valuing the cost of additional flying hours and the time of passengers on a basis similar to that used for the evaluation of delays in the stack. Again, the same problems arise with respect to the value of passenger time that have been reviewed in the case of surface access, and a similar treatment is appropriate.

Methodology of airport investment decisions

From the large studies of airport investment that have been carried out in recent years, one may derive a number of lessons, which we may now review. The most outstanding feature of the studies has been the complexity of the problem; airports have substantial ripple effects, and it is by no means certain when the ripples are small enough (especially if there are a lot of them) to be ignored. Yet the problem is

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[52] A more dramatic change would be the development of MLS radar, which would massively increase the capacity of the terminal air space. But securing the necessary measure of international agreement will be very difficult, as was illustrated with respect to Decca's Area Navigation System in the early 1960s.

[53] On this, see the criticism by Forsyth (1972). Rightly or wrongly the Roskill Commission took the view that its terms of reference did not include recommendations about the appropriate pricing policy and its effect on the timing of the need.

more manageable than, say, the London Motorway issue. And this is because it is possible to carry out the research and investigation with *separable* models. The ATC can be separated from the surface access model, and the urbanisation study from the investigation of noise. Of course there is interaction between these separate models—but it is small and manageable. This distinguishes airport studies from studies of urban motorways; there the interactions of transport with land use and location are central and fearfully complex. Indeed, it appears that there are good reasons for not developing a large integrated model in airport investment planning.

Perhaps the main reason is that technology has changed and is expected to change rapidly in air travel, and it is extremely difficult to make predictions for even a few years ahead.[54] Thus one needs to develop an approach that can easily and cheaply incorporate changes in key parameters. This will also usually ensure that the methodology is transparent, so that one can understand the details of the process and "see" what is happening.[55] Thus one can more readily use non-quantitive information, such as knowledgeable hunches and the variety of informed opinion, to test the robustness of any conclusions.

Such separable models, of course, have their disadvantages. They need to be stitched together and the seams are likely to be weak. One of the main skills is to develop sub-models so that they can be fitted together into a coherent whole. There is no theory of such a model development—it remains an art. One needs to guess what can be ignored and what cannot.

Fortunately, in airport location decisions, there is one important saving grace; one is concerned only with the *differential* costs between airport sites. In Roskill's terminology, one must measure the height of the wave and not the depth of the sea. This enables the analyst to avoid many of the much debated issues which are extraneous to the problem of airport location.

One striking feature of airport investments is worth noting. Virtually all large airport projects—and probably many or most small airport projects—are mooted many years before they are economically desirable. Airport authorities and government officials seem to be congenitally committed to laying down new runways too soon and in too llarge a number.[56] In the case of London, for example, the airport authorities had urged dates for developing a third airport which, in the event, proved to be some ten years before the third airport would be economically justified; a rather similar experience occurred in the New York system.[57] The ones that got away—such as Dulles—have very largely established this proposition of "too much and too soon." Whether these lessons have been truly

[54] As an example, the Roskill Commission's forecast of the speed of introduction of wide-bodied jets was clearly discredited within two years of publication of the Report. See also Bluestone (1975), Candela (1969).

[55] Experience with complex and highly interacting econometric models suggests that this transparency is most important. Nonsense can often lurk unilluminated and unsuspected in the inaccessible recesses of such models; it is less likely to be passed over in models of a simpler structure.

[56] In evidence, at the Roskill CTLA Hearings in 1968, Sir Peter Masefield demonstrated this effect in a claim that nine long runways would be needed for London. In fact, London will manage nicely with four or at most five until the mid-1980s, and probably far beyond.

[57] See National Academy (1972) and Foster *et al* (1974).

absorbed by influential decision-makers, however, is very doubtful. The development of Mirabelle (at Montreal) and the planned second Toronto airport, as well as Dallas-Fort Worth, suggest that, whether or not they have appreciated the proposition, they have not acted upon it. This is in part an effect of the peculiar financial arrangements of airports, in part a consequence of pork-barrel politics (but on rather a grand scale), and in part an iconolatry.

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