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SOME APPLICATIONS

THIS STUDY of the effect of time on the demand for passenger transportation would be incomplete without returning to the opening thesis, i.e., the claim that the theory of the allocation of time provides the analyst with a powerful tool for the estimation of the demand for some of the future modes of transportation. We mentioned several of these modes in the introduction, the supersonic passenger plane (SST), the high-speed train, the short-take-off plane (STOL), and the vertical-take-off plane (VTOL). The precise evaluation of the demand for these modes is clearly outside the scope of this study. It involves a vast amount of data, of which some is still confidential, some in dispute, and some unresolved from the technological point of view. Thus, we will limit ourselves to hypothetical case studies.

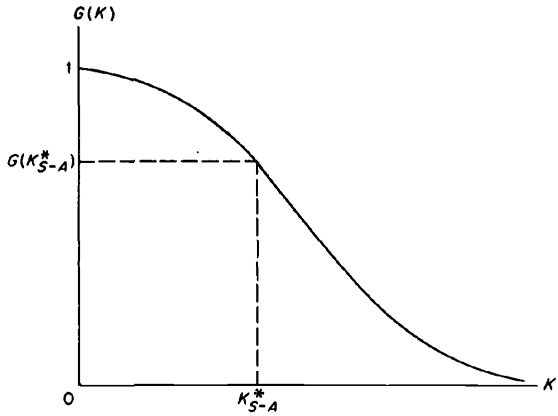
The introduction of new modes provides the traveler with a new, hitherto nonexisting, combination of time and money inputs, and it cuts into the market of the existing modes. Let the new mode (say, mode S) be faster than any existing mode. Let the previously fastest mode be mode A. Given the new mode's fare and traveling time on a specific route (P_S and T_S, respectively), all mode A travelers whose price of time exceeds

$$K > \frac{P_S - P_A}{T_A - T_S} = K^*_{S-A} \tag{6.1}$$

will shift to the new mode. The new mode (or the new equipment) should be able to capture the entire mode A market if the price of time for all passengers exceeds K^*_{S-A} (a sufficient condition being $P_S < P_A$).[1]

[1] We still maintain that the choice of mode rests solely on traveling costs, ignoring other factors affecting the utility derived from the trip, such as prestige, risk, etc.

FIGURE 5



Otherwise, the market will split between the conventional and the new mode. Given the mode A travelers' decreasing cumulative distribution of the price of time $G(K)$ (i.e., the distribution describing the percentage of travelers with a price of time exceeding K), $G(K^*_{S-A})$ of all travelers will shift to the new mode (see Figure 5). This percentage depends on the precise value of K^*_{S-A} and on the shape of $G(K)$.

To illustrate, assume a supersonic plane, whose cruising speed is 1,500 mph, is to be introduced in 1975.[2] Should the new equipment prove to be cheaper to operate than conventional equipment (including the new jumbo-jets), and should the air carriers decide to charge for the use of the new equipment the same or lower fare than that charged for the old mode, the SST should have no difficulties in wresting from the subsonic plane the whole market in which it will operate. If, on the other hand, the air carriers decide to impose a surcharge for the use of the new plane, the market will be split between the two sorts of equipment. In this case one has not only to estimate the size of the air travel market in the mid-seventies but also the share of each kind of equipment in this market.

Addressing ourselves to the second task, we assume that the new equipment does not affect the fixed component of the trip's elapsed

[2] We ignore any possible imposition of speed restrictions on overland flights to limit the effects of sonic booms.

time, and that the introduction of the jumbo-jet will not change the elapsed time and the fare of conventional equipment. Given our estimates of Chapter 4 [equation (4.1)], and a percentage surcharge on the new equipment at a rate of q, the elapsed time and pecuniary costs of subsonic and supersonic planes are

$$T_A = 2.56 + .00210M, \qquad P_A = 7.04 + .06006M,$$
$$T_S = 2.56 + .00067M, \text{ and } \quad P_A = (1 + q)(7.04 + .06006M), \tag{6.2}$$

respectively, where the elapsed time (T_i) is measured in hours, the fare (P_i) in dollars, and the distance (M) in miles. The traveler uses the faster mode only if his price of time exceeds

$$K > q\left(42.00 + \frac{4908.8}{M}\right) = K^*_{S-A}, \tag{6.3}$$

where K^*_{S-A} is measured in dollars per hour.

The proposed supersonic plane cannot compete with conventional equipment for the short-range trips. The unit operating costs of the new equipment decrease with distance relative to those of conventional equipment and it will not be operated for distances smaller than 700 miles. For a range exceeding 700 miles the critical value of K^*_{S-A} becomes almost insensitive to changes in distance. Thus, given a surcharge of 10 per cent ($q = .1$), the value of K^* ranges from \$4.40 to \$4.80 per hour. Assuming a surcharge of 20 or 50 per cent these values are about \$9.50 and \$23.00 per hour, respectively (see Table 11 and Chart 5). Imposing a surcharge of 10 per cent, the SST will be used only by passengers whose price of time exceeds \$4.20 per hour. Raising the surcharge to 20 or 50 per cent limits the SST's clientele to travelers who place on their time a value exceeding \$8.40 and \$21.00 per hour, respectively.

The distribution of the price of time that will face the SST in 1975 depends on the future distribution of earnings and the relationship between the price of time and hourly earnings. Adopting the income distribution of air traveler-trips as reported in the Port of New York Authority survey (Table 12 and Chart 6), we estimated the corresponding distribution of hourly earnings using the 1/1,000 sample of the 1960 Census of Population data on the hourly earnings of professionals and managers (see Table 6). To obtain the 1975 distribution of hourly earnings we assumed that the hourly earnings of all travelers increase at the

TABLE 11

The Critical Value of Time Determining the Choice Between Supersonic and Conventional Equipment

($K^*_{S-A} = q[42.00 + (4908.8/M)]$)

Distance M (miles)	K^*_{S-A}/q (dollars per hour)	K^*_{S-A}		
		$q = .1$	$q = .2$	$q = .5$
250	61.63	6.16	12.33	30.82
500	51.82	5.18	10.36	25.91
750	48.54	4.85	9.71	24.27
1,000	46.91	4.69	9.38	23.46
1,250	45.93	4.59	9.19	22.97
1,500	45.27	4.53	9.05	22.64
1,750	44.80	4.48	8.96	22.40
2,000	44.45	4.45	8.89	22.23
2,250	44.18	4.42	8.84	22.09
2,500	43.96	4.40	8.79	21.98
∞	42.00	4.20	8.40	21.00

constant rate of about 3 per cent per annum (i.e., an increase of 40 per cent for the period 1963–75). Finally, we assume that this distribution (see Chart 7) does not change with distance.[3]

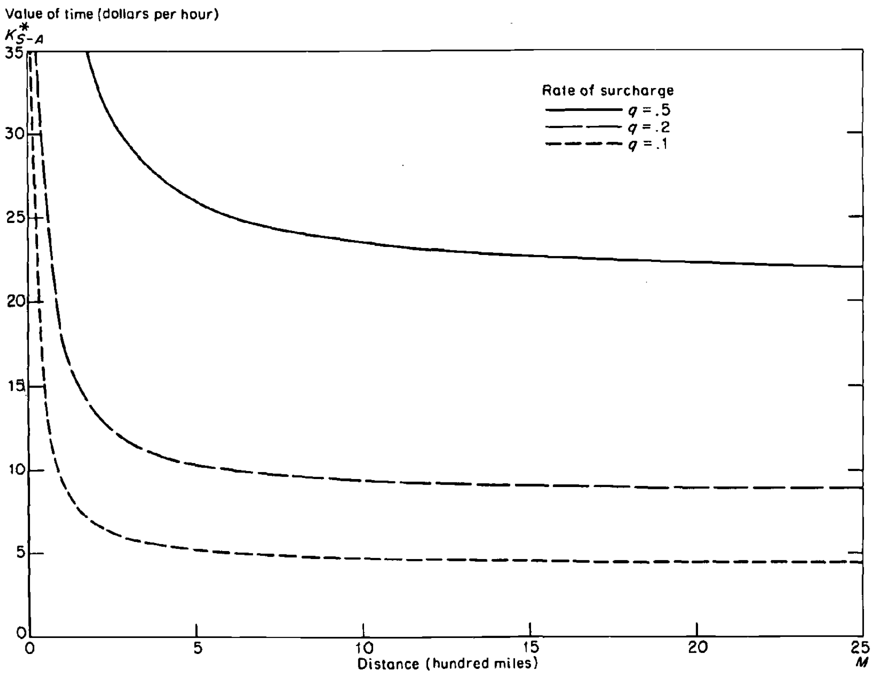
The SST's share of the market depends on the value of K^*_{S-A} and the distribution of the price of time, $G(K)$. Given the information above, this share is a function of two parameters: the surcharge rate (q) and the ratio of the price of time to hourly earnings (k).

To isolate the effect of changes in the SST's surcharge, let us assume that air travelers place on their time a value equal to their hourly earnings (the effect of this assumption is to be examined later). Fixing the surcharge at a rate of 10 per cent discourages all air travelers with a price of time of less than about \$4.50 per hour from using the new plane. Given these hypothetical assumptions, SST travelers would constitute over 80 per cent of all traveler-trips. Any increase in the surcharge

[3] This assumption would be grossly oversimplified were all distance ranges to be concerned. It may serve as a better approximation when one concentrates on the range beyond 700 miles.

CHART 5

The Critical Value of Time Determining the Choice Between Supersonic and Conventional Equipment



cuts into the attractiveness of the new mode. Thus, raising the surcharge to 20 per cent ($K^* = \$9.50$ per hour), the SST's share drops to 35 per cent, and imposing a surcharge of 50 per cent ($K^* \doteq \$23.00$ per hour) leaves the new plane with less than 10 per cent of the market.

About one-third of all air passengers and about two-thirds of all passenger miles in 1964 were to a distance exceeding 700 miles.[4] We assume that the distribution of air travelers by distance of trip will not change over the next decade. Thus, given our illustrative assumptions, with a surcharge of 10 per cent the supersonic plane will be able to capture close to 30 per cent of all air travelers and over 55 per cent of

[4] Civil Aeronautics Board, *Handbook of Airline Statistics, 1965 Edition,* Washington, D.C., December 1965, p. 406.

TABLE 12

Distribution of Income of Air Travelers: 1963

Annual Family Income All Incomes (dollars)	Per Cent	Cumulative Percentage
Under 5,000	5.0	100.0
5,000— 5,999	3.2	95.0
6,000— 6,999	3.7	91.8
7,000— 9,999	11.0	88.1
10,000—10,999	8.0	77.1
11,000—14,999	17.4	69.1
15,000—19,999	16.4	51.7
20,000—24,999	9.6	35.3
25,000 and over	25.7	25.7

SOURCE: *Port of New York Authority Survey,* 38 most heavily trafficked routes.

CHART 6

Distribution of Income of Air Traveler-Trips: 1963

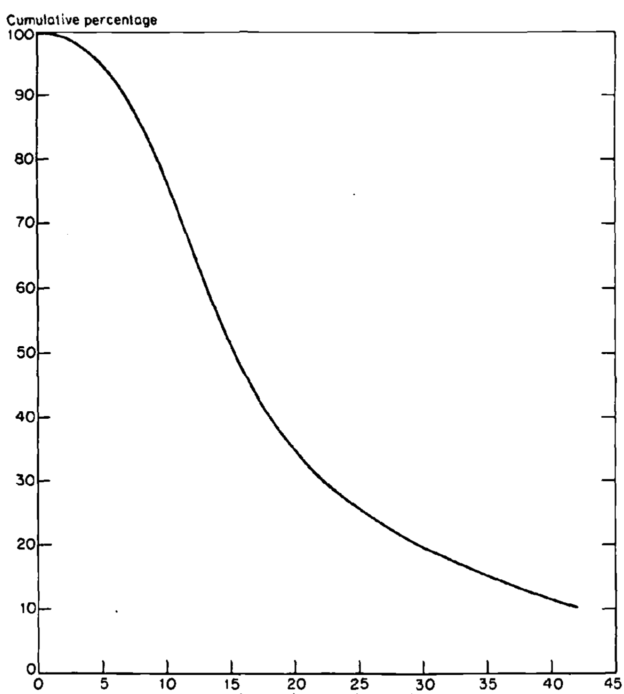
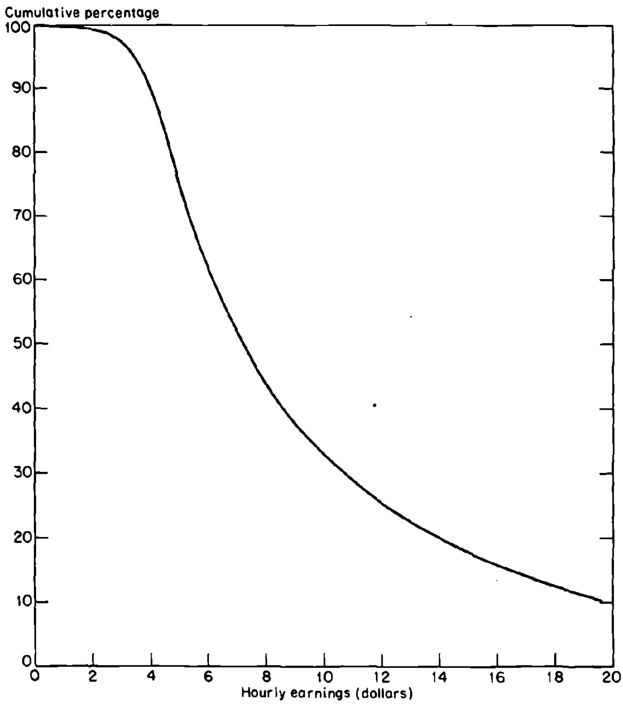


CHART 7

Estimated Distribution of Hourly Earnings of Air Traveler-Trips: 1975



all passenger miles. Doubling the surcharge to 20 per cent, these shares shrink to a little over 10 and 25 per cent, respectively.

The share of travelers switching to the new equipment proves to be very sensitive to changes in the surcharge rate. The same applies to changes in the assumptions on the value the passengers assign to their time. Given a surcharge of 10 per cent and assuming that the passengers value their time at a rate equal to their hourly earnings, we found that over 80 per cent of all long range passenger trips will switch to the SST. Had we assumed that the passengers place on their time a value that is only one half of their hourly earnings, we should have concluded that this share will be cut to about 35 per cent of the market (this assumption having the same effect as that of a surcharge of 20 per cent, where the price of time equals hourly earnings). On the other hand, if the travelers value their time, as some airlines believe, at twice their wage rate [5] the new equipment should be able to squeeze the old one out of the long-range market almost entirely (the SST's share exceeding 95 per cent). Moreover, even an increase in the surcharge rate to 20 per cent would not impair, in this case, the SST's dominance, the SST still being able to maintain over 80 per cent of the market.

We pointed out in Chapter 4 some of the difficulties the railroads face competing with the bus and air carriers in the passenger transportation market. Problems of scheduling, lack of divisibility, and increasingly dispersed origins and destinations hamper the railroads in their rivalry with the other modes of transportation. It was suggested that one way to overcome these handicaps would be to increase the trains' speed.

In Chapter 4 we assumed that there are no costs or time involved in reaching or leaving the railroad station, and, hence, traveling by train involves no fixed time component. The effective marginal speed of the trains was found to be 40 mph, where the distance is measured in terms of city-center-to-city-center great-circle statute miles. The low effective speed is explained by a low cruising speed, a great number of stops, and circuity.[6]

These estimates of a train trip's elapsed time, though high, give the railroads a credit they do not deserve. The assumption that a trip by train does not involve any fixed time component is bold, at best. Traveling to and from the stations does take time. Moreover, infrequent train schedules result in a fixed component of waiting time. This component may be considerable, and it is increasing as the frequency of train departures falls. Any attempt to cut the elapsed time of a trip by train has, therefore, to concentrate on increasing the frequency of trains and their cruising speed and decreasing the number and length of stops.

The fixed time component of air trips is about 2.5 hours [see equation

[5] Institute for Defense Analyses, *Demand Analysis for Air Travel by Supersonic Transport,* Washington, D.C., December 1966, Vol. II, p. 53.

[6] The traveling distance between any two city-pairs by rail was found in the Washington-Boston Corridor to be about 20 per cent greater than that of a plane. See System Analysis and Research Corporation, *Demand for Intercity Passenger Travel in the Washington-Boston Corridor,* Boston, Massachusetts. This estimate may be too high for some areas (e.g., more sparsely populated areas) and too low for others (e.g., mountainous terrain).

(4.1), p. 25].[7] Let us assume that the railroads are able to modify their schedules so as to maintain a one hour edge over the air carriers (i.e., $\alpha_{OA} - \alpha_{OR} = 1$ hour), and are able to increase their cruising speed and cut the number of stops so as to increase their marginal effective speed to:

a. 100 mph (i.e., $\alpha_{IR} = 0.0100$),
b. 150 mph (i.e., $\alpha_{IR} = 0.0067$), and
c. 300 mph (i.e., $\alpha_{IR} = 0.0033$).[8]

In order to predict the effect of the introduction of these new modes on the modal split one has to know the increase in fares associated with the increased speed, and the distribution of the travelers' price of time (or alternatively, the travelers' income) by distance traveled and by mode used. In the absence of these data we will have to revert to some hypothetical calculations of the point at which air carriers will enter into the market.

A plane cruising at a speed of 500 mph overtakes a train that departed one hour earlier and that travels at a speed of 100 mph after traveling only 125 miles. Had the train been traveling at a speed of 150 mph this distance would have been 214 miles, and had the speed been 300 mph the distance would have been 750 miles. Under our illustrative example, the railroads will almost have to quadruple their effective speed in order to recoup the 200 mile range market, and, in particular, the most lucrative routes of the Northeastern corridor.[9] Only an eightfold increase in

[7] This fixed time component consists of traveling to and from the airport, waiting time, and a fixed time component associated with take-off and landing. The above estimate may have an upward bias because it is based on traveling time to the airport by limousine and because the origin of all flights is New York. This bias may be offset by our failure to account for waiting time due to infrequent flights.

[8] These assumptions are quite far reaching. If one takes account of the circuity factor (say, 1.2), then to satisfy these requirements a nonstop train would have to travel at speeds of (a) 120 mph, (b) 180 mph, and (c) 360 mph, respectively. The last of these alternatives resembles a short-take-off or a vertical-take-off plane more than any known form of ground transportation.

[9] The distances of the two most popular air routes, New York–Boston and New York–Washington, are 188 and 205 miles, respectively. Among the Northeast corridor's major routes only Boston-Washington and Boston-Philadelphia exceed 214 miles.

The statement, of course, takes an extreme view. Even more modest increases in the train's speed may increase the railroad's share of this market.

the railroads' speed will insure them of the medium range market. A speed of 300 mph may well be outside the train's reach, befitting more a STOL or VTOL plane. The introduction of these new aircrafts may cost, therefore, the conventional airline equipment over two-thirds of air passengers and one-third of air passenger miles.

The train should be better off if it succeeds in improving schedule frequency further so as to give it a two hour edge over the plane (i.e., $\alpha_{OA} - \alpha_{OR} = 2$ hours). In this case, even a 100 mph train should be able to recapture the short range distance (the plane overtaking the train only after 250 miles). Moreover, a 500 mph subsonic plane competing with a 300 mph train, VTOL, or STOL plane has to travel 1,500 miles before it overcomes the two hour handicap. This leaves the slower mode with most of the domestic market except for the transcontinental routes.

One can indulge in this kind of speculation indefinitely. Unfortunately, this kind of analysis suffers from one major drawback. It ignores any changes in the railroads' operating costs and in their fare. The conclusions in the previous section are based on the tacit assumption that in spite of any possible increase in fare the train will still be able to provide the traveler with a cheaper service (in pecuniary terms) than the air carriers. Given the 1963 pecuniary charges [equation (4.1)], the air carriers' charges exceed those of the train by about 40 per cent.[10] The train should, therefore, be able to recuperate the above mentioned gains from the increased speed only if it succeeds in keeping its fares at a level that is less than 1.4 times their current level. This margin is all the tighter since railroads in the U.S. generally lose considerable sums on their passenger traffic at the current tariff level while airlines have been modestly profitable.

[10] Our estimate in Chapter 4 of the train trip's pecuniary cost (P_R) is biased downward as it ignores costs incurred en route (e.g., meals, sleeping accommodations, etc.). However, the extent of this bias should diminish as the train's speed is increased.